

# VOLTAGE REGULATOR HANDBOOK



FAIRCHILD

# VOLTAGE REGULATOR HANDBOOK



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**FAIRCHILD**

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# INTRODUCTION

Monolithic voltage regulators have been around for about a decade. A considerable effort has been devoted to linear voltage regulators by major IC manufacturers over the last few years, with recent emphasis primarily concerning 3-terminal voltage regulators.

Of the various regulators introduced in the late sixties, one device emerged as the industry standard: the  $\mu$ A723. A simple building block, this circuit provided low output currents (by today's standards), required several external components and a fair amount of design considerations. At last count, this product is produced by over a dozen manufacturers. The emergence of 3-terminal regulators ( $\mu$ A7800,  $\mu$ A78C,  $\mu$ A78M,  $\mu$ A78L,  $\mu$ A7900,  $\mu$ A79M) in the early seventies opened a new avenue for regulators. Circuit complexity moved from outside to inside the linear chip. Designers had at their disposal *positive* and *negative* regulators with output currents up to 3 A in a variety of packages but with a limited number of fixed output voltages. The output voltage limitation was solved by the introduction of the adjustable 4-terminal regulators (78G, 78MG, 79G, 79MG) in the mid seventies. Energy conservation programs of recent years have forced designers to be more conscious about wasted power and as a result they have looked into switching regulators. As a matter of fact, there are major switching regulator design efforts in progress at various IC manufacturers as this book goes to press.

The use of IC regulators is increasing at a rapid rate as the usage of semiconductors is widening. Today, regulators are being used in a variety of applications too numerous to list here. Fairchild is the industry leader in voltage regulators and in fact, Fairchild regulators have become industry standards.

This edition of "The Voltage Regulator Applications Handbook" significantly different in format, covers a larger selection of products and applications than the 1974 edition and is intended to familiarize the designer with the various regulators available from Fairchild as well as helping him select the correct regulator circuit for his application. At the front of this book is a complete regulator selection guide supplemented by an industry cross reference. Chapter 1 describes the various blocks used in regulators as well as the circuit descriptions of the individual regulators. Chapter 2 covers testing procedures and reliability programs. Chapter 3 is devoted to regulator applications, and includes several important precautions required in the design of regulator circuits. Chapter 4 offers power supply design assistance, such as the selection of transformer, rectifier and filter capacitors. Chapter 5 is devoted to power transistors and Chapter 6 outlines the thermal considerations necessary with IC regulators. Technical specification for all Fairchild regulators make up Chapter 7. Definitions, packaging, mounting hardware and ordering information are found in Section 8.

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SELECTION GUIDES AND INDUSTRY  
CROSS REFERENCE

VOLTAGE REGULATORS

TESTING AND RELIABILITY

APPLICATIONS

POWER SUPPLY DESIGN

POWER TRANSISTORS

THERMAL CONSIDERATIONS

PRODUCT INFORMATION

DEFINITIONS, ORDERING INFORMATION  
AND PACKAGE OUTLINES

FAIRCHILD FIELD SALES OFFICES,  
REPRESENTATIVES AND DISTRIBUTORS

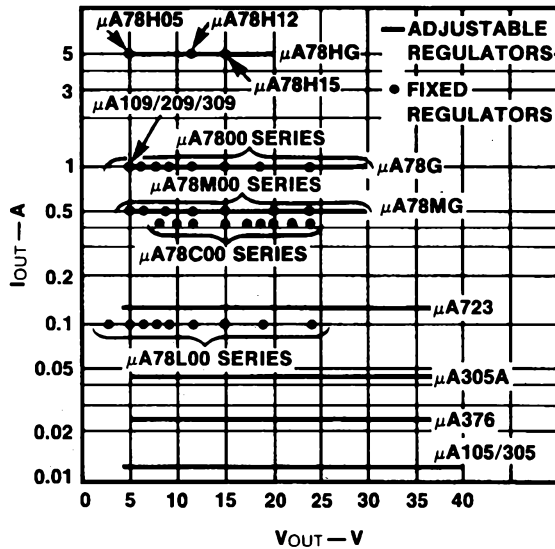
## **VOLTAGE REGULATOR SELECTION**

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# VOLTAGE REGULATOR SELECTION

The selection of the proper regulator is not a simple decision and very much depends on the system requirements and the limitations imposed by the system. There are no set rules; the selection process may vary from one application to another and even from one designer to the next. The following steps are recommended as a guide:

1. Determine the required output voltage  $V_{OUT}$ , output voltage tolerance, and maximum output current  $I_{OUT(max)}$ . These three parameters somewhat narrow the selection. For instance, a system requirement of 1% output voltage tolerance may preclude the 3-terminal regulators since these devices are specified with a 5% tolerance over the operating temperature range unless a special selection is made.
2. Using the Quick Selection Guide below and the Selection Guide by Output Current along with *Table 6.2*, make an initial selection.



Quick Selection Guide

3. Determine the required input voltage such that

$$V_{IN(max)} > V_{IN} > V_{OUT(max)} + V_{DO(max)} + \Delta V_L + V_{R(pk)}$$

where:

$V_{IN(max)}$  = Maximum allowable input voltage

$V_{IN}$  = Regulator input voltage under load

$V_{OUT(max)}$  = Maximum output voltage of the regulator

$V_{DO(max)}$  = Maximum dropout voltage

$\Delta V_L$  = Maximum line voltage change

$V_{R(pk)}$  = Peak ripple voltage.

4. If a filtered dc supply is not available, refer to Chapter 4 for the power-supply design.
5. If a filtered supply is available, or if the selected voltage gives an input-output voltage differential greater than 7 V, check the safe-area characteristics of the device chosen on the "Peak Output Current as a Function of Input-Output Differential Voltage" graph from the data sheet to ensure that sufficient load current is available from the regulator with the chosen input voltage.
6. If the current available is insufficient, either lower the input voltage, choose a device with a higher rating or use a booster circuit (see Chapter 3).
7. Determine the maximum ambient temperature,  $T_{A(max)}$ , and select an operating junction temperature equal to or less than  $T_{J(max)}$ , keeping in mind that the lower the operating junction temperature, the higher the reliability but the greater the heat-sinking requirement.
8. From Chapter 6, Thermal Considerations, determine the heat sink requirement for the selected regulator.



## VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	°C/W Max		Packages	Data Sheet Page
										$\theta_{JC}$	$\theta_{JA}$		
$\mu$ A104	Adjustable Negative	-8 -50	-0.015 -40	0.012	0.1	0.1	5	60	2	50	190	TO-100	7-123
$\mu$ A105	Adjustable Positive	8.5 50	4.5 30	0.012	0.06	0.1	2	60	3	40 190	190 190	MINI DIP TO-99	7-117
$\mu$ A109 <sup>1</sup>	Fixed Positive	7 35	4.7 5.3	1	1	2	4.2		2	5.5	45	TO-3	7-47
$\mu$ A209 <sup>2</sup>	Fixed Positive	7 35	4.7 5.3	1	1	2	4.2		2	5.5	45	TO-3	7-47
$\mu$ A304	Adjustable Negative	-8 -40	-0.035 -30	0.02	0.1	0.2	5	60	3	50	190	TO-100	7-123
$\mu$ A305	Adjustable Positive	8.5 40	4.5 30	0.012	0.06	0.1	2	60	3	40 190	190 190	MINI DIP TO-99	7-117
$\mu$ A305A	Adjustable Negative	8.5 50	4.5 40	0.045	0.06	0.4	2		3	40 190	190 190	MINI DIP TO-99	7-117
$\mu$ A309	Fixed Positive	7 35	4.8 5.2	1	2	2	5.2		2	5.5	45	TO-3	7-51
$\mu$ A376	Adjustable Positive	9 40	5 37	0.025	0.05	0.5	2.5		3	40 190	190 190	MINI DIP TO-99	7-117
$\mu$ A723	Precision	9.5 40	2 37	0.125	0.5	0.2	4	58	3	50	190 160 190	TO-100 C DIP P DIP	7-110
$\mu$ A7805	Fixed Positive	7 35	4.8 5.2	1	1	1	8	62	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7806	Fixed Positive	8 35	5.75 6.25	1	1	1	8	59	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7808	Fixed Positive	10 35	7.7 8.3	1	1	1	8	56	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7812	Fixed Positive	14 35	11.5 12.5	1	1	1	8	55	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7815	Fixed Positive	17 35	14.4 15.6	1	1	1	8	54	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7818	Fixed Positive	20 35	17.3 18.7	1	1	1	8	53	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7824	Fixed Positive	26 40	23 25	1	1	1	8	50	2.5	5 5.5	65 45	TO-220 TO-3	7-34
$\mu$ A7885	Fixed Positive	10.5 35	8.2 8.8	1	1	1	8	54	2.5	5 5.5	65 45	TO-220 TO-3	7-34

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

<sup>1</sup>T<sub>J</sub> = -55°C to 150°C

<sup>2</sup>T<sub>J</sub> = -25°C to 150°C

## VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	°C/W Max		Packages	Data Sheet Page
										$\theta_{JC}$	$\theta_{JA}$		
$\mu$ A78C08	Fixed Positive	11 35	7.7 8.3	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C10	Fixed Positive	13 35	9.6 10.4	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C12	Fixed Positive	15 35	11.5 12.5	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C15	Fixed Positive	18 35	14.4 15.6	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C17	Fixed Positive	20 35	16.3 17.7	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C18	Fixed Positive	21 35	17.3 18.7	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C20	Fixed Positive	23 40	19.2 20.8	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C22	Fixed Positive	25 40	21.1 22.9	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C24	Fixed Positive	27 40	23 25	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78C82	Fixed Positive	11.2 35	7.9 8.5	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
$\mu$ A78CB	Fixed Positive		13.3 14.4	2			8	50	3	5 5.5	65 45	TO-220 TO-3	7-54
$\mu$ A78G	Adjustable Positive	7.5 4	5 30	1	0.75	1	5	62	3	8 6	80 47	Power* Watt TO-3	7-90
$\mu$ A78H05	Fixed Positive	8.5 20	4.8 5.2	5	1	2	10	60	3.5	2.5	38	TO-3	7-60
$\mu$ A78H05A	Fixed Positive	25	5	5	1	1	10	60	2.2	2.5	38	TO-3	7-60
$\mu$ A78H12	Fixed Positive	15.5 20	11.5 12.5	5	1	2	10	60	3.5	2.5	38	TO-3	7-60
$\mu$ A78H15	Fixed Positive		14.4 15.6							2.5	38	TO-3	7-60
$\mu$ A78HG	Adjustable Positive	8.5 25	5 20	5	1	1	10	60	3.5	2.5	38	TO-3	7-60

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

\*Similar to TO-202

# VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	°C/W Max		Packages	Data Sheet Page
										$\theta_{JC}$	$\theta_{JA}$		
$\mu$ A78L05	Fixed Positive	7.2 30	4.8 5.2	0.1	2	1	3.8	49	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L09	Fixed Positive	11.2 30	8.64 9.36	0.1	2	1	4	43	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L12	Fixed Positive	14.2 30	11.5 12.5	0.1	2	1	6	42	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L15	Fixed Positive	17.2 35	14.4 15.6	0.1	2	1	6	39	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L18	Fixed Positive	20.2 35	17.3 18.9	0.1	2	1	3		2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L24	Fixed Positive	26.2 40	23.1 24.9	0.1	2	1	3		2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L26	Fixed Positive	4.3 30	2.5 2.7	0.1	2	1	5.5	43	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L62	Fixed Positive	8.4 30	5.95 6.45	0.1	2	1	3.9	46	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78L82	Fixed Positive	10.4 30	7.9 8.5	0.1	2	1	4	44	2.2	40	190 180	TO-39 TO-92	7-3
$\mu$ A78M05	Fixed Positive	7.5 35	4.8 5.2	0.5	1	1	6	6.2	2.2	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
$\mu$ A78M06	Fixed Positive	8.5 35	5.75 6.25	0.5	1	1	6	59	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
$\mu$ A78M08	Fixed Positive	10.5 35	7.7 8.3	0.5	1	1	6	56	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
$\mu$ A78M12	Fixed Positive	14.5 35	11.5 12.5	0.5	1	1	6	55	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
$\mu$ A78M15	Fixed Positive	17.5 35	14.4 15.6	0.5	1	1	6	54	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
$\mu$ A78M20	Fixed Positive	22.5 40	19.0 21	0.5	1	1	6	53	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
$\mu$ A78M24	Fixed Positive	26.5 40	23 25	0.5	1	1	6	50	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

\*Similar to TO-202

## VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	°C/W Max		Packages	Data Sheet Page
										θ <sub>JC</sub>	θ <sub>JA</sub>		
μA78MG	Adjustable Positive	7.5 40	5 30	0.5	0.75	1	5	62	3	25 11 8	185 80 80	TO-39 MINI DIP Power Watt*	7-102
μA78P05	Fixed Positive	25	5	10	1	1	10	60	2.5	2	38	TO-3	TBA
μA78S40	Switching	2.5 40	1.3 40	1.5			2	100			160 190	C DIP P DIP	7-128
μA7905	Fixed Negative	-7.3 -35	-4.8 -5.2	1	1	1	2	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA7906	Fixed Negative	-8.3 -35	-5.75 -6.25	1	1	1	2	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA7908	Fixed Negative	-10.3 -35	-7.7 -8.3	1	1	1	2	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA7912	Fixed Negative	-14.5 -35	-11.5 -12.5	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA7915	Fixed Negative	-17.6 -35	-14.4 -15.6	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA7918	Fixed Negative	-20.7 -35	-17.3 -18.7	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA7924	Adjustable Negative	-27 -40	-23 -25	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
μA79G	Adjustable Negative	-7 -40	-2.23 -30	1	1	1	2	50	2.3	8 6	80 47	Power Watt* TO-3	7-90
μA79HG	Adjustable Negative	-7 -40	-2.25 -24	5	1	1	5	50	2	2	38	TO-3	7-98
μA79M05	Fixed Negative	-7.5 -35	-4.8 -5.2	0.5	1	1	2	54	1	5 25	70 185	TO-220 TO-39	7-66
μA79M06	Fixed Negative	-7.35 -35	-5.75 -6.25	0.5	1	1	2	54	1	5 25	70 185	TO-220 TO-39	7-66
μA79M08	Fixed Negative	-9.4 -35	-7.7 -8.3	0.5	1	1	2	54	1	5 25	70 185	TO-220 TO-39	7-66
μA79M12	Fixed Negative	-13.6 -35	-11.5 -12.5	0.5	1	1	3	54	1	5 25	70 185	TO-220 TO-39	7-66
μA79M15	Fixed Negative	-16.7 -35	-14.4 -15.6	0.5	1	1	3	54	1	5 25	70 185	TO-220 TO-39	7-66
μA79M20	Fixed Negative	-22.1 -40	-19 -20	0.5	1	1	3.5	54	1	5 25	70 185	TO-220 TO-39	7-66

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

\*Similar to TO-202

## VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	°C/W Max		Packages	Data Sheet Page
										$\theta_{JC}$	$\theta_{JA}$		
$\mu$ A79M24	Fixed Negative	-26.1 -40	-23 -25	0.5	1	1	3.5	54	1	5 25	70 185	TO-220 TO-39	7-66
$\mu$ A79MG	Adjustable Negative	-7 -30	-2.23 -30	0.5	1	1	2.5	50	2.3	25 11 8	185 80 80	TO-39 MINI DIP Power Watt*	7-102
SH123	Fixed Positive	20	5	3	2	2	10	60	2.2	2.5	38	TO-3	7-58
SH223	Fixed Positive	20	5	3	2	2	10	60	2.2	2.5	38	TO-3	7-58
SH323	Fixed Positive	20	5	3	2	2	10	60	2.2	2.5	38	TO-3	7-58
SH1605	Switching	40	2.5 20	5			30 (TYP)			3.5	1.5	TO-3	TBA
SH1705	Fixed Positive	25	5	5	1	1	10		2.2	2.5	38	TO-3	TBA

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

\*Similar to TO-202

## VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature <sup>(1)</sup>	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
<b>Fixed Positive 100 mA</b>										
1	$\mu$ A78L26	2.6	C, V	100	50	43	5.5	4.8 to 35	2.2	7-3
2	$\mu$ A78L05	5.0	C, V	150	60	41	5.5	7.2 to 35	2.2	7-3
3	$\mu$ A78L62	6.2	C, V	175	80	40	5.5	8.4 to 35	2.2	7-3
4	$\mu$ A78L82	8.2	C, V	175	80	39	5.5	10.4 to 35	2.2	7-3
5	$\mu$ A78L09	9.0	C, V	188	90	38	5.5	11.2 to 35	2.2	7-3
6	$\mu$ A78L12	12	C, V	250	100	37	6.0	14.2 to 35	2.2	7-3
7	$\mu$ A78L15	15	C, V	300	150	34	6.0	17.2 to 35	2.2	7-3
8	$\mu$ A78L18	18	C, V	300	170	33	6.0	20.2 to 40	2.2	7-3
9	$\mu$ A78L24	24	C, V	300	200	31	6.0	26.2 to 40	2.2	7-3
<b>Fixed Positive 500 mA</b>										
10	$\mu$ A78M05	5.0	M	50	50	62	6.0	8.0 to 35	2.5	7-22
11	$\mu$ A78M05	5.0	C	100	100	62	6.0	7.5 to 35	2.5	7-22
12	$\mu$ A78M06	6.0	M	60	60	59	6.0	9.0 to 35	2.5	7-22
13	$\mu$ A78M06	6.0	C	100	120	59	6.0	8.5 to 35	2.5	7-22
14	$\mu$ A78M08	8.0	M	60	80	56	6.0	11 to 35	2.5	7-22
15	$\mu$ A78M08	8.0	C	100	160	56	6.0	10.5 to 35	2.5	7-22
16	$\mu$ A78C08	8.0	C, V	100	80	46	6.0	11 to 35	3.0	7-14
17	$\mu$ A78C10	10	C	100	100	55	6.0	13 to 35	3.0	7-14
18	$\mu$ A78M12	12	M	60	120	55	6.0	15 to 35	2.5	7-22
19	$\mu$ A78M12	12	C, V	100	240	55	6.0	14.5 to 35	2.5	7-22
20	$\mu$ A78C12	12	C	100	120	46	6.0	15 to 35	3.0	7-14
21	$\mu$ A78M15	15	M	60	150	54	6.0	18 to 35	2.5	7-22
22	$\mu$ A78M15	15	C	100	300	54	6.0	17.5 to 35	2.5	7-22

<sup>1</sup> Operating junction temperature range:

C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

## VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature <sup>(1)</sup>	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
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### Fixed Positive 500 mA (Cont'd)

1	$\mu$ A78C15	15	C	100	150	46	6.0	18 to 35	3.0	7-14
2	$\mu$ A78C17	17	C	100	170	52	6.0	20 to 35	3.0	7-14
3	$\mu$ A78C18	18	C	100	180	46	6.0	21 to 35	3.0	7-14
4	$\mu$ A78M20	20	M	60	200	53	6.0	23 to 40	2.5	7-22
5	$\mu$ A78M20	20	C	100	400	53	6.0	22.5 to 40	2.5	7-22
6	$\mu$ A78C20	20	C	100	200	46	6.0	23 to 40	3.0	7-14
7	$\mu$ A78C22	22	C	100	220	53	6.0	24.5 to 40	2.5	7-14
8	$\mu$ A78M24	24	M	60	240	50	6.0	27 to 40	2.5	7-22
9	$\mu$ A78M24	24	C	100	480	50	6.0	26.5 to 40	2.5	7-22
10	$\mu$ A78C24	24	C	100	240	46	6.0	27 to 40	3.0	7-14

### Fixed Negative 500 mA

11	$\mu$ A79M05	-5.0	M	50	100	54	2.0	-7.5 to -35	2.5	7-22
12	$\mu$ A79M05	-5.0	C	50	100	54	2.0	-7.3 to -35	2.3	7-22
13	$\mu$ A79M06	-6.0	M	60	120	54	2.0	-8.5 to -35	2.5	7-22
14	$\mu$ A79M06	-6.0	C	60	120	54	2.0	-8.3 to -35	2.3	7-22
15	$\mu$ A79M08	-8.0	M	80	160	54	2.0	-10.5 to -35	2.5	7-22
16	$\mu$ A79M08	-8.0	C	80	160	54	2.0	-10.3 to -35	2.3	7-22
17	$\mu$ A79M12	-12	M	80	240	54	3.0	-14.5 to -35	2.5	7-22
18	$\mu$ A79M12	-12	C	80	240	54	3.0	-14.3 to -35	2.3	7-22
19	$\mu$ A79M15	-15	M	80	240	54	3.0	-17.5 to -35	2.5	7-22
20	$\mu$ A79M15	-15	C	80	240	54	3.0	-17.3 to -35	2.3	7-22
21	$\mu$ A79M20	-20	M	80	300	54	3.5	-22.5 to -40	2.5	7-22
22	$\mu$ A79M20	-20	C	80	300	54	3.5	-22.3 to -40	2.3	7-22
23	$\mu$ A79M24	-24	M	80	300	54	3.5	-26.5 to -40	2.5	7-22
24	$\mu$ A79M24	-24	C	80	300	54	3.5	-26.3 to -40	2.3	7-22

<sup>1</sup> Operating junction temperature range:

C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

## VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature (1)	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
<b>Fixed Positive 1.0 A</b>										
1	$\mu$ A7805	5.0	M	50	50	68	6.0	8.0 to 35	3.0	7-34
2	$\mu$ A7805	5.0	C	100	100	62	8.0	7.5 to 35	2.5	7-34
3	$\mu$ A309	5.0	C	50	100	—	10	—	—	7-51
4	$\mu$ A109	5.0	M	50	100	—	10	—	—	7-47
5	$\mu$ A209	5.0	V	50	100	—	10	—	—	7-47
6	$\mu$ A7806	6.0	M	60	60	65	6.0	9.0 to 35	3.0	7-34
7	$\mu$ A7806	6.0	C	120	120	59	8.0	8.5 to 35	2.5	7-34
8	$\mu$ A7808	8.0	M	80	80	62	6.0	11 to 35	3.0	7-34
9	$\mu$ A7808	8.0	C	160	160	56	8.0	10.5 to 35	2.5	7-34
10	$\mu$ A7885	8.5	M	85	85	60	6.0	11.5 to 35	3.0	7-34
11	$\mu$ A7885	8.5	C	170	170	54	8.0	11 to 35	2.5	7-34
12	$\mu$ A7812	12	M	120	120	61	6.0	15 to 35	3.0	7-34
13	$\mu$ A7812	12	C	240	240	55	8.0	14.5 to 35	2.5	7-34
14	$\mu$ A7815	15	M	150	150	60	6.0	18 to 35	3.0	7-34
15	$\mu$ A7815	15	C	300	300	54	8.0	17.5 to 35	2.5	7-34
16	$\mu$ A7818	18	M	180	180	59	6.0	21 to 35	3.0	7-34
17	$\mu$ A7818	18	C	360	360	53	8.0	20.5 to 35	2.5	7-34
18	$\mu$ A7824	24	M	240	240	56	6.0	27 to 40	3.0	7-34
19	$\mu$ A7824	24	C	480	480	50	8.0	26.5 to 40	2.5	7-34
<b>Fixed Negative 1.0 A</b>										
20	$\mu$ A7905	-5.0	M	50	50	54	2.0	-7.8 to -35	2.8	7-78
21	$\mu$ A7905	-5.0	C	100	100	54	2.0	-7.3 to -35	2.3	7-78
22	$\mu$ A7906	-6.0	M	60	60	54	2.0	-8.8 to -35	2.8	7-78
23	$\mu$ A7906	-6.0	C	120	120	54	2.0	-8.3 to -35	2.3	7-78
24	$\mu$ A7908	-8.0	M	80	80	54	2.0	-10.8 to -35	2.8	7-78

1 Operating junction temperature range:

C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.



## VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature (1)	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
<b>Fixed Negative 1.0 A (Cont'd)</b>										
1	$\mu$ A7908	-8.0	C	160	160	54	2.0	-10.3 to -35	2.3	7-78
2	$\mu$ A7912	-12	M	120	120	54	3.0	-14.8 to -35	2.8	7-78
3	$\mu$ A7912	-12	C	240	240	54	3.0	-14.3 to -35	2.3	7-78
4	$\mu$ A7915	-15	M	150	150	54	3.0	-17.8 to -35	2.8	7-78
5	$\mu$ A7915	-15	C	300	300	54	3.0	-17.3 to -35	2.3	7-78
6	$\mu$ A7918	-18	M	180	180	54	3.0	-20.8 to -35	2.8	7-78
7	$\mu$ A7918	-18	C	360	360	54	3.0	-20.3 to -35	2.3	7-78
8	$\mu$ A7924	-24	M	240	240	54	3.0	-26.8 to -40	2.8	7-78
9	$\mu$ A7924	-24	C	480	480	54	3.0	-26.3 to -40	2.3	7-78
<b>Fixed Positive 2.0 A</b>										
10	$\mu$ A78CB	13.8	C	150	150	50	8.0	17 to 25	2.5	7-54
<b>Fixed Positive 3.0 A</b>										
11	SH123	5.0	M	25	100	—	20	7.5 to 20	2.5	7-58
12	SH223	5.0	M	25	100	—	20	7.5 to 20	2.5	7-58
13	SH323	5.0	C	25	100	—	20	7.5 to 20	2.5	7-58
<b>Fixed Positive 5.0 A</b>										
14	$\mu$ A78H05	5.0	C, M	120	50	60	10	8.5 to 25	3.5	7-60
15	$\mu$ A78H05A	5.0	C, M	25	50	60	10	7.8 to 2.5	2.3	TBA
16	$\mu$ A78H12	12	C	—	120	60	10	15.5 to 25	3.5	7-60
17	$\mu$ A78H15	15	C	30	30	60	10	18.5 to 25	—	7-60
<b>Fixed Positive 10 A</b>										
18	$\mu$ A78P05	5.0	C	25	50	60	10	7.5 to 40	2.5	TBA

1 Operating junction temperature range:

C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

• To be announced

## VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Current (mA)	Output Voltage Range V	Temperature <sup>(1)</sup>	Line Regulation %V <sub>OUT</sub>	Load Regulation %V <sub>OUT</sub>	Ripple Rejection dB	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V	Page
<b>Positive Adjustable</b>											
1	μA105	12	4.5 to 30	M	0.06	0.1	1.0	2.0	8.5 to 50	3.0	7-117
2	μA305	12	4.5 to 30	C	0.06	0.1	1.0	2.0	8.5 to 40	3.0	7-117
3	μA376	25	5.0 to 37	C	0.1	0.5	1.0	2.5	9.0 to 40	3.0	7-117
4	μA305A	45	4.5 to 40	C	0.06	0.4	—	2.0	8.5 to 50	3.0	7-117
5	μA723	150	2.0 to 37	M	0.3	0.15	58	3.5	9.5 to 40	3.0	7-110
6	μA723	150	2.0 to 37	C	0.5	0.2	58	4.0	9.5 to 40	3.0	7-110
7	μA78MG	500	5.0 to 30	M	1.0	1.0	62	5.0	7.5 to 40	3.0	7-102
8	μA78MG	500	5.0 to 30	C	1.0	1.0	62	5.0	7.5 to 40	2.5	7-102
9	μA78G	1000	5.0 to 30	M	1.0	1.0	68	5.0	7.5 to 40	2.5	7-90
10	μA78G	1000	5.0 to 30	C	1.0	1.0	62	5.0	7.5 to 40	3.0	7-90
11	μA78HG	5000	5.0 to 24	C	1.0	1.0	60	10	8.5 to 25	3.5	7-60
<b>Negative Adjustable</b>											
12	μA104	25	-0.015 to -40	M	0.1	5mV	1.0	5.0	-8.0 to -50	2.0	7-123
13	μA304	25	-0.035 to -30	C	0.1	5mV	1.0	5.0	-8.0 to -40	2.0	7-123
14	μA79MG	500	-2.23 to -30	M	1.0	1.0	50	2.5	-7.0 to -30	2.5	7-102
15	μA79MG	500	-2.23 to -30	C	1.0	1.0	50	2.5	-7.0 to -30	2.3	7-102
16	μA79G	1000	-2.23 to -30	M	1.0	2.0	50	2.0	-7.0 to -40	2.8	7-90
17	μA79G	1000	-2.23 to -30	C	1.0	2.0	50	2.0	-7.0 to -40	2.3	7-90
18	μA79HG	5000	-2.25 to -24	C,M	1.0	1.0	50	5.0	-7.0 to -40	2.0	7-98
<b>Adjustable Switching Regulator</b>											
19	μA78S	1500	-1.3 to -40	M	—	—	100	2.0	-2.5 to -40	—	7-128
20	μA78S	1500	-1.3 to -40	C	—	—	100	2.0	-2.5 to -40	—	7-128

1 Operating junction temperature range:

C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

# IC VOLTAGE REGULATORS INDUSTRY CROSS REFERENCE

Type Number	Fairchild Equivalent	Type Number	Fairchild Equivalent	Type Number	Fairchild Equivalent
<b>MOTOROLA</b>		<b>MOTOROLA (Cont'd)</b>		<b>NATIONAL (Cont'd)</b>	
MC1723GC	$\mu$ A723HC	MC7912CK	$\mu$ A7912KC	LM320MP-12*	$\mu$ A79M12AUC
MC1723G	$\mu$ A723HM	MC7912CP	$\mu$ A7912UC	LM320MP-15*	$\mu$ A79M15AUC
MC1723LC	$\mu$ A723DC	MC7915CK	$\mu$ A7915KC	LM320MP-24*	$\mu$ A79M24AUC
MC1723L	$\mu$ A723DM	MC7915CP	$\mu$ A7915UC	LM320T-5	$\mu$ A7905UC
MC7805CK	$\mu$ A7805KC	MC7924CK	$\mu$ A7924KC	LM320T-6	$\mu$ A7906UC
MC7805CP	$\mu$ A7805UC	MC7924CP	$\mu$ A7924UC	LM320T-8	$\mu$ A7908UC
MC7806CK	$\mu$ A7806KC	MC79G00CK	$\mu$ A79GKC	LM320T-12	$\mu$ A7912UC
MC7806CP	$\mu$ A7806UC	MC79G00CT**	$\mu$ A79GU1C	LM320T-15	$\mu$ A7915UC
MC7808CK	$\mu$ A7808KC	MC79G00K	$\mu$ A79GKM	LM320T-24	$\mu$ A7924UC
MC7808CP	$\mu$ A7808UC	MLM104G	$\mu$ A104HM	LM340K-8	$\mu$ A7808KC
MC7812CK	$\mu$ A7812KC	MLM105G	$\mu$ A105HM	LM340K-12	$\mu$ A7812KC
MC7812CP	$\mu$ A7812UC	MLM109K	$\mu$ A109KM	LM340K-15	$\mu$ A7815KC
MC7815CK	$\mu$ A7815KC	MLM205G	$\mu$ A305HC	LM340K-18	$\mu$ A7818KC
MC7815CP	$\mu$ A7815UC	MLM209K	$\mu$ A209KM	LM340K-24	$\mu$ A7824KC
MC7818CK	$\mu$ A7818KC	MLM304G	$\mu$ A304HC	LM340T-6	$\mu$ A7806UC
MC7818CP	$\mu$ A7818UC	MLM305	$\mu$ A305AHC	LM340T-8	$\mu$ A7808UC
MC7824CK	$\mu$ A7824KC	MLM309K	$\mu$ A309KC	LM340T-12	$\mu$ A7812UC
MC7824CP	$\mu$ A7824UC			LM340T-15	$\mu$ A7815UC
MC78G00CK	$\mu$ A78GKC			LM340T-18	$\mu$ A7818UC
MC78G00CT**	$\mu$ A78GU1C			LM341P-5*	$\mu$ A78M05UC
MC78G00K	$\mu$ A78GKM	<b>NATIONAL</b>		LM341P-6*	$\mu$ A78M06UC
MC78L02CP	$\mu$ A78L26AWC	LM104H	$\mu$ A104HM	LM341P-8*	$\mu$ A78M08UC
MC78L05CP	$\mu$ A78L05AWC	LM105H	$\mu$ A105HM	LM341P-12*	$\mu$ A78M12UC
MC78L06CP	$\mu$ A78L06AWC	LM109K	$\mu$ A109KM	LM341P-15*	$\mu$ A78M15UC
MC78L08CP	$\mu$ A78L82AWC	LM120K-5	$\mu$ A7905KM	LM341P-24*	$\mu$ A78M24UC
MC78L12CP	$\mu$ A78L12AWC	LM120K-6	$\mu$ A7906KM	LM376N	$\mu$ A376TC
MC78L13CP	$\mu$ A78L15AWC	LM120K-8	$\mu$ A7908KM	LM723CD	$\mu$ A732DC
MC78L18CP	$\mu$ A78L18AWC	LM120K-12	$\mu$ A7912KM	LM723D	$\mu$ A723DM
MC78L24CP	$\mu$ A78L24AWC	LM120K-15	$\mu$ A7915KM	LM723CH	$\mu$ A723HC
MC78M05CG	$\mu$ A78M05HC	LM120K-24	$\mu$ A7924KM	LM723CN	$\mu$ A723PC
MC78M05CP	$\mu$ A78M05UC	LM140K-5	$\mu$ A7805KM	LM723H	$\mu$ A723HM
MC78M06CG	$\mu$ A78M06HC	LM140K-6	$\mu$ A7806KM	LM7805KC	$\mu$ A7805KC
MC78M06CP	$\mu$ A78M06UC	LM140K-8	$\mu$ A7808KM	LM7806KC	$\mu$ A7806KC
MC78M08CG	$\mu$ A78M08HC	LM140K-12	$\mu$ A7812KM	LM7808KC	$\mu$ A7808KC
MC78M08CP	$\mu$ A78M08UC	LM140K-15	$\mu$ A7815KM	LM7818KC	$\mu$ A7818KC
MC78M12CG	$\mu$ A78M12HC	LM140K-18	$\mu$ A7818LM	LM7812KC	$\mu$ A7812KC
MC78M12CP	$\mu$ A78M12UC	LM140K-24	$\mu$ A7824KM	LM7815KC	$\mu$ A7815KC
MC78M15CG	$\mu$ A78M15HC	LM209K	$\mu$ A209KM	LM7818KC	$\mu$ A7818KC
MC78M15CP	$\mu$ A78M15UC	LM304H	$\mu$ A304HC	LM7824KC	$\mu$ A7824KC
MC78M20CG	$\mu$ A78M20HC	LM305AH	$\mu$ A305AHC	LM78L05ACH	$\mu$ A78L05AHC
MC78M20CP	$\mu$ A78M20UC	LM305H	$\mu$ A305HC	LM78L05ACZ	$\mu$ A78L05AUC
MC78M24CG	$\mu$ A78M24HC	LM309K	$\mu$ A309KC	LM78L06ACH	$\mu$ A78L06AHC
MC78M24CP	$\mu$ A78M24UC	LM320KC-5	$\mu$ A7905KC	LM78L06ACZ	$\mu$ A78L06AUC
MC7905CK	$\mu$ A7905KC	LM320KC-6	$\mu$ A7906KC	LM78L08ACH	$\mu$ A78L82AHC
MC7905CP	$\mu$ A7905UC	LM320KC-8	$\mu$ A7908KC	LM78L08ACZ	$\mu$ A78L82AUC
MC7906CK	$\mu$ A7906KC	LM320KC-12	$\mu$ A7912KC	LM78L12ACH	$\mu$ A78L12AHC
MC7906CP	$\mu$ A7906UC	LM320KC-15	$\mu$ A7915KC	LM78L12ACZ	$\mu$ A78L12AUC
MC7908CK	$\mu$ A7908KC	LM320KC-24	$\mu$ A7924KC	LM78L15ACH	$\mu$ A78L15AHC
MC7908CP	$\mu$ A7908UC	LM320MP-5*	$\mu$ A79M05AUC	LM78L15ACZ	$\mu$ A78L15AUC
		LM320MP-6*	$\mu$ A79M06AUC	LM78L18ACH	$\mu$ A78L18AHC
		LM320MP-8*	$\mu$ A79M08AUC		

\*\* Not Available in VIC package  
\* Not a direct replacement



# IC VOLTAGE REGULATORS INDUSTRY CROSS REFERENCE

Type Number	Fairchild Equivalent	Type Number	Fairchild Equivalent	Type Number	Fairchild Equivalent
<b>TEXAS INSTRUMENTS (Cont'd)</b>		<b>TEXAS INSTRUMENTS (Cont'd)</b>		<b>TEXAS INSTRUMENTS (Cont'd)</b>	
$\mu$ A7912CKA	$\mu$ A7912KC	$\mu$ A79M05CKC	$\mu$ A79M05AUC	SN52109LA***	$\mu$ A109KM
$\mu$ A7912CKC	$\mu$ A7912UC	$\mu$ A79M06CKC	$\mu$ A79M06AUC	SN52723J	$\mu$ A723DM
$\mu$ A7912MKA	$\mu$ A7912KM	$\mu$ A79M08CKC	$\mu$ A79M08AUC	SN52723L	$\mu$ A723HM
$\mu$ A7915CKA	$\mu$ A7915KC	$\mu$ A79M12CKC	$\mu$ A79M12AUC	SN72304L	$\mu$ A304HC
$\mu$ A7915CKC	$\mu$ A7915UC	$\mu$ A79M15CKC	$\mu$ A79M15AUC	SN72305L	$\mu$ A305HC
$\mu$ A7915MKA	$\mu$ A7915KM	$\mu$ A79M20CKC	$\mu$ A79M20AUC	SN72305AL	$\mu$ A305AHC
$\mu$ A7924CKA	$\mu$ A7924KC	$\mu$ A79M24CKC	$\mu$ A79M24AUC	SN72309LA***	$\mu$ A309KC
$\mu$ A7924CKC	$\mu$ A7924UC	$\mu$ A79MGC	$\mu$ A79MGU1C	SN72376P	$\mu$ A376TC
$\mu$ A7924MKA	$\mu$ A7924KM	SN52104L	$\mu$ A104HM	SN72723J	$\mu$ A723DC
$\mu$ A79GC	$\mu$ A79GU1C	SN52105L	$\mu$ A105HM	SN72723L	$\mu$ A723HC
				SN72723N	$\mu$ A723PC

## Voltage Regulators to be Announced

**TEXAS INSTRUMENTS**  
TL430

**FAIRCHILD EQUIVALENT**  
 $\mu$ A430

**NATIONAL SEMICONDUCTORS**  
LM117  
LM317  
LM320  
LM340

**FAIRCHILD EQUIVALENT**  
 $\mu$ A117  
 $\mu$ A317  
 $\mu$ A320  
 $\mu$ A340

UNITED STATES DEPARTMENT OF THE INTERIOR

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Section 21	21	21	21	21	21
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Section 23	23	23	23	23	23
Section 24	24	24	24	24	24
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**TESTING AND RELIABILITY**

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## **IC VOLTAGE REGULATORS**

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- **Switching Regulator Timing Considerations** ..... 1-30



# Chapter 1

## IC VOLTAGE REGULATORS

IC regulators have eliminated the tedious and repetitive task of designing power supply circuits. Today, the designer has a wide choice of fixed or adjustable series-type regulators with either positive or negative output voltages from 2.6 to 30 V and current capabilities from 10 mA to 2 A, as well as an increasing number of switching regulators. Built-in protection circuits improve reliability and make IC regulators virtually immune to failure modes normally encountered when dealing with discrete voltage regulators. This chapter describes the internal circuit features of series-type regulators and the circuit description of the various series regulators offered by Fairchild followed by switching regulator theory and a description of the 78S40 switching regulator.

### INTERNAL CIRCUIT FEATURES

Figure 1-1 shows a block diagram of a typical series-type IC voltage regulator in which an error amplifier compares a reference voltage  $V_{REF}$  with a fraction of the output voltage derived from the feedback resistors  $R_A$  and  $R_B$ . The error amplifier provides the necessary base drive to the series-pass element to maintain a constant output voltage level regardless of changes in input voltage or output current levels.

To assure a stable reference immune to line voltage and temperature variations, the voltage reference is usually fed from a constant current source. If the current source is not self-starting, some type of start-up circuit must be used. In addition to these basic blocks, most regulators have protection circuits to guard against accidental shorts, excessive input-output differentials and thermal overloads.

### Voltage Reference Circuit

The voltage reference is the most important part of the regulator since any abnormality observed in the reference will also be seen at the output. Therefore, it must be stable, free of noise, and must have a low temperature drift. It should also be reproducible with little variation in absolute value from device to device. Zener reference and band-gap or differential  $V_{BE}$  are the most widely used references in regulators with the band-gap type the less noisy of the two.

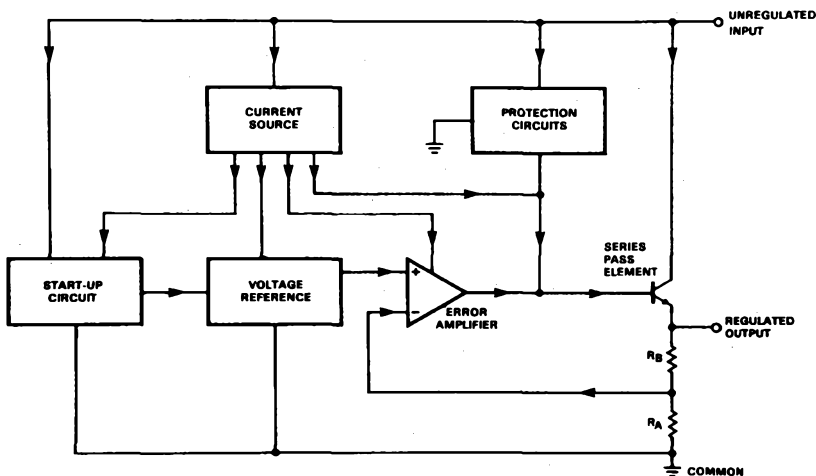
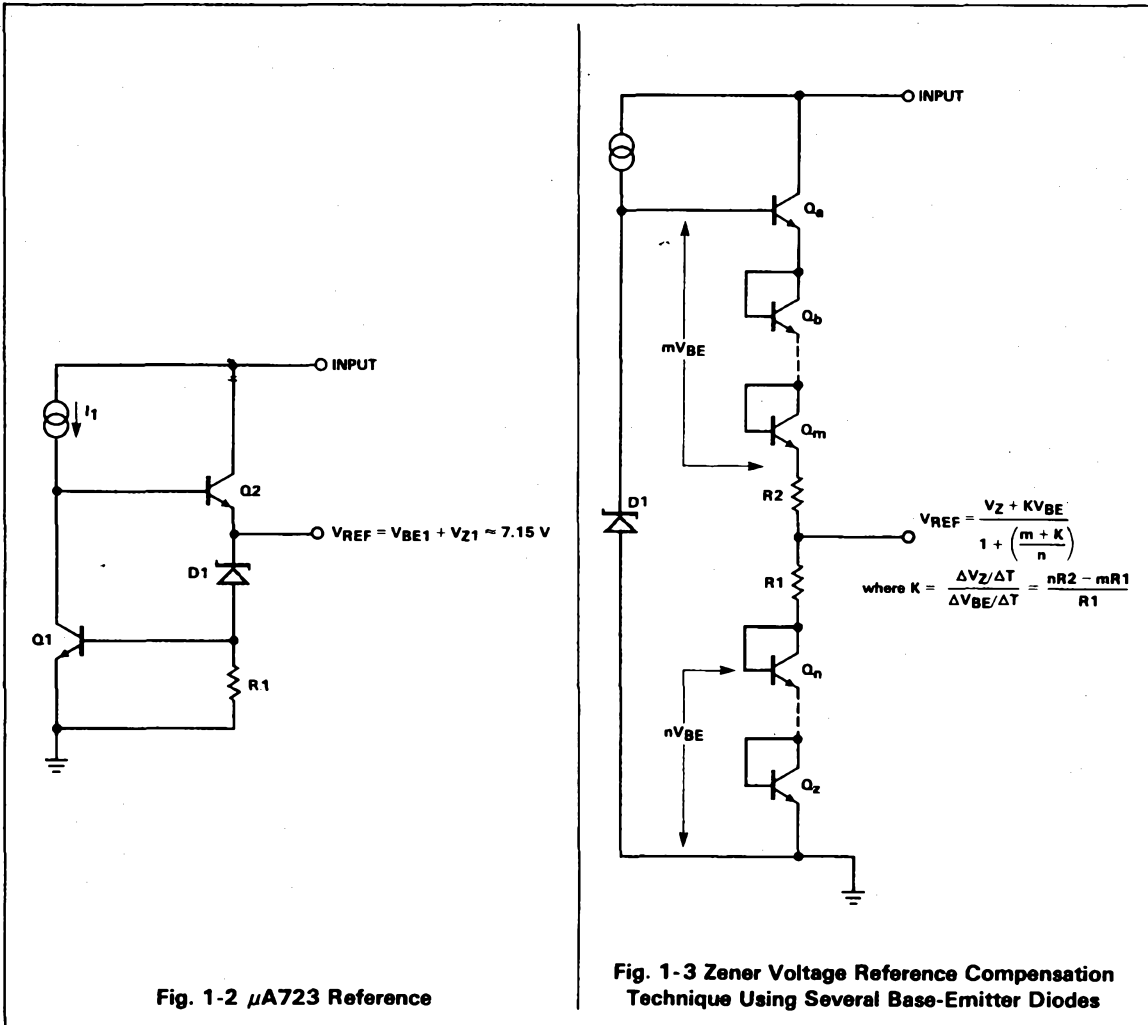


Fig. 1-1 Block Diagram of a Series-Type Voltage Regulator



### Zener References

The  $\mu$ A723, the  $\mu$ A78C00 series, the negative series  $\mu$ A7900 regulators as well as the  $\mu$ A104/105 have Zener voltage reference elements. There are various ways of obtaining the required temperature stability but the basic principles are the same. The technique is to compensate the positive temperature coefficient of a Zener diode with the negative coefficient of a base-emitter diode or diodes.

Figure 1-2 shows the voltage reference used in the  $\mu$ A723 regulator. The current through the Zener diode  $D_1$  is set by resistor  $R_1$ . The temperature coefficient of the  $Q_1$  base-emitter voltage  $V_{BE1}$  is determined by  $Q_1$  collector current, which is set by the current source  $I_1$ . The lower the value of  $I_1$  the higher the temperature coefficient of  $V_{BE1}$ . Therefore,  $I_1$  is set to cancel the positive temperature coefficient of  $D_1$ , thus yielding a nominal reference of about 7.15 V.

Another Zener-derived reference is shown in Figure 1-3. Here, temperature compensation is achieved via a string of diodes;  $m$  represents the number of diodes in the top portion of the circuit and  $n$  represents the number in the bottom portion. The junction of  $R_2$  and transistor  $Q_m$  has a positive temperature coefficient, while the junction of  $R_1$  and  $Q_n$  has a negative temperature coefficient. The reference point  $V_{REF}$  is selected to give a temperature stable reference.

$$V_{REF} = [V_Z - (m V_{BE} + n V_{BE})] \frac{R_1}{R_1 + R_2} + n V_{BE} \quad (1-1)$$

And simplifying

$$V_{REF} = \frac{R_1 V_Z + (n R_2 - m R_1) V_{BE}}{R_1 + R_2} \quad (1-2)$$

For a temperature stable reference

$$\frac{\Delta V_{REF}}{\Delta T} = 0$$

Assuming resistors R1 and R2 have the same temperature coefficient

$$\frac{\Delta V_{REF}}{\Delta T} = \frac{R_1 + (n R_2 - m R_1)}{R_1 + R_2} \quad (1-3)$$

To achieve a stable reference, therefore

$$R_1 \frac{\Delta V_Z}{\Delta T} = - (n R_2 - m R_1) \frac{\Delta V_{BE}}{\Delta T} \quad (1-4)$$

or

$$\frac{R_1}{R_2} = \frac{n}{m + K} \quad (1-5)$$

where

$$K = \frac{-\frac{\Delta V_Z}{\Delta T}}{\frac{\Delta V_{BE}}{\Delta T}} = \frac{n R_2 - m R_1}{R_1} \quad (1-6)$$

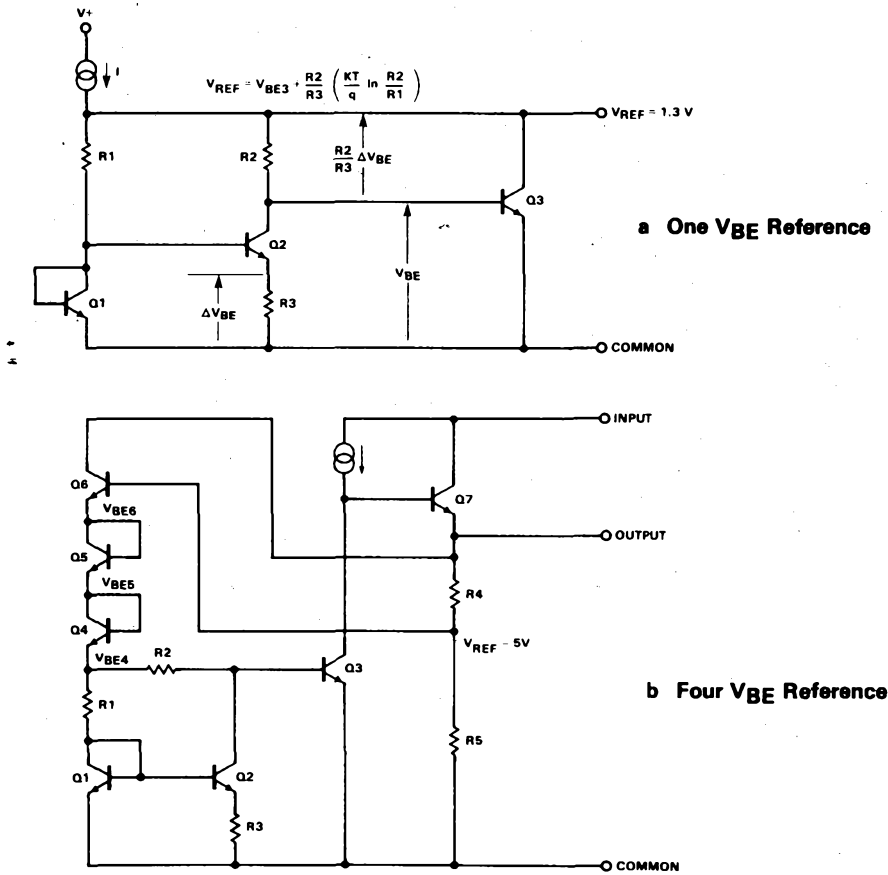
Substituting these values of K and  $\frac{R_1}{R_2}$  in Equation 1-2

$$V_{REF} = \frac{V_Z + K V_{BE}}{1 + \frac{(m + K)}{n}} \quad (1-7)$$

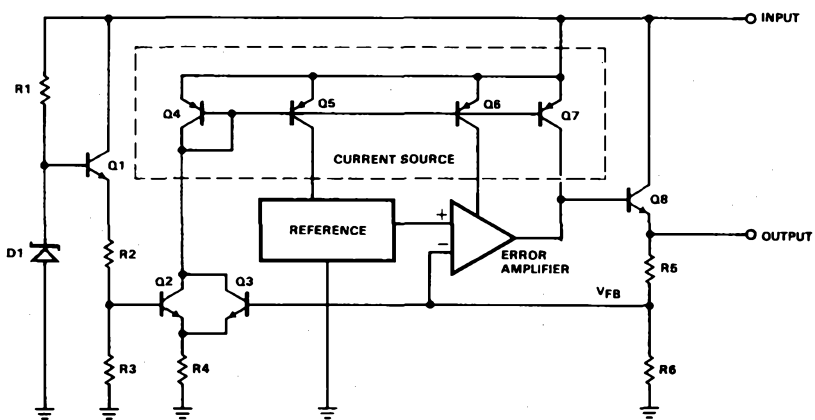
Both of these Zener-derived voltage references offer some advantages. The circuit in *Figure 1-2* provides a higher reference voltage, approximately 7.15 V, which is buffered. Therefore, the user can draw some current out of the reference terminal without appreciably affecting the reference. The circuit in *Figure 1-3* is more complex but it offers a wide range of low voltage references. This reference has a high output impedance since it is not buffered, therefore no current can be drawn out without degrading the regulator.

### Band-Gap References

Each of the  $\mu A7800$ ,  $\mu A78M$  and  $\mu A78L$  positive regulators has a band-gap voltage reference derived from the predictable temperature, current and voltage relationship in a base-emitter junction. To obtain a temperature-compensated reference voltage, the positive temperature coefficient of the emitter-base voltage differential between two transistors, operated at different current densities, is added to the negative temperature coefficient of the emitter-base voltage (see *Figure 1-4a*). Transistor Q1 operates at a considerably higher current density than Q2. The base-emitter differential voltage  $\Delta V_{BE}$  appears across R3. Transistor Q2 is a gain stage and thus develops a voltage drop across R2 that is proportional to the drop



**Fig. 1-4 Band-gap or Differential  $V_{BE}$  Voltage References**



across R3. Transistor Q3 provides additional gain and adjusts the reference voltage  $V_{REF}$  to a value equal to the Q3 base-emitter drop plus the voltage across R2. The reference voltage can thus be expressed as

$$V_{REF} = V_{BE3} + V_{R2} = V_{BE3} + \frac{R2}{R3} \Delta V_{BE} + I_{B3} R2 \quad (1-8)$$

Neglecting the drop due to the Q3 base current

$$V_{REF} \cong V_{BE3} + \frac{R2}{R3} \frac{kT}{q} \ln \frac{J1}{J2} \quad (1-9)$$

where J = Current density; T = ° Kelvin; k = Boltzmann constant; q = Electron Charge

To obtain a temperature stable reference,  $\Delta V_{REF}/\Delta T$  must be set to zero, or

$$\frac{\Delta V_{REF}}{\Delta T} = \frac{\Delta V_{BE3}}{\Delta T} + \frac{R2}{R3} \frac{k}{q} \ln \frac{J1}{J2} = 0 \quad (1-10)$$

Assuming  $V_{BE1} = V_{BE3}$ , the following must be satisfied

$$\frac{\Delta V_{BE3}}{\Delta T} = - \frac{R2}{R3} \frac{k}{q} \ln \frac{J1}{J2} = - \frac{R2}{R3} \frac{k}{q} \ln \frac{R2}{R1} \quad (1-11)$$

where  $\Delta V_{BE3}/\Delta T$  is the negative temperature coefficient of the Q3 base-emitter voltage,  $k/q \ln J1/J2$  is the positive temperature coefficient of the base-emitter differential voltage of Q1 and Q2.

Therefore, by selecting the resistor ratios  $R2/R3$  and  $R2/R1$ , a temperature compensated reference of about 1.3 V is obtained. This reference is used in the  $\mu A78L00$ -series regulators.

To obtain a higher voltage reference, additional diodes can be added in series as shown in *Figure 1-4b*. The reference then becomes:

$$V_{REF} = V_{BE3} + V_{BE4} + V_{BE5} + V_{BE6} + \frac{R2}{R3} \frac{kT}{q} \ln \frac{R2}{R1} \quad (1-12)$$

Resistors R1, R2 and R3 are selected so that the reference voltage is constant over the temperature range and also has a nominal value of 5 V at room temperature. This reference is used in the  $\mu A7800/78M00$ -series positive regulators.

### Current Sources

Stable current sources can easily be realized in monolithic circuits by taking advantage of the good matching and tracking capability of monolithic components. Also, the IC designer can add as many active devices as necessary without significantly increasing die area. A variety of current sources can be designed by scaling emitter areas, thus removing much of the dependence on absolute resistor values.

Operation of the reference circuit at a constant current level reduces fluctuations due to line-voltage variations in the reference voltage and therefore in the output. The error amplifier is operated at a constant current to reduce line-voltage induced errors or offsets at the output. The drive for the output stage is also made constant to insure device operation over the intended line voltage and temperature ranges. In addition, the use of constant currents throughout the regulator causes the quiescent current to remain relatively constant with line voltage and temperature variations.

### Start-up Circuit

Certain current sources in regulator circuits are derived from the regulated output and, as a result, are not self-starting. They, therefore, require some additional circuits to initiate and maintain the flow of cur-

rent independent of output conditions. *Figure 1-5* shows a typical start-up circuit. Zener diode D1 and the emitter-follower transistor Q1 provide a fixed voltage at the base of Q2 through the divider network of R2 and R3. When power is first applied to the circuit, collector and base currents of Q4 flow through Q2. Once Q4 conducts, Q5, Q6 and Q7 also conduct and a regulated output is obtained. Normally, the bias at the base of Q2 is set to a level lower than the reference voltage. Thus, when a regulated output is obtained, Q3 turns on and Q2 turns off, diverting the collector and base currents of Q4 through the Q3 collector. The feedback voltage  $V_{FB}$ , the base-emitter voltage of Q3, and R4 set the pnp current sources Q4, Q5, Q6 and Q7.

### Protection Circuits

Protective circuits are added on chip to improve reliability and to make regulators immune to certain types of overloads. They protect the regulators against short circuit conditions (current limit), against excessive input-output-voltage differential conditions (safe area limit) and against excessive junction temperatures (thermal limit).

#### *Current Limit or Short-Circuit Protection*

The most commonly used protection scheme is current limiting for guarding the output series-pass transistor against excessive output currents or short circuit conditions (see *Figure 1-6*). With low input-output conditions when Zener diode D1 is not conducting, there is no current flowing through R1. The current limiting transistor Q2, then, senses the voltage drop across the current limiting resistor R3. As the output current increases, the drop across R3 increases; and, as a result, the Q2 base-emitter voltage increases until Q2 begins to conduct thereby removing the base drive of the series-pass transistor Q1. No additional output current can be pulled out since any increase in the output current will cause Q2 to conduct harder. This current-limit circuit has a slight disadvantage, *i.e.*, the voltage developed across R3 adds to the regulator drop-out voltage and degrades the load regulation and output impedance.

A simple way of getting around this problem is to pre-bias the base of the current-limit transistor Q2 with a fraction of the base-emitter voltage of the series-pass transistor Q1 via R6 and R7 as shown in *Figures 1-7a* and *b*. In these three current-limit schemes, the output current decreases with increasing temperature since the base-emitter voltage of the current-limit transistor Q2 is the threshold for preventing the flow of additional regulator output current.

Temperature-independent short-circuit current can be achieved with a slight increase in circuit complexity. *Figure 1-7c* shows the circuit used in the  $\mu A79M00$ -series negative regulators to obtain temperature independent peak output current. At low to medium output current levels, Q4 is on and Q5 and Q6 are off. When the voltage drop across R3 reaches a predetermined level, Q4 begins to turn off and current is diverted to Q5, which in turn causes Q6 to turn on. Q1 and consequently Q2 base currents are thus diverted and the output current is prevented from increasing any further. By proper choice of R1:R2 and emitter area ratio of Q4 and Q5, the peak current is set to be independent of temperature.

#### *Safe Operating Area (SOA)\* Protection*

Safe area protection is included in IC regulators to protect the series-pass transistor against excessive power dissipation by reducing the collector current as the collector-emitter voltage is increased (*Figure 1-6*). When the input-output voltage differential exceeds the breakdown voltage differential of Zener diode D1, current flows from the input to the output through D1, R1, R2 and R3. The voltage drop across R3 and, therefore, the Q2 base voltage become a function of not only the output current but also the input-output voltage differential. Hence, maximum output current is available when the input-output voltage differential is less than the D1 breakdown voltage. The safe area protection network reduces the available output current  $I_{OUT}$  as the input-output differential  $\Delta(V_{IN}-V_{OUT})$  increases at a rate determined by

$$\frac{\Delta I_{OUT}}{\Delta(V_{IN} - V_{OUT})} = - \frac{R2}{R1 R3} \quad (1-13)$$

\*See Chapter 5

The safe area protection network thus reduces the available output current as the input-output differential increases and limits the regulator operation to within the safe operating area of the series-pass transistor. Note that the safe area protection network is lumped in with the short circuit protection network and consequently both have the same temperature characteristics.

When selecting a regulator to operate with high input voltage or with high input-output voltage differential, it must be remembered that output current *decreases* with *increased* input-output voltage differential. Under heavy load and high input-voltage conditions, the safe area protection circuit may cause a high

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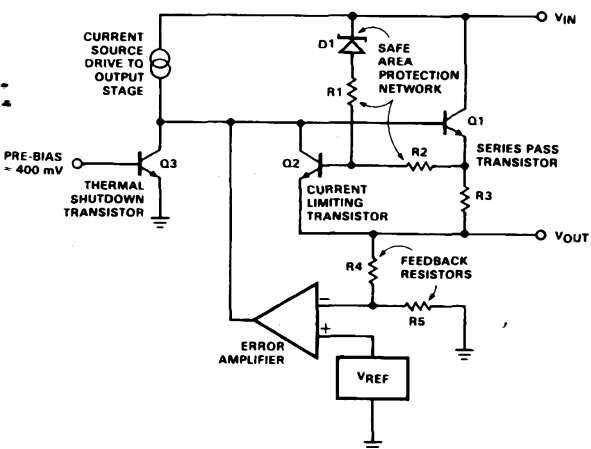


Fig. 1-6 Basic Regulator Protection Circuit

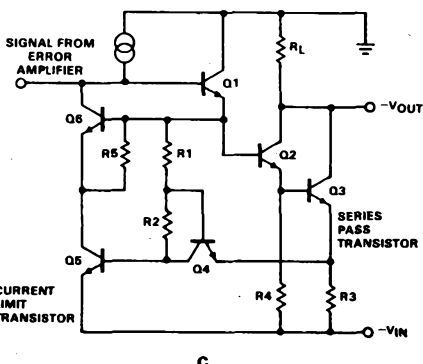
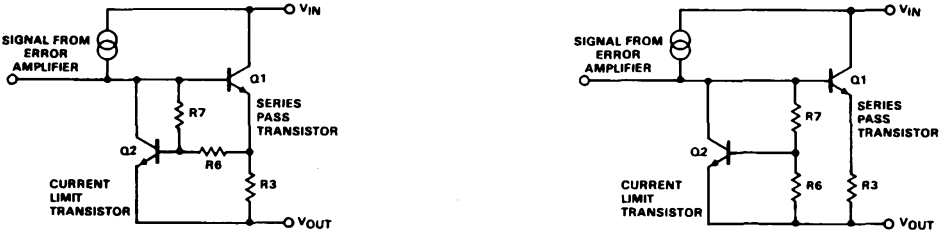


Fig. 1-7 Alternate Current Limit Circuits

output voltage device to latch up after a momentary short, since the input voltage becomes the input-output differential during the short. The regulator may not be able to supply as much current after the fault condition as before. Latching will not damage the regulator; interrupting the power, reducing the load current or the input voltage momentarily will restore normal operation.

### *Thermal Overload Protection*

A discrete regulator usually relies on current limiting for overload protection since there is no practical way to sense junction temperature in a separate series-pass transistor. The dominant failure mechanism of this type of regulator, then, is excessive heating of the series-pass transistor. In a monolithic regulator, the series-pass transistor is contained within the thermal overload-protection circuit where its maximum junction temperature is limited, independent of input voltage, type of overload or degree of package heat sinking. It is, therefore, considerably more effective than current limiting by itself. An added bonus to combined thermal and current overload protection is that a higher output current level under normal conditions can be considered, since there is no excessive regulator heating when a load fault occurs.

The base-emitter junction of a transistor placed as close as practical to the series-pass transistor is used to sense the chip temperature. The thermal shutdown transistor Q3 in *Figure 1-6* is normally biased below its activation threshold so that it does not affect normal operation of the circuit. However, if the chip temperature rises above its maximum limit due to an overload, inadequate heat sinking or other condition, the thermal shutdown transistor turns on, removing the base drive to the output transistor Q1 and shutting down the regulator to prevent any further chip heating.

### **Error Amplifier**

The error amplifier in a regulator can be a simple gain stage or can consist of several amplifier stages depending on the regulator performance. It is an operational amplifier used in a negative feedback mode where the reference is connected to the non-inverting input while the feedback signal from the regulated output is divided down through a pair of feedback resistors (R4 and R5 in *Figure 1-6*). The output voltage in this type of feedback configuration is

$$V_{OUT} = V_{REF} \frac{A}{\beta (1 + A)}$$

where A is the amplifier gain and  $\beta$  is the fraction of the output feedback or  $\beta = \frac{R5}{R4 + R5}$

Improved line and load regulation in regulators results from higher gain. As the amplifier gain is increased, the output impedance drops and the regulator performance improves. Since the error amplifier has a high gain, the output voltage equation can be written as follows.

$$V_{OUT} = \frac{V_{REF}}{\beta} = V_{REF} \frac{R4 + R5}{R5}$$

It is obvious that the lowest output voltage possible with this configuration is when  $R4 = 0$  which results when  $V_{OUT} = V_{REF}$  (unity gain). To obtain a wide range of regulated output voltage, then, a low value of  $V_{REF}$  is an advantage. However, to obtain a high output voltage from a low reference, the feedback ratio  $\beta$  must be low (in other words, high value of R4). As the loop gain decreases the regulator performance degrades, affecting such parameters as line and load regulation and output impedance.

The error amplifier, like an op amp, requires some compensation for stability. Most regulators have on-chip compensation and, depending on the type or the application, may require additional external compensation. Excessive compensation, however, causes the error amplifier gain to fall off at high frequencies, thus deteriorating regulator performance.

### **Series-Pass Element**

The maximum input voltage and the maximum output current of the regulator determine the size of the series-pass transistor. In the higher output current devices, such as the  $\mu A7800$  and the  $\mu A7900$  series, the output transistor and its metallization pattern occupy nearly half of the die area.



One of the benefits of including the series-pass transistor on the chip is that the integrated circuit needs only three terminals, hence, an ordinary transistor power package can be used. Another important advantage is that thermal as well as current overload protection can be incorporated on the chip in close proximity to the series-pass device.

## CIRCUIT DESCRIPTIONS OF SERIES REGULATORS

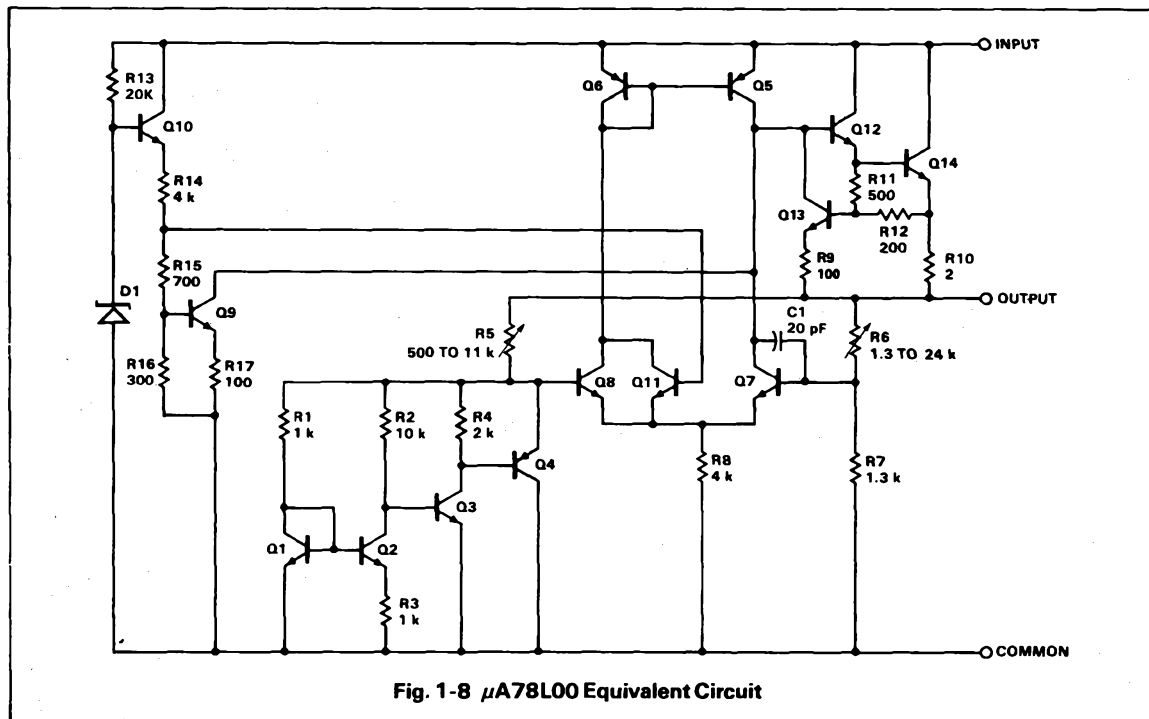
Certain portions of the various regulator circuits are common to one group within the regulator family. For instance, the  $\mu A7800$  and the  $\mu A78M00$  series are identical except for their series-pass transistors. The 4-terminal adjustable regulators are identical to their 3-terminal counterparts (the  $\mu A78G$  and  $\mu A7800$ ,  $\mu A79G$  and  $\mu A7900$ , etc.) except for the feedback resistors. The following descriptions of the various regulator circuits, fixed-voltage devices followed by the adjustable types, are arbitrarily arranged in order of increasing device terminals. The positive versions are followed by the negative counterparts. A selection guide and short form data are provided in Chapter 2.

### Positive 3-Terminal Regulators

The positive 3-terminal regulators cover the largest range of output current, from 100 mA to 5 A, output voltages from 2.6 to 24 V, and are available in a variety of packages.

#### $\mu A78L00$ Series

The  $\mu A78L00$  series is the simplest of the 3-terminal regulators (Figure 1-8). It is capable of delivering 100 mA output current and is available in nine output voltages ranging from 2.6 to 24 V and two popular packages, metal TO-39 and plastic TO-92. The start-up circuit, comprised of Zener diode D1, transistor Q10 and resistors R14, R15, R16, provides a bias level that is less than the reference at the Q11 base. Collector and base currents of Q6 flow through Q11 at the instant the power is turned on. When the device reaches regulation, the reference causes Q8 to turn on thereby diverting the current from Q11.

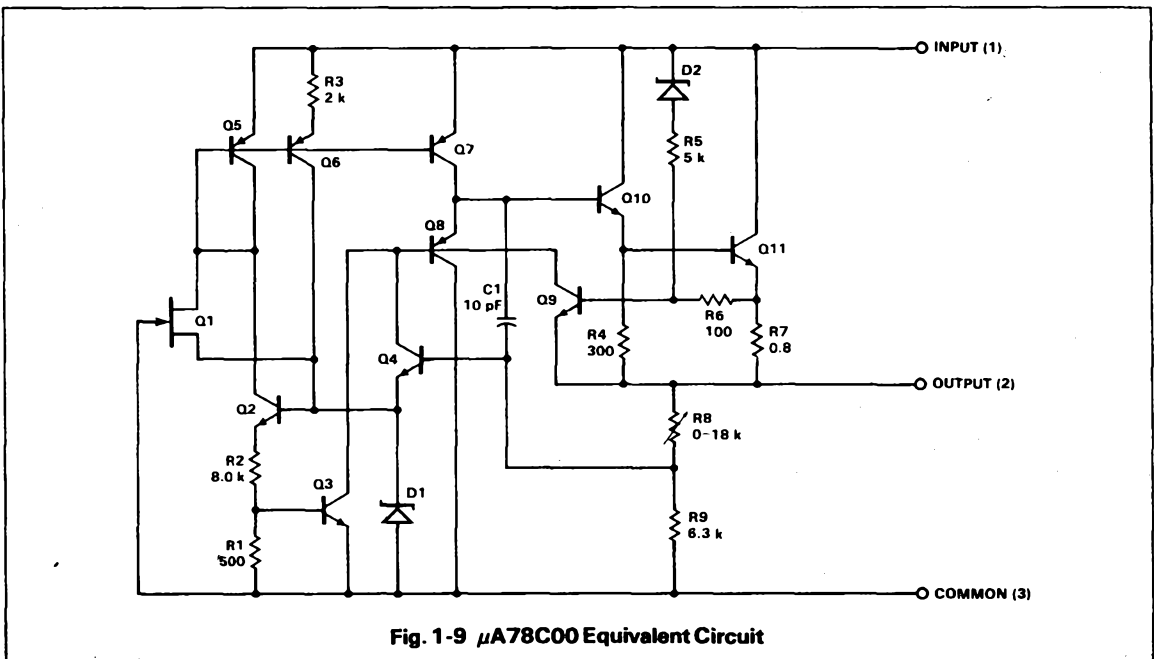


The output voltage also provides a constant current of about 2 mA to the reference through resistor R5. The voltage reference is a band-gap type with a nominal value of 1.3 V consisting of Q1 through Q4 and R1 through R4. The error amplifier is a differential pair consisting of Q7 and Q8 with active pnp loads, Q5 and Q6, for high gain. The current through the error amplifier is set by the reference voltage, the base-emitter drop of Q8, and R8. The feedback resistors, R6 and R7, determine the output voltage.

Capacitor C1 is included on the chip for stability. The output stage uses a Darlington consisting of Q12 and Q14. Thermal-shutdown transistor Q9, which is physically placed near Q14, is pre-biased from the start-up circuit at approximately 400 mV at 25°C and limits the chip temperature to a safe value under overload conditions. Short-circuit protection is achieved by Q13 which is pre-biased by a fraction of the base-emitter voltage of the series-pass transistor. It should be noted that the  $\mu$ A78L00 series does not need safe-area protection because the series-pass transistor is designed to handle the short circuit current at the maximum input voltage. This may appear as an overdesign but, when dealing with current levels this low, the die area needed to include safe area protection would be greater than the area used to over-design the series-pass transistor.

**$\mu$ A78C00 Series**

The  $\mu$ A78C00 series is a low cost regulator intended mainly for consumer applications. It is capable of delivering 0.5 A current and is available in popular output voltages to 24 V in the Power Watt package, (similar to TO-202). Figure 1-9 shows the equivalent circuit of the  $\mu$ A78C00 regulator. The reference is derived from Zener diode D1 and compensated by the base-emitter voltage of the error amplifier Q4. Additional gain is provided by Q7 and Q8 to the Darlington-connected emitter-follower output stage of Q10 and Q11. The output stage is compensated by capacitor C1. A positive start-up condition is ensured by FET transistor Q1 to provide base current to transistors Q2 and Q5. Q2, Q5 and Q6 then form a positive feedback loop which raises the base voltage of Q2 until the reference Zener D1 conducts. Thermal overload protection is achieved by transistor Q3. The bias to the base-emitter voltage of Q3 is derived from D1 via Q2 and the divider network of R1 and R2. At high junction temperatures, Q3 turns on and removes the drive to the output stage. Current limit transistor Q9 protects the device against accidental shorts by sensing the voltage drop across R7 while Zener diode D2 along with Q9 and resistors R5, R6, and R7 limit the power dissipation to a safe value.



**Fig. 1-9  $\mu$ A78C00 Equivalent Circuit**

### $\mu$ A78M00/ $\mu$ A7800 Series

The  $\mu$ A78M00 and the  $\mu$ A7800 regulators are schematically identical (Figure 1-10); they differ only in maximum current capability, 0.5 A and 1 A respectively. Component value differences (R9, R11, R16) are shown with the  $\mu$ A7800 value in parenthesis. Transistors Q1 through Q7 and their associated resistors constitute a temperature compensated reference of 5 V. The Darlington configuration, Q3 and Q4, is the error amplifier lumped into the voltage reference. The error amplifier gain is increased by the pnp transistor Q11 which acts as a buffer to drive the active collector load formed by the pnp current-source transistor pair, Q8 and Q9.

The current through Q8 and Q9 is set up by the current through resistor R1. During regulator turn on, the current in R1 flows first through transistor Q13, part of the start-up circuit containing Zener diode D1, transistors Q12 and Q13, and resistors R5, R6 and R7. After the device is in regulation, Q13 is biased off and the regulator takes over setting the current in R1, which then flows through Q5 and Q10.

Thermal protection is provided by transistor Q14 with the base clamped by the resistive divider string, R5, R6 and R7, in the start-up circuit. At a junction temperature of about 175°C, Q14 turns on and removes the base current to the output stage, thus turning the series-pass transistor Q17 off and preventing further increase in chip temperature.

The short-circuit protection transistor Q15 is pre-biased from the base-emitter voltage drop of the series-pass transistor Q17 via resistors R12 and R21. As the output current increases, the drop across R11 increases, causing the base voltage of Q15 to increase also. When the output current reaches the preset level, Q15 begins to turn on, shunting the base current of the output stage and preventing any further increase in output current.

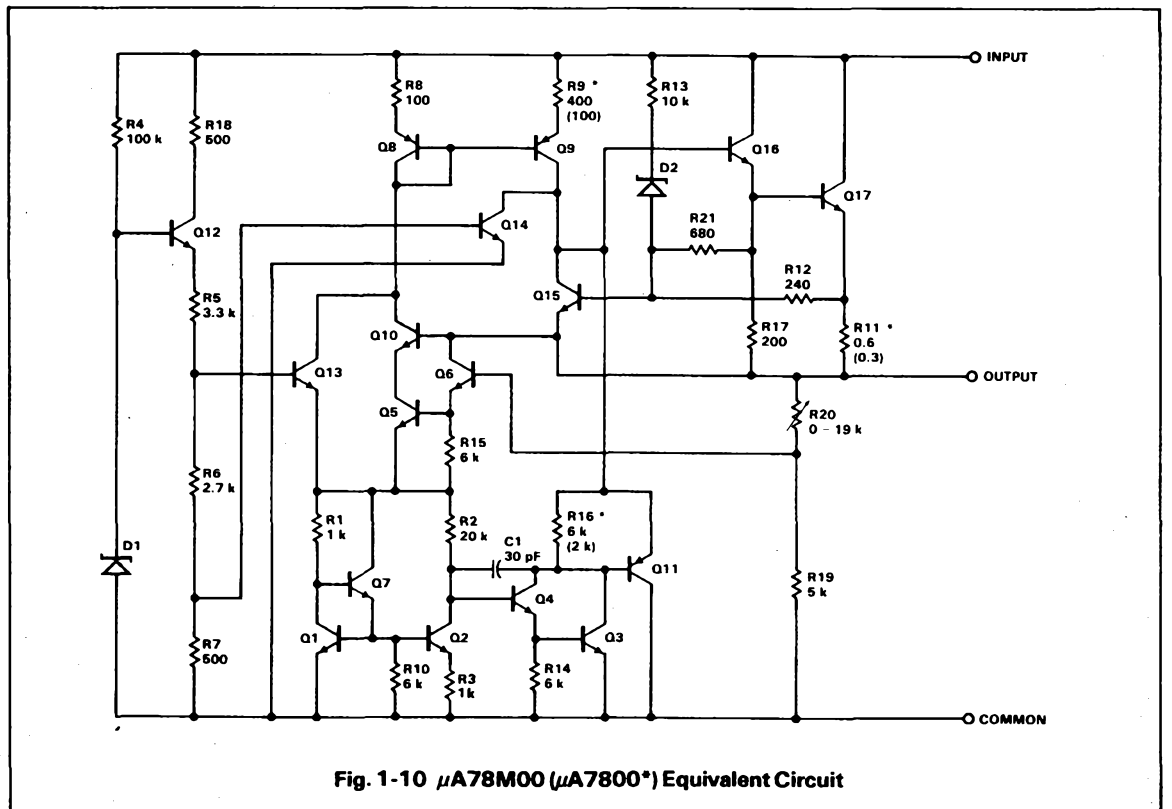


Fig. 1-10  $\mu$ A78M00 ( $\mu$ A7800\*) Equivalent Circuit

Safe-area protection, accomplished via resistors R11, R12, R13, Zener diode D2 and Q15, limits the instantaneous power through the series-pass transistor to a safe value by decreasing the maximum regulator current as the input-output voltage differential is increased.

The  $\mu$ A7800 and  $\mu$ A78M00 are available in popular fixed output voltage options ranging from 5 to 24 V. The output voltages are internally fixed during manufacture by selection of the feedback resistor ratio of R19 and R20. The  $\mu$ A78M00 series is available in the metal TO-39 and plastic TO-220 while the  $\mu$ A7800 series is packaged in the metal TO-3 and plastic TO-220.

#### *$\mu$ A109 Series*

The  $\mu$ A109 series includes the  $\mu$ A109,  $\mu$ A209 and  $\mu$ A309 3-terminal regulators with fixed output voltages of 5 V and 1 A output current capabilities. Schematically, the circuit is identical to that of the  $\mu$ A7805 (Figure 1-10) except for R12 which is a 180  $\Omega$  resistor; device operation is the same. The lower value of R12 increases the peak output current and changes the characteristics of the safe-area circuit so that the device can deliver higher output current for the same input-output voltage. The  $\mu$ A109 operates over the full military temperature range while the  $\mu$ A209 is for industrial-temperature operation. The  $\mu$ A309 is the relaxed version. All are packaged in the TO-3.

#### *$\mu$ A78CB, 13.8 V, 2 A Positive Regulator*

The  $\mu$ A78CB is a positive 13.8 V 2 A regulator available in metal TO-3 and plastic TO-220 packages. It has the same features as the  $\mu$ A7800 series with 20 W dissipation capability. Schematically, it is identical to the  $\mu$ A7800 of Figure 1-10 except for the short-circuit sense resistor R11 which is 0.2  $\Omega$  to set the peak current over 3 A at 25°C, and the feedback resistor R20 which is 8 k to set the output voltage to a nominal value of 13.8 V. The device is intended as a fixed 13.8 V regulator for home-base CB stations, and as an automotive power supply for driving accessories directly from the AC line through a transformer, a full wave rectifier and a filter capacitor.

#### *$\mu$ A78H00 Series*

The  $\mu$ A78H00 series are hybrid regulators with 5 A output current capability with all the inherent characteristics of the monolithic 3-terminal regulators, *i.e.*, full thermal overload, short-circuit and safe-area protection. The 78H00s are constructed using state-of-the-art hybrid circuit technology and are packaged in hermetically sealed TO-3s providing 50 W power dissipation. They are available with 5, 12 and 15 V options. Each regulator consists of a  $\mu$ A78M00 monolithic chip driving a discrete series-pass element Q1 and two short-circuit detection transistors Q2 and Q3 (Figure 1-11). A beryllium-oxide substrate is used in conjunction with an isothermal layout to optimize the thermal characteristics of the device and still maintain electrical isolation between the various chips. This ensures nearly ideal thermal transfer between the series-pass device Q1 and the temperature sensing circuit within the  $\mu$ A78M00, thus providing the thermal-limiting feature to the regulator. Output voltage  $V_{OUT}$  is derived from the  $\mu$ A78M00 chip which also provides the basic blocks for the regulator as well as serving as buffer and driver for the series-pass element. When a load is placed across the output terminals, the load current supplied by the  $\mu$ A78M00 is sensed by resistor R2 which then develops a voltage drop that forward biases the emitter-base junction of Q1. At this time, the  $\mu$ A78M00 begins to supply base current to Q1 which supplies the bulk of the load current ( $\approx 95\%$ ) during operation.

The output circuit is designed so that the worst-case current requirement of the Q1 base added to the current through R2 always remains below the current-limit threshold of the  $\mu$ A78M00. Resistor R1 in conjunction with Q2 and Q3 make up a current sense and limit circuit to protect the series-pass device from excessive current drain. As the output current begins to increase, the voltage drop across R1 starts to forward bias the Q3 emitter-base junction. As Q3 conducts, its collector current flows through the Q2 base; thus Q2 begins to conduct and therefore shunts away some of the current available to the Q1 base. This process continues until a natural state of electrical equilibrium is reached, at which time 78H00 is in a current-limit mode of operation. Capacitor C1 provides frequency stability by adding a pole in the output-circuit transfer function that lowers the overall loop gain below the critical levels at high frequencies.

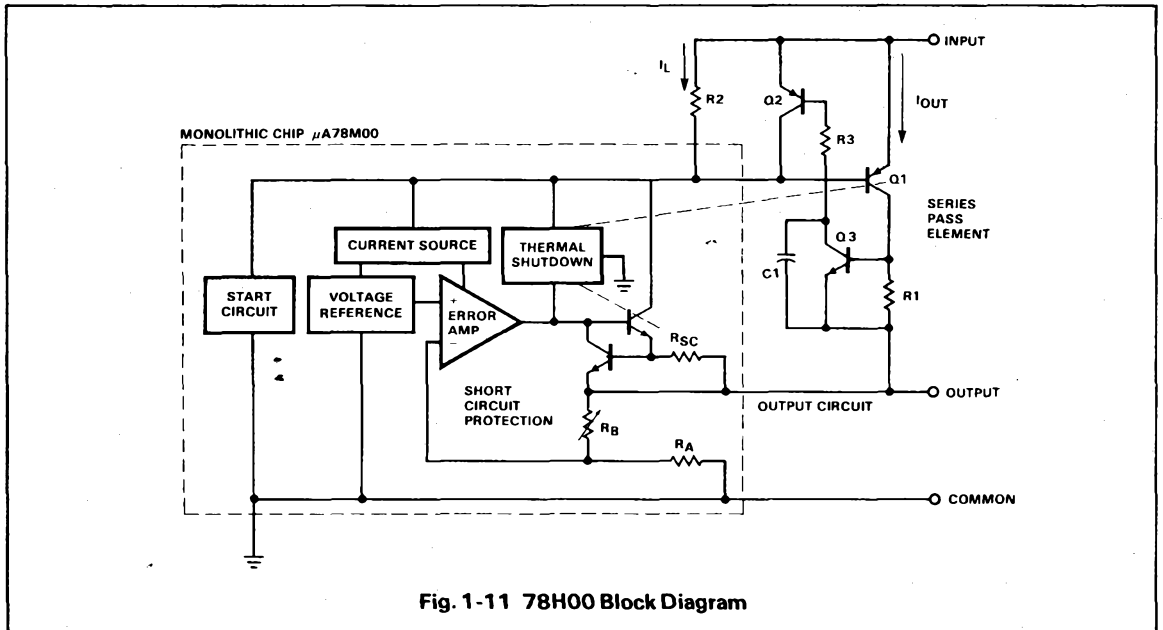


Fig. 1-11 78H00 Block Diagram

Safe area protection is achieved by brute force. The series-pass transistor is capable of handling the short-circuit current at the maximum input voltage rating of the 78H00. Output voltage sensing is performed at the device output pin so that the error amplifier can correct for any output voltage errors caused by finite impedances in the output circuit such as lead bonds and metal traces.

### Negative 3-Terminal Regulators

The negative 3-terminal regulators are the complements of the positive regulators discussed above. They are available in the same output voltage options, have the same protective features, and can be used in combination with positive regulators or by themselves. They are available with 0.5 A output current ( $\mu\text{A79M00}$ ) in TO-39 and TO-220 packages, and 1 A output ( $\mu\text{A7900}$ ) in TO-3 and TO-220 packages.

#### $\mu\text{A79M00}$ Series

The equivalent circuit for the  $\mu\text{A79M00}$  series is shown in Figure 1-12. The start-up circuit consists of Zener diode D1 and transistors Q1 and Q2. Once the regulator starts, transistor Q2 is turned off and the reference Zener diode D2 is biased from a current source transistor Q7 whose current is set by the Zener reference D2, Q3, Q4 and the reference resistors R1, R2 and R20. The reference circuit has two temperature compensated levels. The lower reference is a  $-2.23$  V derived from Zener diode D2 and transistors Q3 and Q4. This reference is used in the 5 to 8 V output options. Higher output voltage options use a  $-6.2$  V reference derived from D2, Q6, Q7 and their associated resistors. Note that a fraction of the Q6 base-emitter voltage obtained from R3 and R4 compensates for the positive temperature coefficient of Zener diode D2. The purpose of the two voltage references is to allow a wide output voltage range without a sacrifice in device performance as explained in the Error Amplifier section.

The voltage reference circuit also provides the bias for the error amplifier consisting of Q10 through Q13 via Q9 and R8. The error amplifier is a differential pair with an active load, Q14 and Q15. The reference input ( $-2.23$  V or  $-6.20$  V) to the error amplifier is applied to the base of Q10 (non-inverting input) while the error voltage is applied from the feedback network of R24 and R25 to the base of Q11 (inverting input). The output of the error amplifier is fed to the series-pass transistor Q20 via Q17, R12 and Q18. Frequency compensation of the error amplifier is accomplished with resistors R9, R10 and capacitors C1 and C2. In addition, an external capacitor (from output to ground) is necessary since the series-pass transistor is operating in the common-emitter mode.

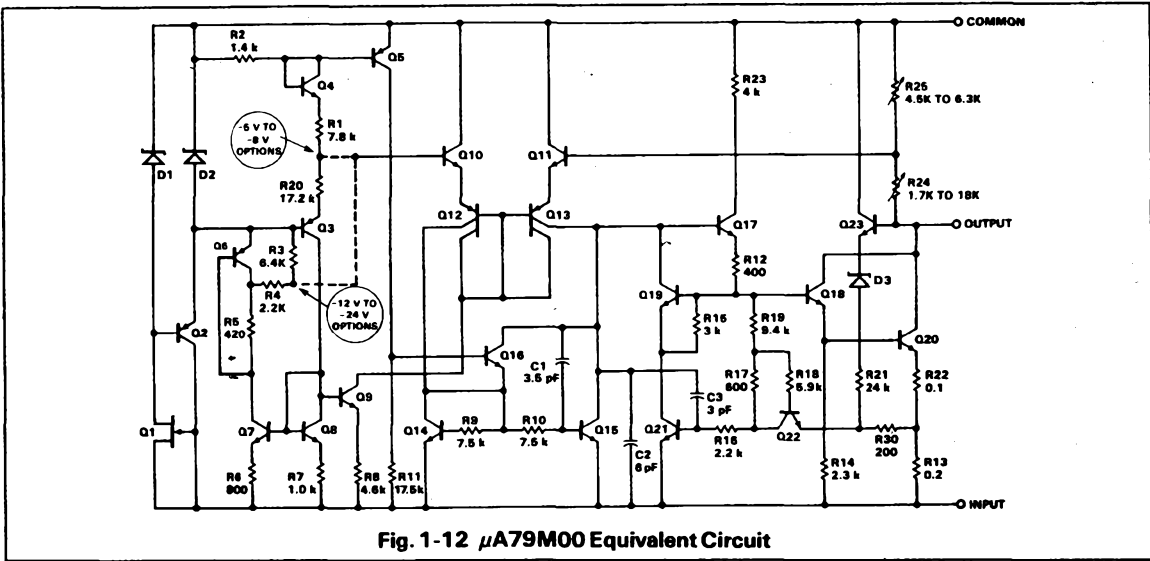


Fig. 1-12  $\mu\text{A79M00}$  Equivalent Circuit

The  $\mu\text{A79M00}$  series has three protective circuits. Short-circuit protection is provided by sensing the voltage drop across R13. When this drop exceeds 130 mV, transistor Q22 is biased off and Q19 and Q21 are turned on, shunting base drive from Q17 via Q19. As explained earlier in this chapter, the short circuit current is made nearly temperature independent by selecting the area ratio of Q21 and Q22 and the resistance ratio of R17 and R19. R16, R18 and C3 provide compensation for the short-circuit protection circuit, preventing oscillations during short circuit conditions. Thermal overload protection is provided by Q5, Q16, R2 and R11. When the  $V_{BE}$  of Q5 decreases sufficiently with rising temperature, Q16 is turned on and current is shunted from Q17. Finally, the safe-area protection circuit, formed by Q23, D3 and resistors R21 and R30, detects the collector-to-emitter voltage of the series-pass transistor Q20 and decreases the maximum available regulator current as the input-output differential voltage is increased.

#### $\mu\text{A7900}$ Series

The  $\mu\text{A7900}$  series is very similar to the  $\mu\text{A79M00}$  series except for the short circuit protection scheme (Figure 1-13). By removing Q22 and its associated resistors from the  $\mu\text{A79M00}$ , the peak output current of the  $\mu\text{A7900}$  is made temperature dependent with a negative temperature coefficient just like the positive 3-terminal regulators.

#### Positive Adjustable Regulators

Although versatile and easy to use, the 3-terminal regulator has one drawback – the output voltage is internally fixed, thereby limiting the user to around a half-dozen popular output voltages. Applications requiring variable or non-standard output voltages dictate the use of either external components with the 3-terminal devices at a sacrifice in performance or multi-terminal devices at an increase in complexity.

#### $\mu\text{A78MG}/\mu\text{A78G}/\mu\text{A78HG}$ Positive Adjustable 4-Terminal Regulators

The 4-terminal regulator has solved the dilemma by offering all of the unique features of its 3-terminal counterpart along with an adjustable output determined by an external resistor ratio. The equivalent circuit diagram of the  $\mu\text{A78MG}/\mu\text{A78G}$  regulators in Figure 1-14 is identical to that of the  $\mu\text{A78M00}/\mu\text{A7800}$  series in Figure 1-10 except that the feedback resistors are omitted and the base of Q6 is brought out as the Control terminal. Component value differences (R9, R11, R16) are shown with the 78G values in parentheses. The  $\mu\text{A78MG}$  is a 0.5 A device while the  $\mu\text{A78G}$  is a 1 A device. The output current capability can be increased substantially by the use of one or more external transistors. With an available control or feedback terminal and two external resistors, the designer can set the output voltage anywhere from 5 to 30V. The  $\mu\text{A78MG}$  is available in the Power Watt, (similar to TO-202) the power mini DIP or the 4-lead TO-39 package. The  $\mu\text{A78G}$  is offered in the Power Watt (similar to TO-202) and the 4-lead TO-3 packages.

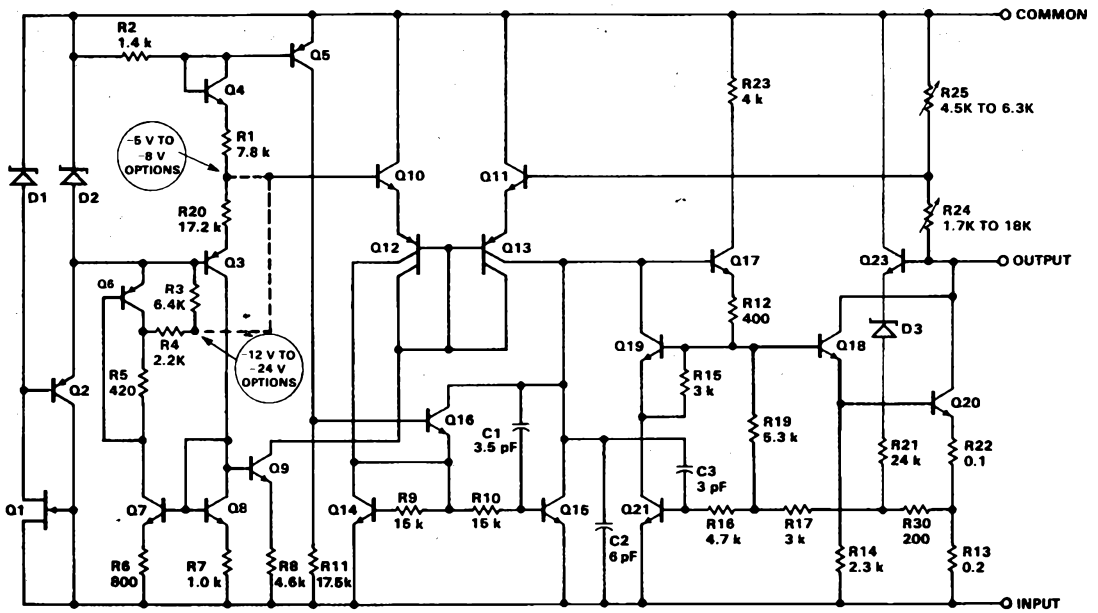


Fig. 1-13  $\mu$ A7900 Equivalent Circuit

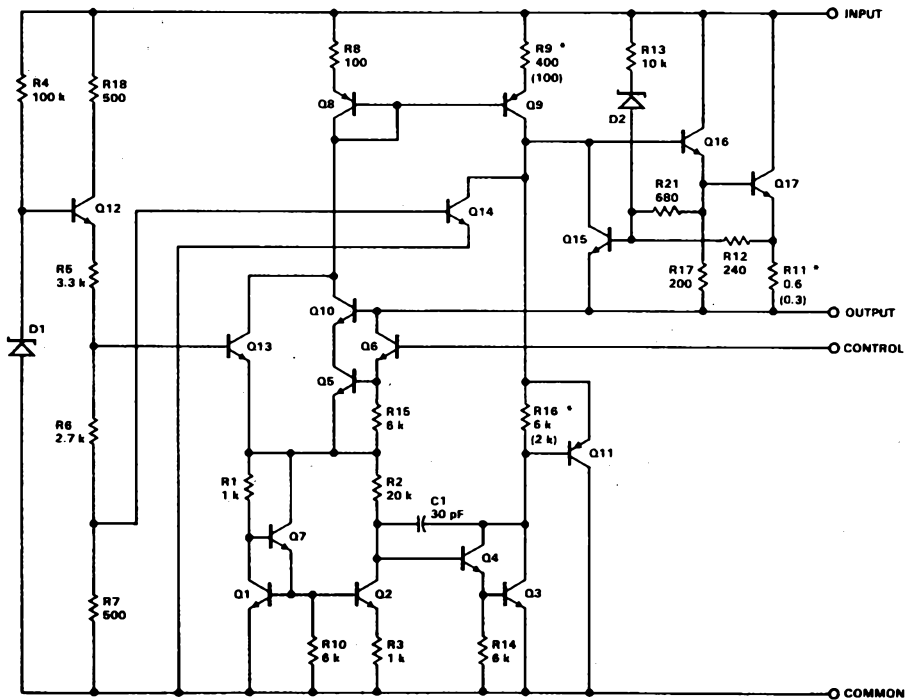


Fig. 1-14  $\mu$ A78MG ( $\mu$ A78G\*) Equivalent Circuit

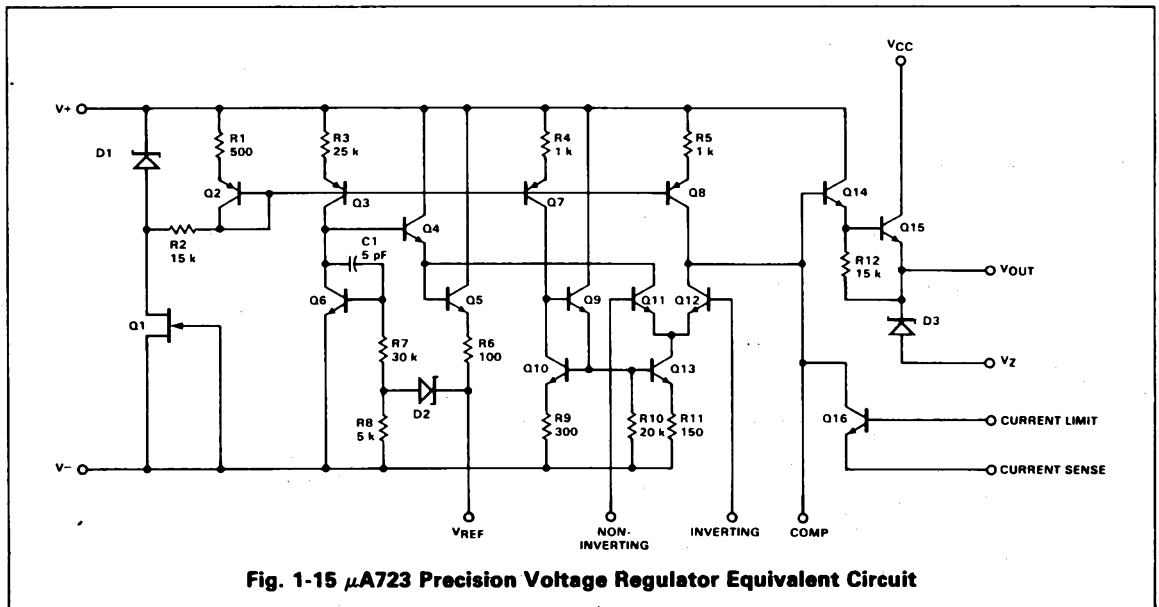
The 78HG hybrid 4-terminal adjustable regulator with 5 A output current capability is schematically identical to the 78H00 series (*Figure 1-11*) except that the feedback resistors RA and RB are omitted and the inverting input of the error amplifier is brought out as the control terminal. The regulator consists of a  $\mu$ A78MG monolithic chip driving a discrete series-pass transistor Q1 and two short-circuit detection transistors Q2 and Q3. Just as the 78H00 series, the 78HG has all the inherent characteristics of the monolithic regulators and is constructed using state-of-the-art hybrid circuit technology. It is packaged in the 4-lead TO-3 package and is capable of 50 W power dissipation.

#### $\mu$ A723 Precision Regulator

The  $\mu$ A723, commonly regarded as a universal building block (*Figure 1-15*) in power supply design, is available in the 14-lead ceramic or plastic DIP and the 10-lead TO-100 and has the following features.

- Internally generated reference voltage directly available in buffered form.
- Both inputs of the error amplifier available for use with other than positive grounded configurations.
- Collector of the internal series-pass device available at a separate lead ( $V_C$ ).
- Voltage level shifting available ( $V_Z$  output) through an internal Zener diode (14-lead DIP version only).
- Adjustable output voltage from 2 to 37 V.
- Output current to 150 mA with no external pass transistor.

Bias supplies for the entire circuit are obtained by first generating a stabilized voltage with respect to the  $V_+$  line across Zener diode D1, which is supplied with a constant current from FET Q1. The Zener voltage is then used to drive the bias voltage that controls the current sources to the rest of the regulator. The basic voltage reference elements are Zener diode D2 and the Q6 base-emitter voltage. Q4 and Q5 provide current as well as buffering to D2 so that current may be taken from the reference terminal for certain applications. Resistor R7 and MOS capacitor C1 are included on the chip to eliminate the need for external compensation of the reference loop. Note that the full 7.1 V of the reference need not be tied to the error amplifier. For applications requiring output voltages less than 7.1 V, a fraction of the reference can be taken to the non-inverting input of the error amplifier by merely adding a pair of resistors to divide down the reference.



**Fig. 1-15  $\mu$ A723 Precision Voltage Regulator Equivalent Circuit**



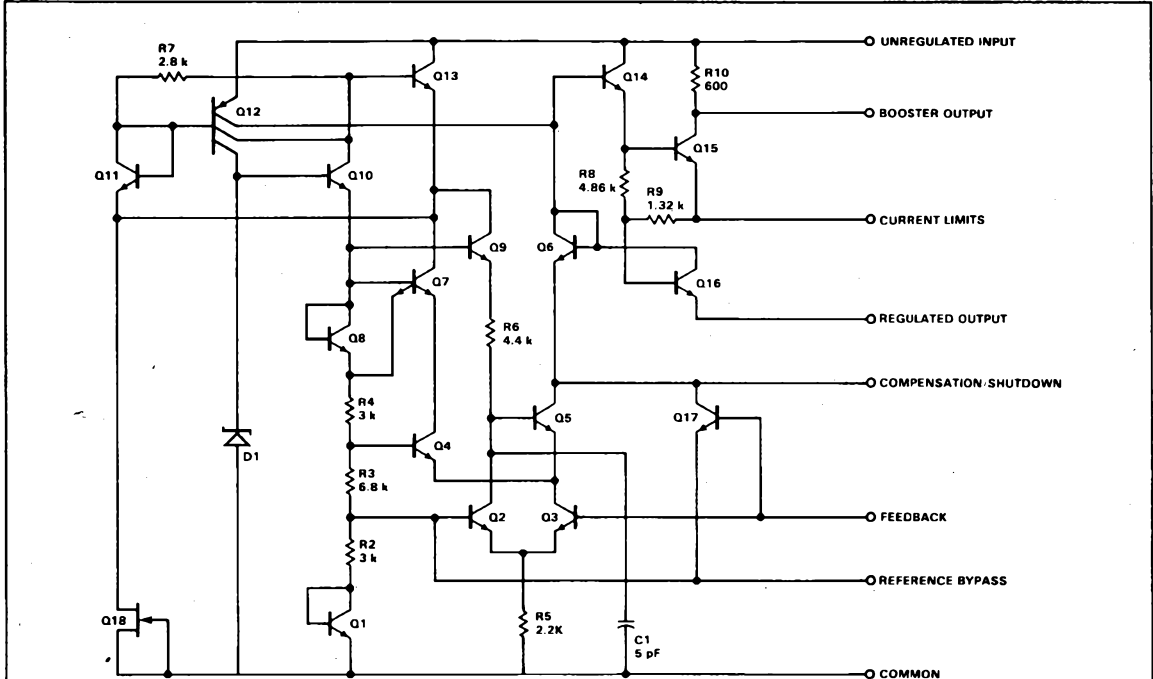
The error amplifier consists of the differential pair Q11 and Q12 driven by current source Q13 which is mirrored from Q7 by Q10. The active load for Q12 is a pnp current source Q8; therefore, in a balanced condition, *i.e.*, when Q11 and Q12 base voltages are equal, Q11 and Q12 collector currents are both equal. Q11 collector is returned to a stabilized voltage source in the reference supply to maintain high line rejection in the amplifier. In operation,  $V_{REF}$ , or a voltage derived from  $V_{REF}$ , is applied to the noninverting input (Q11 base) and a voltage proportional to the required output voltage is applied to the inverting input, Q12 base. When the feedback loop is closed via the  $\mu A723$  output stage and an external series-pass transistor, if used, the two error amplifier inputs are forced into a balanced condition, thus defining the output voltage in terms of  $V_{REF}$  and the appropriate resistor ratios.

The output stage consists of a double emitter follower, Q14 and Q15, to prevent excessive loading on the Q12 collector. This, in conjunction with the high impedance of the active load, Q8, allows adequate gain to be obtained from the single stage amplifier. This also simplifies frequency compensation; a single capacitor connected from Q12 collector, Comp terminal, to either Q12 base or ground is sufficient to provide stable operation in all applications. Zener diode D3, available in the dual in-line package version only, is included for level shifting purposes.

Transistor Q16 is the current limiting transistor. When an external current-sensing resistor forward biases the Q16 base-emitter junction at a particular load-current level, the Q16 collector sinks most of the available current from the current source Q8. This cuts off the output stage and limits the output current. Note, by applying a command signal to the base, the current limiting transistor can be used to turn the regulator output voltage completely off.

**$\mu A105$  Series Regulators**

The  $\mu A105$  series includes the  $\mu A105$  and  $\mu A305$ , each rated with a maximum output current of 12 mA, the  $\mu A305A$  rated at 45 mA and the  $\mu A376$  rated at 25 mA (Figure 1-16). These regulators have an adjustable output voltage range as low as 4.5 V. They are packaged in the 8-lead TO-99 or 8-lead Mini Dip.



**Fig. 1-16  $\mu A105$  Series Equivalent Circuit.**

The  $\mu$ A105 voltage reference is derived from Zener diode D1 and transistors Q10, Q8 and Q1. By proper selection of R2, R3 and R4, a temperature stable reference of 1.7 V is obtained at the base of Q2. This point is accessible to the user at Reference Bypass, pin 5, so that an external capacitor can be added to bypass any noise coming from the reference Zener diode D1. Start-up of the regulator is achieved through FET Q18 and the multi-collector pnp current-source transistor Q12, which provides the bias current for the reference as well as the error amplifier and the output stage.

The differential pair, Q2 and Q3, forms the first stage of the error amplifier which has a gain of 20. The 1.7 V reference is internally tied to the non-inverting input of the error amplifier and is brought out for external bypassing of the reference. This configuration differs from that of the  $\mu$ A723 since it commits the reference to the non-inverting input and restricts the user to a fixed reference (1.7 V). The inverting input of the error amplifier is the base of Q3 and is brought out to the Feedback terminal. The second stage of the error amplifier consists of Q4 and Q5 with one of the collectors of Q12 as the load. In normal operation, both stages of the error amplifier are balanced over the device operating temperature range, regardless of the absolute value of components, thus giving the error amplifier a good drift characteristic. Frequency compensation is accomplished with internal capacitor C1, which prevents loop oscillations due to the high gain of the error amplifier, and an external integrating capacitor around the error amplifier, which makes the error amplifier insensitive to loading conditions.

The output stage is a double emitter follower consisting of Q14 and Q15. Transistors Q6 and Q16 perform the current-limiting function by removing the drive to the output stage when an overload condition is sensed externally between Current Limit and Regulated Output terminals. Q17 prevents latch-up that may occur with low output voltage settings. Without Q17, should Q3 saturate, it would cut off the second stage of the error amplifier, Q4 and Q5, and cause the output voltage to latch at a voltage nearly equal to the unregulated input.

### **Negative Adjustable Regulators**

Negative regulators are not widely used as positive regulators, therefore, as one might expect, the selection is not as large. Nevertheless, sufficient options are available to cover most applications.

#### *79MG/79G Negative Adjustable 4-Terminal Regulators*

The 78MG/79G negative adjustable regulators are similar to their positive counterparts, the 78MG/78G 4-terminal adjustable regulators, and are offered in the same package options. They are derived from the  $\mu$ A79M00 and  $\mu$ A7900 respectively, using the lower of the two available references. Except for the feedback resistors, the  $\mu$ A79MG is schematically identical to the  $\mu$ A79M00 (compare *Figures 1-12 and 1-17*), and the  $\mu$ A79G to the  $\mu$ A7900 (*Figures 1-13 and 1-18*). In the  $\mu$ A79MG/79G, the base of Q11 is brought out as the Control terminal. Device operation is the same except that output adjustment of the  $\mu$ A79MG/79G is left to the user's choice of a pair of external resistors. Both the 79MG and the 79G have an adjustable output range from  $-30$  to  $-2.23$  V with input voltage range from  $-40$  to  $-7$  V. They are designed to deliver continuous load currents of up to 0.5 A for the 79MG and 1 A for the 79G.

#### *$\mu$ A104 Series Regulators*

The  $\mu$ A104 family includes the  $\mu$ A104 and the  $\mu$ A304 regulators that can supply up to 25 mA output current without external pass transistors. The voltage reference and error amplifier circuits are designed so that the output voltage range is adjustable from 0 to  $-30$  V for the  $\mu$ A304 and 0 to  $-40$  V for the  $\mu$ A104. They are packaged in the 10-lead TO-100.

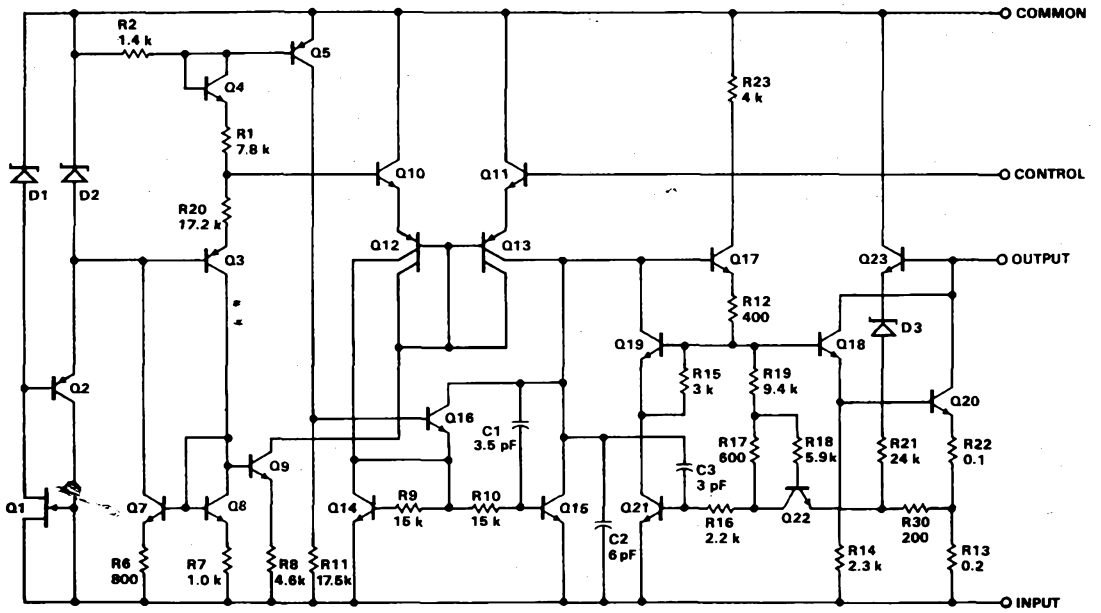


Fig. 1-17  $\mu$ A79MG Equivalent Circuit

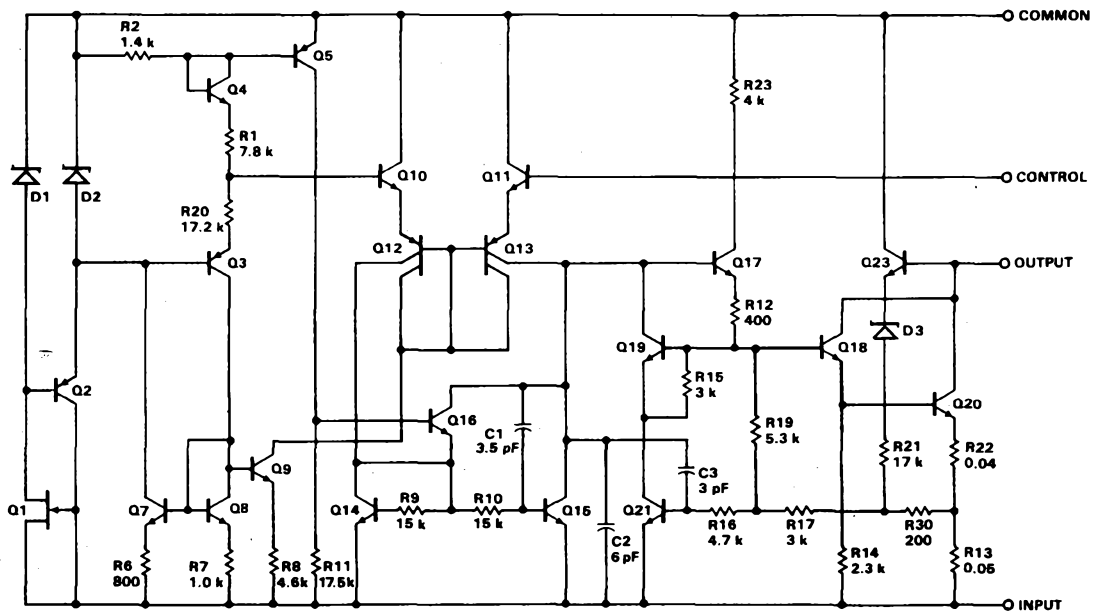


Fig. 1-18  $\mu$ A79G Equivalent Circuit

Figure 1-19 shows the equivalent circuit of the  $\mu$ A104 family. The reference voltage between the Reference and Reference-Supply terminals is derived from Zener diode D1 and compensated by the series network, Q7, R4, Q2, Q1, Q4, Q5, and R3. This configuration yields a compensated reference of  $-2.4$  V. When a known value resistor is placed between these two terminals, the collector currents of Q1 and Q2 can be fixed. A second resistor connected between the Common and Adjustment terminals provides the reference to the error amplifier, Q18 and Q19, through R17. Emitter-follower transistors Q18 and Q19 drive the common-base dual pnp transistor Q17. Epitaxial FET Q9 biases the current-source transistors Q12 and Q13. By using active collector loads and a triple Darlington output stage, sufficient gain is achieved to prevent the output stage from loading the input stage. R14 limits the base drive to Q23 during saturation, a condition that may occur with low input voltages. The error amplifier operates with common-mode voltages up to ground and consequently the regulator functions with output voltages to 0 V. To prevent the reference circuit from saturating with low input-output differentials, the inverting input of the error amplifier is connected through the divider network of R15 and R16 to the output. R17 matches the impedance seen by the Q19 base and also minimizes offset errors in the amplifier. Transistor Q24 is the current limiter and the current limit loop is compensated by R11 and C1.

For stable device operation, an external capacitor is required between output and common. On-chip capacitor C2 compensates for the series resistance of the external capacitor and is brought to the outside for use if additional compensation is required.

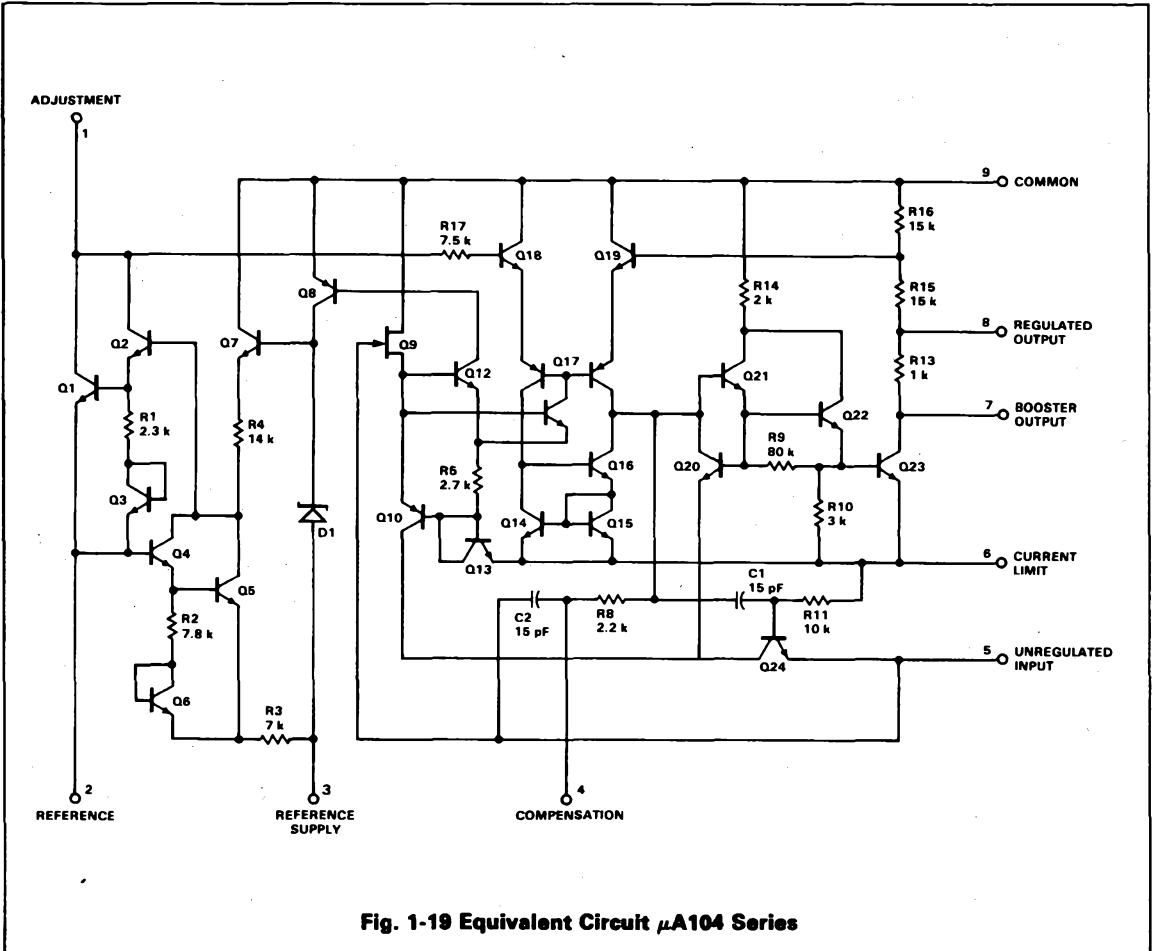


Fig. 1-19 Equivalent Circuit  $\mu$ A104 Series

## SWITCHING REGULATORS

*Series-pass* regulators have dominated the power supply regulator market because they are simple, easy to use, offer high performance, and a wide range of high quality circuits is available from a number of manufacturers. Increasing concern about wasted power has caused designers to seriously consider switching regulators, which are not only much more efficient but also provide output voltages *higher or lower* than the input voltage supplied. In addition, they can provide an output voltage of the *opposite polarity*.

The switching mode voltage regulator offers the advantage of high efficiency over the more common series or shunt regulation schemes. This is particularly apparent when there is a large difference between the input voltage and the regulated output voltage. Consider, for example, a voltage regulator with 28 V input and an output of 5 V at 1 A. A conventional series regulator would require a drop of 23 V across the pass transistor. Thus, 23 W are wasted, and the efficiency is only 18%. Switching regulators, however, can be simply designed to give efficiencies greater than 75% under the same input and output restrictions.

Switching regulators are also useful in applications where cost, rather than efficiency, is the prime design criterion. The designer may trade the cost of a high power series pass transistor for a slight increase in circuit complexity that allows the use of lower power switching transistors.

One area of caution when using switching regulators is the generation of electromagnetic and radio frequency interference (EMI and RFI). Solutions to these problems generally revolve around the use of feed-through low pass filters isolating the lines to the regulator, and careful mechanical design to suppress radiated interference.

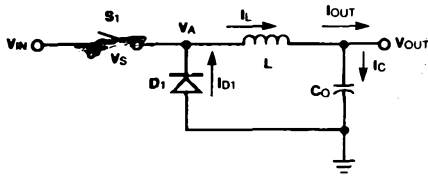
Switching regulators do have some drawbacks. They are complex, require some external components, and should be used with some degree of care. They generate noise and an output ripple, and are slower to respond to transient load conditions. However, these disadvantages can be minimized and are overshadowed by the very high efficiency (up to 90%) of switching regulators. With good control electronics, attention to timing, and some filtering, switching regulators can be used in power supply designs that provide lower operating costs and reduce power dissipation. A new integrated circuit switching regulator subsystem, the  $\mu$ A78S40, makes possible a variety of switching or series-pass regulator systems with minimum external parts.

Switching regulators are capable of storing energy and cycling on and off as necessary to supply adequate power to the load. They store energy in inductors and capacitors, which do not dissipate power. (Series-pass regulators apply the input/output differential voltage across a pass transistor, which *does* dissipate power.) Output transistors act as switches with the on/off cycle rate determined by the input/output voltages and the load current. Control circuitry monitors the output voltage and modifies timing to maintain a constant output voltage. While the regulator is off, energy is stored in an output capacitor which averages the current flow to the load. The basic modes of operation provide *increased, decreased, or inverted* voltage at the output from a fixed input voltage.

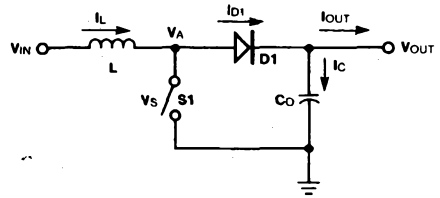
Figure 1-20 illustrates the three basic operating modes of a switching regulator. The same basic components – a switch, a diode to direct current, an inductor and a capacitor to store energy – are used for the step-down, step-up, and inverting modes.

### Step-Down Regulator

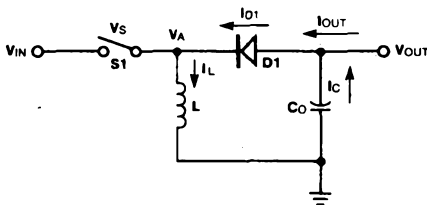
A simple step-down voltage regulator is shown in Figure 1-20a. When Switch  $S_1$  closes, the voltage  $V_A$  rises close to  $V_{IN}$  ( $V_{IN}-V_S$ ), and the voltage  $V_A-V_{OUT}$  is applied across the inductor causing the



**a Step-Down Voltage Regulator**



**b Step-Up Voltage Regulator**



**c Voltage Inverter**

$V_{OUT}$  = Unregulated Output Voltage, V  
 $V_{IN}$  = Unregulated Input Voltage, V  
 $V_S$  = Switch Voltage, V  
 $V_D$  = Diode Voltage Drop, V  
 $i_{pk}$  = Peak Current in A  
 $t_{on}$  = On Time in  $\mu s$   
 $t_{off}$  = Off Time in  $\mu s$   
 $L$  = Inductor in  $\mu H$   
 $C_O$  = Output Capacitor in  $\mu F$

**Fig. 1-20 Basic Operating Modes**

current to increase from zero at a rate of  $(V_A - V_{OUT})/L$ . This current flows from the switch through the inductor and into the load and output capacitor. If the instantaneous inductor current,  $i_L$ , is less than the load current, the capacitor provides the additional current and  $V_{OUT}$  decreases slightly. When  $i_L$  exceeds the output current the remaining current flows into the capacitor, increasing  $V_{OUT}$ ;  $i_L$  will increase until the switch turns off. At this instant, since the inductor current cannot change instantly,  $V_A$  falls to  $-V_D$  so diode  $D_1$  can turn on and provide the inductor current. The voltage across the inductor is now  $-(V_{OUT} + V_D)$ ; so the inductor current will change at a rate of  $-(V_{OUT} + V_D)/L$ . The inductor current continues to fall toward zero until  $S_1$  turns on again, and the cycle is repeated. The electronics in the system controls the on- and off-time of  $S_1$  so that the average inductor current equals the output current; the average capacitor current will be zero and  $V_{OUT}$  will remain constant. The control circuit generally consists of an oscillator whose on- and off-times are set so that  $i_L$  will increase to a maximum current of  $I_{pk}$  and then decrease to zero, and a sense circuit that senses the output voltage and increases the off-time (by blocking the oscillator output) if  $V_{OUT}$  increases too high. In this type of system a maximum  $i_{OUT}$  of  $I_{pk}/2$  is possible, and for  $i_{OUT}$  less than  $I_{pk}/2$  the control circuit increases the off-time by an amount such that the average  $i_L$  equals  $i_{OUT}$ .

The peak current for a step-down regulator is determined by the input voltage, switch voltage, output voltage, inductor size, and the switch on-time, or conversely the on-time is set to give the desired peak current.

$$I_{pk} = \frac{V_{IN} - V_S - V_{OUT}}{L} \cdot t_{on}$$

In a similar manner, the off-time for  $i_L$  to drop to zero is related to  $I_{pk}$ ,  $V_{OUT}$ ,  $V_D$ , and  $L$ .

$$I_{pk} = \frac{V_{OUT} + V_D}{L} \cdot t_{off}$$

The ideal ratio of  $t_{on}$  to  $t_{off}$  is a function of  $V_{IN}$ ,  $V_{OUT}$ ,  $V_D$ , and  $V_S$ .

$$\frac{t_{on}}{t_{off}} = \frac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$$

The maximum output current for this timing is

$$I_{OUT(MAX)} = I_{pk}/2$$

the average input current is  $I_{pk}/2$  times the percentage of time the switch is on.

$$I_{IN(avg)} = \frac{I_{pk}}{2} \cdot \frac{t_{on}}{t_{on} + t_{off}} = \frac{I_{pk}}{2} \cdot \frac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$$

The efficiency of this regulator is

$$EFFICIENCY = \frac{V_{OUT}}{V_{OUT} + V_D} \cdot \frac{V_{IN} - V_S + V_D}{V_{IN}}$$

If  $V_S$  and  $V_D$  go to zero the efficiency goes to 100%; therefore if  $V_S$  and  $V_D$  are small compared to  $V_{IN}$  and  $V_{OUT}$  very high efficiencies can be achieved. The ripple on the output is a function of  $I_p$ ,  $t_{on}$ ,  $t_{off}$  and  $C_O$  and can always be reduced by increasing  $C_O$  without affecting any other portion of the circuit.

$$V_{PEAK \text{ RIPPLE}} = I_{pk} \cdot \frac{(t_{on} + t_{off})}{8 C_O}$$

## Step-Up Regulator

Switching regulators operating in a step-up mode, *Figure 1-20b*, provide an output voltage greater than the input voltage. In the case of a step-up regulator, when the switch closes, the applied voltage drops to almost zero ( $V_A = V_S$ ), and voltage  $V_{IN} - V_S$  is applied across the inductor, causing the inductor current to increase linearly. Because the applied voltage is less than the output voltage, the diode is reverse-biased and current cannot flow to the output. Again, when the switch opens, the inductor current cannot change instantly, and the applied voltage changes to the total of the output voltage plus the diode voltage. At this time current can flow through the diode to the load capacitor, and the inductor current decreases at a linear rate, determined by  $V_{OUT} - V_D - V_{IN}$ . Timing adjustments control the average diode current ( $I_{D1}$ ) so it is equal to the load current. The diode current can only flow during off-time, so the maximum output current is  $(I_{pk}/2) (t_{off}/t_{on} + t_{off})$ . If the load current is less than the maximum output current, off-time is increased by a dead time with no current to the output. Input current can flow during both on and off-times, so the average input current is always greater than the maximum output current.

The on-time in a step-up regulator is a function of  $V_{IN}$ ,  $V_S$ , and  $L$  while  $t_{off}$  is a function of  $V_{IN}$ ,  $V_{OUT}$ ,  $V_D$ , and  $L$ .

$$t_{on} = \frac{I_{pk} \cdot L}{V_{IN} - V_S}$$

$$t_{off} = \frac{I_{pk} \cdot L}{V_{OUT} + V_D - V_{IN}}$$

The  $t_{on}$  to  $t_{off}$  ratio is a function of circuit voltages as is the maximum output current.

$$\frac{t_{on}}{t_{off}} = \frac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$$

$$I_{OUT(MAX)} = \frac{I_{pk}}{2} \cdot \frac{V_{IN} - V_S}{V_{OUT} + V_D - V_{IN}}$$

$$I_{IN(AVG)} = \frac{I_{pk}}{2}$$

The efficiency is also a function of  $V_{IN}$ ,  $V_{OUT}$ ,  $V_S$ , and  $V_D$  and approaches 100% as  $V_S$  and  $V_D$  become small compared with  $V_{IN}$  and  $V_{OUT}$ .

$$\text{EFFICIENCY} = \frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D - V_S}$$

Output ripple is a function of  $I_{pk}$ ,  $I_{OUT}$ ,  $t_{off}$ , and  $C_O$  and can again be reduced by increasing  $C_O$  without affecting circuit performance.

$$V_{PEAK \text{ RIPPLE}} = \frac{(I_{pk} - I_{OUT})^2}{2 I_{pk}} \cdot \frac{t_{off}}{C_O}$$

### Voltage Inverter Regulator

The basic voltage inverter is shown in Figure 1-20c. This circuit generates a negative output for a positive input. When  $S_1$  turns on,  $V_A$  rises to  $V_{IN} - V_S$ , and this voltage is impressed on the inductor, causing current to increase at a linear rate. When  $S_1$  turns off, the inductor current cannot change instantaneously, so  $V_A$  drops to  $(-V_{OUT} - V_O)$ , forward biasing  $D_1$ . Current now decays at a linear rate.  $i_{D1}$  supplies current to the output capacitor and load and its average value must be equal to the load current. Input current flows only when  $S_1$  is on and is therefore equal to  $I_{pk}/2 \cdot (t_{on}/t_{on} + t_{off})$ .



The basic formulas for the voltage inverter are shown below. As in the other circuits, optimum  $t_{on}$  and  $t_{off}$  values are functions of  $V_{IN}$ ,  $V_{OUT}$ ,  $V_S$ ,  $V_D$ , and  $L$  while the ratio of  $t_{on}/t_{off}$  is dependent only on the voltages.  $I_{OUT(max)}$  is always less than  $I_{pk}/2$ , but then so is the average input current. Efficiency depends on input and output voltages and is basically independent of current level. Ripple can be minimized as usual by increasing the value of  $C_O$ .

$$I_{pk} = \frac{V_{IN} - V_S}{L} \cdot t_{on}$$

$$I_{pk} = \frac{|V_{OUT}| + V_D}{L} \cdot t_{off}$$

$$\frac{t_{on}}{t_{off}} = \frac{|V_{OUT}| + V_D}{V_{IN} - V_S}$$

$$I_{OUT(MAX)} = \frac{I_{pk}}{2} \cdot \frac{V_{IN} - V_S}{V_{IN} + |V_{OUT}| + V_D - V_S}$$

$$I_{IN(avg)} = \frac{I_{pk}}{2} \cdot \frac{|V_{OUT}| + V_D}{V_{IN} + |V_{OUT}| + V_D - V_S}$$

$$EFFICIENCY = \frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{|V_{OUT}|}{|V_{OUT}| + V_D}$$

$$V_{PEAK RIPPLE} = \frac{(I_{pk} - I_{OUT})^2}{2 I_{pk}} \cdot \frac{t_{off}}{C_O}$$

**The  $\mu A78S40$  Universal Regulator**

In order to operate effectively in step-down, step-up, and inverting modes, a switching regulator should have several functional building blocks common to all of its operational modes, minimizing the need for external parts and maximizing its versatility. The  $\mu A78S40$  universal regulator meets this goal and allows a wide variety of regulators to be built with minimum external parts. This regulator's functional blocks are illustrated in *Figure 1-21* and outlined below; design formulas are shown in Table 1-1.

- A Current-Controlled Oscillator
- A Temperature-Compensated Current-Limiting Circuit
- A Temperature-Compensated Voltage Reference
- An Error Amplifier
- A Power-Switching Circuit
- A High-Gain Amplifier

The current-controlled oscillator has drive circuitry for the transistor power switch. Oscillator frequency is set by an external capacitor so it can be varied according to application. The oscillator duty cycle is internally fixed at 8:1. A current-limiting circuit controls oscillator on-time, adjusting the duty cycle for optimum timing. This temperature-compensated current-limiting circuit senses the switching transistor current across an external resistor and modifies the oscillator on-time, limiting the peak current and protecting the switching transistors.

CHARACTERISTIC	STEP DOWN	STEP UP	INVERTING
$I_{pk}$	$2 I_{OUT(max)}$	$2 I_{OUT(max)} \cdot \frac{V_{OUT} + V_D - V_S}{V_{IN} - V_S}$	$2 I_{OUT(max)} \cdot \frac{V_{IN} +  V_{OUT}  + V_D - V_S}{V_{IN} - V_S}$
$R_{SC}$	$0.33 V/I_{pk}$	$0.33 V/I_{pk}$	$0.33 V/I_{pk}$
$t_{on}$	$\frac{I_{pk} \cdot L}{V_{IN} - V_S - V_{OUT}}$	$\frac{I_{pk} \cdot L}{V_{IN} - V_S}$	$\frac{I_{pk} \cdot L}{V_{IN} - V_S}$
$t_{off}$	$\frac{I_{pk} \cdot L}{V_{OUT} + V_D}$	$\frac{I_{pk} \cdot L}{V_{OUT} + V_D - V_{IN}}$	$\frac{I_{pk} \cdot L}{ V_{OUT}  + V_D}$
$\frac{t_{on}}{t_{off}}$	$\frac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$	$\frac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$	$\frac{ V_{OUT}  + V_D}{V_{IN} - V_S}$
$L$	$\frac{V_{OUT} + V_D}{I_{pk}} \cdot t_{off}$	$\frac{V_{OUT} + V_D - V_{IN}}{I_{pk}} \cdot t_{off}$	$\frac{ V_{OUT}  + V_D}{I_{pk}} \cdot t_{off}$
$C_T (\mu F)$	$45 \times 10^{-5} t_{off}(\mu S)$	$45 \times 10^{-5} t_{off}(\mu S)$	$45 \times 10^{-5} t_{off}(\mu S)$
$C_O$	$\frac{I_{pk} \cdot (t_{on} + t_{off})}{8 V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \cdot t_{off}}{2 I_{pk} \cdot V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \cdot t_{off}}{2 I_{pk} \cdot V_{ripple}}$
Efficiency	$\frac{V_{IN} - V_S + V_D}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D}$	$\frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D - V_S}$	$\frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{ V_{OUT} }{ V_{OUT}  + V_D}$
$I_{IN(avg)}$ (Max load condition)	$\frac{I_{pk}}{2} \cdot \frac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$	$\frac{I_{pk}}{2}$	$\frac{I_{pk}}{2} \cdot \frac{ V_{OUT}  + V_D}{V_{IN} +  V_{OUT}  + V_D - V_S}$
$V_{ripple}$	$\frac{I_{pk} (t_{on} + t_{off})}{8 C_O}$	$\frac{(I_{pk} - I_{OUT})^2}{2 I_{pk}} \cdot \frac{t_{off}}{C_O}$	$\frac{(I_{pk} - I_{OUT})^2}{2 I_{pk}} \cdot \frac{t_{off}}{C_O}$

**Table 1-1. 78S40 Design Formulas**

A 1.3 V temperature-compensated voltage reference source can provide up to 10 mA of current without an external pass transistor. A high-gain differential comparator disables the power switch when the output voltage becomes too high. A power Darlington switching transistor handles 1.5 A of current and can withstand up to 40 V. The switch collectors and the emitter drive are externally available to allow optimized connection of the switch. A power-switching diode handles 1.5 A of forward current and 40 V of reverse voltage.

The high-gain independent operational amplifier has 150 mA output current capability and a separate positive voltage supply connection. Its input common mode range *includes* ground. It may be connected to provide series-pass regulation or feedback control for switching regulators.

This switching regulator can operate over a wide range of power conditions, from battery power to high-voltage, high-current supplies. Low voltage requirements with minimum current drain make the regulator very useful in battery or 5V systems. It typically operates from 2.2 to 40 V dc. At the 5 V level, the regulator draws only 2 mA. A low standby-current drain significantly improves regulator efficiency in low-power applications and greatly increases battery lifetime in battery applications. This high efficiency in low-power applications is *not* typical of other switching systems. Combined with the capability of the  $\mu A78S40$  to handle up to 40 V input and provide as much as 1.5 A switching current, efficient low power operation makes the regulator performance over a wide operating range unmatched.

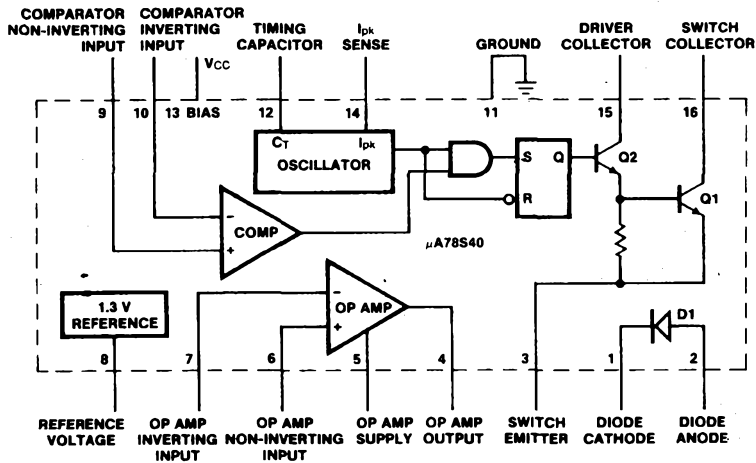


Fig. 1-21  $\mu A78S40$  Universal Regulator Partitioning

Using a versatile circuit such as this requires some care, but the benefits are well worth the attention since this IC subsystem provides the user with the flexibility for optimizing power supply performance. A critical parameter is oscillator timing. Although the on-time/off-time ratio is internally fixed at 8:1, the user can adjust this ratio down through the proper selection of peak current, the oscillator capacitor value, the inductor value, and the input/output voltages. Peak current is determined solely by the current-limiting circuit. Selection of the timing capacitor is based on the off-time required. The user should establish the off-time and let the current-limiting circuit modify the on-time. This off-time can be set by the user for either intermittent or continuous operation. For intermittent operation, the user should set the off-time equal to the time required for the inductor current to drop to zero. For continuous operation, the off-time should be set at something less than the time required for the inductor current to drop to zero. When operated in the continuous mode, average inductor current exceeds 1/2 of the peak current, making more power available at the output. However, timing is very critical (*see box on following page*), and if on-time and off-time periods are too short, switching losses can significantly reduce efficiency. With this regulator, on-time and off-time should be kept greater than 10  $\mu s$ .

Switching is accomplished by a Darlington pair with the switch emitter as well as both transistor collectors available for external connection. Either the collector inputs or the emitter output can be used. If the emitter output is used, the collector inputs can be shorted, resulting in a switch voltage of 1.6 V typical. If the collector inputs are used with the emitter grounded, the user must consider the performance tradeoffs between shorting both collectors or using the switch output. System performance is affected by the input and output voltages, the output current, and the expected variations of the input voltage. If both collectors are shorted, there is no switching loss due to base current (switch voltage is typically 1.1 V). If the switch output is used, base drive through the driver is provided by connecting an external resistor to the input voltage line (switching voltage is typically 0.5 V). A switching diode in the circuit is capable of handling voltage up to 40 V and current up to 1.5 A for both step-up and step-down modes. To use the regulator for inverting applications, an external diode is required because the diode voltage drops below the circuit common.

## **SWITCHING REGULATOR TIMING CONSIDERATIONS**

Optimization of regulator on-time and off-time depends on **CIRCUIT VARIABLES** such as inductance and switch and diode voltage – and on **SYSTEM VARIABLES** such as input/output voltages. Consider the following conditions and consequences.

- On-time too short – Inductor peak current isn't high enough, so the maximum output current is reduced. However, efficiency does not suffer.
- On-time too long, or off-time too short – Without current limiting, after several cycles the inductor current will exceed the expected peak current and continue to increase, which could lead to excessive current flow and **DEVICE DESTRUCTION**.
- Off-time too long – Inductor current falls to zero and stays there for some time before the switch turns on again. Consequently, average inductor current is less than half of peak current, and the available output current is reduced. However, efficiency does not suffer.
- On-time too long – Current limiting for the switch is unacceptable when the inductor current is constant at the peak current, because inductor voltage drops to zero. Therefore, switch voltage increases (to  $V_{IN}-V_{OUT}$ ), creating a large efficiency loss and possibly **DESTROYING** the switch.
- Off-time too short with on-time adjusted by current limit – No efficiency is lost, but the inductor current does not drop to zero. Therefore, average inductor current is in excess of half of peak current, and the maximum output current exceeds half of the peak current.



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## **TESTING AND RELIABILITY**

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## Chapter 2 TESTING AND RELIABILITY

### TESTING VOLTAGE REGULATORS

All Fairchild voltage regulators are factory-tested with automated equipment to ascertain that they meet or exceed guaranteed specifications. The testing equipment operates at relatively high speeds and automatically measures output voltage tolerances, line and load regulation, quiescent current, short-circuit current, and a long list of other voltage regulator parameters. To adequately interpret published voltage-regulator specifications, it is advisable to have some understanding of the testing as performed at Fairchild. This is also important for customer incoming inspection, as some correlation is necessary between factory testing and customer acceptance testing.

Individual parameter tests performed on Fairchild voltage regulators require only a few milliseconds, so a complete regulator test can be accomplished in a fraction of a second. Such short testing times mean that the device junction temperature is very close to ambient. If the devices were tested under steady-state conditions, costs would unfortunately increase, and the increased expense would be passed on to the customer. Consequently, published parameters are based on fast testing and usually specified with a constant junction temperature of 25°C. Exceptions are noted in the individual data sheet tables.

When a regulator is operated with high dissipation, however, the effect of temperature drift must be evaluated or at least considered. For example, a  $\mu$ A7805 1 A positive voltage regulator with a junction temperature of 25°C, a 10 V input, and a load current variation of 1.5 A has a guaranteed load regulation of less than 50 mV for military-grade units and less than 100 mV for commercial-grade units. Under steady-state testing conditions, as opposed to pulsed testing conditions, junction temperature would increase by 30°C to 55°C (based on a 4°C/W junction-to-case thermal resistance and an infinite heat sink). The  $\mu$ A7805 regulator has a temperature coefficient of -1.1 mV/°C, so a 30°C junction-temperature increase means an output voltage drift of -33 mV. This drift must be considered if load regulation is being measured under steady-state conditions.

Incoming inspection tests should accommodate these conditions. One approach would be to duplicate the testing procedure used by manufacturing, i.e., maintain a constant junction temperature of 25°C. If steady-state testing is performed during acceptance evaluation, a correlation between the method used in incoming inspection and the method used by Fairchild must be established. In this case, the temperature coefficients of each regulator type must be considered.

### 3-Terminal Regulators

Testing of 3-terminal regulators is performed at input voltages that reflect actual use conditions. The input-output voltage differential considers all of the variations associated with nominal, unregulated power supplies. For example, a 12 V regulator ( $\mu$ A7812) test uses a 7 V I/O voltage differential and considers the following parameters:

- Device Input-Output Voltage Differential - 2 V Nominal
- Line Voltage Reference - 10%
- Filtered Supply Ripple - 10%
- Line Regulation - 10%
- Diode Drop and Source Impedance Variations - 1 V.

This is expressed in the following equation:

$$V_{IN} = V_{OUT(max)} + (V_{IN} - V_{OUT}) + \text{Ripple} + \text{Line Reg} + V_D = 12.6 \text{ V} + 2 \text{ V} + 1.46 \text{ V} + 1.6 \text{ V} + 1 \text{ V} = 18.66 \text{ V}$$

A 12 V regulator, then, is not only tested with a guard band, but the input voltage range used allows for greater variation than is present in actual operating conditions. All Fairchild 3-terminal regulator tests are based on similar practical considerations.

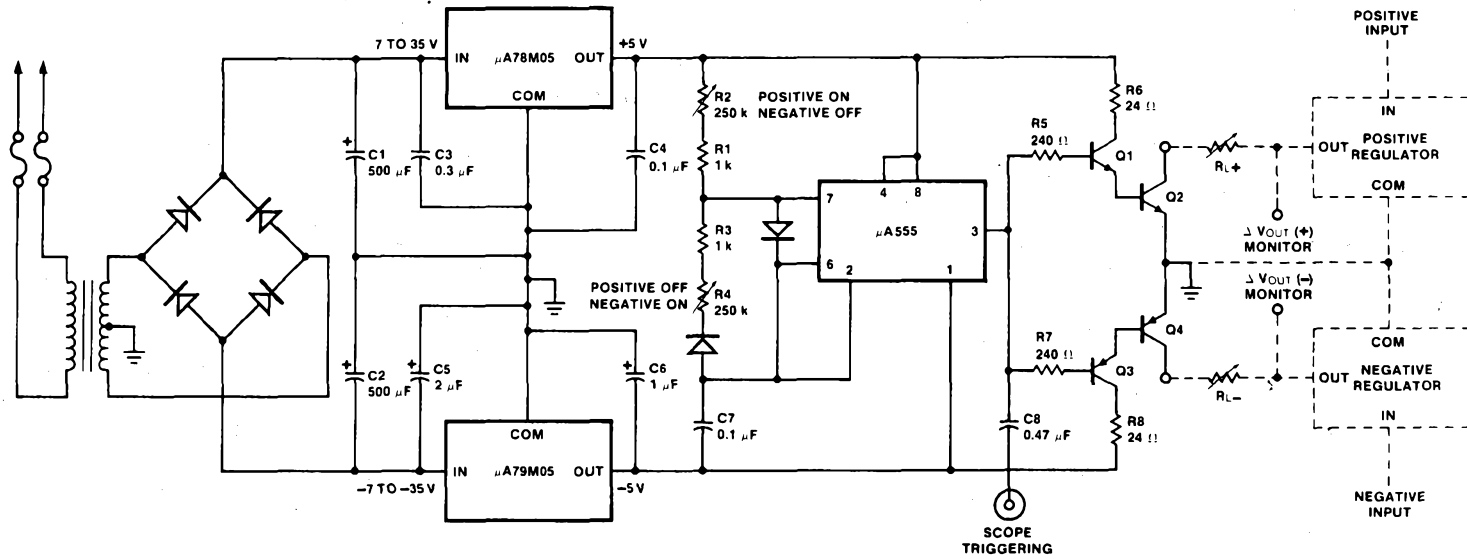




Figure 2-1 shows a self-contained load-pulsing circuit that can be used for measuring load regulation of either a positive or negative regulator. The  $\mu$ A555 timer operates in the astable mode as a free-running multivibrator. Transistors Q2 and Q4, along with the load resistors  $R_L$ , provide the required loading across the regulator outputs. The on and off times of Q2 and Q4 are set by potentiometers R2 and R4. Transistors Q2 and Q4 must be capable of handling the load current levels to be measured. Line regulation of positive or negative regulators can be measured using the circuits in Figure 2-2. Here a pulse generator switches the input voltages between  $V_{IN (min)}$  and  $V_{IN (max)}$  but a similar arrangement could be used by substituting a  $\mu$ A555 timer for the pulse generator.

**Ripple Rejection**

Ripple rejection is the ratio (in dB) of the regulator input ac component (or the output of the sine wave generator) to the output ac component of the device under test. Its measurement is quite straightforward.

Ripple rejection of Fairchild regulators is normally specified at a load current of 30 to 50% of the rated output of the device. This is more realistic than the 20 mA or so specified by some other manufacturers. A regulator with good ripple rejection at low output currents may not necessarily maintain this feature at moderate-to-high current levels unless special effort is made during the layout of the integrated circuit to keep the reference circuit on isotherms (equal temperature lines) and away from the heat source (series-pass element).

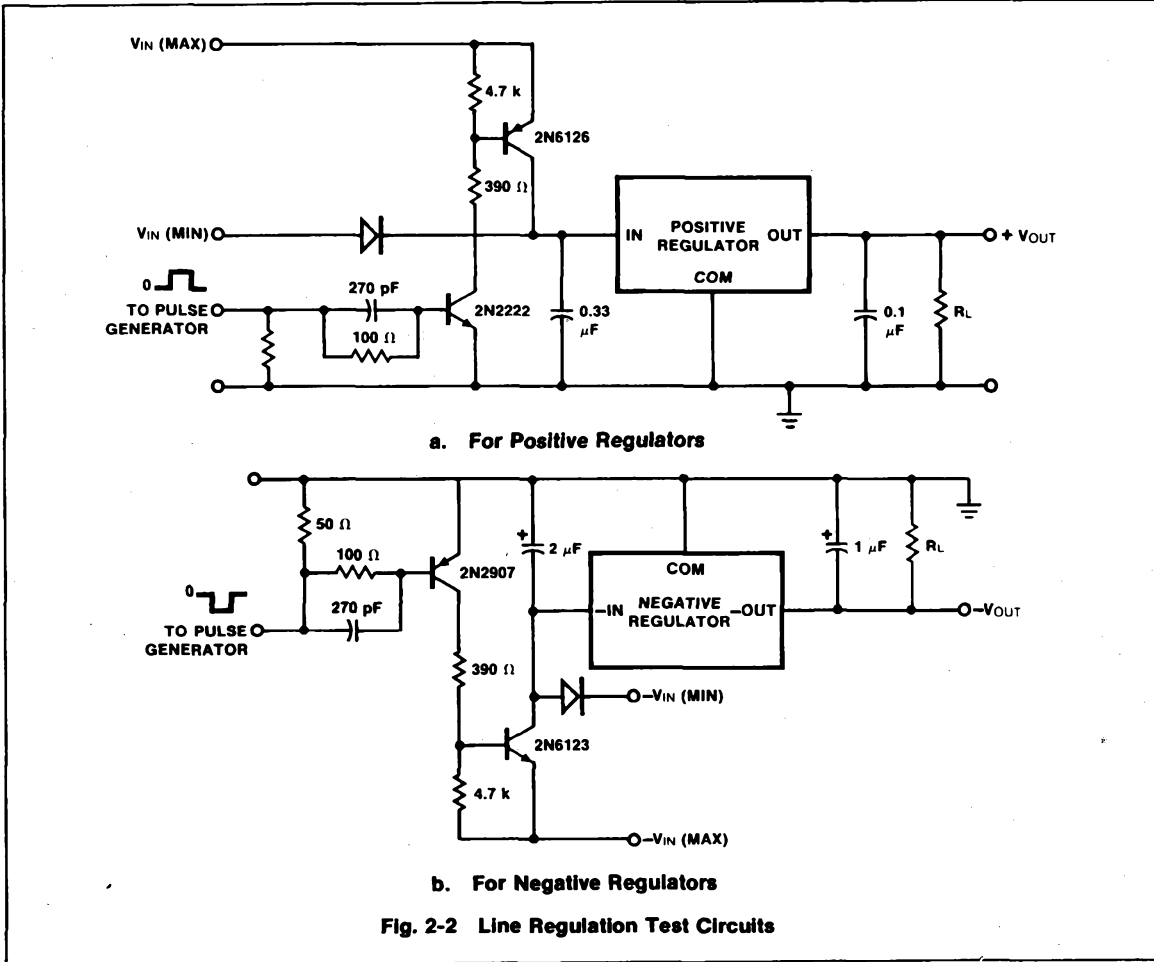


Fig. 2-2 Line Regulation Test Circuits

Figure 2-3 shows two simple circuits for measuring ripple rejection of positive and negative regulators. The 5k potentiometers in both circuits provide the bias necessary to produce the dc level of the input voltage to the regulator. The sine-wave generators are used to produce the ac component of the regulator input voltage.

**Life Test and Burn-In** (See Figure 2-4)

Burn-in information is provided here as a guide to perform regulator life testing. The burn-in performed by Fairchild is based on the thermal resistance of the regulator package. The power dissipation level is selected so that the junction temperature is near the maximum specified level (150° C for most products). The power level is then determined based on the chosen ambient. In general, burn-in is performed at 25° C ambient without a heat sink but it can also be done with a heat sink or a different ambient.

Example: Determine a burn-in circuit, operating at a 25° C ambient, for a  $\mu$ A7805 in the TO-220 package. From the data sheet:

$$\theta_{J-A} = 65^{\circ}\text{C/W max}$$

$$P_D = \frac{T_{J(\text{max})} - T_A}{\theta_{J-A}} = \frac{150 - 25}{65} = 1.92 \text{ W}$$

If  $R_L = 30\Omega$  and the effects of  $I_Q$  are neglected,

$$P_D = (V_{IN} - V_{OUT}) \frac{V_{OUT}}{R_L}$$

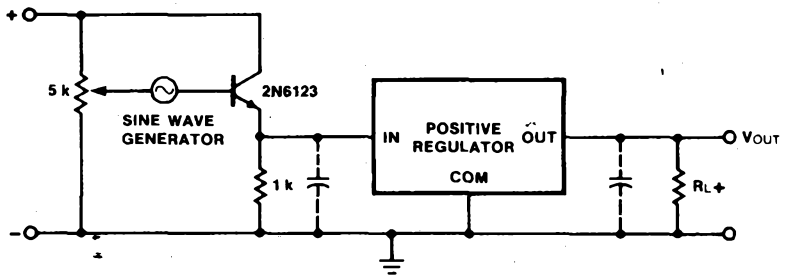
or

$$V_{IN} = P_D \left( \frac{R_L}{V_{OUT}} \right) + V_{OUT} = 16.5 \text{ V}$$

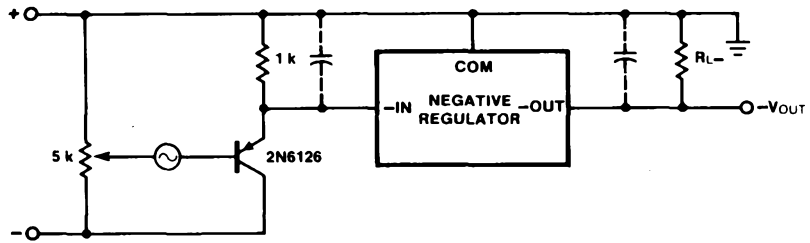
If the same circuit is used at an ambient of 125° C,

$$V_{IN} = P_D \left( \frac{R_L}{V_{OUT}} \right) + V_{OUT} = \frac{150-125}{65} \times \frac{30}{5} + 5 = 7.3 \text{ V}$$

Note that the value of the load resistor chosen here (30  $\Omega$ ) is arbitrary. Any other value giving output currents within the rating of the device could be used. If the burn-in is to be performed at more than one temperature, selecting a common load resistor for all temperatures and changing the input voltage to give the required power dissipations simplifies the design and construction of the burn-in fixtures.

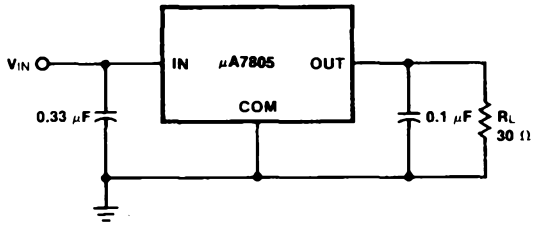


a For Positive Regulators



b For Negative Regulators

Fig. 2-3 Ripple Rejection Measurement Circuits



$V_{IN} = 16.5 \text{ V FOR } T_A = 25^\circ\text{C}$   
 $V_{IN} = 7.3 \text{ V FOR } T_A = 125^\circ\text{C}$   
NO HEAT SINK

Fig. 2-4 Burn-in Circuit for  $\mu A7805$  Regulator in TO-220 Package

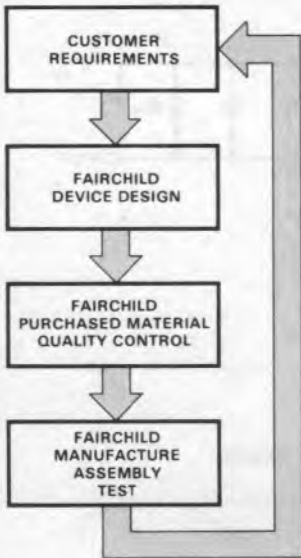
## RELIABILITY

There are three basic ingredients in the manufacture of reliable voltage regulators. First, the device must be designed with the user's applications and reliability requirements in mind. Secondly, the device must be manufactured with the optimum technology for the application. Thirdly, controls must be established to assure maintenance of the quality/reliability levels established in the design of the device. Consideration is given to the reliability influence of each part of the manufacturing and testing cycle with constant feedback from internal reliability monitoring; customer feedback on the results is a vital factor. The Fairchild reliability concept can be presented as constant feedback system which begins and ends with the customer (Figure 2-5).

### Areas of Consideration

#### *Device Applications and Reliability*

The reliability cycle begins with the customer. His device application, environment for its usage and end-product reliability requirements are major factors in establishing the quality/reliability levels for voltage regulators. The customer is the final judge.



Customer Design Breadboard

Fig. 2-5 Customer Feedback System

## Device Design

Inherent component reliability is a function of the product/process design. New Fairchild regulator designs as well as modifications or extensions of existing designs with known performance and reliability characteristics are rigorously evaluated. Three different factors in the manufacture of an IC significantly affect its reliability.

**The Silicon Chip**— Fairchild's design-technology capability utilizes epitaxial layer to achieve the desired electrical parameter characteristics. The surface influences long-term gain and voltage/leakage stability. The metallization determines mechanical integrity and current distribution.

**Chip Assembly**— The process and materials used to assemble the chip and package must preserve the inherent reliability of the chip and be inherently reliable to withstand thermal, mechanical and electrical stresses.

**The Package**— The package must effectively transfer heat from the chip to the outside world and protect the chip during handling and use.

2

## Incoming Quality Control (IQC)

All purchased materials for Fairchild voltage regulators are controlled through central specification control, product engineering, and reliability and quality assurance (R&QA) located in Mountain View. Materials are purchased and inspected per control documents using three IQC methods.

Direct visual and mechanical inspection

Functional testing

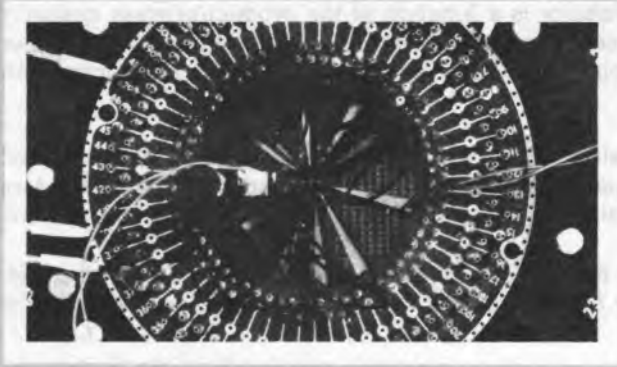
Composition analysis utilizing chemical and x-ray techniques from both internal and external sources.

In addition to centralized IQC, each manufacturing facility has a local, fully equipped IQC department. These facilities concentrate on cleanliness, plating quality and functionality. A computer file is made on each vendor's performance and quarterly reports are generated and analyzed.

## Wafer Manufacture

All wafers used to fabricate Fairchild voltage regulators are made at Fairchild. This includes crystal pulling, slicing, polishing and epitaxial layer growth. Fairchild voltage-regulator designs rely on accurate control of thickness and resistivity over a three-inch diameter wafer. All critical operations have laminar-flow clean-air hoods directly over the work areas. Wafer fabrication is essentially a series of masking and furnace cycles in which geometries are defined and impurities (dopants) introduced to form emitter, base and resistor regions. Daily controls are maintained on furnace temperatures to within  $\pm 1^\circ\text{C}$ . Resistivities ( $\rho_s$ ) of diffused layers are recorded on every run. Each masking step defines a new portion of the device geometry. A post develop inspection is performed to assure that each wafer has been properly exposed and chemically developed before final etching. When the masking and etching procedures are completed, a final inspection assures that the geometry is properly aligned, etched and cleaned. Following each production masking step, a sample inspection is performed by quality control inspectors to verify correct process implementation.

After masking and diffusion, the metallization process completes wafer manufacture. Fairchild uses electron-beam evaporation techniques to deposit gold and aluminum. Deposits are controlled through utilization of automated process sequencing, which includes an automatic thickness controller. Every run is gated through a first optical (1st opt.) inspection before it leaves the wafer fabrication area. Cleanliness, mask alignment, metal adherence (front and back) and general workmanship are inspected.



Wafer Probing



IQC Area



Crystal Puller

## Wafer Testing

Before the wafers are scribed and broken into dice for assembly onto headers or shipment to a customer as probed dice, they are electrically sorted. Each wafer is automatically probed with multiple tests to duplicate or correlate the dice to the final product test requirements. Rejected dice are ink marked and later scrapped. A final quality control gate is performed before the probed wafers can be forwarded to assembly.

## Device Assembly

After the wafers are scribed and broken, a second optical (2nd opt.) QC inspection is performed. The dice are inspected for wafer fabrication (handling) damage, as well as for defects which may cause assembly problems or result in latent reliability problems.

Monitors are performed on both assembly equipment and operators. Machines are shut down if defect control limits are exceeded and suspect material is rejected and 100% screened. Key items inspected are die orientation, voids under die, proper bond formation, wirepull strength and cleanliness.

A third optical (3rd opt.) gate is performed prior to final device sealing. If rejected, the lot is 100% screened by production and resubmitted to QC. Accepted lots are sent to the final seal operation, where the packages are monitored for weld strength and hermeticity (except plastic packages).

## Device Testing

Before shipment, all devices are 100% production tested to the following minimum inspection levels.

Functional dc	0.25% AQL
25° C dc	0.65% AQL
25° C ac	1.5% AQL
Temperature dc	1.5% AQL
Mechanical/Visual	0.65% AQL
Marking Performance	15/0 LTPD
Fine Leak	1.0% AQL
Gross Leak	0.4% AQL

Customers with special testing requirements are accommodated through an internal specification system. All internal test specifications formatted from customer documents are signed off by QA before they can be issued to the test area.

## Device Application

The total reliability effort is completed full-cycle with the customer. Operation in the customer application is the final consideration in device reliability. How each device is handled during system assembly by the customer, heat-sunk (mounted) and cooled during operation, and the amount of overload stresses (due to the system malfunction or misuse) greatly impacts the device reliability. Thus, the customer's specification requirements, the manufacturer's device design, manufacture, test, the actual circuit into which the device is inserted and the equipment containing that circuit in the field all affect the device and reliability.

## Failure Analysis

Failure analysis results performed by customers and by Fairchild on returned devices provide one of the most important inputs for consideration in Fairchild's total linear reliability concept. Failures generated by line monitors, life tests and field applications are analyzed to provide corrective action in terms of product design, assembly and testing methods. A scanning electron microscope (SEM) and an Auger electron microscope for chemical analysis are available for inspection of materials.



**Die Probing**



**Device Testing**



**IQC Sign-off**



**Failure Analysis**



## Reliability Monitor and Control

### Line Monitors

Line monitors are used to monitor the production line on a weekly basis. These monitors are designed to provide a constant feedback on product reliability. The following assembly/test monitors are conducted on a routine basis.

Assembly	Test
Package integrity	High-temperature reverse bias
Lead integrity	Intermittent operating life (power cycling)
Die integrity	High-temperature storage
Die-attach integrity	Temperature cycling
Bond integrity	Thermal shock
	Autoclave*
	85% R.H./85° C biased*

\*Applied to plastic devices only.

### Extended Reliability Tests

In conjunction with the weekly line-monitor program, Fairchild employs an extended reliability test program which is designed to reflect the long-term stability of Fairchild's regulator products. A summary of these reliability tests is shown in *Table 2-1*.

### Quality and Reliability Data

Supplemental brochures are published on an annual basis which provide detailed failure rate data. Please contact Fairchild Sales Offices for additional reliability and quality information.

### HI REL PROCESSING — MIL-M-38510/MIL STD-883

A unique "company", within Fairchild Linear, is totally dedicated to the processing of high reliability products and to serving the special needs of the HI REL community. It consists of marketing, engineering, production control, manufacturing and quality assurance. Fairchild's HI REL processing facilities are among the most modern and sophisticated in the semiconductor industry. Screening procedures are set up to conform to the most recent version of MIL-STD-883, in conjunction with MIL-M-38510, which establishes standardized requirements for design, material, performance, control and documentation needed to achieve prescribed levels of device quality and reliability.

### HI REL Unique II Program

Fairchild's Unique II program fills a longstanding need for a definite and comprehensive program covering HI REL semiconductor products...a program offering users a selection among multi-level screening flows and reliability requirements...a program providing clear and precise definitions on all areas of contractual performance...a program designed to reduce the high costs and delivery delays normally associated with HI REL. The objectives and benefits of the Unique II program for integrated circuits are these:

- Offers a full spectrum of processing options, including full compliance JAN and 883 Classes S, B, and C.
- Offers full compliance with JAN MIL-M-38510 and emphasizes the importance of this program.
- Accommodates the special needs of users' source control and specification control drawings.
- Offers models to aid users in development of source control drawings.

## EXTENDED RELIABILITY TESTS

## METAL CAN

## PLASTIC

	METAL CAN	PLASTIC
<b>High Temperature Operating Life</b> $T_A = 150^\circ\text{C}$ Readouts at 0, 168, 500, 1000 Hours	<b>X</b>	<b>X</b>
<b>Temperature Cycling <math>-65^\circ\text{C}</math> to <math>+150^\circ\text{C}</math></b> (MIL-STD-883, Method 1010.1, Cond. C) Readouts at 0, 10, 100 Cycles Hermeticity ( $1 \times 10^{-7}$ - TO-5, $1 \times 10^{-6}$ - TO-3)	<b>X</b>	
<b>Constant Acceleration</b> $F = 20\text{K g}$ 1 Min. Ea. 6 Axis - (MIL-STD-883, Method 2001.1)	<b>X</b>	
<b>Impact Shock</b> 1500 g x 5 Blows (MIL-STD-883, Method 2002.1)	<b>X</b>	
<b>Vibration, Variable Frequency</b> 10 g (MIL-STD-883, Method 2007)	<b>X</b>	
<b>Biased Humidity</b> $T_A = 85^\circ\text{C}$ , RH = 85% Readouts at 0, 168, 500, 1000 Hours		<b>X</b>
<b>Thermal Shock</b> $-55^\circ\text{C}$ to $+125^\circ\text{C}$ Readouts at 0, 10, 100 Cycles MIL-STD-883, Method 1011.1, Condition C	<b>X</b>	<b>X</b>
<b>Autoclave</b> $T_A = 125^\circ\text{C} \pm 2^\circ\text{C}$ 15 PSI, 24 Hours		<b>X</b>

Table 2-1 Reliability Test Summary

- Takes the mystery out of in-house processing to MIL-STD-883 and to MIL-M-38510 detail specifications. The Unique II program is definitive as to the similarities and differences in these requirements.
- Provides users with alternatives that may be used when JAN slash sheets or QPLs are unavailable, or for programs that demand the highest level of quality and reliability.

Fairchild offers a complete processing capability to fulfill requirements ranging from the least demanding to the most complex, including the following:

- Scanning Electron Microscope (SEM) Inspection
- Level A Visual
- Bond Pull and Die Shear Testing
- Read and Record and  $\Delta$  Drift Parameters
- Particle Impact Noise Detection (Pin-D) Testing
- Group A, B, C and D Qualification Testing.

Standard Unique II processing flows are given on the following pages; special flows will be quoted on an individual basis.

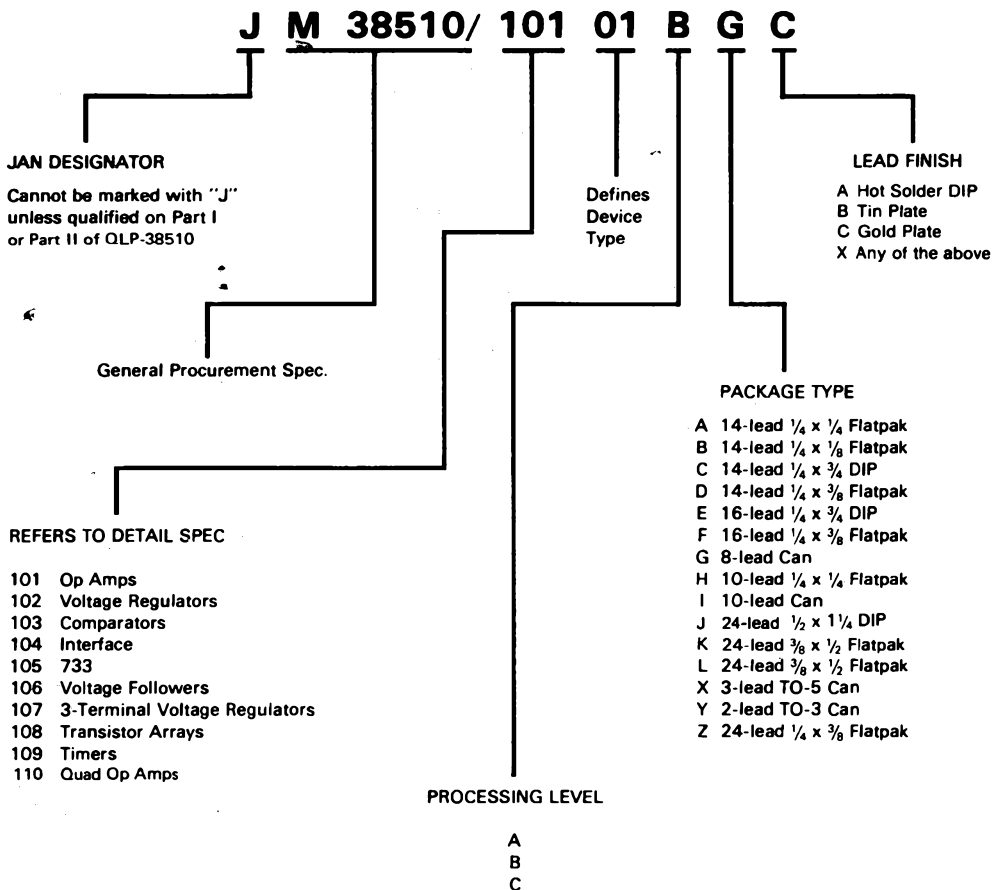
### **MATRIX VI — COMMERCIAL AND INDUSTRIAL RELIABILITY PROGRAM**

Commercial and industrial users increasingly demand optimized quality and reliability for the semiconductor integrated circuits purchased for their systems. Specific factors — increased integrated circuit usage per board, high costs for receiving inspection, pc board and systems repair, and the frequently immeasurable cost associated with field failures — require the user to attain high quality and reliability coupled with total cost. Matrix VI is designed to meet these user requirements.

Fairchild's Matrix VI Program offers a broad spectrum of screens and high technology/high volume integrated circuit products to meet the user's quality and reliability requirements typically associated with the commercial and industrial marketplace. There are two screening options for each package type, each with a separate degree of reliability and cost level. To simplify a cost-effective analysis, reliability factors have been assigned to each screening level. (See following pages.)

It is the goal of Matrix VI to achieve the highest possible reliability consistent with the user's needs and to avoid "over-buying". Cost-effective reliability is the essence of Matrix VI, the most comprehensive program of its kind now offered to the industrial/commercial marketplace.

## JAN PART NUMBERING SYSTEM



### LINEAR JAN GENERIC PART NUMBERS - EXAMPLES

JM38510/	01	02	03	04	05	06	07	08	09	10
101	741	747	101A	108A	2101	2108	118			
102	723									
103	710	711	106	111	2111					
104	55107	55108	9614	9615	55113	7831	7832	7820	7830	
105	733									
106	102	110	2110							
107	109	78M05	78M12	78M15	78M24	7805	7812	7815	7824	
108	3018	3045								
109	555	556								
110	148	149	4741	4136	124					

Note: Dated material. Please contact Fairchild for latest revisions.

# HI REL PROCESS SCREENING REQUIREMENTS

## JAN M38510

MIL-STD-883A TEST METHODS	DESCRIPTION	CLASS B	CLASS C
Preseal Visual MTD 2010	Cond. A Maximum Visual Criteria Cond. B. Optimum Visual Criteria	PRESEAL VISUAL COND. B	PRESEAL VISUAL COND. B
Bond Strength MTD 2011	Bond strength is monitored on a sample basis three times per shift per machine	BOND STRENGTH COND. D	BOND STRENGTH COND. D
Seal	Devices are hermetically sealed for compliance to MIL-STD-883 requirements	SEAL	SEAL
High Temp Storage MTD 1008	Cond. C Tstg = 150°C	BAKE COND. C MIN 24 HRS.	BAKE COND. C MIN 24 HRS.
Temperature Cycle MTD 1010	Cond. C -65°/150°C 10 cycles	TEMP CYCLE COND. C	TEMP CYCLE COND. C
Constant Acceleration MTD 2001	Cond. E 30000 G's X <sub>1</sub> , X <sub>2</sub> , Y <sub>1</sub> , Y <sub>2</sub>	CENTRIFUGE COND. E Y <sub>1</sub> ONLY	CENTRIFUGE COND. E Y <sub>1</sub> ONLY
Hermetic Seal MTD 1014	Cond. A Fine-Helium 5x10 <sup>-8</sup> cc/sec Cond. B Fine-Radiflo 5x10 <sup>-8</sup> cc/sec Cond. C Gross-FC43/Hot 10 <sup>-3</sup> cc/sec or Gross-FC78/Vacuum 10 <sup>-5</sup> cc/sec	HERMETICITY COND. A/B COND. C	HERMETICITY COND. A/B COND. C
Pre Burn-in Electrical MTD 5004	25°C dc electrical testing to remove rejects prior to submission to burn-in screen	PRE B/I ELECT 25°C dc	
Burn-in Screen MTD 1015	Cond. A, Cond. B, Cond. C Cond. D, Cond. E, Cond. F	BURN IN* 160 HRS 125°C	
Post Burn-in Electrical MTD 5004	Post Burn-in electrical screening to cull out devices which failed as a result of burn-in. Test Parameters may include: 25°C dc, 125°C dc, -55°C dc, 25°C dc, 25°C ac and 25°C Functional tests.	PST B/I ELECT 25°C dc +125°C dc -55°C dc 25°C ac 10% PDA	ELECTRICAL 25°C dc 25°C FUNCTIONAL
Quality Conformance Inspection MTD 5005	Group A: Electrical Characteristics Group B: Package oriented Tests Group C: Life Tests Group D: Environmental Tests	QUALITY CONFORMANCE Gp A, B, C and D	QUALITY CONFORMANCE Gp A, B, C and D
External Visual MTD 2009	3X, 10X magnification. Verify dimensions, configuration, lead structure, marking and workmanship	EXTERNAL VISUAL 100%	EXTERNAL VISUAL 100%

RELIABILITY Figure of Merit

15

2

ORDERING Part Number  
Part Marking

JM38510/  
10101BCB  
JM38510/  
10101BCB

JM38510/  
10101CCB  
JM38510/  
10101CCB

NOTE: RELIABILITY Figure of Merit is the Reliability Improvement Factor from RADC Reliability Notebook, Vol. II, RADC-TR-67-10B, Table XII-6, page 419.

\*Time Temperature Curve (method 1015) may be used.

CLASS  
OS  
(883S)

CLASS  
OB  
(883B)

CLASS  
OC  
(883C)

PRESEAL VISUAL  
COND. A  
2010

PRESEAL VISUAL  
COND. B  
2010

PRESEAL VISUAL  
COND. B  
2010

BOND STRENGTH  
ACCEPTANCE  
2011 COND. D

BOND STRENGTH  
ACCEPTANCE  
2011 COND. D

BOND STRENGTH  
ACCEPTANCE  
2011 COND. D

SEAL

SEAL

SEAL

BAKE  
COND. C MIN  
1008 24 HRS.

BAKE  
COND. C MIN  
1008 24 HRS.

BAKE  
COND. C MIN  
1008 24 HRS.

THERMAL SHOCK  
COND. A  
1011

TEMP CYCLE  
COND. C  
1010

TEMP CYCLE  
COND. C  
1010

MECHANICAL SHOCK  
COND. B, Y1  
2002

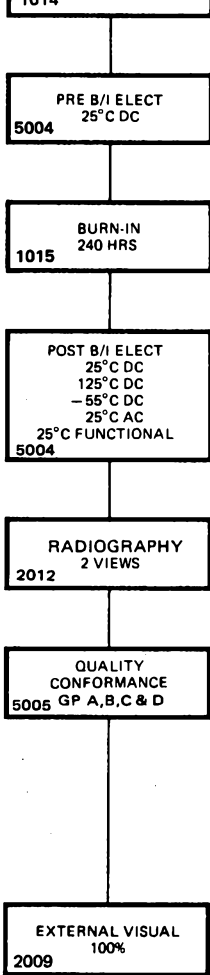
TEMP CYCLE  
COND. C  
1010

TEMP CYCLE  
COND. C  
1010

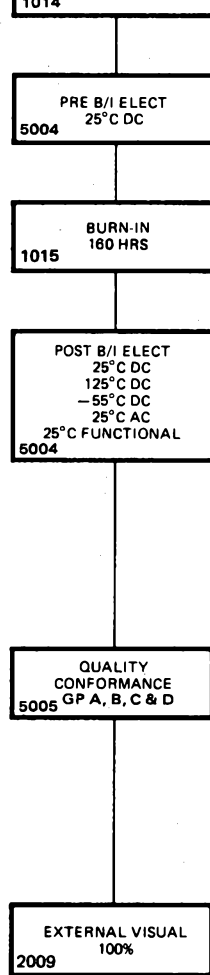
MECHANICAL SHOCK  
COND. B, Y1  
2002

TEMP CYCLE  
COND. C  
1010

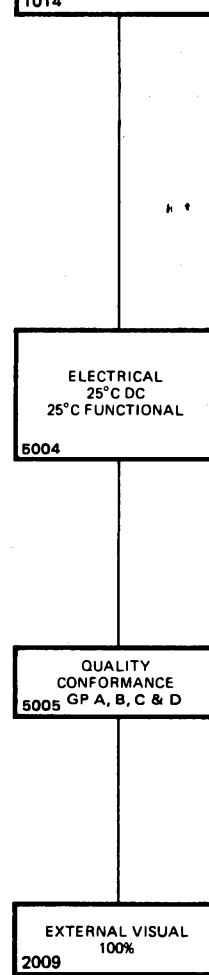
TEMP CYCLE  
COND. C  
1010



μA741 DMQS

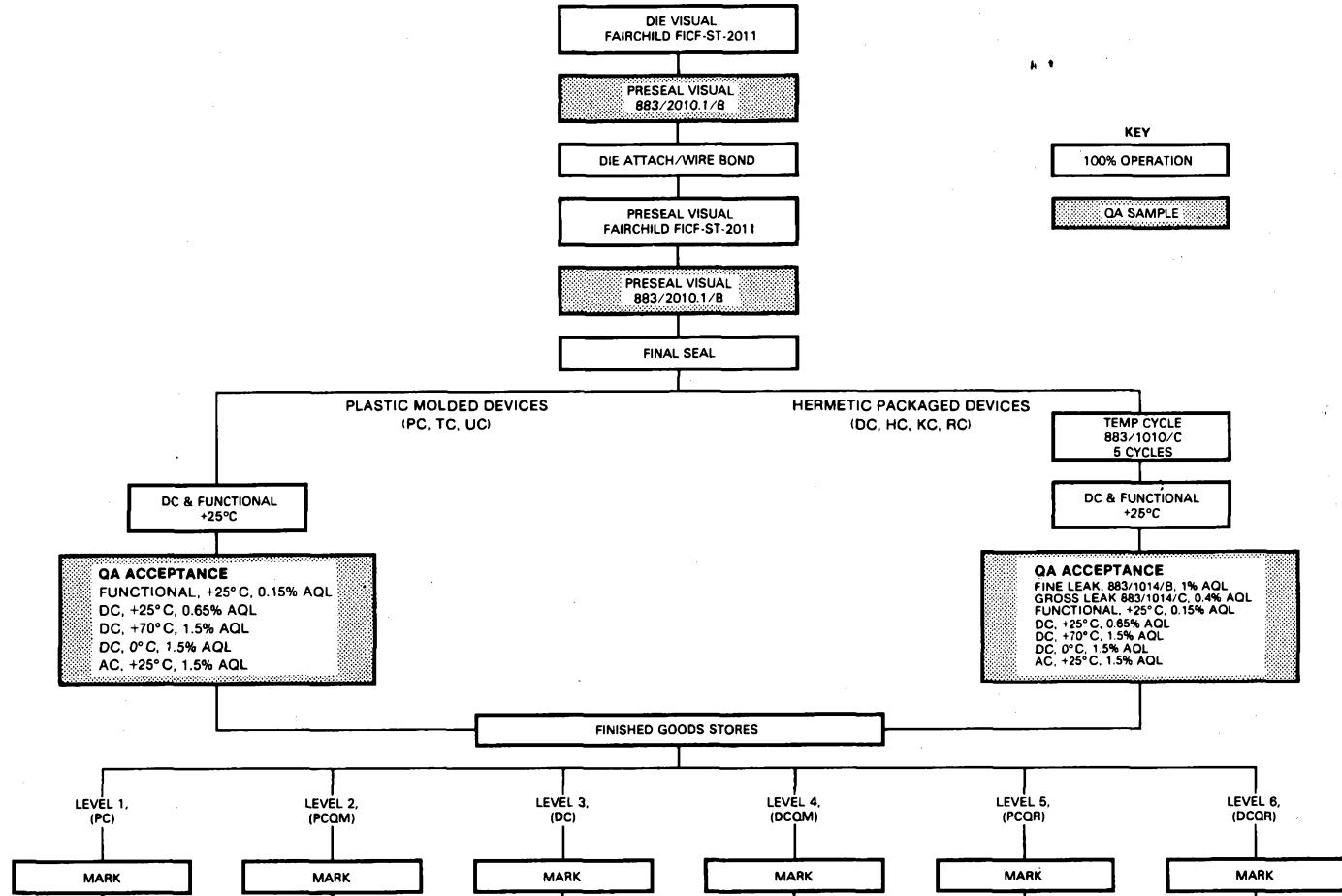


μA741 DMQB

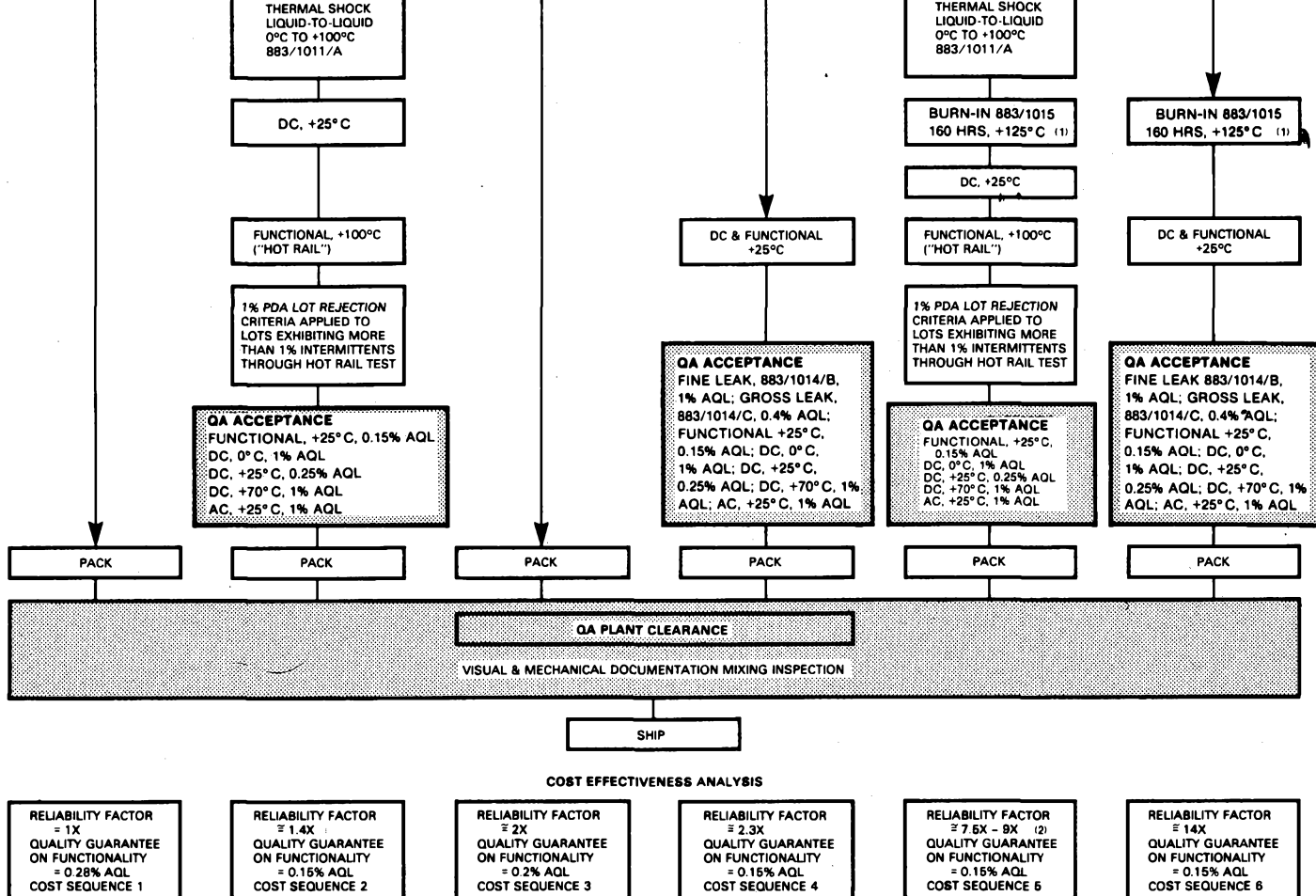


μA741 DMQC

# MATRIX VI PROCESS FLOW OPTIONS & COST EFFECTIVENESS







## NOTE:

(1) Temperature Accelerated Testing may be used for MIL-STD-883 method 1015 Test Condition F.

(2) Burn-In has the same relative effectiveness for plastic molded devices as for ceramic/hermetic packaged devices. Assuming a controlled (air conditioned and constant power) field application/environment, the reliability factor would be approximately 9x. But should the field application be in a less controlled and power on/off application, the reliability would be approximately 7.5X.

1. 1948

2. 1949

3. 1950

4. 1951

5. 1952

6. 1953

7. 1954

8. 1955

9. 1956

10. 1957

11. 1958

12. 1959

13. 1960

14. 1961

15. 1962

16. 1963

17. 1964

18. 1965

19. 1966

20. 1967

21. 1968

22. 1969

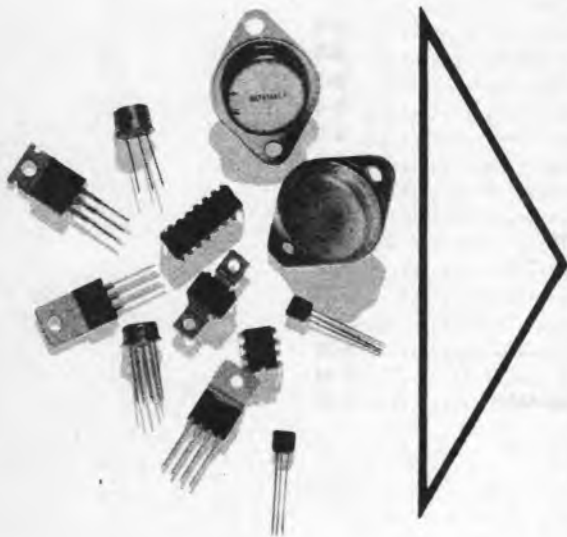
23. 1970

24. 1971

25. 1972

26. 1973

27. 1974



SELECTION GUIDES AND INDUSTRY CROSS REFERENCE

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TESTING AND RELIABILITY 2

APPLICATIONS 3

POWER SUPPLY DESIGN 4

POWER TRANSISTORS 5

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PRODUCT INFORMATION 7

DEFINITIONS, ORDERING INFORMATION AND PACKAGE OUTLINES 8

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# Chapter 3

## IC VOLTAGE REGULATOR APPLICATIONS

A few of the most popular and widely used series as well as switching regulator applications are discussed in this chapter. There is also a compendium of regulator applications for each Fairchild regulator at the end of this chapter. Similarities and differences in regulator types are described in Chapter 1.

### SELECTING THE CORRECT SERIES TYPE REGULATOR

The regulator selection guides provide concise tables of key regulator specifications by device number, or by ascending  $I_{OUT}$ . Select the device that provides the desired output voltage and current, then proceed as follows.

Determine the required input voltage ( $V_{IN}$ ).

$$V_{IN(max)} > V_{IN} > V_{O(max)} + V_{DO(max)} + \Delta V_L + V_{R(pk)}$$

where

$V_{IN(max)}$  = Maximum allowable input voltage

$V_{IN}$  = Regulator input voltage under load

$V_{O(max)}$  = Maximum output voltage of regulator

$V_{DO(max)}$  = Maximum dropout voltage

$\Delta V_L$  = Maximum line voltage change

$V_{R(pk)}$  = Peak ripple voltage

Also determine  $T_{A(max)}$  = Maximum ambient temperature and select  $T_J < T_{J(max)}$  from the data sheet and see Chapter 6 for thermal and heat-sink requirements.

### DESIGN PRECAUTIONS

When designing and laying out a regulator circuit, follow these guidelines to save time, money and simplify design.

- Keep all ground leads as short as possible. Use ground conductors sufficiently large enough to handle rated currents to reduce unwanted voltage drops across leads, and to minimize heating effects and lead inductance.
- Use single-point grounding at the regulator common terminal whenever possible to prevent circulating currents or ground loops.
- When using the adjustable multi-terminal regulators, especially at high output current levels, derive the feedback sense voltage from across the load rather than from across the regulator to improve circuit performance.
- Note that some devices are offered with the case or tab connected to either ground (positive regulators) or to the input (negative regulators). For example, the  $\mu A78G$  4-terminal positive adjustable regulator is offered in an aluminum (TO-3) type or plastic Power Watt (similar to TO-202) package with the case or tab connected to common. In the complementary or negative version, the  $\mu A79G$ , the case or tab is connected to the negative input. Precautions should be taken to avoid accidentally grounding the case or tab of negative regulators. Negative regulators should be electrically insulated from the mounting surface, or the mounting surface should be insulated from ground or chassis.

### BYPASSING

Monolithic 3 and 4-terminal regulators are particularly attractive for providing local on card regulation because of the small number of required external components. Positive regulators, in general, use npn

emitter-follower output stages whereas negative regulators use npn common-emitter stages with the load connected to the collector. The emitter-follower output-stage configuration is not used in negative regulators because monolithic pnp series-pass transistors are difficult to make. Because of their output-stage configurations, positive regulators are more stable than negative regulators; therefore, bypassing of positive regulators can be omitted in certain applications. It is a good practice, however, to use bypass capacitors at all times. Input bypass capacitors ( $0.33 \mu\text{F}$ ) for positive 3 and 4-terminal regulators are required if the regulator is located an appreciable distance from the power supply filter. Output bypass capacitors ( $0.1 \mu\text{F}$ ) are not normally needed but they do improve the transient response of the regulator.

On the other hand, bypass capacitors *are a must* for stable operation of the 3 and 4-terminal negative regulators over the input voltage and output current ranges. The bypass capacitors ( $2 \mu\text{F}$  on the input,  $1 \mu\text{F}$  on the output) should be mylar, ceramic or tantalum with good high frequency characteristics. If more than one bypass capacitor source or more than one type is used, stability should be checked on each source or type. Stable operation with one capacitor from one vendor may not necessarily result in stable operation with a capacitor of the same type from a second vendor, since the characteristics of the capacitors may vary.

Regulator output impedance is in the order of  $100 \text{ m}\Omega$  or less and increases as a function of frequency above  $10 \text{ kHz}$  due to the gain rolloff of the error amplifier. A tantalum electrolytic bypass capacitor connected to the regulator output will maintain low impedance for frequencies up to  $1 \text{ MHz}$ . A ceramic capacitor should be placed in parallel with the tantalum capacitor for driving fast switching loads to compensate for the rising impedance of the electrolytic capacitor above  $1 \text{ MHz}$ . If switching loads are distributed over a large area, additional ceramic bypass capacitors should be located at the loads. Very large-value output bypass capacitors should not be used unless adequate measures are taken to prevent the output from rising above the input, or to avoid discharging the bypass capacitor through the series-pass transistor of the regulator if the input is accidentally grounded. A reverse-biased diode connected from input to output is normally sufficient to achieve this protection.

To assure stable operation of a regulator using the  $\mu\text{A}723$ , dc and ac performance of the internal gain stage and external components must be determined. Then, the required compensation may be applied using standard operational amplifier techniques. Compensation of  $\mu\text{A}723$  circuits is explained in detail on pages 3-26 and 3-27.

## PROTECTION CIRCUITS

Internal protection circuits are provided in all 3 and 4-terminal voltage regulators to improve reliability and make these regulators immune to certain types of overloads. These on-chip components protect the regulators against short-circuit conditions (current limit), excessive input-output voltage differential conditions (safe-area limit) and excessive junction temperatures (thermal limit). The protection circuits protect the device against abuse and fault conditions that may be encountered *occasionally*. Continuous operation of the device under fault conditions such as a short or in a thermal shutdown mode is *not* a recommended procedure.

Proper attention must be paid to the safe-area protection network when 3 and 4-terminal regulators are operating with excessive input voltage or excessive input-output differential-voltage conditions. In addition to reducing the available output current with high input-output differential conditions, the safe-area protection network may, under certain conditions, cause the device to latch-up if the output is shorted to ground. This situation is aggravated as the input voltage, load current or the operating junction temperature is increased. This mode of operation does not damage the device but power (input voltage or load current) must be interrupted momentarily for the device to recover from the latched condition. The details of the protection circuits are discussed in Chapter 1.

Precautions must also be taken to avoid regulator operation beyond its maximum ratings. Switching transients exceeding the maximum input voltage rating of a regulator, for instance, can destroy a regu-

lator. These transients, which occur especially if the regulator input voltage is switched instantaneously rather than ramped by the natural smoothing provided by the ac line and the filter capacitors, are usually hard to track and normally caused by lead inductance and fast switching currents. Good quality bypass capacitors that have low series resistance cause the inrush current to increase further, thereby causing a higher magnitude transient at the input of the regulator. In such cases, a lower quality and cheaper bypass capacitor may be the answer.

Because of their output stage configurations, positive regulators source current and negative regulators sink current. These restrictions should be kept in mind and, under no circumstance, should a regulator output terminal be allowed to go more than a few volts higher than the regulated output of the regulator. The power should be turned off before removing or inserting a regulator into a test socket. However, if it is necessary to insert a regulator into a "live" socket, care must be taken to ensure that the common terminal connection is made prior to, or simultaneously with, the input terminal connection. In the absence of the common terminal connection, the output voltage of the regulator is 1 or 2 V below the input voltage. This type of fault condition can cause an excessive output voltage which may adversely affect the circuits supplied by the regulator. If the common terminal is quickly connected, the regulator can be destroyed. Also, damage to the regulator may result from the discharging of the bypass capacitor through the output and common terminals.

## THERMAL CONSIDERATIONS

The thermal properties and limitations of voltage regulators are extremely important in circuit design. Whether or not a heat sink is required should be determined before the circuit is laid out. See Chapter 6 for a detailed discussion of thermal considerations and how to choose the proper heat sink.

## APPLICATIONS

The capabilities of regulators can be increased beyond their basic capacities by the addition of external components. Two or more regulators can be connected to increase output current, or widen the input and output voltage ranges. The applications discussed are divided into the following seven groups:

- Fixed Positive – 3-Terminal Regulators
- Fixed Negative – 3-Terminal Regulators
- Adjustable Positive – 3 and 4-Terminal Regulators
- Adjustable Negative – 3 and 4-Terminal Regulators
- Dual Regulators – Tracking and Non-tracking Regulators
- Precision Multi-terminal Regulators –  $\mu A723$
- Switching Regulators

Note that apart from power and current considerations, the  $\mu A7800$ ,  $\mu A78M00$ ,  $\mu A78C00$  and  $\mu A78L00$  are interchangeable in most positive 3-terminal regulator applications, and the  $\mu A7900$  and  $\mu A79M00$  in 3-terminal negative regulator applications. The same applies for their 4-terminal counterparts. Appropriate changes may be necessary, however, in the external components when changing from one regulator to another. Line and load regulation data provided for the applications pertain to the circuit using the specific device indicated. This data would naturally vary somewhat with the use of different devices and is not meant to be a worst-case representation.

### Fixed Positive 3-Terminal Regulators

#### *Basic Regulator Configuration*

The basic configuration of the 3-terminal positive regulator with a bypass capacitor and single-point grounding is shown in *Figure 3-1*. Currents in excess of the output capability of the basic 3-terminal regulators can be obtained with the circuit shown in *Figure 3-2*. Resistor R1 determines the point at which

the external series-pass transistor Q1 begins to conduct; its value is determined by the following formula.

$$R1 = \frac{V_{BE1}}{I_{REG(max)} - \frac{I_{OUT(max)}}{\beta_{Q1(min)}}}$$

where  $\beta_{Q1} > 10$

Maximum available current with this circuit is expressed as follows.

$$I_{OUT(max)} = \beta_{Q1} \left[ I_{REG(max)} - \frac{V_{BE1}}{R1} \right]$$

It should be noted that Q1 is not short-circuit protected but protection can be achieved by adding a short-circuit sense resistor  $R_{SC}$  and a pnp transistor Q2 as shown in Figure 3-3. In this circuit, Q2 must be able to handle the short-circuit current of the regulator since, when Q1 is bypassed, the regulator goes into the short-circuit mode. The short-circuit current is determined by the base-emitter voltage of Q2 and the short-circuit resistor  $R_{SC}$ .

$$R_{SC} = \frac{V_{BE2}}{I_{SC}}$$

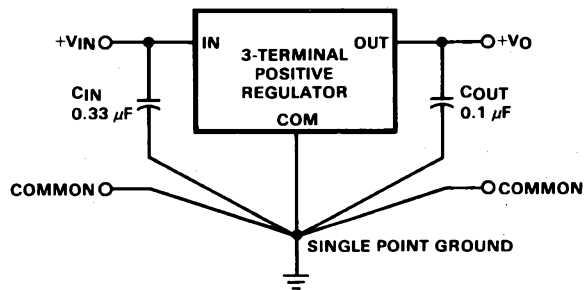
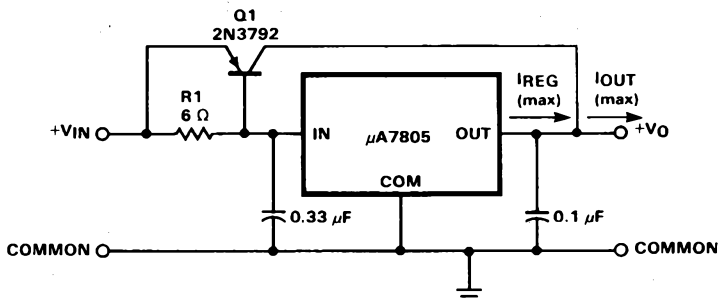


Fig. 3-1. Basic 3-Terminal Positive Regulator with Bypass Capacitors



NOTES:

Line Regulation:  $I_{OUT} = 100 \text{ mA}$ ,  $\Delta V_{IN} = 5 \text{ V}$ ,  $\Delta V_O = 1 \text{ mV}$   
 Load Regulation:  $V_{IN} = 10 \text{ V}$ ,  $\Delta I_{OUT} = 5 \text{ A}$ ,  $\Delta V_O = 10 \text{ mV}$

Fig. 3-2. High Current Voltage Regulator



Another method of achieving short-circuit protection with an external series-pass element is to use a diode as shown in *Figure 3-4*. Resistors R1 and R2 are used to set the ratio of the current handled by the regulator and the series-pass transistor, so that, assuming the diode drop  $V_{D1} = V_{BE1}$

$$\frac{R1}{R2} = \frac{I1}{I_{REG}}$$

Maximum current achievable with this circuit is expressed as follows.

$$I_{OUT(max)} = \frac{(R1 + R2)}{R1} I_{REG(max)}$$

By proper selection of the regulator and transistor heat sinks, the thermal protection of the regulator can be extended to the series-pass transistor. This circuit has one drawback – the dropout voltage is considerably higher than that in the circuit of *Figure 3-3*. This is due to the voltage drop across the current sharing resistors R1 and R2.

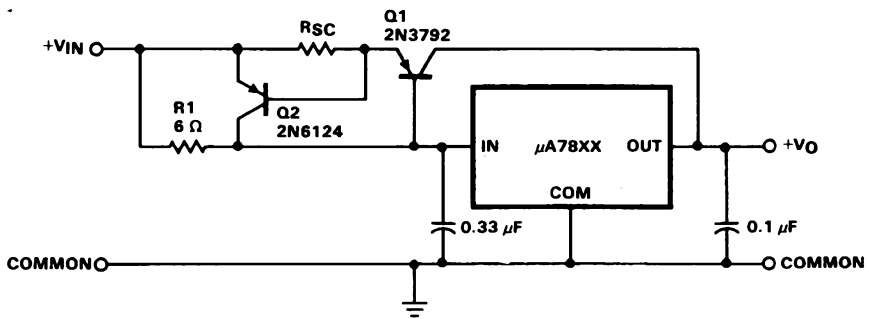
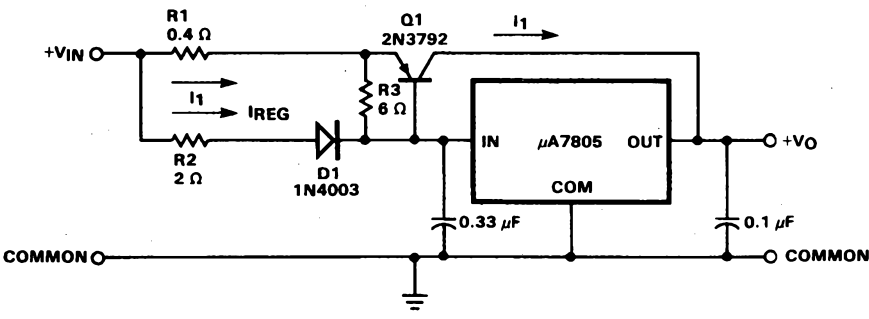


Fig. 3-3. High Output Current Voltage Regulator (Short Circuit Protected)



NOTES:  
 Line Regulation:  $\Delta V_{IN} = 10 \text{ V}, I_{OUT} = 3 \text{ A}, \Delta V_O = 1 \text{ mV}$   
 Load Regulation:  $V_{IN} = 12 \text{ V}, \Delta I_{OUT} = 5 \text{ A}, \Delta V_O = 30 \text{ mV}$

Fig. 3-4. 5-Amp Regulator (with Short Circuit Protection)

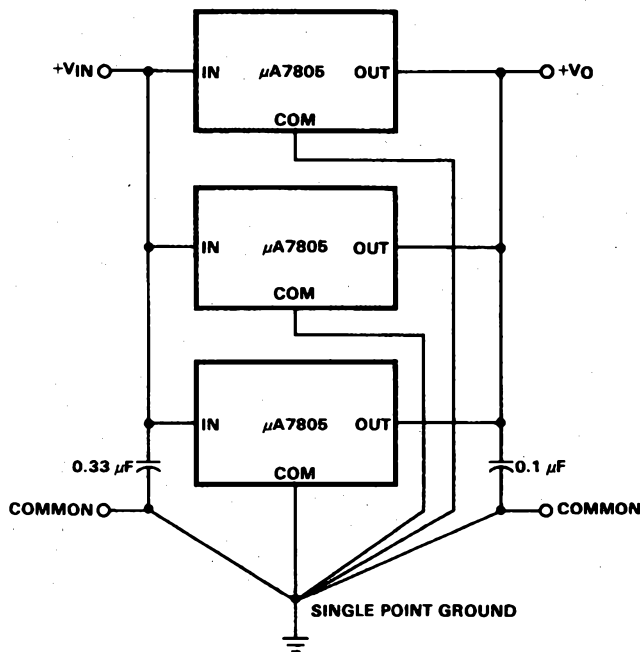
### Parallel Regulators

To obtain higher output current without using a power transistor as a booster, several regulators in parallel may be used. Regulation of the overall system can be improved if the individual devices are matched for output voltages as shown in *Figure 3-5*. If the outputs are not matched, it is likely that the output current will not be shared between the regulators and, as a result, some of the regulators will operate at or near the current limit while others are at their quiescent no-load levels.

### Excessive Input/Output Differential

When a regulator is operating with a large input-output differential, the addition of a series resistor with the input extends the operating range of the device by sharing the power dissipation, see *Figure 3-6*. The value of the series resistor R1 must be low enough so that, under worst-case conditions, (lowest supply voltage, highest output voltage, and highest load) the device remains in regulation. R1 can be calculated as follows.

$$R1 = \frac{V_{S(\min)} - V_{O(\max)} - V_{DO(\max)}}{I_{OUT(\max)} + I_{Q(\max)}}$$



#### NOTES:

Line Regulation:  $I_{OUT} = 1 \text{ A}$ ,  $\Delta V_{IN} = 10 \text{ V}$ ,  $\Delta V_{OUT} = 3 \text{ mV}$

Load Regulation:  $V_{IN} = 10 \text{ V}$ ,  $\Delta I_{OUT} = 1.5 \text{ A}$ ,  $\Delta V_O = 30 \text{ mV}$ ,  $\Delta I_{OUT} = 2.5 \text{ A}$ ,  $\Delta V_O = 65 \text{ mV}$

**Fig. 3-5. Parallel Operation of Regulators (High Output Current without a Power Transistor) – Output Voltages Matched to  $\pm 50 \text{ mV}$**

where

$V_{S(\min)}$  is the minimum supply voltage

$V_{DO(\max)}$  is the maximum dropout voltage

$I_{Q(\max)}$  is the maximum quiescent current

Maximum regulator dissipation, however, occurs with highest supply voltage and highest load current.

$$P_{D(\max)} = [V_{IN(\max)} - V_{O(\min)}] I_{OUT(\max)}$$

where

$$V_{IN(\max)} = V_{S(\max)} - [I_{OUT(\max)} + I_{Q(\max)}] R_1$$

For a constant load, the regulator input voltage varies by the same amount as the supply voltage and consequently the line regulation of the device remains essentially the same.

For load regulation, assuming constant supply voltage, the combined effects of the change at the input due to the voltage change across  $R_1$  must be taken into consideration. In this configuration, as the load is increased, the regulator input voltage decreases and the net result, in most cases, is a slight degradation in the performance of the regulator since these two effects are additive.

The load regulation can therefore be calculated as follows.

Load regulation at constant  $V_S$  = load regulation at constant  $V_{IN}$  + line regulation

Example: Assume a supply range of 25 to 35 V used with a  $\mu A78M12$  regulator delivering an output current of 100 to 300 mA.

From the data sheet:  $V_{O(\min)} = 11.4$  V

$$V_{O(\max)} = 12.6$$
 V

Assume  $V_{DO(\max)} = 2.5$  V,

$$I_{Q(\max)} = 6$$
 mA

$$R_1 = \frac{25 - 12.6 - 2.5}{.300 + .006} = 33 \Omega$$

With this value of  $R_1$  and a load varying from 100 to 300 mA, the input voltage to the regulator varies,

$$\Delta V_{IN} = \Delta I_{OUT} R_1 = 6.6$$
 V

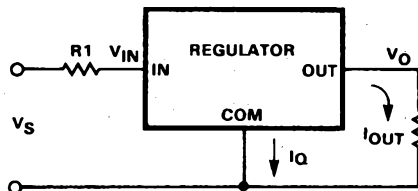


Fig. 3-6. Reducing Power Dissipation in a Regulator with Dropping Resistor  $R_1$

The effect of the 6.6 V change at the regulator input under the worst case condition is  $50/14 \times 6.6 = 24$  mV additional change at the output terminal. The inclusion of the  $33 \Omega$  reduces the maximum power dissipation of the regulator as shown below.

$$\text{From } P_{D(\max)} = (35 - 11.4) \times 0.306 = 7.22 \text{ W (without R1),}$$

$$\text{To } P_{D(\max)} = (35 - 33 \times 0.306 - 11.4) \times .306 = 4.13 \text{ W (with R1)}$$

Note that the power dissipation is shared between the regulator and R1.

### Input Voltage $> V_{IN(\max)}$

When a regulator is used with supply voltages greater than the rated regulator maximum input voltage, the circuit shown in *Figure 3-7* can be used. This circuit essentially provides a constant voltage to the regulator with supply voltage variations. The choice of Zener diode voltage is dictated by  $V_{IN(\min)}$  of the regulator and  $V_{BE(\max)}$  of Q1.

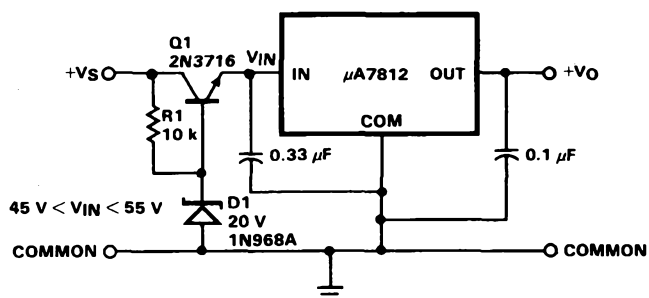
### High Output Voltages

*Figure 3-8* shows a simple circuit that can be used to obtain an output voltage greater than the standard fixed voltages available. The quiescent current biases Zener diode D1 and the regulator common terminal rides on the pedestal established by D1. If the Zener must be operated at currents greater than the quiescent current level of the regulator, then R1 can be used to increase the Zener current. If, on the other hand, lower Zener current is satisfactory, R1 can be placed in parallel with D1 to shunt some of the current. **Caution:** this circuit configuration cannot utilize the thermal shutdown or short-circuit protection features of the regulator if the input voltage exceeds the maximum input voltage rating of the regulator.

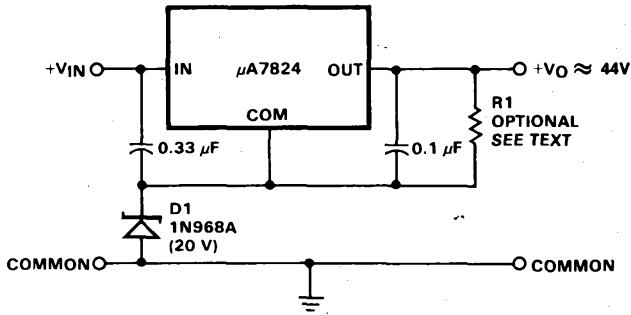
*Figure 3-9* can be used to take advantage of the protective features of the regulator. Here too, the regulator common terminal operates on the pedestal established by Zener diode D1. Zener diode D2 and the Darlington configuration of Q1, Q2 reduces the regulator input voltage to a safe value. The Darlington configuration prevents loading of Zener diode D2, and thus maintains a high level of regulation. Diode D3 protects the regulator against accidental shorts by clamping the common terminal of the regulator to a diode drop above the shorted output.

### Remote Shutdown

Electronic shutdown is used in some applications where, under certain conditions, the removal of power from the load is desired. This function can easily be achieved with multi-terminal regulators, such as the  $\mu A723$ ,  $\mu A105$ ,  $\mu A104$ , since these regulators are either equipped with shutdown capability or the non-inverting input of the error amplifier is accessible (*See Figure 3-67*). With the 4-terminal regulators, the control terminal is the inverting input and therefore some external parts are necessary to turn off these devices. The same applies for the 3-terminal devices. The 3-terminal regulator circuit of *Figure 3-10* has a remote shutdown feature. Under normal conditions, Q2 is on and provides the base current of Q1.

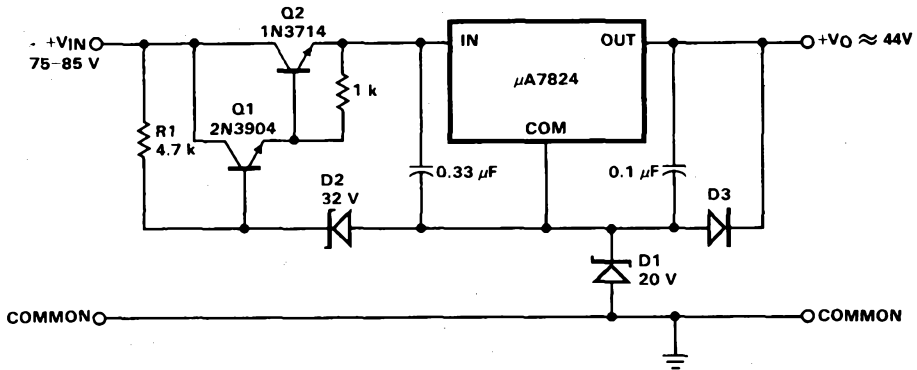


**Fig. 3-7. Regulator Input Circuit for Input Voltage Source Greater than  $V_{IN(\max)}$**



NOTES:  
Line Regulation:  $\Delta V_{IN} = 10\text{ V}$ ,  $I_{OUT} = 0.5\text{ A}$ ,  $\Delta V_O = 60\text{ mV}$   
Load Regulation:  $V_{IN} = 50\text{ V}$ ,  $\Delta I_{OUT} = 1\text{ A}$ ,  $\Delta V_O = 70\text{ mV}$

Fig. 3-8. High Output Voltage Regulator, No Short-Circuit Protection



NOTES:  
Line Regulation:  $I_{OUT} = 1\text{ A}$ ,  $\Delta V_{IN} = 10\text{ V}$ ,  $\Delta V_O = 230\text{ mV}$   
Load Regulation:  $V_{IN} = 75\text{ V}$ ,  $\Delta I_{OUT} = 1\text{ A}$ ,  $\Delta V_O = 18\text{ mV}$

Fig. 3-9. High Output Voltage Regulator with Short-Circuit Protection

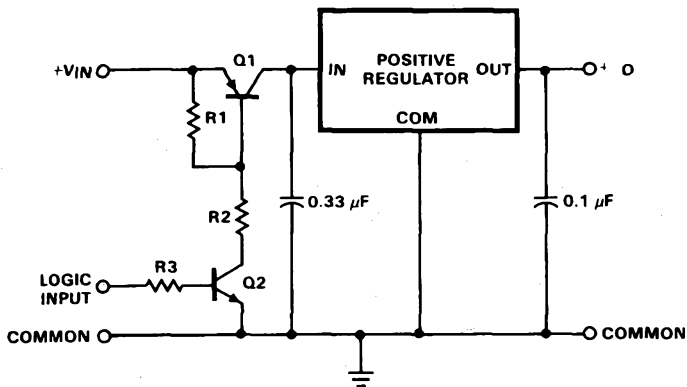


Fig. 3-10. Remote Shutdown

Q1 acts as a switch and is either in saturation, when the signal to the base of Q2 is high, or is off when the signal to the base of Q2 is low. It must have a current rating equal to the load current. Turn-off time is dependent on C2 and the load current; the higher the load current, the faster the turn-off time.

**Constant Current Regulator**

Any 3-terminal regulator can be used as a constant-current regulator as shown in Figure 3-11. The current  $I_{OUT}$  which dictates the regulator type to be used is determined by this equation.

$$I_{OUT} = \frac{V_O}{R_1} + I_Q$$

where  $V_O$  is the regulator output voltage and  $I_Q$  is the quiescent current.

The input voltage  $V_{IN}$  must be high enough to accommodate the dropout voltage at the low end, but must not exceed the maximum input voltage rating at the high end.

**Fixed Negative 3-Terminal Voltage Regulators**

Since negative voltage regulators are complements of the positive voltage regulator, almost all the positive-regulator applications can be converted into negative versions by appropriate changes in the polarity of the input voltages. If external active components such as series-pass transistors are used, they should be the complements of those used in the positive-regulator application, i.e., npn transistors replaced by pnp and vice versa. The basic configuration of the 3-terminal negative voltage regulator is shown in Figure 3-12, below.

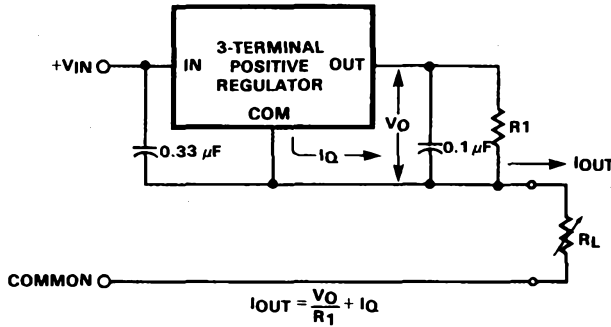


Fig. 3-11. Constant Current Regulator (Positive Output)

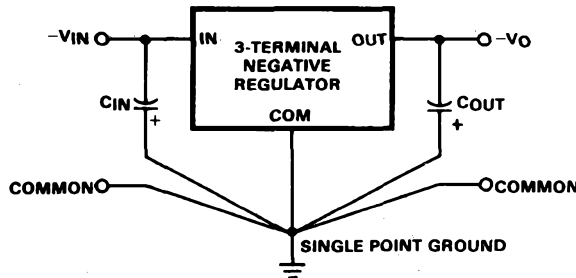


Fig. 3-12. Basic 3-Terminal Negative Regulator with Bypass Capacitors

Figures 3-13 and 3-14 show the negative complements of the positive voltage-regulator circuits in Figures 3-2, 3-3 to obtain higher output currents, while Figure 3-15 shows a negative current regulator with an output current expressed as follows.

$$I_{OUT} = \frac{V_O}{R_1} + I_Q$$

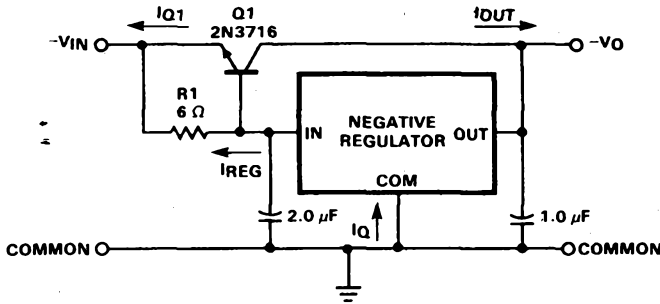


Fig. 3-13. High Output Negative Current, Short-Circuit Protected Regulator

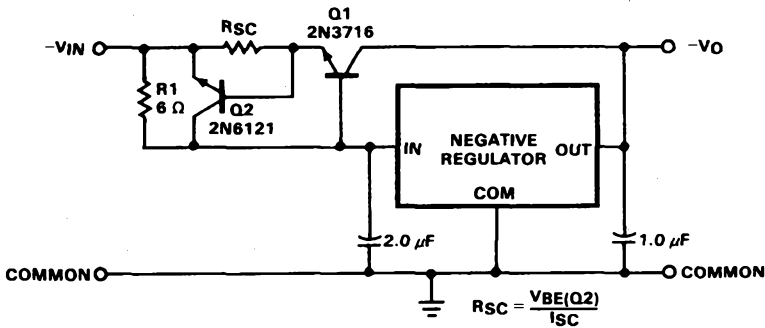


Fig. 3-14. High Negative Current Voltage Regulator

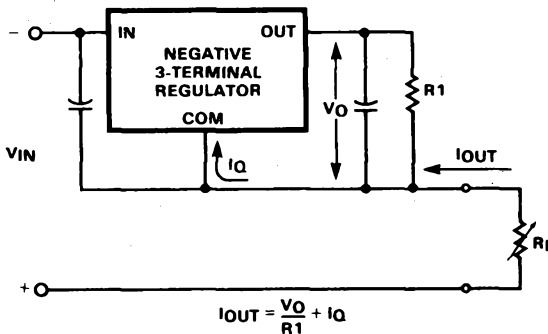


Fig. 3-15. Negative Current Regulator

### Adjustable Positive 3 and 4-Terminal Voltage Regulators

The circuits covered so far are restricted to the fixed voltages of the 3-terminal regulators. With some external components, the normal output voltage of a 3-terminal regulator can be changed to meet other voltage requirements. This often results in a slight degradation of the regulator parameters; therefore, before selecting a 3-terminal regulator for these applications, an adjustable 4-terminal regulator should be considered. Usually, the same function can be attained by an adjustable regulator with fewer components and no sacrifice in performance.

### Non-Standard Fixed Positive Output Voltage Regulator

Non-standard regulated output voltages greater than the regulator voltage can be obtained from a fixed 3-terminal regulator as shown in Figure 3-16. The voltage pedestal developed across R2 is added to the normal regulated output voltage,  $V_{REG}$ .

$$V_{OUT} = V_{REG} \left( 1 + \frac{R_2}{R_1} \right) + I_Q R_2$$

The current through R1 is set much higher than  $I_Q$  to minimize the effects of the change in  $I_Q$  that occurs with a change in the load current or the input voltage. The values of R1 and R2 can be calculated as follows.

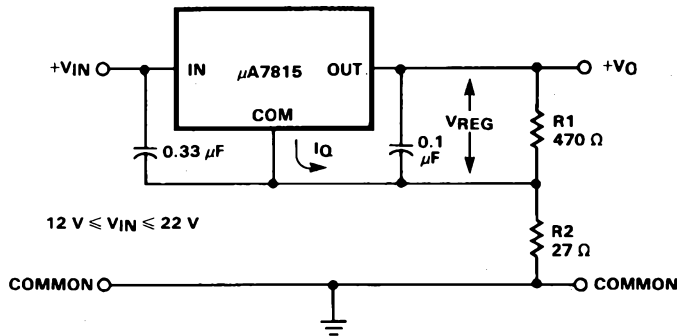
$$R_1 = \frac{V_{REG}}{I_{R1}}$$

and

$$R_2 = \frac{V_O - V_{REG}}{I_{R1} + I_Q}$$

if  $I_{R1} = 5I_Q$ , then

$$R_1 = \frac{V_{REG}}{5I_Q}$$



**NOTES:**

- With  $R_2 = 0 \Omega$ ,  $V_O = 14.85 \text{ V}$
- Line Regulation:  $\Delta V_{IN} = 10 \text{ V}$ ,  $I_{OUT} = 0.5 \text{ A}$ ,  $\Delta V_O = 5 \text{ mV}$
- Load Regulation:  $\Delta I_{OUT} = 1 \text{ A}$ ,  $V_{IN} = 25 \text{ V}$ ,  $\Delta V_O = 28 \text{ mV}$
- With  $R_2 = 27 \Omega$ ,  $V_O = 16 \text{ V}$
- Line Regulation:  $\Delta V_{IN} = 10 \text{ V}$ ,  $I_{OUT} = 0.5 \text{ A}$ ,  $\Delta V_O = 8 \text{ mV}$
- Load Regulation:  $\Delta I_{OUT} = 1 \text{ A}$ ,  $V_{IN} = 25 \text{ V}$ ,  $\Delta V_O = 32 \text{ mV}$

**Fig. 16. Non-Standard Fixed Positive Output Voltage Regulator**



and

$$R_2 = \frac{V_O - V_{REG}}{6I_Q}$$

Example: Assuming 16 V output from a  $\mu A7815$  and  $I_Q = 5.1$  mA, with  $R_1 = 470 \Omega$

$$I_{R1} = \frac{15}{470} = 31.9 \text{ mA}$$

$$R_2 = \frac{16-15}{37} = 27 \Omega$$

To compensate for fluctuations in quiescent current, output voltage tolerance and resistor tolerance,  $R_2$  may have to be an adjustable resistor if a tight tolerance  $V_O$  is desired.

Another method of obtaining non-standard output voltages or adjustable outputs from a fixed 3-terminal regulator is to use an operational amplifier as shown in *Figure 3-17*. The voltage pedestal developed across  $R_2$  is added to the normal regulated output  $V_{REG}$ , so that, for the component values shown,

$$V_O = \frac{V_{REG}}{11} + \frac{R_1 + R_2}{R_1}$$

The negative supply is required to allow adjustment to the lower output voltages. The maximum supply voltage is restricted by the maximum supply voltage rating of the  $\mu A741$ .

#### Basic 4-Terminal Positive Regulators

The 4-terminal adjustable regulators are ideal for applications that require non-standard output voltages. Fixed or adjustable output voltages are determined by the following equation.

$$V_O = V_{cont} \frac{(R_1 + R_2)}{R_2}$$

where  $V_{cont}$  = control pin voltage which is nominally 5.0 V for the  $\mu A78G$  or  $\mu A78MG$ .

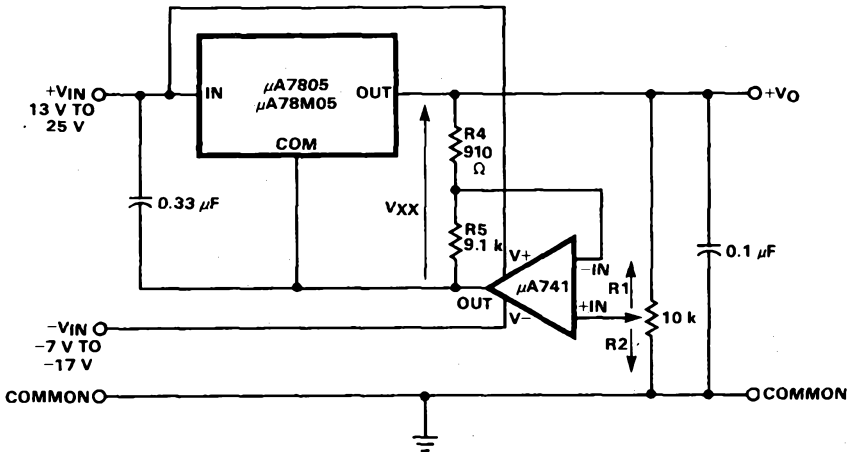
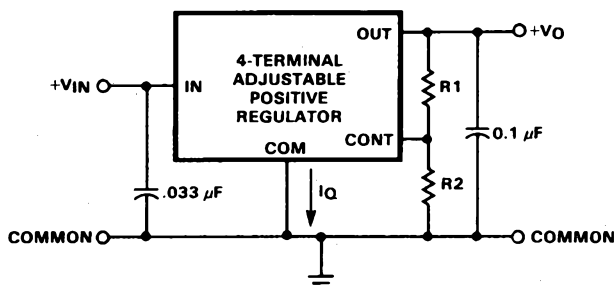


Fig. 17. Variable Output Voltage, 0.5 to 10 V

Output voltage ranges from the value of the control voltages to 30 V can be obtained using the circuit in *Figure 3-18*. Load regulation of the 4-terminal regulators can be improved if the feedback resistors R1 and R2 are connected to the load side of the output rather than directly across the regulator.

### Adjustable Regulator with Increased Output Current

For applications that require higher output current, the bootstrapped emitter-follower output circuit shown in *Figure 3-19* provides current in excess of 20 A. Note that the base-emitter junction of the external series-pass transistor Q1 is in the feedback loop and consequently does not affect the temperature coefficient of the output voltage. Also note that Q1 is not protected against output shorts. Protection can be added as shown in *Figure 3-20a*. Here Q2 protects Q1 and Q2 must have a current rating equal to the short circuit current of the regulator. *Figure 3-20b* illustrates how short-circuit protection can be added when more than one device is used as a series-pass element. Another method of-obtaining increased output currents is shown in *Figure 3-21* and 3-22. These are basically the same circuits covered under fixed regulators (*Figures 3-2* and 3-3).



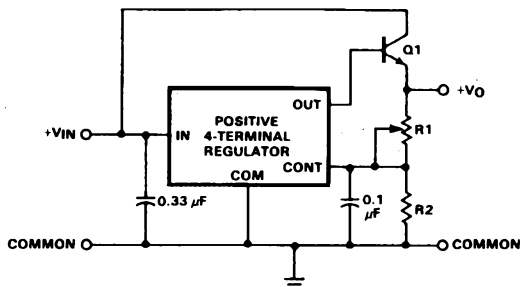
NOTES:

$$V_O = \frac{R_1 + R_2}{R_2} V_{\text{CONTROL}}$$

$V_{\text{CONTROL}}$  Nominal = 5 V

Recommended R2 current  $\approx 1$  mA

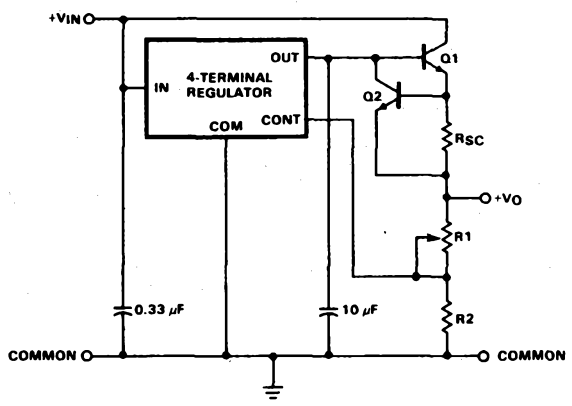
**Fig. 3-18. Basic 4-Terminal Fixed or Adjustable Positive Regulator**



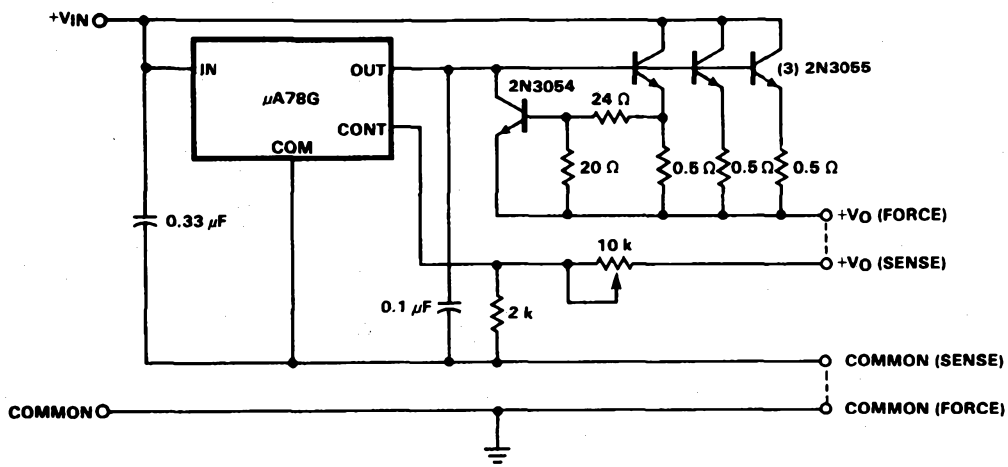
**Fig. 3-19. Adjustable Positive Regulator with Increased Output Current**

**Low Output Voltage Regulator**

For applications requiring output voltages below the capabilities of the 4-terminal regulator, another regulator of opposite polarity can be used to offset output voltage by the required amount. *Figure 3-23* shows a supply with an adjustable output from 0 to 25 V. The negative  $\mu A79M05$  is used to offset the  $\mu A78MG$  common by 5 V to achieve an adjustable output range down to 0 V. The drawback of this circuit is that it requires a dual supply. The addition of the  $\mu A79M05$  increases the circuit complexity, but the resulting increase in output range will compensate for the additional number of circuit components.



**Fig. 3-20a. Positive High Current Short Circuit Protected Regulator**



**NOTES:**  
 Typical Performance:  $V_O = 10\text{ V}$   
 Line Regulation:  $I_{OUT} = 5\text{ A}$ ,  $\Delta V_{IN} = 10\text{ V}$ ,  $\Delta V_O = 4\text{ mV}$   
 Load Regulation:  $V_{IN} = 18\text{ V}$ ,  $\Delta I_{OUT} = 10\text{ A}$ ,  $\Delta V_O = 2\text{ mV}$   
 Short Circuit Current:  $V_{IN} = 18\text{ V}$ ,  $I_{OUT} = 13\text{ A}$

**Fig. 3-20b. 10 A, 5 to 30 V Adjustable Regulator with Short Circuit Protection**

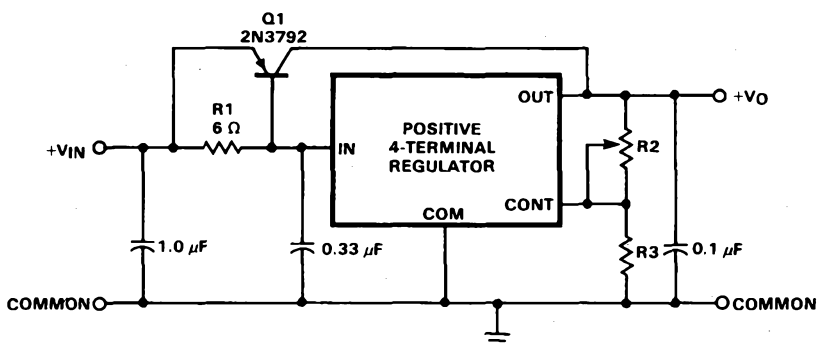
### Adjustable 3 and 4-Terminal Negative Regulators

The concepts used for the positive regulators can be expanded to include negative regulators. The fixed 3-terminal or adjustable 4-terminal negative regulators can be used to obtain the required outputs.

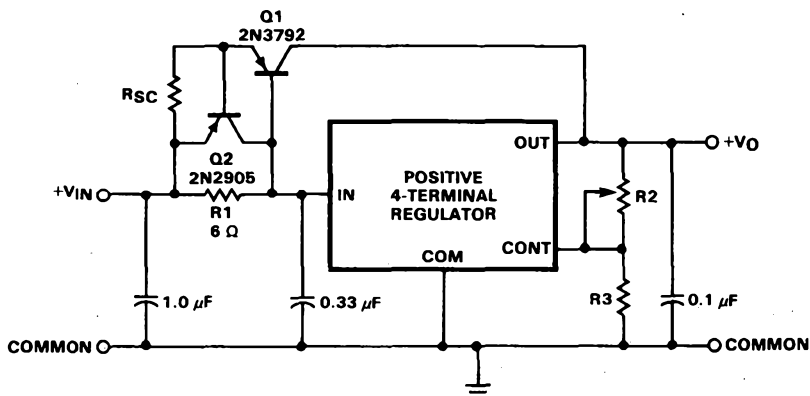
#### Non-Standard Fixed Negative Output Voltage

Figure 3-24 shows the method for obtaining a non-standard negative output voltage from a standard negative 3-terminal regulator. The design procedure is exactly the same as that used for the positive regulator. The voltage pedestal across R2 raises the output voltage to the required level. The output voltage can be calculated as follows.

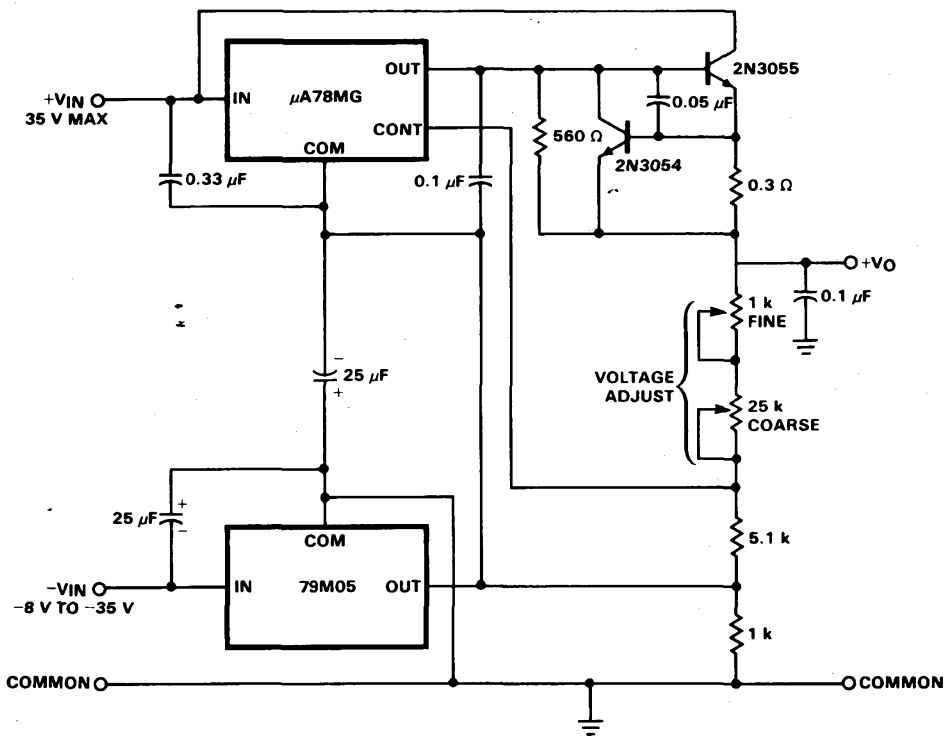
$$V_O = V_{xx} \frac{(R1 + R2)}{R1} + I_O R2$$



**Fig. 3-21. Positive High Current Adjustable Regulator (No Short Circuit Protection)**



**Fig. 3-22. Positive High Current Adjustable Regulator (With Short Circuit Protection)**



NOTES:  
 Load Regulation:  $V_{IN} = 30\text{ V}$   
 $V_O =$                     2 V        6 V        26 V  
 $\Delta V_{OUT} = 1\text{ A}$         -26 mV   -28 mV   -12 mV  
 $\Delta I_{OUT} = 2\text{ A}$         -30 mV   -35 mV   -18 mV  
 $V_O = 0\text{ to }25\text{ V}$   
 $I_{OUT} = 0\text{ to }2\text{ A}$

Fig. 3-23. Adjustable Power Supply with Short Circuit Protection

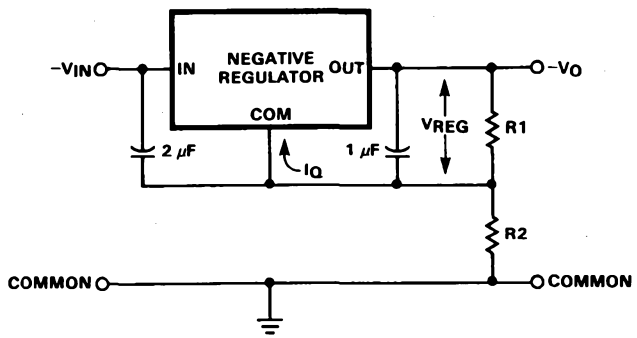


Fig. 3-24. Non-Standard Fixed Negative Output Voltage

Figure 3-25 shows an adjustable output negative regulator circuit with an output voltage range from -0.5 to -10 V. It requires a dual polarity supply. If a 5 V regulator is used, the output voltage is determined by the following formula.

$$V_O = V_{REG} \frac{R_1 + R_2}{11R_1} \text{ or } 0.45 \left(1 + \frac{R_2}{R_1}\right) V$$

#### Basic 4-Terminal Negative Regulators

The  $\mu A79G$  and  $\mu A79MG$  4-terminal negative adjustable voltage regulators have a nominal reference of -2.23 V. The output voltage is determined as follows:

$$V_{OUT} = V_{cont} \frac{(R_1 + R_2)}{R_2}$$

Output voltages from the control voltage to -30 V can be obtained using the circuit in Figure 3-26. The output-current capability of the 4-terminal negative adjustable regulators can also be increased by using

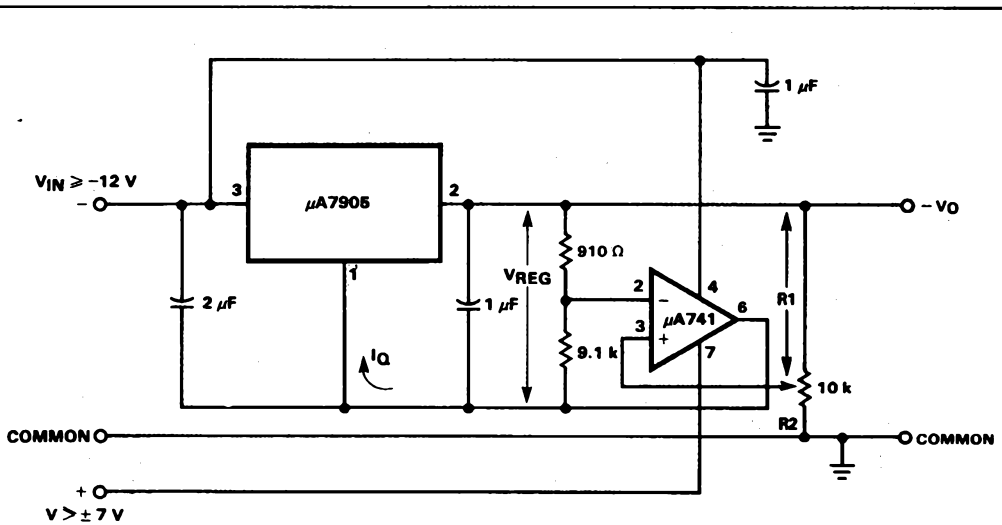
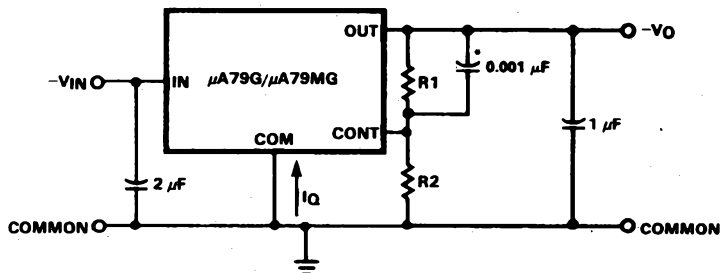


Fig. 3-25. Adjustable Output Negative Regulator (-0.5 V to -10 V)



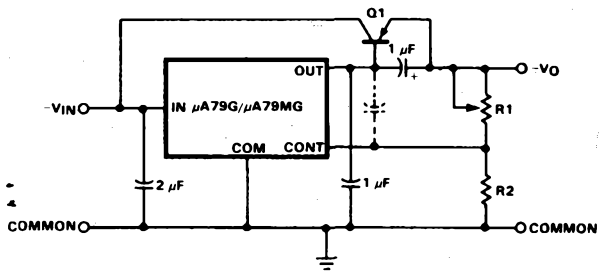
\*may be necessary with long leads

$$V_O = \left(\frac{R_1 + R_2}{R_2}\right) V_{CONTROL}$$

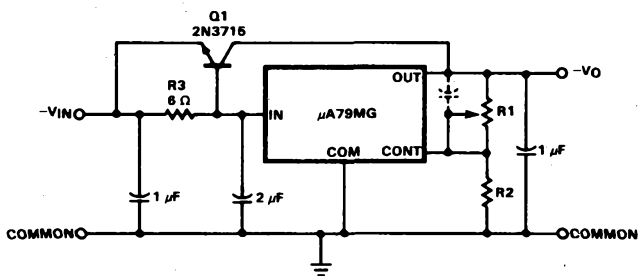
$$V_{CONTROL} \text{ Nominal} = -2.23 V$$

Fig. 3-26. Basic 4-Terminal Fixed or Adjustable Negative Regulator

an external pnp or npn series-pass transistor as shown in *Figure 3-27* and *3-28*. These two circuits do not have short-circuit protection. *Figure 3-29* shows an adjustable high-current negative regulator with short-circuit protection. Transistor Q2, which protects the external series-pass transistor Q1 against shorts must have a current rating equal to the short-circuit current of the IC regulator.

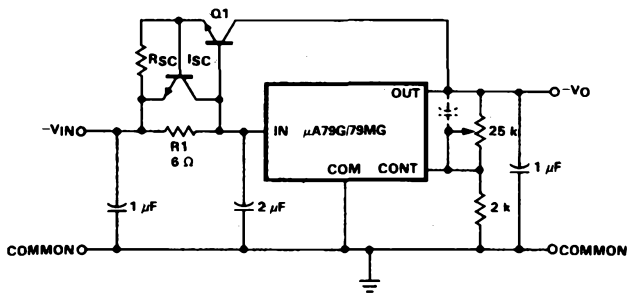


**Fig. 3-27. Adjustable High Current Negative Regulator**



NOTES:  $V_{IN} = -10\text{ V}$ ,  $V_O = -5\text{ V}$   
 Line Regulation:  $\Delta V_{IN} = 10\text{ V}$ ,  $I_{OUT} = 2\text{ A}$ ,  $\Delta V_O = 20\text{ mV}$   
 Load Regulation:  $\Delta I_{OUT} = 4\text{ A}$ ,  $\Delta V_O = 15\text{ mV}$

**Fig. 3-28. Negative High Current Adjustable Regulator**



NOTES:  $V_O = -2.2\text{ V to } -30\text{ V}$   

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{SC}}$$
  

$$R1 = \frac{\beta \times V_{BE}(Q1)}{I_{REG(max)}\beta - I_{OUT(max)}}$$

**Fig. 3-29. Negative High Current Regulator with Short Circuit Protection**

## Dual Regulators

Dual regulators, or dual power supplies, are normally used for applications requiring two output voltages of opposite polarities that do not necessarily have equal magnitudes, for example,  $+12\text{ V}$ ,  $-5\text{ V}$ . However, the word dual can also imply two supplies of the same polarity but of different magnitudes, such as  $+5\text{ V}$ ,  $+12\text{ V}$ . With dual tracking, not only are the output voltages of different polarities, but one output voltage always follows the other one, *i.e.*, an increase in the positive voltage results in a decrease in the negative output voltage.

### Dual Supplies

The simplest dual-polarity supply can be obtained by using a positive and a negative 3-terminal regulator with a center-tapped transformer as shown in *Figure 3-30*. The same type of dual supply can be achieved with two positive (or two negative) regulators if a transformer with two isolated windings is used as shown in *Figure 3-31*.

The reverse-biased diodes connected across the outputs of the dual regulator circuits are not necessary if the loads are referenced to ground. If the loads are tied between the two outputs, however, a latch-up may occur at the instant power is turned on, especially if one regulator input voltage rises faster than the second one. The diodes, that ensure proper start-up of the regulators by preventing a parasitic action from taking place when power is turned on, should have a current rating equal to half the load current.

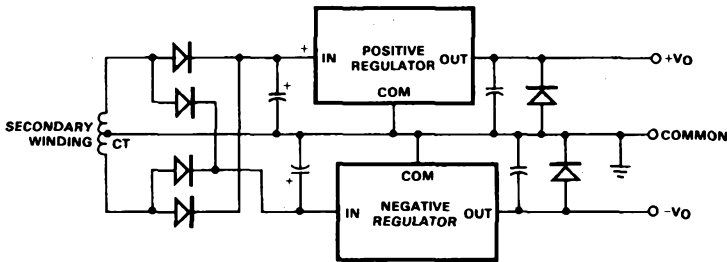


Fig. 3-30. Dual Supply using a Center Tapped Transformer with a Positive and a Negative 3-Terminal Regulator

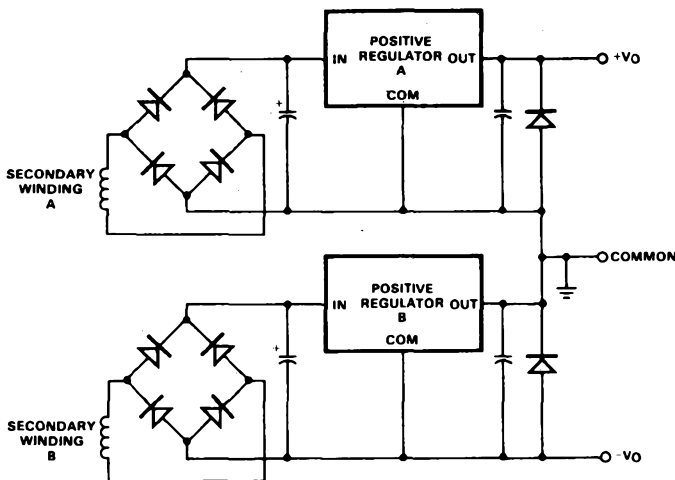


Fig. 3-31. Dual Supply using a Transformer with Two Windings and Two Positive 3-Terminal Regulators



Figure 3-32 shows a single positive-polarity dual supply with +5 and +10 V output. It uses two 5 V  $\mu$ A78M05 regulators operating from a single positive voltage source. The +10 V output is achieved by connecting the common terminal of the top regulator A to the output of the bottom regulator B. Diode D1 ensures proper start-up of the top regulator and prevents a latch-up that may occur under a heavy load condition on regulator A. Resistor R1 provides a path for the quiescent current of regulator A and can be eliminated if regulator B has a minimum load current greater than the quiescent current of regulator A.

The concept of Figure 3-32 can be used to achieve a dual-polarity output from a floating single supply as shown in Figure 3-33. This circuit is restricted in that  $R_{L+} > R_{L-}$ , since all of the current provided by the positive regulator A must flow through  $R_{L-}$ .

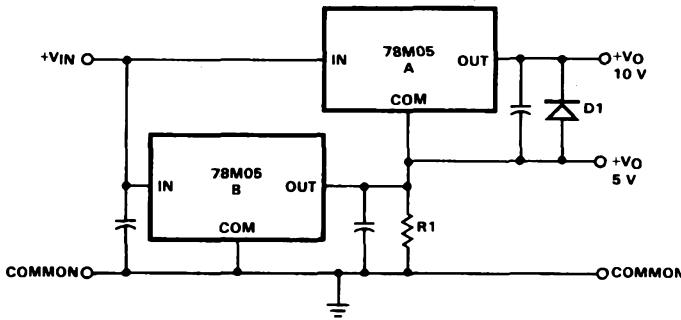
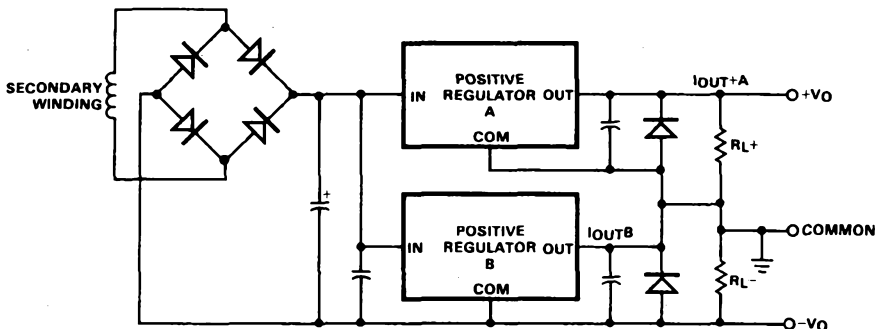


Fig. 3-32. A Dual Positive Supply with a +5 V and +10 V Output



NOTE:  $R_{L+} > R_{L-}$

Fig. 3-33. A Dual Polarity Supply from a Single Transformer Winding

### Fixed Dual Tracking Regulators

Figure 3-34 illustrates a power supply for applications that require tracking between dual supplies. This circuit has a positive and a negative regulator, an operational amplifier used as a comparator, and two matched resistors. Tracking is accomplished by connecting the two regulator common terminals to the output of the  $\mu A741$  that provides a potential on which the common terminals of the regulators float. The summed regulator outputs,  $V_{O+}$  and  $V_{O-}$ , are then compared to the power supply common.

The positive and negative regulator outputs track as follows: any change in the positive regulator output causes an opposite change on the common terminals and also on the negative regulator output. For example, a decrease in the positive regulator output voltage causes a like change in the amplitude of the negative regulator output. Since each regulator has a reference, no slaving exists between the outputs and, as a result, tracking is true and independent of polarity.

The degree of tracking depends on the matching of  $R_1$  and  $R_2$  since  $V_{O+}/V_{O-} \approx R_1/R_2$ . This configuration is also valid for non-symmetrical voltages. Proper care must be taken to insure that the maximum supply voltage rating of the  $\mu A741$  is not exceeded when the regulators are operating with high input voltage sources.

### Adjustable Dual Tracking Regulators

For applications requiring independently adjustable tracking outputs, the circuit of Figure 3-35 can be used. Tracking is accomplished by connecting a common resistor between the control terminals of the two 4-terminal adjustable regulators. Because of the internal feedback of the 4-terminal regulators, a constant voltage is developed across the resistor string  $R_1$ ,  $R_2$  and  $R_3$ . Variations at one of the output nodes are reflected at the control nodes causing corresponding variations at the opposite output node. Note that tracking between the two outputs is not one to one but rather depends on the absolute value of the two references and the feedback resistors  $R_1$ ,  $R_2$ , and  $R_3$ . The output voltages are determined by

$$V_{O+} = V_{REF+} + \frac{R_1}{R_2} (V_{REF+} - V_{REF-})$$

$$V_{O-} = V_{REF-} - \frac{R_3}{R_2} (V_{REF+} - V_{REF-})$$

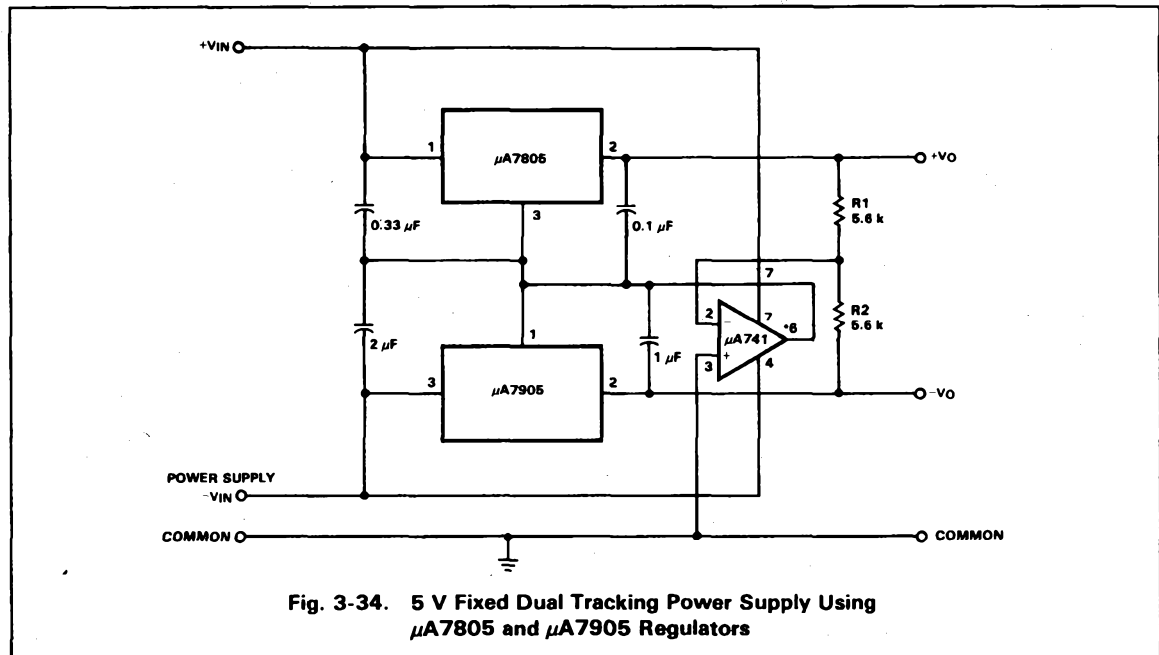


Fig. 3-34. 5 V Fixed Dual Tracking Power Supply Using  $\mu A7805$  and  $\mu A7905$  Regulators

Tracking between the outputs can be improved by adding a  $\mu A741$  and modifying the circuit as shown in *Figure 3-36*. This circuit yields an adjustable true dual-tracking regulator with internal short-circuit protection, safe-area limiting, thermal overload protection, and is capable of a 500 mA maximum output current. The outputs of the regulators are independently adjustable by potentiometers P1 and P2. With the component values shown, the output voltage of the positive  $\mu A78MG$  can be varied from 5 to 30 V, and the negative  $\mu A79MG$  can be varied from  $-2.2$  to 27.2 V. Operation of this circuit is the same as the circuit shown in *Figure 3-34*.

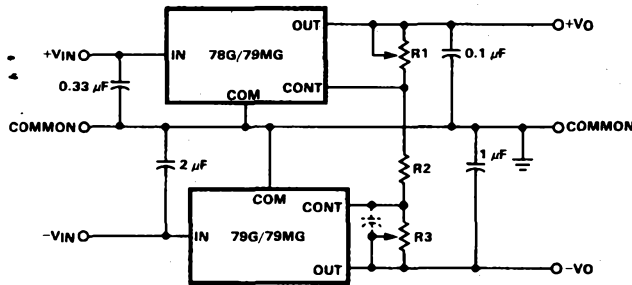


Fig. 3-35. Adjustable Dual Tracking Regulator

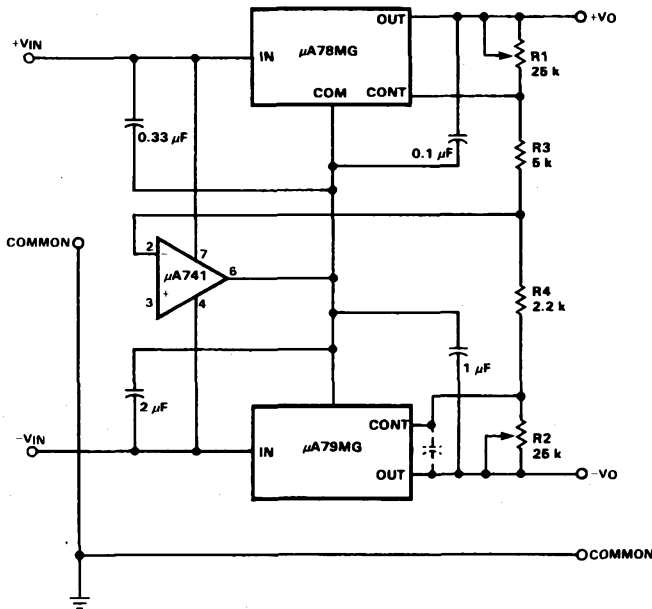
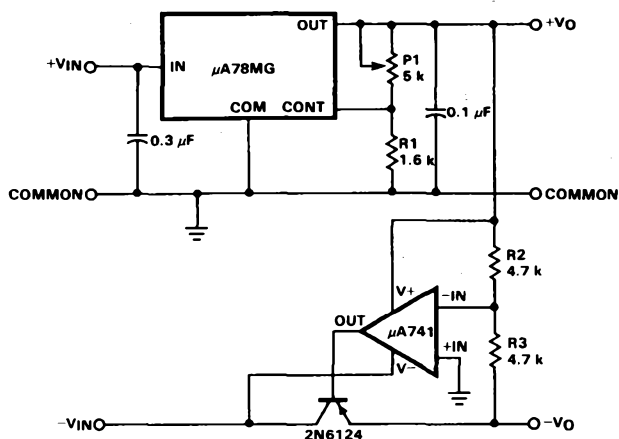


Fig. 3-36. Independently Adjustable True Dual Tracking Power Supply

Another method of obtaining dual tracking is to use a 4-terminal regulator with a  $\mu A741$  and an external series-pass transistor as shown in *Figures 3-37* and *3-38*. Operation of the circuits is as follows.

The 4-terminal regulator is used in its normal way as an adjustable regulator with the output adjusted by potentiometer P1. The  $\mu A741$  functions as an inverting amplifier and drives an external transistor that serves as a series pass for the complementary output. By grounding the non-inverting input of the  $\mu A741$  and connecting the inverting input to the junction of feedback resistors R2 and R3, the output of the external series pass transistor becomes a slave of the regulator output and, consequently, potentiometer P1 adjusts both outputs simultaneously. The output of the transistor side tracks the regulator output, because any change in the regulator output causes a proportionate change in the inverting input of the  $\mu A741$  and results in a corresponding change in the complementary output. Since the regulator output functions independently of the complementary output obtained from the external series-pass transistor, any change in the output from the series-pass has no effect on the regulator output. The transistor output is a slave of the regulator output and is not protected against shorts. The outputs for both circuits can be adjusted to a maximum of  $\pm 30$  V at the high end by the proper selection of R1 and P1. The low end can be adjusted to  $\pm 5$  V for the circuit of *Figure 3-37*, and to  $\pm 2.23$  V for *Figure 3-38*. For high input voltage conditions, proper care must be taken to insure that the maximum supply voltage rating of the  $\mu A741$  is not exceeded.

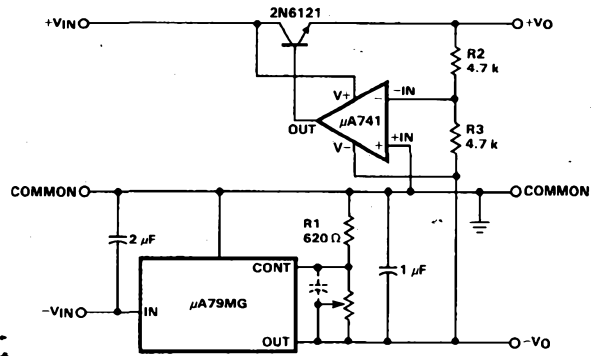
The  $\mu A741$  and the external series-pass transistor of *Figures 3-37* and *3-38* can be replaced by a power op amp such as the  $\mu A759$  as shown in *Figures 3-39* and *3-40*. Operation of these circuits is identical to the previous two, but since the  $\mu A759$  has internal short-circuit protection, thermal shutdown and safe-area protection, both outputs are therefore protected. Output currents in excess of  $+350/-200$  mA and  $+200/-350$  are achievable from the circuits of *Figures 3-37* and *3-38*, over the operating temperature ranges of the two parts. The output voltage range of *Figure 3-39* is limited by the 5 V reference of the  $\mu A78MG$  at the low end, and the maximum supply voltage of the  $\mu A759$  at the high end. The output voltage of *Figure 3-40*, however, is adjustable over a wider range ( $\pm 2.2$  V to  $\pm 30$  V) because of the lower reference voltage of the  $\mu A79MG$  and the common-mode range of the  $\mu A759$ .



**NOTES:**

- Negative output is a slave of the positive output
- Output voltage balance ( $V_O = 10$  V): 10 mV
- Load regulation ( $\Delta I_{OUT} = 0.5$  A): 6 mV
- Line regulation ( $\Delta V_{IN} = 10$  V): 2 mV

**Fig. 3-37. Dual Tracking Adjustable Regulator**



NOTES:  
 Positive output is a slave of the negative output.  
 Performance is similar to the circuit of Fig. 3-37.

Fig. 3-38. Dual Tracking Adjustable Regulator

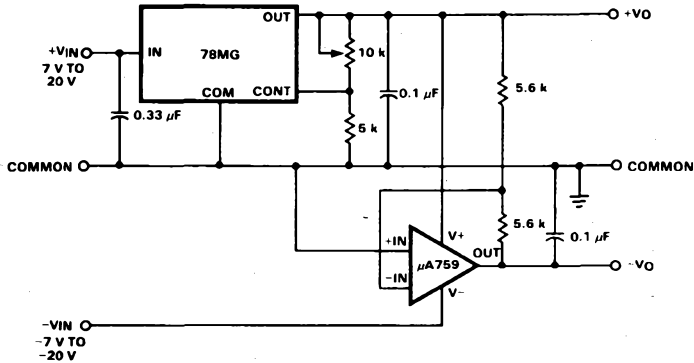


Fig. 3-39.  $\pm 5$  to  $\pm 15$  V Adjustable Dual Tracking Supply using a Positive Adjustable Regulator with a Power Op Amp

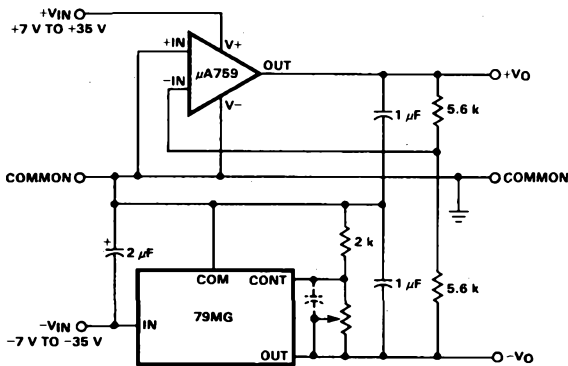


Fig. 3-40.  $\pm 2.2$  to  $\pm 30$  V Adjustable Dual Tracking Regulator using a Negative Adjustable Regulator and a Power Op Amp

## PRECISION VOLTAGE REGULATOR – $\mu$ A723

The  $\mu$ A723 is an industry standard universal building block for power supply design. The device consists of a temperature compensated reference amplifier, error amplifier, power series pass transistor and current limit circuitry. Additional npn or pnp pass elements may be used when output currents exceeding 150 mA are required. Provisions are made for adjustable current limiting and remote shutdown. In addition, the device features low standby current drain, low temperature drift and high ripple rejection. The  $\mu$ A723 is intended for use with positive or negative supplies as a series, shunt, switching or floating regulator.

Figure 3-41 shows the open loop frequency response of the  $\mu$ A723 voltage gain stage. The increase in the rate of phase shift is due to the beta fall off of the output stage at higher frequencies. This increasing phase shift rate requires device compensation whether or not the  $\mu$ A723 is used with external components.

Recommended frequency compensation for the unity gain is either a 5000 pF capacitor from the compensation terminal to the V- terminal or a 20 pF Miller compensation capacitor connected from the frequency compensation terminal to the inverting input. To allow proper operation when using the Miller compensation, the inverting input must be isolated from the remaining circuitry by some impedance. This is illustrated in Figure 3-48a. For output voltages greater than  $V_{REF}$ , the closed loop gain is greater than unity. If higher closed loop gains are used, the compensation capacitor can be reduced in direct proportion to the increase in gain.

When using an external series pass device, the 3 dB bandwidth of this device must also be considered, particularly since the majority of these devices have a much lower bandwidth than the  $\mu$ A723. For instance, if a 2N3055 is selected as the series pass device to be used in a unity gain configuration power supply, this device has a minimum  $f_T$  of 800 kHz and a maximum beta of 70. This introduces a 3 dB point in the overall loop gain at approximately 11 kHz, which means that heavier frequency compensation of the regulator is required to assure stability. Since the first break point of 11 kHz is due to the external power device, the regulator should have less than unity gain at the second break point. The second break point is the first break point of the  $\mu$ A723 gain stage, which occurs at approximately 80 kHz as shown in Figure 3-41. Adequate compensation is provided by a 0.02  $\mu$ F capacitor from the compensation terminal to common – or by a 40 pF Miller capacitor from the compensation terminal to the inverting input. As before, for any increase from unity gain, there can be a proportional reduction in the compensation capacitor.

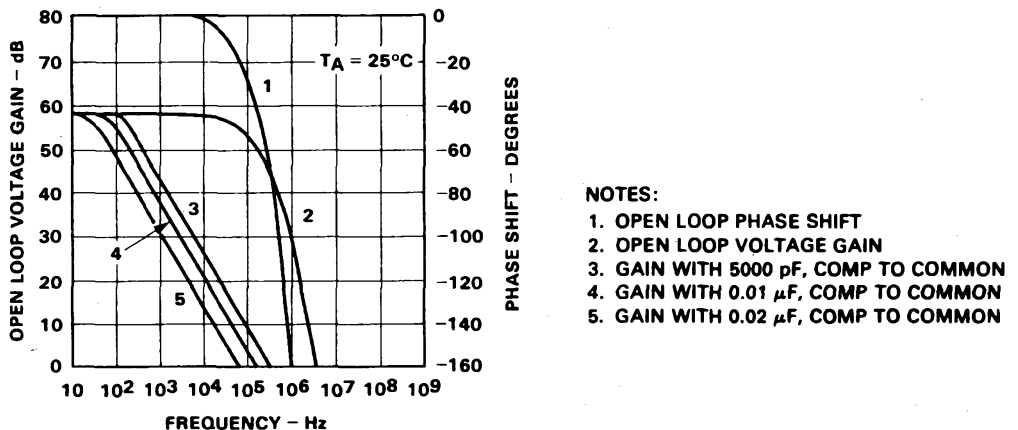


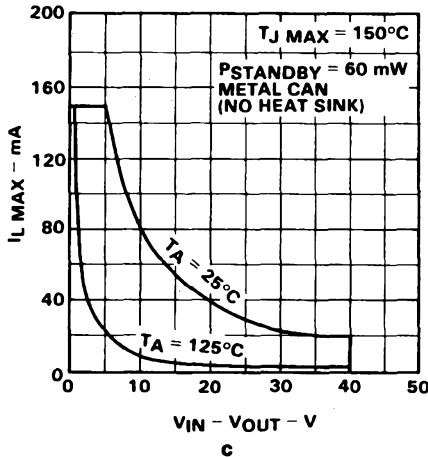
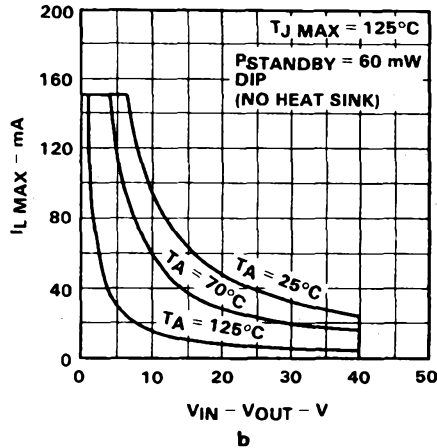
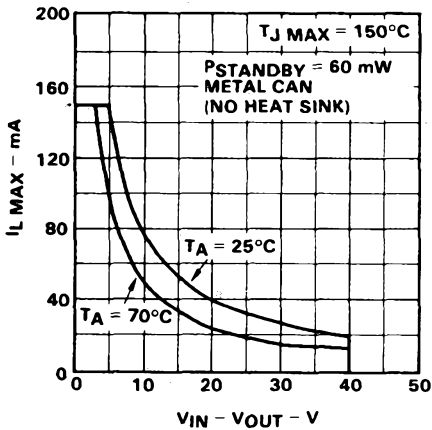
Fig. 3-41.  $\mu$ A723 Open Loop Voltage Gain and Phase Shift as a Function of Frequency

However, the value of the Miller capacitor may not be reduced in direct proportion to the standard compensation reduction; this is to allow for gain variations in the  $\mu A723$  and for parasitic capacitances. Extra capacitance may be required at both the input and the output of any power supply due to the inductive effects of long lines. Adding output capacitance provides the additional benefit of reducing the output impedance occurring at higher frequencies.

**THERMAL CONSIDERATIONS**

**$\mu A723$  Load Current Capabilities**

Figure 3-42 provides a quick reference to the allowable power dissipation of the  $\mu A723$  in terms of the input/output differential voltage and load current. Figure 3-42a is for the  $\mu A723C$  in the TO-100 package (10-lead metal can), Figure 3-42b is for the  $\mu A723/\mu A723C$  in the TO-116 package (14-lead, hermetic dual in-line); and Figure 3-42c refers to the MIL temperature range  $\mu A723$  in the metal can.



**Fig. 3-42.  $\mu A723$  Load Current Capabilities for Maximum Load Current as a Function of Input/Output Voltage Differential**

### $\mu$ A723 Maximum Power Dissipation in Free Air

The previous curves are based on the free-air dissipation ratings shown in *Figure 3-43*. The thermal derating factor is 6.8 mW/°C for the TO-100 metal can and 8 mW/°C for the TO-116 hermetic DIP. When it is necessary to heat sink the TO-100 package, a thermal resistance 50°C/W junction-to-case may be used. The relationship between power dissipation  $P_D$ , maximum ambient temperature  $T_A$ , and thermal resistance from case to ambient  $\theta_{CA}$ , is shown in the following equations. These equations may be used to calculate the maximum allowable power dissipation,  $P_D$ , or the maximum allowable heat sink resistance,  $\theta_{CA}$ , from a given set of conditions.

$$P_D = \left( \frac{150^\circ\text{C} - T_A}{50^\circ\text{C/W} - \theta_{CA}} \right) W, \text{ or } \theta_{CA} = \left( \frac{150^\circ\text{C} - T_A}{P_D} \right) - 50^\circ\text{C/W}$$

### FUNCTIONAL TEST CIRCUIT

#### Simplified Tester Schematic

A simplified functional test circuit for the  $\mu$ A723 is given in *Figure 3-44*. The output voltage is set for a nominal +5.0 V. The basic test steps are as follows.

1. Load Regulation at 50 mA, Close S1  
Measure output voltage change with S2 open and closed, (a load current change of 50 mA).
2. Line Regulation,  
Open S2  
Measure output voltage change resulting from a change in input voltage  $V_{IN}$
3. Short Circuit Current, Open S1 and S2  
Measure output current when the output is shorted to ground

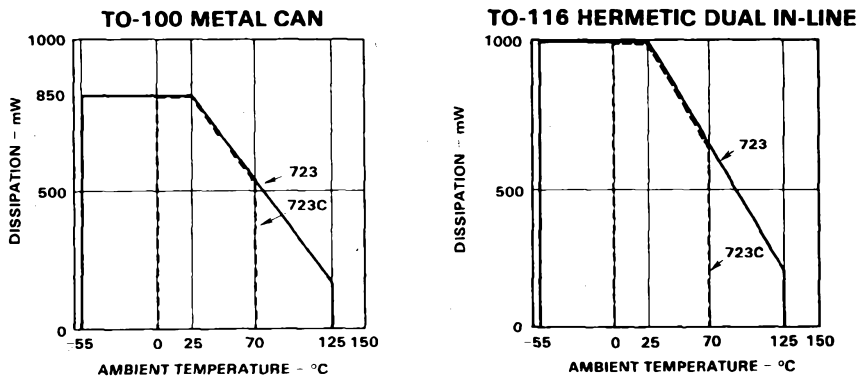


Fig. 3-43.  $\mu$ A723 Maximum Power Dissipation in Free Air

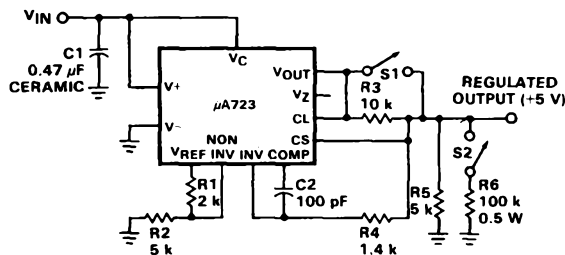


Fig. 3-44. Simplified Tester Schematic



# TYPICAL APPLICATIONS

## Introduction

The required output voltage for the following  $\mu A723$  applications can be calculated from the equation accompanying each circuit. In all cases the resulting resistor values are assumed to include any potentiometer resistance used. In addition, *Table 3-1*, included at the end of the section, affords a quick reference for many standard output voltage requirements. The previous section on frequency compensation is a guide to the suitable values of compensating capacitors used in the various applications. Specific transistor types are not included in this section. However, Chapter 5 includes a discussion of the selection of power devices.

In the following applications, the  $\mu A723$  is represented in a number of ways. In those circuits where the regulator operation is very basic, the symbol of *Figure 3-45* is used. In those applications where the circuit operation is clarified by the use of a functional schematic of the  $\mu A723$ , *Figure 3-46* is used. In some cases the individual components of this block may be rearranged to simplify a particular schematic. The reference voltage is represented by a single Zener diode, nominal voltage 7.15 V supplied from a constant current source. The output Zener diode,  $V_{OUT}$  to  $V_Z$ , is shown only in the required applications.

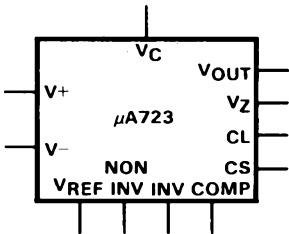


Fig. 3-45.  $\mu A723$  Logic Symbol

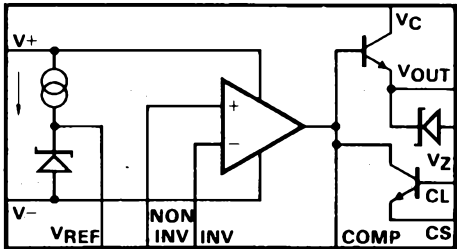


Fig. 3-46.  $\mu A723$  Functional Symbol

## Output Configurations

Many of the applications use internal Zener diodes for level shifting or for the generation of stabilized voltages. An explanation of where these diodes exist in the  $\mu A723$  circuit may help to avoid any problems arising from improper biasing.

The  $\mu A723$  output stage schematic is shown in *Figure 3-47a*. The  $V_Z$  terminal provides direct access to a 6.2 V Zener diode whose cathode is internally connected to  $V_{OUT}$ . Provided the internal current limit transistor is not required for output short circuit protection, its base-emitter junction provides another 6.2 V Zener diode (See *Figure 3-47b*). Note, however, that the anode of this diode, terminal CL, is connected internally by the collector-base junction diode to the base of the output drive transistor. When using the CL - CS Zener diode, the collector-base diode must always be reverse biased. Maximum permissible CL - CS Zener current is 5 mA. Correct biasing is assured in *Figure 3-47c* by interconnecting the  $V_{OUT}$  and CL terminals to provide both positive and negative 6.2 V Zener diodes referenced to the  $V_{OUT}$  terminal.

### Positive Regulators, 150 mA Maximum

*Figure 3-48a* shows the basic low voltage configuration suitable for output voltages ranging from 2 to 7 V. The reference voltage,  $V_{REF}$  is first divided down by  $R_1$ ,  $R_2$ , and, if desired, potentiometer  $P_1$ . Then it is applied to the non-inverting input of the error amplifier.  $C_{REF}$  may be added if ripple rejection greater than that specified for the  $\mu A723$  (74dB) is required. The presence of  $C_{REF}$  also reduces the regulated output noise voltage considerably.

Capacitor  $C_1$  provides frequency compensation.  $C_1$  is isolated from the low impedance output by  $R_3$  which also balances the error amplifier source impedances to give minimum temperature drift. To minimize component count at the expense of temperature drift,  $R_3$  may be omitted. In this case,  $C_1$  cannot be used for frequency compensation. Instead,  $C_2$  may be used from the compensation terminal to ground as shown in *Figure 3-48b*. To minimize power dissipation, the  $V_+$  and  $V_C$  terminals may be supplied separately, with  $V_+$  requiring a minimum of 9.5 V, while the  $V_C$  supply may be as low as 3 V above the regulated output voltage. The schematics shown in *Figure 3-48a* and *3-48b* have output voltages given by this equation.

$$V_O = \left( \frac{R_2}{R_1 + R_2} \right) V_{REF} \text{ where } (R_1 + R_2) > 1.5 \text{ k}\Omega$$

Output voltages from 7 to 37 V are obtainable with *Figure 3-48c*, with the equation below.

$$V_O = \left( \frac{R_1 + R_2}{R_2} \right) V_{REF}$$

If the reference bypass capacitor is required in this circuit, it should be connected from the non-inverting input to ground using  $R_3$  to increase the reference source impedance and improve the effectiveness of the reference capacitance. A 150 mA output current is available with  $R_{SC}$  set to zero. When short circuit current limiting is desired,  $R_{SC}$  may be used to limit the maximum output current as follows

$$I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}}$$

where  $V_{SENSE}$  (the sense voltage, or the voltage between terminals CL and CS) is given in *Figure 3-48d*. The resulting output current limit has a temperature coefficient of  $-0.3\%/^{\circ}\text{C}$ .

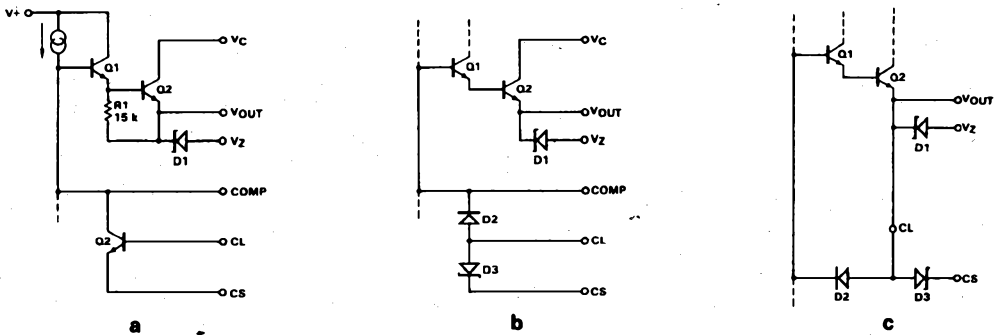
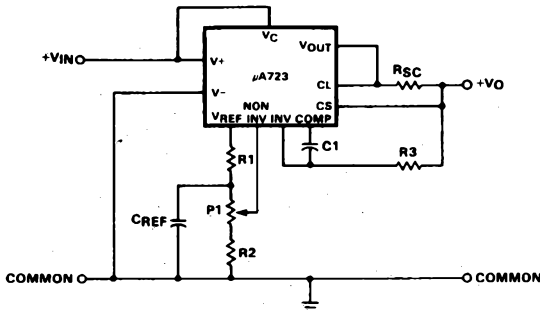


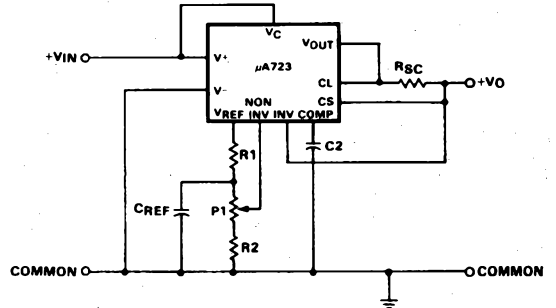
Fig. 3-47. Output Configurations



TYPICAL PERFORMANCE

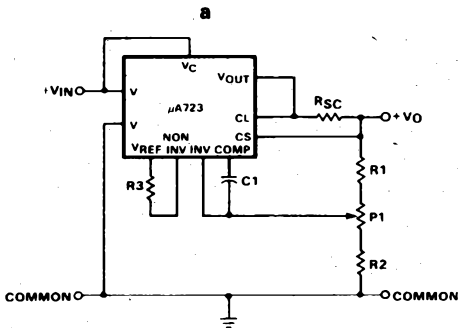
Regulated Output Voltage 5 V  
 Line Regulation ( $\Delta V_{IN} = 3$  V) 0.5 mV  
 Load Regulation ( $\Delta I_L = 50$  mA) 1.5 mV

NOTE:  $R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$  for minimum temperature drift



TYPICAL PERFORMANCE

Regulated Output Voltage 5 V  
 Line Regulation ( $\Delta V_{IN} = 3$  V) 0.5 mV  
 Load Regulation ( $\Delta I_L = 50$  mA) 1.5 mV



TYPICAL PERFORMANCE

Regulated Output Voltage 15 V  
 Line Regulation ( $\Delta V_{IN} = 3$  V) 1.5 mV  
 Load Regulation ( $\Delta I_L = 50$  mA) 4.5 mV

NOTE:  $R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$  for minimum temperature drift

R3 may be eliminated for minimum component count

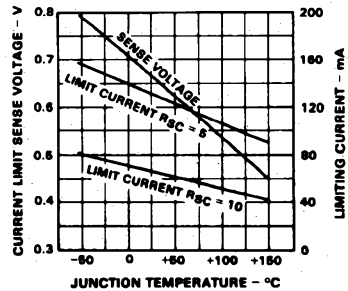


Fig. 3-48. Basic Regulator Configurations

### Positive Regulators, High Output Current

In *Figure 3-49a* an npn transistor, Q1, boosts the available output current beyond the capability of the  $\mu\text{A723}$ . Q1 can consist of several transistors cascaded to satisfy very high current requirements. In this circuit, one  $V_{BE}$  voltage must be added to the 3 V minimum input/output differential requirement for each transistor added. Depending on the type of transistor used for Q1,  $R_3$  should be added giving  $I_{CBO}$  compensation, and alleviating the safe area limitation of the output device. With  $R_{SC}$  set to zero, the maximum output current capability is  $(Q1 \text{ beta}) \times (150 \text{ mA})$ .  $R_{SC}$  may be used to limit the short circuit current to any desired value up to this maximum in the same manner as outlined previously in *Figure 3-48*.

An alternate circuit is shown in *Figure 3-49b*. Using an external pnp transistor, maximum output current is again  $(Q1 \text{ beta}) \times (150 \text{ mA})$ . One  $V_{BE}$  should be added to the minimum input-output differential voltage requirement for each additional transistor. The circuits in *Figure 3-49* may support outputs in the range of 2 to 37 V by selecting the appropriate feedback network. *Figure 3-49a* is shown for output voltages from 7 to 37 V, whereas *Figure 3-49b* is shown for output voltages from 2 to 7 V.

If it is required to vary the output continuously over a 10 to 1 range, it is necessary first to attenuate  $V_O$  so that  $V_{INV}$  never exceeds  $V_{REF}$  even when  $V_O$  is at its maximum value, then provide a potentiometer adjustment from  $V_{REF}$  to the non-inverting input. This is illustrated in *Figure 3-49c*, where  $V_O$  is attenuated by a ratio of 5:2:1. Maximum permissible  $V_O$  is then 35 V (giving a  $V_{INV}$  of 6.8 V), which requires  $38.6 \text{ V} \leq V_{IN} \leq 40 \text{ V}$ . Minimum  $V_O$  is determined by the minimum value for  $V_{INV}$ . The specified minimum  $V_{INV}$  is 2 V; however, typically,  $V_{INV}$  may be reduced to approximately 0.72 V before the circuit no longer regulates. This corresponds to a  $V_O$  of 3.7 V. Other 10 to 1 voltage ranges may be obtained by varying the attenuation ratio,  $(R_3 + R_4)/R_4$ , from 5.2 to, say, 1.4. Then  $V_O$  range will be 1 V to 10 V ( $13.6 \text{ V} \leq V_{IN} \leq 39 \text{ V}$ ).

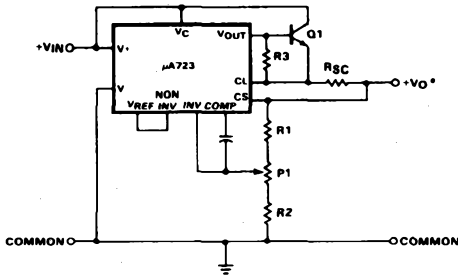
$$V_O = V_{REF} \left( \frac{R_2}{R_4} \right) \left( \frac{R_3 + R_4}{R_1 + R_2} \right)$$

or, with the values of  $R_3$  and  $R_4$  as shown,

$$V_O = 5.2 V_{REF} \left( \frac{R_2}{R_1 + R_2} \right)$$

### Positive Shunt Regulator

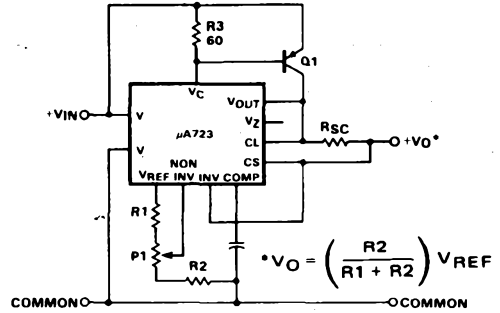
The  $\mu\text{A723}$  may be used in a shunt regulating mode by adding an external transistor, Q1. Special attention should be paid to ensure that the series limiting resistor,  $R_4$ , is capable of handling the high power dissipation inherent in this mode of operation. *Figure 3-50a* is used with the 14-lead DIP version of the  $\mu\text{A723}$ . When the 10-lead metal can is used, however, it is necessary to add a 6.2 V Zener diode externally, as in *Figure 3-50b*.



**TYPICAL PERFORMANCE**

Regulated Output Voltage +15 V  
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ ) 1.5 mV  
 Load Regulation ( $\Delta I_L = 1\text{ A}$ ) 15 mV

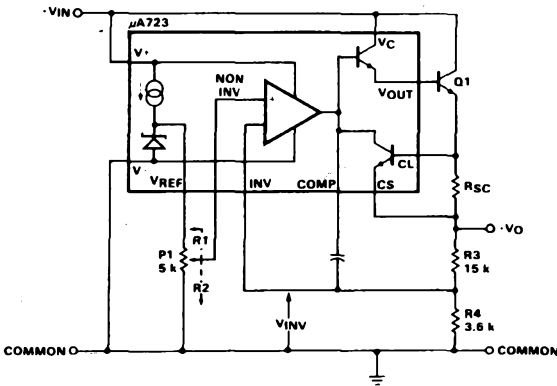
**a**



**TYPICAL PERFORMANCE**

Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ ) 0.5 mV  
 Load Regulation ( $\Delta I_L = 1\text{ A}$ ) 5 mV

**b**

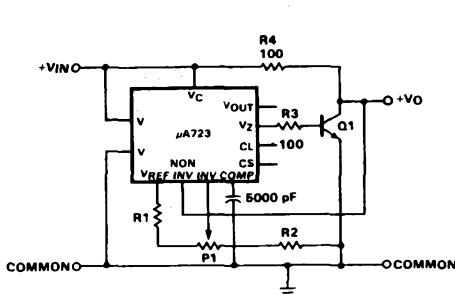


**TYPICAL PERFORMANCE**

Regulated Output Voltage 4-35 V  
 Line Regulation ( $\Delta V_{IN} = 10\text{ V}$ ) 1 mV  
 Load Regulation ( $\Delta I_L = 100\text{ mA}$ ) 1 mV

**c**

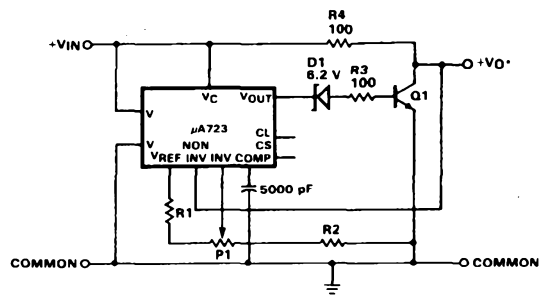
**Fig. 3-49. High Current Regulators**



**TYPICAL PERFORMANCE**

Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 10\text{ V}$ ) 0.5 mV  
 Load Regulation ( $\Delta I_L = 100\text{ mA}$ ) 1.5 mV

**a**



$$V_{O} = \left( \frac{R_2}{R_1 + R_2} \right) V_{REF}$$

**b**

**Fig. 3-50. Positive Shunt Regulators**

### Positive Regulators, High Line Rejection

As shown in *Figure 3-51a* and *b*, the circuits each use the internal current limit transistor to preregulate the V+ supply, thereby increasing the line rejection to more than 100 dB. The CS - CL terminals provide a 6.2 V Zener diode referenced to the output voltage, which is then used to supply V+. In these applications R3 must be chosen so that the current into the CS terminal is limited to 5 mA maximum.

### Positive Regulators, High Input Voltage

Input voltages greater than 40 V may be applied when the  $\mu A723$  is connected as shown in *Figure 3-52a*. The regulated output voltage must remain less than 38 V to protect the regulator. R3 may be replaced with a regulated current source in those cases where the variation of input voltage imposes excessive power dissipation in the internal series pass device. Q2 provides short circuit protection, if required (the internal current limit transistor cannot be used in this application). The maximum input voltage is determined by the breakdown characteristics of Q1. When using the  $\mu A723$  DIP version, D1 may be omitted and the V<sub>Z</sub> terminal grounded; in this case V<sub>REF</sub> must be resistively divided by two before being applied to the inverting input.

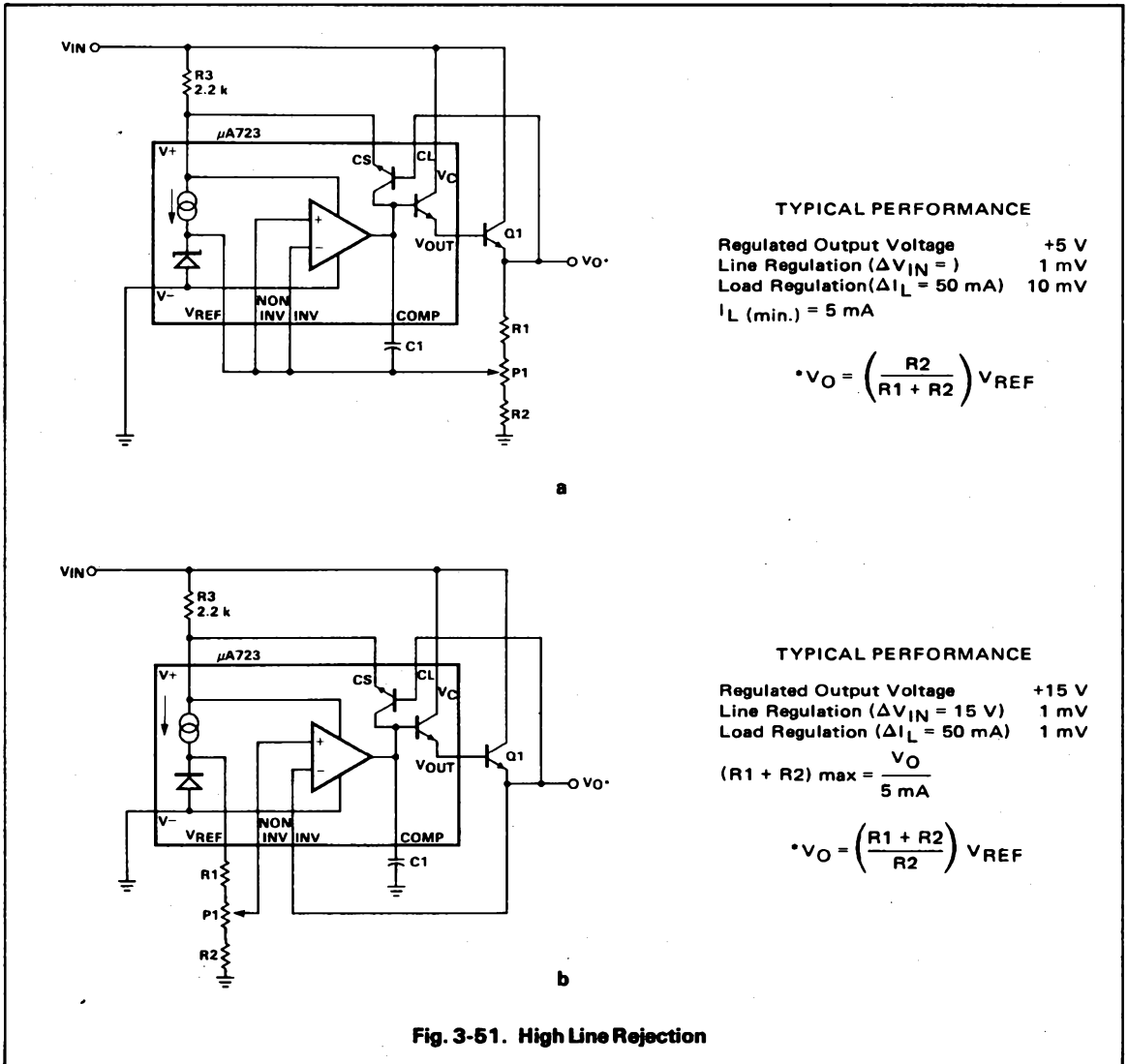


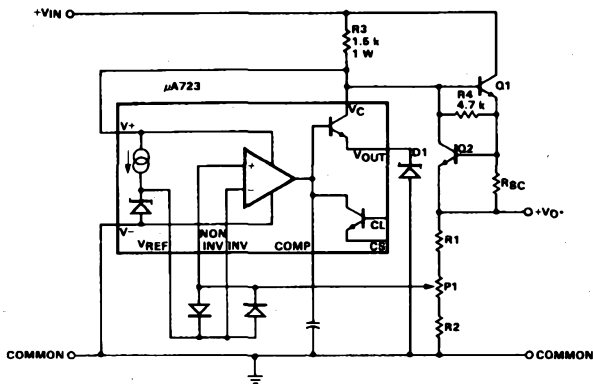
Fig. 3-51. High Line Rejection

Note that in this type of application where the  $\mu A723$  output stage is used as an additional inverting amplifier rather than the usual emitter follower,  $V_{REF}$  must be connected to the inverting input of the error amplifier to maintain correct phase relationships around the regulating loop, i.e., negative feedback from the output.

When using a pnp series pass device, high input voltages may be tolerated by using a Zener diode to reduce the voltage appearing across the  $\mu A723$ , as in *Figure 3-52b*. For example, if D1 is a 20 V Zener diode, input voltages to 60 V are permissible. D1 must be selected such that no more than 40 V is applied to the  $\mu A723$   $V_+$  and  $V_C$  terminals under maximum input voltage conditions. Similarly, the regulated output voltage must not exceed 37 V to maintain the specified input-to-output differential.

### Positive Regulator, Floating

The  $\mu A723$  may be used to directly regulate hundreds of volts using the configuration shown in *Figure 3-53*, in which a floating power source is provided for the regulator by D1. The series pass transistor becomes the only limiting factor in determining the maximum voltage and current which may be controlled. The  $V_{REF}$  terminal supplies all the current drawn by the sensing resistors and the total current must not exceed 5 mA.  $R_5$  must be selected to provide sufficient current to bias D1 and to supply the  $\mu A723$  standby current at the minimum input voltage condition. D2, D3 and D4 are for protection purposes; fast switching diodes should be used.

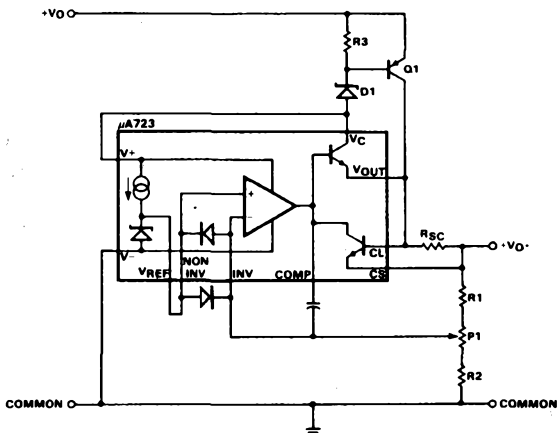


#### TYPICAL PERFORMANCE

Regulated Output Voltage +30 V  
 Line Regulation ( $\Delta V_{IN} = 20$  V) 90 mV  
 Load Regulation ( $\Delta I_L = 100$  mA) 8 mV

$$V_O = \left( \frac{R_1 + R_2}{R_2} \right) V_{REF}$$

a



#### TYPICAL PERFORMANCE

Regulated Output Voltage +15 V  
 Line Regulation ( $\Delta V_{IN} = 20$  V) 10 mV  
 Load Regulation ( $\Delta I_O = 100$  mA) 30 mV

$$V_O = \left( \frac{R_1 + R_2}{R_2} \right) V_{REF}$$

b

Fig. 3-52. High Input Voltage

If Q1 is a high  $f_T$  device, it may be necessary to add C2 to reduce the output noise level. If  $V_{IN}$  is switched on and off, causing a very high  $dV_{IN}/dt$  to appear at the  $\mu A723$  terminals, C3 may be added to ensure correct biasing throughout the circuit. In normal use, the on/off switch is in front of the rectifier/filter supply for  $V_{IN}$ , therefore C3 is not necessary. Note from Figure 3-53 the following.

$$V_O = V_{REF} \left[ \left( \frac{R_2}{R_1} \right) - \left( \frac{R_3}{R_1} \right) \left( \frac{R_1 + R_2}{R_3 + R_4} \right) \right]$$

If R3 and R4 are made equal,

$$V_O = \frac{V_{REF}}{2} \left( \frac{R_2 - R_1}{R_1} \right)$$

The normal minimum regulated output voltage limitation of 2 V for the  $\mu A723$  does not apply to this circuit, since output voltages down to zero volts are readily obtainable. Assuming the regulator is operating correctly, then the INV input equals the NON-INV input, i.e.,

$$(V_O + V_{REF}) \left( \frac{R_2}{R_1 + R_2} \right) = (V_{REF}) \left( \frac{R_3}{R_3 + R_4} \right) + V_O$$

$$V_O \left( \frac{R_2}{R_1 + R_2} - 1 \right) = V_{REF} \left[ \left( \frac{R_3}{R_3 + R_4} \right) - \left( \frac{R_2}{R_1 + R_2} \right) \right]$$

$$V_O = V_{REF} \left[ \left( \frac{R_2}{R_1} \right) - \left( \frac{R_3}{R_1} \right) \left( \frac{R_1 + R_2}{R_3 + R_4} \right) \right]$$

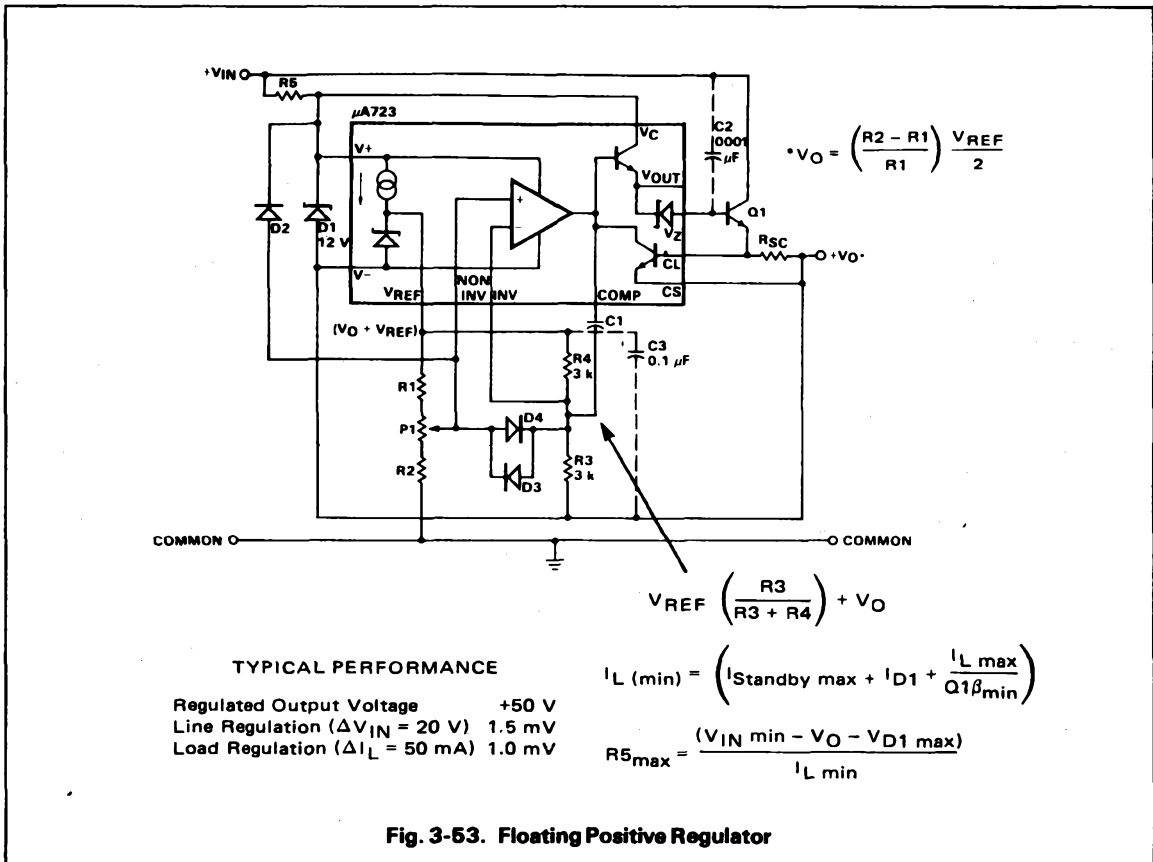
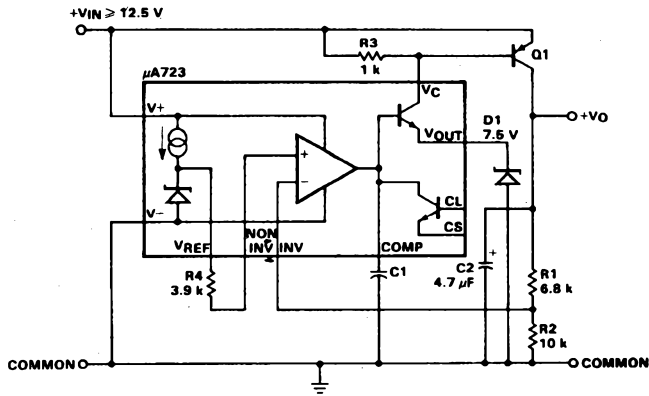


Fig. 3-53. Floating Positive Regulator





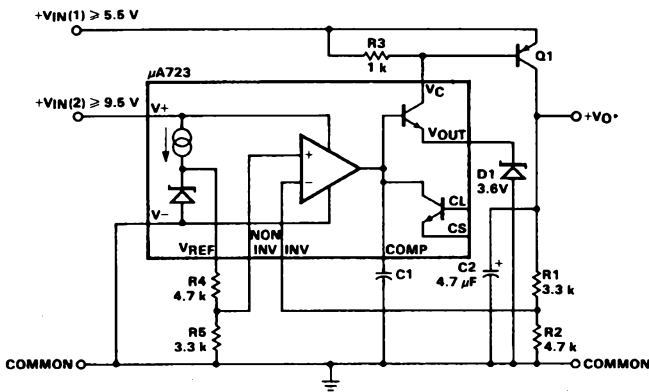
**TYPICAL PERFORMANCE**

Regulated Output Voltage	12 V
Line Regulation ( $12.5\text{ V} < V_{IN} < 15\text{ V}$ )	3 mV
Load Regulation ( $\Delta I_L = 1\text{ A}$ )	5 mV

$$V_O = \left( \frac{R_1 + R_2}{R_2} \right) V_{REF} = 12\text{ V}$$

a

3



**TYPICAL PERFORMANCE**

Regulated Output Voltage	5 V
Line Regulation ( $5.5\text{ V} < V_{IN(1)} < 10\text{ V}$ )	1 mV
Load Regulation ( $\Delta I_L = 1\text{ A}$ )	4 mV

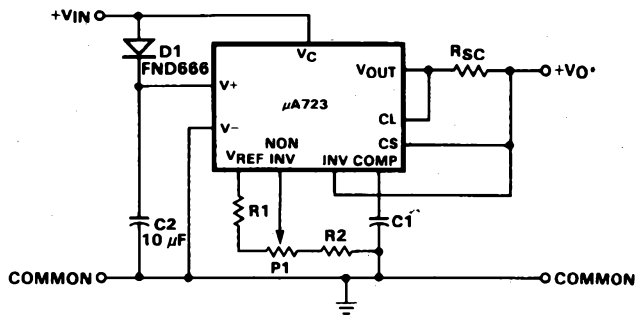
$$V_O = \left( \frac{R_1 + R_2}{R_2} \right) V_{REF} \left( \frac{3.3}{8} \right) = 5\text{ V}$$

b

**Fig. 3-54. Low Input/Output Differential**

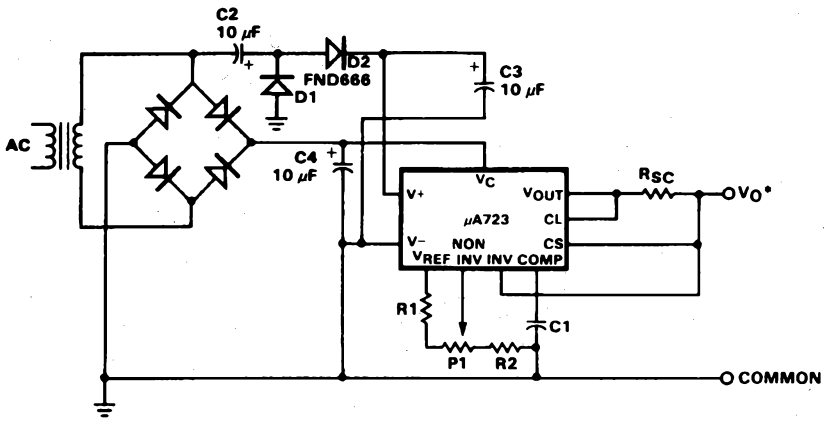
**Positive Regulators, Low Input/Output Differential**

Either of the two circuits shown in *Figure 3-54* allows an input-to-output voltage difference close to the saturation point of the series pass device. As in all applications, the  $V_{IN(2)}$  of *Figure 3-54b* must be 9.5 V minimum. The 7.5 V Zener diode may be eliminated (see *Figure 3-54a*) when using the dual in-line package by grounding the  $V_Z$  terminal and reducing the  $V_{REF}$  to 3 V by a 4.7 kΩ/3.3 kΩ voltage divider to the non-inverting input of the  $\mu\text{A723}$ .



$$V_O = \left( \frac{R_2}{R_1 + R_2} \right) V_{REF}$$

a



$$V_O = \left( \frac{R_2}{R_1 + R_2} \right) V_{REF}$$

b

Fig. 3-55. Marginal Input Voltage

### Positive Regulators, Marginal Input Voltage

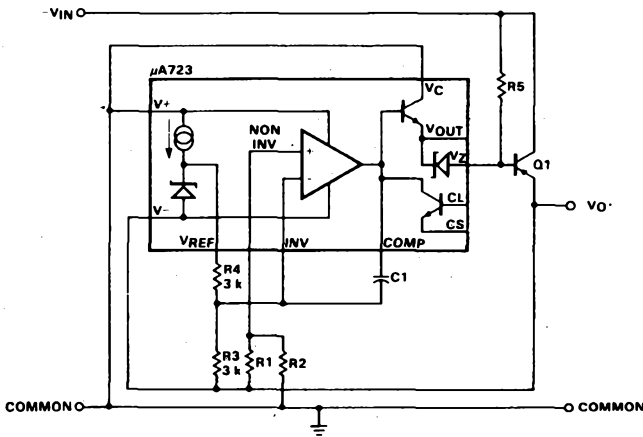
The two circuits shown in *Figure 3-55* offer some relief from the 9.5 V minimum  $V_+$  voltage when regulating lower voltages. In those cases where the average voltage applied to the input is greater than the required minimum – but the negative ripple peaks are lower – a diode-capacitor peak detector provides the solution (*Figure 3-54a*). *Figure 3-55b* shows one method of using a voltage doubler to assure that, using a minimum of external components, the proper bias voltage is applied to the  $V_+$  terminal.

### Negative Regulators, Medium/High Output Current

This configuration (*Figure 3-56a*) regulates any negative voltage between  $-9.5$  V and  $-40$  V. Since the  $\mu A723$  is operated between ground and the regulated output, the maximum unregulated input voltage is determined by the voltage breakdown and power dissipation capabilities of the pnp series pass

device, Q1. Base current Q1 is supplied through resistor R5 such that the minimum input-to-output differential is controlled both by the base current required by Q1 and the value of R5. A Darlington connection may be used for Q1 to reduce the base current requirement (*Figure 3-56b*) and to increase the output current capability. Either the complementary Darlington as shown, or a standard pnp pair can be used.

For output voltages in the range  $-2\text{ V}$  to  $-9.5\text{ V}$ , the output voltage alone is insufficient to bias the  $\mu\text{A}723$  in *Figure 3-56a*. This condition is satisfied in *Figure 3-57* by an external, regulated or unregulated, positive voltage applied to the  $V^+$  and  $V_C$  terminals. The  $40\text{ V}$  maximum limit between  $V^+$  and  $V^-$  terminals must be observed. Maximum values for  $-V_{IN(2)}$  and for the input-to-output differential are determined as for *Figure 3-56a*. In all cases, if the  $V_Z$  terminal is unavailable, then the  $V_{OUT}$  terminal may be used with a series  $6.2\text{ V}$  Zener diode.



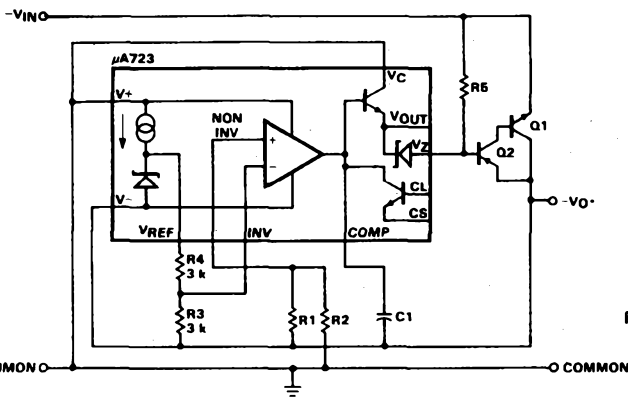
a

**TYPICAL PERFORMANCE**

Regulated Output Voltage	-15 V
Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )	1 mV
Load Regulation ( $\Delta I_L = 100\text{ mA}$ )	2 mV

$$R5 = (V_{IN\text{ min}} - V_O - V_{BE}) \left( \frac{Q1\beta_{\text{min}}}{I_L\text{ max}} \right)$$

$$-V_O = - \left( \frac{R1 + R2}{R1} \right) \frac{V_{REF}}{2}$$



b

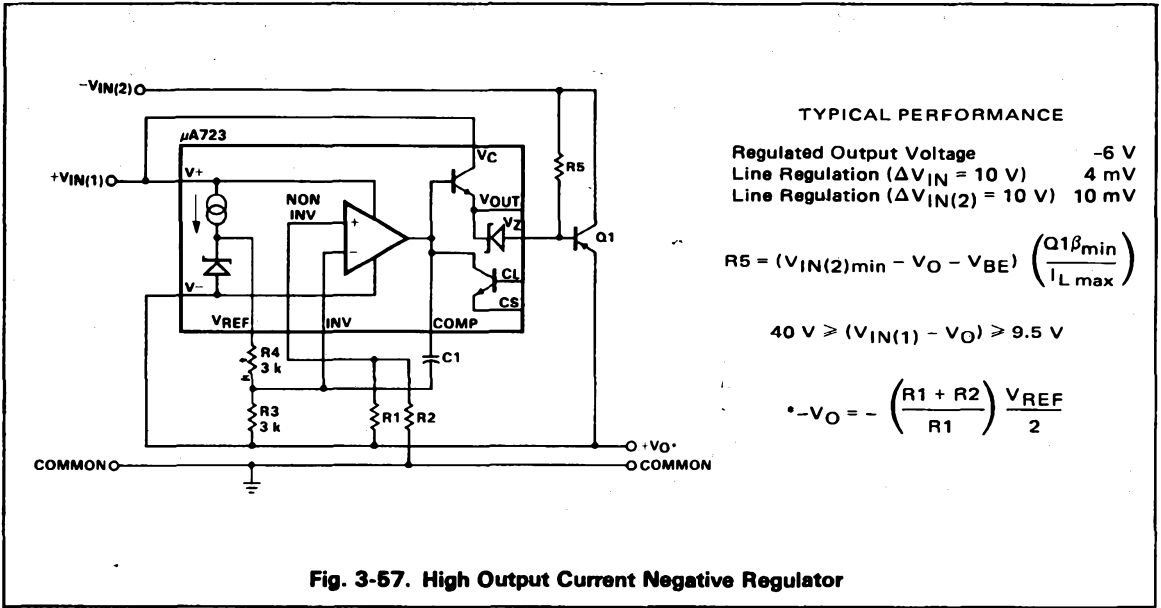
**TYPICAL PERFORMANCE**

Regulated Output Voltage	-15 V
Line Regulation ( $\Delta V_{IN} = 10\text{ V}$ )	4 mV
Load Regulation ( $\Delta I_L = 50\text{ mA}$ )	2 mV

$$-V_O = - \left( \frac{R1 + R2}{R1} \right) \frac{V_{REF}}{2}$$

$$R5 = \frac{(V_{IN\text{ min}} - V_O - V_{BE}) (Q1\beta_{\text{min}}) (Q2\beta_{\text{min}})}{I_L\text{ max}}$$

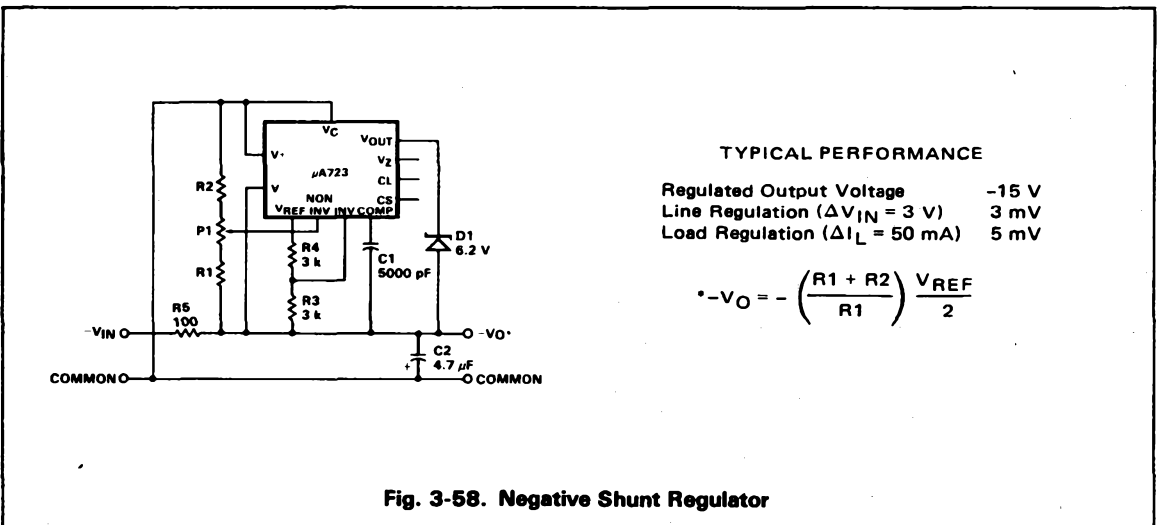
**Fig. 3-56. Medium/High Output Current Negative Regulators**



### Negative Shunt Regulator

For low to medium output currents, the series pass transistor of the previous circuits can be omitted. However, special attention must be paid to the dissipation of D1 and R5, and the internal dissipation of the  $\mu\text{A723}$ . Maximum permissible current shunted to ground via the  $V_{OUT}$  terminal is 150 mA.

Figure 3-58 as shown is suitable for output voltages in the range -9.5 V to -40 V. By removing the  $V^+$  and  $V_C$  terminals from ground and supplying them with a low value positive voltage as in Figure 3-57, output voltages from -2 V to -9.5 V are obtainable. Total voltage from  $V^-$  to  $V^+$  of 9.5 V minimum and 40 V maximum must be observed. If the maximum current from the  $V_{OUT}$  terminal is less than 20 mA in a particular application, then D1 may be omitted and the output connected to  $V_Z$  instead of  $V_{OUT}$ .



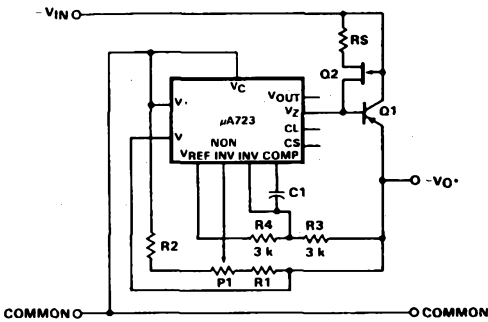
### Negative Regulator, High Line Rejection

In the negative regulators with a series pass device, the only variation seen by the control circuitry under varying input conditions is the current variation caused by the fixed resistance across the collector-base junction of the series transistor.

By replacing the resistor with a FET current source in *Figure 3-59* the line rejection is greatly improved, typically exceeding 100 dB. Output voltage range is  $-9.5\text{ V}$  to  $-40\text{ V}$ , extendable down to  $-2\text{ V}$  by the addition of positive supply as in *Figure 3-57*.  $R_5$  and  $Q_2$  must be selected to provide sufficient base current for  $Q_1$  under worst case conditions. With  $R_5$  equal to zero, a good choice for  $Q_2$  would be a 2N5484 since its  $I_{DSS}$  (zero-gate voltage-drain current) of 1 to 5 mA provides sufficient current for  $Q_1$  in most applications.

### Negative Regulator, Floating

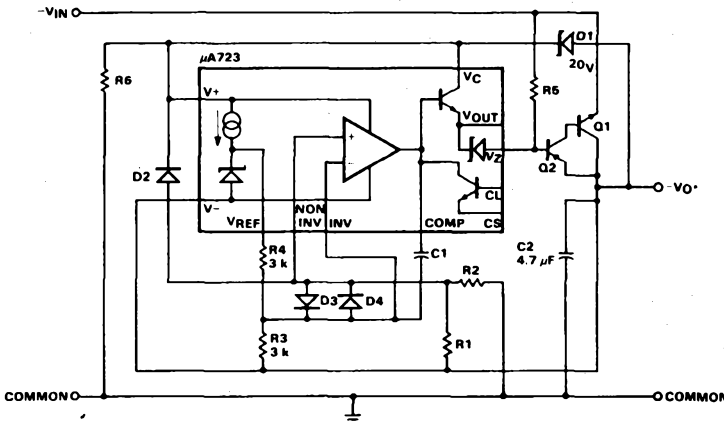
When the desired output voltage exceeds the 40 V maximum which may be applied across the device, then a Zener diode should be used to limit the voltage, as shown (*Figure 3-60*). The actual Zener voltage selected may be between 9.5 V and 40 V with little change in performance. This circuit is the complement of *Figure 3-53*.  $R_6$  must be selected to provide sufficient current to bias  $D_1$  and to supply the  $\mu\text{A}723$  standby current under minimum input voltage condition. Select  $R_6$  according to the requirements outlined in *Figure 3-56b*.



**TYPICAL PERFORMANCE**  
 Regulated Output Voltage  $-15\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )  $< 1\text{ mV}$   
 Load Regulation ( $\Delta I_L = 50\text{ mA}$ )  $2\text{ mV}$

$$-V_O = - \left( \frac{R_1 + R_2}{R_1} \right) \frac{V_{REF}}{2}$$

**Fig. 3-59. Negative High Line Rejection Regulator**



**TYPICAL PERFORMANCE**  
 Regulated Output Voltage  $-100\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )  $30\text{ mV}$   
 Load Regulation ( $\Delta I_L = 1\text{ A}$ )  $20\text{ mV}$

$$-V_O = - \left( \frac{R_1 + R_2}{R_1} \right) \frac{V_{REF}}{2}$$

**Fig. 3-60. Negative Floating**

### Current Regulators

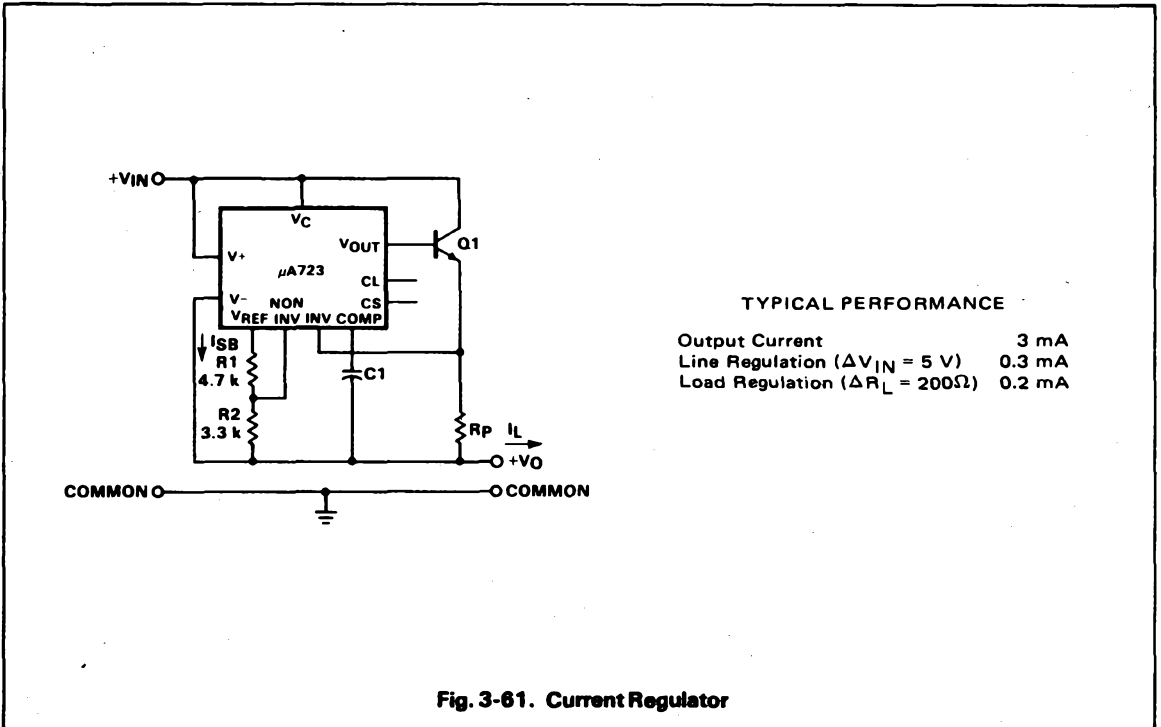
In *Figure 3-61*, the regulator forces a voltage to appear across  $R_p$  which is equal to the voltage existing across  $R_2$ . The resulting current is summed with the regulator standby current,  $I_{SB}$ , and the current through  $R_2$ , to provide a regulated current,  $I_L$ , into the load,  $R_L$ . Due to this summation, line regulation decreases for output currents below 10 mA.

The input voltage must be greater than  $I_L R_L(\max) + 9.5 \text{ V}$  to ensure sufficient voltage across the  $\mu\text{A}723$ . In *Figure 3-61*, the source current is from a positive voltage  $+V_{IN}$ .  $V_{IN}$  can, of course, be grounded while returning  $R_L$  to a negative voltage. Similarly, the output terminal may be grounded or taken to a negative voltage, at which time, the  $V_{IN}$  terminal provides a regulated current sink of magnitude  $I_L$ . In no case may the voltage from  $V^-$  to  $V^+$  exceed 40 V.

$$I_L = \left( \frac{R_2}{R_1 + R_2} \right) \left( \frac{V_{REF}}{R_p} \right) + I_{SB} + I_{R2} = \left( \frac{V_{REF}}{R_1 + R_2} \right) \left( 1 + \frac{R_2}{R_p} \right) + I_{SB}$$

For output currents in excess of 10 mA, this approximates to the following with the values of  $R_1$  and  $R_2$  shown.

$$I_L = \left( \frac{R_2}{R_1 + R_2} \right) \left( \frac{V_{REF}}{R_p} \right) + I_{SB} \approx \left( \frac{3000}{R_p(\Omega)} \right) + I_{SB} \text{ mA}$$



If a voltage compliance greater than 40 V is required, or if the regulation of *Figure 3-61* is insufficient, the configuration in *Figure 3-62* may be used. It is a precision floating current source capable of 0.05% regulation. In this circuit, a floating 20 V supply (typically a half-wave rectified output from a separate transformer winding of the main supply) is used to power the  $\mu A723$ , such that standby and reference currents do not add to the programmed output current.

$$I_L = \left( \frac{R_2}{R_1 + R_2} \right) \left( \frac{V_{REF}}{R_P} \right)$$

If P1 is adjusted so that  $V_{R2} = 3.0$  V, as indicated in the schematic, then

$$I_L = \frac{3000}{R_P(\Omega)} \text{ mA.}$$

Both output current and voltage compliance are limited by the capabilities of the series pass device Q1. Diodes D2 through D4 are protection diodes which should be included whenever  $V_{IN}$  exceeds 40 V.

3

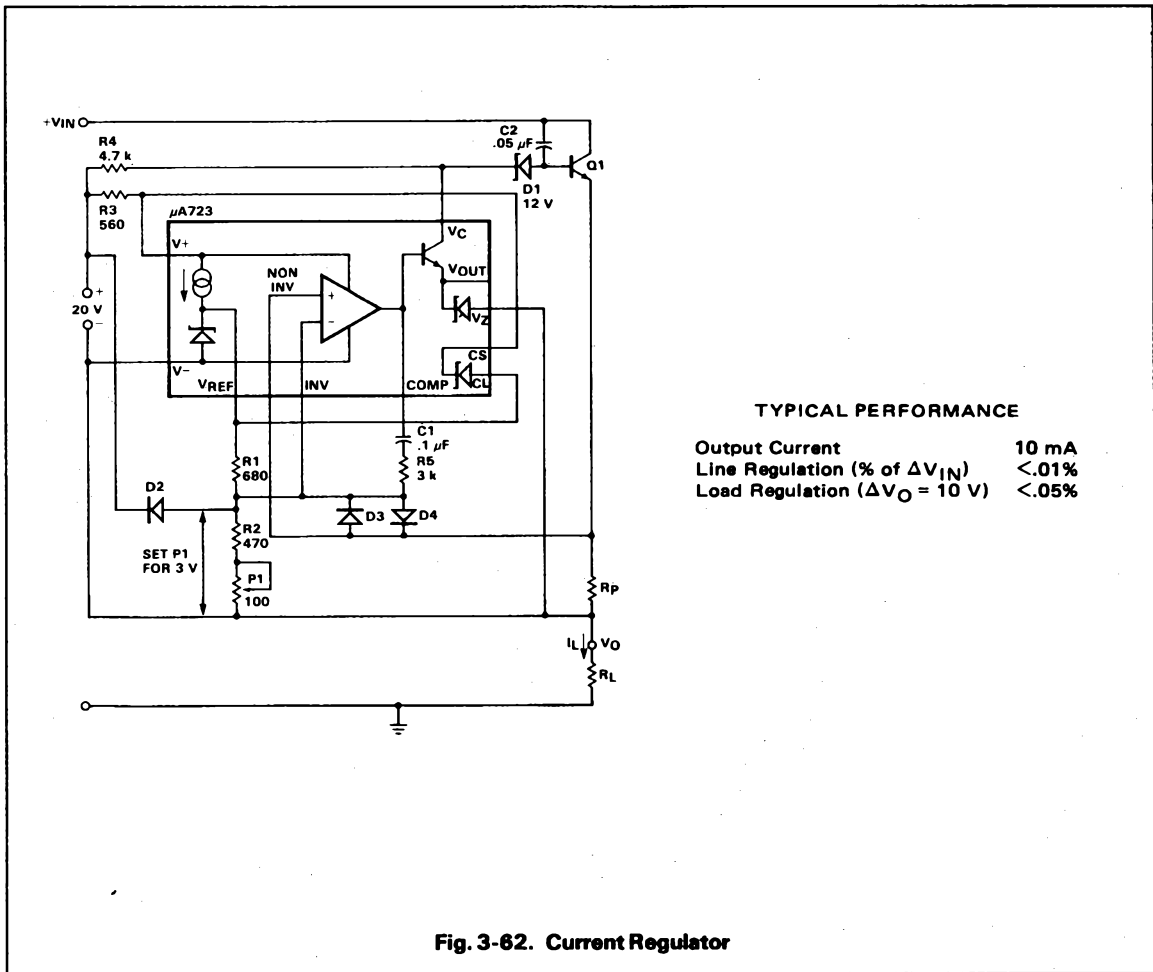
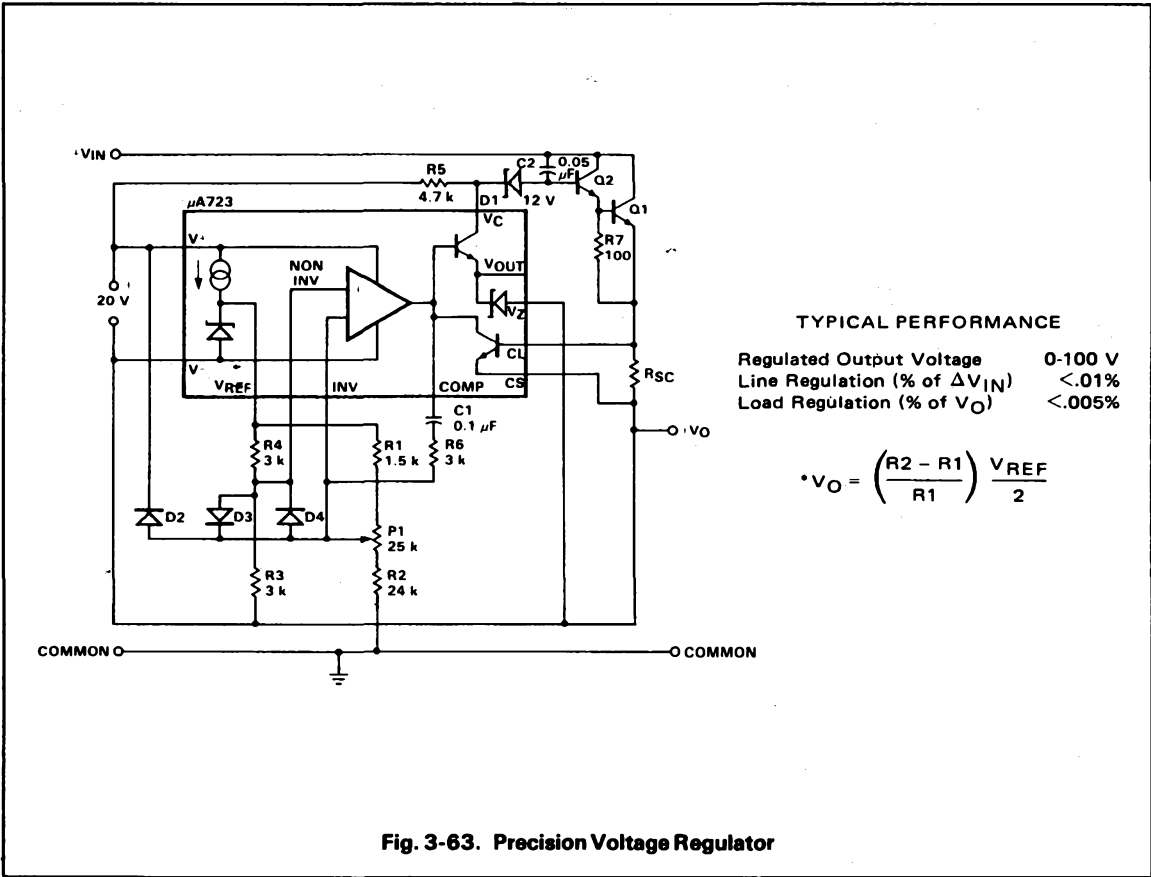


Fig. 3-62. Current Regulator



### Precision Voltage Regulator

Figure 3-63 uses the same principle as the previous circuit to give a voltage output capable of 0.005% load regulation. Output voltage range is from zero volts up to the series pass device limit. Output current is also limited only by the series pass device; short circuit protection is available in this configuration by selecting  $R_{SC}$  as previously described. Protection diodes D1, D3 and D4 should be added whenever  $V_{IN}$  exceeds 40 V. With the component values shown, this gives an output voltage range of 0 to 100 V.

$$V_O = \left( \frac{R_2 - R_1}{R_1} \right) \frac{V_{REF}}{2}$$

### Foldback Current Limiting

Foldback current limiting is a superior alternative to standard current limiting techniques particularly where intolerable output device power dissipation is a problem. Typically, this is a consequence of device/heat sink limitations under short circuit conditions.

In the following discussions, it is assumed that a regulated output voltage is available up to a maximum output current  $I_M$ . The output current then folds back with decreasing load resistance to a value of  $I_{SC}$  (with a short circuit load). The "knee" of the current limiting characteristic will be similar to that shown in the data sheet for normal current limiting. The regulation degrades considerably as  $I_M$  is approached and in a practical regulator the useful output current may be limited to approximately 80% of  $I_M$ .



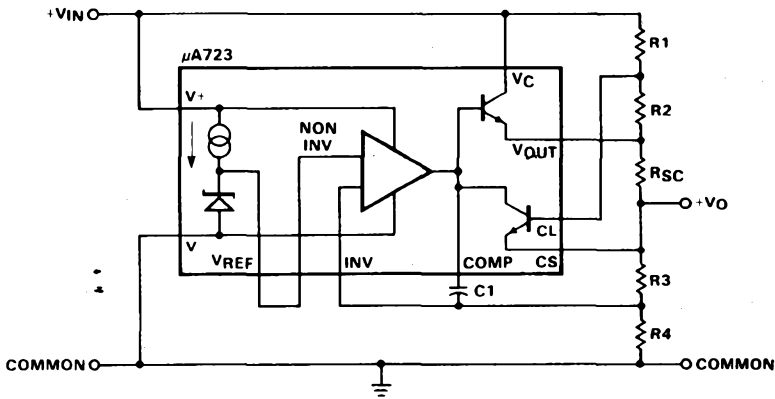


Fig. 3-64a. Foldback Current Limiting Positive Regulator

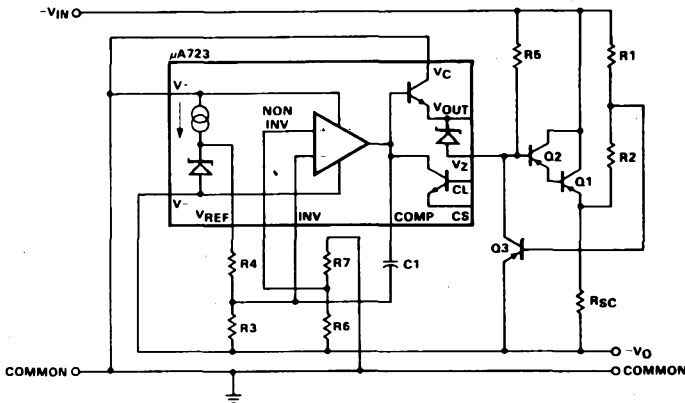


Fig. 3-64b. Foldback Current Limiting Negative Regulator

A minimum parts/cost method for providing the positive feedback required for foldback action is shown in Figures 3-64a and b. This technique introduces positive feedback by increased current flow through R1 and R2 under short circuit conditions. This forward biases the sensing-transistor base-emitter junction. The final percentage of foldback depends on the relative contributions of the voltage drop across R2 and R<sub>SC</sub> to the base current of the sensing transistor. In the active region where the voltage buildup of R2 and R<sub>SC</sub> provides base current to the sensing transistor, recovery of the full output capability takes place whenever a short circuit is removed from the output. As soon as there is no voltage buildup across R<sub>SC</sub> providing a portion of the base current, 100% positive feedback is realized and a reset is required to restore normal operation once the short is removed.

In *Figures 3-64a* and *b*, input to the current limit transistor is  $(V_{RSC} + V_{R2})$ .

$$I_{SC} = \frac{V_{SENSE}}{R_{SC}} \left( \frac{R1 + R2}{R1} \right) - \frac{V_{IN}}{R_{SC}} \left( \frac{R2}{R1} \right) \text{ and } I_M = I_{SC} + \frac{V_O}{R_{SC}} \left( \frac{R2}{R1} \right)$$

Design equations to give a desired  $I_M$  with approximately zero  $I_{SC}$  are shown below.

$$R1 \text{ (k}\Omega\text{)} = V_{IN} - V_{SENSE} \text{ (V)}, \quad R2 \text{ (k}\Omega\text{)} = V_{SENSE} \text{ (V)} \text{ (i.e. } R2 = 620 \Omega\text{)}$$

$$\text{and } R_{SC} = \frac{V_O}{I_M} \left( \frac{R2}{R1} \right), \text{ or } R_{SC} = \frac{V_O}{I_M} \left( \frac{V_{SENSE}}{V_{IN} - V_{SENSE}} \right)$$

In *Figure 3-64b*, a Darlington configuration is recommended for the bypass transistors, Q1 and Q2. This enables R5 to be a relatively high value, typically  $> 50 \text{ k}\Omega$  which requires Q3 to sink a low current under short circuit conditions. As R5 is reduced, the current through it increases drastically when  $-V_O$  goes to zero volts, and Q3 base current increases to a point where the foldback circuit is no longer operative. From the start of base-emitter conduction of the sense transistor to the full shut off of the regulator series-pass devices requires a  $2 \mu\text{A}$  base current. This represents a 10 mV increase in base-emitter voltage over the base-emitter zero-current threshold.

The latch condition, or 100% positive feedback, is generated by any change in the input voltage which increases the voltage drop across R2 past the 10 mV window with a short circuit applied. It can only be removed by breaking the positive feedback path by some manual reset to allow the series pass devices to once more be driven in a normal fashion. The addition of an external transistor Q1 in *Figure 3-64c* provides the same foldback limiting as *Figure 3-64a* but allows the extension of the active recovery region by several times that of the basic approach.

Latch problems are due to saturation of the current-sensing transistor. Because the additional circuitry shown operates as an antisaturation circuit, it bypasses base current above a value set by the voltage divider R3, R4 and the base-emitter threshold of Q1. This additional transistor acts as a  $V_{BE}$  voltage regulator and, assuming a good thermal link, temperature tracks the threshold changes of the current sensing transistor, tending to keep the foldback current drive at a constant level.

Foldback resistors R1 and R2 are calculated using the above equations. The 2N3641 used for Q1 was selected for both high base-emitter diode conductivity and reasonable beta at  $2 \mu\text{A}$  collector current. Final adjustment under short circuit conditions occurs when R4 in *Figure 3-64c* is set just above the point of minimum output current under short circuit load and high ac line operation.

Another approach to low power dissipation under short circuit condition is shown in *Figure 3-64d*. This circuit does not follow the decreasing current, decreasing voltage load line which occurs with the standard foldback technique. Instead, under a short circuit, the output voltage decreases in a normal current limiting fashion, i.e., at a constant high output current until the output voltage is below that necessary to keep the FET pinched off. As soon as the output voltage reaches the pinch-off voltage, a low impedance path is established around the drivers and the output device, which turns off the compound followers. A voltage across the normal load resistor exceeding the pinch-off voltage of the FET whenever the short is removed provides recovery. Bypass resistor R1 supplies this voltage. The FET should be selected with a maximum pinch-off voltage approximately two-thirds the value of  $V_O$ . Its minimum pinch-off voltage should not be so low as to demand excessive safe area requirements in the  $\mu\text{A723}$  output stage.

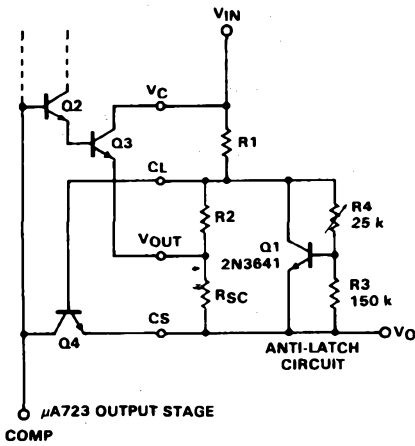


Fig. 3-64c. Foldback Current Limiting (Modified)

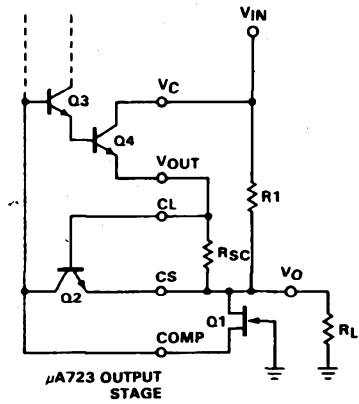


Fig. 3-64d. Foldback Current Limiting (FET)

$$R_{SC} = \frac{V_{SENSE}}{1M}$$

$$R_1 < \left( \frac{V_{IN \text{ min}} - V_{GS(\text{off}) \text{ max}}}{V_{GS(\text{off}) \text{ max}}} \right) R_L (\text{min})$$

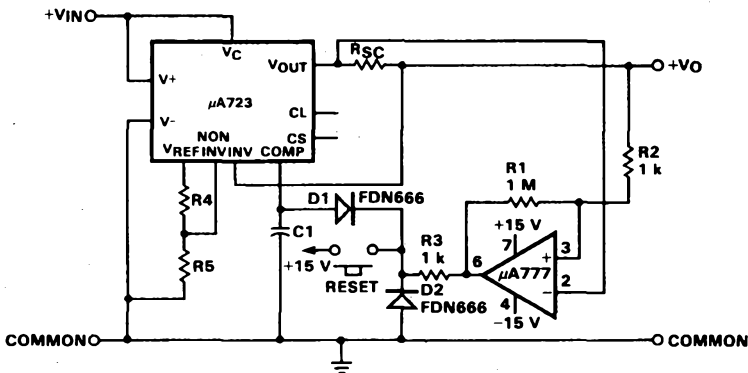


Fig. 3-65. Low Loss Short Circuit Sensing

### Short Circuit Sensing, Temperature Stabilized

This circuit modification takes advantage of the internal temperature tracking which occurs in an integrated circuit. Since the current limit transistor and the internal series pass devices are at the same temperature and were fabricated at the same time, their base-emitter temperature coefficients are approximately the same. In *Figure 3-65* the current limit transistor is connected so that the temperature coefficients cancel. This is accomplished with a bridge circuit via resistors R4 and R5 which reduces the voltage drop (and therefore the temperature coefficient) to a 1 diode drop level. This voltage, appearing across R4, is balanced by an equal and opposite voltage developed across R3 by a FET current source. The current limit transistor is connected across these two voltages, plus the voltage across  $R_{SC}$  due to the output current. At room temperature, the current source is adjusted by P2 such that there is zero voltage between points A and B. Therefore, at room temperature, the current limit transistor is activated when the  $\mu A723$  sense voltage is developed across  $R_{SC}$ , the voltages across R3 and R4 cancelling each other.

The threshold of the current limit transistor tends to track the voltage across R4 with temperature. Therefore, providing the current source remains constant with temperature, current limit set by  $R_{SC}$  also remains constant with temperature. *Figure 3-66* is shown for an output voltage of 15 V from a 25 V unregulated input. A higher breakdown FET is required for use with higher input voltages.

### Remote Shutdown

A  $\mu A723$  regulator may be turned off by pulling down the compensation terminal, thereby shunting the drive current for the output stage to ground. The simplest method of achieving this in a positive regulator is shown in *Figure 3-67a*. When the current limiting function is required, an external transistor may be substituted (Q1 in *Figure 3-67b*). The logic input may be from any positive voltage source, e.g., TTL or CMOS, capable of driving greater than 100  $\mu A$  into the CL terminal or Q1 base. Typically, R3 may be 3 k $\Omega$  from a 5 V TTL systems, or 10 k $\Omega$  from a 10 V CMOS system. To protect the output stage from excessive reverse base-emitter voltage transients during the shutdown, D1 should be included when the output voltage  $V_O$  is greater than 10 V. R4 reduces the peak current that flows when Q1 saturates.

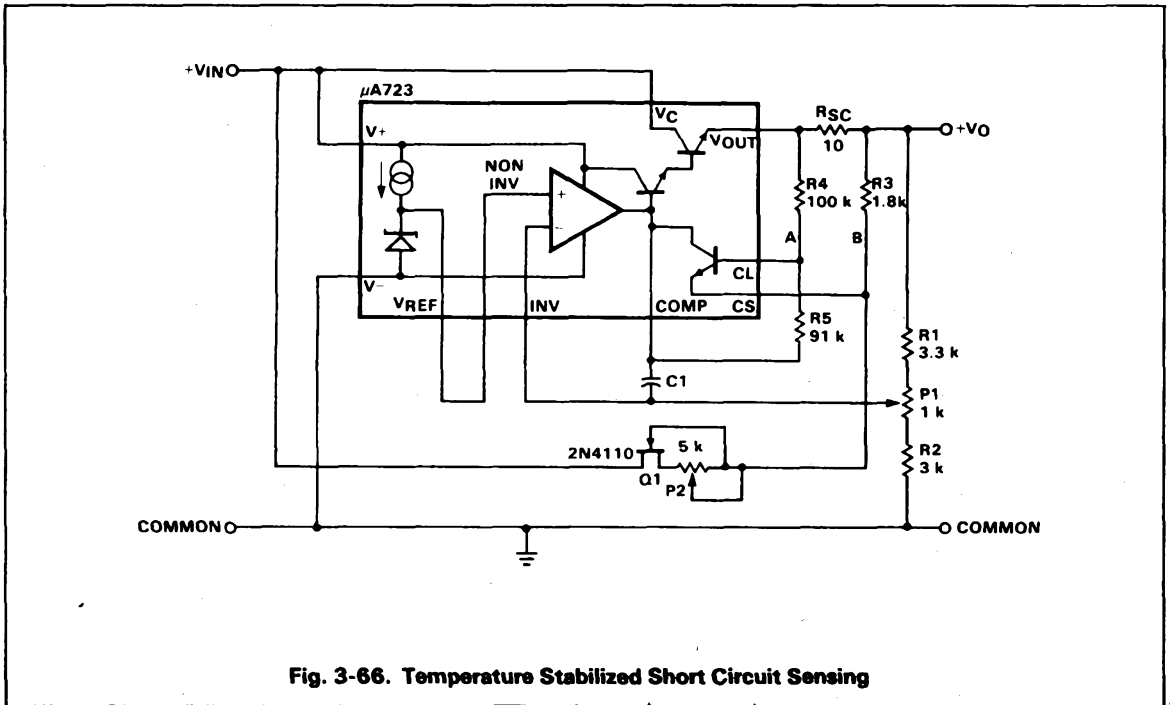


Fig. 3-66. Temperature Stabilized Short Circuit Sensing

Remote shutdown, when applied to a negative regulator, requires the additional circuitry to the right of the dashed line in *Figure 3-67c*. In operation, a logic LOW input,  $V_{IL(max)}$ , holds Q3 off, disabling the shutdown circuit. A logic HIGH input,  $V_{IH(min)}$ , from a TTL or CMOS gate turns Q3 on with the base drive limited by R8. Resistor R5 is calculated in the normal worst case manner for the series pass devices selected.

$$R5 = \frac{(V_{IN(min)} - V_O - 2V_{BE})}{Q2I_{B(max)}}$$

\*(This term becomes  $3V_{BE}$  if D2 is included.)

When Q3 is turned on, D1 is forward biased at a current limited by R7. The ratio of R5 and R7 is calculated such that the output of the supply is always at ground when the logic input is HIGH.

$$\frac{R7}{R5} = \frac{V_{IH(min)}}{V_{IN(max)}}$$

This formula guarantees that the junction of R5 and R7 is always positive during shutdown —  $R8 = 10R7$ , to give a forced  $\beta$  of 10 for Q3, fully saturating that device. Diode D2 protects the output devices from reverse base-emitter transient voltages, and should be included when the output voltage is greater than the combined base-emitter breakdown voltages of the series pass devices.

3

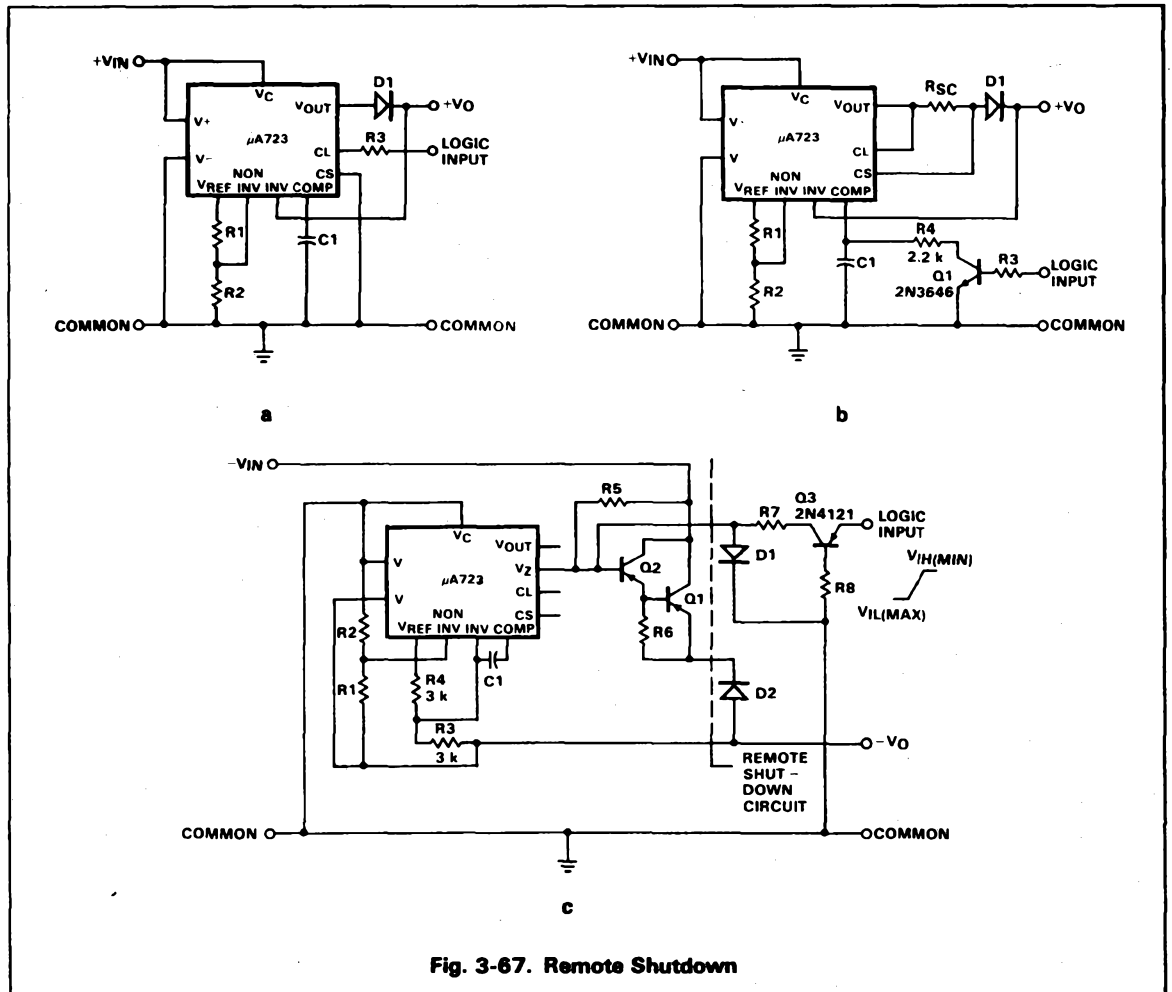


Fig. 3-67. Remote Shutdown

### Overvoltage Crowbar Protection

Figure 3-38 shows a  $\mu\text{A723}$  used as a latched comparator and SCR driver. It also provides the temperature compensated reference necessary for accurate overvoltage sensing. In normal operation, P1 is adjusted so that the voltage at point A is more negative than the reference voltage,  $V_{\text{REF}}$  (typically 7.15 V). Therefore, the voltage across R2 will bias the comparator (the  $\mu\text{A723}$  error amplifier) such that its output,  $V_{\text{OUT}}$  is driven toward  $V^-$ , and the internal 6.2 V Zener diode is cut off. Hence no gate current is able to flow into the SCR D2, which remains in an OFF state. Diode D1 blocks the positive feedback path in this condition. therefore, no current flows through R4.

By "crowbar" action, the comparator changes state as soon as the voltage across R2 reverses polarity, that is, as soon as the voltage at point A becomes more positive than  $V_{\text{REF}}$ . Potentiometer P1 is set so that this occurs at the desired over-voltage trip point, typically ( $V_O + 10\%$ ). When the comparator switches,  $V_{\text{OUT}}$  is pulled up toward  $V^+$ , and the SCR is fired with gate current limited by R5. When  $V_{\text{OUT}}$  exceeds  $V_{\text{REF}}$ , the positive feedback loop R4/D1 latches the comparator into its switched state.

Firing the SCR places a low impedance across the unregulated supply to ground, and this blows fuse F1. From the initial overvoltage to the SCR clamping takes approximately 1  $\mu\text{s}$ ; if required the switching action can be slowed down by a capacitor from the  $\mu\text{A723}$  COMP terminal to the inverting input.

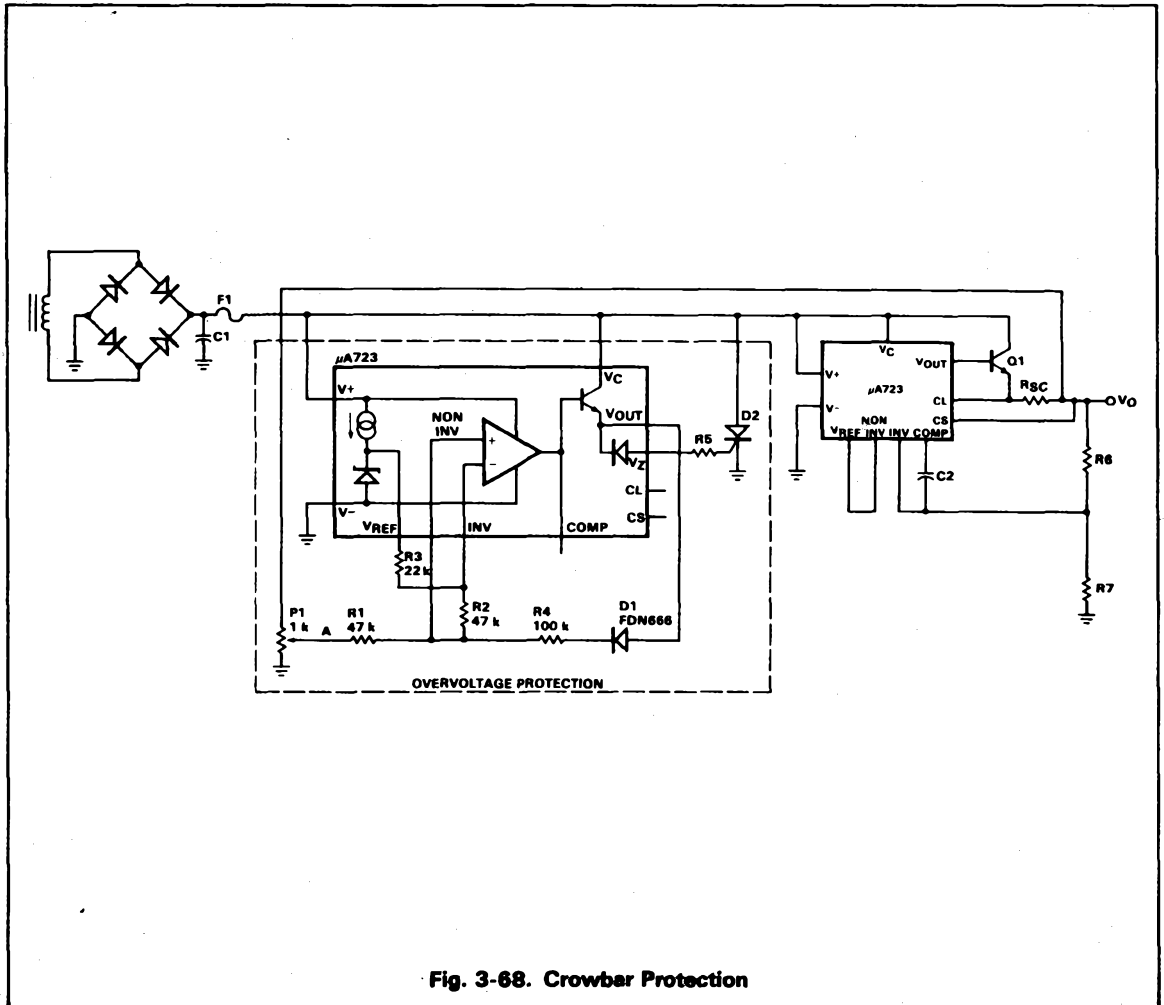


Fig. 3-68. Crowbar Protection

### Over/Under Voltage Monitoring

There are many systems where it is important that, when the regulated supply lines deviate from their nominal values, an alarm is indicated and some action, such as system shutdown or system changeover, is initiated. Such a fault detection system requires overvoltage and undervoltage monitors for both positive and negative power supplies. The  $\mu A723$  may be used very effectively in this application and provides a TTL-compatible output signal.

Figure 3-69 gives an indication of an undervoltage on a positive supply line. The internal reference voltage of the  $\mu A723$ ,  $V_{REF}$ , is used to generate a threshold voltage of 2.0 V across R4. The voltage to be monitored,  $V_M$ , is divided down by  $R_M$  and R1. The voltage across R1 is compared to the threshold voltage across R4 by the  $\mu A723$  error amplifier. When  $V_M$  is at its nominal value, the output of the  $\mu A723$  is in its HIGH state, which is set at approximately 3.3 V by clamping the COMP terminal to the junction of R2 and R3 on the  $V_{REF}$  voltage divider. Current drain from  $V_{OUT}$  through R6 is nominally 15 mA.

If the monitored supply,  $V_M$ , should fall by a predetermined amount, the error amplifier changes state, and the output voltage  $V_O$  assumes its LOW state. R6 can drive one TTL load (1.6 mA at 0.4  $V_{max}$   $V_O$ ). Positive switching action is assured by the hysteresis applied through R5.  $R_M$  is adjusted so that the voltage across R1 equals the threshold voltage (2.0 V) when  $V_M$  is at the desired undervoltage trip level. This circuit gives an overvoltage indication on a positive supply line when the amplifier inputs are interchanged as shown by the dashed lines.

3

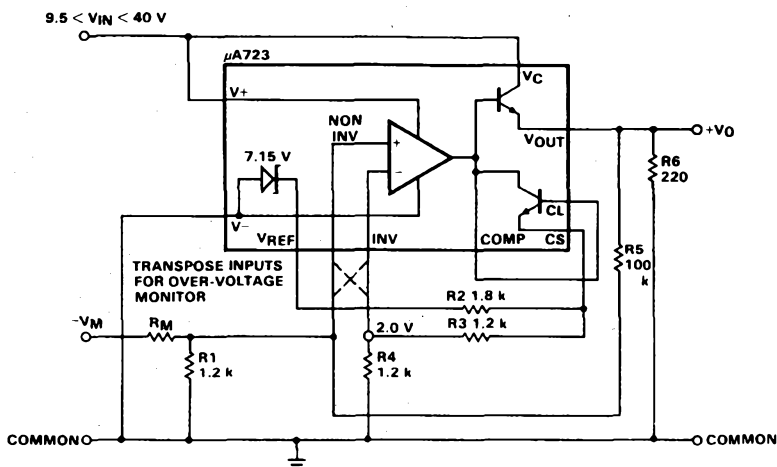


Fig. 3-69. Positive Supply Undervoltage Monitor

Figure 3-70 performs the same functions for a negative supply line. The monitored supply voltage,  $-V_M$ , is referenced to  $V_{REF}$  in this circuit, to provide the level shifting from any negative input to the +2.0 V threshold voltage. Response times for these monitor circuits are typically less than 1  $\mu$ s.

The voltage necessary to turn on the current-limiting transistor is the sum of  $V_{SENSE}$  (the  $V_{BE}$  of the current-limiting transistor) and the voltage across R9. Then as shown in the formula below,

$$V_{RSC} = V_{SENSE} + (V_{IN} - V_O) \left( \frac{R_9}{R_8 + R_9} \right) \quad \text{and} \quad I_{LIMIT} = \left( \frac{V_{SENSE}}{R_{SC}} \right) + \frac{(V_{IN} - V_O)}{R_{SC}} \left( \frac{R_9}{R_8 + R_9} \right)$$

R8 and R9 are included to supply positive feedback and, hence, maintain switching action even under short circuit conditions. This prevents over-dissipation if the regulator were allowed to go into a linear mode. Typically, R8 may be 3 k $\Omega$  and R9 30 $\Omega$  so that to a first approximation, current limit is derived as follows:

$$I_{LIMIT} = \left( \frac{V_{SENSE}}{R_{SC}} \right) + \frac{(V_{IN} - V_O)}{100 R_{SC}}$$

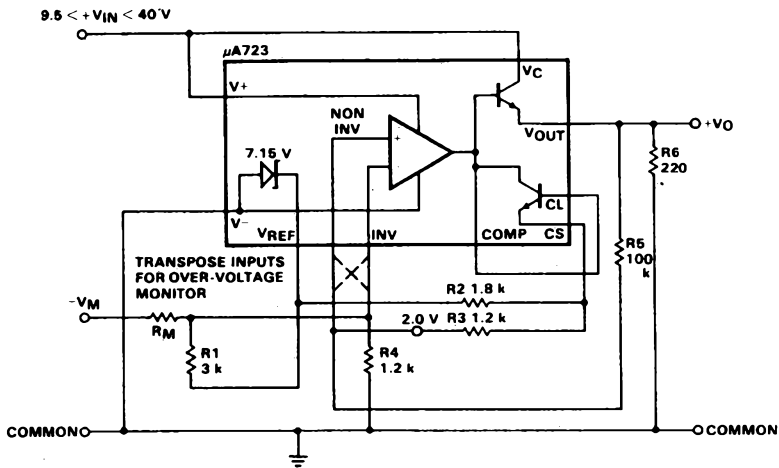


Fig. 3-70. Negative Supply Undervoltage Monitor



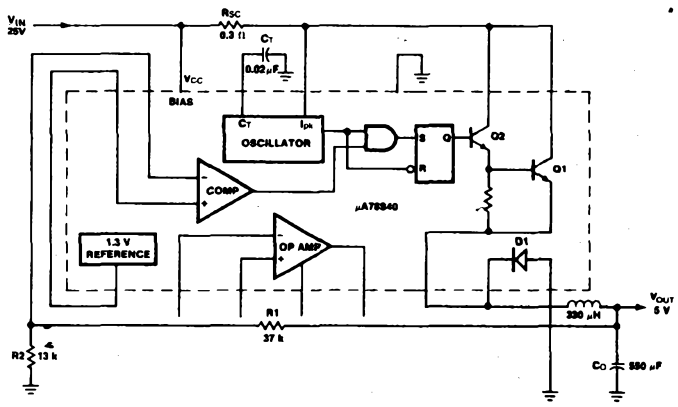


Fig. 3-71. Step-Down Voltage Regulator

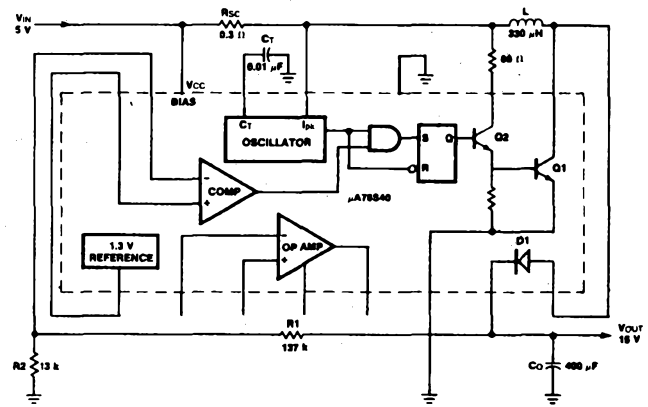
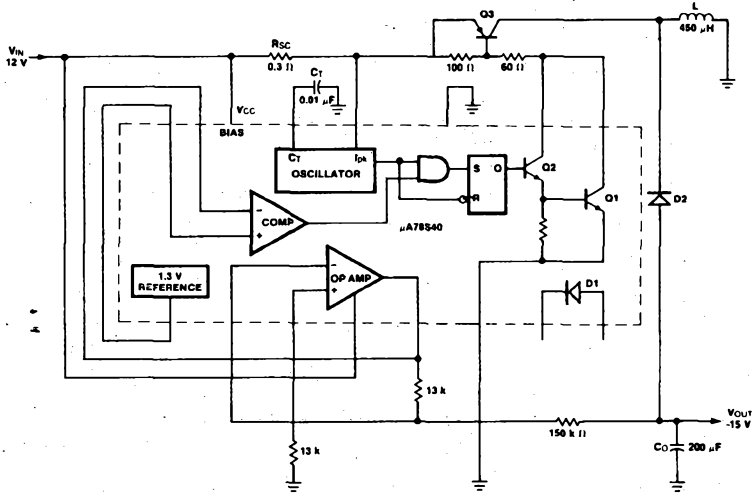


Fig. 3-72. Step-Up Voltage Regulator

**USING THE μA78S40 UNIVERSAL SWITCHING REGULATOR**

Typical applications of the universal regulator include the three switching regulator modes previously discussed; step-down, step-up, and inverting. *Figure 3-71* illustrates the necessary connections for using the μA78S40 in the step-down mode. This version satisfies a requirement for a 5 V output at 500 mA with output ripple less than 25 mV. In this application, the power switch (Q1 and Q2) is connected between the +25 V supply and the inductor. Switch voltage is determined by the emitter output limit of 1.6 V. For this value, off-time is approximately three times the on-time. Considering that the on-time should be greater than 10 μs, off-time is set by the user at 60 μs ( $C_T = 0.02 \mu F$ ), and the inductor value is selected at 330 μH. The output voltage is set by resistors R1 and R2. Output capacitance is calculated to be 400 μF. The circuit standby power is less than 50 mW. Efficiency at full load is 79%; at 10% of full load it is 70%.

For operation as a step-up voltage regulator, the μA78S40 is connected as shown in *Figure 3-72*. In this case, the objective is to use a 5 V input and get a 15 V output at 150 mA, again with output ripple less than 25 mV. Using  $V_S = 0.5 V$  and  $V_D = 1 V$ , on-time is approximately 2 1/2 times the off-time. Timing capacitance is selected at 0.01 μF, setting the off-time at 30 μs. On-time is consequently approximately 73 μs. An 80 Ω resistor on the drive collector provides a 50 mA base drive to the switch. With a peak input current of 1.1 A,  $R_{SC}$  is selected at 0.3 Ω. At full load with an average input current of 555 mA, efficiency is 80%. At 10% of full load, regulator efficiency is 78%. Output capacitance is calculated to be 492 μF.



**Fig. 3-73. Inverting Voltage Regulator**

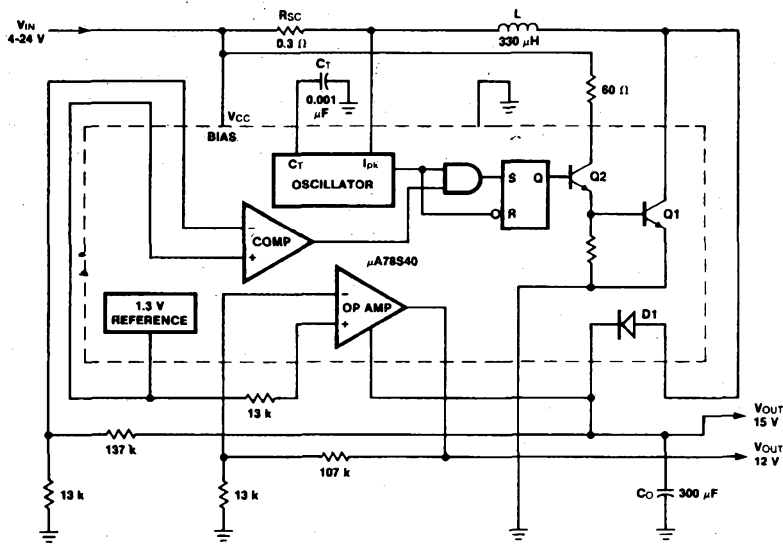
A voltage inverter configuration is shown in *Figure 3-73*. This mode requires an external pnp transistor (Q3) and a catch diode (D2). With a +12 V input, output voltage is -15 V at 200 mA, with output ripple less than 50 mV. With a timing capacitor value of 0.01  $\mu\text{F}$ , off-time is 30  $\mu\text{s}$ . Peak current can be calculated (0.96 A) as can the value of the inductor (500  $\mu\text{H}$ ). Average input current for this inverter mode is 2.75 mA with a regulator efficiency of 93% at full load and 90 % at 10% load. Output ripple is held to 50 mV by using an output capacitor with a value of 251  $\mu\text{F}$ . In this inverter mode, the internal operational amplifier inverts the output voltage to compare it to the 1.3 V reference. This is only possible because the common mode range of the op amp includes ground. Circuit breakdown does not limit output voltage, because no portion of the control circuitry sees any negative voltage.

### More Sophisticated Applications

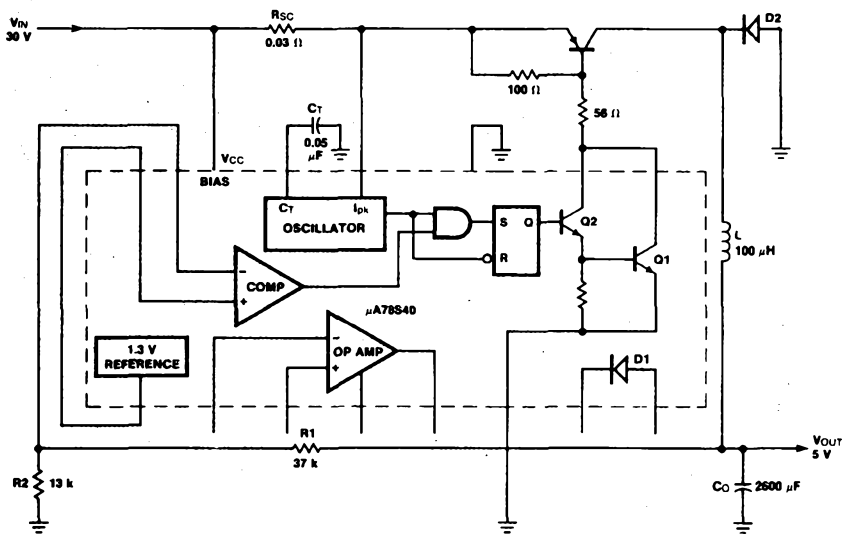
With the addition of a few external parts, the  $\mu\text{A78S40}$  can provide output power up to 100 W and output voltages up to and even exceeding 100 V. Two regulated outputs can be made available by using a switching output and a series-pass output.

One such interesting variation is the use of the universal regulator to provide a constant output for voltage inputs that are both higher and lower than the output, *Figure 3-74*. In this case, 12 V at 100 mA is provided at the output for input voltages over a 4 V to 24 V range. This is done by using a step-up mode similar to the version shown in *Figure 3-72* to provide a 15 V output and then using the internal op amp as a series-pass regulator to reduce the 15 V output to a 12 V output. When the input voltage exceeds 16 V, the step-up regulator circuit follows the input at approximately the input voltage minus 1 V, but the series-pass output remains constant at 12 V. The op amp exhibits excellent noise rejection, so output ripple is virtually non-existent at the 12 V output. Regulator efficiency is about 50% for the upper and lower limits of the input range (4 V and 24 V) and increases to a maximum of about 75% for intermediate voltages.

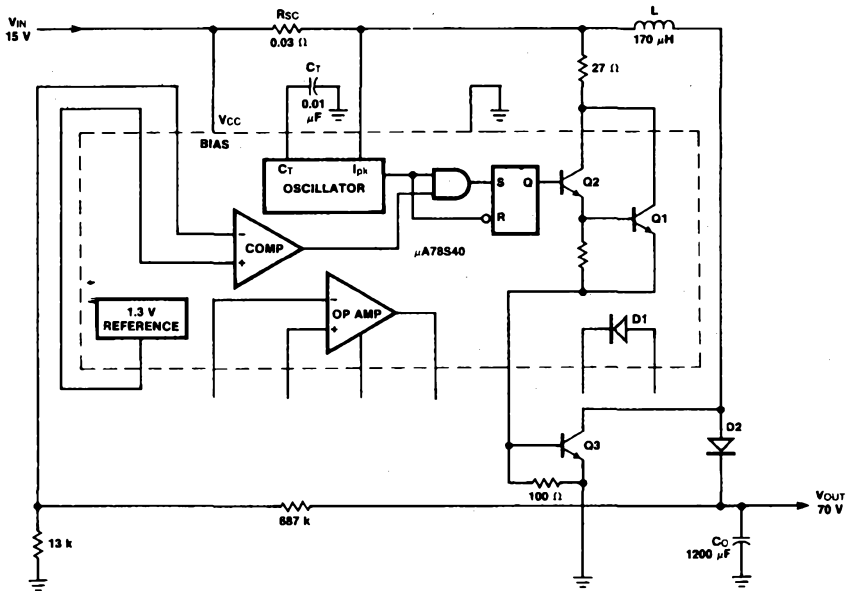
Another variation involves the addition of an external pnp transistor and an external catch diode to the step-down regulator, *Figure 3-75*. The transistor (Q3) increases output current capability by a factor of 10 and also improves switching efficiency because the switching voltage drops from 1.6 V to 1 V. The npn Darlington pair switch is connected to provide the base drive for Q3, with a 56  $\Omega$  resistor limiting the base drive to 500 mA. A peak input current of 10 A (plus the 0.5 A base drive) with an input voltage of 30 V provides a 5 V, 5 A output. The average input current is 1.1 A. Efficiency of the regulator is approximately 73%, with the control circuit dissipating the base drive



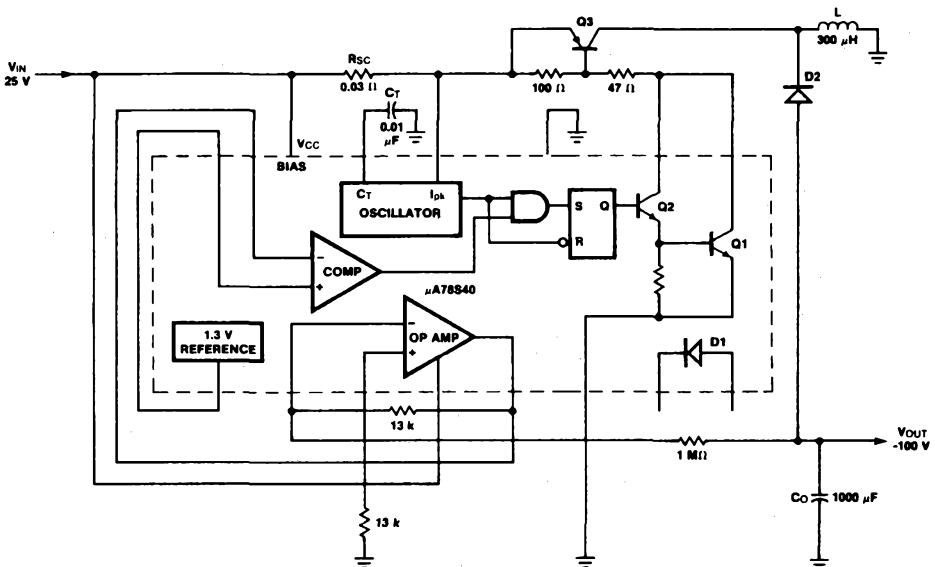
**Fig. 3-74. Constant Output Voltage Regulator Over 4-24 V Input Range**



**Fig 3-75. Modified Step-Down Regulator with 5 A, 5 V Output**



**Fig. 3-76. Switching Regulator with 15 V Input, 70 V Output**



**Fig. 3-77. Switching Regulator with 25 V Input, -100 V Output**

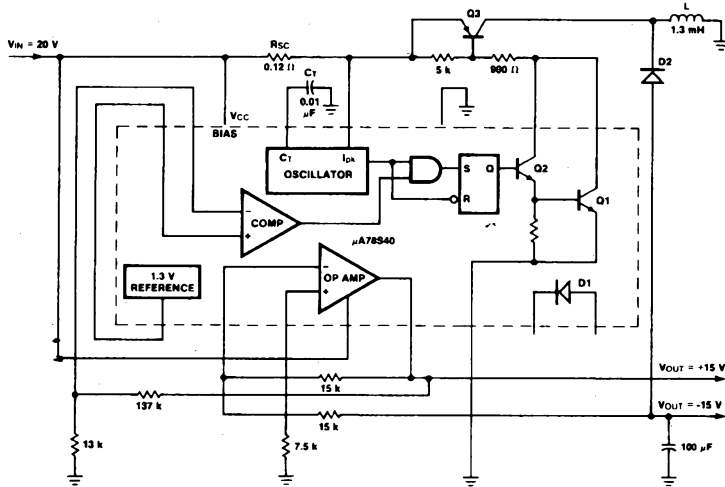


Fig. 3-78. Dual Tracking Supply

power (0.5 A x 30 V). In this case the off-time/on-time ratio is about 4:1, with the off-time at 150  $\mu$ s and on-time at 38  $\mu$ s. Output capacitance of 2500  $\mu$ F keeps output ripple to 100 mV. The external diode (D2) is required to handle the 10 A switching current.

The addition of a boost transistor and a flyback diode to the step-up regulator configuration develops a regulated 70 V, 1 A output, *Figure 3-76*. The Darlington pair switch emitter output provides base drive to the external npn transistor Q3. Output voltage is limited by this transistor and diode breakdown voltages, not by the IC. The base drive to Q3 is limited to 0.5 A by a 27  $\Omega$  series resistor on the switch collector. For this situation (15 V in - 70 V, 1 A out) the on/off ratio is 4:1 with on-time at 120  $\mu$ s and off-time at 30  $\mu$ s ( $C_T = 0.01 \mu$ F). Average input current is 5.4 A, (1/2 the peak current plus the 0.5 A base drive). Regulator efficiency is 84%, and output ripple is limited to 100 mV by a 1200  $\mu$ F output capacitor.

A voltage inverting regulator with an external pnp switch (Q3) and an external diode (D2) can generate almost any negative voltage, because the external transistor and diode limit the output voltage, *Figure 3-77*. This particular version provides -100 V at 1 A from a +25 V input. The peak current is 10.5 A, average current is 4.44 A, and the regulator efficiency is 83%. The on-time to off-time ratio is a little more than 4:1, resulting in an off-time of 30  $\mu$ s and an on-time of 126  $\mu$ s. A 1000  $\mu$ F output capacitor limits output ripple to 120 mV.

*Figure 3-78* illustrates a dual-tracking regulator that provides both +15 V and -15 V outputs from a single +20 V input. The negative output voltage is generated with an inverter circuit similar to the circuit of *Figure 5*, but the op amp is connected in a gain-of-1 configuration with its output divided down and compared to the 1.3 V reference voltage. As shown, this regulator provides  $\pm 15$  V at 100 mA with 80% efficiency - 75% positive voltage, 85% negative voltage - with output ripple limited to 30 mV.

A high-output regulator with two outputs is illustrated in *Figure 3-79*. From a single 5 V input voltage, a 12 V and a 15 V output are provided. Two external npn transistors are used; Q3 boosts the step-up function, and Q4 increases the series-pass output to 1 A. A total of 1.5 A is available from the two outputs, with 80% efficiency on the 15 V output and 64% efficiency on the 12 V output.

The final switching regulator variation shown is a negative input/output regulator, *Figure 3-80*. This presents a slightly more difficult challenge, since the reference voltage is referred to a negative input rather than ground. A ground reference of -2.6 V can be generated by using the op amp as a differential amplifier. Then, using a typical step-down regulator configuration, a -48 V input produces a -12 V output at 300 mA with a regulator efficiency of 85%.

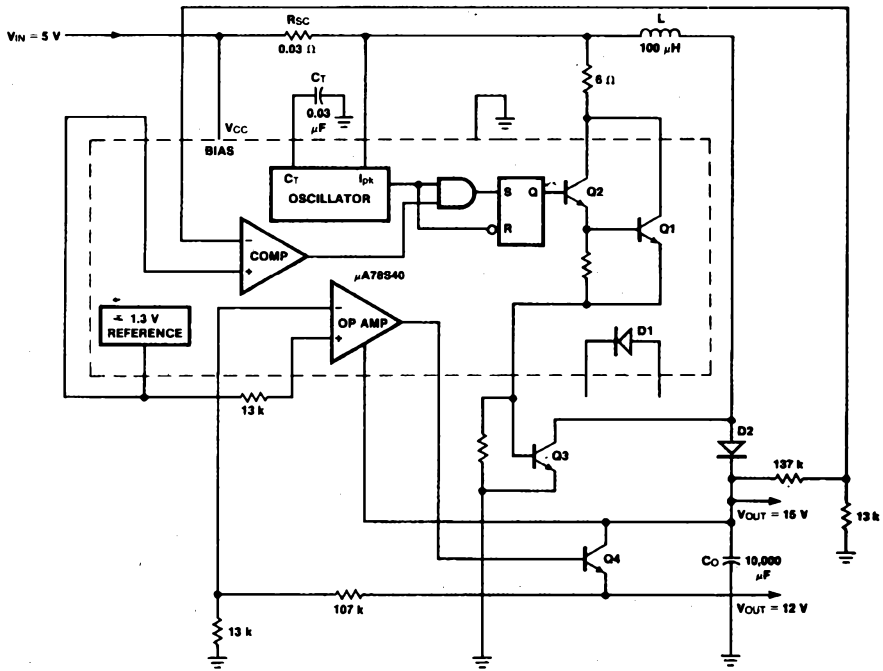


Fig. 3-79. Step-Up and Series-Pass Regulator

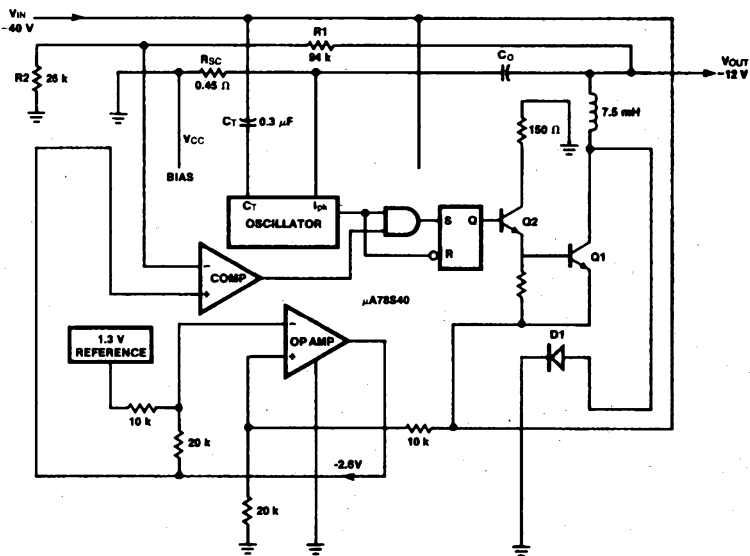


Fig. 3-80. Negative Input/Output Regulator

### 78S40 Design Formulae

CHARACTERISTIC	STEP DOWN	STEP UP	INVERTING
$I_{pk}$	$2 I_{OUT(max)}$	$2 I_{OUT(max)} \cdot \frac{V_{OUT} + V_D - V_S}{V_{IN} - V_S}$	$2 I_{OUT(max)} \cdot \frac{V_{IN} +  V_{OUT}  + V_D - V_S}{V_{IN} - V_S}$
$R_{SC}^*$	$0.33 V/I_{pk}$	$0.33 V/I_{pk}^*$	$0.33 V/I_{pk}$
$t_{on}$	$\frac{I_{pk} \cdot L}{V_{IN} - V_S - V_{OUT}}$	$\frac{I_p \cdot L}{V_{IN} - V_S}$	$\frac{I_p \cdot L}{V_{IN} - V_S}$
$t_{off}$	$\frac{I_{pk} \cdot L}{V_{OUT} + V_D}$	$\frac{I_{pk} \cdot L}{V_{OUT} + V_D - V_{IN}}$	$\frac{I_{pk} \cdot L}{ V_{OUT}  + V_D}$
$\frac{t_{on}}{t_{off}}$	$\frac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$	$\frac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$	$\frac{ V_{OUT}  + V_D}{V_{IN} - V_S}$
$L^*$	$\frac{V_{OUT} + V_D}{I_{pk}} \cdot t_{off}$	$\frac{V_{OUT} + V_D - V_{IN}}{I_{pk}} \cdot t_{off}$	$\frac{ V_{OUT}  + V_D}{I_{pk}} \cdot t_{off}$
$C_T^* (\mu F)$	$45 \times 10^{-5} t_{off} (\mu S)$	$45 \times 10^{-5} t_{off} (\mu S)$	$45 \times 10^{-5} t_{off} (\mu S)$
$C_O^*$	$\frac{I_{pk} \cdot (t_{on} + t_{off})}{8 V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \cdot t_{off}}{2 I_{pk} \cdot V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \cdot t_{off}}{2 I_{pk} \cdot V_{ripple}}$
Efficiency	$\frac{V_{IN} - V_S + V_D}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D}$	$\frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D - V_S}$	$\frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{ V_{OUT} }{ V_{OUT}  + V_D}$
$I_{IN(avg)}$ (Max load condition)	$\frac{I_{pk}}{2} \cdot \frac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$	$\frac{I_{pk}}{2}$	$\frac{I_{pk}}{2} \cdot \frac{ V_{OUT}  + V_D}{V_{IN} +  V_{OUT}  + V_D - V_S}$
$V_{ripple}$	$\frac{I_p (t_{on} + t_{off})}{8 C_O}$	$\frac{(I_p - I_{OUT})^2}{2 I_{pk}} \cdot \frac{t_{off}}{C_O}$	$\frac{(I_p - I_{OUT})^2}{2 I_{pk}} \cdot \frac{t_{off}}{C_O}$

# RESISTOR SELECTION GUIDE

The following table is a quick reference guide for the selection of resistance values for given output voltages. The applicable circuits that can be used with the table are indicated (see Note 1).

OUTPUT VOLTAGE	APPLICABLE CIRCUITS	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10%		
		R1	R2	R1	P1	R2
	(Note 1)					
3.0	3-48a 3-48b	4.12	3.01	1.8	0.5	1.2
3.6	(3-49a) 3-49b	3.57	3.65	1.5	0.5	1.5
5.0	3-50	2.15	4.99	.75	0.5	2.2
6.0	3-51b (3-52a) (3-52b) 3-55a 3-55b	1.15	6.04	0.5	0.5	2.7
9.0	3-48c	1.87	7.15	.75	1.0	2.7
12	3-49a (3-49b)	4.87	7.15	2.0	1.0	3.0
15	(3-50)	7.87	7.15	3.3	1.0	3.0
28	3-51a 3-52a 3-52b	21.0	7.15	5.6	1.0	2.0
45	3-53	3.57	48.7	2.2	10	39
75	3-63	3.57	78.7	2.2	10	68

OUTPUT VOLTAGE	APPLICABLE CIRCUITS	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10%		
		R1	R2	R1	P1	R2
100	3-53	3.57	102	2.2	10	91
250	3-63	3.57	255	2.2	10	240
-6 (Note 2)	3-56a 3-56b	3.57	2.43	1.2	0.5	.75
-9	3-56b	3.48	5.36	1.2	0.5	2.0
-12	3-57	3.57	8.45	1.2	0.5	3.3
-15	3-58	3.65	11.5	1.2	0.5	4.3
-28	3-59	3.57	24.3	1.2	0.5	10
-45		3.57	41.2	2.2	10	33
-100	3-60	3.57	97.6	2.2	10	91
-250		3.57	249	2.2	0	240

## NOTES:

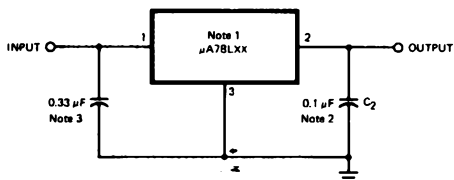
1. Circuits in parenthesis may be used if R1/R2 divider is placed on opposite side of error amplifier.
2. V<sup>+</sup> must be connected to a +2.5 V or greater supply.



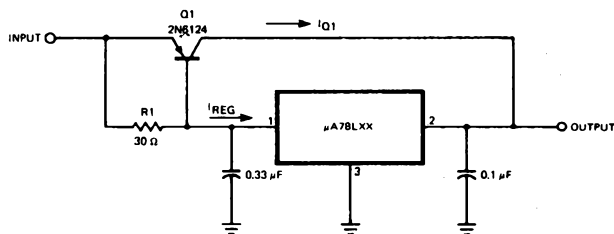
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu$ A78L00 SERIES

### FIXED OUTPUT REGULATOR



### HIGH CURRENT VOLTAGE REGULATOR



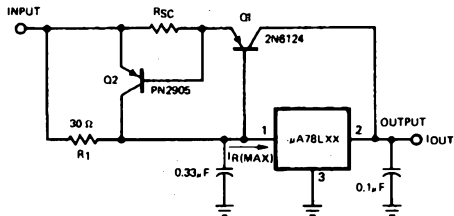
#### NOTES:

- ① To specify an output voltage, substitute voltage value for "XX".
- ② Although no output capacitor is needed for stability, it does improve transient response.
- ③ Required if regulator is located an appreciable distance from power supply filter.

$$\text{For } I_{REG} \approx 23 \text{ mA}$$

$$I_{REG} = \frac{0.7}{R1} \quad I_{Q1} = \beta I_{REG}$$

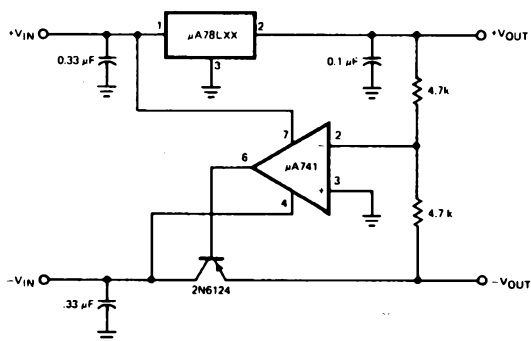
### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



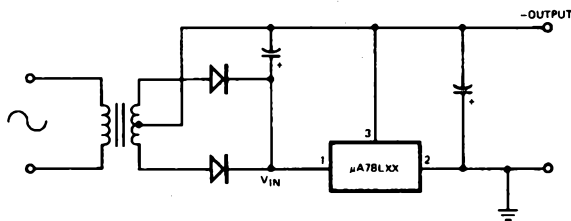
$$R_{SC} = \frac{0.7}{I_{SC}}$$

$$R1 = \frac{\mu V_{BE}(Q2)}{I_{R(MAX)}(\beta + 1) - I_{OUT(MAX)}}$$

### ± TRACKING VOLTAGE REGULATOR



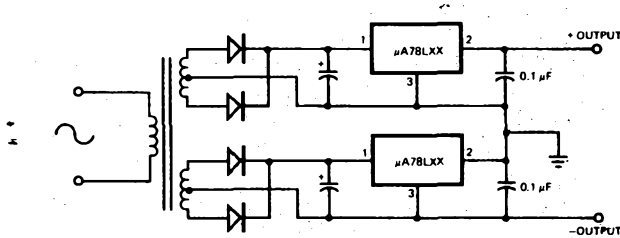
### NEGATIVE OUTPUT VOLTAGE CIRCUIT



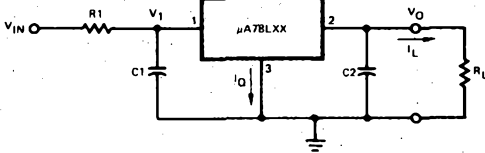
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu$ A78L00 SERIES

### POSITIVE AND NEGATIVE REGULATOR



### HIGH DISSIPATION APPLICATIONS



As an example, consider a 15 V regulator with a supply voltage of  $30 \pm 5$  V, required to supply a maximum load current of 30 mA.  $I_Q$  is 4.3 mA, and minimum load current is to be 10 mA.

$$R1 = \frac{25 - 15 - 2}{30 + 4.3} = \frac{8}{34.3} \cong 240 \Omega$$

$$V1 = 35 - (30 + 4.3) \cdot 24 = 35 - 8.2 = 26.8 \text{ V}$$

$$P_D(\text{MAX}) = (26.8 - 15) 30 + 26.8 (4.3)$$

$$= 354 + 115$$

$$= 470 \text{ mW, which will permit operation up to } 70^\circ\text{C in most applications.}$$

When it is necessary to operate a  $\mu$ A78L00 regulator with a large input-output differential voltage, the addition of series resistor  $R1$  will extend the output current range of the device by sharing the total power dissipation between  $R1$  and the regulator.

$R1$  may be calculated from

$$R1 = \frac{V_{IN(\text{MIN})} - V_{OUT} - 2.0 \text{ V}}{I_{L(\text{MAX})} + I_Q}$$

where  $I_Q$  is the regulator quiescent current.

Regulator power dissipation at maximum input voltage and maximum load current is now

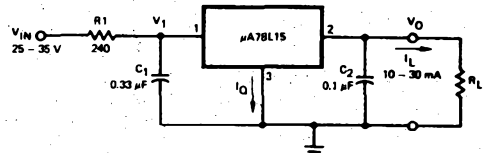
$$P_D(\text{MAX}) = (V1 - V_{OUT}) I_{L(\text{MAX})} + V1 I_Q$$

where

$$V1 = V_{IN(\text{MAX})} - (I_{L(\text{MAX})} + I_Q) R1$$

The presence of  $R1$  will affect load regulation according to the equation:

$$\begin{aligned} \text{load regulation (at constant } V_{IN}) &= \text{load regulation (at constant } V1) \\ &+ (\text{line regulation, mV per V}) \times \\ & (R1) \times (\Delta I_L). \end{aligned}$$



Line regulation of this circuit is typically 110 mV for an input range of 25-35 V at a constant load current, i.e. 11 mV/V.

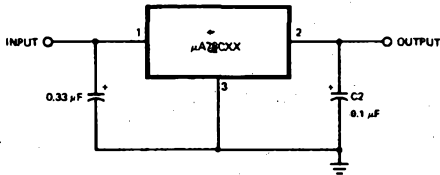
$$\begin{aligned} \text{Load regulation} &= \text{constant } V1 \text{ load regulation (typically 10 mV, } \\ & \text{10-30 mA } I_L) \\ &+ (11 \text{ mV/V}) \times 0.24 \times 20 \text{ mA (typically 53 mV)} \\ &= 63 \text{ mV for a load current change of 20 mA at a } \\ & \text{constant } V_{IN} \text{ of 30 V.} \end{aligned}$$

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

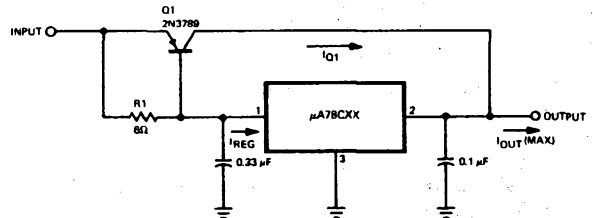
## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu A78C00$ SERIES

In many  $\mu A78C00$  applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output ( $0.33 \mu F$  and  $0.1 \mu F$ , respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

### FIXED OUTPUT REGULATOR



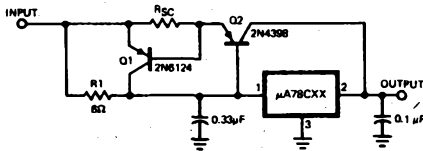
### HIGH CURRENT VOLTAGE REGULATOR



$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ}(MAX) (\beta + 1) - I_{OUT}(MAX)}$$

$$\beta_{Q1} > \frac{I_{OUT}}{I_{REG}}$$

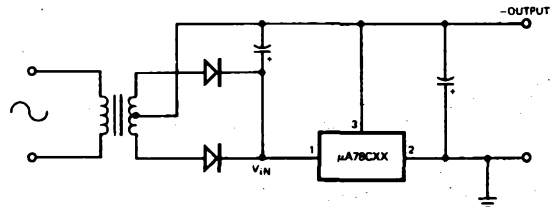
### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



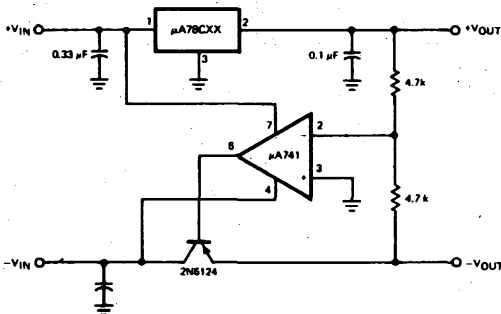
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(MAX) (\beta + 1) - I_{OUT}(MAX)}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}}$$

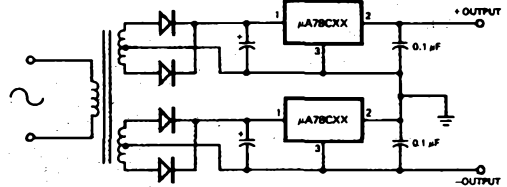
### NEGATIVE OUTPUT VOLTAGE CIRCUIT



### ± TRACKING VOLTAGE REGULATOR



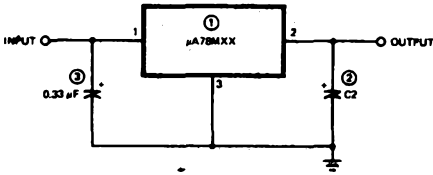
### POSITIVE AND NEGATIVE REGULATOR



# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu A78M00$ SERIES

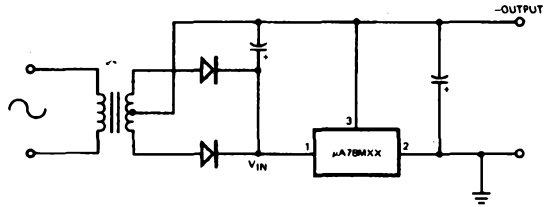
### FIXED OUTPUT REGULATOR



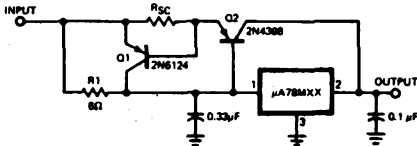
**NOTES:**

- ① To specify an output voltage, substitute voltage value for "XX".
- ② Although no output capacitor is needed for stability, it does improve transient response.
- ③ Required if regulator is located an appreciable distance from power supply filter.

### NEGATIVE OUTPUT VOLTAGE CIRCUIT



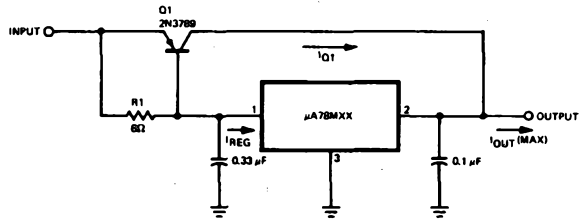
### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(MAX) (\beta + 1) - I_{OUT}(MAX)}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}}$$

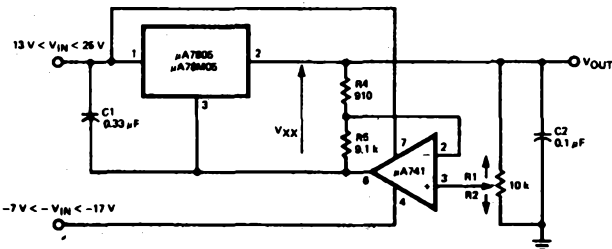
### HIGH CURRENT VOLTAGE REGULATOR



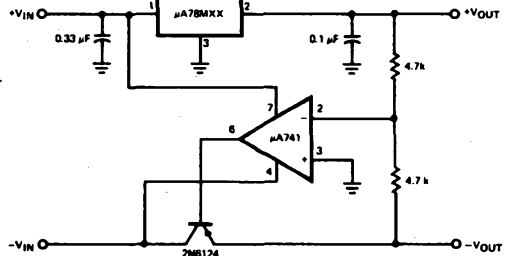
$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ}(MAX) (\beta + 1) - I_{OUT}(MAX)}$$

$$\beta_{Q1} > \frac{I_{OUT}}{I_{REG}}$$

### VARIABLE OUTPUT VOLTAGE, 0.5 TO 10 V



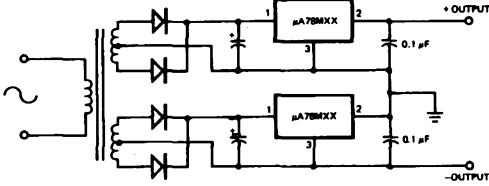
### ± TRACKING VOLTAGE REGULATOR



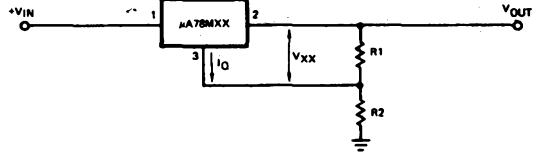
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu$ A78M00 SERIES

### POSITIVE AND NEGATIVE REGULATOR

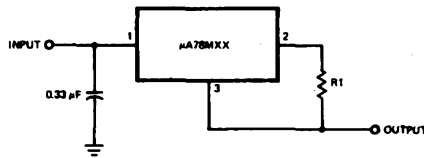


### CIRCUIT FOR INCREASING OUTPUT VOLTAGE



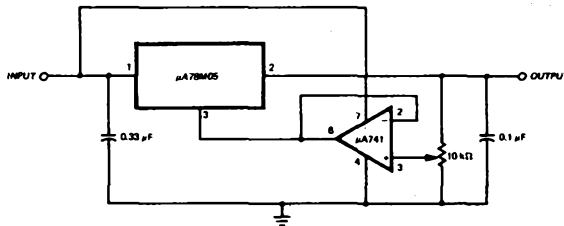
$$V_{OUT} = V_{XX} \left( 1 + \frac{R_2}{R_1} \right) + I_Q R_2$$

### CURRENT REGULATOR



$$\text{Output Current} = \frac{V_{OUT}}{R_1}$$

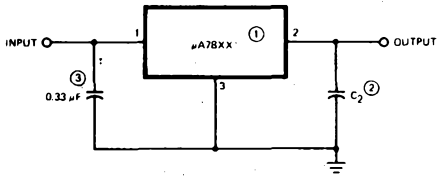
### ADJUSTABLE OUTPUT REGULATOR, 7 V TO 30 V



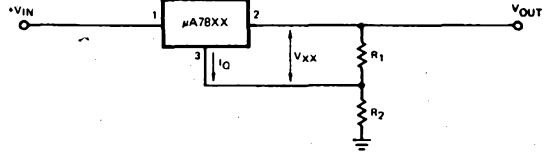
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu$ A7800 SERIES

### FIXED OUTPUT REGULATOR



### CIRCUIT FOR INCREASING OUTPUT VOLTAGE

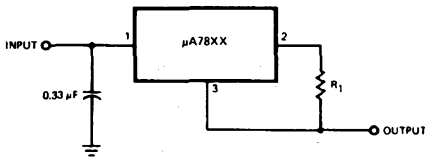


#### NOTES:

- ① To specify an output voltage, substitute voltage for "XX".
- ② Although no output capacitor is needed for stability, it does improve transient response.
- ③ Required if regulator is located an appreciable distance from power supply filter.

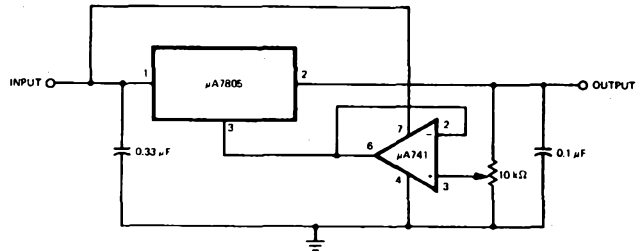
$$V_{OUT} = V_{XX} \left( 1 + \frac{R_2}{R_1} \right) + I_Q R_2$$

### CURRENT REGULATOR

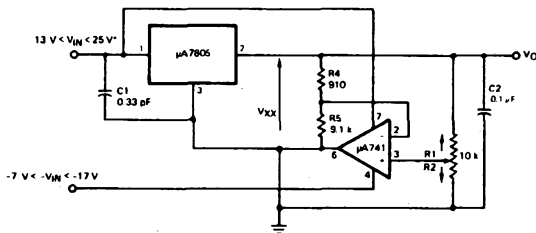


$$\text{Output Current} = \frac{V_{OUT}}{R_1}$$

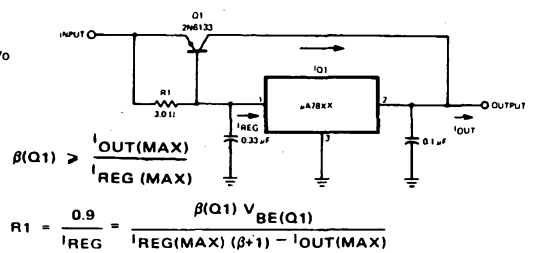
### ADJUSTABLE OUTPUT REGULATOR, 7 TO 30 VOLTS



### 0.5 TO 10 V REGULATOR



### HIGH CURRENT VOLTAGE REGULATOR



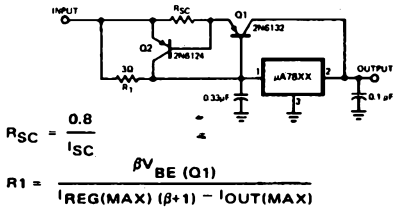
$$\beta(Q1) > \frac{I_{OUT(MAX)}}{I_{REG(MAX)}}$$

$$R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1) V_{BE(Q1)}}{I_{REG(MAX)} (\beta+1) - I_{OUT(MAX)}}$$

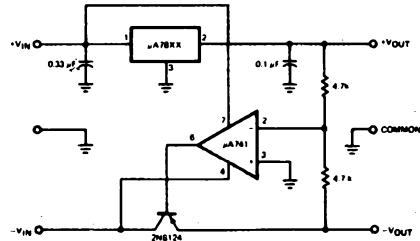
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu$ A7800 SERIES

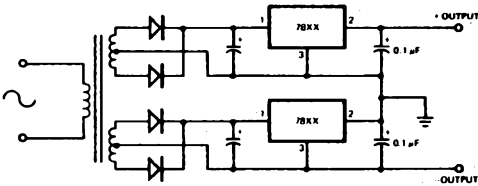
### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



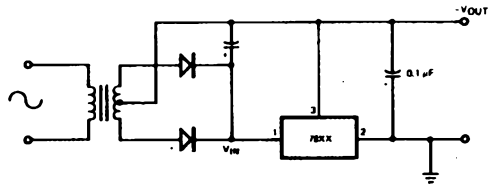
### $\pm$ TRACKING VOLTAGE REGULATOR



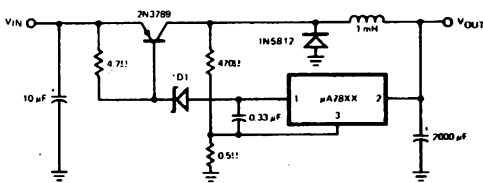
### POSITIVE AND NEGATIVE REGULATOR



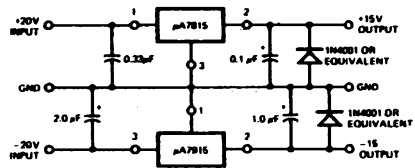
### NEGATIVE OUTPUT VOLTAGE CIRCUIT



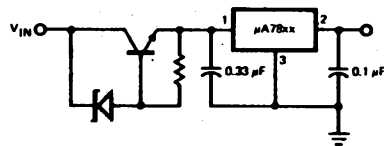
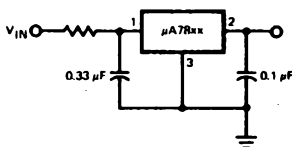
### SWITCHING REGULATOR



### DUAL SUPPLY OPERATIONAL AMPLIFIER SUPPLY ( $\pm 15$ V @ 1.0 A)



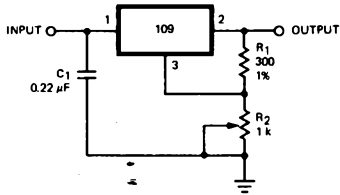
### HIGH INPUT VOLTAGE CIRCUITS



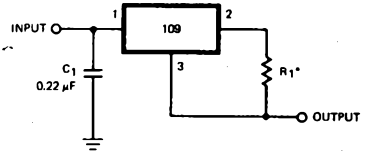
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS — $\mu$ A109 SERIES

### ADJUSTABLE OUTPUT REGULATOR

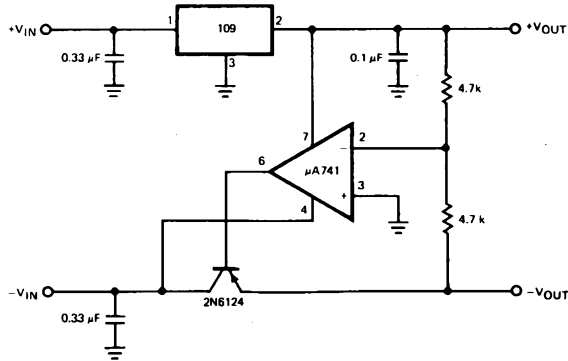


### CURRENT REGULATOR

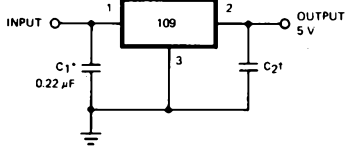


NOTE: Determines output current.

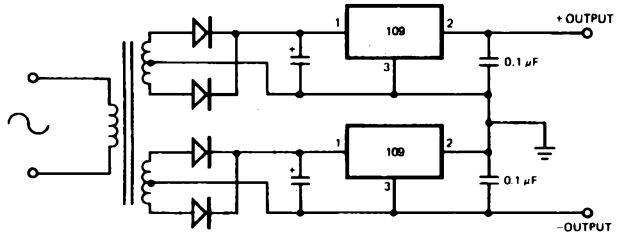
### TRACKING VOLTAGE REGULATOR



### FIXED 5 V REGULATOR



### POSITIVE AND NEGATIVE REGULATOR



#### NOTES:

Required if regulator is located an appreciable distance from power supply filter.

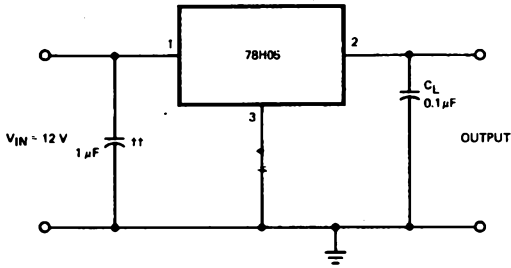
†Although no output capacitor is needed for stability, it does improve transient response.



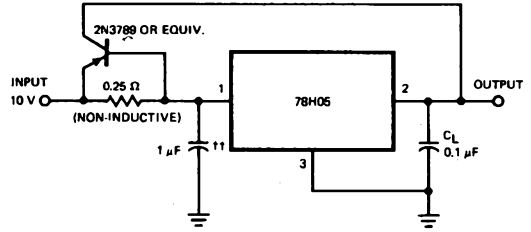
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED POSITIVE 3-TERMINAL REGULATORS – 78H05 SERIES

### 5 AMP REGULATOR



### 10+ AMP REGULATOR

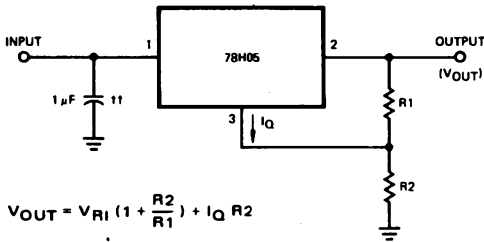


#### NOTES:

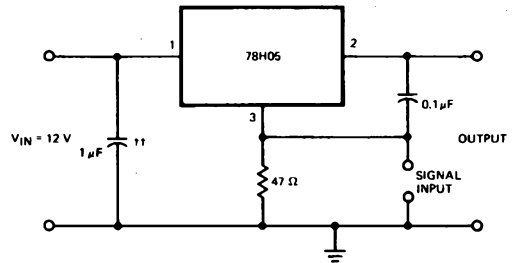
- No current limit in effect
- At 10 A out 78H05 passes 4.0 A
- For 10 A output change,  $V_{OUT}$  changes approx. 80 mV

3

### INCREASED OUTPUT VOLTAGE



### SIGNAL DRIVER/MODULATOR



††Required if regulator is located an appreciable distance from power supply filter.

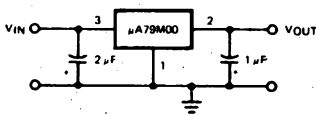
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED NEGATIVE 3-TERMINAL REGULATORS — $\mu A79M00$ SERIES

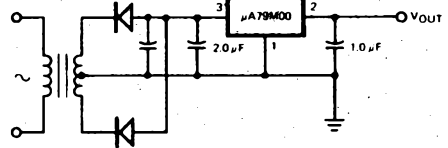
Bypass capacitors are recommended for stable operation of the 79M00 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, ( $2 \mu F$  on the input,  $1 \mu F$  on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be  $10 \mu F$  or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

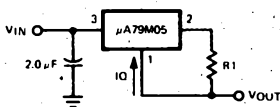
### FIXED OUTPUT REGULATOR



### NEGATIVE OUTPUT VOLTAGE CIRCUIT

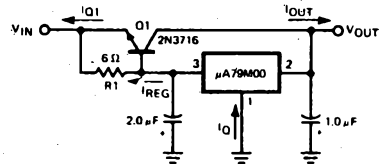


### BASIC CURRENT REGULATOR



$$\text{OUTPUT CURRENT} = \frac{5.0 \text{ V}}{R1} + I_Q$$

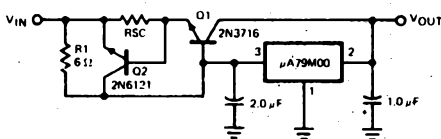
### HIGH CURRENT VOLTAGE REGULATOR



$$I_{Q1} = \beta(Q1) I_{REG}$$

$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

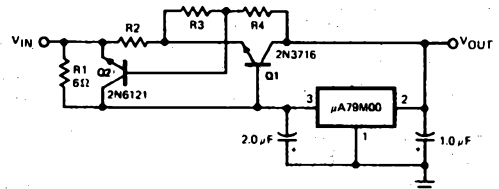
### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

$$R_{SC} = \frac{V_{BE}(Q2)}{I_{SC}}$$

### HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED

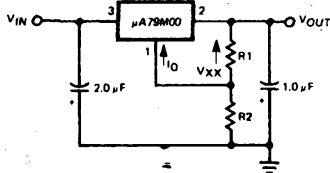


$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

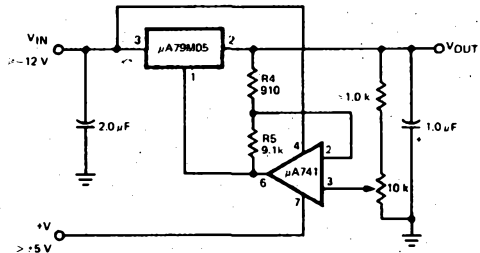
## FIXED NEGATIVE 3-TERMINAL REGULATORS – $\mu$ A79M00 SERIES

### VARIABLE OUTPUT VOLTAGE REGULATOR

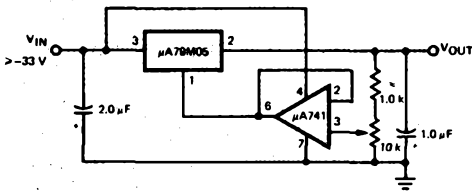


$$|V_{OUT}| = V_{XX} \left(1 + \frac{R_2}{R_1}\right) + I_Q R_2$$

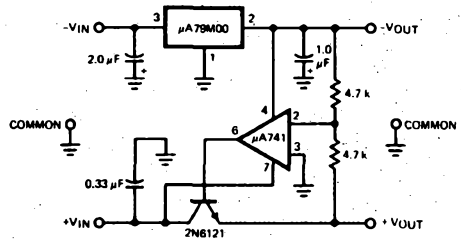
### VARIABLE OUTPUT VOLTAGE, –0.5 V TO –10V



### VARIABLE OUTPUT VOLTAGE, –30 V TO –7 V



### POSITIVE AND NEGATIVE TRACKING VOLTAGE REGULATOR



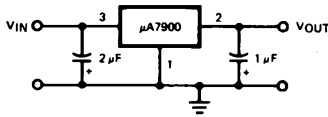
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## FIXED NEGATIVE 3-TERMINAL REGULATORS — $\mu\text{A}7900$ SERIES

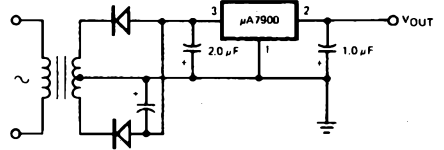
Bypass capacitors are recommended for stable operation of the  $\mu\text{A}7900$  series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, ( $2\ \mu\text{F}$  on the input,  $1\ \mu\text{F}$  on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be  $10\ \mu\text{F}$  or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

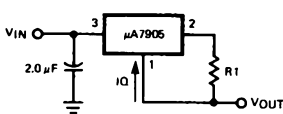
### FIXED OUTPUT REGULATOR



### NEGATIVE OUTPUT VOLTAGE CIRCUIT

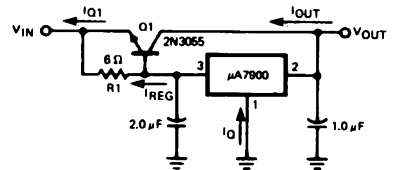


### BASIC CURRENT REGULATOR



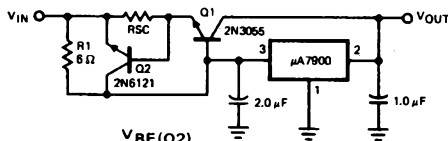
$$\text{OUTPUT CURRENT} = \frac{5.0\ \text{V}}{R1} + I_Q$$

### HIGH CURRENT VOLTAGE REGULATOR



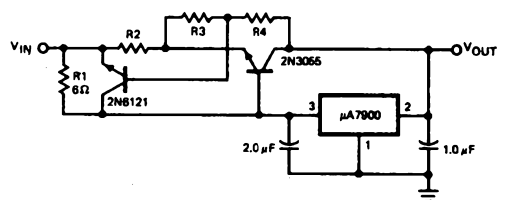
$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} \quad I_{Q1} = \beta(Q1)I_{REG}$$

### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



$$R_{SC} = \frac{V_{BE}(Q2)}{I_{SC}}$$

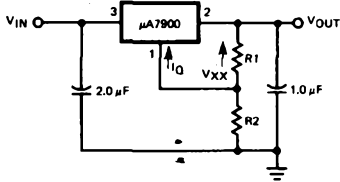
### HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED



# TYPICAL VOLTAGE REGULATOR APPLICATIONS

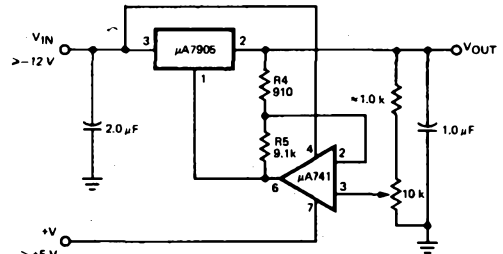
## FIXED NEGATIVE 3-TERMINAL REGULATORS — $\mu$ A7900 SERIES

### VARIABLE OUTPUT VOLTAGE REGULATOR

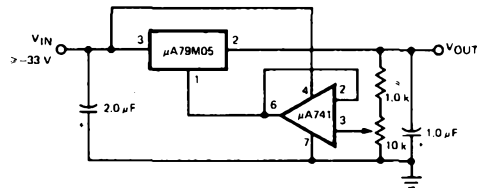


$$|V_{OUT}| = V_{XX} \left(1 + \frac{R_2}{R_1}\right) + I_{QR} R_2$$

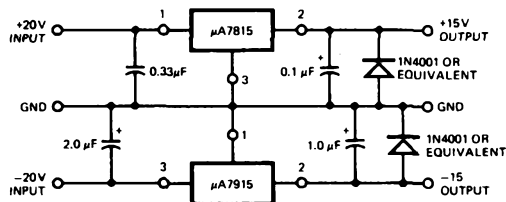
### VARIABLE OUTPUT VOLTAGE, -0.5 V TO -10 V



### VARIABLE OUTPUT VOLTAGE, -30 V TO -7 V



### OPERATIONAL AMPLIFIER SUPPLY ( $\pm 15$ V @ 1.0 A)

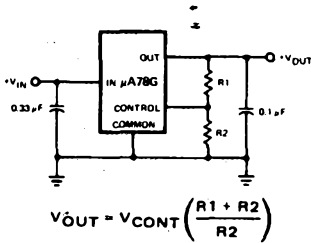


# TYPICAL VOLTAGE REGULATOR APPLICATIONS

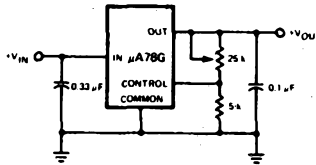
## ADJUSTABLE POSITIVE 4-TERMINAL REGULATORS – $\mu$ A78G SERIES

In many  $\mu$ A78G applications, compensation capacitors may be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33  $\mu$ F and 0.1  $\mu$ F, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

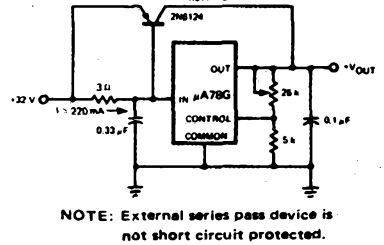
### BASIC POSITIVE REGULATOR



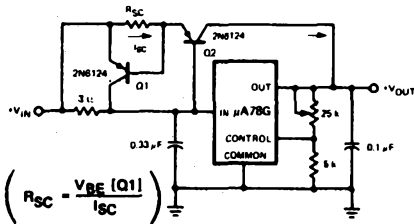
### POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR



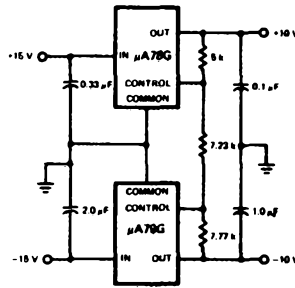
### POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR $I_{OUT} > 5.0$ A



### POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR

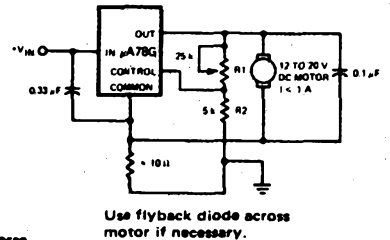


### $\pm 10$ V, 500 mA DUAL TRACKING REGULATOR

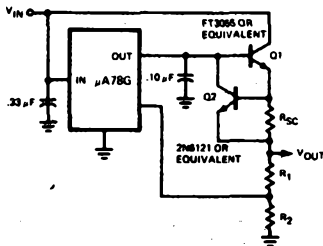


If load is not ground referenced, connect reverse biased diodes from outputs to ground.

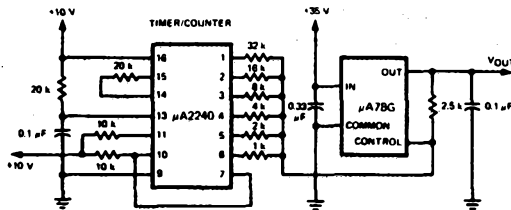
### MOTOR SPEED CONTROL



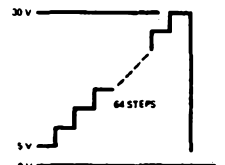
### POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



### PROGRAMMABLE SUPPLY



### OUTPUT WAVEFORM

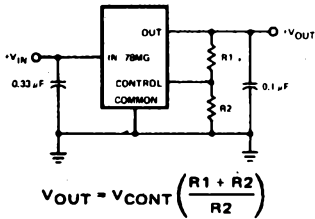


# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## ADJUSTABLE POSITIVE 4-TERMINAL REGULATORS — $\mu$ A78MG SERIES

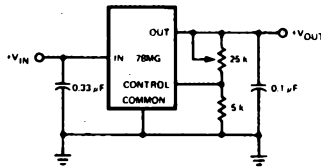
In many  $\mu$ A78MG applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output ( $0.33 \mu\text{F}$  and  $0.1 \mu\text{F}$ , respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

### BASIC POSITIVE REGULATOR

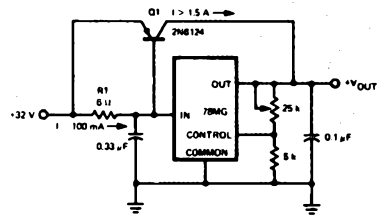


$$V_{OUT} = V_{CONT} \left( \frac{R1 + R2}{R2} \right)$$

### POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR



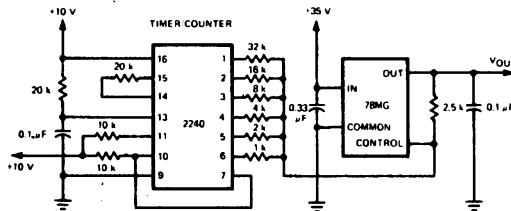
### POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR $I_{OUT} > 1.5 \text{ A}$



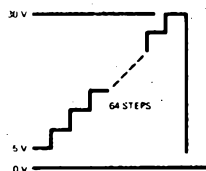
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{R(\text{MAX})}(\beta) - I_{OUT(\text{MAX})}}$$

NOTE: External series pass device is not short circuit protected.

### PROGRAMMABLE SUPPLY



### OUTPUT WAVEFORM

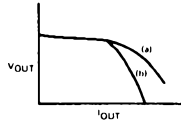
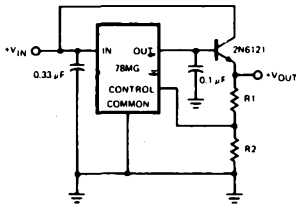


# TYPICAL VOLTAGE REGULATOR APPLICATIONS

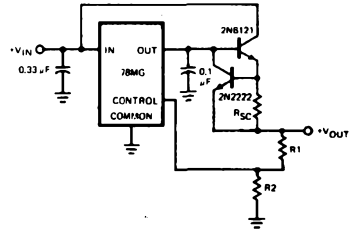
## ADJUSTABLE POSITIVE 4-TERMINAL REGULATORS – $\mu$ A78MG SERIES

### POSITIVE HIGH CURRENT VOLTAGE REGULATOR

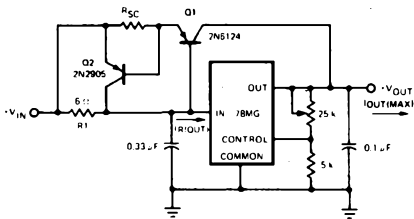
EXTERNAL SERIES PASS (a)



SHORT CIRCUIT LIMIT (b)

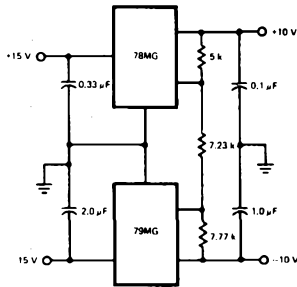


POSITIVE HIGH CURRENT  
SHORT CIRCUIT  
PROTECTED REGULATOR



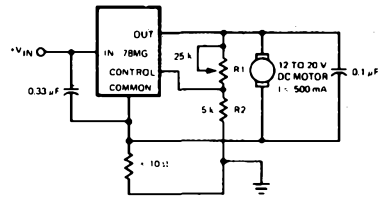
$$R1 = \frac{\beta V_{BE(Q1)}}{V_{R1(MAX)} (\beta + 1) - I_{OUT(MAX)}}$$

$\pm 10$  V, 1.0 A  
DUAL TRACKING REGULATOR



If load is not ground referenced, connect reverse biased diodes from outputs to ground.

MOTOR SPEED CONTROL



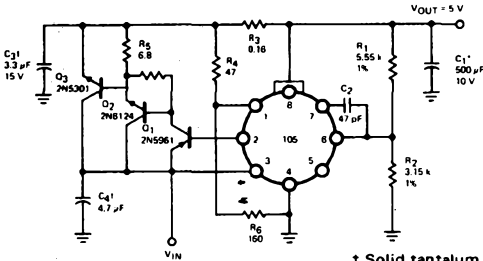
Use flyback diode across motor if necessary.



# TYPICAL VOLTAGE REGULATOR APPLICATIONS

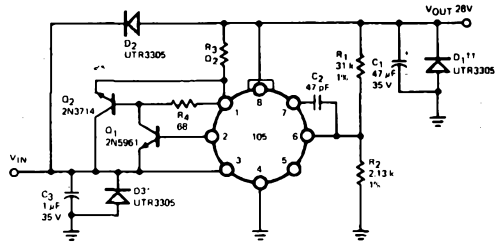
## ADJUSTABLE POSITIVE REGULATORS – $\mu$ A105 SERIES

### 10 A REGULATOR WITH FOLDBACK CURRENT LIMITING



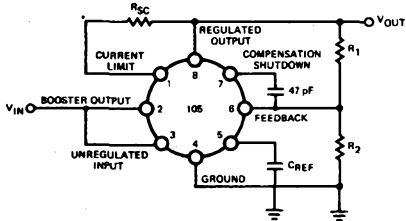
† Solid tantalum  
\* Electrolytic

### 1.0 A REGULATOR WITH PROTECTIVE DIODES



\* Protects against input voltage reversal  
† Protects against shorted input or inductive loads on unregulated supply  
†† Protects against output voltage reversal

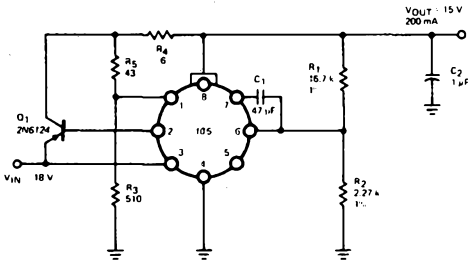
### BASIC POSITIVE REGULATOR WITH CURRENT LIMITING



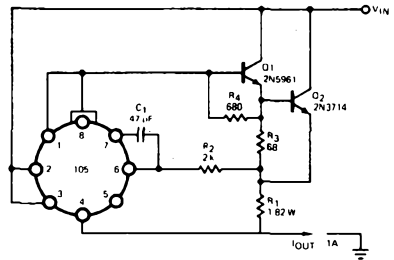
$$V_{OUT} \approx 1.72 \frac{R_1 + R_2}{R_2} V$$

$$I_{SC} \approx \frac{V_{SENSE}}{R_{SC}} \text{ mA}$$

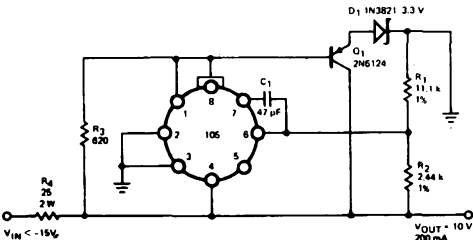
### LINEAR REGULATOR WITH FOLDBACK CURRENT LIMITING



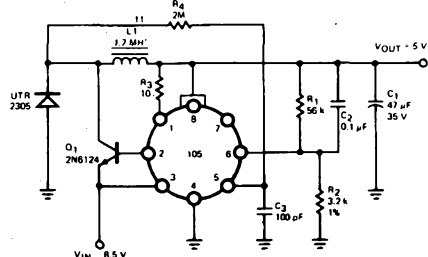
### CURRENT REGULATOR



### SHUNT REGULATOR



### SWITCHING REGULATOR



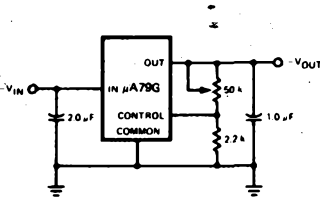
† Solid tantalum  
†† 125 turns #22 on Arnold Engineering A262123-2 molybdenum permalloy core.

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

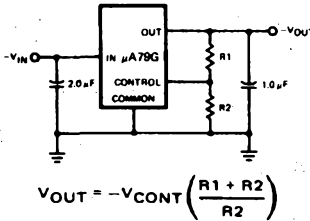
## ADJUSTABLE NEGATIVE 4-TERMINAL REGULATORS — $\mu$ A79G SERIES

All  $\mu$ A78G applications apply to the  $\mu$ A79G under the following conditions; R2 values are 2.2 k $\Omega$ , all external transistors and diodes reverse polarity.

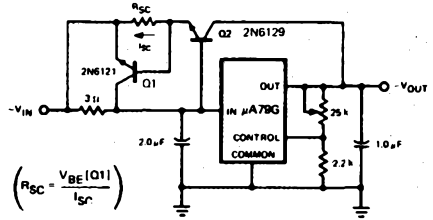
### -30 V TO -2.2 V ADJUSTABLE REGULATOR



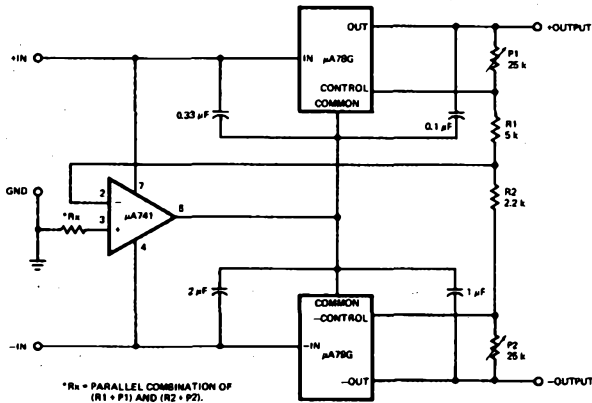
### BASIC NEGATIVE REGULATOR



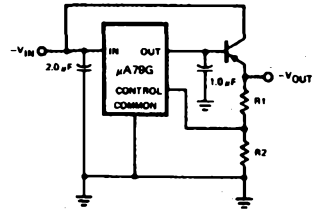
### NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



### ADJUSTABLE DUAL TRACKING REGULATOR



### NEGATIVE HIGH CURRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS



#### NOTE:

Bypass capacitors are recommended for stable operation of the  $\mu$ A79G series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2  $\mu$ F on the input, 1  $\mu$ F on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10  $\mu$ F or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

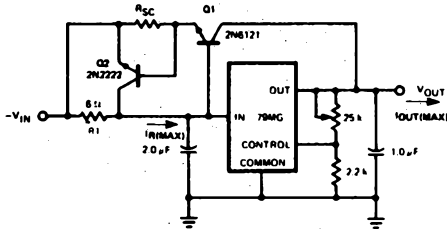
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## ADJUSTABLE NEGATIVE 4-TERMINAL REGULATORS — $\mu$ A79MG SERIES

Bypass capacitors are recommended for stable operation of the  $\mu$ A79MG over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

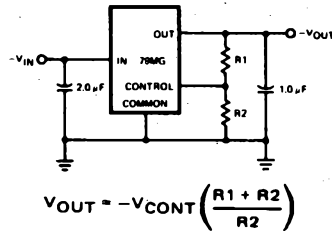
The bypass capacitors, ( $2 \mu\text{F}$  on the input,  $1 \mu\text{F}$  on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be  $10 \mu\text{F}$  or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

### NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



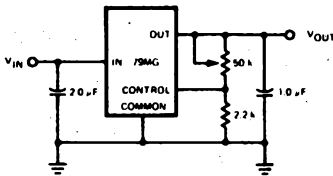
$$R1 = \frac{\beta V_{BE}(Q1)}{I_R(\text{MAX}) (\beta) - I_{\text{OUT}}(\text{MAX})}$$

### BASIC NEGATIVE REGULATOR

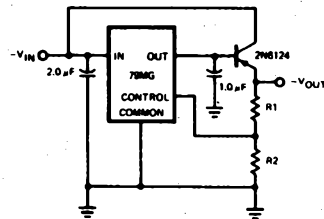


$$V_{\text{OUT}} = -V_{\text{CONT}} \left( \frac{R1 + R2}{R2} \right)$$

### -30 V TO -2.2 V ADJUSTABLE REGULATOR



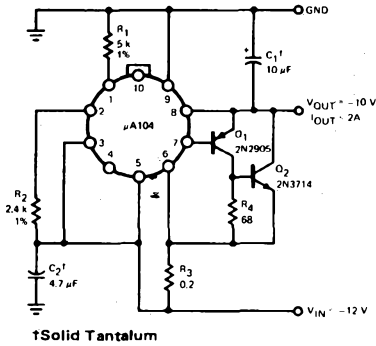
### NEGATIVE HIGH CURRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS



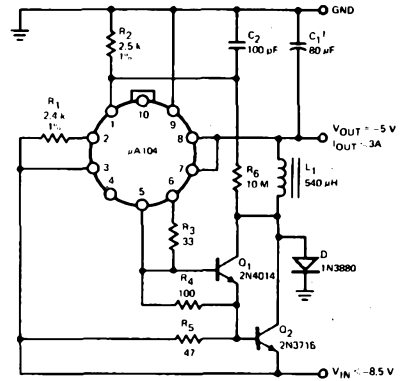
# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## ADJUSTABLE NEGATIVE REGULATORS – $\mu$ A104 SERIES

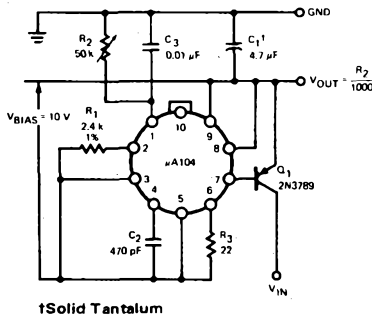
### HIGH CURRENT REGULATOR



### SWITCHING REGULATOR

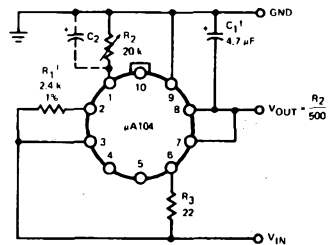


### OPERATING WITH SEPARATE BIAS SUPPLY



### BASIC REGULATOR CIRCUIT

†Solid Tantalum  
‡Trim  $R_1$  for exact scale factor

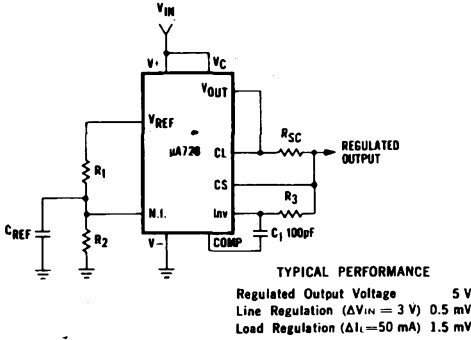


NOTE 1: A 0.01  $\mu$ F capacitor may be required across the input if long leads are used from the unregulated power source. Line transient response, noise and ripple rejection can be improved by shunting R2 with a 10  $\mu$ F capacitor C2.

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

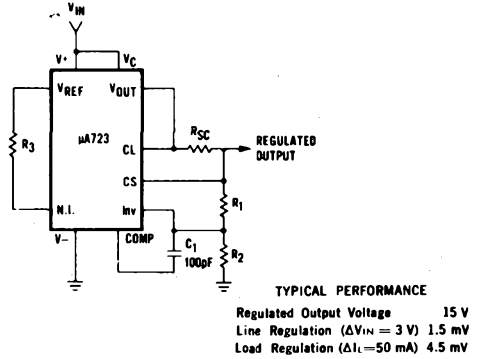
## PRECISION REGULATORS — $\mu$ A723 SERIES

### BASIC LOW VOLTAGE REGULATOR ( $V_{OUT} = 2$ TO $7$ V)



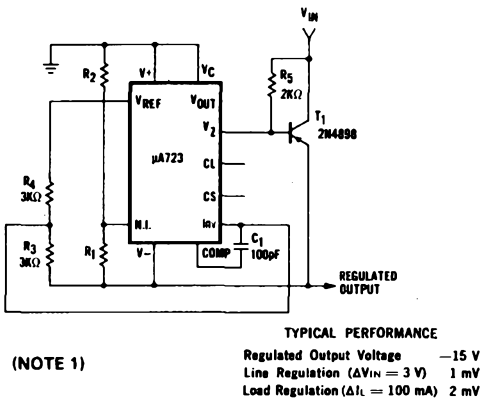
Note:  $R_1 = \frac{R_1 R_2}{R_1 + R_2}$  for minimum temperature drift.

### BASIC HIGH VOLTAGE REGULATOR ( $V_{OUT} = 7$ TO $37$ V)



Note:  $R_1 = \frac{R_1 R_2}{R_1 + R_2}$  for minimum temperature drift.  
 $R_1$  may be eliminated for minimum component count.

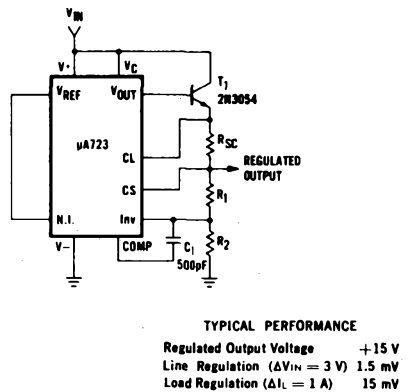
### NEGATIVE VOLTAGE REGULATOR



(NOTE 1)

Regulated Output Voltage -15 V  
Line Regulation ( $\Delta V_{IN} = 3$  V) 1 mV  
Load Regulation ( $\Delta I_L = 100$  mA) 2 mV

### POSITIVE VOLTAGE REGULATOR (External NPN Pass Transistor)



TYPICAL PERFORMANCE

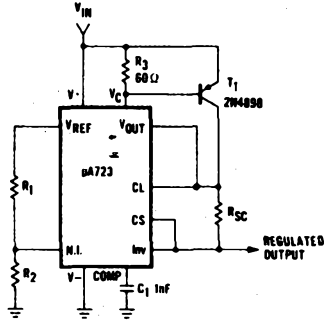
Regulated Output Voltage +15 V  
Line Regulation ( $\Delta V_{IN} = 3$  V) 1.5 mV  
Load Regulation ( $\Delta I_L = 1$  A) 15 mV

NOTE 1: For metal can applications where  $V_Z$  is required, an external 6.2 V Zener diode should be connected in series with  $V_{OUT}$ .

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## PRECISION REGULATORS — $\mu$ A723 SERIES

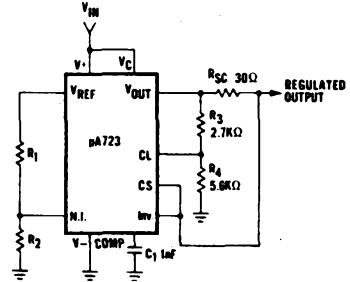
### POSITIVE VOLTAGE REGULATOR (External NPN Pass Transistor)



**TYPICAL PERFORMANCE**

Regulated Output Voltage	+5 V
Line Regulation ( $\Delta V_{IN} = 3$ V)	0.5 mV
Load Regulation ( $\Delta I_L = 1$ A)	5 mV

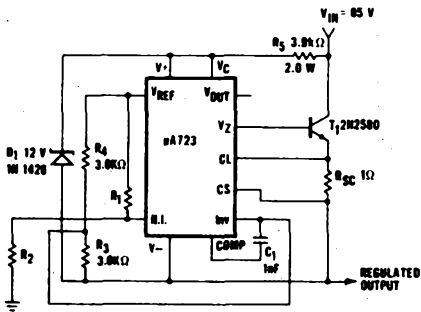
### FOLDBACK CURRENT LIMITING



**TYPICAL PERFORMANCE**

Regulated Output Voltage	+5 V
Line Regulation ( $\Delta V_{IN} = 3$ V)	0.5 mV
Load Regulation ( $\Delta I_L = 10$ mA)	1 mV
Short Circuit Current	20 mA

### POSITIVE FLOATING REGULATOR

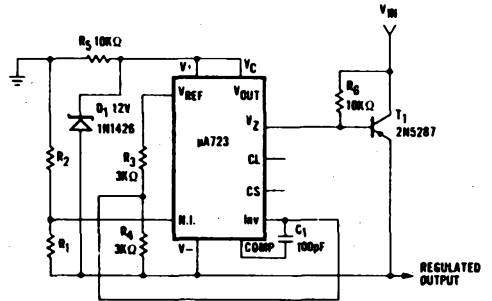


**TYPICAL PERFORMANCE**

Regulated Output Voltage	+50 V
Line Regulation ( $\Delta V_{IN} = 20$ V)	15 mV
Load Regulation ( $\Delta I_L = 50$ mA)	20 mV

(NOTE 1)

### NEGATIVE FLOATING REGULATOR



**TYPICAL PERFORMANCE**

Regulated Output Voltage	-100 V
Line Regulation ( $\Delta V_{IN} = 20$ V)	30 mV
Load Regulation ( $\Delta I_L = 100$ mA)	20 mV

(NOTE 1)

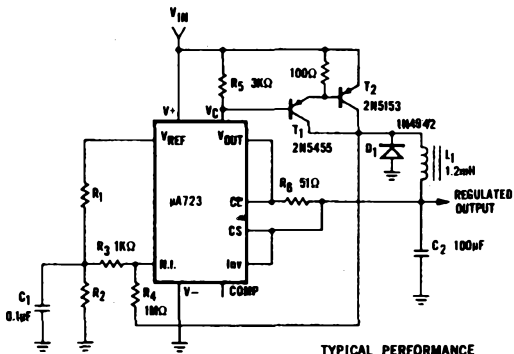
#### NOTES:

- For metal can applications where  $V_Z$  is required, an external 6.2 V Zener diode should be connected in series with  $V_{OUT}$ .

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## PRECISION REGULATORS — $\mu$ A723 SERIES

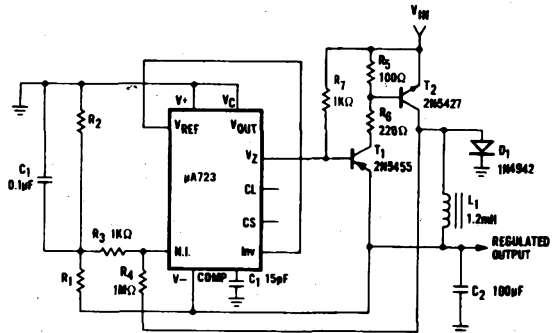
### POSITIVE SWITCHING REGULATOR



**TYPICAL PERFORMANCE**  
 Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 30$  V) 10 mV  
 Load Regulation ( $\Delta I_L = 2$  A) 80 mV

NOTE 1

### NEGATIVE SWITCHING REGULATOR

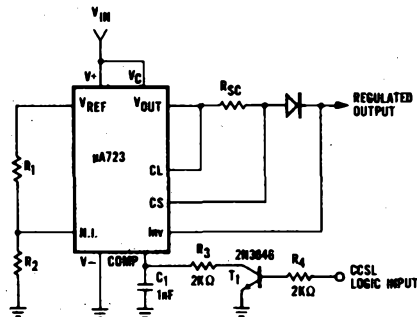


**TYPICAL PERFORMANCE**  
 Regulated Output Voltage -15 V  
 Line Regulation ( $\Delta V_{IN} = 20$  V) 8 mV  
 Load Regulation ( $\Delta I_L = 2$  A) 6 mV

(NOTE 2)

3

### REMOTE SHUTDOWN REGULATOR WITH CURRENT LIMITING

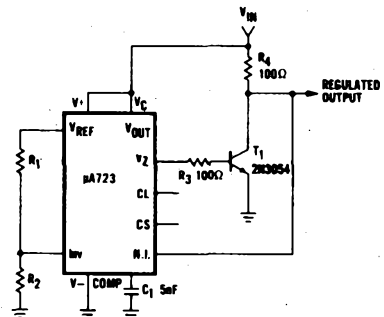


Current limit transistor may be used for shutdown if current limiting is not required. Add if  $V_{out} > 10$  V

**TYPICAL PERFORMANCE**  
 Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 3$  V) 0.5 mV  
 Load Regulation ( $\Delta I_L = 50$  mA) 1.5 mV

NOTE 1

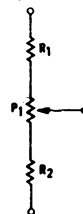
### SHUNT REGULATOR



**TYPICAL PERFORMANCE**  
 Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 10$  V) 0.5 mV  
 Load Regulation ( $\Delta I_L = 100$  mA) 1.5 mV

(NOTE 2)

### OUTPUT VOLTAGE ADJUST

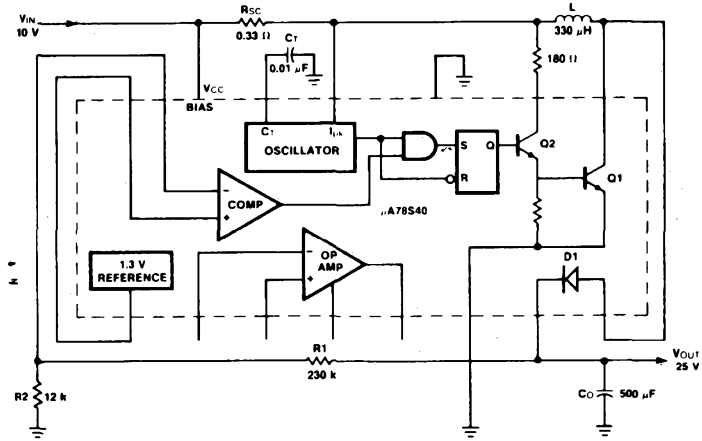


#### NOTES:

- $L_1$  is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009" air gap.
- Figures in parentheses may be used if R1/R2 divider is placed on opposite side of error amp.

# TYPICAL VOLTAGE REGULATOR APPLICATIONS

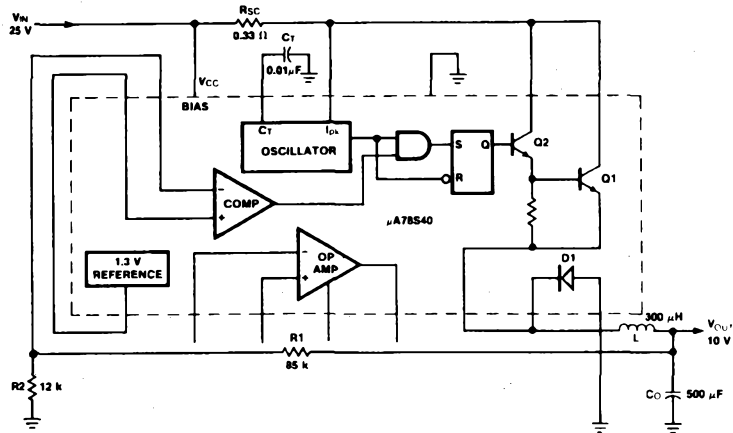
## SWITCHING REGULATORS – $\mu$ A78S40 SERIES



TYPICAL STEP-UP OPERATIONAL PERFORMANCE

$T_A = 25^\circ\text{C}$

CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 50 \text{ mA}$	25V
LINE REGULATION	$5\text{V} \leq V_{IN} \leq 15\text{V}$	4.0 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 100 \text{ mA}$	2.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 23.75$	160 mA
OUTPUT RIPPLE	$I_{OUT} = 50 \text{ mA}$	30 mV
EFFICIENCY	$I_{OUT} = 50 \text{ mA}$	79%
STANDBY CURRENT	$I_{OUT} = 50 \text{ mA}$	2.6 mA



TYPICAL STEP-DOWN PERFORMANCE

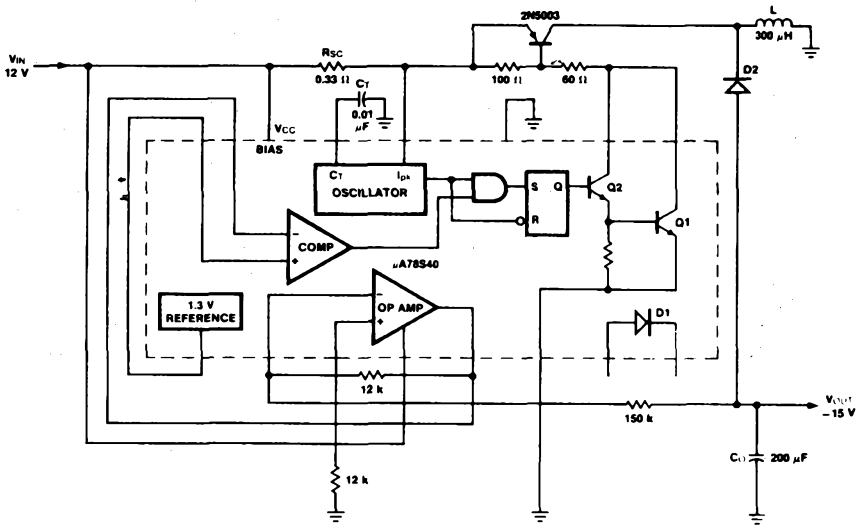
$T_A = 25^\circ$

CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 200 \text{ mA}$	10 V
LINE REGULATION	$20 \leq V_{IN} \leq 30 \text{ V}$	1.5 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 300 \text{ mA}$	3.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 9.5 \text{ V}$	500 mA
OUTPUT RIPPLE	$I_{OUT} = 200 \text{ mA}$	50 mV
EFFICIENCY	$I_{OUT} = 200 \text{ mA}$	74%
STANDBY CURRENT	$I_{OUT} = 200 \text{ mA}$	2.8 mA



# TYPICAL VOLTAGE REGULATOR APPLICATIONS

## SWITCHING REGULATORS - $\mu A78S40$ SERIES



### TYPICAL INVERSION OPERATIONAL PERFORMANCE

$T_A = 25^\circ$

CHARACTERISTIC	CONDITIONS	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 100 \text{ mA}$	-15 V
LINE REGULATION	$8 \text{ V} \leq V_{IN} \leq 18 \text{ V}$	5.0 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 150 \text{ mA}$	3.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 14.25 \text{ V}$	160 mA
OUTPUT RIPPLE	$I_{OUT} = 100 \text{ mA}$	20 mV
EFFICIENCY	$I_{OUT} = 100 \text{ mA}$	70%
STANDBY CURRENT		2.3 mA





**SELECTION GUIDES AND INDUSTRY  
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## POWER SUPPLY DESIGN

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# Chapter 4

## POWER SUPPLY DESIGN

A power supply normally operates from an ac line. Therefore, this ac input voltage must be converted to unregulated dc by some form of rectifier/filter combination and then to regulated dc using a voltage regulator. This chapter discusses the performance characteristics of the most common forms of rectifier/filter combinations and provides appropriate design equations for any output voltage and current.

### DEFINITION OF TERMS

Parameter	Definition	
$V_M$	peak input voltage	current $\sqrt{I_{ac}^2 + I_O^2}$
$V_O$	dc output voltage	$P_{in}$ ac input power
$V_{pk}$	transformer peak voltage	$P_O$ dc output power
$V_S$	ac input voltage	$R_L$ load resistance
F	form factor of the load current: $I_{rms}/I_O$	$R_S$ total series resistance, or the source resistance plus any added resistance plus the diode series resistance
$I_{ac}$	effective value of all alternating components of load current, <i>i.e.</i> , the current reading on an ac meter	$\gamma$ ripple factor in all charts normalized as 100% equal to 1,
$I_M$	peak current through each rectifier	$\gamma = (F^2 - 1) = \left[ \left( \frac{I_{rms}}{I_O} \right)^2 - 1 \right]^{1/2}$
$I_O$	average value of the load current, the reading on a dc meter	$\eta_R$ rectification efficiency, $\frac{P_O}{P_{in}} \times 100\%$
$I_{rms}$	effective value of the total load	$\omega$ $2\pi f$ where $f$ = line frequency

4

### SINGLE PHASE, HALF WAVE RECTIFIER

Figure 4-1 is a half wave rectifier and capacitor filter. Without the capacitor, peak current is

$$I_M = \frac{V_M}{R_S + R_L}$$

on the positive half cycle (or forward conduction cycle) of the input voltage. Some additional electrical characteristics follow.

$$I_{rms} = \frac{I_M}{2}$$

$$I_O = \frac{I_M}{\pi}$$

$$P_O = \frac{1}{\pi^2} \left( \frac{V_M^2 R_L}{(R_S + R_L)^2} \right)$$

$$\eta_R = \frac{40.6}{\left( 1 + \frac{R_S}{R_L} \right)} \%$$

$$\gamma = 1.21$$

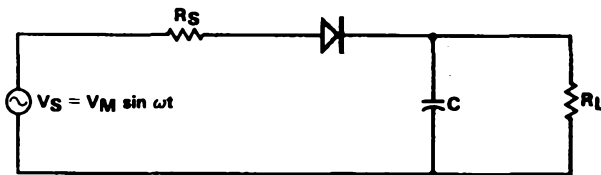


Fig. 4-1. Half-Wave Rectifier Circuit with Capacitive Filtering

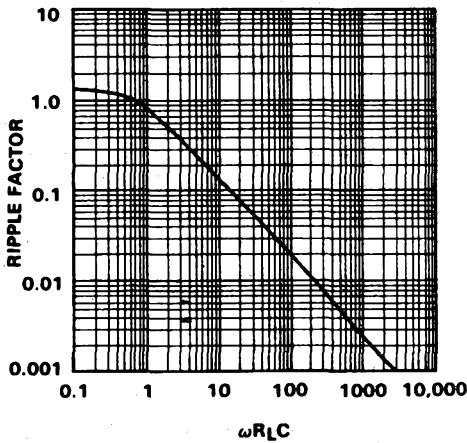


Fig. 4-2. Ripple Factor vs  $\omega R_L C$

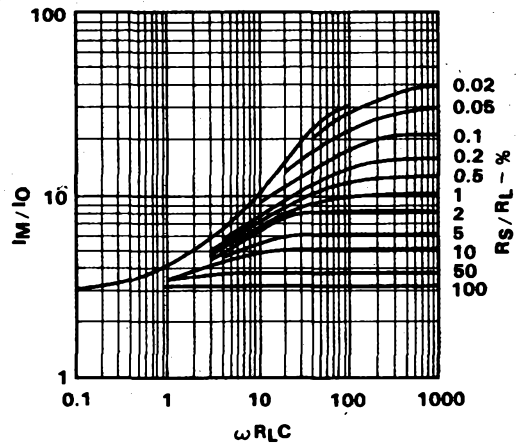


Fig. 4-3.  $I_M/I_O$  vs  $\omega R_L C$

Note that for a resistive load, the maximum ripple factor is 121% which, under most circumstances, requires filtering. When the capacitor is added across the load resistor, the ripple is reduced proportionate to the  $R_L C$  product (Figure 4-2).

One possible problem with any capacitive filter is the high peak current drawn due to the diode back-bias present throughout most of the input cycle. This is a result of the voltage stored across the filter capacitor. The rectifier conducts only during that short period of time when the input voltage exceeds the capacitor voltage by one diode drop. During conduction, the rectifier must supply the capacitor with sufficient energy to hold the ripple within specification until the next conduction cycle. Figure 4-3 is a plot of the  $I_M/I_O$  ratio versus the  $R_L C$  product with the  $R_S/R_L$  ratio as a variable. Notice that the surge-to-dc ratio of current increases as a function of both increasing capacitor value and of a reduced source-to-load impedance ratio.

When the ripple factor, load impedance, and  $\omega$  are known, the required capacitance can be determined from Figure 4-2. Because of the high turn-on surge, an external series limiting resistor is normally needed. Figure 4-4 is a plot of the dc-to-peak voltage ratio with the filter product as the X axis and the source/load impedance ratio as the third parameter. Note that the dc output-to-peak input voltage ratio approaches unity as the filter factor goes up and also as the source-to-load impedance ratio decreases. Because of the relatively large value of the filter capacitor required for a given ripple factor, the use of the half-wave capacitor filter is usually limited to low current applications such as the subsidiary power supply for the  $\mu A723$  in a floating regulator configuration.

#### HALF WAVE RECTIFIER WITH SERIES INDUCTIVE FILTER

Figure 4-5 is a half-wave rectifier with series inductive filtering. The inductor, in series with the load, prevents any rapid changes in the current flow and thus reduces the ripple factor by acting as an energy storage device. When the current flow is above the average current required, energy is stored in the inductor, and when the current is below the average, the stored energy is released. Figure 4-6 is the plot of ripple factor versus filter product for the inductor input filter. Because of the energy storage available with an inductor, the peak current through the rectifier is little more than the average current. However, the peak inverse voltage PIV seen by the rectifier is simply  $V_M$ , the peak input voltage. Figure 4-7 is a plot of  $V_O/V_M$  ratio as a function of the inductor filter product.

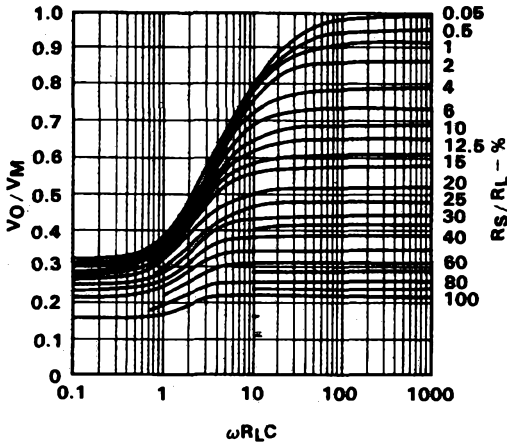


Fig. 4-4. DC-to-Peak Ratio

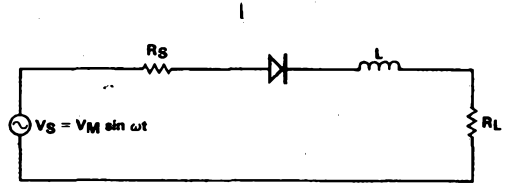


Fig. 4-5. Half-Wave Rectifier

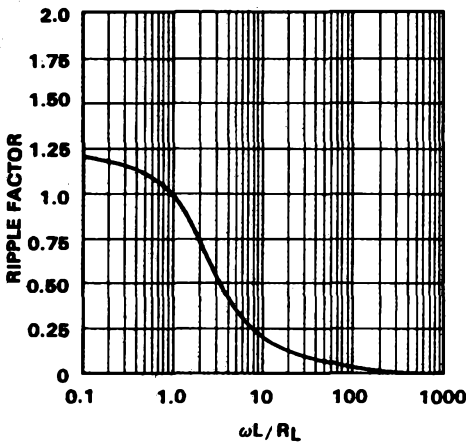


Fig. 4-6. Ripple Factor vs Filter Product

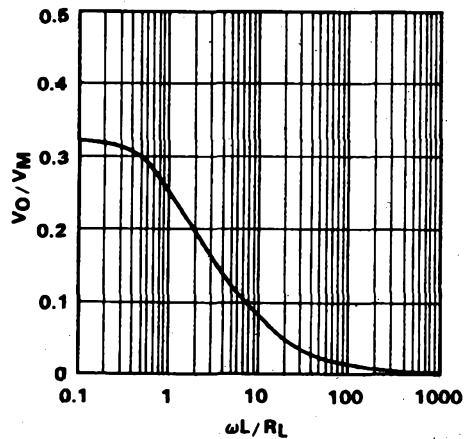


Fig. 4-7.  $V_O/V_M$  Ratio

4

### SINGLE-PHASE FULL-WAVE RECTIFIER

Figure 4-8, a basic full wave rectifier, has the following electrical characteristics.

$$I_{rms} = \frac{I_M}{\sqrt{2}} \quad I_O = \frac{2I_M}{\pi} \quad P_O = \left(\frac{2}{\pi}\right)^2 \frac{V_M^2 R_L}{(R_S + R_L)^2} \quad \eta_R = \frac{81.2}{\left(1 + \frac{R_S}{R_L}\right)} \% \quad \gamma = 0.48$$

There are two interesting features. Efficiency has doubled, as can be expected when doubling the number of rectifiers. In addition, the ripple factor has decreased from 121% to 48% in comparison with the half-wave circuit. Even with ripple reduction, a 48% factor is normally too high to be useful and must be filtered. Figure 4-9 is the filter product plot for both capacitive and inductive filters, assuming  $R_S \ll R_L$ . High peak currents are always associated with capacitive filters and Figure 4-10 plots the ratio of peak-to-dc current as a function of the filter product. The relationship between the filter product, the  $R_S/R_L$  ratio and the dc output-to-peak input voltage is given in Figure 4-11 for the capacitive input filter. Load regulation may also be determined from Figure 4-11 by using the high and low limits for  $R_L$ .

### Design Example

For a full-wave circuit with the following requirements,

$$V_O = 20 \text{ V}$$

$$I_O = 1 \text{ A}$$

$$\gamma < 0.1$$

$$\text{with } R_S = 1 \Omega$$

proceed with the following steps.

Step 1 Find the filter product from *Figure 4-9*

$$\text{for } \gamma < 0.1. (\omega R_L C = 10)$$

Step 2 Calculate  $R_L$

$$R_L = \frac{20}{1} = 20 \Omega$$

Step 3 Calculate  $C$

$$C = \frac{10}{\omega R_L} = \frac{10}{120 \times 20 \pi} = \frac{1}{240 \pi} = 1300 \mu\text{F}$$

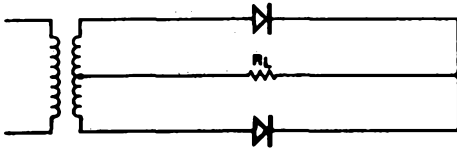


Fig. 4-8. Basic Full-Wave Rectifier

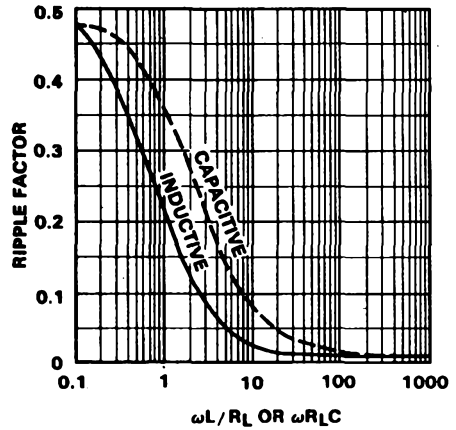


Fig. 4-9. Filter Product

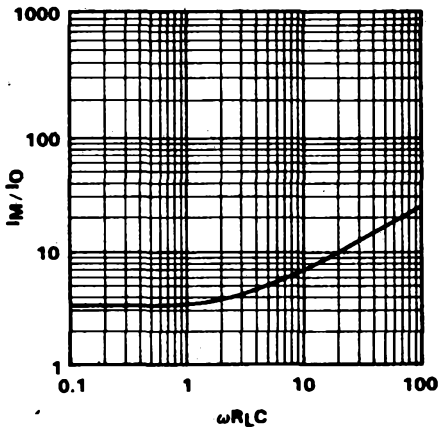


Fig. 4-10. Peak-to-DC Ratio

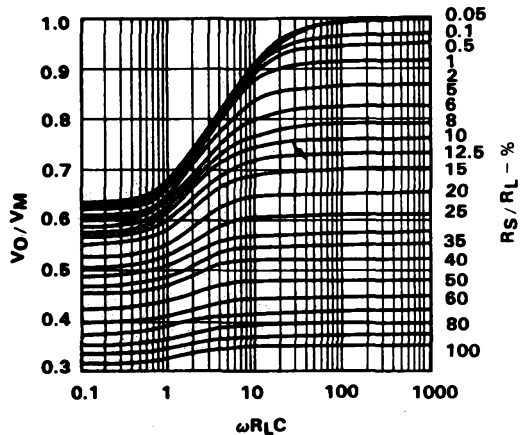


Fig. 4-11. Load Regulation



Step 4 Calculate  $\frac{R_S}{R_L}$

$$\frac{R_S}{R_L} = \frac{1}{20} = 5\%$$

Step 5 Find the transformer peak input voltage from the following.

$V_{pk}$  = diode forward voltage. One diode forward-voltage drop for a center-tapped full-wave input, two diode forward-voltage drops for a full-wave bridge

$$+ \frac{V_O}{V_O/V_M}$$

using the filter values from *Figure 4-11*.

$$V_{pk} = 0.7 + \frac{.20}{0.82} \text{ (intersection of } 5\% \frac{R_S}{R_L} \text{ and } \omega R_L C = 10 \text{ from } \textit{Figure 4-11}.$$

$$V_{pk} = 0.7 + 25.3 = 26 \text{ V peak or } 52 \text{ V pk-pk or } 18.6 \text{ V}_{rms}$$

Step 6 Check peak diode current from *Figure 4-10*. For this example at a filter product of 10, the peak current is seven times the dc current, or 7 A.

### LC SECTION FILTER

The LC section filter is one method of reducing ripple levels without the need for single, large value filter components. The basic circuit is shown in *Figure 4-12*. As a general rule, the capacitive reactance should always be less than 10% of the load resistance at the second harmonic of the incoming frequency. All the succeeding information is based upon this ratio. The ripple factor for an L-section filter has the form:

$$\gamma = \frac{0.47}{4\omega^2 LC - 1}$$

or, if n L-section filters are cascaded, then the ripple factor is:

$$\gamma = \frac{0.47}{(4\omega^2 L_1 C_1 - 1)(4\omega^2 L_2 C_2 - 1) \dots (4\omega^2 L_n C_n - 1)}$$

*Figure 4-13* is a plot of the filter factor versus the  $\omega^2 LC$  product. The one additional requirement is continuous current flow through the inductance. This says, in effect, that there is a critical inductor size. To assure this continuous current flow, a bleeder resistor  $R_K$  must be used at the filter output. The critical

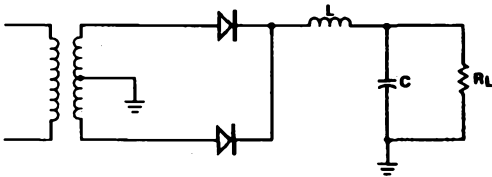


Fig. 4-12. LC Filter

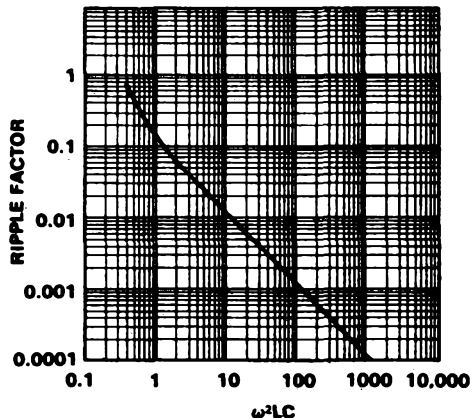


Fig. 4-13. Filter Factor vs  $\omega^2 LC$

value of inductance is

$$L_C = \frac{R_S + R_{\text{eff}}}{3\omega} \quad \text{where} \quad R_{\text{eff}} = \frac{R_K R_{L(\text{max})}}{R_K + R_{L(\text{max})}} \quad \text{and} \quad R_K = \frac{V_O}{I_K}$$

Bleeder current  $I_K$  may be assumed to be 10% of minimum load current or, if this is not a practical value, then some reasonable minimum bleeder current is selected. Once the critical inductance is found, then the capacitor value may be determined by the following steps: Set  $L = 2 L_C$ . Determine  $\omega^2 L C$  from *Figure 4-13* for the required ripple factor. Solve for  $C$  from  $\omega^2 L C = X$ , where  $X$  is the product from *Figure 4-13*.

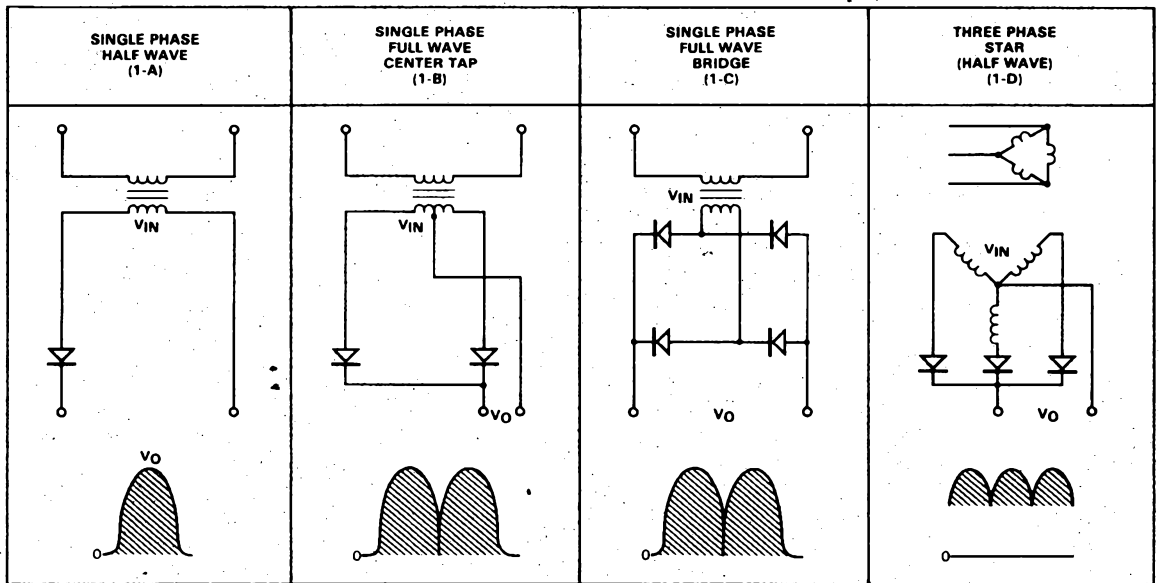
The peak rectifier currents depend upon the size of the inductor selected such that if  $L = L_C$  then  $I_M = 2 I_L$  and if  $L = 2 L_C$  then  $I_M = 1.5 I_L$ . The transformer secondary voltage is given by

$$V_{\text{rms}} = 1.11 \left[ V_O + R_S (I_{L(\text{max})} + I_K) \right]$$

and the minimum PIV for the rectifier is  $1.57 V_{O(\text{max})}$  for a full-wave bridge rectifier.

For minimum power dissipation,  $R_K$  should be as large as possible. In some cases, since the value of critical inductance is proportional to the value of the bleeder resistor, the selection of a high value results in an inductance too large to be practical. In this case, a swinging choke or a choke whose inductance decreases with increasing current flow is needed.

<p><b>Design Example</b> Full wave, single-section, choke input filter design,</p> <p><math>V_O = 50 \text{ V}</math>    <math>I_K = 100 \text{ mA}</math> <math>I_O = 1 \text{ A}</math>    <math>R_S = 10 \Omega</math>    <math>\gamma = 1\%</math></p> <p><b>Step 1 Calculate <math>R_K</math></b></p> $R_K = \frac{V_O}{I_K} = \frac{50 \text{ V}}{100 \text{ mA}} = 500 \Omega$ <p><b>Step 2 Calculate <math>R_{\text{eff}}</math></b></p> $R_{\text{eff}} = \frac{R_K R_{L(\text{max})}}{R_K + R_{L(\text{max})}} = 500 \Omega \quad (R_{L(\text{max})} = \infty)$ <p><b>Step 3 Calculate <math>L_C</math></b></p> $L_C = \frac{R_{\text{eff}} + R_S}{3\omega} = \frac{500 + 10}{1130} = \frac{510}{1130} \approx 0.5 \text{ H}$ <p><b>Step 4 Calculate <math>C</math></b></p> <p style="text-align: center;"><math>\gamma = 0.01</math></p> <p>then, <math>\omega^2 L_C C = 12</math> from <i>Figure 4-13</i></p> $C = \frac{12}{\omega^2 L_C} = \frac{12}{(120\pi)^2 0.5} = \frac{12}{142 \times 10^3 \times 0.5} = 0.169 \times 10^{-3} = 169 \mu\text{F}$	<p><b>Step 5 Calculate <math>I_M</math></b></p> <p>Since <math>L = L_C</math> then <math>I_M = 2 (I_O + I_K)</math> <math>I_M = 2 \times 1.1 = 2.2 \text{ A}</math></p> <p><b>Step 6 Calculate voltage drop both at no load and full load</b></p> <p><math>V_D \text{ no load} = I_K (R_S) = 0.1 \times 10 = 1 \text{ V}</math> <math>V_D \text{ full load} = (I_O + I_K) R_S = 1.1 \times 10 = 11 \text{ V}</math></p> <p><b>Step 7 Calculate transformer minimum rms voltages</b></p> $V_{\text{rms}} = 1.11 \left[ V_O + R_S (I_{O(\text{max})} + I_K) \right]$ $V_{\text{rms}} = 1.11 (50 + 10 \times 1.1)$ $V_{\text{rms}} = 1.11 (61)$ $V_{\text{rms}} = 67.5 \text{ V}_{\text{rms}}$ <p><b>Step 8 Calculate maximum output voltage</b></p> $V_{O(\text{max})} = \frac{V_{\text{rms}}}{1.11} - I_K R_S$ $V_{O(\text{max})} = \frac{67.5}{1.11} - 0.1 \times 10 = 61 - 1 = 60 \text{ Vdc}$ <p><b>Step 9 Calculate PIV rating required</b></p> <p>PIV = (1.57) <math>V_{O(\text{max})}</math> (See <i>Table 4-1</i>) PIV = <math>1.57 \times 60 = 94 \text{ V}</math></p> <p>Transformer ratios are determined from <i>Table 4-1</i>.</p>
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Characteristic	Load	Single Phase	Single Phase	Single Phase	Three Phase	Three Phase	Six-Phase	Three Phase	
		Half Wave (See 1-A)	Full Wave Center-Tap (See 1-B)	Full Wave Bridge (See 1-C)	Star (Half Wave) (See 1-D)	Full Wave Bridge (See 1-E)	Star (Three Phase Diametric) (See 1-F)	Double Wave With Interphase Transformer (See 1-G)	
R M S Input Voltage Per Transformer Leg ( $V_I$ )	Resistive & Inductive	2.22 $V_O$	1.11 $V_O$	1.11 $V_O$	0.855 $V_O$	0.428 $V_O$	0.741 $V_O$	0.855 $V_O$	
	Capacitive	0.707 $V_O$	0.707 $V_O$	0.707 $V_O$	0.707 $V_O$	0.408 $V_O$	0.707 $V_O$	0.707 $V_O$	
Peak Inverse Voltage Per Rectifier ( $P I V$ )	R & L	3.14 $V_O$	3.14 $V_O$	1.57 $V_O$	2.09 $V_O$	1.05 $V_O$	2.09 $V_O$	2.09 $V_O$	
	C	2.00 $V_O$	2.00 $V_O$	1.00 $V_O$	2.00 $V_O$	1.00 $V_O$	2.00 $V_O$	2.00 $V_O$	
Average Current Through Rectifier ( $I_F$ )	R,L. & C	1.00 $I_O$	0.50 $I_O$	0.50 $I_O$	0.333 $I_O$	0.333 $I_O$	0.167 $I_O$	0.167 $I_O$	
	R	3.14 $I_O$	1.57 $I_O$	1.57 $I_O$	1.21 $I_O$	1.05 $I_O$	1.05 $I_O$	0.525 $I_O$	
Peak Current Through Rectifier ( $I_M$ )	L		1.00 $I_O$	1.00 $I_O$	1.00 $I_O$	1.00 $I_O$	1.00 $I_O$	0.500 $I_O$	
	C		Depends on Size of Capacitor						
	Sine Wave	3.49 $P_O$	1.75 $P_O$	1.23 $P_O$	1.50 $P_O$	1.05 $P_O$	1.81 $P_O$	1.49 $P_O$	
Transformer Total Secondary VA	Sq. Wave	3.14 $P_O$	1.57 $P_O$	1.11 $P_O$	1.48 $P_O$	1.05 $P_O$	1.81 $P_O$	1.48 $P_O$	
	Sine Wave	3.49 $P_O$	1.23 $P_O$	1.23 $P_O$	1.23 $P_O$	1.05 $P_O$	1.28 $P_O$	1.06 $P_O$	
Transformer Total Primary VA	Sine Wave	3.49 $P_O$	1.11 $P_O$	1.11 $P_O$	1.21 $P_O$	1.05 $P_O$	1.28 $P_O$	1.05 $P_O$	
	Sq. Wave	3.14 $P_O$	1.11 $P_O$	1.11 $P_O$	1.21 $P_O$	1.05 $P_O$	1.28 $P_O$	1.05 $P_O$	
% Ripple	Sine Wave Resistive Load	121%	47%	47%	17%	4%	4%	4%	
Lowest Ripple Frequency	-	1 $F_I$	2 $F_I$	2 $F_I$	3 $F_I$	6 $F_I$	6 $F_I$	6 $F_I$	
Conversion Efficiency	-	40.6%	81.2%	81.2%	97%	99.5%	99.5%	99.5%	

Table 4-1. Electrical Reference Table and Rectifier Circuit Wave Shapes

(Cont'd)

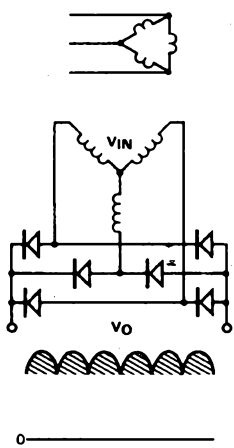
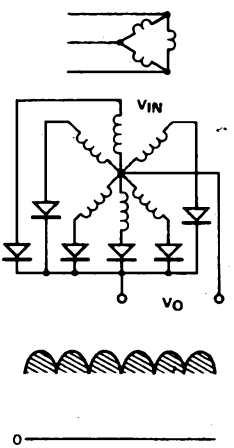
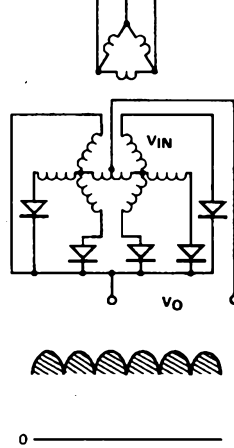
THREE PHASE FULL WAVE BRIDGE (1-E)	SIX PHASE STAR (THREE PHASE DIAMETRIC) (1-F)	THREE PHASE DOUBLE WAVE WITH INTERPHASE TRANSFORMER (1-G)
		

Table 4-1. Electrical Reference Table and Rectifier Circuit Wave Shapes (Cont'd)

### SWINGING CHOKE LC SECTION FILTER

When designing a swinging choke section filter, the inductance required at the minimum and maximum output currents can be determined as follows.

1. Find  $L_C$  (critical inductance)

$$L_C = \frac{R_S + R_{eff}}{3\omega}$$

where, as before:

$$R_{eff} = \frac{R_K R_{L(max)}}{R_K + R_{L(max)}}$$

2. Find  $L_2$  (inductance at maximum load current)

$$L_2 = \frac{R_S + R_{eff2}}{3\omega}$$

where:

$$R_{eff2} = \frac{R_{L(min)} R_K}{R_{L(min)} + R_K}$$

When  $L_C$  has been determined, then the capacitor value may be calculated as before. The condition  $\omega^2 L_C \leq 1/4$  should be avoided due to possible filter instabilities.

### CAPACITIVE INPUT FILTER CHARACTERISTICS

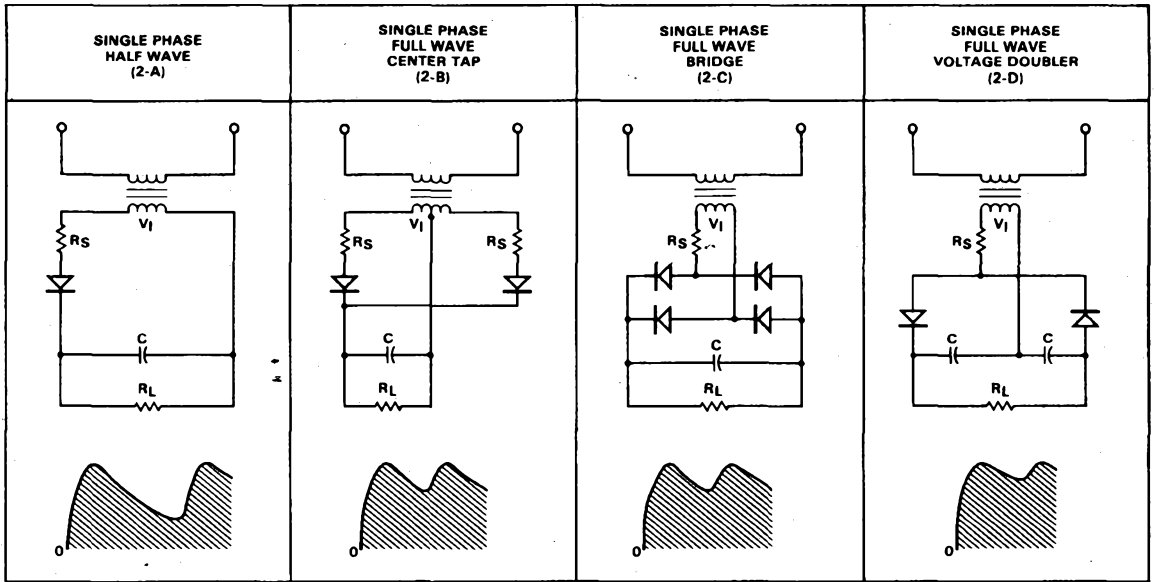
$$R_S/R_{L(min)} = 0.02$$

$$\omega C R_{L(min)} = 12$$

When the voltage and current levels are known, *Table 4-2* can be used to select the optimum configuration and determine transformer and rectifier characteristics.

### VOLTAGE DOUBLERS

Increased dc output voltage from a transformer winding can be obtained using a voltage multiplier circuit. However, this method requires additional components, *i.e.*, two filter capacitors, and reduces the output current. A full-wave doubler and a half-wave doubler are shown in *Figure 4-14*. The half-wave doubler is generally preferred since it has a common input and output terminal. In operation,  $C_2$  is



Characteristic	Single Phase Half Wave (See 2-A)	Single Phase Full Wave Center-Tap (See 2-B)	Single Phase Full Wave Bridge (See 2-C)	Single Phase Full Wave Voltage Doubler (See 2-D)
$V_I$	$0.910 V_O$	$0.825 V_O$	$0.805 V_O$	$0.552 V_O$
PIV	$2.56 V_O$	$2.34 V_O$	$1.14 V_O$	$1.56 V_O$
Ripple	$0.12 V_O$	$0.06 V_O$	$0.06 V_O$	$0.09 V_O$
$I_M/Rect.$	$7.80 I_O$	$4.75 I_O$	$4.75 I_O$	$3.00 I_O$
$I_{RMS}/Rect.$	$2.50 I_O$	$1.33 I_O$	$1.33 I_O$	$1.10 I_O$
SEC VA	$2.35 P_O$	$2.16 P_O$	$2.16 P_O$	$1.22 P_O$
PRI VA	$2.35 P_O$	$3.05 P_O$	$2.16 P_O$	$1.72 P_O$

Table 4-2. Capacitive Input Filter Characteristics and Rectifier Circuit Wave Shapes

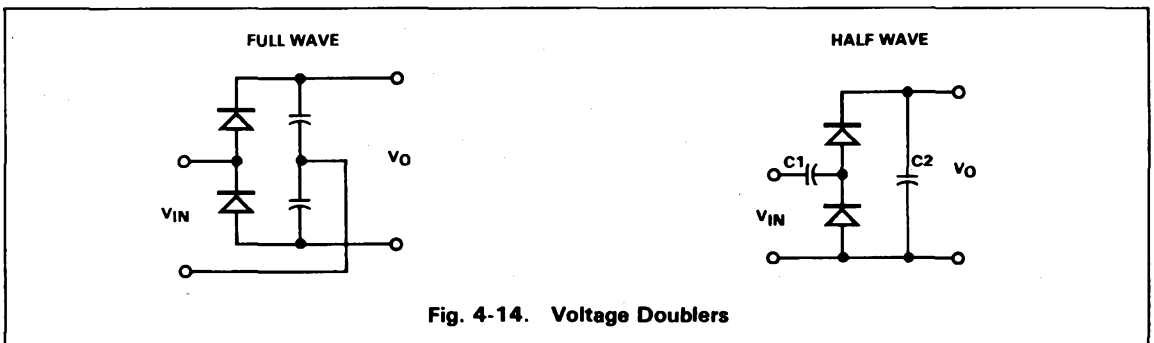


Fig. 4-14. Voltage Doublers

charged on one half cycle; on the second half cycle, C1 is charged thereby summing the voltages across each capacitor. This provides a doubling effect since the output voltage is approximately twice the input voltage.

## PRE-REGULATORS

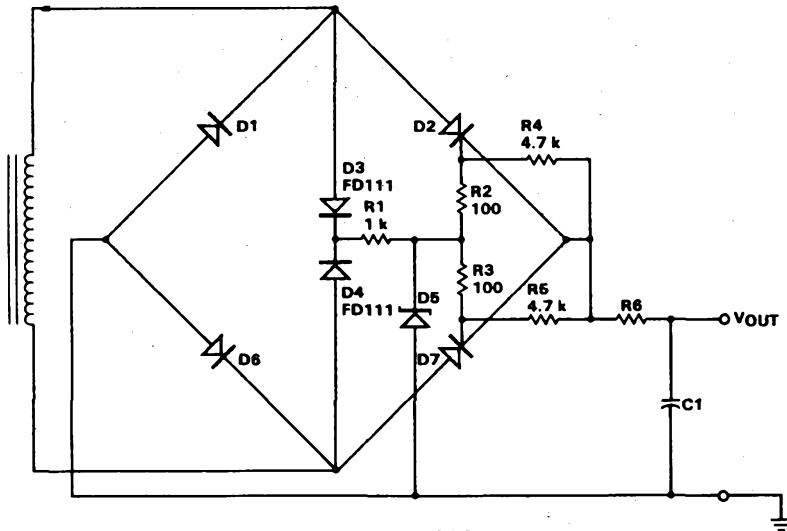
Pre-regulators for use in power supplies take one of two forms.

- Fixed output circuit for use with limited output adjustment range supplies (Figure 4-15).
- Tracking pre-regulators which maintain a fixed minimum input/output differential (Figure 4-16).

In both cases this circuitry operates by holding the SCR gates at some dc potential which fires the forward biased (anode to cathode) device whenever the ripple voltage on the filter capacitor drops to a level sufficient to exceed the gate-to-cathode threshold of the SCR.

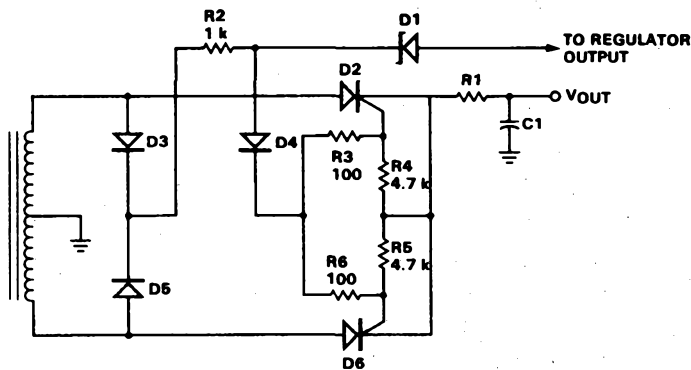
Two precautions are necessary when either pre-regulator circuit is used.

- The firing of the SCR is done on a dc drive basis, and represents a "soft fire" condition, *i.e.*, no gate overdrive; this should be considered when selecting power devices.
- RFI should be considered in the application of these circuits as the SCRs operate effectively as phase control devices.



$$V_{OUT(\min)} \cong V_Z(D5) - \text{SCR gate losses}$$

Fig. 4-15. Fixed Output Circuit



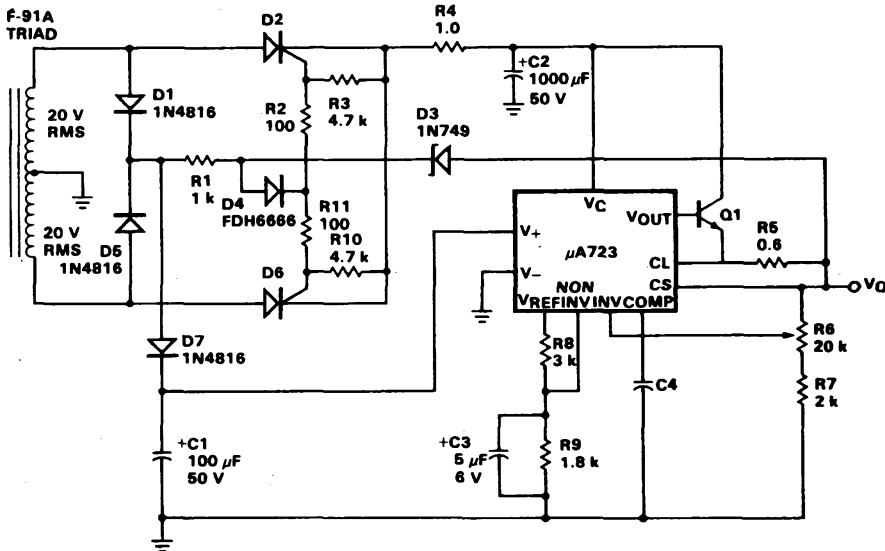
$$V_{OUT(\min)} \cong V_{OUT(\text{reg})} + V_Z(D1) - \text{SCR gate threshold}$$

Fig. 4-16. Fixed Input/Output Differential

## COMPLETE CIRCUITS

Two circuits are included to show combinations of several of the circuit techniques previously presented. *Figure 4-17* is a grounded, tracking pre-regulator design adjustable from 3 to 25 V using the transformer shown with the minimum input/output differential set by the 1N749 Zener diode. The power for the regulator control portion is provided by a separate voltage source to insure efficient operation at low output voltages, while maintaining a voltage greater than the 9.5 V minimum specified for the  $\mu A723$  internal circuitry.

*Figure 4-18* again provides a controlled voltage across the series-pass device. But, due to the floating configuration, the device is capable of regulation from 0 to 150 V using the specified isolation transformers. In this example, the power for the integrated circuit is provided by the combination of the voltage doubler C1, C2, D1, D2 and a transistor-buffered Zener diode which provides approximately 20 V for the regulator. In both *Figures 4-17* and *4-18*, the maximum output capability is limited by the power components; therefore the selection of a heavy-duty transformer, diodes, SCRs and output devices allows power capability expansion of the basic circuitry to fit almost any requirement.

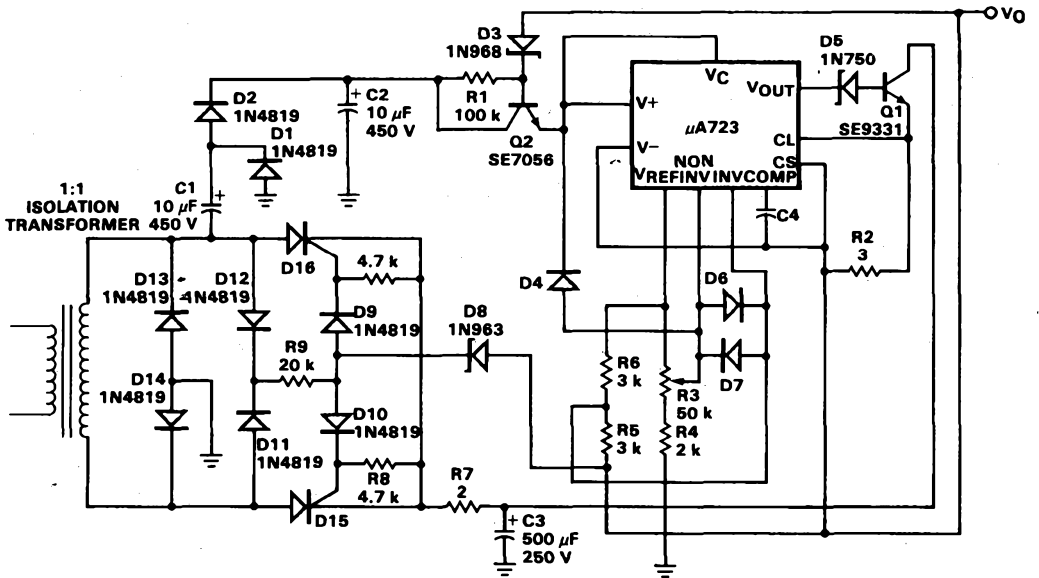


### TYPICAL PERFORMANCE

$V_O$  3 V to 25 V (Transformer Limit)  
 $I_{OUT}$  current limited at 0.8 A  
 Line Regulation < 1 mV any Voltage and Load  
 $\Delta V_{IN} = 95 \text{ V rms to } 125 \text{ V rms}$

Load Regulation .04% of  $V_O$   
 $\Delta I_{OUT} = 50 \text{ mA to } 500 \text{ mA}$   
 Ripple and Noise = < 2 mV pk-pk over full  $V_O$  Range

Fig. 4-17. Tracking Pre-Regulator



TYPICAL PERFORMANCE

$V_O = 0$  to  $+150 V_O$  (Transformer Limit)  
 $I_{OUT}$  current limited at 170 mA  
 Line Regulation = 0.04% of  $V_O$   
 $\Delta V_{IN} = 95$  V rms to 125 V rms

Load Regulation 0.1% of  $V_O$   
 $\Delta I_{OUT} = 15$  mA to 150 mA  
 Ripple  $< 0.05\%$  of  $V_O$

Fig. 4-18. High Voltage Tracking Regulator

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## POWER TRANSISTORS

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# Chapter 5

## POWER TRANSISTORS

When using power transistors in voltage regulators, the designer should be fully aware of the capabilities and limitations of these components, particularly the mechanisms affecting performance under high electrical and thermal stress. Power transistors are typically used in high current, high voltage and high temperature applications, *e.g.*, in resistive and clamped inductive switching circuits, unclamped inductive switching circuits, and Class B amplifiers. These conditions, separately or in combination, can be destructive; therefore, the power transistor selected for a specific application must be capable of safely withstanding all operating conditions forced by the circuit.

A number of factors such as second breakdown, dissipation capability, current and voltage ratings, and ambient temperature critically affect the performance of power transistors in circuit applications. These factors define the safe operating areas (SOA) for the forward-biased and reverse-biased modes within which each device can be safely operated without failure or degradation. Most manufacturers publish SOA curves to provide the circuit designer with an easy method for specifying power transistors.

### DC FORWARD-BIASED SAFE OPERATING AREA

In a typical safe area diagram, *Figure 5-1*, collector current  $I_C$  is shown as a function of collector-to-emitter voltage  $V_{CE}$ . Each curve is labeled with the duration of the on pulse – from the worst-case dc condition to a minimum duration of  $5 \mu s$  – at  $T_C = 100^\circ C$  and a 1% duty cycle. The four factors limiting the dc forward-biased SOA of a particular power transistor are the collector current (1), thermal limitations (2), second breakdown limitation (3), and  $V_{CE(sus)}$  (4).

Operation above the  $I_C$  boundary (rated  $I_{C(max)}$ ) may cause melting of the emitter lead wire, lifting of the lead wire bonds, or damage to the chip itself. Operation above the thermal limitation boundary causes overheating of the chip which may impair reliability. The second inclined portion of the right boundary

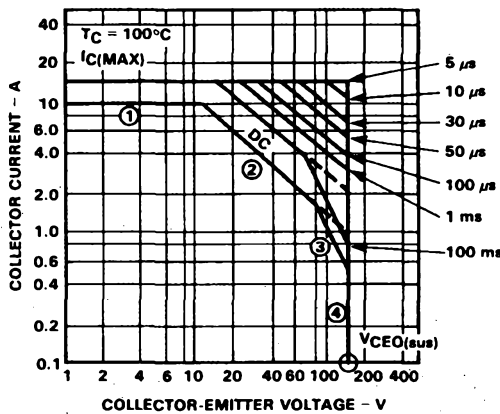


Fig. 5-1. Typical Safe Area

represents the second breakdown limitation. Operation to the right of this boundary causes second breakdown, which may destroy the device due to localized overheating. The vertical portion of the right boundary represents the primary voltage breakdown limitation,  $V_{CEO(sus)}$ . Operation to the right of this boundary results in voltage breakdown and excess current that may destroy the device. Within these four boundaries, operation at any point (any combination of voltage and current) is safe. For example, 30 W (30 V x 1 A) can safely be dissipated in this example when the case temperature is 100°C.

Power dissipation at high voltages is limited by second breakdown, boundary (3) in *Figure 5-1*. Under second breakdown conditions, the output impedance changes almost instantaneously from a large value to a small limiting value. This condition is distinguished from normal transistor operation in that once it occurs, the base no longer controls normal collector characteristics. Physically, second breakdown is caused by localized current concentrations resulting in uncontrollable generation and multiplication of carriers causing a sudden reduction of collector impedance. As the duration of this phenomenon exceeds the thermal time constant of the area, the transistor is irreversibly damaged. The forward-bias second breakdown current  $I_{SB}$  is defined as the current at the onset of second breakdown. To increase the  $I_{SB}$  rating of a power device, wide base-width and uniform base-dopant concentration are key factors. Wide base width improves second breakdown capability in three ways. First, it reduces intensity of the transverse electric field; second, a wide base promotes fanning out of the current before it reaches the collector-base junction, thus tending to eliminate generation of hot spots; third, it also acts to thermally isolate the emitter-base junction from the hot spots generated in the collector base region, thus tending to prevent thermal runaway. Uniform base doping such as obtained by the Fairchild multiple epitaxial process, utilizing epitaxial base material, improves second breakdown capability by reducing the transverse electric field in the base.

The fourth limitation of the SOA area is the open-base breakdown voltage  $V_{CEO(sus)}$  which can be written as a function of three variables,  $Q_B$ ,  $N$  and  $W_C$ , where  $Q_B$  is the charge in the base,  $N$  is the collector impurity concentration and  $W_C$  is the metallurgical collector width.  $V_{CEO(sus)}$  is reduced from the collector base breakdown voltage  $BV_{CBO}$  by a factor that decreases with increasing peak gain. The equation showing this relationship is

$$\frac{V_{CEO(sus)}}{BV_{CBO}} = (1 - \alpha)^{1/n}$$

where  $n$  has values ranging from 2 to 6 and  $\alpha$  = common base current gain, which in turn is a function of  $Q_B$ ,  $N$  and  $W_C$ .

### PULSED FORWARD-BIASED SAFE OPERATING AREA

So far, discussion of forward-biased safe area has been limited to dc operation. Another forward-bias operating mode, namely, pulsed operation, must be considered. Refer to the typical safe area diagram in *Figure 5-1*. Very high peak power dissipation is possible during pulsed operation. For example, peak power of 360 W at 60 V is permissible for a pulse width of 0.1 ms, compared with maximum power of only about 115 W at 60 V for dc conditions. This high peak power capability arises from the inherent thermal capacitance of the device which enables it to absorb short bursts of energy without exceeding the maximum junction temperature or going into second breakdown. If the time between power pulses is relatively long (low duty cycle), most of the stored thermal energy is dissipated before the next power pulse arrives; thus, temperature build-up in the device is prevented. As indicated in *Figure 5-1*, allowable peak power increases as pulse width decreases. This follows from the fact that total energy absorbed is equal to the product of power and time. If the time duration of the pulse decreases, peak power can increase without increasing total energy absorbed.

### REVERSE-BIASED SAFE OPERATING AREA

When the emitter-base junction of a transistor is reverse biased, the device begins to turn off. In an unclamped inductive circuit, an electrical stress occurs that can result in reverse-biased second breakdown. When the load is resistive or a clamped inductance, the transistor sees very little energy in the reverse-

biased mode; but, when the load is an unclamped inductance, almost all of the energy contained in the coil is dumped into the transistor, *i.e.*,

$$E = 1/2 LI_C^2$$

Second breakdown energy  $E_{SB}$  is the guaranteed reverse-biased energy the transistor is capable of withstanding. When the emitter-base junction is reverse biased, a transverse voltage gradient appears in the base region forcing severe current crowding under the center of the emitter (*Figure 5-2*). This condition is further aggravated by thermal feedback. If the energy in this hot spot raises the temperature of the silicon above approximately 400°C, the emitter-base junction goes into avalanche and the sustaining voltage collapses within nanoseconds. Usually, the transistor is destroyed.

During reverse-bias operation, current is concentrated in a small centralized area rather than in a relatively larger area under the emitter periphery as is the case during forward-biased operation. Therefore, since the current crowding is greater,  $E_{SB}$  is much less than the energy capability when the transistor is forward biased.

The  $E_{SB}$  capability of a power transistor depends on both the transistor and the circuit design. For low  $E_{SB}$  stress, the transistor design must include a large emitter area, a high resistive collector and graded collector doping to reduce current crowding. The circuit should be designed with low inductance (*Figure 5-3*) and low  $I_C$  to maintain low energy, keeping in mind that for a specified energy level, as  $L$  increases, second breakdown stress on the transistor becomes more severe. To reduce the transverse voltage gradient in the base, and therefore reduce current crowding, low reverse bias  $V_{BE}$  and large base resistance  $R_{BE}$  are required.

The effective capacitance  $C_{eff}$  on the collector should be low, otherwise it takes too long for the  $C_{eff}$  to charge to  $V_{CE(sus)}$  and the device turns off completely (Curve 3a in *Figure 5-4*). When this happens, the voltage rises to the blocking voltage and the  $C_{eff}$  discharges into the transistor (snap back). This is a very stressing situation since the collector current goes high during total cutoff thus causing extreme current crowding. Generally, an  $E_{SB}$  stress is safe as long as the dissipated energy is less than that specified on the data sheet and provided  $L \leq L_{spec}$ ,  $R_{BE} \geq R_{BE(spec)}$ ,  $|V_{BE}| < |V_{BE(spec)}|$ , and the device is operated in the sustaining mode and snapback is avoided by holding  $C_{eff}$  low (See *Figure 5-5*). When  $L > L_{spec}$ , the SOA limit follows an approximate curve,  $LI_C^d = \text{constant}$ ; it is usually safe to consider  $d = 1$ .

5

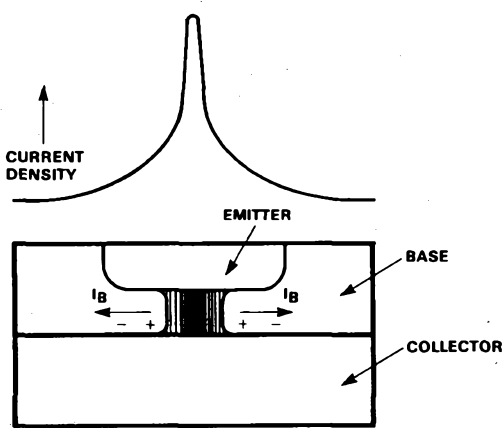


Fig. 5-2. Current Crowding During Reverse-Biased Cutoff

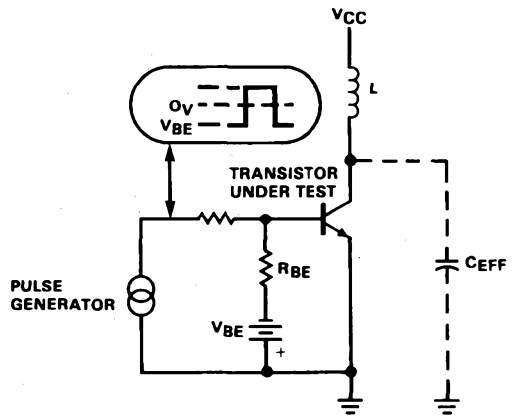
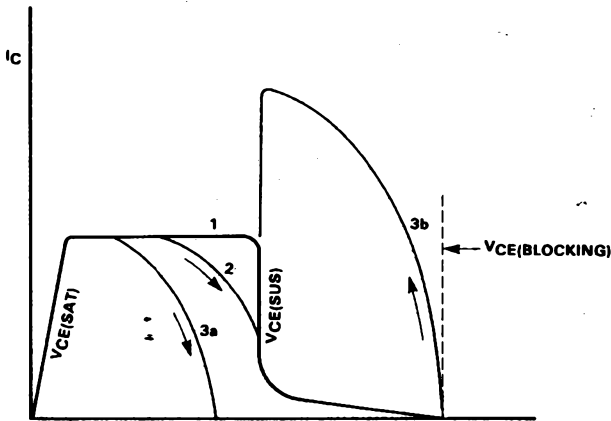


Fig. 5-3. Reverse-Biased Transistor with Inductive Load



- NOTES:
- Curve 1: Turn off with very small  $C_{eff}$
  - Curve 2:  $C_{eff}$  softens the curve; it must be charged before  $V_{ce(sus)}$  is reached.
  - Curve 3: Large  $C_{eff}$  allows the transistor to turn off (3a) before the energy stored in L is discharged. Snap back occurs at 3b.

Fig. 5-4. Inductive Turn Off

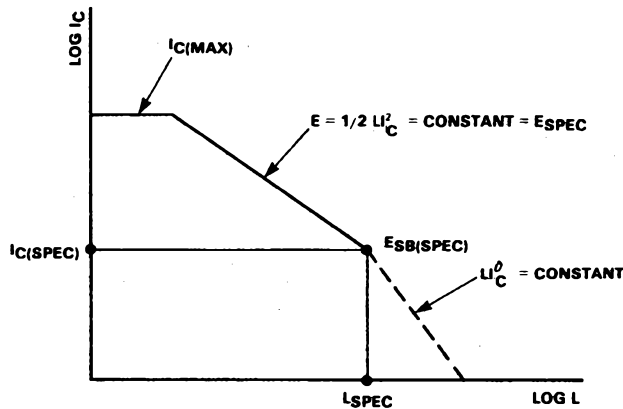


Fig. 5-5. Reverse-Biased Safe-Operating Area

Although this is a valid rating system, it is good design practice to avoid reverse-biased stress by clamping or waveshaping. While the power-transistor manufacturer can guarantee an  $E_{SB}$  rating, it must be kept in mind that non-destructive testing is difficult, lot-to-lot and unit-to-unit variations are significant and the fast high voltage power transistors, in particular, have limited  $E_{SB}$  capabilities.

### THERMAL LIMITATION

The thermal limits placed on power dissipation are established to prevent overheating of the chip, and depend upon the junction-to-case thermal resistance  $\theta_{JC}$  of the device. This resistance determines how readily the heat generated in the chip during operation is conducted to the outside surface of the case (package). It is measured by comparing the temperature of the collector base junction with the temperature of the case at a known power dissipation level.  $\theta_{JC}$  is expressed in units of degrees centigrade per watt. The industry specifies a maximum permissible junction temperature of 200°C for metal can power transistors and 150°C for plastic devices. Based on this limit and the  $\theta_{JC}$  value, maximum allowable power dissipation in the thermally limited region can be determined for any case temperature. See Chapter 6 for additional information on the thermal resistance.

## FAIRCHILD POWER TRANSISTORS (Figure 5-6)

*Double-Diffused Epitaxial Planar\** power transistors, made by the same process used for small-signal transistors, are characterized by shallow diffusions into an epitaxial layer. The junctions are normally passivated with silicon dioxide to ensure low leakage currents and optimum stability. This is the most common form of Planar power transistor and both npn and pnp types can easily be made. The devices typically have very low leakage, high gain, low saturation voltage and high gain-bandwidth product. Typical values for the latter range from 20 to 200 MHz. Double-diffused epitaxial Planar transistors are primarily used in high frequency, high reliability switching and amplifying applications with  $f_T$  ratings greater than 30 MHz and maximum collector current ratings up to 10 A.

These transistors have a relatively poor safe operating area because of the narrow base region and the depletion of the entire voltage into the collector region. Maximum die yield depends on expert photo-resist techniques for diffusing impurities through an opening etched in the surface oxide. The oxide-masked and phosphorus-passivated Planar structures allow lower leakage than mesa junction devices. The structure is limited to approximately 400 V breakdown voltage. This is a result of uncontrolled surface charge introduced into the high field region associated with the finite radius of curvature of the impurity diffusion front. This results in premature breakdown. The use of metallic overlay (junction field plate) and resistive films is employed to combat these effects.

*Single Epitaxial-Base Mesa* transistors are manufactured by diffusing an emitter into an epitaxial base region deposited on the collector substrate. The collector voltage depletes into the base region. The device is fairly rugged with reasonable gain and medium  $f_T$ . The safe operating area capability is between Planar triple diffused and single diffused mesa. Epitaxial base devices gain ruggedness as a result of the wide and homogeneous base region. Both npn and pnp-type transistors can be made by this process. Performance is somewhat limited by low voltage ratings imposed by the abrupt base-collector junction formed between the heavily doped collector substrate and the epitaxially deposited base layer, and by the thickness of this layer.

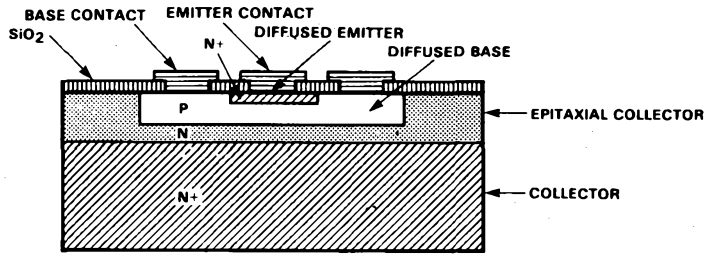
*Multiple Epitaxial-Base Mesa* processing uses two epitaxial layers to form the collector and base regions, a mesa etch to define the collector-base junction, and Planar processing to form the emitter-base junction. This produces low-cost, high-current devices with excellent safe-area capabilities. Epitaxial-base transistors gain ruggedness as the result of the wide homogeneous base region. When compared to conventional single-diffused devices, epitaxial-base mesa transistors exhibit higher working voltage capabilities, lower saturation voltages, and lower leakage currents. Beta linearity is also improved and npn and pnp complementary devices are readily produced. Maximum current ratings extend to 50 A and  $f_T$  ratings to 15 MHz.

*Multiple-Epitaxial Double-Diffused Base Mesa* structures are identical to the double-diffused epitaxial except that multiple-epitaxial layers are used in the collector region and the collector-base junction is formed by a mesa etch. A low resistivity thin layer is epitaxially grown between the highly doped substrate and the low-epitaxial collector region. The advantages of the multiple-epitaxial double-diffused structure are high speed ( $f_T = 50$  MHz), low saturation voltage and increased  $E_{SB}$  capability due to the epitaxial intermediate collector.

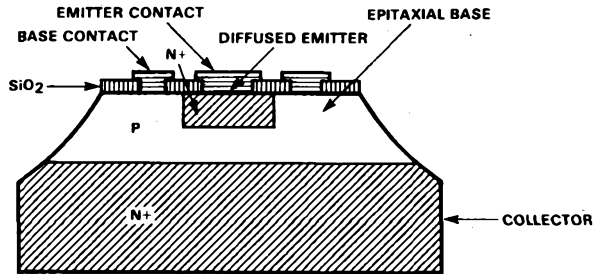
## SUMMARY

While the manufacturer can specify device performance limitations, it is imperative that the circuit designer operate the power transistor within its SOA and use appropriate heat sinking and careful mounting techniques to eliminate the threat of device failure or degradation. However, since each mode of operation has a specific set of electrical and thermal stress conditions, the SOA curves on the data sheet cannot possibly define all absolute maximum ratings. This is especially the case when the power transistor is used in pulsed operation.

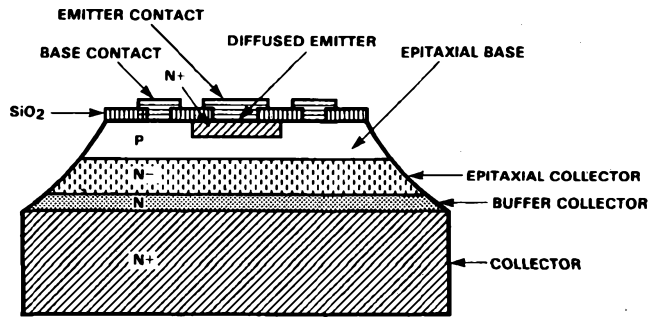
\*Planar is a patented Fairchild process.



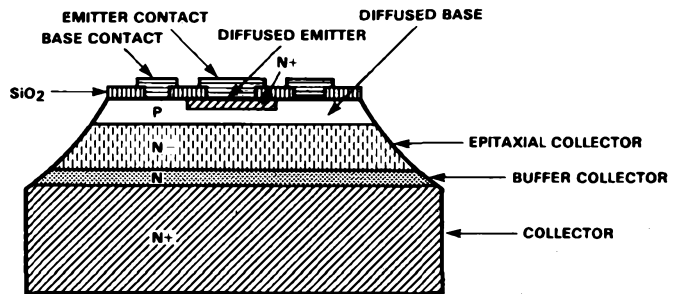
**Double-Diffused Epitaxial Planar**



**Single Epitaxial-Base Mesa**



**Multiple Epitaxial-Base Mesa**



**Multiple-Epitaxial Double-Diffused Base Mesa**

**Fig. 5-6. Basic Power Transistor Structures**



# POWER

## POWER TRANSISTORS (BY $I_C$ max, POLARITY AND ASCENDING $V_{CE0}$ )

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	hFE Min/Max	@ $I_C$ A	$V_{CE(sat)}$ V Max	@ $I_C$ A	$f_T$ MHz Min(Typ)	$P_D(\text{Max})$ W $T_C = 25^\circ\text{C}$	Package No.
	NPN	PNP								
<b><math>I_C = 0.1</math> A Max Continuous</b>										
1	BF257		160	25/-	0.03	1.0	0.03	75	1.0	TO-39
2	BF336		180	20/-	0.03	—	—	50	1.0	TO-39
3	BF337		200	20/-	0.03	—	—	50	1.0	TO-39
4	BF338		225	20/-	0.03	—	—	50	1.0	TO-39
5	BF258		250	25/-	0.03	1.0	0.03	75	1.0	TO-39
6	D40N1F		250	30/90	0.02	—	—	40	10	Dynawatt
7	D40N2F		250	60/180	0.02	—	—	40	10	Dynawatt
8	BF259		300	25/-	0.03	1.0	0.03	75	1.0	TO-39
9	D40N3F		300	30/90	0.02	—	—	40	10	Dynawatt
10	D40N4F		300	60/180	0.02	—	—	40	10	Dynawatt
<b><math>I_C = 0.15</math> A Max Continuous</b>										
11	2N5059		250	30/150	0.03	1.0	0.03	30	1.0	TO-39
12	2N5058		300	35/150	0.03	1.0	0.03	30	1.0	TO-39
<b><math>I_C = 0.5</math> A Max Continuous</b>										
13	TIP61	TIP62	40	40/-	0.05	0.07	0.50	3.0	15	TO-220
14	TIP61A	TIP62A	60	40/-	0.05	0.07	0.50	3.0	15	TO-220
15	TIP61B	TIP62B	80	40/-	0.05	0.07	0.50	3.0	15	TO-220
16	TIP61C	TIP62C	100	40/-	0.05	0.07	0.50	3.0	15	TO-220
17	SE7055		220	40/-	0.03	1.00	0.02	50	1.0	TO-39
18	SE7056		300	40/-	0.03	1.00	0.02	50	1.0	TO-39
19	MPS-U10F		300	40/-	0.03	—	—	40	10	Dynawatt
<b><math>I_C = 1.0</math> A Max Continuous</b>										
20	FT427		30	20/-	0.50	—	—	—	10	Dynawatt
21	FT527		30	20/-	0.50	—	—	—	10	TO-220
22	D40D1F	D41D1F	30	50/150	0.10	0.5	0.5	—	10	Dynawatt
23	TIP29	TIP30	40	15/75	1.00	0.7	1.0	3.0	30	TO-220
24		2N4898	40	20/100	0.50	0.6	1.0	3.0	25	TO-66
25	2N4910		40	20/100	0.50	0.6	1.0	4.0	25	TO-66
26	D40D4F	D41D4F	45	50/150	0.10	0.5	0.5	—	10	Dynawatt
27	TIP29A	TIP30A	60	15/75	1.00	0.7	1.0	3.0	30	TO-220
28		2N3740	60	30/100	0.25	0.6	1.0	4.0	25	TO-66

# POWER

## POWER TRANSISTORS (BY $I_C$ max, POLARITY AND ASCENDING $V_{CE0}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ @ $I_C$ A Min/Max	$V_{CE(sat)}$ V Max	@ $I_C$ A	$f_T$ MHz Min(Typ)	$P_D(\text{Max})$ W $T_C=25^\circ\text{C}$	Package No.	
	NPN	PNP								
<b><math>I_C = 1.0</math> A Max Continuous (Cont'd)</b>										
1	2N4911		60	20/100	0.50	0.5	1.0	4.0	25	TO-66
2		2N4899	60	20/100	0.50	0.6	1.0	3.0	25	TO-66
3	D40D7F	D41D7F	60	50/150	0.10	0.5	0.5	—	10	Dynawatt
4	D40D10F	D41D10F	75	50/150	0.10	0.5	0.5	—	10	Dynawatt
5	D40D13F	D41D13F	75	50/150	0.10	0.5	0.5	—	10	Dynawatt
6	TIP29B	TIP30B	80	15/75	1.00	0.7	1.0	3.0	30	TO-220
7		2N3741	80	30/100	0.25	0.6	1.0	4.0	25	TO-66
8		2N4900	80	20/100	0.50	0.6	1.0	3.0	25	TO-66
9	2N4912		80	20/100	0.50	0.6	1.0	4.0	25	TO-66
10	TIP29C	TIP30C	100	15/75	1.00	0.7	1.0	3.0	30	TO-220
11	2N5681	2N5679	100	40/150	0.25	1.0	0.5	30	10	TO-39
12	2N5682	2N5680	120	40/150	0.25	1.0	0.5	30	10	TO-39
13		2N5415	200	30/150	0.05	2.5	0.5	15	10	TO-39
14		FTD5415	200	30/150	0.05	2.5	0.05	15	10	Dynawatt
15	FTD3440		250	40/160	0.02	0.5	0.05	15	10	Dynawatt
16	2N3440		250	40/160	0.02	0.5	0.05	15	10	TO-39
17	FT47		250	30/150	0.30	1.0	1.0	10	40	TO-220
18	SE9331		300	30/250	0.10	2.5	0.10	10	20	TO-66
19	FT48		300	30/150	0.30	1.0	1.00	10	40	TO-220
20		2N5416	300	30/120	0.05	2.0	0.05	15	10	TO-39
21		FTD5416	300	30/120	0.05	2.0	0.05	15	10	Dynawatt
22	2N3439		350	40/160	0.02	0.5	0.05	15	10	TO-39
23	FT49		350	30/150	0.30	1.0	1.00	10	40	TO-220
24	FTD3439		350	40/160	0.02	0.5	0.05	15	10	Dynawatt
25	FT50		400	30/150	0.30	1.0	1.00	10	40	TO-220
<b><math>I_C = 2.0</math> A Max Continuous</b>										
26	FT428		25	20/-	0.5	—	—	—	10	Dynawatt
27	FT528		25	20/-	0.5	—	—	—	10	TO-220
28	FTD5321	FTD5323	50	40/250	0.5	0.8	0.5	40	10	Dynawatt
29	2N5321	2N5323	50	40/250	0.5	0.8	0.5	50	10	TO-39
30	MPS-U05F	MPS-U55F	60	50/-	0.25	0.5	0.25	40	10	Dynawatt

# POWER

## POWER TRANSISTORS (BY $I_{Cmax}$ , POLARITY AND ASCENDING $V_{CEO}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CEO}$ V Max	$h_{FE}$ Min/Max	@ $I_C$ A	$V_{CE(sat)}$ V Max	@ $I_C$ A	$f_T$ MHz Min(Typ)	$P_D(Max)$ W $T_C=25^\circ C$	Package No.
	NPN	PNP								
<b><math>I_C = 2.0</math> A Max Continuous (Cont'd)</b>										
1	TIP110*	TIP115*	60	1000/-	1.0	2.5	2.0	—	50	TO-220
2	2N5320	2N5322	75	30/130	0.5	0.5	0.5	50	10	TO-39
3	FTD5320	FTD5322	75	30/130	0.5	0.5	0.5	40	10	Dynawatt
4	MPS-U06F	MPS-U56F	80	50/-	0.25	0.5	0.25	40	10	Dynawatt
5	TIP111*	TIP116*	80	1000/-	1.0	2.5	2.0	—	50	TO-220
6	TIP112*	TIP117*	100	1000/-	1.0	2.5	2.0	—	50	TO-220
7	MPS-U07F	MPS-U57F	100	30/-	0.25	0.05	0.25	40	10	Dynawatt
8	FT401		300	20/100	0.5	0.8	0.5	2.0	100	TO-3
<b><math>I_C = 3.0</math> A Max Continuous</b>										
9	TIP31	TIP32	40	10/50	3.0	1.2	3.0	3.0	40	TO-220
10		2N4234	40	30/150	0.25	0.6	1.0	3.0	6.0	TO-39
11		2N4235	60	30/150	0.25	0.6	1.0	3.0	6.0	TO-39
12	2N3766		60	40/160	0.5	1.0	0.5	10	20	TO-66
13	2N5334		60	30/150	1.0	0.7	2.0	40	6.0	TO-39
14	TIP31A	TIP32A	60	10/50	3.0	1.2	3.0	3.0	40	TO-220
15	TIP31B	TIP32B	80	10/50	3.0	1.2	3.0	3.0	40	TO-220
16		2N4236	80	30/150	0.25	0.6	1.0	3.0	6.0	TO-39
17	2N3767		80	40/160	0.5	1.0	0.5	10	20	TO-66
18	2N5335		80	30/150	1.0	0.7	2.0	40	6.0	TO-39
19	TIP31C	TIP32C	100	10/50	3.0	1.2	3.0	3.0	40	TO-220
20	2N5838		250	8/40	3.0	1.0	3.0	5.0	100	TO-3
21	2N5839		275	10/50	2.0	1.5	2.0	5.0	100	TO-3
22	FT402		325	20/100	0.5	2.0	3.0	2.0	100	TO-3
23	2N5840		350	10/50	2.0	1.5	2.0	5.0	100	TO-3
<b><math>I_C = 4.0</math> A Max Continuous</b>										
24	2N5296		40	30/120	1.0	1.0	1.0	0.8	36	TO-220
25	BD221	BD224	40	30/120	1.0	1.0	1.0	0.8	36	TO-220
26	2N4231		40	25/100	1.5	0.7	1.5	4.0	35	TO-66
27	2N4237		40	30/150	0.25	0.6	1.0	1.0	6.0	TO-39
28	2N6121	2N6124	45	25/100	1.5	0.6	1.5	2.5	40	TO-220

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# POWER

## POWER TRANSISTORS (BY $I_C$ max, POLARITY AND ASCENDING $V_{CEO}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CEO}$ V Max	hFE Min/Max	@ $I_C$ A	$V_{CE(sat)}$ V Max	@ $I_C$ A	$f_T$ MHz Min(Typ)	$P_D(Max)$ W $T_C=25^\circ C$	Package No.
	NPN	PNP								
<b><math>I_C = 4.0</math> A Max Continuous (Cont'd)</b>										
1	2N3054		55	25/150	0.5	1.0	0.5	—	25	TO-66
2	2N5298	-	60	20/80	1.5	1.0	1.5	0.8	36	TO-220
3	BD222	BD225	60	20/80	1.5	1.0	1.5	0.8	36	TO-220
4	2N6122	2N6125	60	25/100	1.5	0.6	1.5	2.5	40	TO-220
5	2N4232		60	25/100	1.5	0.7	1.5	4.0	35	TO-66
6	2N4238		60	30/150	0.25	0.6	1.0	1.0	6.0	TO-39
7	2N5294		70	30/120	0.5	1.0	0.5	0.8	36	TO-220
8	BD220	BD223	70	30/120	0.5	1.0	0.5	0.8	36	TO-220
9	2N6123	2N6126	80	20/80	1.5	0.6	1.5	2.5	40	TO-220
10	2N4233		80	25/100	1.5	0.7	1.5	4.0	35	TO-66
11	2N4239		80	30/150	0.25	0.6	1.0	1.0	6.0	TO-39
12	FT317	FT417	100	35/-	1.0	0.5	1.0	20	40	TO-220
13	2N6473	2N6475	100	15/150	1.5	1.2	1.5	10	40	TO-220
14	FT317A	FT417A	120	35/-	1.0	0.5	1.0	20	40	TO-220
15	2N6474	2N6476	120	15/150	1.5	1.2	1.5	10	40	TO-220
16	FT317B	FT417B	140	35/-	1.0	0.5	1.0	20	40	TO-220
<b><math>I_C = 5.0</math> A Max Continuous</b>										
17	2N5067	2N4901	40	20/80	1.0	0.4	1.0	4.0	87.5	TO-3
18	2N4913	2N4904	40	25/100	2.5	1.5	5.0	4.0	87.5	TO-3
19	2N5490		40	20/100	2.0	1.0	2.0	0.8	50	TO-220
20	2N5494		40	20/100	3.0	1.0	3.0	0.8	50	TO-220
21	2N5492		55	20/100	2.5	1.0	2.5	0.8	50	TO-220
22	TIP120*	TIP125*	60	1000/-	0.5	2.0	3.0	—	65	TO-220
23	BC323		60	50/250	0.5	0.15	0.5	—	7.0	TO-39
24	2N5068	2N4902	60	20/80	1.0	0.4	1.0	4.0	87.5	TO-3
25	2N4895		60	40/120	2.0	1.0	5.0	50	7.0	TO-39
26	BFX34		60	40/150	2.0	1.0	0.5	70	5.0	TO-39
27	2N4896		60	100/300	2.0	1.0	5.0	80	7.0	TO-39
28	2N4914	2N4905	60	25/100	2.5	1.5	5.0	4.0	87.5	TO-3
29	2N5496		70	20/100	3.5	1.0	3.5	0.8	50	TO-220

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# POWER

## POWER TRANSISTORS (BY $I_C$ max, POLARITY AND ASCENDING $V_{CE0}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ @ $I_C$ A		$V_{CE(sat)}$ @ $I_C$ V A		$f_T$ MHz Min(Typ)	$P_D(\text{Max})$ W $T_C=25^\circ\text{C}$	Package No.
	NPN	PNP		Min/Max		Max				
<b><math>I_C = 5.0</math> A Max Continuous (Cont'd)</b>										
1	TIP121*	TIP126*	80	1000/-	0.5	2.0	3.0	—	65	TO-220
2	2N5069	2N4903	80	20/80	1.0	0.4	1.0	4.0	87.5	TO-3
3	2N4897		80	40/120	2.0	1.0	5.0	50	7.0	TO-39
4	2N5336		80	30/120	2.0	0.7	2.0	30	6.0	TO-39
5	2N5337		80	60/240	2.0	0.7	2.0	30	6.0	TO-39
6	2N4915	2N4906	80	25/100	2.5	1.5	5.0	4.0	87.5	TO-3
7	TIP122*	TIP127*	100	1000/-	0.5	2.0	3.0	—	65	TO-220
8	2N5338		100	30/120	2.0	0.7	2.0	30	6.0	TO-39
9	2N5339		100	60/240	2.0	0.7	2.0	30	6.0	TO-39
<b><math>I_C = 6.0</math> A Max Continuous</b>										
10	TIP41	TIP42	40	30/-	0.3	1.5	6.0	3.0	65	TO-220
11	TIP41A	TIP42A	60	30/-	0.3	1.5	6.0	3.0	65	TO-220
12	TIP41B	TIP42B	80	30/-	0.3	1.5	6.0	3.0	65	TO-220
13	TIP41C	TIP42C	100	30/-	0.3	1.5	6.0	3.0	65	TO-220
<b><math>I_C = 7.0</math> A Max Continuous</b>										
14	2N6111		30	30/150	3.0	1.0	3.0	10	40	TO-220
15	2N6129	2N6132*	40	20/100	2.5	1.4	7.0	2.5	50	TO-220
16	2N6109		50	30/150	2.5	1.0	2.5	10	40	TO-220
17	2N5873	2N5871	60	20/100	2.5	1.0	4.0	4.0	115	TO-3
18	2N6130	2N6133	60	20/100	2.5	1.4	7.0	2.5	50	TO-220
19	2N6107		70	30/150	2.0	1.0	2.0	10	40	TO-220
20	2N5874	2N5872	80	20/100	2.5	1.0	4.0	4.0	115	TO-3
21	2N6131	2N6134	80	20/100	2.5	2.8	7.0	2.5	50	TO-220
<b><math>I_C = 7.5</math> A Max Continuous</b>										
22	FT410		200	30/90	1.0	0.8	1.0	(5.0)	100	TO-3
23	FT411		300	30/90	1.0	0.8	1.0	(5.0)	100	TO-3
24	FT413		325	20/80	0.5	0.8	0.5	(5.0)	100	TO-3
25	FT423		325	30/90	1.0	0.8	1.0	(5.0)	100	TO-3
<b><math>I_C = 8.0</math> A Max Continuous</b>										
26	2N5877	2N5875	60	20/100	4.0	1.0	5.0	4.0	150	TO-3

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# POWER

## POWER TRANSISTORS (BY $I_C$ max, POLARITY AND ASCENDING $V_{CEO}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CEO}$ V Max	$h_{FE}$ @ $I_C$ A		$V_{CE(sat)}$ @ $I_C$ V Max		$f_T$ MHz Min(Typ)	$P_D$ (Max) W $T_C=25^\circ C$	Package No.
	NPN	PNP		Min/Max						
<b><math>I_C = 8.0</math> A Max Continuous (Cont'd)</b>										
1	2N6055*	2N6053*	60	750/18K	4.0	2.0	4.0	4.0	100	TO-3
2	2N5878	2N5876	80	20/100	4.0	1.0	5.0	4.0	150	TO-3
3	2N6056*	2N6054*	80	750/18K	4.0	2.0	4.0	4.0	100	TO-3
4	2N6306		250	15/75	3.0	0.8	3.0	5.0	125	TO-3
5	2N6307M		300	15/75	3.0	1.0	3.0	5.0	125	TO-3
6	2N6308M		350	12/60	3.0	1.5	3.0	5.0	125	TO-3
<b><math>I_C = 10.0</math> A Max Continuous</b>										
7	2N6103		40	15/60	8.0	2.5	16	—	75	TO-220
8	2N6386*		40	1K/20K	3.0	2.0	3.0	20	40	TO-220
9		2N4907	40	20/80	4.0	0.75	4.0	4.0	150	TO-3
10	2N6383*		40	1K/20K	5.0	2.0	5.0	20	100	TO-3
11	2N3713		60	25/75	1.0	1.0	5.0	4.0	150	TO-3
12		2N3789	60	25/90	1.0	1.0	5.0	4.0	150	TO-3
13	2N6099		60	20/80	4.0	2.5	10	—	75	TO-220
14	2N3715		60	50/150	1.0	0.8	5.0	4.0	150	TO-3
15		2N3791	60	50/180	1.0	1.0	5.0	4.0	150	TO-3
16	2N6387*		60	1K/20K	3.0	2.0	3.0	20	40	TO-220
17	MJE3055F		60	20/70	4.0	1.1	4.0	2.0	70	TO-220
18		2N4908	60	20/80	4.0	0.75	4.0	4.0	150	TO-3
19	SE9300*	SE9400*	60	1000/-	4.0	2.0	4.0	1.0	70	TO-220
20	SE9303*	SE9403*	60	1000/-	4.0	2.0	4.0	1.0	100	TO-3
21	2N6384*		60	1K/20K	5.0	2.0	5.0	20	100	TO-3
22	MJ2500*	MJ3000*	60	1000/-	5.0	2.0	10	—	150	TO-3
23	2N6101		70	20/80	5.0	2.5	10	—	75	TO-220
24	2N3714		80	25/75	1.0	1.0	5.0	4.0	150	TO-3
25		2N3790	80	25/90	1.0	1.0	5.0	4.0	150	TO-3
26	2N3716		80	50/150	1.0	0.8	5.0	4.0	150	TO-3
27		2N3792	80	50/180	1.0	1.0	5.0	4.0	150	TO-3
28	2N6388*		80	1K/20K	3.0	2.0	3.0	20	40	TO-220
29		2N4909	80	20/80	4.0	0.75	4.0	4.0	150	TO-3

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## POWER

### POWER TRANSISTORS (BY $I_{Cmax}$ , POLARITY AND ASCENDING $V_{CE0}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ Min/Max	@ $I_C$ A	$V_{CE(sat)}$ V Max	@ $I_C$ A	$f_T$ MHz Min(Typ)	$P_D(Max)$ W $T_C=25^\circ C$	Package No.
	NPN	PNP								
<b><math>I_C = 10.0</math> A Max Continuous (Cont'd)</b>										
1	SE9304*	SE9404*	80	1K/-	4.0	2.0	4.0	1.0	100	TO-3
2	SE9301*	SE9401*	80	1K/-	4.0	2.0	4.0	1.0	70	TO-220
3	2N6385*		80	1K/20K	5.0	2.0	5.0	20	100	TO-3
4	MJ2501	MJ3001	80	1000/-	5.0	2.0	10		150	TO-3
5	SE9302*	SE9402*	100	1K/-	4.0	2.0	1.0		70	TO-220
6	SE9305*	SE9405*	100	1K/-	4.0	2.0	40	1.0	100	TO-3
7	2N6249		200	10/50	10	1.5	10	2.5	100	TO-3
8	2N6250		275	8/50	10	1.5	10	2.5	100	TO-3
9	FT430		300	15/45	2.5	0.9	2.5	—	125	TO-3
10	FT160		300	55/-	4.0	1.9	5.0	—	70	TO-220
11	FT431		325	15/35	2.5	0.7	2.5	—	125	TO-3
12	FT161		330	55/-	4.0	1.9	5.0	—	70	TO-220
13	FT162		350	55/-	4.0	1.9	5.0	—	70	TO-220
14	FT359*		350	250/-	3.0	2.8	7.0	—	125	TO-3
15	2N6251		350	6/50	10	1.5	10	2.5	100	TO-3
<b><math>I_C = 12.0</math> A Max Continuous</b>										
16	2N6569		40	15/200	0.2	1.5	4.0	1.5	100	TO-3
17	2N6057*	2N6050*	60	750/18K	6.0	2.0	6.0	4.0	150	TO-3
18	2N5881	2N5879	60	20/100	6.0	1.0	7.0	4.0	160	TO-3
19	2N5882	2N5880	80	20/100	6.0	1.0	7.0	4.0	160	TO-3
20	2N6058*	2N6051*	80	750/18K	6.0	2.0	6.0	4.0	150	TO-3
21	2N6059*	2N6052*	100	750/18K	6.0	2.0	6.0	4.0	150	TO-3
<b><math>I_C = 15.0</math> A Max Continuous</b>										
22	2N6486	2N6489	40	20/150	5.0	1.3	5.0	5.0	75	TO-220
23	MJ2955		60	20/70	4.0	1.1	4.0	4.0	150	TO-3
24	2N6576*		60	2K/20K	4.0	4.0	15	10	120	TO-3
25	2N3055SD		60	20/70	4.0	1.1	4.0	0.8	115	TO-3
26	FT3055	FT2955	60	20/70	4.0	1.1	4.0	2.0	70	TO-220
27	2N3055		60	20/70	4.0	1.1	4.0	—	117	TO-3
28	2N6487	2N6490	60	20/150	5.0	1.3	5.0	5.0	75	TO-220

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## POWER

### POWER TRANSISTORS (BY $I_{Cmax}$ , POLARITY AND ASCENDING $V_{CE0}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ Min/Max	@ $I_C$ A	$V_{CE(sat)}$ V Max	@ $I_C$ A	$f_T$ MHz Min(Typ)	$P_D(Max)$ W $T_C=25^\circ C$	Package No.
	NPN	PNP								
<b><math>I_C = 15.0</math> A Max Continuous (Cont'd)</b>										
1	2N6488	2N6491	80	20/150	5.0	1.3	5.0	5.0	75	TO-220
2	2N6577*		90	2K/20K	4.0	4.0	15	10	120	TO-3
<b><math>I_C = 16.0</math> A Max Continuous</b>										
3	2N5629		100	25/100	8.0	1.0	10	0.5	200	TO-3
4		2N6029	100	25/100	8.0	2.0	16	1.0	200	TO-3
5	2N5630		120	20/80	8.0	1.0	10	0.5	200	TO-3
6		2N6030	120	20/80	8.0	2.0	16	1.0	200	TO-3
7	2N5631		140	15/60	8.0	1.0	10	0.5	200	TO-3
8		2N6031	140	15/60	8.0	2.0	16	1.0	200	TO-3
<b><math>I_C = 20.0</math> A Max Continuous</b>										
9	2N3772		60	15/60	10	1.4	10	0.2	150	TO-3
10	2N5885	2N5883	60	20/100	10	1.0	15	4.0	200	TO-3
11	2N6282*	2N6285*	60	750/18K	10	2.0	10	4.0	160	TO-3
12	2N5039		75	20/100	10	1.0	10	60	140	TO-3
13	2N6283*	2N6286*	80	750/18K	10	2.0	10	4.0	160	TO-3
14	2N5886	2N5884	80	20/100	10	1.0	15	4.0	200	TO-3
15	2N5303		80	15/60	10	2.0	20	2.0	200	TO-3
16	2N5038		90	20/100	12	1.0	12	60	140	TO-3
17	2N6284*	2N6287*	100	750/18K	10	2.0	10	4.0	160	TO-3
<b><math>I_C = 30.0</math> A Max Continuous</b>										
18	2N3771		40	15/60	15	2.0	15	0.2	150	TO-3
19		2N4398	40	15/60	15	1.0	15	4.0	200	TO-3
20	2N5301		40	15/60	15	2.0	20	2.0	200	TO-3
21		2N4399	60	15/60	15	1.0	15	4.0	200	TO-3
22	2N5302		60	15/60	15	2.0	20	2.0	200	TO-3
23	SE9306	SE9406	60	1000/-	10	2.0	10	4.0	160	TO-3
24	SE9307	SE9407	80	1000/-	10	2.0	10	4.0	160	TO-3
25	MJ802	MJ4502	90	25/100	7.5	0.8	7.5	2.0	200	TO-3
26	SE9308	SE9408	100	1000/-	10	2.0	10	4.0	160	TO-3

\*Darlington



## POWER

### POWER TRANSISTORS (BY $I_{Cmax}$ , POLARITY AND ASCENDING $V_{CE0}$ ) Continued

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ @ $I_C$ A		$V_{CE(sat)}$ @ $I_C$ V A		$f_T$ MHz Min(Typ)	$P_D$ (Max) W $T_C=25^\circ C$	Package No.
	NPN	PNP		Min/Max	Max	Max	Max			
<b><math>I_C = 50.0</math> A Max Continuous (Cont'd)</b>										
1	2N5685	2N5683	60	15/60	25	1.0	25	2.0	300	TO-3
2	2N5686	2N5684	80	15/60	25	1.0	25	2.0	300	TO-3

### POWER SWITCHING TRANSISTORS (BY $I_{Cmax}$ , POLARITY)

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ @ $I_C$ A		Switching Times (Typ)				$P_D$ W $T_C=25^\circ C$	Package No.
	NPN	PNP		Min/Max	Max	$t_{on}$ $\mu s$	$t_s$ $\mu s$	$t_f$ $\mu s$	@ $I_C$ A		
<b><math>I_C</math> Max = 1.0 A</b>											
3	2N3440		250	40/160	0.2	0.07	2.2	0.35	0.1	10	TO-39
4	FT47		250	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
5	FT48		300	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
6	FT49		350	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
7	FT50		400	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220

#### $I_C$ Max = 3.0 A

8	2N5839		275	10/50	2.0	0.45	3.0	0.3	2.0	100	TO-3
9	2N5840		350	10/50	2.0	0.45	3.0	0.3	2.0	100	TO-3

#### $I_C$ Max = 10 A

10	2N3716		80	50/150	1.0	0.4	.8	0.4	5.0	150	TO-3
11	FT430		300	115/45	2.5	0.5	2.6	0.3	2.5	125	TO-3
12	FT431		325	15/35	2.5	0.5	2.6	0.3	2.5	125	TO-3
13	2N6249		200	10/50	10	0.5	1.0	0.4	10	175	TO-3
14	2N6250		275	8/50	10	0.5	1.0	0.4	10	175	TO-3
15	2N6251		350	6/50	10	0.5	1.0	0.4	10	175	TO-3
16	FT3055	FT2955	60	20/70	4.0	.65/.35	.5/.25	.4/.15	10	70	TO-220
17	2N6386*		40	1K/20K	3.0	0.8	4.0	5.0	3.0	40	TO-220
18	2N6387*		60	1K/20K	5.0	0.8	3.5	5.0	5.0	40	TO-220
19	2N6388*		80	1K/20K	5.0	0.8	3.5	5.0	5.0	40	TO-220

\*Darlington

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# POWER

## POWER SWITCHING TRANSISTORS (BY $I_C$ max, POLARITY) Continued

Item	DEVICE NO. Polarity		$V_{CE0}$ V Max	$h_{FE}$ Min/Max	@ $I_C$ A	Switching Times			@ $I_C$ A	$P_D$ W $T_C=25^\circ C$	Package No.
	NPN	PNP				$t_{on}$ $\mu s$ Typ	$t_s$ $\mu s$ Typ	$t_f$ $\mu s$ Typ			
<b><math>I_C</math> Max = 20 A</b>											
1	2N5038	-	90	20/100	10	0.30	0.75	0.15	10	140	TO-3
2	2N6282*	2N6285*	60	750/18K	10	.8/6	3.3/2.5	4/1.5	10	160	TO-3
3	2N6283*	2N6286*	80	750/18K	10	.8/6	3.3/2.5	4/1.5	10	160	TO-3
4	2N6284*	2N6287*	100	750/18K	10	.8/6	3.3/2.5	4/1.5	10	160	TO-3
<b><math>I_C</math> Max = 30 A</b>											
5	2N5301	2N4398	40	15/60	15	.35/3	1.2/7	.5/4	10	200	TO-3

\*Darlington



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## Chapter 6

# THERMAL CONSIDERATIONS

To fully utilize the various available regulator packages, sufficient attention must be paid to proper heat removal. For efficient thermal management, the user must rely on important parameters supplied by the manufacturer, such as junction-to-case and junction-to-ambient thermal resistance and maximum operating junction temperature. The device temperature depends on the power dissipation level, the means for removing the heat generated by this power dissipation and the temperature of the body (heat sink) to which this heat is removed.

Figure 6-1 shows a simplified equivalent circuit for a typical semiconductor device in equilibrium. The power dissipation, which is analogous to current flow in electrical terms, is caused by a heat source similar to a voltage source. Temperature is analogous to voltage potential and thermal resistance to ohmic resistance. Extending the analogy of Ohm's law to

$$\theta_{JA(\text{tot})} = \theta_{JC} + \theta_{CS} + \theta_{SA} = \left| \frac{T_J - T_A}{P_D} \right|$$

Thermal resistance, then, is the rise in the temperature of a package above some reference level per unit of power dissipation in that package, usually expressed in degrees centigrade per watt. The reference temperature may be ambient or it may be the temperature of a heat sink to which the package is connected. There are several factors that affect thermal resistance including die size, the size of the heat source on the die (series-pass transistor in an IC regulator), die-attach material and thickness, leadframe material, construction and thickness.

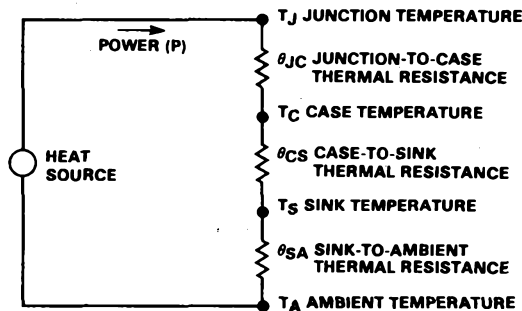


Fig. 6-1. Simplified Thermal Circuit

## THERMAL EVALUATION OF REGULATORS

To measure thermal resistance, the difference between the junction temperature and the chosen reference temperature, case, sink or ambient, must be determined. Ambient or sink temperature measurement is straightforward. For case-temperature measurement, the device should have a sufficiently large heat sink and the power level should be close to the specified rating of the package-die combination. The case or tab temperature can be measured by an infrared microradiometer or by using a thermocouple soldered to a point in the center of the case or tab at the tab-heat-sink interface as close to the die as practical.

Measurement of the junction temperature, unfortunately, is not as simple and involves some calibrations. There are several methods available for junction-temperature measurement; the two most commonly used are described here.

### Thermal Shutdown Method

With this method, the thermal shutdown temperature of each device is used as the thermometer in determining the thermal resistance. The device is first heated externally, with as little internal power dissipation as practical, until it reaches thermal shutdown. Then, with the device mounted on a heat sink, the regulator is powered externally until it reaches thermal shutdown again. With some packages, the ambient of the device and its heat sink may have to be elevated sufficiently to force the regulator into shutdown. The thermal resistance of the device can then be calculated by using

$$\theta_{JC} = \frac{T_J - T_C}{P_D}$$

where  $\theta_{JC}$  is the junction-to-case thermal resistance  
 $T_J$  is the measured thermal shutdown temperature  
 $T_C$  is the measured case temperature  
 $P_D$  is the power dissipated to force the device into shutdown  
and is equal to

$$(V_{IN} - V_{OUT}) I_{OUT} + V_{IN} I_Q$$

$I_Q$  is the quiescent current of the device and can be neglected for low thermal resistance packages such as the TO-3 and TO-220.

### Substrate or Isolation Diode Method

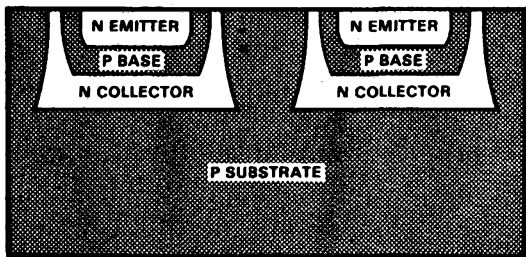
The second method of thermal-resistance measurement utilizes the isolation diodes within the integrated circuits as temperature sensing element\*. Under normal operating conditions, the substrate diodes are reverse biased and separate or "isolate" active as well as passive components within an integrated circuit. (See *Figure 6-2*). When the regulator is reverse biased and a constant current is forced through the device between the input terminal and ground, the substrate diodes become forward biased; naturally, when the forward drop is measured, the diode with the highest temperature (lowest forward drop) is detected. Measurement of the thermal resistance of the regulator then involves two steps:

Calibrating the substrate diode at a fixed  $I_{SUBS}$  level in an oven or bath at two temperatures, preferably near the device operating junction temperature. It is assumed that this voltage drop changes linearly with temperature.

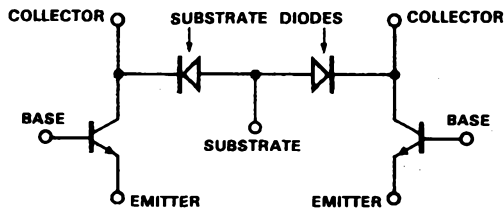
Measuring the junction temperature. The device is powered through a switching circuit S1 at a duty cycle greater than 99% (*Figure 6-3*); thus the device is electrically heated until it reaches equilibrium. During short measuring intervals (< 1% duty cycle), the switching circuit de-energizes the device and the forward drop of the substrate diode is measured at the previously calibrated  $I_{SUBS}$  current level. This voltage drop must be measured as soon as possible (several microseconds) after the

\*For more detailed explanation of this method, see Fairchild Application Note 205, "Thermal Evaluation of Integrated Circuits". For  $\mu A723$  thermal considerations, see page 3-29.

removal of the power pulse to avoid inaccurate readings due to cooling of the chip. Diode D1 prevents reverse current from flowing through the load resistor  $R_L$  during the substrate-diode measuring interval. Since the change in the isolation diode drop is assumed to be linear with temperature, the measured voltage drop can be converted to its corresponding junction temperature by interpolation or extrapolation. Thermal resistance can then be calculated by the same formula used in the thermal-shutdown method.

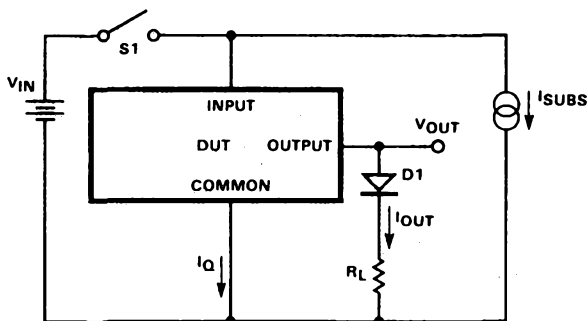


**Cross-sectional Diagram Showing Two Monolithic Transistors Isolated by Substrate Diodes**



**Equivalent Circuit**

**Fig. 6-2 Monolithic Transistor Isolation**



**Fig. 6-3. Thermal Resistance Measurement Circuit Using Substrate Diode Technique**

## HEAT SINK REQUIREMENTS

When is a heat sink necessary, and what type of a heat sink should one use? The answers to these questions depend on reliability and cost requirements. Heat sinking is necessary to keep the operating junction temperature  $T_J$  of the regulator below the specified maximum value. Since semiconductor reliability improves as operating junction temperature is lowered, a reliability/cost compromise is usually made in the device design.

Table 6-1 is a tabulation by package of the various regulators available from Fairchild. It also lists the average and maximum values of thermal resistance for the regulator chip-package combinations and can be used as a guide in selecting a suitable package when designing a regulator circuit.

Thermal characteristics of voltage-regulator chips and packages determine that some form of heat sinking is mandatory whenever the power dissipation exceeds the following.

- 0.67 W for the TO-39 package
- 0.69 W for the TO-92 package
- 1.56 W for the Mini Batwing and Power Watt (similar to TO-202) packages
- 1.8 W for the TO-220 package
- 2.8 W for the TO-3 package

at 25°C ambient or lower power levels at ambients above 25°C.

To choose or design a heat sink, the designer must determine the following regulator parameters.

$P_{D(max)}$  - Maximum power dissipation:  $(V_{IN} - V_{OUT}) I_{OUT} + V_{IN} I_Q$

$T_{A(max)}$  - Maximum ambient temperature the regulator will encounter during operation.

$T_{J(max)}$  - Maximum operating junction temperature, specified by the manufacturer.

$\theta_{JC}$ ,  $\theta_{JA}$  - Junction-to-case and junction-to-ambient thermal resistance values, also specified by the regulator manufacturer.

$\theta_{CS}$  - Case-to-heat-sink thermal resistance which, for large packages, can range from about 0.2°C/W to about 1°C/W depending on the quality of the contact between the package and the heat sink.

$\theta_{SA}$  - Heat-sink-to-ambient thermal resistance, specified by heat-sink manufacturer.

Maximum permissible dissipation without a heat sink is determined by

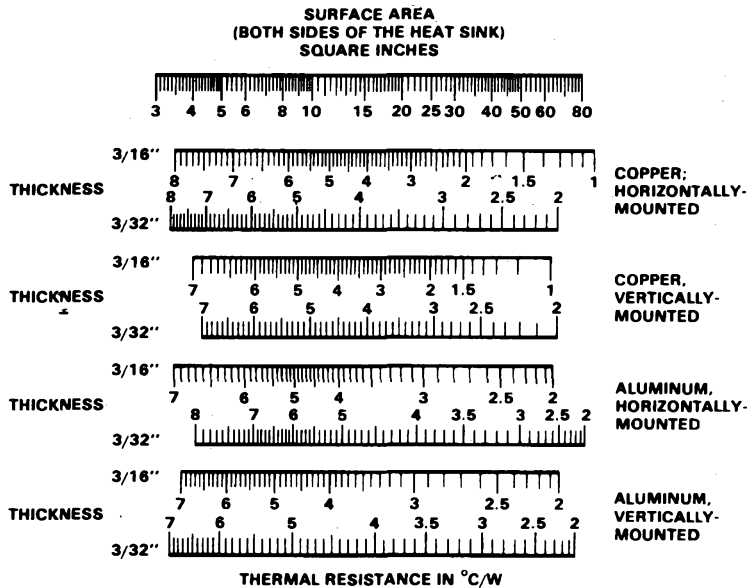
$$P_{D(max)} = \frac{T_{J(max)} - T_{A(max)}}{\theta_{JA}}$$

If the device dissipation  $P_D$  exceeds this figure, a heat sink is necessary. The total required thermal resistance may then be calculated.

$$\theta_{JA(tot)} = \theta_{JC} + \theta_{CS} + \theta_{SA} = \frac{T_{J(max)} - T_{A(max)}}{P_D}$$

Case-to-sink and sink-to-ambient thermal resistance information on commercially available heat sinks is normally provided by the heat sink manufacturer. A summary of some commercially available heat sinks is shown in Table 6-2. However, if a chassis or other conventional surface is used as a heat sink, Figure 6-4 can be used as a guide to estimate the required surface area.





**NOTE:**

To determine either area required or thermal resistance of a given area, draw a vertical line between the top (or area) line down to the material of interest.

**Fig. 6-4. Heat Sink Material Selection Guide**

**How to Choose a Heat Sink – Example**

Determine the heat sink required for a regulator which has the following system requirements:

- Operating ambient temperature range: 0°C–60°C
- Maximum junction temperature: 125°C
- Maximum output current: 800 mA
- Maximum input to output differential: 10 V

From *Table 6-1*, the choice is narrowed down to the  $\mu A7800$  family, available in TO-3 and TO-220 packages. The TO-220 package is sufficient (lower cost, better thermal resistance).

$$\theta_{JC} = 5^\circ\text{C/W maximum (from data sheet or Table 6-1)}$$

$$\theta_{JA(\text{tot})} = \theta_{JC} + \theta_{CS} + \theta_{SA} = \frac{T_J - T_A}{P_D}$$

$$\theta_{CS} + \theta_{SA} = \frac{125 - 60}{0.8 \times 10} - 5 = 3.13^\circ\text{C/W}$$

Assuming  $\theta_{CS} = 0.13^\circ\text{C/W}$  then  $\theta_{SA} = 3^\circ\text{C/W}$

This thermal resistance value can be achieved by using either 22 square inches of 3/16 inch thick vertically mounted aluminum (*Figure 6-4*) or a commercial heat sink (*Table 6-2*).

### **Tips for Better Regulator Heat Sinking**

Avoid placing heat-dissipating components such as power resistors next to regulators.














When using low dissipation packages such as TO-5, TO-39, and TO-92, keep lead lengths to a minimum and use the largest possible area of the printed board traces or mounting hardware to provide a heat dissipation path for the regulator.

When using larger packages, be sure the heat sink surface is flat and free from ridges or high spots. Check the regulator package for burrs or peened-over corners. Regardless of the smoothness and flatness of the package and heat-sink contact, air pockets between them are unavoidable unless a lubricant is used. Therefore, for good thermal conduction, use a thin layer of thermal lubricant such as Dow Corning DC-340, General Electric 662 or Thermacote by Thermalloy.

In some applications, especially with negative regulators, it is desirable to electrically insulate the regulator case from the heat sink. Hardware kits for this purpose are commercially available for such packages as the TO-3 and TO-220. They generally consist of a 0.003 to 0.005 inch thick piece of mica or bonded fiberglass to electrically isolate the two surfaces, yet provide a thermal path between them. As expected, the thermal resistance will increase but, as in the direct metal-to-metal joint, some improvement can be realized by using thermal lubricant on each side of the mica.

If the regulator is mounted on a heat sink with fins, the most efficient heat transfer takes place when the fin is in a vertical plane, as this type of mounting forces the heat transfer from fin to air in a combination of radiation and convection.

If it is necessary to bend any of the regulator leads, handle them carefully to avoid straining the package. Furthermore, lead bending should be restricted since repeated bending will fatigue and eventually break the leads.

RESISTANCES LISTED AS FOLLOWS: <small>                     @JC(TYP)    @JC(MAX)                      @JA(TYP)    @JA(MAX)                 </small>															
REG. TYPE	DEVICE NO./SERIES	I <sub>OUT</sub> (A)	TO-3 K	4-LEAD TO-3 K	TO-220 U	MINI BATWING T2	POWER WATT U1*	TO-39 H	4-LEAD TO-39 H	TO-92 W	TO-99 8-LEAD TO-5 H	TO-100 10-LEAD TO-5 H	TO-116 14-PIN PLASTIC D	TO-116 14-PIN CERAMIC D	8 PIN MINIDIP T
POS. 3-TERM.	μA78LXX	0.1						20 40 140 190		160 180					
	μA78MXX	0.5			3.0 5.0 62 70			18 25 120 185							
	μA78CXX	0.5					6 8 75 80								
	μA109, μA209, μA309, 5 V	1	3.5 5.5 40 45												
	μA78XX	1	3.5 5.5 40 45		3.0 5.0 60 65										
	μA78CB	2	3.5 5.5 40 45		3.0 5.0 60 65										
	78H05, 5V	5	1.5 2.0 37 40												
μA78HXX	5	2.0 2.5 32 38													
NEG. 3-TERM.	μA79MXX	0.5			3.0 5.0 62 70			18 25 120 185							
	μA79XX	1	3.5 5.5 40 45		3.0 5.0 60 65										
POS. ADJ.	μA105/ 308/376	0.012 to 0.045									25 40 150 190				160 190
	μA723	0.125										25 50 150 190	150 190	125 160	
	μA78MG 4-TERM.	0.5				7.5 11 75 80	6 8 75 80		18 25 125 185						
	μA78G 4-TERM.	1		4.0 6.0 44 47			6 8 75 80								
	μA78HG	5	2.0 2.5 32 38												
NEG. ADJ.	μA104/304	0.020										25 50 150 190			
	μA79MG 4-TERM.	0.5				7.5 11 75 80	6 8 75 80		18 25 125 185						
	μA79G 4-TERM.	1		4.0 6.0 44 47			6 8 75 80								

\*Similar to TO-202





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# μA78L00 SERIES

## 3-TERMINAL POSITIVE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

**GENERAL DESCRIPTION** — The μA78L00 series of 3-Terminal Positive Voltage Regulators is constructed using the Fairchild Planar\* epitaxial process. These regulators employ internal current limiting and thermal shutdown, making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 100 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local or on card regulation for elimination of noise and distribution problems associated with single point regulation. In addition, they can be used with power pass elements to make high current voltage regulators. The μA78L00 used as a Zener diode/resistor combination replacement, offers an effective output impedance improvement of typically two orders of magnitude, along-with lower quiescent current and lower noise.

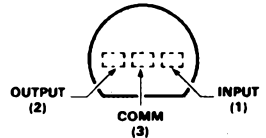
- OUTPUT CURRENT UP TO 100 mA
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- AVAILABLE IN JEDEC TO-92 AND LOW PROFILE TO-39 PACKAGES
- OUTPUT VOLTAGES OF 2.6 V, 5 V, 6.2 V, 8.2 V, 9 V, 12 V, 15 V, 18 V and 24 V
- OUTPUT VOLTAGE TOLERANCES OF ±5% OVER THE TEMPERATURE RANGE

#### ABSOLUTE MAXIMUM RATINGS

Input Voltage		35 V
2.6 V to 15 V		40 V
18 V to 24 V		Internally Limited
Internal Power Dissipation		
Storage Temperature Range		
Metal Can (TO-39 Type)		-65°C to +150°C
Molded TO-92		-55°C to +150°C
Operating Junction Temperature Ranges		
μA78L00C (Commercial)		0°C to +150°C
μA78L00V (Vehicular-Automotive)		-40°C to +150°C
Lead Temperatures		
Metal Can (Soldering, 60 s)		300°C
Molded TO-92 (Soldering, 10 s)		260°C

#### CONNECTION DIAGRAM

JEDEC (TO-92) PACKAGE  
(TOP VIEW)

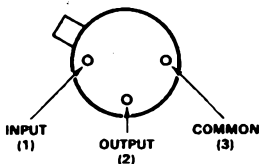


#### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
2.6 V	μA78L26AC	μA78L26AWC
5.0 V	μA78L05AC	μA78L05AWC
6.2 V	μA78L62AC	μA78L62AWC
8.2 V	μA78L82AC	μA78L82AWC
9.0 V	μA78L09AC	μA78L09AWC
12 V	μA78L12AC	μA78L12AWC
15 V	μA78L15AC	μA78L15AWC
18 V	μA78L18AC	μA78L18AWC
24 V	μA78L24AC	μA78L24AWC
2.6 V	μA78L26AV	μA78L26AWV
5.0 V	μA78L05AV	μA78L05AWV
6.2 V	μA78L62AV	μA78L62AWV
8.2 V	μA78L82AV	μA78L82AWV
9.0 V	μA78L09AV	μA78L09AWV
12 V	μA78L12AV	μA78L12AWV
15 V	μA78L15AV	μA78L15AWV
18 V	μA78L18AV	μA78L18AWV
24 V	μA78L24AV	μA78L24AWV

#### CONNECTION DIAGRAM

TO-39 TYPE METAL CAN  
(TOP VIEW)



#### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
2.6 V	μA78L26AC	μA78L26AHC
5.0 V	μA78L05AC	μA78L05AHC
6.2 V	μA78L62AC	μA78L62AHC
8.2 V	μA78L82AC	μA78L82AHC
9.0 V	μA78L09AC	μA78L09AHC
12 V	μA78L12AC	μA78L12AHC
15 V	μA78L15AC	μA78L15AHC
18 V	μA78L18AC	μA78L18AHC
24 V	μA78L24AC	μA78L24AHC

\*Planar is a patented Fairchild process.

# FAIRCHILD • $\mu$ A78L00 SERIES

## $\mu$ A78L26AC and $\mu$ A78L26AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 9.0 \text{ V}$ ,  $I_{OUT} = 40 \text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33 \mu\text{F}$ ,  $C_{OUT} = 0.1 \mu\text{F}$ , unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^\circ\text{C}$	2.5	2.6	2.7	V	
Line Regulation		$T_J = 25^\circ\text{C}$	$4.75 \text{ V} < V_{IN} < 20 \text{ V}$		40	100	mV
			$5 \text{ V} < V_{IN} < 20 \text{ V}$		30	75	mV
Load Regulation		$T_J = 25^\circ\text{C}$	$1 \text{ mA} < I_{OUT} < 100 \text{ mA}$		10	50	mV
			$1 \text{ mA} < I_{OUT} < 40 \text{ mA}$		4.0	25	mV
Output Voltage		$4.75 \text{ V} < V_{IN} < 20 \text{ V}$	$1 \text{ mA} < I_{OUT} < 40 \text{ mA}$	2.45		2.75	V
			$1 \text{ mA} < I_{OUT} < 70 \text{ mA}$	2.45		2.75	V
Quiescent Current		$T_J = 25^\circ\text{C}$		3.6	6.0	mA	
		$T_J = 125^\circ\text{C}$			5.5	mA	
Quiescent Current Change		$5 \text{ V} < V_{IN} < 20 \text{ V}$			2.5	mA	
			$1 \text{ mA} < I_{OUT} < 40 \text{ mA}$		0.1	mA	
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10 \text{ Hz} < f < 100 \text{ kHz}$		30		$\mu\text{V}$	
Temp. Coef. of $V_{OUT}$		$I_{OUT} = 5 \text{ mA}$		-0.4		$\text{mV}/^\circ\text{C}$	
Ripple Rejection		$f = 120 \text{ Hz}$ , $6 \text{ V} < V_{IN} < 16 \text{ V}$ , $T_J = 25^\circ\text{C}$	43	51		dB	
Dropout Voltage		$T_J = 25^\circ\text{C}$		1.7		V	
Peak Output/Short Circuit Current		$T_J = 25^\circ\text{C}$		140		mA	

## $\mu$ A78L05AC and $\mu$ A78L05AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 10 \text{ V}$ ,  $I_{OUT} = 40 \text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33 \mu\text{F}$ ,  $C_{OUT} = 0.1 \mu\text{F}$ , unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^\circ\text{C}$	4.8	5.0	5.2	V	
Line Regulation		$T_J = 25^\circ\text{C}$	$7 \text{ V} < V_{IN} < 20 \text{ V}$		55	150	mV
			$8 \text{ V} < V_{IN} < 20 \text{ V}$		45	100	mV
Load Regulation		$T_J = 25^\circ\text{C}$	$1 \text{ mA} < I_{OUT} < 100 \text{ mA}$		11	60	mV
			$1 \text{ mA} < I_{OUT} < 40 \text{ mA}$		5.0	30	mV
Output Voltage		$7 \text{ V} < V_{IN} < 20 \text{ V}$	$1 \text{ mA} < I_{OUT} < 40 \text{ mA}$	4.75		5.25	V
			$1 \text{ mA} < I_{OUT} < 70 \text{ mA}$	4.75		5.25	V
Quiescent Current		$T_J = 25^\circ\text{C}$		3.8	6.0	mA	
		$T_J = 125^\circ\text{C}$			5.5	mA	
Quiescent Current Change		$8 \text{ V} < V_{IN} < 20 \text{ V}$			1.5	mA	
			$1 \text{ mA} < I_{OUT} < 40 \text{ mA}$		0.1	mA	
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10 \text{ Hz} < f < 100 \text{ kHz}$		40		$\mu\text{V}$	
Temp. Coef. of $V_{OUT}$		$I_{OUT} = 5 \text{ mA}$		-0.65		$\text{mV}/^\circ\text{C}$	
Ripple Rejection		$f = 120 \text{ Hz}$ , $8 \text{ V} < V_{IN} < 18 \text{ V}$ , $T_J = 25^\circ\text{C}$	41	49		dB	
Dropout Voltage		$T_J = 25^\circ\text{C}$		1.7		V	
Peak Output/Short Circuit Current		$T_J = 25^\circ\text{C}$		140		mA	



# FAIRCHILD • $\mu$ A78L00 SERIES

## $\mu$ A78L62AC and $\mu$ A78L62AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 12\text{ V}$ ,  $I_{OUT} = 40\text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ , unless otherwise specified. Note 1

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^\circ\text{C}$		5.95	6.2	6.45	V
Line Regulation	$T_J = 25^\circ\text{C}$	$8.5\text{ V} < V_{IN} < 20\text{ V}$		65	175	mV
		$9\text{ V} < V_{IN} < 20\text{ V}$		55	125	mV
Load Regulation	$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$		13	80	mV
		$1\text{ mA} < I_{OUT} < 40\text{ mA}$		6.0	40	mV
Output Voltage	$8.5\text{ V} < V_{IN} < 20\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	5.90		6.5	V
		$1\text{ mA} < I_{OUT} < 70\text{ mA}$	5.90		6.5	V
Quiescent Current	$T_J = 25^\circ\text{C}$			3.9	6.0	mA
	$T_J = 125^\circ\text{C}$				5.5	mA
Quiescent Current Change	with line	$9.0\text{ V} < V_{IN} < 20\text{ V}$			1.5	mA
	with load	$1\text{ mA} < I_{OUT} < 40\text{ mA}$			0.1	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			50		$\mu\text{V}$
Temp. Coef. of $V_{OUT}$	$I_{OUT} = 5\text{ mA}$			-0.75		$\text{mV}/^\circ\text{C}$
Ripple Rejection	$f = 120\text{ Hz}$ , $10\text{ V} < V_{IN} < 20\text{ V}$ , $T_J = 25^\circ\text{C}$		40	46		dB
Dropout Voltage	$T_J = 25^\circ\text{C}$			1.7		V
Peak Output/Short Circuit Current	$T_J = 25^\circ\text{C}$			140		mA

## $\mu$ A78L82AC and $\mu$ A78L82AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 14\text{ V}$ ,  $I_{OUT} = 40\text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ , unless otherwise specified. Note 1

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^\circ\text{C}$		7.87	8.2	8.53	V
Line Regulation	$T_J = 25^\circ\text{C}$	$11\text{ V} < V_{IN} < 23\text{ V}$		80	175	mV
		$12\text{ V} < V_{IN} < 23\text{ V}$		70	125	mV
Load Regulation	$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$		15	80	mV
		$1\text{ mA} < I_{OUT} < 40\text{ mA}$		8.0	40	mV
Output Voltage	$11\text{ V} < V_{IN} < 23\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	7.8		8.5	V
		$1\text{ mA} < I_{OUT} < 70\text{ mA}$	7.8		8.6	V
Quiescent Current	$T_J = 25^\circ\text{C}$			3.9	6.0	mA
	$T_J = 125^\circ\text{C}$				5.5	mA
Quiescent Current Change	with line	$12\text{ V} < V_{IN} < 23\text{ V}$			1.5	mA
	with load	$1\text{ mA} < I_{OUT} < 40\text{ mA}$			0.1	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			60		$\mu\text{V}$
Temp. Coef. of $V_{OUT}$	$I_{OUT} = 5\text{ mA}$			-0.8		$\text{mV}/^\circ\text{C}$
Ripple Rejection	$f = 120\text{ Hz}$ , $12\text{ V} < V_{IN} < 22\text{ V}$ , $T_J = 25^\circ\text{C}$		39	45		dB
Dropout Voltage	$T_J = 25^\circ\text{C}$			1.7		V
Peak Output/Short Circuit Current	$T_J = 25^\circ\text{C}$				140	mA

# FAIRCHILD • $\mu$ A78L00 SERIES

## $\mu$ A78L09AC and $\mu$ A78L09AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 15\text{ V}$ ,  $I_{OUT} = 40\text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ , unless otherwise specified. Note 1

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^\circ\text{C}$		8.64	9.0	9.36	V
Line Regulation	$T_J = 25^\circ\text{C}$	$11.5\text{ V} < V_{IN} < 24\text{ V}$		90	200	mV
		$13\text{ V} < V_{IN} < 24\text{ V}$		100	150	mV
Load Regulation	$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$		20	90	mV
		$1\text{ mA} < I_{OUT} < 40\text{ mA}$		10	45	mV
Output Voltage	$11.5\text{ V} < V_{IN} < 24\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	8.55		9.45	V
		$1\text{ mA} < I_{OUT} < 70\text{ mA}$	8.55		9.45	V
Quiescent Current	$T_J = 25^\circ\text{C}$			4.2	6.5	mA
	$T_J = 125^\circ\text{C}$				6.0	mA
Quiescent Current Change	with line	$11.5\text{ V} < V_{IN} < 24\text{ V}$			1.5	mA
	with load	$1\text{ mA} < I_{OUT} < 40\text{ mA}$			0.1	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			70		$\mu\text{V}$
Temp. Coef. of $V_{OUT}$	$I_{OUT} = 5\text{ mA}$			-9		$\text{mV}/^\circ\text{C}$
Ripple Rejection	$f = 120\text{ Hz}$ , $15\text{ V} < V_{IN} < 25\text{ V}$ , $T_J = 25^\circ\text{C}$		38	44		dB
Dropout Voltage	$T_J = 25^\circ\text{C}$			1.7		V
Peak Output/Short Circuit Current	$T_J = 25^\circ\text{C}$			140		mA

## $\mu$ A78L12AC and $\mu$ A78L12AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 19\text{ V}$ ,  $I_{OUT} = 40\text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ , unless otherwise specified. Note 1

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^\circ\text{C}$		11.5	12	12.5	V
Line Regulation	$T_J = 25^\circ\text{C}$	$14.5\text{ V} < V_{IN} < 27\text{ V}$		120	250	mV
		$16\text{ V} < V_{IN} < 27\text{ V}$		100	200	mV
Load Regulation	$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$		20	100	mV
		$1\text{ mA} < I_{OUT} < 40\text{ mA}$		10	50	mV
Output Voltage	$14.5\text{ V} < V_{IN} < 27\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	11.4		12.6	V
		$1\text{ mA} < I_{OUT} < 70\text{ mA}$	11.4		12.6	V
Quiescent Current	$T_J = 25^\circ\text{C}$			4.2	6.5	mA
	$T_J = 125^\circ\text{C}$				6.0	mA
Quiescent Current Change	with line	$16\text{ V} < V_{IN} < 27\text{ V}$			1.5	mA
	with load	$1\text{ mA} < I_{OUT} < 40\text{ mA}$			0.1	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			80		$\mu\text{V}$
Temp. Coef. of $V_{OUT}$	$I_{OUT} = 5\text{ mA}$			-1.0		$\text{mV}/^\circ\text{C}$
Ripple Rejection	$f = 120\text{ Hz}$ , $15\text{ V} < V_{IN} < 25\text{ V}$ , $T_J = 25^\circ\text{C}$		37	42		dB
Dropout Voltage	$T_J = 25^\circ\text{C}$			1.7		V
Peak Output/Short Circuit Current	$T_J = 25^\circ\text{C}$			140		mA

## FAIRCHILD • $\mu$ A78L00 SERIES

### $\mu$ A78L15AC and $\mu$ A78L15AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 23$  V,  $I_{OUT} = 40$  mA,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified. Note 1

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^\circ\text{C}$		14.4	15	15.6	V
Line Regulation	$T_J = 25^\circ\text{C}$	$17.5\text{ V} < V_{IN} < 30\text{ V}$		130	300	mV
		$20\text{ V} < V_{IN} < 30\text{ V}$		110	250	mV
Load Regulation	$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$		25	150	mV
		$1\text{ mA} < I_{OUT} < 40\text{ mA}$		12	75	mV
Output Voltage	$17.5\text{ V} < V_{IN} < 30\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	14.25		15.75	V
		$1\text{ mA} < I_{OUT} < 70\text{ mA}$	14.25		15.75	V
Quiescent Current	$T_J = 25^\circ\text{C}$			4.4	6.5	mA
	$T_J = 125^\circ\text{C}$				6.0	mA
Quiescent Current Change	with line	$20\text{ V} < V_{IN} < 30\text{ V}$			1.5	mA
	with load	$1\text{ mA} < I_{OUT} < 40\text{ mA}$			0.1	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			90		$\mu$ V
Temp. Coef. of $V_{OUT}$	$I_{OUT} = 5\text{ mA}$			-1.3		$\text{mV}/^\circ\text{C}$
Ripple Rejection	$f = 120\text{ Hz}$ , $18.5\text{ V} < V_{IN} < 28.5\text{ V}$ , $T_J = 25^\circ\text{C}$		34	39		dB
Dropout Voltage	$T_J = 25^\circ\text{C}$			1.7		V
Peak Output/Short Circuit Current	$T_J = 25^\circ\text{C}$			140		mA

### $\mu$ A78L18AC and $\mu$ A78L18AV (Note 2)

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 27$  V,  $I_{OUT} = 40$  mA,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified. Note 1

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	LIMITS
Output Voltage	$T_J = 25^\circ\text{C}$		17.3	18	18.7	V
Line Regulation	$T_J = 25^\circ\text{C}$	$21\text{ V} < V_{IN} < 33\text{ V}$		45	300	mV
		$22\text{ V} < V_{IN} < 33\text{ V}$		35	250	mV
Load Regulation	$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$		30	170	mV
		$1\text{ mA} < I_{OUT} < 40\text{ mA}$		15	85	mV
Output Voltage	$21\text{ V} < V_{IN} < 33\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	17.1		18.9	V
		$1\text{ mA} < I_{OUT} < 70\text{ mA}$	17.1		18.9	V
Quiescent Current	$T_J = 25^\circ\text{C}$			3.1	6.5	mA
	$T_J = 125^\circ\text{C}$				6.0	mA
Quiescent Current Change	with line	$21\text{ V} < V_{IN} < 33\text{ V}$			1.5	mA
	with load	$1\text{ mA} < I_{OUT} < 40\text{ mA}$			0.1	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 10\text{ kHz}$			150		$\mu$ V
Temp. Coef. of $V_{OUT}$	$I_{OUT} = 5\text{ mA}$			-1.8		$\text{mV}/^\circ\text{C}$
Ripple Rejection	$f = 120\text{ Hz}$ , $23\text{ V} < V_{IN} < 33\text{ V}$ , $T_J = 25^\circ\text{C}$		34	48		dB
Dropout Voltage	$T_A = 25^\circ\text{C}$			1.7		V
Peak Output/Short Circuit Current	$T_J = 25^\circ\text{C}$			140		mA

# FAIRCHILD • $\mu$ A78L00 SERIES

$\mu$ A78L24AC and  $\mu$ A78L24AV (Note 2)

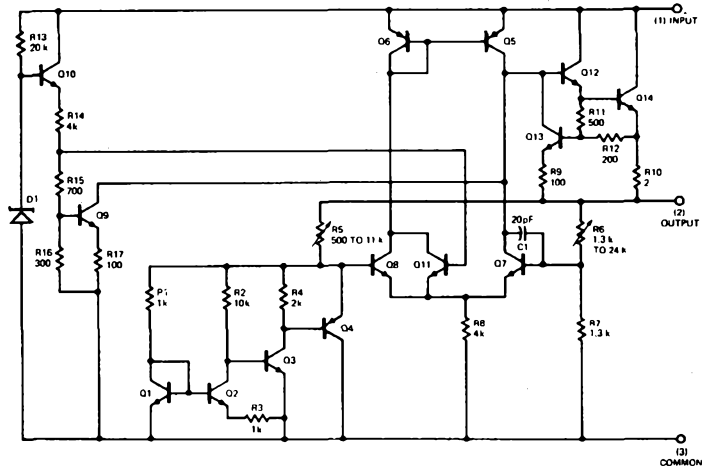
**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 33$  V,  $I_{OUT} = 40$  mA,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS	MIN	TYP	MAX	LIMITS
Output Voltage		$T_J = 25^\circ\text{C}$	23	24	25	V
Line Regulation		$T_J = 25^\circ\text{C}$	$27\text{ V} < V_{IN} < 38\text{ V}$	60	300	mV
			$28\text{ V} < V_{IN} < 38\text{ V}$	50	250	mV
Load Regulation		$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 100\text{ mA}$	40	200	mV
			$T_J = 25^\circ\text{C}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	20	100
Output Voltage		$27\text{ V} < V_{IN} < 38\text{ V}$	$1\text{ mA} < I_{OUT} < 40\text{ mA}$	22.8	25.2	V
			$1\text{ mA} < I_{OUT} < 70\text{ mA}$	22.8	25.2	V
Quiescent Current		$T_J = 25^\circ\text{C}$		3.1	6.5	mA
		$T_J = 125^\circ\text{C}$			6.0	mA
Quiescent Current Change		with line with load	$28\text{ V} < V_{IN} < 38\text{ V}$		1.5	mA
			$1\text{ mA} < I_{OUT} < 40\text{ mA}$		0.1	mA
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 10\text{ kHz}$ (Note 2)		200		$\mu$ V
Temp. Coef. of $V_{OUT}$		$I_{OUT} = 5\text{ mA}$		-2.0		$\text{mV}/^\circ\text{C}$
Ripple Rejection		$f = 120\text{ Hz}$ , $28\text{ V} < V_{IN} < 38\text{ V}$ , $T_J = 25^\circ\text{C}$	34	45		dB
Dropout Voltage		$T_A = 25^\circ\text{C}$		1.7		V
Peak Output/Short Circuit Current		$T_J = 25^\circ\text{C}$		140		mA

**NOTES:**

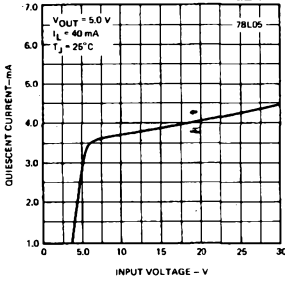
1. The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of tests.
2. Vehicular product grade is guaranteed to have output voltage tolerance less than  $\pm 8\%$  @  $-40^\circ\text{C}$ .

### EQUIVALENT CIRCUIT

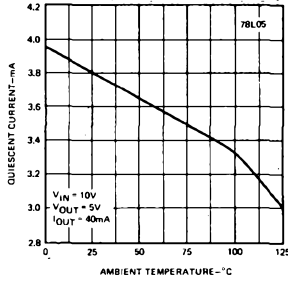


TYPICAL ELECTRICAL PERFORMANCE CURVES

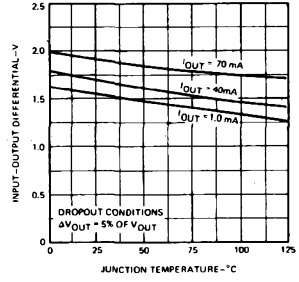
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



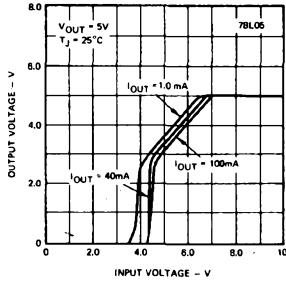
QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE



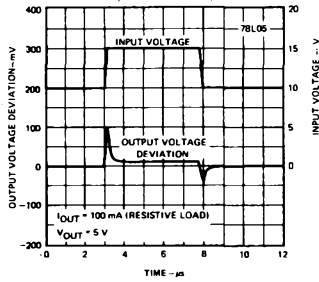
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



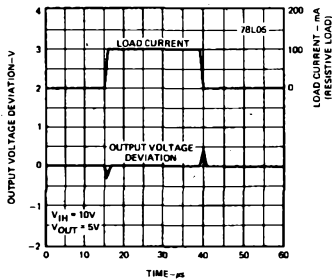
DROPOUT CHARACTERISTICS



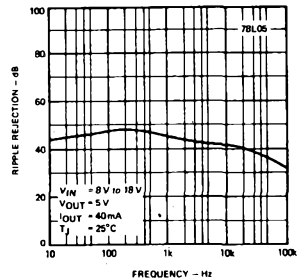
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE

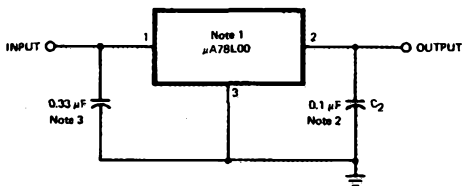


RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



NOTE: Other  $\mu$ A78L00 Series Device have similar curves.

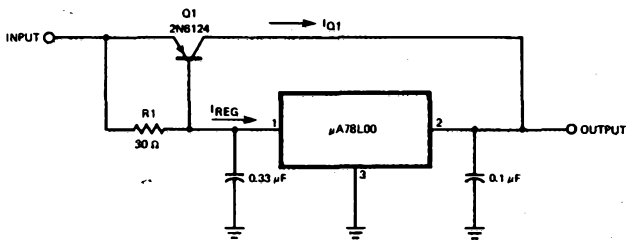
APPLICATIONS



NOTES:

- 1 To specify an output voltage, substitute voltage value for "XX".
- 2 Although no output capacitor is needed for stability, it does improve transient response.
- 3 Required if regulator is located an appreciable distance from power supply filter.

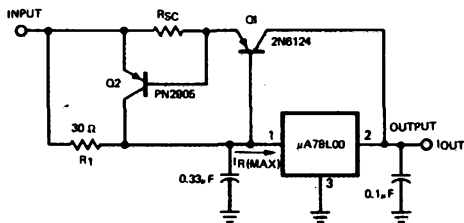
FIXED OUTPUT REGULATOR



For  $I_{REG} \approx 23 \text{ mA}$

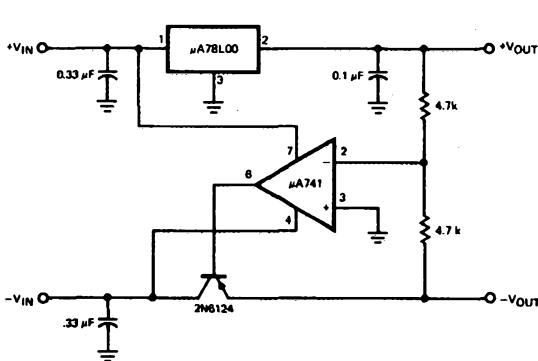
$$I_{REG} = \frac{0.7}{R_1} \quad I_{Q1} = \beta I_{REG}$$

HIGH CURRENT VOLTAGE REGULATOR

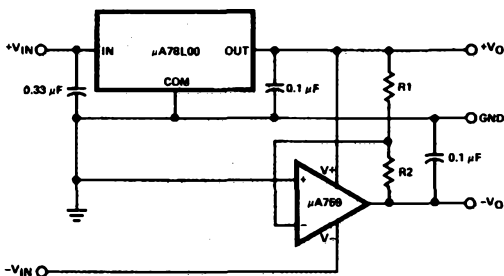


$$R_{SC} = \frac{0.7}{I_{SC}} \quad R_1 = \frac{\beta V_{BE}(Q2)}{I_{R(MAX)}(\beta+1) - I_{OUT(MAX)}}$$

HIGH OUTPUT CURRENT,  
SHORT CIRCUIT PROTECTED

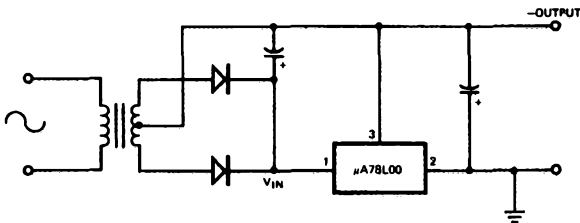


± TRACKING VOLTAGE REGULATOR

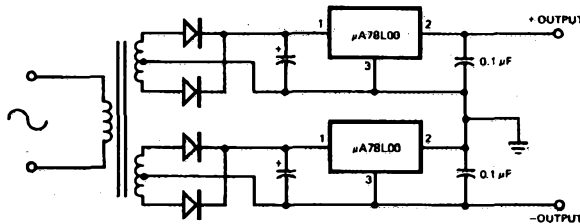


For Symmetrical Outputs  $R_1 = R_2$   
 $+I_{OUT} > 100 \text{ mA}$   
 $-I_{OUT} > 250 \text{ mA}$

DUAL TRACKING SUPPLY USING A  
78L00 REGULATOR WITH A POWER OP AMP



NEGATIVE OUTPUT VOLTAGE CIRCUIT



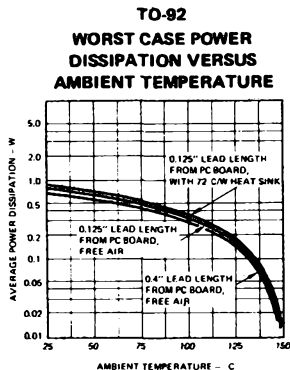
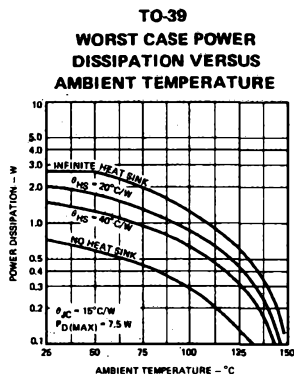
POSITIVE AND NEGATIVE REGULATOR

**DESIGN CONSIDERATIONS**

The  $\mu$ A78L series regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	Typ	Max	Typ	Max
	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JA}$	$\theta_{JA}$
TO-39	20	40	140	190
TO-92			180	190



**THERMAL CONSIDERATIONS**

The TO-92 molded package manufactured by Fairchild is capable of unusually high power dissipation due to the lead frame design. However, its thermal capabilities are generally overlooked because of a lack of understanding of the thermal paths from the semiconductor junction to ambient temperature. While thermal resistance is normally specified for the device mounted 1 cm above an infinite heat sink, very little has been mentioned of the options available to improve on the conservatively rated thermal capability.

An explanation of the thermal paths of the TO-92 and comparison of the thermal equivalent circuit of the TO-39 metal package with that of the TO-92 will allow the designer to determine the thermal stress he is applying in any given application.

**THE METAL CAN THERMAL MODEL**

In the TO-39 case, where the die is attached directly to the base of a metal package, the thermal equivalent circuit is often represented simply as a series connection of the junction-to-case thermal resistance,  $\theta_{JC}$ , and the case-to-ambient thermal resistance,  $\theta_{CA}$ , as shown in Figure 1.

In this model, the current source represents the thermal energy source;  $T_J$  is the junction temperature, assuming a constant surface temperature across the die;  $\theta_{JC}$  is the junction-to-case thermal resistance, measured at a point on the case directly beneath the die location;  $\theta_{CA}$  is the thermal resistance from the case to the ultimate heat sink, ambient temperature, as represented by the battery. The heat flow is analogous to electrical current, and temperature to voltage. The total thermal resistance from junction to ambient is then:

$$\theta_{JA} = \theta_{JC} + \theta_{CA}$$

The maximum power dissipation is a function of the maximum permissible junction temperature (which is a function of the package materials and construction) and the total thermal resistance from the junction to ambient temperature. Junction temperature is assumed to be the limiting factor.

Thus: maximum power dissipation  $P_D = \frac{T_J(\text{MAX}) - T_A}{\theta_{JC} + \theta_{CA}}$

Since  $\theta_{JA} = \theta_{JC} + \theta_{CA}$

Then  $\theta_{JA} = \frac{T_J(\text{MAX}) - T_A}{P_D}$

Or  $\theta_{JA} P_D = T_J - T_A$   
 $P_D = \frac{T_J - T_A}{\theta_{JA}}$

Therefore, using the VBE method of junction temperature sensing, and attaching a thermocouple to the case at the location specified, the relative values of  $\theta_{JC}$  and  $\theta_{CA}$  can readily be determined.

The thermal ratings of the metal can package are normally presented with the case attached to an infinite heat sink at still air ambient temperature. This causes  $\theta_{CA}$  to go to zero resulting in  $\theta_{JC}$  representing the total  $\theta_{JA}$ . The infinite heat sink is an unrealizable condition in the practical world, but serves to project a goal.

**THE TO-92 PACKAGE**

The TO-92 package thermal paths are considerably more complex than those of the TO-39 metal can package. In addition to the path through the molding compound to ambient temperature, there is another path through the leads, in parallel with the case path, to ambient temperature, as shown in Figure 2.

The total thermal resistance in this model is then:

$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})(\theta_{JL} + \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL} + \theta_{LA}} \quad (3)$$

Where:  $\theta_{JC}$  = thermal resistance of the case between the regulator die and a point on the case directly above the die location.

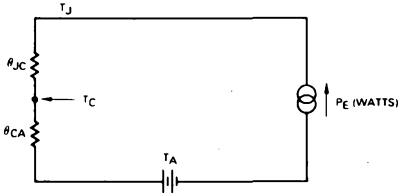
$\theta_{CA}$  = thermal resistance between the case and air at ambient temperature.

$\theta_{JL}$  = thermal resistance from transistor die through the collector lead to a point 1/16" below the regulator case.

$\theta_{LA}$  = total thermal resistance of the collector-base-emitter leads to ambient temperature.

$\theta_{JA}$  = junction to ambient thermal resistance.

As one can see from Figure 1, the metal can package generally does not have the lead cooling path because of the high thermal



**THERMAL EQUIVALENT CIRCUIT TO-39 PACKAGE (DIE ATTACHED TO METAL PACKAGE BASE)**

Fig. 1

**METHODS OF HEAT SINKING**

With two external thermal resistances in each leg of a parallel network available to the circuit designer as variables, he can choose the method of heat sinking most applicable to his particular situation. To demonstrate, consider the effect of placing a small 72°C/W flag type heat sink, such as the Staver F1-7D-2, on the 78LXX molded case. The heat sink effectively replaces the  $\theta_{CA}$  (Figure 2) and the new thermal resistance,  $\theta'_{JA}$ , is:

$$\theta'_{JA} = 145^\circ\text{C/W} \quad (\text{assuming } .125 \text{ inch lead length})$$

The net change of 15°C/W increases the allowable power dissipation to 0.86W with an inserted cost of 1-2 cents. A still further decrease in  $\theta_{JA}$  could be achieved by using a sink rated at 46°C/W, such as the Staver FS-7A. Also, if the case sinking does not provide an adequate reduction in total  $\theta_{JA}$ , the other external thermal resistance,  $\theta_{LA}$ , may be reduced by shortening the lead length from package base to mounting medium. However, one point must be kept in mind. The lead thermal path includes a thermal resistance,  $\theta_{SA}$ , from the leads at the mounting point to ambient, that is, the

resistances resulting from the construction of the header, case and leads. Normally, this material is kovar. Now,  $\theta_{JC}$  and  $\theta_{JL}$  are within the package and not variable by the user. However,  $\theta_{CA}$  and  $\theta_{LA}$  are outside the package and can be effectively used to control the total thermal resistance and, therefore, junction temperature.

Replacing  $\theta_{JA}$  of equation (1) with  $\theta_{JA}$  of equation (3) gives:

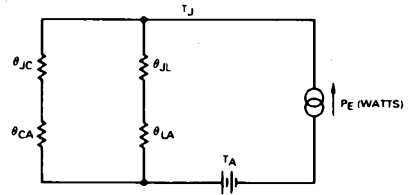
$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})(\theta_{JL} + \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL} + \theta_{LA}} = \frac{T_J - T_A}{P_D} \quad (4)$$

The maximum  $T_J$  allowed in equation (4) is 150°C. The maximum power dissipation is determined by the net total thermal resistance  $\theta_{JA}$ , the parallel equivalent networks of the case series path and lead series path, divided into the difference of the maximum junction temperature, 150°C, and ambient temperature generally specified as 25°C. In the case of the 78LXX, the maximum dissipation in a .4 inch condition is:

$$P_D = \frac{150 - 25}{\theta_{JA}}, \quad \theta_{JA} = 180^\circ\text{C/W}$$

$$P_D = 0.7 \text{ W}$$

If lead length is reduced to .125 inch  $\theta_{JA}$  becomes 160°C, and  $P_{D(\text{MAX})} = 0.78 \text{ W}$ .



**TO-92 THERMAL EQUIVALENT CIRCUIT**

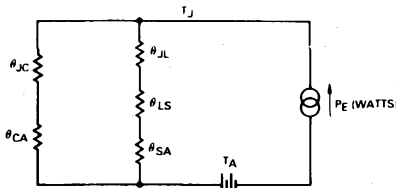
Fig. 2

mounting medium.  $\theta_{LA}$  is then equal to  $\theta_{LS} + \theta_{SA}$ . The new model is shown in Figure 3.

In the case of a socket,  $\theta_{SA}$  could be as high as 270°C/W, thus causing a net increase in  $\theta_{JA}$  and a consequent decrease in the maximum dissipation capability. Shortening the lead length may return the net  $\theta_{JA}$  to the original value, but lead sinking would not be accomplished.

In those cases where the regulator is inserted into a copper clad printed circuit board, it is advantageous to have a maximum area of copper at the entry points of the leads. While it would be desirable to rigorously define the effect of PC board copper, the real world variables are too great to allow anything more than a few general observations.

The best analogy for PC board copper is to compare it with parallel resistors. Beyond some point, additional resistors are not significantly effective; beyond some point, additional copper area is not effective.

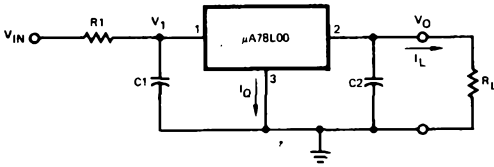


**TO-92 THERMAL EQUIVALENT CIRCUIT (LEAD AT OTHER THAN AMBIENT TEMPERATURE)**

Fig. 3



HIGH DISSIPATION APPLICATIONS



When it is necessary to operate a  $\mu$ A78L00 regulator with a large input-output differential voltage, the addition of series resistor R1 will extend the output current range of the device by sharing the total power dissipation between R1 and the regulator.

R1 may be calculated from

$$R1 = \frac{V_{IN(MIN)} - V_{OUT} - 2.0 \text{ V}}{I_{L(MAX)} + I_Q}$$

where  $I_Q$  is the regulator quiescent current.

Regulator power dissipation at maximum input voltage and maximum load current is now

$$PD(MAX) = (V_1 - V_{OUT}) I_{L(MAX)} + V_1 I_Q$$

where

$$V_1 = V_{IN(MAX)} - (I_{L(MAX)} + I_Q) R1$$

The presence of R1 will affect load regulation according to the equation:

$$\begin{aligned} \text{load regulation (at constant } V_{IN}) = & \text{load regulation (at constant } V_1) \\ & + (\text{line regulation, mV per V}) \times \\ & (R1) \times (\Delta I_L). \end{aligned}$$

As an example, consider a 15 V regulator with a supply voltage of  $30 \pm 5$  V, required to supply a maximum load current of 30 mA.  $I_Q$  is 4.3 mA, and minimum load current is to be 10 mA.

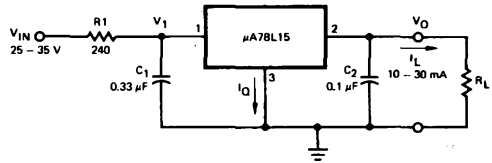
$$R1 = \frac{25 - 15 - 2}{30 + 4.3} = \frac{8}{34.3} \approx 240 \Omega$$

$$V_1 = 35 - (30 + 4.3) \cdot 240 = 35 - 8.2 = 26.8 \text{ V}$$

$$PD(MAX) = (26.8 - 15) 30 + 26.8 (4.3)$$

$$= 354 + 115$$

= 470 mW, which will permit operation up to 70°C in most applications.



Line regulation of this circuit is typically 110 mV for an input range of 25-35 V at a constant load current, i.e. 11 mV/V.

Load regulation = constant  $V_1$  load regulation (typically 10 mV, 10-30 mA  $I_L$ )

$$+ (11 \text{ mV/V}) \times 0.24 \times 20 \text{ mA (typically 53 mV)}$$

$$= 63 \text{ mV for a load current change of 20 mA at a constant } V_{IN} \text{ of 30 V.}$$

# μA78C00 SERIES

## 3-TERMINAL POSITIVE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

**DESCRIPTION** — The μA78C00 series is a 3-terminal positive voltage regulator capable of delivering 500mA of output current. It is similar in performance to the popular μA78M00 series but has a zener reference as opposed to a band gap reference. Because of this the μA78C00 has a noise level higher than that of the μA78M00 and is not available in the 5 V and 6 V options.

The μA78C00 employs internal current limiting, thermal shut-down, and safe area compensation that make the part virtually indestructible.

The μA78C00 is intended for use in the low cost consumer applications such as T.V., stereo, etc. and is offered in the plastic Power Watt (similar to TO-202) package.

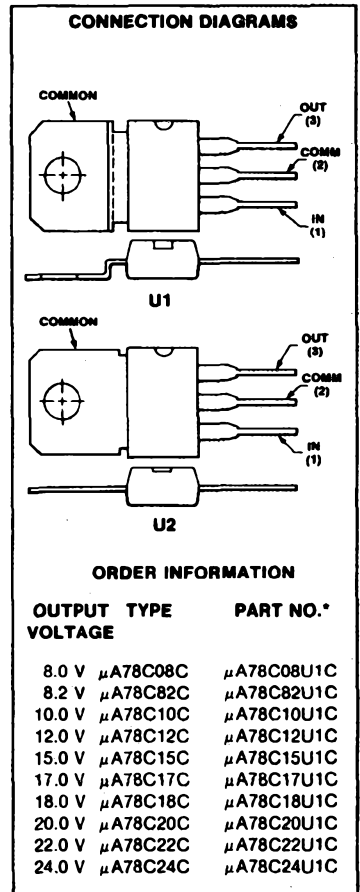
The fixed voltage series designated 78C00 is available in 10 options from 8-24 V and is capable of delivering 500 mA.

A 0.33 μF decoupling capacitor should be used at the input pin. a 0.1 μF capacitor at the output pin will improve the transient response.

- OUTPUT CURRENT IN EXCESS OF 0.5 A
- EXCELLENT TRANSIENT RESPONSE
- 1/2% LOAD AND LINE REGULATION
- MAX DROPOUT VOLTAGE 2.5 V
- THERMAL OVERLOAD PROTECTION
- OUTPUT TRANSISTOR SAFE AREA PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMIT
- LOW OUTPUT IMPEDANCE

#### ABSOLUTE MAXIMUM RATINGS

Input Voltage	
(V <sub>O</sub> 8 V thru 18 V)	35 V
(V <sub>O</sub> 20 V thru 24 V)	40 V
Internal Power Dissipation	Internally Limited
Operating Temperature Range	0°C to +125°C
Maximum Junction Temperature	+150°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 s)	230°C
Maximum Power Dissipation (P <sub>D</sub> )	7.5 W



# FAIRCHILD • $\mu$ A78C00 SERIES

**ELECTRICAL CHARACTERISTICS:**  $I_O = 350$  mA,  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ ,  $C_{IN} = 0.3$   $\mu$ F,  $C_O = 0.1$   $\mu$ F,  $V_{IN} = V_O + 5$  V unless otherwise specified (Note 1)

SYMBOL	CHARACTERISTICS	CONDITIONS	8 V			8.2 V			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_O$	Output Voltage	$T_J = 25^\circ\text{C}$	7.7	8.0	8.3	7.9	8.2	8.5	V
		$5\text{ mA} \leq I_O \leq 350\text{ mA}$ $2.5\text{ V} \leq V_{IN} - V_O \leq 15\text{ V}$ ( $V_{IN}$ Max = 35 V)	7.6		8.4	7.8		8.6	V
$\Delta V_O$	Line Regulation	$T_J = 25^\circ\text{C}$ , $V_{IN} = 11 - 21\text{ V}$ $V_{IN} = 12 - 22\text{ V}$			40			40	mV
$\Delta V_O$	Load Regulation	$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_O < 500\text{ mA}$			80			85	mV
		$T_J = 25^\circ\text{C}$ , $100\text{ mA} < I_O < 300\text{ mA}$			40			40	mV
$I_O$	Quiescent Current	$T_J = 25^\circ\text{C}$ , $I_O = 0$		2.5	6.0		2.5	6.0	mA
$\Delta I_O$	Quiescent Current Change	$3\text{ V} \leq V_{IN} - V_O \leq 13\text{ V}$			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5	mA
$e_n$	Output Noise Voltage	$T_J = 25^\circ\text{C}$ , $10\text{ Hz} \leq f \leq 100\text{ kHz}$		200			200		$\mu$ V
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	$T_J = 25^\circ\text{C}$ , $3\text{ V} \leq V_{IN} - V_O \leq 13\text{ V}$ ( $V_{IN}$ Max = 39 V), $f = 120\text{ Hz}$	46	54		46	54		dB
$V_{IN} - V_O$	Dropout Voltage	$T_J = 25^\circ\text{C}$ , Note 3			2.5			2.5	V
$I_{SC}$	Short Circuit Current	$T_J = 25^\circ\text{C}$ , $V_{IN} = 35\text{ V}$ , Note 2		400			400		mA
$I_O$ Max	Peak Output Current	$T_J = 25^\circ\text{C}$ , $V_{IN} - V_O = 8\text{ V}$		1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-2.1			-2.2		mV/ $^\circ\text{C}$
Cont'd)			10 V			12 V			
$V_O$	Output Voltage	$T_J = 25^\circ\text{C}$	9.6	10	10.4	11.5	11	12.5	V
		$5\text{ mA} \leq I_O \leq 350\text{ mA}$ $2.5\text{ V} \leq V_{IN} - V_O \leq 15\text{ V}$ ( $V_{IN}$ Max = 35 V)	9.5		10.5	11.4		12.6	V
$\Delta V_O$	Line Regulation	$T_J = 25^\circ\text{C}$ , $V_{IN} = 13 - 23\text{ V}$ $V_{IN} = 15 - 25\text{ V}$			50			50	mV
$\Delta V_O$	Load Regulation	$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_O < 500\text{ mA}$			100			120	mV
		$T_J = 25^\circ\text{C}$ , $100\text{ mA} < I_O < 300\text{ mA}$			50			60	mV
$I_O$	Quiescent Current	$T_J = 25^\circ\text{C}$ , $I_O = 0$		2.5	6.0		2.5	6.0	mA
$\Delta I_O$	Quiescent Current Change	$3\text{ V} \leq V_{IN} - V_O \leq 13\text{ V}$			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5	mA
$e_n$	Output Noise Voltage	$T_J = 25^\circ\text{C}$ , $10\text{ Hz} \leq f \leq 100\text{ kHz}$		250			300		$\mu$ V
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	$T_J = 25^\circ\text{C}$ , $3\text{ V} \leq V_{IN} - V_O \leq 13\text{ V}$ ( $V_{IN}$ Max = 39 V), $f = 120\text{ Hz}$	46	54		46	54		dB
$V_{IN} - V_O$	Dropout Voltage	$T_J = 25^\circ\text{C}$ , Note 3			2.5			2.5	V
$I_{SC}$	Short Circuit Current	$T_J = 25^\circ\text{C}$ , $V_{IN} = 35\text{ V}$ , Note 2		400			400		mA
$I_O$ Max	Peak Output Current	$T_J = 25^\circ\text{C}$ , $V_{IN} - V_O = 8\text{ V}$		1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-2.3			-2.3		mV/ $^\circ\text{C}$

**NOTES:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_W \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.
- Refer to peak output current vs  $\Delta(V_{IN} - V_{OUT})$  curves for temperature relationships.
- Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.

# FAIRCHILD • $\mu$ A78C00 SERIES

**ELECTRICAL CHARACTERISTICS:**  $I_O = 350$  mA,  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ ,  $C_{IN} = 0.3$   $\mu$ F,  $C_O = 0.1$   $\mu$ F,  $V_{IN} = V_O + 5$  V unless otherwise specified (Note 1)

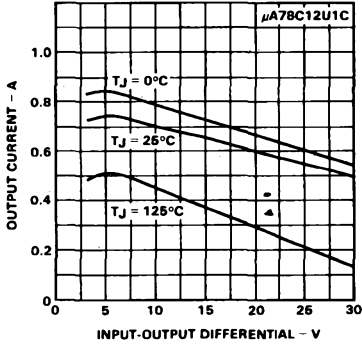
SYMBOL	CHARACTERISTICS	CONDITIONS	15 V			17 V			18 V			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V <sub>O</sub>	Output Voltage	T <sub>J</sub> = 25°C	14.4	15	15.6	16.3	17	17.7	17.3	18	18.7	V
		5 mA ≤ I <sub>O</sub> ≤ 350 mA 2.5 V ≤ V <sub>IN</sub> - V <sub>O</sub> ≤ 15 V (V <sub>IN</sub> Max = 39 V)	14.25		15.75	16.15		17.85	17.1		18.9	V
ΔV <sub>O</sub>	Line Regulation	T <sub>J</sub> = 25°C, V <sub>IN</sub> = 20-30 V V <sub>IN</sub> = 21-31 V V <sub>IN</sub> = 22-32 V			50			50			50	mV
ΔV <sub>O</sub>	Load Regulation	T <sub>J</sub> = 25°C, 5 mA < I <sub>O</sub> < 500 mA			150			170			180	mV
		T <sub>J</sub> = 25°C, 100 mA < I <sub>O</sub> < 300 mA			75			85			90	mV
I <sub>O</sub>	Quiescent Current	T <sub>J</sub> = 25°C, I <sub>O</sub> = 0		2.5	6.0		2.5	6.0		2.5	6.0	mA
ΔI <sub>O</sub>	Quiescent Current Change	3 V ≤ V <sub>IN</sub> - V <sub>O</sub> ≤ 13 V			0.8			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5			0.5	mA
e <sub>n</sub>	Output Noise Voltage	T <sub>J</sub> = 25°C, 10 Hz ≤ f ≤ 100 kHz		375			400			450		μV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	T <sub>J</sub> = 25°C, 3 V ≤ V <sub>IN</sub> - V <sub>O</sub> ≤ 13 V (V <sub>IN</sub> Max = 39 V), f = 120 Hz	46	54		46	54		46	54		dB
V <sub>IN</sub> - V <sub>O</sub>	Dropout Voltage	T <sub>J</sub> = 25°C, Note 3			2.5			2.5			2.5	V
I <sub>SC</sub>	Short Circuit Current	T <sub>J</sub> = 25°C, V <sub>IN</sub> = 35 V, Note 2		400			400			400		mA
I <sub>O</sub> Max	Peak Output Current	T <sub>J</sub> = 25°C, V <sub>IN</sub> - V <sub>O</sub> = 8 V		1.0			1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-4.0			-4.5			-4.8		mV/°C
(Cont'd)			20 V			22 V			24 V			
V <sub>O</sub>	Output Voltage	T <sub>J</sub> = 25°C	19.2	20	20.8	21.1	22	22.9	23	24	25	V
		5 mA ≤ I <sub>O</sub> ≤ 350 mA 2.5 V ≤ V <sub>IN</sub> - V <sub>O</sub> ≤ 15 V (V <sub>IN</sub> Max = 39 V)	19		21	20.9		23.1	22.8		25.2	V
ΔV <sub>O</sub>	Line Regulation	T <sub>J</sub> = 25°C, V <sub>IN</sub> = 24-34 V V <sub>IN</sub> = 26-36 V V <sub>IN</sub> = 28-38 V			50			50			50	mV
ΔV <sub>O</sub>	Load Regulation	T <sub>J</sub> = 25°C, 5 mA < I <sub>O</sub> < 500 mA			200			220			240	mV
		T <sub>J</sub> = 25°C, 100 mA < I <sub>O</sub> < 300 mA			100			110			120	mV
I <sub>O</sub>	Quiescent Current	T <sub>J</sub> = 25°C, I <sub>O</sub> = 0		2.5	6.0		2.5	6.0		2.5	6.0	mA
ΔI <sub>O</sub>	Quiescent Current Change	3 V ≤ V <sub>IN</sub> - V <sub>O</sub> ≤ 13 V			0.8			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5			0.5	mA
e <sub>n</sub>	Output Noise Voltage	T <sub>J</sub> = 25°C, 10 Hz ≤ f ≤ 100 kHz		500			550			600		μV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	T <sub>J</sub> = 25°C, 3 V ≤ V <sub>IN</sub> - V <sub>O</sub> ≤ 13 V (V <sub>IN</sub> Max = 39 V), f = 120 Hz	46	54		46	54		46	54		dB
V <sub>IN</sub> - V <sub>O</sub>	Dropout Voltage	T <sub>J</sub> = 25°C, Note 3			2.5			2.5			2.5	V
I <sub>SC</sub>	Short Circuit Current	T <sub>J</sub> = 25°C, V <sub>IN</sub> = 35 V, Note 2		400			400			400		mA
I <sub>O</sub> Max	Peak Output Current	T <sub>J</sub> = 25°C, V <sub>IN</sub> - V <sub>O</sub> = 8 V		1.0			1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-5.3			-6.0			-6.4		mV/°C

**NOTES:**

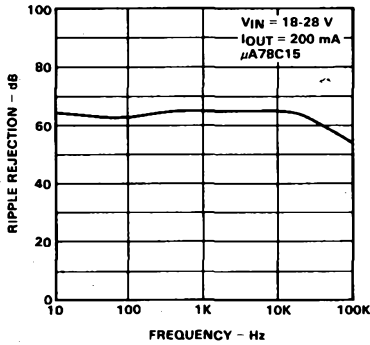
1. All characteristics except noise voltage and ripple rejection are measured using pulse techniques (t<sub>W</sub> ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.
2. Refer to peak output current vs Δ(V<sub>IN</sub> - V<sub>O</sub>)<sub>T</sub> curves for temperature relationships.
3. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.

ELECTRICAL PERFORMANCE CURVES

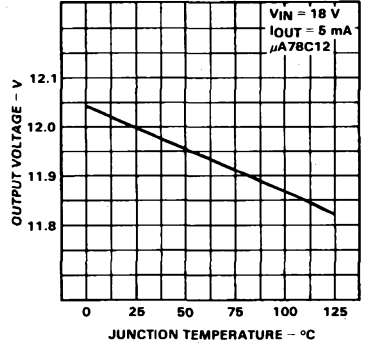
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



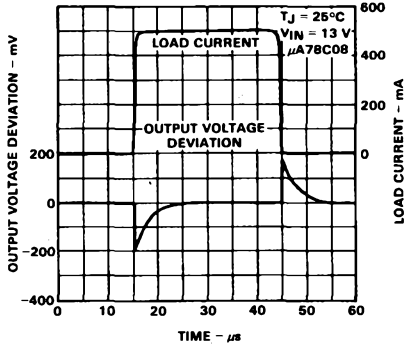
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



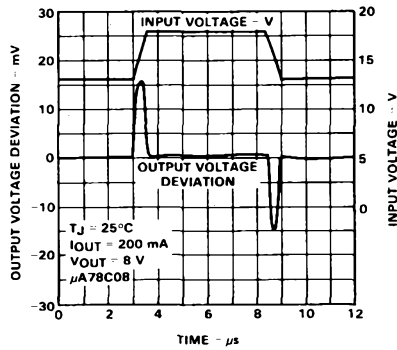
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



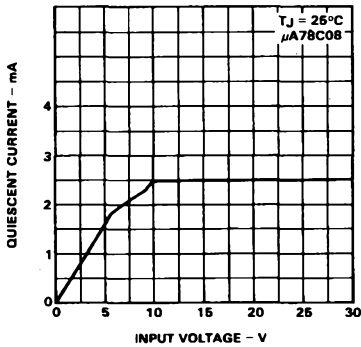
LOAD TRANSIENT RESPONSE



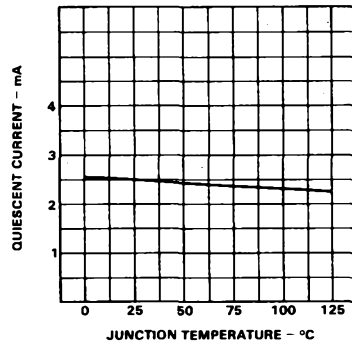
LINE TRANSIENT RESPONSE



QUIESCIENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCIENT CURRENT AS A FUNCTION OF JUNCTION TEMPERATURE



# FAIRCHILD • $\mu$ A78C00 SERIES

## $\mu$ A78C00 FIXED VOLTAGE VOLTAGE REGULATOR

Figure 1 shows the equivalent circuit of the  $\mu$ A78C00 regulator. The reference is derived from Zener diode D1 and compensated by the base-emitter voltage of the error amplifier Q4. Additional gain is provided by Q7 and Q8 to the Darlington-connected emitter-follower output stage of Q10 and Q11. The output stage is compensated by capacitor C1. A positive start-up condition is ensured by FET transistor Q1 to provide base current to transistors Q2 and Q5. Q2, Q5 and Q6 then form a positive feedback loop which raises the base voltage of Q2 until the reference Zener D1 conducts. Thermal overload protection is achieved by transistor Q3. The bias to the base-emitter voltage of Q3 is derived from D1 via Q2 and the divider network of R1 and R2. At high junction temperatures, Q3 turns on and removes the drive to the output stage. Current-limit transistor Q9 protects the device against accidental shorts by sensing the voltage drop across R7 while Zener diode D2 along with Q9 and resistors R5, R6 and R7 limit the power dissipation to a safe value.

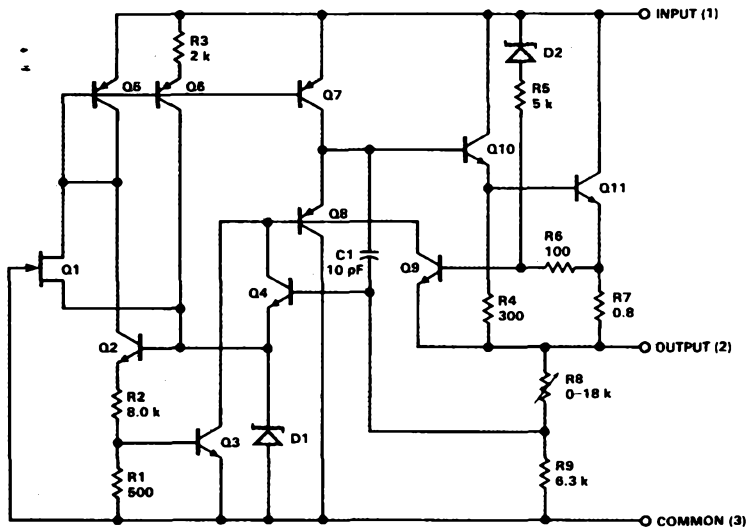
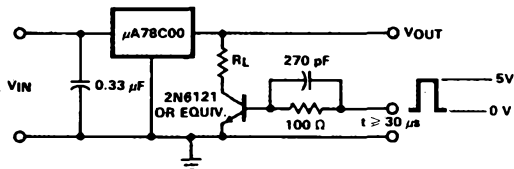
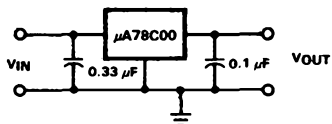


Fig. 1  
SCHEMATIC DIAGRAM  
FIXED VOLTAGE 3-TERMINAL VOLTAGE REGULATOR

## TEST CIRCUITS



LOAD REGULATION TEST CIRCUIT



DC PARAMETER TEST CIRCUIT

# FAIRCHILD • $\mu$ A78C00 SERIES

## DESIGN CONSIDERATIONS

The  $\mu$ A78C00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output short circuit current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP $\theta_{JC}$	MAX $\theta_{JC}$	TYP $\theta_{JA}$	MAX $\theta_{JA}$
Power Watt	6.0	8.0	75	80

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J(MAX)} - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

$$\text{Solving for } T_J: T_J = T_A + P_D (\theta_{JC} + \theta_{CA}) \text{ or } T_A + P_D \theta_{JA} \text{ (Without heat sink)}$$

Where:

$T_J$  = Junction Temperature

$T_A$  = Ambient Temperature

$P_D$  = Power Dissipation

$\theta_{JA}$  = Junction to ambient thermal resistance

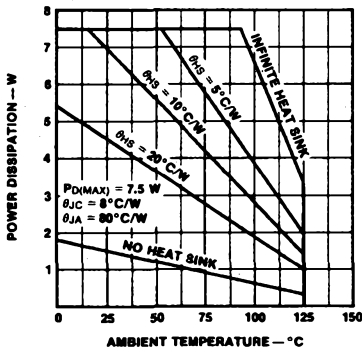
$\theta_{JC}$  = Junction to case thermal resistance

$\theta_{CA}$  = Case to ambient thermal resistance

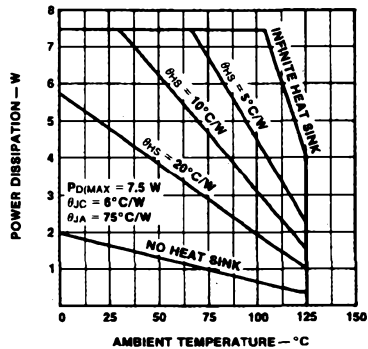
$\theta_{CS}$  = Case to heat sink thermal resistance

$\theta_{SA}$  = Heat sink to ambient thermal resistance

**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE**



**TYPICAL POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE**

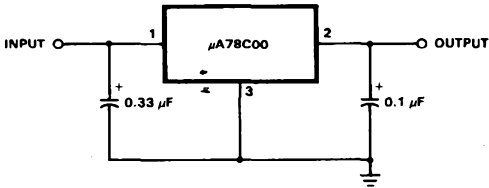


# FAIRCHILD • $\mu$ A78C00 SERIES

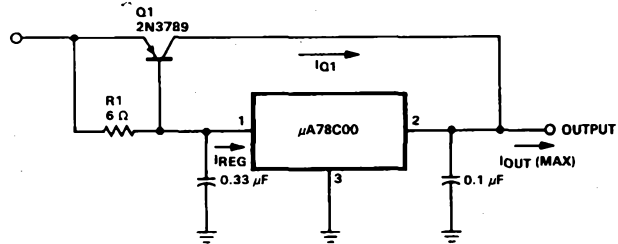
## TYPICAL APPLICATIONS

In many  $\mu$ A78C00 applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output ( $0.33 \mu\text{F}$  and  $0.1 \mu\text{F}$ , respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

### FIXED OUTPUT REGULATOR



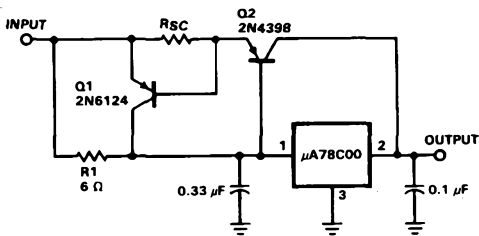
### HIGH CURRENT VOLTAGE REGULATOR



$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

$$\beta_{Q1} \geq \frac{I_{OUT}}{I_{REG}}$$

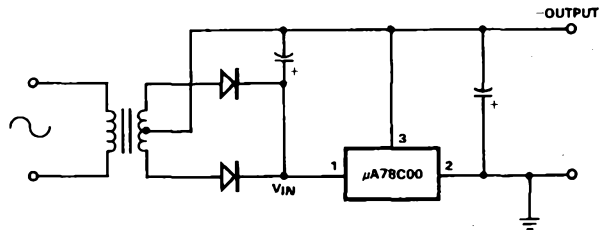
### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



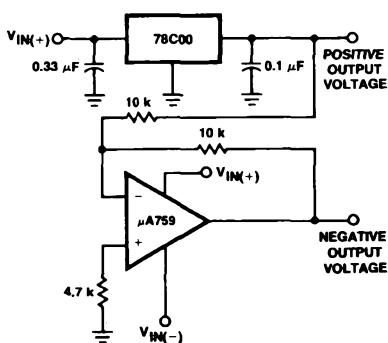
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}(\text{MAX})}$$

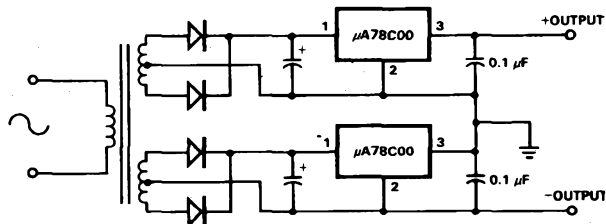
### NEGATIVE OUTPUT VOLTAGE CIRCUIT



### ± TRACKING VOLTAGE REGULATOR



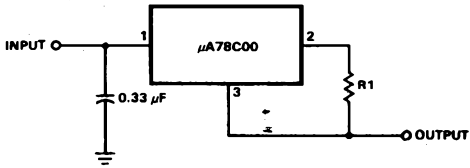
### POSITIVE AND NEGATIVE REGULATOR





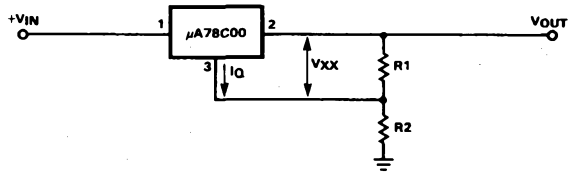
TYPICAL APPLICATIONS (Cont'd)

CURRENT REGULATOR



$$\text{Output Current} = \frac{V_{\text{OUT}}}{R_1}$$

CIRCUIT FOR INCREASING OUTPUT VOLTAGE



$$V_{\text{OUT}} = V_{\text{XX}} \left( 1 + \frac{R_2}{R_1} \right) + I_{\text{Q}} R_2$$

# μA78M00 SERIES

## 3-TERMINAL POSITIVE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

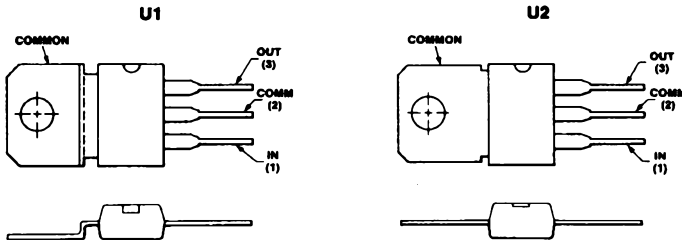
**GENERAL DESCRIPTION** — The μA78M00 series of 3-Terminal Medium Current Positive Voltage Regulators is constructed using the Fairchild Planar<sup>®</sup> epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe area compensation making them essentially indestructible. If adequate heat sinking is provided, they can deliver in excess of 500 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local or on-card regulation for elimination of noise and distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

- OUTPUT CURRENT IN EXCESS OF 0.5 A
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- OUTPUT TRANSISTOR SAFE AREA COMPENSATION
- AVAILABLE IN JEDEC TO-220 AND TO-39 PACKAGES
- OUTPUT VOLTAGES OF 5 V, 6 V, 8 V, 12 V, 15 V, 20 V and 24 V
- MILITARY AND COMMERCIAL TEMPERATURE RANGE

#### ABSOLUTE MAXIMUM RATINGS

Input Voltage		
(5 V through 15 V)		35 V
(20 V, 24 V)		40 V
Internal Power Dissipation		Internally Limited
Storage Temperature Range		
TO-39		-65°C to +150°C
TO-220 and Power Tab		-55°C to +150°C
Operating Junction Temperature Range		
μA78M00		-55°C to +150°C
μA78M00C		0°C to +150°C
Lead Temperatures (Soldering, 60 s time limit)	TO-39	300°C
(Soldering, 10 s time limit)	TO-220 and Power Tab	230°C

#### CONNECTION DIAGRAMS POWER TAB PACKAGES (TO-202 EQUIVALENT)

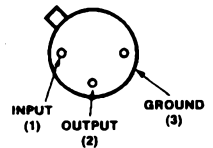


#### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA78M05	μA78M05U1C
6 V	μA78M06	μA78M06U1C
8 V	μA78M08	μA78M08U1C
12 V	μA78M12	μA78M12U1C
15 V	μA78M15	μA78M15U1C
20 V	μA78M20	μA78M20U1C
24 V	μA78M24	μA78M24U1C

\*or U2C for straight heatsink

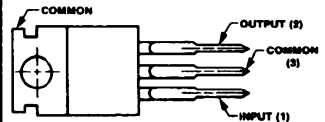
#### CONNECTION DIAGRAM TO-39 PACKAGE (TOP VIEW)



#### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA78M05	μA78M05HM
6 V	μA78M06	μA78M06HM
8 V	μA78M08	μA78M08HM
12 V	μA78M12	μA78M12HM
15 V	μA78M15	μA78M15HM
20 V	μA78M20	μA78M20HM
24 V	μA78M24	μA78M24HM
5 V	μA78M05C	μA78M05HC
6 V	μA78M06C	μA78M06HC
8 V	μA78M08C	μA78M08HC
12 V	μA78M12C	μA78M12HC
15 V	μA78M15C	μA78M15HC
20 V	μA78M20C	μA78M20HC
24 V	μA78M24C	μA78M24HC

#### TO-220 PACKAGE



#### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA78M05C	μA78M05UC
6 V	μA78M06C	μA78M06UC
8 V	μA78M08C	μA78M08UC
12 V	μA78M12C	μA78M12UC
15 V	μA78M15C	μA78M15UC
20 V	μA78M20C	μA78M20UC
24 V	μA78M24C	μA78M24UC

# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M05

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 10$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu\text{F}$ ,  $C_{OUT} = 0.1$   $\mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	4.8	5.0	5.2	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$7\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$		3.0	50	mV
			$8\text{ V} < V_{IN} < 20\text{ V}, I_{OUT} = 200\text{ mA}$		1.0	25	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		20	50	mV
			$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	25	mV
Output Voltage		$8\text{ V} < V_{IN} < 20\text{ V}, 5\text{ mA} < I_{OUT} < 350\text{ mA}$	4.7		5.3	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.5	6.0	mA	
Quiescent Current Change	with line	$8\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$			0.8	mA	
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}, 10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz},$ $8\text{ V} < V_{IN} < 18\text{ V}$	$I_{OUT} = 100\text{ mA}$		62		dB
			$I_{OUT} = 300\text{ mA},$ $T_J = 25^{\circ}\text{C}$		62	80	dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}, I_{OUT} = 350\text{ mA}$		2.0	2.5	V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}, V_{IN} = 35\text{ V}$		300	600	mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	0.4	0.7	1.4	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	$\text{mV}/^{\circ}\text{C}$
			$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A78M05C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 10$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu\text{F}$ ,  $C_{OUT} = 0.1$   $\mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	4.8	5.0	5.2	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$7\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$		3.0	100	mV
			$8\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$		1.0	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		20	100	mV
			$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	50	mV
Output Voltage		$7\text{ V} < V_{IN} < 20\text{ V}, 5\text{ mA} < I_{OUT} < 350\text{ mA}$	4.75		5.25	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.5	6.0	mA	
Quiescent Current Change	with line	$8\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$			0.8	mA	
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}, 10\text{ Hz} < f < 100\text{ kHz}$		40		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz},$ $8\text{ V} < V_{IN} < 18\text{ V}$	$I_{OUT} = 100\text{ mA}$		62		dB
			$I_{OUT} = 300\text{ mA},$ $T_J = 25^{\circ}\text{C}$		62	80	dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}$		2.0		V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}, V_{IN} = 35\text{ V}$		300		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		700		mA	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		-1.0		$\text{mV}/^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M06

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 11\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	5.75	6.0	6.25	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$8\text{ V} < V_{IN} < 25\text{ V}$ , $I_{OUT} = 200\text{ mA}$		5.0	60	mV
			$9\text{ V} < V_{IN} < 20\text{ V}$ , $I_{OUT} = 200\text{ mA}$		1.5	30	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		20	60	mV
			$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	30	mV
Output Voltage		$9\text{ V} < V_{IN} < 21\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	5.7		6.3	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.5	6.0	mA	
Quiescent Current Change		with line	$9\text{ V} < V_{IN} < 25\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
		with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $9\text{ V} < V_{IN} < 19\text{ V}$	$I_{OUT} = 100\text{ mA}$	59			dB
			$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	59	80		dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}$ , $I_{OUT} = 350\text{ mA}$		2.0	2.5	V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		300	600	mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	0.4	0.7	1.4	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$		0.4	.4	$\text{mV}/^{\circ}\text{C}$
			$+25^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$		0.3	.3	$V_{OUT}$

## $\mu$ A78M06C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 11\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	5.75	6.0	6.25	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$8\text{ V} < V_{IN} < 25\text{ V}$ , $I_{OUT} = 200\text{ mA}$		5.0	100	mV
			$9\text{ V} < V_{IN} < 25\text{ V}$ , $I_{OUT} = 200\text{ mA}$		1.5	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		20	120	mV
			$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	60	mV
Output Voltage		$8\text{ V} < V_{IN} < 21\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	5.7		6.3	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.5	6.0	mA	
Quiescent Current Change		with line	$9\text{ V} < V_{IN} < 25\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
		with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		45		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $9\text{ V} < V_{IN} < 19\text{ V}$	$I_{OUT} = 100\text{ mA}$	59			dB
			$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	59	80		dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}$		2.0		V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		270		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		700		mA	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		-0.5		$\text{mV}/^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M08

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 14$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$		7.7	8.0	8.3	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$		$10.5\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$		6.0	60	mV
				$11\text{ V} < V_{IN} < 20\text{ V}, I_{OUT} = 200\text{ mA}$		2.0	30	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$		$5\text{ mA} < I_{OUT} < 500\text{ mA}$		25	80	mV
				$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	40	mV
Output Voltage		$11.5\text{ V} < V_{IN} < 23\text{ V}, 5\text{ mA} < I_{OUT} < 350\text{ mA}$		7.6		8.4	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$			4.6	6.0	mA	
Quiescent Current Change		with line	$11.5\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$			0.8	mA	
		with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}, 10\text{ Hz} < f < 100\text{ kHz}$			8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}, 11.5\text{ V} < V_{IN} < 21.5\text{ V}$		$I_{OUT} = 100\text{ mA}$		56		dB
				$I_{OUT} = 300\text{ mA}, T_J = 25^{\circ}\text{C}$		56	80	dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}, I_{OUT} = 350\text{ mA}$			2.0	2.5	V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}, V_{IN} = 35\text{ V}$			300	600	mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		0.4	0.7	1.4	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	mV/ $^{\circ}\text{C}$
				$+25^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$			0.3	

## $\mu$ A78M08C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 14$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$		7.7	8.0	8.3	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$		$10.5\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$		6.0	100	mV
				$11\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$		2.0	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$		$5\text{ mA} < I_{OUT} < 500\text{ mA}$		25	160	mV
				$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	80	mV
Output Voltage		$10.5\text{ V} < V_{IN} < 23\text{ V}, 5\text{ mA} < I_{OUT} < 350\text{ mA}$		7.6		8.4	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$			4.6	6.0	mA	
Quiescent Current Change		with line	$10.5\text{ V} < V_{IN} < 25\text{ V}, I_{OUT} = 200\text{ mA}$			0.8	mA	
		with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}, 10\text{ Hz} < f < 100\text{ kHz}$			52		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}, 11.5\text{ V} < V_{IN} < 21.5\text{ V}$		$I_{OUT} = 100\text{ mA}$		56		dB
				$I_{OUT} = 300\text{ mA}, T_J = 25^{\circ}\text{C}$		56	80	dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}$			2.0		V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}, V_{IN} = 35\text{ V}$			250		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$			700		mA	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$			-0.5		mV/ $^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M12

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 19\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		11.5	12	12.5	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$14.5\text{ V} < V_{IN} < 30\text{ V}$ , $I_{OUT} = 200\text{ mA}$		8.0	60	mV
		$16\text{ V} < V_{IN} < 25\text{ V}$ , $I_{OUT} = 200\text{ mA}$		2.0	30	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		25	120	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	60	mV
Output Voltage	$15.5\text{ V} < V_{IN} < 27\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		11.4		12.6	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			4.8	6.0	mA
Quiescent Current Change	with line	$15\text{ V} < V_{IN} < 30\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			8	40	$\mu\text{V}/\sqrt{\text{OUT}}$
Ripple Rejection	$f = 120\text{ Hz}$ , $15\text{ V} < V_{IN} < 25\text{ V}$	$I_{OUT} = 100\text{ mA}$	55			dB
		$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	55	80		dB
Dropout Voltage	$T_A = 25^{\circ}\text{C}$ , $I_{OUT} = 350\text{ mA}$			2.0	2.5	V
Short Circuit Current	$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$			300	600	mA
Peak Output Current	$T_J = 25^{\circ}\text{C}$		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	$\text{mV}/^{\circ}\text{C}$
		$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A78M12C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 19\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		11.5	12	12.5	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$14.5\text{ V} < V_{IN} < 30\text{ V}$ , $I_{OUT} = 200\text{ mA}$		8.0	100	mV
		$16\text{ V} < V_{IN} < 30\text{ V}$ , $I_{OUT} = 200\text{ mA}$		2.0	50	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		25	240	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	120	mV
Output Voltage	$14.5\text{ V} < V_{IN} < 27\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		11.4		12.6	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			4.8	6.0	mA
Quiescent Current Change	with line	$14.5\text{ V} < V_{IN} < 30\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			75		$\mu\text{V}$
Ripple Rejection	$f = 120\text{ Hz}$ , $15\text{ V} < V_{IN} < 25\text{ V}$	$I_{OUT} = 100\text{ mA}$	55			dB
		$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	55	80		dB
Dropout Voltage	$T_A = 25^{\circ}\text{C}$			2.0		V
Short Circuit Current	$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$			240		mA
Peak Output Current	$T_J = 25^{\circ}\text{C}$			700		mA
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$			-1.0		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M15

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 23$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F,  
unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		14.4	15	15.6	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$17.5\text{ V} < V_{IN} < 30\text{ V}, I_{OUT} = 200\text{ mA}$		10	60	mV
		$20\text{ V} < V_{IN} < 30\text{ V}, I_{OUT} = 200\text{ mA}$		3.0	30	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		25	150	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	75	mV
Output Voltage	$18.5\text{ V} < V_{IN} < 30\text{ V}, 5\text{ mA} < I_{OUT} < 350\text{ mA}$		14.25		15.75	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			4.8	6.0	mA
Quiescent Current Change	with line	$18.5\text{ V} < V_{IN} < 30\text{ V}, I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}, 10\text{ Hz} < f < 100\text{ kHz}$			8	40	$\mu\text{V}/V_{OUT}$
Ripple Rejection	$f = 120\text{ Hz},$ $18.5\text{ V} < V_{IN} < 28.5\text{ V}$	$I_{OUT} = 100\text{ mA}$	54			dB
		$I_{OUT} = 300\text{ mA},$ $T_J = 25^{\circ}\text{C}$	54	70		dB
Dropout Voltage	$T_A = 25^{\circ}\text{C}$			2.0	2.5	V
Short Circuit Current	$T_J = 25^{\circ}\text{C}, V_{IN} = 35\text{ V}$			300	600	mA
Peak Output Current	$T_J = 25^{\circ}\text{C}$		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	$\text{mV}/^{\circ}\text{C}$
		$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A78M15C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 23$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F,  
unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		14.4	15	15.6	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$17.5\text{ V} < V_{IN} < 30\text{ V}, I_{OUT} = 200\text{ mA}$		10	100	mV
		$20\text{ V} < V_{IN} < 30\text{ V}, I_{OUT} = 200\text{ mA}$		3.0	50	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		25	300	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	150	mV
Output Voltage	$17.5\text{ V} < V_{IN} < 30\text{ V}, 5\text{ mA} < I_{OUT} < 350\text{ mA}$		14.25		15.75	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			4.8	6.0	mA
Quiescent Current Change	with line	$17.5\text{ V} < V_{IN} < 30\text{ V}, I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}, 10\text{ Hz} < f < 100\text{ kHz}$			90		$\mu\text{V}$
Ripple Rejection	$f = 120\text{ Hz},$ $18.5\text{ V} < V_{IN} < 28.5\text{ V}$	$I_{OUT} = 100\text{ mA}$	54			dB
		$I_{OUT} = 300\text{ mA},$ $T_J = 25^{\circ}\text{C}$	54	70		dB
Dropout Voltage	$T_A = 25^{\circ}\text{C}$			2.0		V
Short Circuit Current	$T_J = 25^{\circ}\text{C}, V_{IN} = 35\text{ V}$			240		mA
Peak Output Current	$T_J = 25^{\circ}\text{C}$			700		mA
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$			-1.0		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M20

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 29\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $-55^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		19.2	20	20.8	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$23\text{ V} < V_{IN} < 35\text{ V}$ , $I_{OUT} = 200\text{ mA}$		10	60	mV
		$24\text{ V} < V_{IN} < 35\text{ V}$ , $I_{OUT} = 200\text{ mA}$		5.0	30	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		30	200	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	100	mV
Output Voltage	$24\text{ V} < V_{IN} < 35\text{ V}$ , $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$		19		21	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			4.9	6.0	mA
Quiescent Current Change	with line	$24\text{ V} < V_{IN} < 35\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} \leq 350\text{ mA}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			8	40	$\mu\text{V}/V_{OUT}$
Ripple Rejection	$f = 120\text{ Hz}$ , $24\text{ V} < V_{IN} < 34\text{ V}$	$I_{OUT} = 100\text{ mA}$	53			dB
		$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	53	70		dB
Dropout Voltage	$T_A = 25^{\circ}\text{C}$ , $I_{OUT} = 350\text{ mA}$			2.0	2.5	V
Short Circuit Current	$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$			300	600	mA
Peak Output Current	$T_J = 25^{\circ}\text{C}$		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	$\text{mV}/^{\circ}\text{C}$
		$+25^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A78M20C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 29\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		19.2	20	20.8	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$23\text{ V} < V_{IN} < 35\text{ V}$ , $I_{OUT} = 200\text{ mA}$		10	100	mV
		$24\text{ V} < V_{IN} < 35\text{ V}$ , $I_{OUT} = 200\text{ mA}$		5.0	50	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		30	400	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	200	mV
Output Voltage	$23\text{ V} < V_{IN} < 35\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		19		21	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			4.9	6.0	mA
Quiescent Current Change	with line	$23\text{ V} < V_{IN} < 35\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} \leq 350\text{ mA}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			110		$\mu\text{V}$
Ripple Rejection	$f = 120\text{ Hz}$ , $24\text{ V} < V_{IN} < 34\text{ V}$	$I_{OUT} = 100\text{ mA}$	53			dB
		$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	53	70		dB
Dropout Voltage	$T_A = 25^{\circ}\text{C}$			2.0		V
Short Circuit Current	$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$			240		mA
Peak Output Current	$T_J = 25^{\circ}\text{C}$			700		mA
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$			-1.1		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



# FAIRCHILD • $\mu$ A78M00 SERIES

## $\mu$ A78M24

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 33$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	23	24	25	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$27\text{ V} < V_{IN} < 38\text{ V}$ , $I_{OUT} = 200\text{ mA}$		10	60	mV
		$30\text{ V} < V_{IN} < 36\text{ V}$ , $I_{OUT} = 200\text{ mA}$		5.0	30	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		30	240	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	120	mV
Output Voltage		$28\text{ V} < V_{IN} < 38\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	22.8		25.2	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		5.0	6.0	mA
Quiescent Current Change	with line	$28\text{ V} < V_{IN} < 38\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$
Ripple Rejection	$f = 120\text{ Hz}$ , $28\text{ V} < V_{IN} < 38\text{ V}$	$I_{OUT} = 100\text{ mA}$	50			dB
		$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	50	70		dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}$ , $I_{OUT} = 350\text{ mA}$		2.0	2.5	V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		300	600	mA
Peak Output Current		$T_J = 25^{\circ}\text{C}$	0.4	0.7	1.4	mA
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	$\text{mV}/^{\circ}\text{C}$
		$+25^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A78M24C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 33$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	23	24	25	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$27\text{ V} < V_{IN} < 38\text{ V}$ , $I_{OUT} = 200\text{ mA}$		10	100	mV
		$28\text{ V} < V_{IN} < 38\text{ V}$ , $I_{OUT} = 200\text{ mA}$		5.0	50	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 500\text{ mA}$		30	480	mV
		$5\text{ mA} < I_{OUT} < 200\text{ mA}$		10	240	mV
Output Voltage		$27\text{ V} < V_{IN} < 38\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	22.8		25.2	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		5.0	6.0	mA
Quiescent Current Change	with line	$27\text{ V} < V_{IN} < 38\text{ V}$ , $I_{OUT} = 200\text{ mA}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		170		$\mu\text{V}$
Ripple Rejection	$f = 120\text{ Hz}$ , $28\text{ V} < V_{IN} < 38\text{ V}$	$I_{OUT} = 100\text{ mA}$	50			dB
		$I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	50	70		dB
Dropout Voltage		$T_A = 25^{\circ}\text{C}$		2.0		V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		240		mA
Peak Output Current		$T_J = 25^{\circ}\text{C}$		700		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		-1.2		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A78M00 SERIES

## DESIGN CONSIDERATIONS

The  $\mu$ A78M00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output short circuit current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature ( $150^{\circ}\text{C}$  for 78M00,  $125^{\circ}\text{C}$  for 78M00C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	TYP	MAX	TYP	MAX
	$\theta_{\text{JC}}$	$\theta_{\text{JC}}$	$\theta_{\text{JA}}$	$\theta_{\text{JA}}$
TO-39	18	25	120	185
TO-220	3	5	62	70
POWER TAB (TO-202 EQUIVALENT)	6	8	75	80

$$P_D (\text{MAX}) = \frac{T_J (\text{MAX}) - T_A}{\theta_{\text{JC}} + \theta_{\text{CA}}} \text{ or } \frac{T_J (\text{MAX}) - T_A}{\theta_{\text{JA}}} \text{ (Without a heat sink)}$$

$$\theta_{\text{CA}} = \theta_{\text{CS}} + \theta_{\text{SA}}$$

Solving for  $T_J$ :  $T_J = T_A + P_D(\theta_{\text{JC}} + \theta_{\text{CA}})$  or  $T_A + P_D \theta_{\text{JA}}$  (Without a heat sink)

Where  $T_J$  = Junction Temperature

$T_A$  = Ambient Temperature

$P_D$  = Power Dissipation

$\theta_{\text{JC}}$  = Junction to case thermal resistance

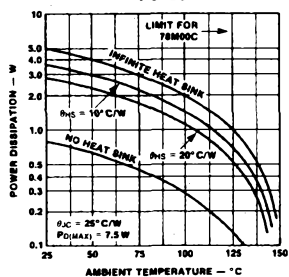
$\theta_{\text{CA}}$  = Case to Ambient thermal resistance

$\theta_{\text{CS}}$  = Case to heat sink to resistance

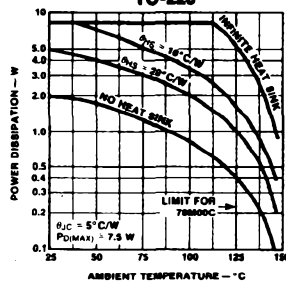
$\theta_{\text{SA}}$  = Heat sink to ambient thermal resistance

$\theta_{\text{JA}}$  = Junction to Ambient thermal resistance

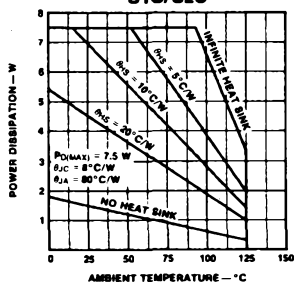
**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
TO-39**



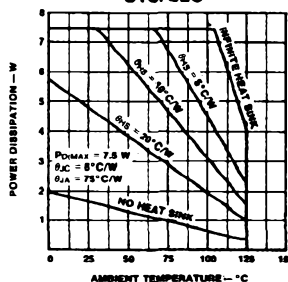
**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
TO-220**



**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
U1C/U2C**



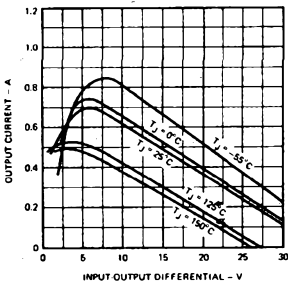
**TYPICAL POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
U1C/U2C**



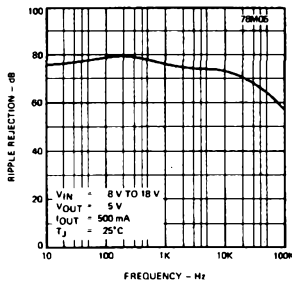
# FAIRCHILD • $\mu$ A78M00 SERIES

## ELECTRICAL PERFORMANCE CURVES

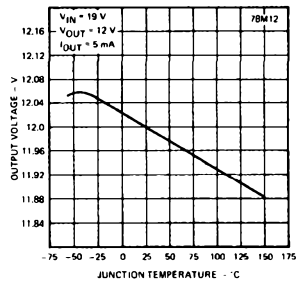
**PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE**



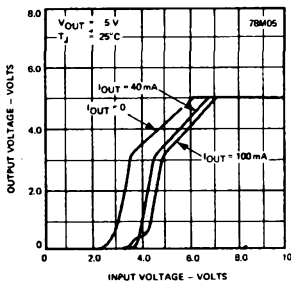
**RIPPLE REJECTION AS A FUNCTION OF FREQUENCY**



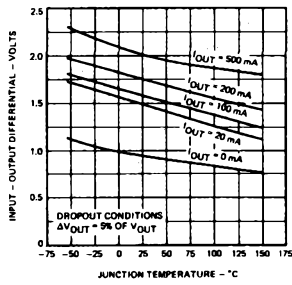
**OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE**



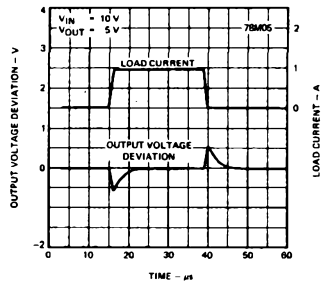
**DROPOUT CHARACTERISTICS**



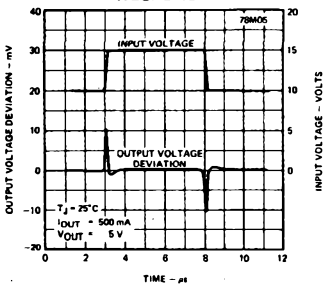
**DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE**



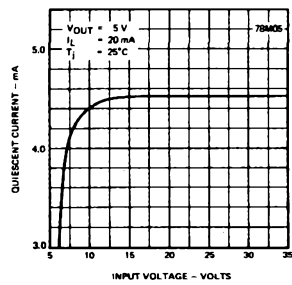
**LOAD TRANSIENT RESPONSE**



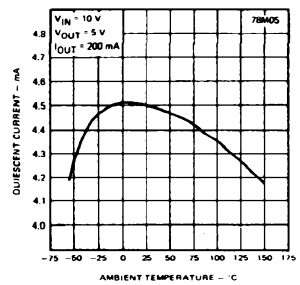
**LINE TRANSIENT RESPONSE**



**QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE**

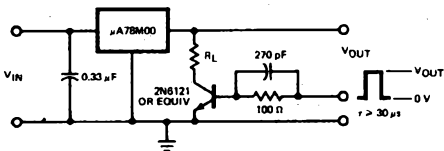


**QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE**

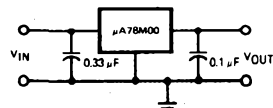


NOTE: Other  $\mu$ A78M00 Series devices have similar curves.

## TEST CIRCUITS

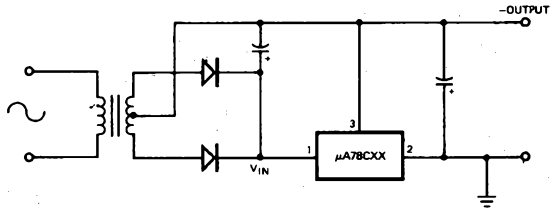
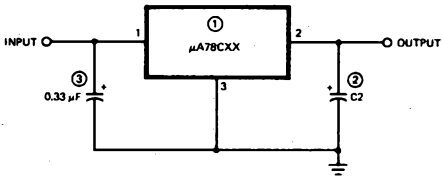


**LOAD REGULATION TEST CIRCUIT**



**DC PARAMETER TEST CIRCUIT**

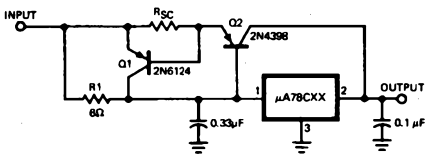
APPLICATIONS



NOTES:

- ① To specify an output voltage, substitute voltage value for "XX".
- ② Although no output capacitor is needed for stability, it does improve transient response.
- ③ Required if regulator is located an appreciable distance from power supply filter.

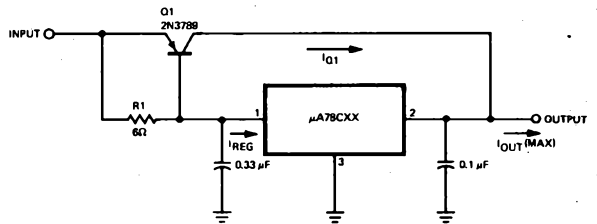
FIXED OUTPUT REGULATOR



$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(MAX) (\beta + 1) - I_{OUT}(MAX)}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}}$$

NEGATIVE OUTPUT VOLTAGE CIRCUIT

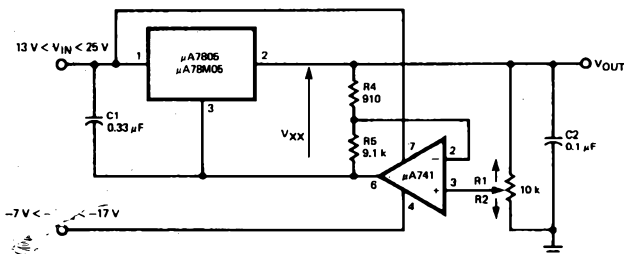


$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ}(MAX) (\beta + 1) - I_{OUT}(MAX)}$$

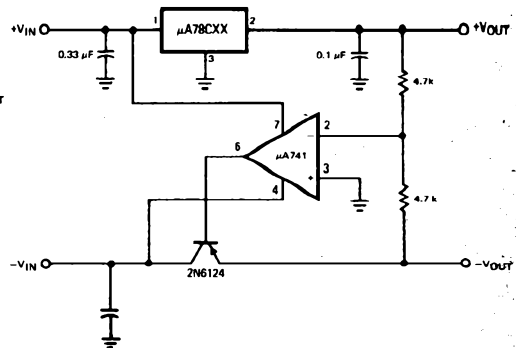
$$\beta_{Q1} > \frac{I_{OUT}}{I_{REG}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

HIGH CURRENT VOLTAGE REGULATOR

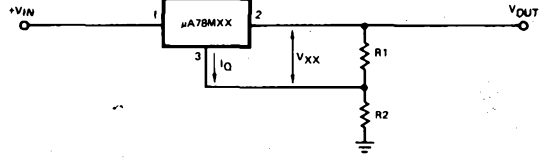
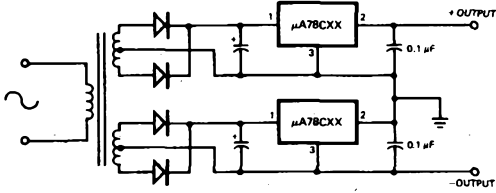


VARIABLE OUTPUT VOLTAGE, 0.5 TO 10 V



$\pm$  TRACKING VOLTAGE REGULATOR

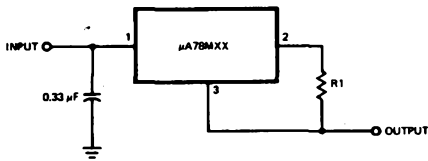
APPLICATIONS (Cont'd)



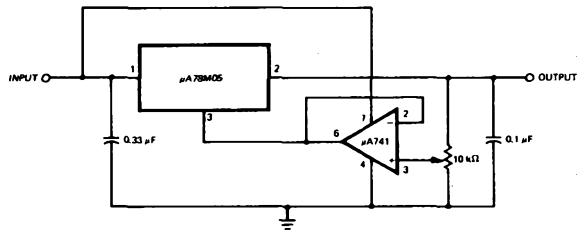
$$V_{OUT} = V_{XX} \left( 1 + \frac{R_2}{R_1} \right) + I_Q R_2$$

POSITIVE AND NEGATIVE REGULATOR

CIRCUIT FOR INCREASING OUTPUT VOLTAGE



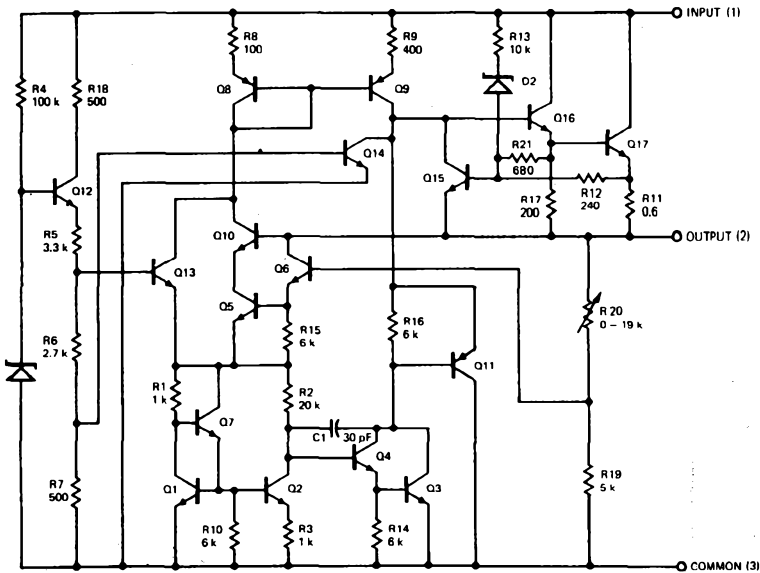
$$\text{Output Current} = \frac{V_{OUT}}{R_1}$$



CURRENT REGULATOR

ADJUSTABLE OUTPUT REGULATOR, 7 V TO 30 V

EQUIVALENT CIRCUIT



# μA7800 SERIES

## 3-TERMINAL POSITIVE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

**GENERAL DESCRIPTION** — The μA7800 series of monolithic 3-Terminal Positive Voltage Regulators is constructed using the Fairchild Planar\* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1 A output current. They are intended as fixed voltage regulators in a wide range of applications including local (on card) regulation for elimination of distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

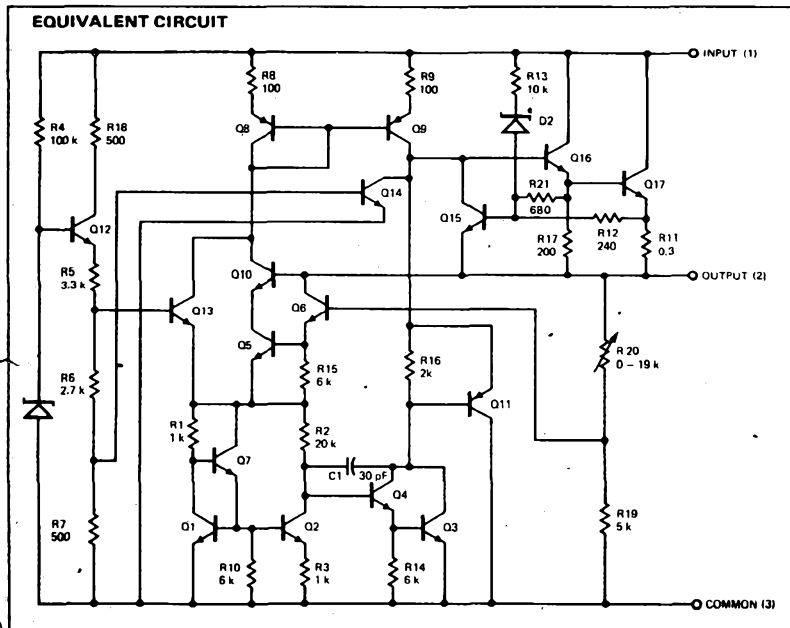
### OUTPUT CURRENT IN EXCESS OF 1 A

- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- OUTPUT TRANSISTOR SAFE AREA COMPENSATION
- AVAILABLE IN THE TO-220 AND THE TO-3 PACKAGE
- OUTPUT VOLTAGES OF 5, 6, 8, 8.5, 12, 15, 18, AND 24 V

### ABSOLUTE MAXIMUM RATINGS

Input Voltage (5 V through 18 V)	35 V
(24 V)	40 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	-65°C to +150°C
Operating Junction Temperature Range	-55°C to +150°C
	μA7800
	μA7800C
	0°C to +150°C
Lead Temperature (Soldering, 60 s time limit) TO-3 Package	300°C
(Soldering, 10 s time limit) TO-220 Package	230°C

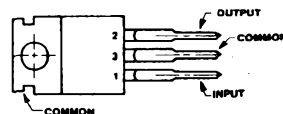
### EQUIVALENT CIRCUIT



### CONNECTION DIAGRAMS

#### TO-220 PACKAGE

(SIDE VIEW)

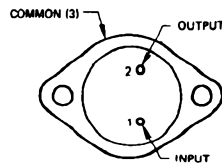


### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA7805C	μA7805UC
6 V	μA7806C	μA7806UC
8 V	μA7808C	μA7808UC
8.5 V	μA7885C	μA7885UC
12 V	μA7812C	μA7812UC
15 V	μA7815C	μA7815UC
18 V	μA7818C	μA7818UC
24 V	μA7824C	μA7824UC

### TO-3 PACKAGE

(TOP VIEW)



### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA7805	μA7805KM
6 V	μA7806	μA7806KM
8 V	μA7808	μA7808KM
8.5 V	μA7885	μA7885KM
12 V	μA7812	μA7812KM
15 V	μA7815	μA7815KM
18 V	μA7818	μA7818KM
24 V	μA7824	μA7824KM
5 V	μA7805C	μA7805KC
6 V	μA7806C	μA7806KC
8 V	μA7808C	μA7808KC
8.5 V	μA7885C	μA7885KC
12 V	μA7812C	μA7812KC
15 V	μA7815C	μA7815KC
18 V	μA7818C	μA7818KC
24 V	μA7824C	μA7824KC

\*Planar is a patented Fairchild process.

Regulation	$T_J = 25^\circ\text{C}$	$7\text{ V} \leq V_{IN} \leq 25\text{ V}$		3	50
		$8\text{ V} \leq V_{IN} \leq 12\text{ V}$		1	25
Load Regulation	$T_J = 25^\circ\text{C}$	$5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		15	100
		$250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		5	25
Line Regulation		$8.0\text{ V} \leq V_{IN} \leq 20\text{ V}$ $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$ $P \leq 15\text{ W}$	4.65		5.35
Quiescent Current		$T_J = 25^\circ\text{C}$		4.2	6.0
Load Current Change	with line	$8\text{ V} \leq V_{IN} \leq 25\text{ V}$			0.8
	with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$			0.5
Load Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} \leq f \leq 100\text{ kHz}$		8	40
Line Rejection		$f = 120\text{ Hz}$ , $8\text{ V} \leq V_{IN} \leq 18\text{ V}$	68	78	
Load Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^\circ\text{C}$		2.0	2.5
Line Resistance		$f = 1\text{ kHz}$		17	
Circuit Current		$T_J = 25^\circ\text{C}$ , $V_{IN} = 35\text{ V}$		0.75	1.2
Output Current		$T_J = 25^\circ\text{C}$	1.3	2.2	3.3
Temperature Coefficient of Voltage	$I_{OUT} = 5\text{ mA}$	$-55^\circ\text{C} \leq T_J \leq +25^\circ\text{C}$			0.4
		$+25^\circ\text{C} \leq T_J \leq +150^\circ\text{C}$			0.3

## C

**Typical Characteristics**  $V_{IN} = 10\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ ,  $C_{IN} = 0.33\text{ }\mu\text{F}$ ,  $C_{OUT} =$  unless otherwise specified.

Characteristic	Condition (Note)	Min	Typ	Max	
Line Regulation	$T_J = 25^\circ\text{C}$	4.8	5.0	5.2	
Load Regulation	$T_J = 25^\circ\text{C}$	$7\text{ V} \leq V_{IN} \leq 25\text{ V}$		3	100
		$8\text{ V} \leq V_{IN} \leq 12\text{ V}$		1	50
Load Regulation	$T_J = 25^\circ\text{C}$	$5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		15	100
		$250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		5	50
Line Regulation		$7\text{ V} \leq V_{IN} \leq 20\text{ V}$ $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$ $P \leq 15\text{ W}$	4.75		5.25
Quiescent Current		$T_J = 25^\circ\text{C}$		4.2	8.0
Load Current Change	with line	$7\text{ V} \leq V_{IN} \leq 25\text{ V}$			1.3
	with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$			0.5
Load Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} \leq f \leq 100\text{ kHz}$		40	
Line Rejection		$f = 120\text{ Hz}$ , $8\text{ V} \leq V_{IN} \leq 18\text{ V}$	62	78	
Load Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^\circ\text{C}$		2.0	

on	$T_J = 25^\circ\text{C}$	$8\text{ V} \leq V_{IN} \leq 25\text{ V}$		5	120	mV
		$9\text{ V} \leq V_{IN} \leq 13\text{ V}$		1.5	60	mV
tion	$T_J = 25^\circ\text{C}$	$5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		14	120	mV
		$250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		4	60	mV
ge		$8\text{ V} \leq V_{IN} \leq 21\text{ V}$ $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$ $P \leq 15\text{ W}$	5.7		6.3	V
urrent	$T_J = 25^\circ\text{C}$			4.3	8.0	mA
urrent Change	with line	$8\text{ V} \leq V_{IN} \leq 25\text{ V}$			1.3	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$			0.5	mA
Voltage		$T_A = 25^\circ\text{C}, 10\text{ Hz} \leq f \leq 100\text{ kHz}$		45		$\mu\text{V}$
tion		$f = 120\text{ Hz}, 9\text{ V} \leq V_{IN} \leq 19\text{ V}$	59	75		dB
age		$I_{OUT} = 1.0\text{ A}, T_J = 25^\circ\text{C}$		2.0		V
tance		$f = 1\text{ kHz}$		19		m $\Omega$
Current		$T_J = 25^\circ\text{C}, V_{IN} = 35\text{ V}$		550		mA
Current		$T_J = 25^\circ\text{C}$		2.2		A
emperature Coefficient of ge		$I_{OUT} = 5\text{ mA}, 0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		0.8		mV



# FAIRCHILD • $\mu$ A7800 SERIES

## $\mu$ A7808

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 14\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	7.7	8.0	8.3	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$10.5\text{ V} < V_{IN} < 25\text{ V}$		6.0	80	mV
			$11\text{ V} < V_{IN} < 17\text{ V}$		2.0	40	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	100	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	40	mV
Output Voltage		$11.5\text{ V} < V_{IN} < 23\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	7.6		8.4	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.3	6.0	mA	
Quiescent Current Change	with line	$11.5\text{ V} < V_{IN} < 25\text{ V}$			0.8	mA	
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $11.5\text{ V} < V_{IN} < 21.5\text{ V}$	62	72		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0	2.5	V	
Output Resistance		$f = 1\text{ kHz}$		16		$\text{m}\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		0.75	1.2	A	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.2	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$		0.4	$\text{mV}/^{\circ}\text{C}$	
			$+25^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$		0.3	$V_{OUT}$	

## $\mu$ A7808C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 14\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	7.7	8.0	8.3	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$10.5\text{ V} < V_{IN} < 25\text{ V}$		6.0	160	mV
			$11\text{ V} < V_{IN} < 17\text{ V}$		2.0	80	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	160	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	80	mV
Output Voltage		$10.5\text{ V} < V_{IN} < 23\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	7.6		8.4	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.3	8.0	mA	
Quiescent Current Change	with line	$10.5\text{ V} < V_{IN} < 25\text{ V}$			1.0	mA	
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		52		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $11.5\text{ V} < V_{IN} < 21.5\text{ V}$	56	72		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0		V	
Output Resistance		$f = 1\text{ kHz}$		16		$\text{m}\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		450		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.2		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$		-0.8		$\text{mV}/^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7800 SERIES

## $\mu$ A7885

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 15\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^\circ\text{C}$	8.15	8.5	8.85	V
Line Regulation		$T_J = 25^\circ\text{C}$	$10.5\text{ V} < V_{IN} < 25\text{ V}$	6.0	85	mV
			$11\text{ V} < V_{IN} < 17\text{ V}$	2.0	40	mV
Load Regulation		$T_J = 25^\circ\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$	12	85	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$	4.0	40	mV
Output Voltage		$12\text{ V} < V_{IN} < 23.5\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	8.1		8.9	V
Quiescent Current		$T_J = 25^\circ\text{C}$		4.3	6.0	mA
Quiescent Current Change		with line	$11.5\text{ V} < V_{IN} < 25\text{ V}$		0.8	mA
			$5\text{ mA} < I_{OUT} < 1.0\text{ A}$		0.5	mA
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$f = 120\text{ Hz}$ , $11.5\text{ V} < V_{IN} < 21.5\text{ V}$	62	70		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^\circ\text{C}$		2.0	2.5	V
Output Resistance		$f = 1\text{ kHz}$		16		m $\Omega$
Short Circuit Current		$T_J = 25^\circ\text{C}$ , $V_{IN} = 35\text{ V}$		0.75	1.2	A
Peak Output Current		$T_J = 25^\circ\text{C}$	1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^\circ\text{C} < T_J < +25^\circ\text{C}$		0.4	mV/ $^\circ\text{C}$
			$+25^\circ\text{C} < T_J < +150^\circ\text{C}$		0.3	$V_{OUT}$

## $\mu$ A7885C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 15\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $-55^\circ\text{C} < T_J < 150^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^\circ\text{C}$	8.15	8.5	8.85	V
Line Regulation		$T_J = 25^\circ\text{C}$	$10.5\text{ V} < V_{IN} < 25\text{ V}$	6.0	170	mV
			$11\text{ V} < V_{IN} < 17\text{ V}$	2.0	85	mV
Load Regulation		$T_J = 25^\circ\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$	12	170	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$	4.0	85	mV
Output Voltage		$11\text{ V} < V_{IN} < 23.5\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	8.1		8.9	V
Quiescent Current		$T_J = 25^\circ\text{C}$		4.3	8.0	mA
Quiescent Current Change		with line	$10.5\text{ V} < V_{IN} < 25\text{ V}$		1.0	mA
			$5\text{ mA} < I_{OUT} < 1.0\text{ A}$		0.5	mA
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		55		$\mu\text{V}$
Ripple Rejection		$f = 120\text{ Hz}$ , $11.5\text{ V} < V_{IN} < 21.5\text{ V}$	56	70		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^\circ\text{C}$		2.0		V
Output Resistance		$f = 1\text{ kHz}$		16		m $\Omega$
Short Circuit Current		$T_J = 25^\circ\text{C}$ , $V_{IN} = 35\text{ V}$		450		mA
Peak Output Current		$T_J = 25^\circ\text{C}$		2.2		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^\circ\text{C} < T_J < 125^\circ\text{C}$		-0.8		mV/ $^\circ\text{C}$

**NOTE:**  
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7800 SERIES

## $\mu$ A7812

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 19\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	11.5	12.0	12.5	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$14.5\text{ V} < V_{IN} < 30\text{ V}$		10	120	mV
			$16\text{ V} < V_{IN} < 22\text{ V}$		3.0	60	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	120	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	60	mV
Output Voltage		$15.5\text{ V} < V_{IN} < 27\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	11.4		12.6	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.3	6.0	mA	
Quiescent Current Change		with line with load	$15\text{ V} < V_{IN} < 30\text{ V}$		0.8	mA	
			$5\text{ mA} < I_{OUT} < 1.0\text{ A}$		0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $15\text{ V} < V_{IN} < 25\text{ V}$	61	71		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0	2.5	V	
Output Resistance		$f = 1\text{ kHz}$		18		$\text{m}\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		0.75	1.2	A	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.2	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$		0.4	$\text{mV}/^{\circ}\text{C}$	
			$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$		0.3	$V_{OUT}$	

## $\mu$ A7812C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 19\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	11.5	12.0	12.5	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$14.5\text{ V} < V_{IN} < 30\text{ V}$		10	240	mV
			$16\text{ V} < V_{IN} < 22\text{ V}$		3.0	120	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	240	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	120	mV
Output Voltage		$14.5\text{ V} < V_{IN} < 27\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	11.4		12.6	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.3	8.0	mA	
Quiescent Current Change		with line with load	$14.5\text{ V} < V_{IN} < 30\text{ V}$		1.0	mA	
			$5\text{ mA} < I_{OUT} < 1.0\text{ A}$		0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		75		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $15 < V_{IN} < 25\text{ V}$	55	71		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0		V	
Output Resistance		$f = 1\text{ kHz}$		18		$\text{m}\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		350		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.2		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$		-1.0		$\text{mV}/^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7800 SERIES

## $\mu$ A7815

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 23$  V,  $I_{OUT} = 500$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	14.4	15.0	15.6	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$17.5\text{ V} < V_{IN} < 30\text{ V}$		11	150	mV
			$20\text{ V} < V_{IN} < 26\text{ V}$		3	75	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	150	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4	75	mV
Output Voltage		$18.5\text{ V} < V_{IN} < 30\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	14.25		15.75	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.4	6.0	mA	
Quiescent Current Change		with line	$18.5\text{ V} < V_{IN} < 30\text{ V}$			0.8	mA
		with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $18.5\text{ V} < V_{IN} < 28.5\text{ V}$	60	70		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0	2.5	V	
Output Resistance		$f = 1\text{ kHz}$		19		$\text{m}\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		0.75		A	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.2	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	$\text{mV}/^{\circ}\text{C}$
			$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A7815C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 23$  V,  $I_{OUT} = 500$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	14.4	15.0	15.6	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$17.5\text{ V} < V_{IN} < 30\text{ V}$		11	300	mV
			$20\text{ V} < V_{IN} < 26\text{ V}$		3	150	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	300	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4	150	mV
Output Voltage		$17.5\text{ V} < V_{IN} < 30\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	14.25		15.75	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.4	8.0	mA	
Quiescent Current Change		with line	$17.5\text{ V} < V_{IN} < 30\text{ V}$			1.0	mA
		with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		90		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $18.5\text{ V} < V_{IN} < 28.5\text{ V}$	54	70		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0		V	
Output Resistance		$f = 1\text{ kHz}$		19		$\text{m}\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		230		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.1		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$		-1.0		$\text{mV}/^{\circ}\text{C}$	

**NOTE:**

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7800 SERIES

## $\mu$ A7818

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 27\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	17.3	18.0	18.7	V
Line Regulation		$T_J = 25^{\circ}\text{C}$	$21\text{ V} < V_{IN} < 33\text{ V}$	15	180	mV
			$24\text{ V} < V_{IN} < 30\text{ V}$	5.0	90	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$	12	180	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$	4.0	90	mV
Output Voltage		$22\text{ V} < V_{IN} < 33\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	17.1		18.9	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.5	6.0	mA
Quiescent Current Change	with line	$22\text{ V} < V_{IN} < 33\text{ V}$			0.8	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$f = 120\text{ Hz}$ , $22\text{ V} < V_{IN} < 32\text{ V}$	59	69		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0		V
Output Resistance		$f = 1\text{ kHz}$		22	2.5	$\text{m}\Omega$
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		0.75	1.2	A
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$		0.4	$\text{mV}/^{\circ}\text{C}/V_{OUT}$
			$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$		0.3	$V_{OUT}$

## $\mu$ A7818C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 27\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	17.3	18.0	18.7	V
Line Regulation		$T_J = 25^{\circ}\text{C}$	$21\text{ V} < V_{IN} < 33\text{ V}$	15	360	mV
			$24\text{ V} < V_{IN} < 30\text{ V}$	5.0	180	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$	12	360	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$	4.0	180	mV
Output Voltage		$21\text{ V} < V_{IN} < 33\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	17.1		18.9	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.5	8.0	mA
Quiescent Current Change	with line	$21\text{ V} < V_{IN} < 33\text{ V}$			1.0	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		110		$\mu\text{V}$
Ripple Rejection		$f = 120\text{ Hz}$ , $22\text{ V} < V_{IN} < 32\text{ V}$	53	69		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0		V
Output Resistance		$f = 1\text{ kHz}$		22		$\text{m}\Omega$
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		200		mA
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$		-1.0		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7800 SERIES

## $\mu$ A7824

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 33$  V,  $I_{OUT} = 500$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	23.0	24.0	25.0	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$27\text{ V} < V_{IN} < 38\text{ V}$		18	240	mV
			$30\text{ V} < V_{IN} < 36\text{ V}$		6	120	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	240	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4	120	mV
Output Voltage		$28\text{ V} < V_{IN} < 38\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	22.8		25.2	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.6	6.0	mA	
Quiescent Current Change		$28\text{ V} < V_{IN} < 38\text{ V}$	with line			0.8	mA
			with load			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		8	40	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $28\text{ V} < V_{IN} < 38\text{ V}$	56	66		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0	2.5	V	
Output Resistance		$f = 1\text{ kHz}$		28		m $\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		0.75	1.2	A	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.2	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$	$-55^{\circ}\text{C} < T_J < +25^{\circ}\text{C}$			0.4	mV/ $^{\circ}\text{C}$
			$+25^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$V_{OUT}$

## $\mu$ A7824C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 33$  V,  $I_{OUT} = 500$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 0.33$   $\mu$ F,  $C_{OUT} = 0.1$   $\mu$ F,  
unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	23.0	24.0	25.0	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$27\text{ V} < V_{IN} < 38\text{ V}$		18	480	mV
			$30\text{ V} < V_{IN} < 36\text{ V}$		6	240	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	480	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4	240	mV
Output Voltage		$27\text{ V} < V_{IN} < 38\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 15\text{ W}$	22.8		25.2	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		4.6	8.0	mA	
Quiescent Current Change		$27\text{ V} < V_{IN} < 38\text{ V}$	with line			1.0	mA
			with load			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		170		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $28\text{ V} < V_{IN} < 38\text{ V}$	50	66		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		2.0		V	
Output Resistance		$f = 1\text{ kHz}$		28		m $\Omega$	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = 35\text{ V}$		150		mA	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.1		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$		-1.5		mV/ $^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7800 SERIES

## DESIGN CONSIDERATIONS

The  $\mu$ A7800 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the regulator's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 7800, 125°C for 7800C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	Typ $\theta_{JC}$	Max $\theta_{JC}$	Typ $\theta_{JA}$	Max $\theta_{JA}$
TO-3	3.5	5.5	40	45
TO-220	3.0	5.0	60	65

$$P_D(\text{MAX}) = \frac{T_J(\text{MAX}) - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_J(\text{MAX}) - T_A}{\theta_{JA}} \quad (\text{Without a heat sink})$$

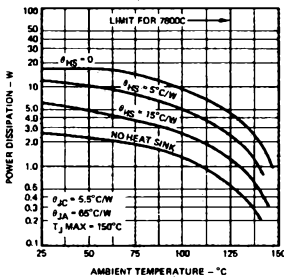
$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

solving for  $T_J$ :  $T_J = T_A + P_D (\theta_{JC} + \theta_{CA})$  or  $T_A + P_D \theta_{JA}$  (without a heat sink)

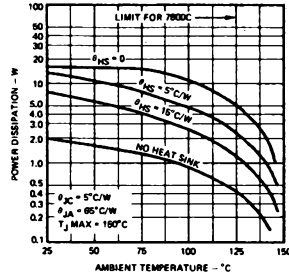
where  $T_J$  = Junction Temperature  
 $T_A$  = Ambient Temperature  
 $P_D$  = Power Dissipation

$\theta_{JC}$  = Junction to case thermal resistance  
 $\theta_{CA}$  = Case to ambient thermal resistance  
 $\theta_{CS}$  = Case to heat sink to resistance  
 $\theta_{SA}$  = Heat sink to ambient thermal resistance  
 $\theta_{JA}$  = Junction to ambient thermal resistance

**WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-3)**

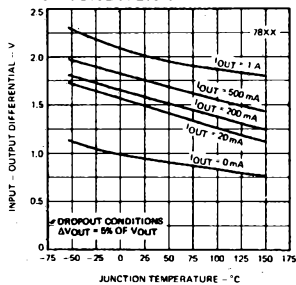


**WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-220)**

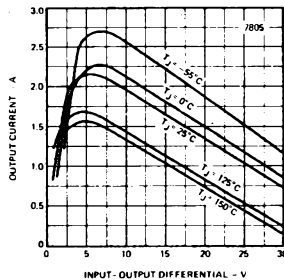


## TYPICAL PERFORMANCE CURVES

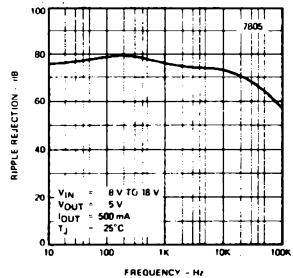
**DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE**



**PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT/OUTPUT DIFFERENTIAL VOLTAGE**

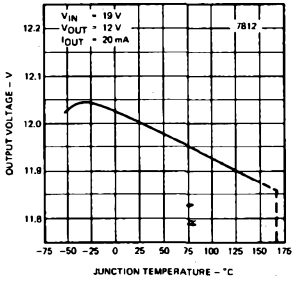


**RIPPLE REJECTION AS A FUNCTION OF FREQUENCY**

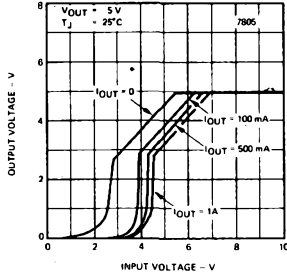


TYPICAL PERFORMANCE CURVES (Cont'd)

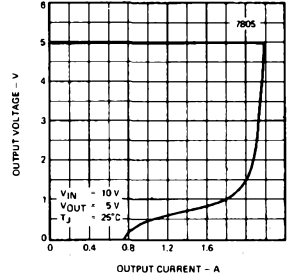
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



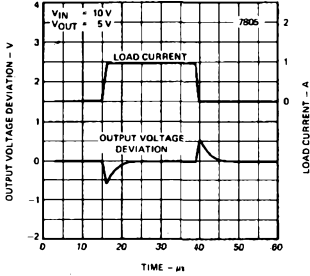
DROPOUT CHARACTERISTICS



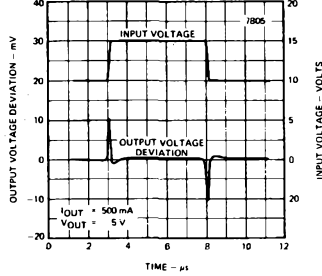
CURRENT LIMITING CHARACTERISTICS



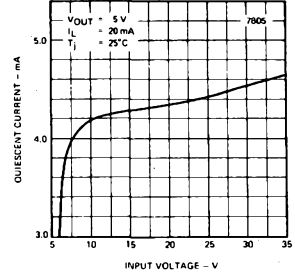
LOAD TRANSIENT RESPONSE



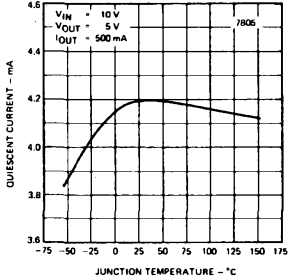
LINE TRANSIENT RESPONSE



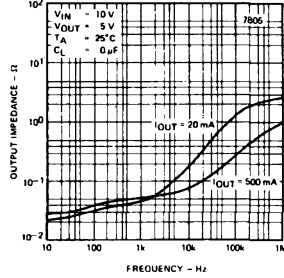
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

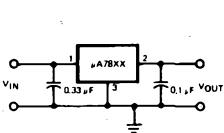


OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY

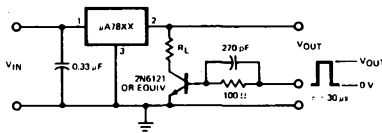


Note: The other  $\mu$ A7800 series devices have similar curves.

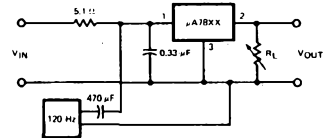
EQUIVALENT TEST CIRCUITS



DC PARAMETER TEST CIRCUIT



LOAD REGULATION TEST CIRCUIT

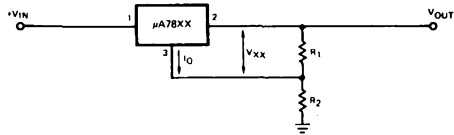
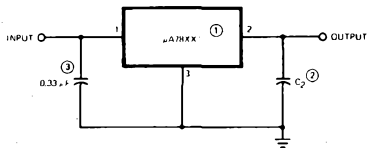


RIPPLE REJECTION TEST CIRCUIT



# FAIRCHILD • $\mu$ A7800 SERIES

## TYPICAL APPLICATIONS



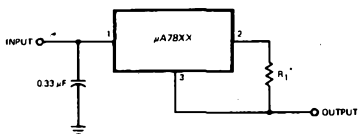
### NOTES:

- ① To specify an output voltage, substitute voltage value for "XX".
- ② Although no output capacitor is needed for stability, it does improve transient response.
- ③ Required if regulator is located an appreciable distance from power supply filter.

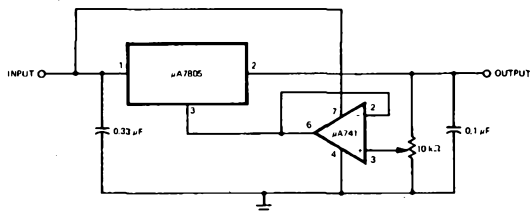
$$V_{OUT} = V_{XX} \left( 1 + \frac{R_2}{R_1} \right) + I_{O} R_2$$

### FIXED OUTPUT REGULATOR

### CIRCUIT FOR INCREASING OUTPUT VOLTAGE

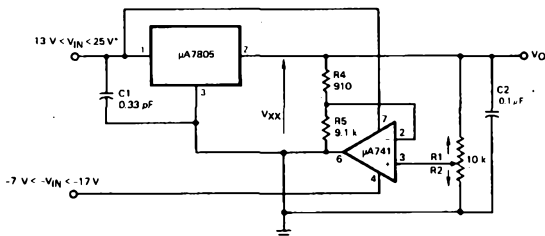


$$\text{Output Current} = \frac{V_{OUT}}{R_1}$$

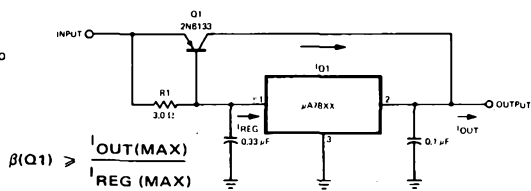


### CURRENT REGULATOR

### ADJUSTABLE OUTPUT REGULATOR, 7 to 30 VOLTS



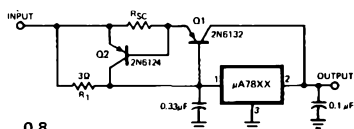
### 0.5 TO 10 V REGULATOR



$$\beta(Q1) \geq \frac{I_{OUT(MAX)}}{I_{REG(MAX)}}$$

$$R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1) V_{BE}(Q1)}{I_{REG(MAX)} (\beta+1) - I_{OUT(MAX)}}$$

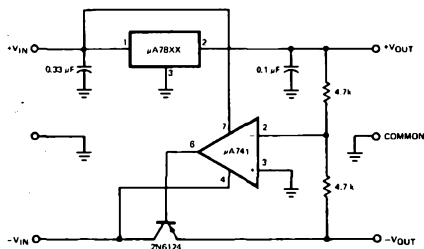
### HIGH CURRENT VOLTAGE REGULATOR



$$R_{SC} = \frac{0.8}{I_{SC}}$$

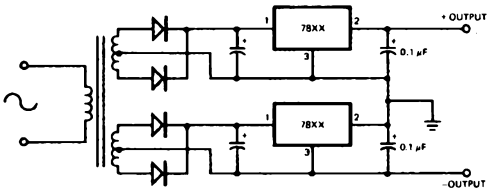
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REG(MAX)} (\beta+1) - I_{OUT(MAX)}}$$

### HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

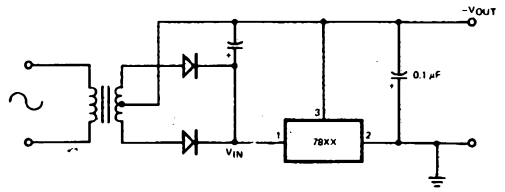


### ± TRACKING VOLTAGE REGULATOR

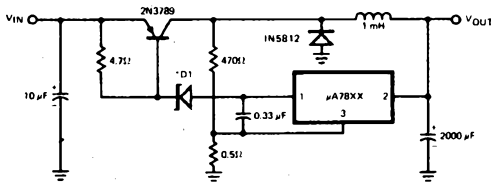
TYPICAL APPLICATIONS (Cont'd)



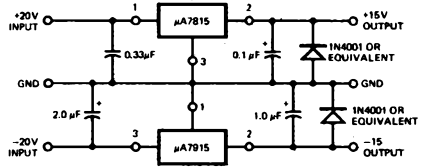
POSITIVE AND NEGATIVE REGULATOR



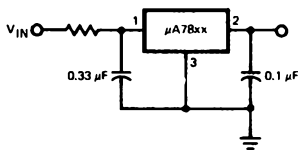
NEGATIVE OUTPUT VOLTAGE CIRCUIT



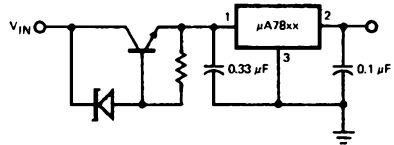
SWITCHING REGULATOR



DUAL SUPPLY  
OPERATIONAL AMPLIFIER SUPPLY ( $\pm 15$  V @ 1.0 A)



HIGH INPUT VOLTAGE CIRCUITS



# μA109 • μA209

## 5 VOLT REGULATOR

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

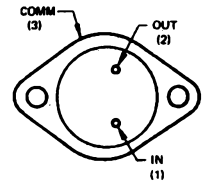
**GENERAL DESCRIPTION** — The 109 and 209 are complete Five Volt Regulators constructed using the Fairchild Planar\* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe-area compensation making them essentially indestructible. They are intended for use as local regulators, eliminating noise and distribution problems associated with single point regulation. If adequate heat sinking is provided, they can provide over 1A output current. The 109 and 209 are intended primarily for use with TTL and DTL logic and are completely specified under worst case conditions to match the power supply requirements of these logic families. In addition to use as a fixed 5 V regulator, these devices can be used with external components to obtain adjustable output voltages and currents and as the power pass element in precision regulators.

- OUTPUT CURRENT IN EXCESS OF 1 A
- SPECIFIED TO MATCH WORST CASE TTL AND DTL REQUIREMENTS
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- OUTPUT TRANSISTOR SAFE-AREA COMPENSATION

**ABSOLUTE MAXIMUM RATINGS**

Input Voltage	35 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	-65° C to +150° C
Operating Junction Temperature Range	
Military Grade (μA109)	-55° C to +150° C
Industrial Grade (μA209)	-25° C to +150° C
Lead Temperature (Soldering, 60 seconds)	300° C

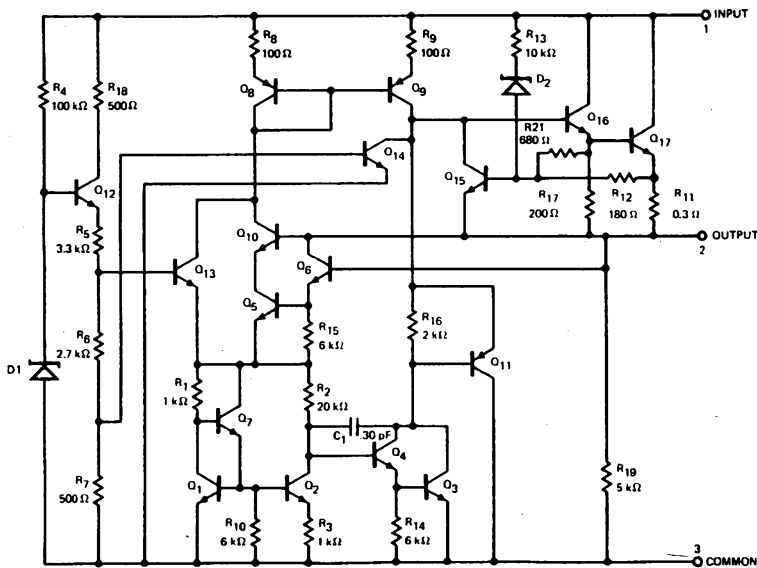
**CONNECTION DIAGRAM  
TO-3 PACKAGE  
(TOP VIEW)**



Case is connected to ground.

<b>ORDER INFORMATION</b>	
<b>TYPE</b>	<b>PART NO.</b>
μA109	μA109KM
μA209	μA209KM

**EQUIVALENT CIRCUIT**



\*Planar is a patented Fairchild process.

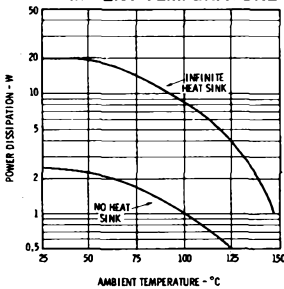
ELECTRICAL CHARACTERISTICS:  $T_J = -55^\circ\text{C}$  to  $+150^\circ\text{C}$  for 109,  $-25^\circ\text{C}$  to  $+150^\circ\text{C}$  for 209,  $V_{IN} = 10\text{ V}$ ,  $I_{OUT} = 0.5\text{ A}$ , unless otherwise specified

CHARACTERISTICS		CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^\circ\text{C}$	4.7	5.05	5.3	V
Line Regulation		$T_J = 25^\circ\text{C}$ , $7\text{ V} < V_{IN} < 25\text{ V}$		4	50	mV
Load Regulation		$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_{OUT} < 1.5\text{ A}$		15	100	mV
Output Voltage		$8\text{ V} < V_{IN} < 20\text{ V}$ , $5\text{ mA} < I_{OUT} < 1\text{ A}$ , $P < 15\text{ W}$	4.6		5.4	V
Quiescent Current		$7\text{ V} < V_{IN} < 25\text{ V}$			10	mA
			$T_J = 25^\circ\text{C}$		4.2	mA
Quiescent Current Change	with Line	$8\text{ V} < V_{IN} < 25\text{ V}$			0.8	mA
	with Load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		40		$\mu\text{V}$
Long Term Stability					10	mV
Thermal Resistance Junction to Case (Note 1)				3.0		$^\circ\text{C/W}$

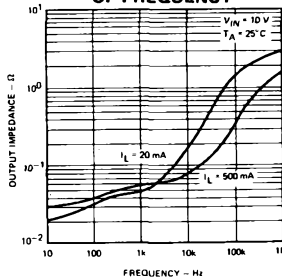
NOTE1: Without a heat sink, the thermal resistance is  $\theta_{JA(max)}$   $45^\circ\text{C/W}$ . With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

TYPICAL PERFORMANCE CURVES FOR  $\mu$ A109 AND  $\mu$ A209

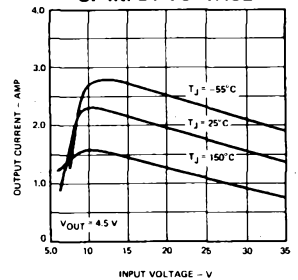
MAXIMUM AVERAGE POWER DISSIPATION AS A FUNCTION OF AMBIENT TEMPERATURE



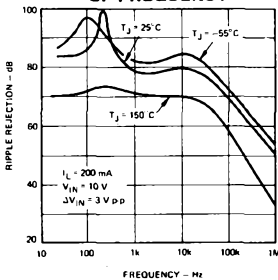
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



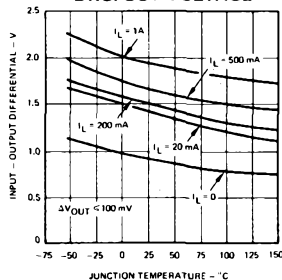
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT VOLTAGE



RIPPLE REJECTION AS A FUNCTION OF FREQUENCY

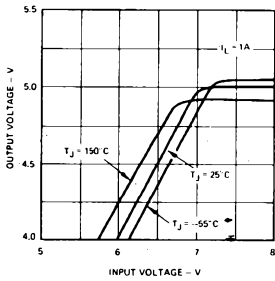


DROPOUT VOLTAGE

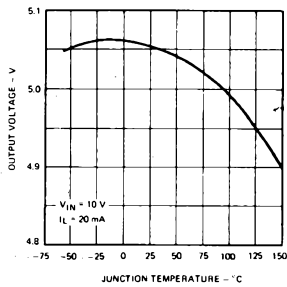


TYPICAL PERFORMANCE CURVES FOR  $\mu A109$  AND  $\mu A209$  (Cont'd)

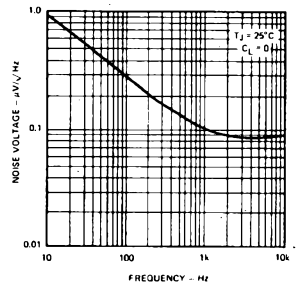
DROPOUT CHARACTERISTIC



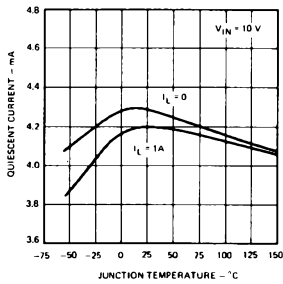
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



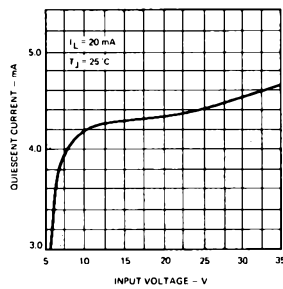
OUTPUT NOISE VOLTAGE AS A FUNCTION OF FREQUENCY



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

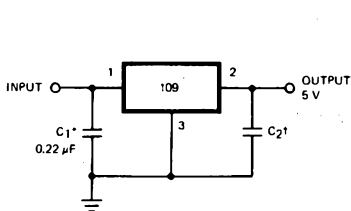


QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



APPLICATIONS

FIXED 5 V REGULATOR

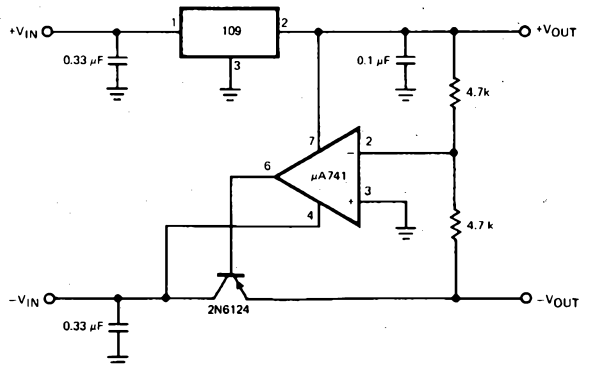


NOTES:

\*Required if regulator is located an appreciable distance from power supply filter.

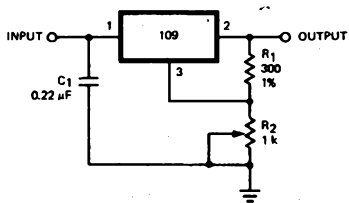
†Although no output capacitor is needed for stability, it does improve transient response.

TRACKING VOLTAGE REGULATOR

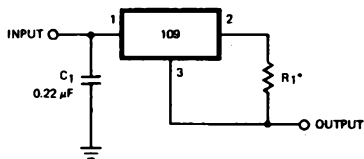


APPLICATIONS (Cont'd)

ADJUSTABLE OUTPUT REGULATOR

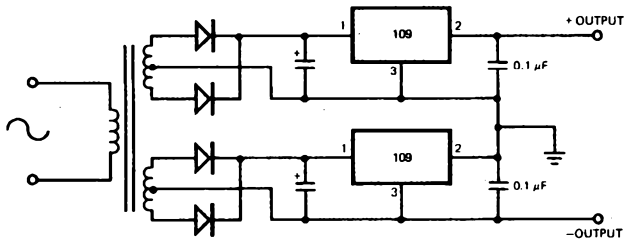


CURRENT REGULATOR



NOTE: \*Determines output current.

POSITIVE AND NEGATIVE REGULATOR



# μA309

## 5 VOLT REGULATOR

### FAIRCHILD LINEAR INTEGRATED CIRCUIT

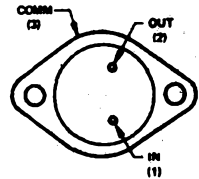
**GENERAL DESCRIPTION** — The μ309 is a monolithic 5 Volt Regulator constructed using the Fairchild Planar\* epitaxial process. This regulator employs internal current limiting, thermal shutdown and safe-area compensation making it essentially indestructible. The 309 is intended for use as a local regulator, eliminating noise and distribution problems associated with single point regulation. If adequate heat sinking is provided, it can provide over 1A output current. The 309 is intended primarily for use with TTL and DTL logic and is completely specified under worst case conditions to match the power supply requirements of these logic families. In addition to use as a fixed 5 volt regulator, this device can be used with external components to obtain adjustable output voltages and currents and as the power pass element in precision regulators.

- OUTPUT CURRENT IN EXCESS OF 1 AMP
- SPECIFIED TO MATCH WORST CASE TTL AND DTL REQUIREMENTS
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- OUTPUT TRANSISTOR SAFE-AREA COMPENSATION
- INTERNAL SHORT CIRCUIT LIMITING

**ABSOLUTE MAXIMUM RATINGS**

Input Voltage	35 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	-65°C to +150°C
Operating Junction Temperature Range	0°C to +125°C
Lead Temperature (Soldering, 60 s time limit)	300°C

**CONNECTION DIAGRAM**  
T-O-3 PACKAGE  
(TOP VIEW)

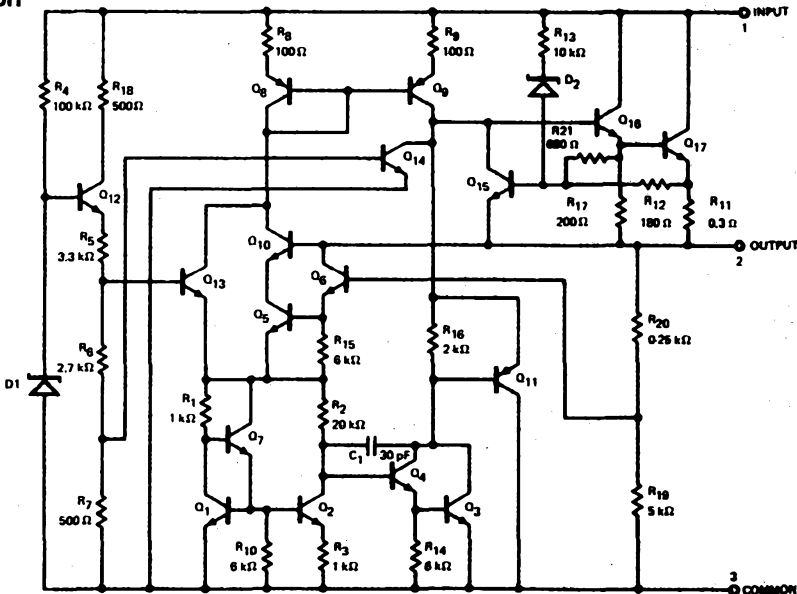


Case is connected to ground.

**ORDER INFORMATION**

<b>TYPE</b>	<b>PART NO.</b>
μA309	μA309KC

**EQUIVALENT CIRCUIT**



\*Planar is a patented Fairchild process.

# FAIRCHILD • $\mu$ A309

## ELECTRICAL CHARACTERISTICS: Note 1

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^\circ\text{C}$	4.8	5.05	5.2	V
Line Regulation	$T_J = 25^\circ\text{C}$ $7.0\text{ V} < V_{IN} < 25\text{ V}$		4.0	50	mV
Load Regulation	$T_J = 25^\circ\text{C}$ $5.0\text{ mA} < I_{OUT} < 1.5\text{ A}$		50	100	mV
Output Voltage	$7.0\text{ V} < V_{IN} < 25\text{ V}$ $5.0\text{ mA} < I_{OUT} < 1.0\text{ A}$ $P < 20\text{ W}$	4.75		5.25	V
Quiescent Current	$7.0\text{ V} < V_{IN} < 25\text{ V}$		5.2	10	mA
Quiescent Current Change	with line			0.5	mA
	with load			0.8	mA
Output Noise Voltage	$T_A = 25^\circ\text{C}$ $10\text{ Hz} < f < 100\text{ kHz}$		40		$\mu\text{V}$
Long Term Stability				20	mV

**NOTE:**

1. Unless otherwise specified, these specifications apply for  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $V_{IN} = 10\text{ V}$  and  $I_{OUT} = 0.5\text{ A}$ .

### DESIGN CONSIDERATIONS

$\mu$ A309 regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature ( $125^\circ\text{C}$ ) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP $\theta_{JC}$	MAX $\theta_{JC}$	TYP $\theta_{JA}$	MAX $\theta_{JA}$
TO-3	$3.5^\circ\text{C/W}$	$5.5^\circ\text{C/W}$	$40^\circ\text{C/W}$	$45^\circ\text{C/W}$

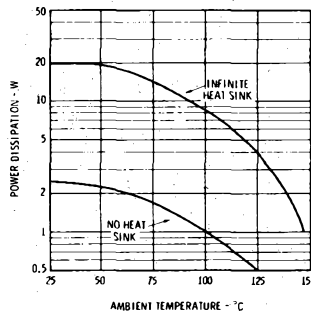
$$P_D(\text{MAX}) = \frac{T_J(\text{MAX}) - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_J(\text{MAX}) - T_A}{\theta_{JA}} \quad (\text{Without a heat sink})$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

$$\text{Solving for } T_J: \quad T_J = T_A + P_D(\theta_{JC} + \theta_{CA}) \quad \text{or} \quad T_A + P_D\theta_{JA} \quad (\text{Without heat sink})$$

Where $T_J$ = Junction Temperature	$\theta_{JC}$ = Junction to case thermal resistance
$T_A$ = Ambient Temperature	$\theta_{CA}$ = Case to ambient thermal resistance
$P_D$ = Power Dissipation	$\theta_{CS}$ = Case to ambient thermal resistance
$\theta_{JA}$ = Junction to ambient thermal resistance	$\theta_{SA}$ = Heat sink to ambient thermal resistance

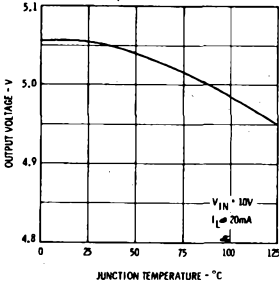
### TO-3 PACKAGE MAXIMUM AVERAGE POWER DISSIPATION



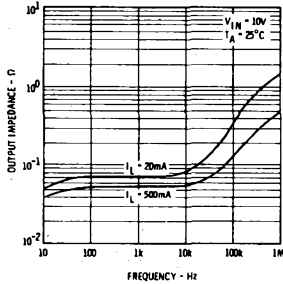


TYPICAL PERFORMANCE CURVES

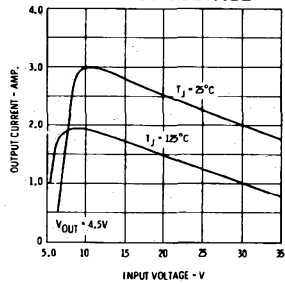
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



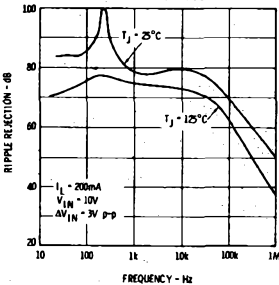
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



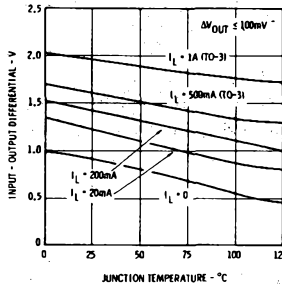
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT VOLTAGE



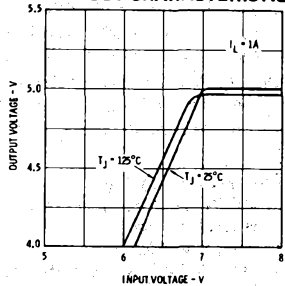
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



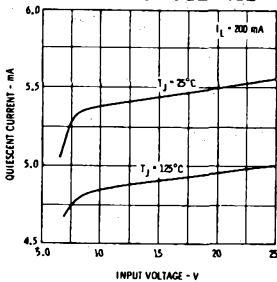
DROPOUT VOLTAGE



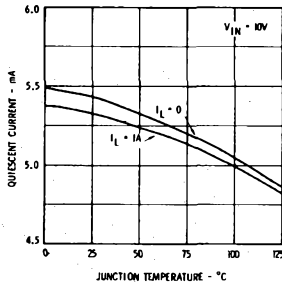
DROPOUT CHARACTERISTIC



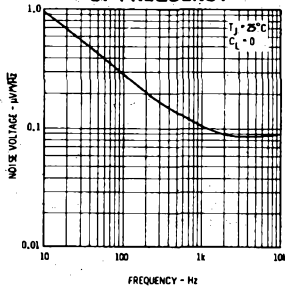
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF JUNCTION TEMPERATURE

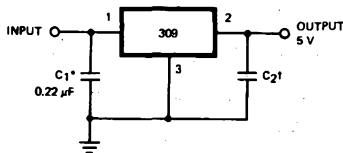


OUTPUT NOISE VOLTAGE AS A FUNCTION OF FREQUENCY



APPLICATIONS

FIXED 5 V REGULATOR

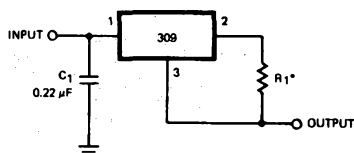


NOTES:

\*Required if regulator is located an appreciable distance from power supply filter.

†Although no output capacitor is needed for stability, it does improve transient response.

CURRENT REGULATOR



NOTES:

\*Determines output current.

# μA78CB

## POSITIVE 13.8 V, 2 AMP VOLTAGE REGULATOR

FAIRCHILD LINEAR INTEGRATED CIRCUITS

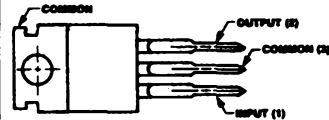
**GENERAL DESCRIPTION** - The μA78CB is a monolithic 3-Terminal Positive Regulator with a 13.8 V nominal output voltage. With adequate heat sinking, it can deliver output current in excess of 2.0 A. Just like its predecessors, the industry standard μA7800 series of regulators, the μA78CB employs current limiting, thermal shutdown and safe area protection and is essentially indestructible. The device is intended as a fixed voltage regulator for home base CB stations, and power supplies for driving automotive accessories directly from the AC line through a transformer, a fullwave rectifier and a filter capacitor. In addition to use as a fixed voltage regulator, the μA78CB can be used with external components to obtain adjustable output voltages and/or increased output currents.

- OUTPUT VOLTAGE OF 13.8 V
- OUTPUT CURRENT IN EXCESS OF 2 A
- 20 W POWER DISSIPATION
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- OUTPUT TRANSISTOR SAFE AREA COMPENSATION
- AVAILABLE IN THE TO-220 AND THE TO-3 PACKAGE

### ABSOLUTE MAXIMUM RATINGS

Input Voltage	35 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	-65°C to +150°C
Operating Junction Temperature Range	0°C to +150°C
Lead Temperature	
(Soldering, 60 s time limit) TO-3 Package	300°C
(Soldering, 10 s time limit) TO-220 Package	230°C

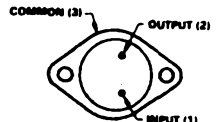
### CONNECTION DIAGRAMS TO-220 PACKAGE (SIDE VIEW)



### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
13.8 V	μA78CB	μA78CBUC

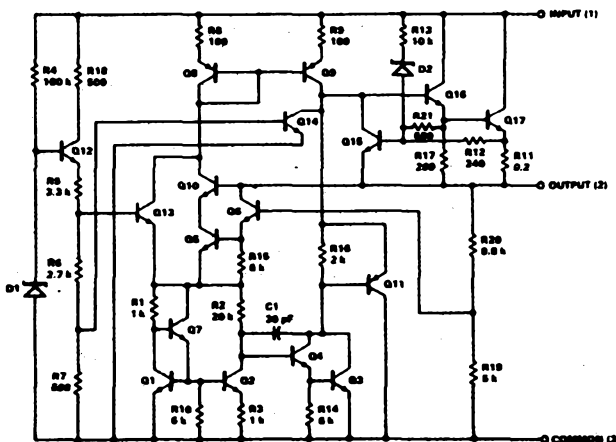
### TO-3 PACKAGE (TOP VIEW)



### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
13.8 V	μA78CB	μA78CBKC

### EQUIVALENT CIRCUIT



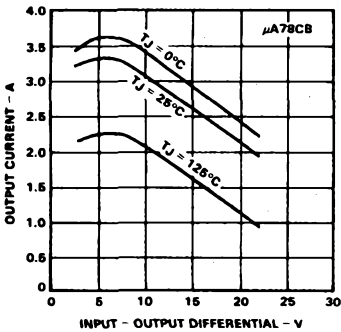
# FAIRCHILD • $\mu$ A78CB

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 19\text{ V}$ ,  $I_{OUT} = 1.0\text{ A}$ ,  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ ,  $C_{IN} = 0.33\ \mu\text{F}$ ,  $C_{OUT} = 0.1\ \mu\text{F}$ ,  
unless otherwise specified

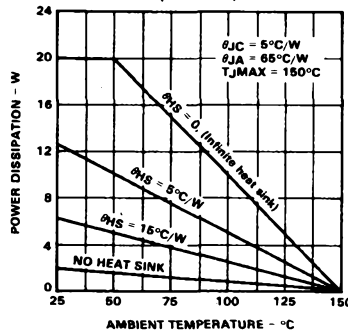
CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS	
Output Voltage	$T_J = 25^\circ\text{C}$	13.25	13.8	14.35	V	
Line Regulation	$T_J = 25^\circ\text{C}$ , $17\text{ V} \leq V_{IN} \leq 25\text{ V}$		8	150	mV	
Load Regulation	$T_J = 25^\circ\text{C}$	$5\text{ mA} \leq I_{OUT} \leq 2.0\text{ A}$		50	150	mV
				25	100	mV
Output Voltage	$17\text{ V} \leq V_{IN} \leq 23\text{ V}$ $5\text{ mA} \leq I_{OUT} \leq 2.0\text{ A}$	13.1		14.5	V	
Quiescent Current	$T_J = 25^\circ\text{C}$		4.3	8.0	mA	
Quiescent Current Change	with line	$17\text{ V} \leq V_{IN} \leq 25\text{ V}$		1.0	mA	
	with load	$5\text{ mA} \leq I_{OUT} \leq 2.0\text{ A}$		1.5	mA	
Output Noise Voltage	$T_A = 25^\circ\text{C}$ , $10\text{ Hz} \leq f \leq 100\text{ kHz}$		75		$\mu\text{V}$	
Ripple Rejection	$f = 120\text{ Hz}$ , $17 \leq V_{IN} \leq 22\text{ V}$	50	71		dB	
Dropout Voltage	$I_{OUT} = 2.0\text{ A}$ , $T_J = 25^\circ\text{C}$		2.5		V	
Short Circuit Current	$T_J = 25^\circ\text{C}$		2.2		A	
Peak Output Current	$T_J = 25^\circ\text{C}$		3.3		A	
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$ , $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		-1.0		mV/ $^\circ\text{C}$	

## TYPICAL PERFORMANCE CURVES

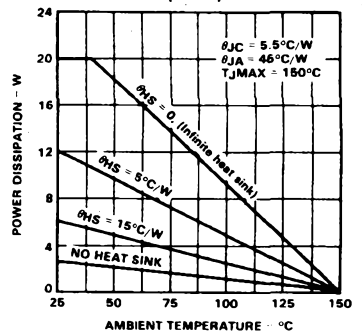
**PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT/OUTPUT DIFFERENTIAL VOLTAGE**



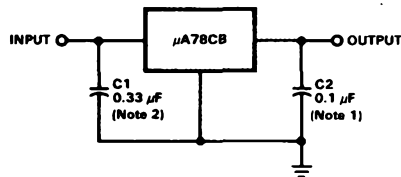
**WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-220)**



**WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-3)**



## TYPICAL APPLICATIONS

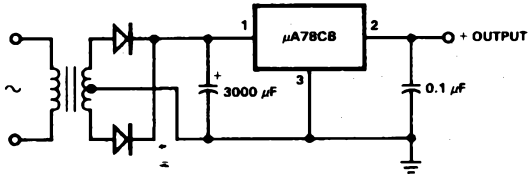


**NOTES:**

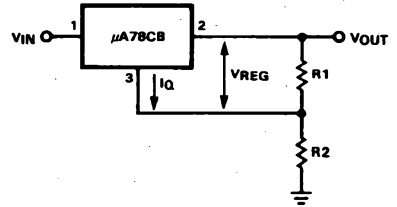
1. Although no output capacitor is needed for stability, it does improve transient response.
2.  $C_1$  required if regulator is located an appreciable distance from power supply filter.

### FIXED OUTPUT REGULATOR

TYPICAL APPLICATIONS (Cont'd)

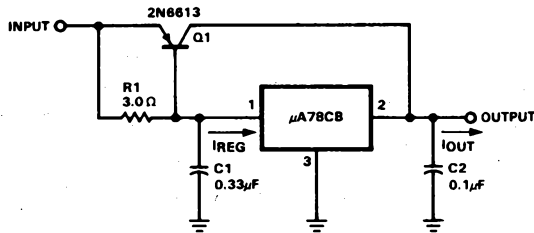


BASIC REGULATED POWER SUPPLY FOR  
CB HOME BASE STATIONS



$$V_{OUT} = V_{REG} \left(1 + \frac{R_2}{R_1}\right) + I_Q R_2$$

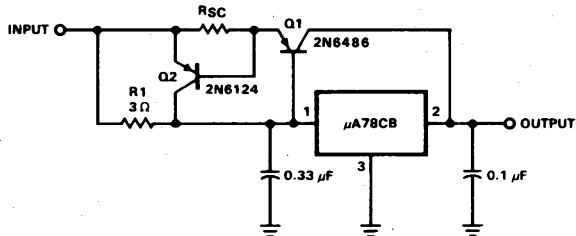
CIRCUIT FOR INCREASING OUTPUT VOLTAGE



$$I_{OUT(MAX)} > \beta(Q1) \times 2$$

$$R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1) V_{BE}(Q1)}{I_{REG(MAX)} (\beta + 1) - I_{OUT(MAX)}}$$

HIGH CURRENT VOLTAGE REGULATOR



$$R_{SC} = \frac{0.9}{I_{SC}}$$

$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REG(MAX)} (\beta + 1) - I_{OUT(MAX)}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

**DESIGN CONSIDERATIONS** – The  $\mu$ A78CB voltage regulator has thermal overload protection from excessive power, internal short circuit protection which limits the regulator's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature of 125°C in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP	MAX	TYP	MAX
	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JA}$	$\theta_{JA}$
TO-3	3.5	5.5	40	45
TO-220	3.0	5.0	60	65

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_{J(MAX)} - T_A(\text{Without a heat sink})}{\theta_{JA}}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

solving for  $T_J$ :  $T_J = T_A + P_D(\theta_{JC} + \theta_{CA})$  or  $T_A + P_D\theta_{JA}$  (without a heat sink)

where  $T_J$  = Junction Temperature       $\theta_{JC}$  = Junction to case thermal resistance  
 $T_A$  = Ambient Temperature           $\theta_{CA}$  = Case to ambient thermal resistance  
 $P_D$  = Power Dissipation               $\theta_{CS}$  = Case to heat sink thermal resistance  
     $\theta_{SA}$  = Heat sink to ambient thermal resistance  
     $\theta_{JA}$  = Junction to ambient thermal resistance

# SH123 • SH223 • SH323

## 3-TERMINAL VOLTAGE REGULATORS

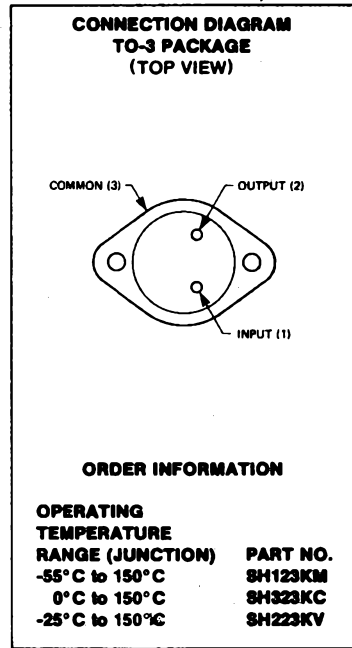
### FAIRCHILD HYBRID PRODUCTS

**GENERAL DESCRIPTION** — The SH123/SH223/SH323 are hybrid integrated circuit positive voltage regulators. The output voltage is  $5\text{ V} \pm 200\text{ mV}$  and the output current capability exceeds 3.0 A. Internal current limiting and thermal shutdown circuitry make the device essentially indestructible. The SH123/SH223/SH323 are intended for a wide range of systems where a regulated 5 V supply is required and can be used for a variety of on-card regulation and circuit isolation applications.

- 3 A OUTPUT CURRENT
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- STANDARD TO-3 PACKAGE

#### ABSOLUTE MAXIMUM RATINGS (SH323)

Input Voltage	25 V
Internal Power Dissipation	50 W @ 25°C Case
Operating Junction Temperature Range	0°C to +150°C
Storage Temperature	-55°C to +150°C

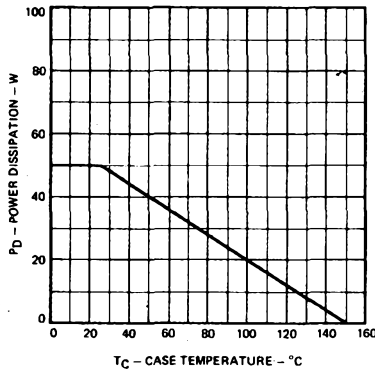


**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 10\text{ V}$ ,  $I_{OUT} = 2.0\text{ A}$ ,  $T_C = 25^\circ\text{C}$ , unless otherwise specified

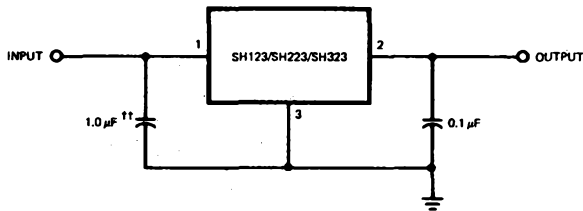
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	$V_{IN} = 10\text{ V}$ , $I_{OUT} = 2.0\text{ A}$ , $T_C = 25^\circ\text{C}$	4.8	5.0	5.2	V
Line Regulation	$8.5\text{ V} < V_{IN} < 20\text{ V}$		10	50	mV
Load Regulation	$10\text{ mA} < I_{OUT} < 3.0\text{ A}$			50	mV
Quiescent Current	$I_{OUT} = 0\text{ A}$			10	mA
Input Voltage	$10\text{ mA} < I_{OUT} < 3.0\text{ A}^*$	8.5		25	V
Ripple Rejection	$f = 120\text{ Hz}$ , $I_{OUT} = 1.0\text{ A}$	60			dB

\*Maximum power dissipation must be observed. (See Maximum Power Dissipation graph.)

MAXIMUM POWER DISSIPATION



TYPICAL APPLICATION



†† Required if regulator is located an appreciable distance from power supply filter.

# μA78H00/μA78HG SERIES

## 5 AMP VOLTAGE REGULATOR

FAIRCHILD LINEAR INTEGRATED CIRCUITS

### GENERAL DESCRIPTION

**Fixed Output** – The μA78H00 series hybrids are regulators with fixed output voltages and 5 A output current capability with all the inherent characteristics of the monolithic 3-terminal regulators, i.e., full thermal overload, short-circuit and safe-area protection. The μA78H00 is packaged in a hermetically sealed TO-3 providing 50 W power dissipation. The regulator consists of a monolithic chip driving a discrete series-pass element and two short-circuit detection transistors. A beryllium-oxide substrate is used in conjunction with an isothermal layout to optimize the thermal characteristics of the device and still maintain electrical isolation between the various chips. This unique circuit design limits the maximum junction temperature of the power output transistor to provide full automatic thermal overload protection. If the safe operating area is ever exceeded, the device simply shuts down, rather than failing or damaging other system components. This feature eliminates the need to design costly output circuitry and overly conservative heat sinking arrangements typical of high-current regulators built from discrete components.

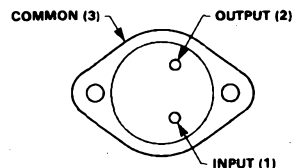
**Adjustable Regulators** – The μA78HG is an adjustable 4-terminal positive voltage regulator capable of supplying in excess of 5 A over a 5.0 V to 24 V output range. The same features and construction details of the μA78H00 series have been incorporated into the μA78HG. Only two (2) external resistors are required to set the output voltage. Input and output capacitors should be used to improve input filtering and transient response.

- 5 A OUTPUT CURRENT
- INTERNAL CURRENT AND THERMAL LIMITING
- INTERNAL SHORT-CIRCUIT CURRENT LIMIT
- LOW DROP-OUT VOLTAGE
- 50 W POWER DISSIPATION

### ABSOLUTE MAXIMUM RATINGS

Input Voltage		
μA78H05, 12, 15		25 V
μA78HG		40 V
Internal Power Dissipation		50 W @ 25°C Case
Maximum Input-to-Output Voltage Differential		25 V
Operating Junction Temperature Range		
μA78H00C (fixed voltage series)		-0°C to 150°C
μA78HGC (adjustable voltage series)		-0°C to 150°C
Military Temperature Range (consult factory)		-55°C to 150°C
Storage Temperature Range		-55°C to 150°C
Lead Temperature (Soldering, 60 s)		300°C

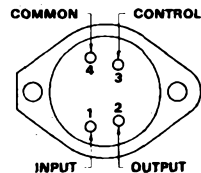
### CONNECTION DIAGRAMS TO-3 PACKAGE (TOP VIEW)



### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5.0 V	78H05C	μA78H05KC
12 V	78H12C	μA78H12KC
15 V	78H15C	μA78H15KC

### TO-3 PACKAGE (TOP VIEW)



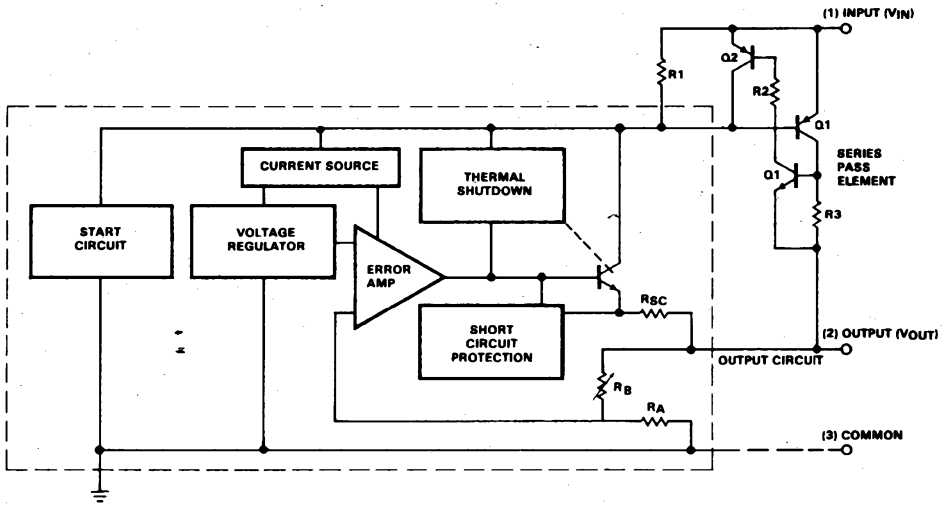
### ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5–24 V Adjustable	78HGC	μA78HGKC

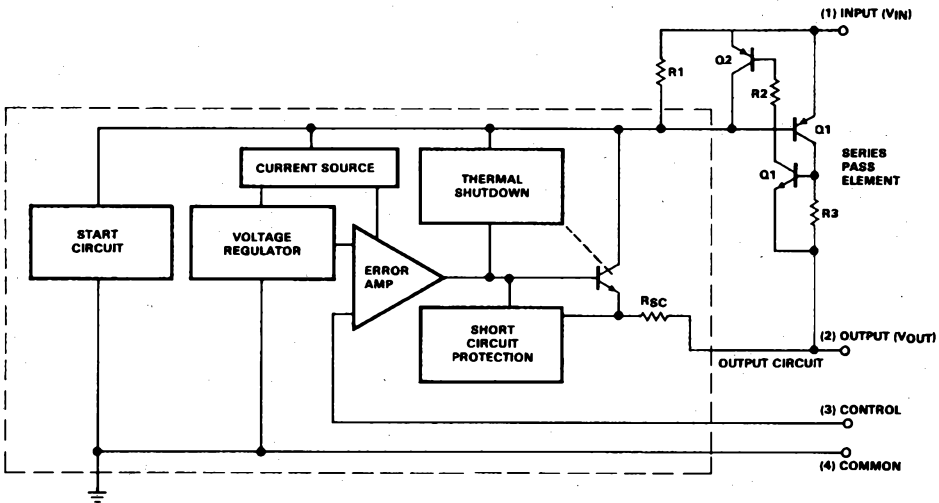


# FAIRCHILD • $\mu$ A78H00/ $\mu$ A78HG SERIES

### BLOCK DIAGRAM - FIXED OUTPUT 78H00 SERIES



### BLOCK DIAGRAM - ADJUSTABLE OUTPUT 78HG



**ELECTRICAL CHARACTERISTICS:**  $T_J = 25^\circ\text{C}$ ,  $I_{OUT} = 2.0\text{ A}$  unless otherwise specified.

CHARACTERISTICS	CONDITIONS	$\mu$ A78H05C			UNITS
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0\text{ A}$ , $V_{IN} = 10\text{ V}$	4.8	5.0	5.2	V
Line Regulation (Note 1)	$V_{IN} = 8.5\text{ to }25\text{ V}$		10	50	mV
Load Regulation (Note 1)	$10\text{ mA} \leq I_{OUT} \leq 5.0\text{ A}$ , $V_{IN} = 10\text{ V}$		10	50	mV
Quiescent Current	$I_{OUT} = 0$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$			10	mA
Ripple Rejection	$I_{OUT} = 1.0\text{ A}$ , $f = 210\text{ Hz}$ , $5.0\text{ V P-P}$	60			dB
Output Noise	$10\text{ Hz} \leq f \leq 100\text{ kHz}$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$		40		$\mu\text{VRMS}$
Dropout Voltage	$I_O = 5.0\text{ A}$		3.0		V
	$I_O = 3.0\text{ A}$		2.6		V
Short Circuit Current Limit	$V_{IN} = 10\text{ V}$		7.0		$A_{pk}$

**FAIRCHILD •  $\mu$ A78H00/ $\mu$ A78HG SERIES**

**ELECTRICAL CHARACTERISTICS:**  $T_J = 25^\circ\text{C}$ ,  $I_{OUT} = 2.0\text{ A}$  unless otherwise specified.

CHARACTERISTICS	CONDITIONS	$\mu$ A78H12C			UNITS
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0\text{ A}$ , $V_{IN} = 19\text{ V}$	11.5	12	12.5	V
Line Regulation (Note 1)	$V_{IN} = 16\text{ to }25\text{ V}$		20	120	mV
Load Regulation (Note 1)	$10\text{ mA} \leq I_{OUT} \leq 5.0\text{ A}$ , $V_{IN} = 19\text{ V}$		20	120	mV
Quiescent Current	$I_{OUT} = 0$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$			10	mA
Ripple Rejection	$I_{OUT} = 1.0\text{ A}$ , $f = 210\text{ Hz}$ , $5.0\text{ V P-P}$	60			dB
Output Noise	$10\text{ Hz} \leq f \leq 100\text{ kHz}$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$		75		$\mu\text{VRMS}$
Dropout Voltage $^{\dagger}$	$I_O = 5.0\text{ A}$		3.0		V
	$I_O = 3.0\text{ A}$		2.6		V
Short Circuit Current Limit	$V_{IN} = 19\text{ V}$		7.0		A <sub>pk</sub>

**ELECTRICAL CHARACTERISTICS:**  $T_J = 25^\circ\text{C}$ ,  $I_{OUT} = 2.0\text{ A}$  unless otherwise specified.

CHARACTERISTICS	CONDITIONS	$\mu$ A78H15C			UNITS
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0\text{ A}$ , $V_{IN} = 20\text{ V}$	14.4	15	15.6	V
Line Regulation (Note 1)	$V_{IN} = 19\text{ to }25\text{ V}$		30	150	mV
Load Regulation (Note 1)	$10\text{ mA} \leq I_{OUT} \leq 5.0\text{ A}$ , $V_{IN} = 20\text{ V}$		30	150	mV
Quiescent Current	$I_{OUT} = 0$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$			10	mA
Ripple Rejection	$I_{OUT} = 1.0\text{ A}$ , $f = 210\text{ Hz}$ , $5.0\text{ V P-P}$	60			dB
Output Noise	$10\text{ Hz} \leq f \leq 100\text{ kHz}$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$		75		$\mu\text{VRMS}$
Dropout Voltage	$I_O = 5.0\text{ A}$		3.0		V
	$I_O = 3.0\text{ A}$		2.6		V
Short Circuit Current Limit	$V_{IN} = 20\text{ V}$		7.0		A <sub>pk</sub>

**ELECTRICAL CHARACTERISTICS:**  $T_J = 25^\circ\text{C}$ ,  $I_{OUT} = 2.0\text{ A}$  unless otherwise specified.

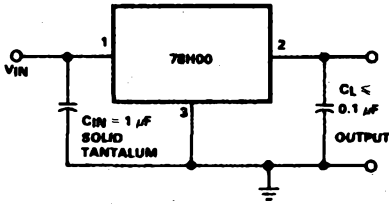
CHARACTERISTICS	CONDITIONS	$\mu$ A78HGC (Adjustable)			UNITS (Note 2)
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0\text{ A}$ , $V_{IN} = V_{OUT} + 3.5\text{ V}$	5.0	Note 3	24	V
Line Regulation (Note 1)	$V_{IN} = 8.5\text{ to }25\text{ V}$			1%	$V_{OUT}$
Load Regulation (Note 1)	$10\text{ mA} \leq I_{OUT} \leq 5.0\text{ A}$ , $V_{IN} = 10\text{ V}$			1%	$V_{OUT}$
Quiescent Current	$I_{OUT} = 0$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$			10	mA
Ripple Rejection	$I_{OUT} = 1.0\text{ A}$ , $f = 210\text{ Hz}$ , $5.0\text{ V P-P}$	60			dB
Output Noise	$10\text{ Hz} \leq f \leq 100\text{ kHz}$ , $V_{IN} = V_{OUT} + 5.0\text{ V}$		50		$\mu\text{VRMS}$
Dropout Voltage	$I_O = 5.0\text{ A}$		3.0		V
	$I_O = 3.0\text{ A}$		2.6		V
Short Circuit Current Limit	$V_{IN} = 10\text{ V}$		7.0		A <sub>pk</sub>
Control Pin Voltage	$V_{IN} = 10\text{ V}$	4.8	5.0	5.2	V

**NOTES:**

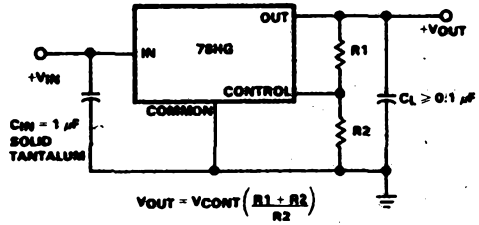
- Load and line regulation are specified at constant junction temperature. Pulse testing is required with a pulse width  $\leq 1\text{ ms}$  and a duty cycle  $\leq 5\%$ . Full Kelvin connection methods must be used to measure these parameters.
- The performance characteristics of the adjustable series ( $\mu$ A78HG) is specified for  $V_{OUT} = 5.0\text{ V}$ .
- $V_{OUT}$  for ( $\mu$ A78HG) is defined as  $V_{OUT} = \frac{R1 + R2}{R2} (V_{CONT})$

BASIC TEST CIRCUITS

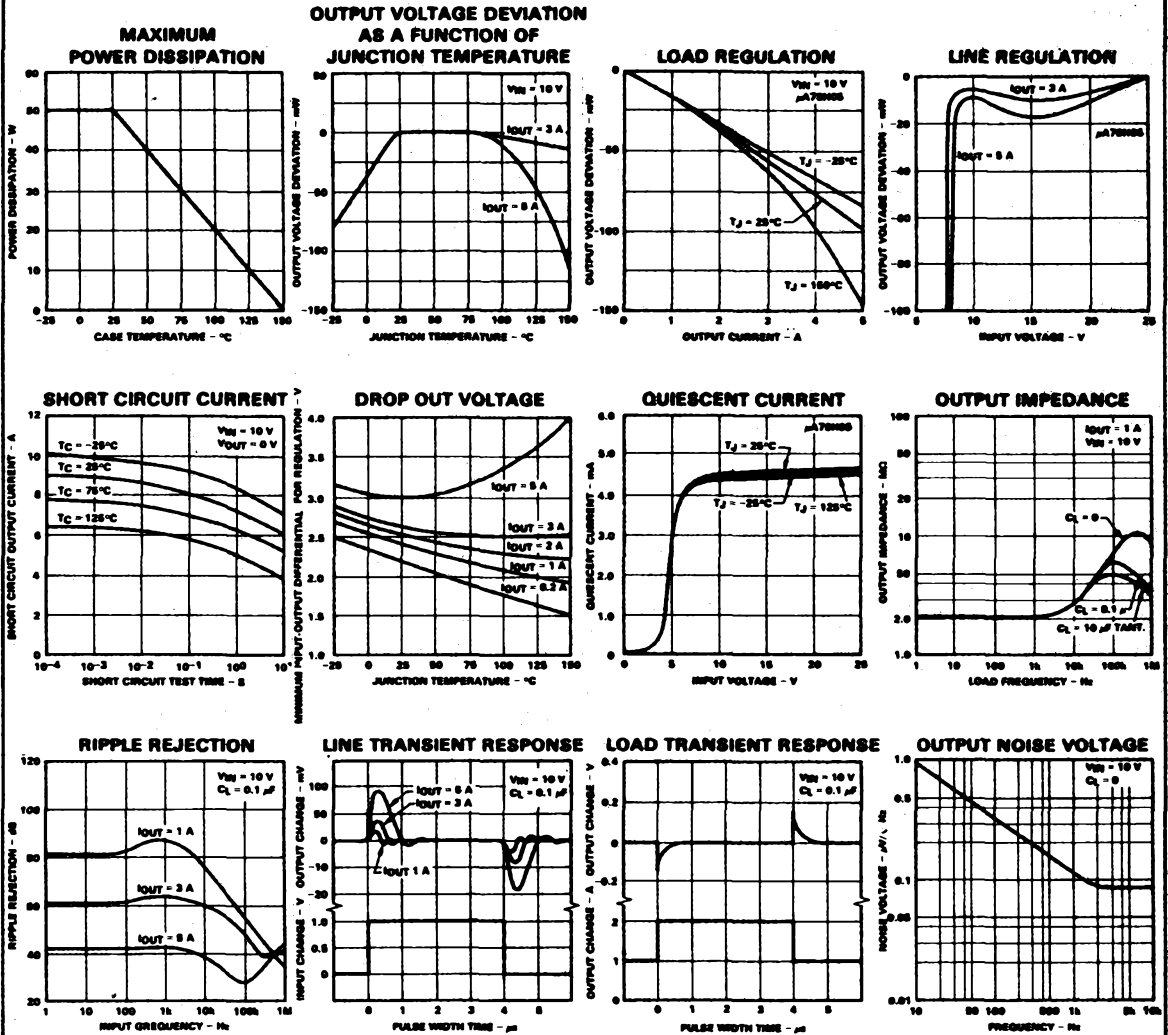
$\mu$ A78H00 SERIES  
FIXED OUTPUT VOLTAGE



$\mu$ A78HG  
ADJUSTABLE OUTPUT VOLTAGE



TYPICAL PERFORMANCE CHARACTERISTICS



**DESIGN CONSIDERATIONS**

**78H00 Series** – The  $\mu$ A78H00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation to prevent excessive instantaneous power appearing across the pass transistor as the voltage across it increases. Thus, the device is fully protected from all overload abnormalities.

**78HG Series** – The  $\mu$ A78HG variable voltage regulator has an output voltage which varies from  $V_{CONTROL}$  to typically  $V_{IN} - 3.0$  V by  $V_{OUT} = V_{CONTROL} (R1 + R2)/R2$ . The nominal reference in the  $\mu$ A78HG is 5.0 V. If we allow 1.0 mA to flow across the control string to eliminate bias current effects, we can make  $R2 = 5$  k $\Omega$  in the  $\mu$ A78HG. The output voltage is then:  $V_{OUT} = (R1 + R2) V$ , where  $R1$  and  $R2$  are in k $\Omega$ s.

Example: If  $R2 = 5$  k $\Omega$  and  $R1 = 10$  k $\Omega$  then  $V_{OUT} = 15$  V nominal, for the  $\mu$ A78HG.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

The regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection to prevent excessive instantaneous power appearing across the pass transistor as the voltage across it increases. Thus the device is fully protected from all overload abnormalities.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP $\theta_{JC}$	MAX $\theta_{JC}$	TYP $\theta_{JA}$	MAX $\theta_{JA}$
TO-3	2.0	2.5	32	38

$$P_{D(MAX)} = \frac{T_J(MAX) - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_J(MAX) - T_A}{\theta_{JA}}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

Solving for  $T_J$ :  $T_J = T_A + P_D (\theta_{JC} + \theta_{CA})$  or  $T_A + P_D \theta_{JA}$  (Without heat sink)

Where:

$T_J$  = Junction Temperature

$T_A$  = Ambient Temperature

$P_D$  = Power Dissipation

$\theta_{JC}$  = Junction to case thermal resistance

$\theta_{CA}$  = Case to ambient thermal resistance

$\theta_{CS}$  = Case to heat sink thermal resistance

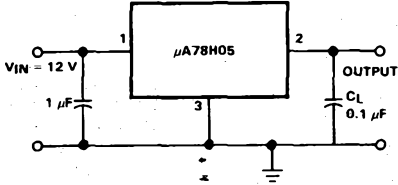
$\theta_{SA}$  = Heat sink to ambient thermal resistance

$\theta_{JA}$  = Junction to ambient thermal resistance

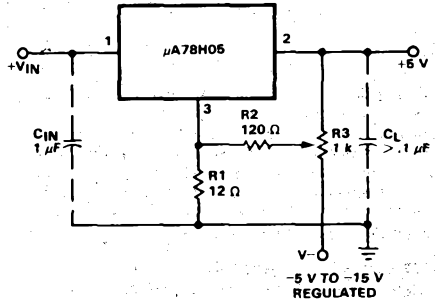
TYPICAL APPLICATIONS FOR  $\mu$ A78H00/78HG SERIES

In many applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output ( $1.0 \mu\text{F}$  solid tantalum and  $0.1 \mu\text{F}$  respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

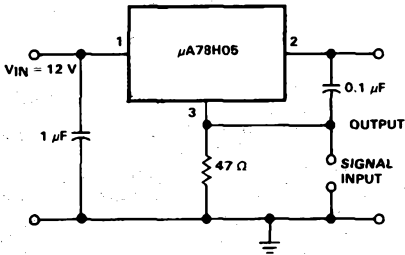
5 AMP REGULATOR



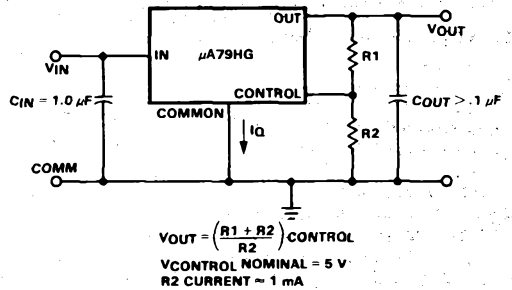
TRIMMING OUTPUT TO 5 V



SIGNAL DRIVER/MODULATOR



ADJUSTABLE VOLTAGE OUTPUT  
5-20 VOLTS



# μA79M00 SERIES

## 3-TERMINAL NEGATIVE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

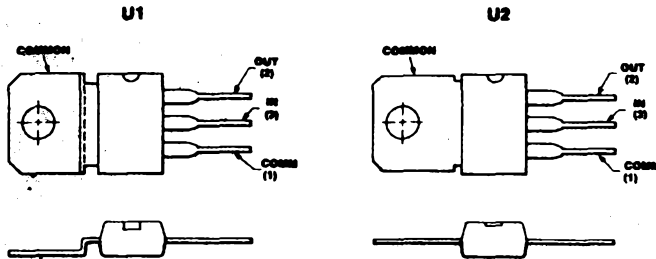
**GENERAL DESCRIPTION** — The μA79M00 series of 3-Terminal Medium Current Negative Voltage Regulators are constructed using the Fairchild Planar\* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe area compensation making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 500 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

- OUTPUT CURRENT IN EXCESS OF 0.5 A
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- OUTPUT TRANSISTOR SAFE AREA COMPENSATION
- AVAILABLE IN JEDEC TO-220 AND TO-39 PACKAGES
- OUTPUT VOLTAGES OF -5 V, -6 V, -8 V, -12 V, -15 V, -20 V AND -24 V

#### ABSOLUTE MAXIMUM RATINGS

Input Voltage		
(-5 V through -15 V)		-35 V
(-20 V, -24 V)		-40 V
Internal Power Dissipation		Internally Limited
Storage Temperature Range		
TO-39	-65°C to +150°C	
TO-220 and Power Tab	-55°C to +125°C	
Operating Junction Temperature Range		
TO-39 Military (μA79M00)	-55°C to +150°C	
Commercial (μA79M00C)	0°C to +150°C	
TO-220 Commercial (μA79M00C)	0°C to +150°C	
Lead Temperature (Soldering, 60 s) TO-39		300°C
(Soldering, 10 s) TO-220 and Power Tab		230°C

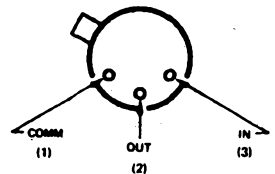
#### CONNECTION DIAGRAMS POWER TAB PACKAGES (TO-202 EQUIVALENT)



OUTPUT VOLTAGE	TYPE	PART NO.*
-5 V	μA79M05	μA79M05U1C
-6 V	μA79M06	μA79M06U1C
-8 V	μA79M08	μA79M08U1C
-12 V	μA79M12	μA79M12U1C
-15 V	μA79M15	μA79M15U1C
-20 V	μA79M20	μA79M20U1C
-24 V	μA79M24	μA79M24U1C

\* or U2C for straight heatsink.

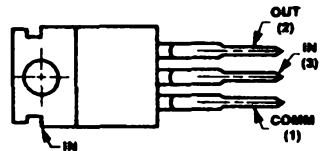
#### CONNECTION DIAGRAMS TO-39 PACKAGE (TOP VIEW)



#### ORDER INFORMATION

OUTPUT VOLTAGE	PART NO.	PART NO.
-5 V	μA 79M05HM	μA 79M05AHC
-6 V	μA 79M06HM	μA 79M06AHC
-8 V	μA 79M08HM	μA 79M08AHC
-12 V	μA 79M12HM	μA 79M12AHC
-15 V	μA 79M15HM	μA 79M15AHC
-20 V	μA 79M20HM	μA 79M20AHC
-24 V	μA 79M24HM	μA 79M24AHC

#### TO-220 PACKAGE



#### ORDER INFORMATION

OUTPUT VOLTAGE	PART NO.
-5 V	μA 79M05AUC
-6 V	μA 79M06AUC
-8 V	μA 79M08AUC
-12 V	μA 79M12AUC
-15 V	μA 79M15AUC
-20 V	μA 79M20AUC
-24 V	μA 79M24AUC

\*Planar is a patented Fairchild process.

# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M05HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -10$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified. Notes 1 and 2

CHARACTERISTICS		CONDITIONS (Note 3)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-5.2	-5.0	-4.8	V
Line Regulation		$T_J = 25^{\circ}\text{C}$ $-25\text{V} < V_{IN} < -7\text{V}$		7.0	50	mV
		$-18\text{V} < V_{IN} < -8\text{V}$		3.0	30	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{mA} < I_{OUT} < 500\text{mA}$		75	100	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{mA} < I_{OUT} < 350\text{mA}$		50		mV
Output Voltage		$-25\text{V} < V_{IN} < -7\text{V}$ , $5\text{mA} < I_{OUT} < 350\text{mA}^*$	-5.25		-4.75	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA
Quiescent Current Change		with line $-25\text{V} < V_{IN} < -8\text{V}$			0.4	mA
		with load $5\text{mA} < I_{OUT} < 350\text{mA}$			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{Hz} < f < 100\text{kHz}$		25	80	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$-18\text{V} < V_{IN} < -8\text{V}$ , $I_{OUT} = 100\text{mA}$	50			dB
		$f = 120\text{Hz}$ , $I_{OUT} = 300\text{mA}$ , $T_J = 25^{\circ}\text{C}$	54	60		dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -35\text{V}$			0.6	A
Peak Output Current			0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}/V_{OUT}$

## $\mu$ A79M05AHC AND $\mu$ A79M05AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -10$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 3)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-5.2	-5.0	-4.8	V
Line Regulation		$T_J = 25^{\circ}\text{C}$ $-25\text{V} < V_{IN} < -7\text{V}$		7.0	50	mV
		$-18\text{V} < V_{IN} < -8\text{V}$		3.0	30	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{mA} < I_{OUT} < 500\text{mA}$		75	100	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{mA} < I_{OUT} < 350\text{mA}$		50		mV
Output Voltage		$-25\text{V} < V_{IN} < -7\text{V}$ , $5\text{mA} < I_{OUT} < 350\text{mA}^*$	-5.25		-4.75	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA
Quiescent Current Change		with line $-25\text{V} < V_{IN} < -8\text{V}$			0.4	mA
		with load $5\text{mA} < I_{OUT} < 350\text{mA}$			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{Hz} < f < 100\text{kHz}$		125		$\mu\text{V}$
Ripple Rejection		$-18\text{V} < V_{IN} < -8\text{V}$ , $I_{OUT} = 100\text{mA}$	50			dB
		$f = 120\text{Hz}$ , $I_{OUT} = 300\text{mA}$ , $T_J = 25^{\circ}\text{C}$	54	60		dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1		V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -30\text{V}$		140		mA
Peak Output Current				650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{mA}$			-0.4	$\text{mV}/^{\circ}\text{C}$

\* $P_D < 4$  W

**NOTES:**

- See Test Circuit.
- The convention for negative regulators is the algebraic values, thus  $-15$  V is less than  $-10$  V.
- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $< 5\%$ ). Output voltage changes due to changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M06HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -11$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-6.25	-6.0	-5.75	V
Line Regulation		$T_J = 25^{\circ}\text{C}$		7.0	60	mV
		$-25\text{ V} < V_{IN} < -8\text{ V}$		3.0	40	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		80	120	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$		55		mV
Output Voltage		$-25\text{ V} < V_{IN} < -8\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$	-6.3		-5.7	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA
Quiescent Current Change		with line			0.4	mA
		with load			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$-19\text{ V} < V_{IN} < -9\text{ V}$ , $I_{OUT} = 100\text{ mA}$		50		dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$		54	60	dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -35\text{ V}$			0.6	A
Peak Output Current			0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}/V_{OUT}$

## $\mu$ A79M06AHC AND $\mu$ A79M06AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -11$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-6.25	-6.0	-5.75	V
Line Regulation		$T_J = 25^{\circ}\text{C}$		7.0	60	mV
		$-25\text{ V} < V_{IN} < -8\text{ V}$		3.0	40	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		80	120	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		55		mV
Output Voltage		$-25\text{ V} < V_{IN} < -8\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	-6.3		-5.7	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA
Quiescent Current Change		with line			0.4	mA
		with load			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		150		$\mu\text{V}$
Ripple Rejection		$-19\text{ V} < V_{IN} < -9\text{ V}$ , $I_{OUT} = 100\text{ mA}$		50		dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$		54	60	dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1		V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -30\text{ V}$		140		mA
Peak Output Current				650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		-0.4		$\text{mV}/^{\circ}\text{C}$

\* $P_D < 4$  W

NOTE:

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M08HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -14$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	-8.3	-8.0	-7.7	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$-25\text{ V} < V_{IN} < -10.5\text{ V}$		8.0	80	mV
			$-21\text{ V} < V_{IN} < -11\text{ V}$		4.0	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		90	160	mV	
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		60		mV	
Output Voltage		$-25\text{ V} < V_{IN} < -10.5\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$	-8.4		-7.6	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA	
Quiescent Current Change		with line $-25\text{ V} < V_{IN} < -10.5\text{ V}$			0.4	mA	
		with load $5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.4	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{V}/V_{OUT}$	
Ripple Rejection		$-21.5\text{ V} < V_{IN} < -11.5\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB	
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	59		dB	
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1	2.3	V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -35\text{ V}$			0.6	A	
Peak Output Current			0.4	0.65	1.4	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}/V_{OUT}$	

## $\mu$ A79M08AHC AND $\mu$ A79M08AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -14$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	-8.3	-8.0	-7.7	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$-25\text{ V} < V_{IN} < -10.5\text{ V}$		8.0	80	mV
			$-21\text{ V} < V_{IN} < -11\text{ V}$		4.0	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		90	160	mV	
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		60		mV	
Output Voltage		$-25\text{ V} < V_{IN} < -10.5\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	-8.4		-7.6	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA	
Quiescent Current Change		with line $-25\text{ V} < V_{IN} < -10.5\text{ V}$			0.4	mA	
		with load $5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.4	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		200		$\mu\text{V}$	
Ripple Rejection		$-21.5\text{ V} < V_{IN} < -11.5\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB	
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	59		dB	
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1		V	
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -30\text{ V}$		140		mA	
Peak Output Current				650		mA	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		-0.6		$\text{mV}/^{\circ}\text{C}$	

\* $P_D < 4$  W

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M12HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -11$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-12.5	-12	-11.5	V
Line Regulation		$T_J = 25^{\circ}\text{C}$   $-30\text{ V} < V_{IN} < -14.5\text{ V}$		9.0	80	mV
		$-25\text{ V} < V_{IN} < -15\text{ V}$		5.0	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		65	240	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		45		mV
Output Voltage		$-30\text{ V} < V_{IN} < -14.5\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$	-12.6		-11.4	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.0	mA
Quiescent Current Change	with line	$-30\text{ V} < V_{IN} < -14.5\text{ V}$			0.4	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{V}/\text{V}/\text{OUT}$
Ripple Rejection		$-25\text{ V} < V_{IN} < -15\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	60		dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -35\text{ V}$			0.6	A
Peak Output Current			0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}/\text{V}_{OUT}$

## $\mu$ A79M12AHC AND $\mu$ A79M12AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -19$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-12.5	-12	-11.5	V
Line Regulation		$T_J = 25^{\circ}\text{C}$   $-30\text{ V} < V_{IN} < -14.5\text{ V}$		9.0	80	mV
		$-25\text{ V} < V_{IN} < -15\text{ V}$		5.0	50	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		65	240	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		45		mV
Output Voltage		$-30\text{ V} < V_{IN} < -14.5\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	-12.6		-11.4	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.0	mA
Quiescent Current Change	with line	$-30\text{ V} < V_{IN} < -14.5\text{ V}$			0.4	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		300		$\mu\text{V}$
Ripple Rejection		$-25\text{ V} < V_{IN} < -15\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	60		dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1		V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -30\text{ V}$		140		mA
Peak Output Current				650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$			-0.8	$\text{mV}/^{\circ}\text{C}$

\* $P_D < 4$  W

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M15HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -23$  V,  $I_{OUT} = 350$  mA,  $0^\circ\text{C} < T_J < 125^\circ\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^\circ\text{C}$		-15.6	-15	-14.4	V
Line Regulation		$T_J = 25^\circ\text{C}$	$-30\text{ V} < V_{IN} < -17.5\text{ V}$		9.0	80	mV
			$-28\text{ V} < V_{IN} < -18\text{ V}$		7.0	50	mV
Load Regulation		$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$			65	240	mV
		$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$			45		mV
Output Voltage		$-30\text{ V} < V_{IN} < -17.5\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$		-15.75		-14.25	V
Quiescent Current		$T_J = 25^\circ\text{C}$			1.5	3.0	mA
Quiescent Current Change		with line				0.4	mA
		with load		$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.4
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			25	80	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$-28.5\text{ V} < V_{IN} < -18.5\text{ V}$ , $I_{OUT} = 100\text{ mA}$		50			dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^\circ\text{C}$		54	59		dB
Dropout Voltage		$T_J = 25^\circ\text{C}$			1.1	2.3	V
Short Circuit Current		$T_J = 25^\circ\text{C}$ , $V_{IN} = -35\text{ V}$				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^\circ\text{C} < T_J < +150^\circ\text{C}$				0.3	$\text{mV}/^\circ\text{C}/V_{OUT}$

## $\mu$ A79M15AHC AND $\mu$ A79M15AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -23$  V,  $I_{OUT} = 350$  mA,  $-55^\circ\text{C} < T_J < 150^\circ\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^\circ\text{C}$		-15.6	-15	-14.4	V
Line Regulation		$T_J = 25^\circ\text{C}$	$-30\text{ V} < V_{IN} < -17.5\text{ V}$		9.0	80	mV
			$-28\text{ V} < V_{IN} < -18\text{ V}$		7.0	50	mV
Load Regulation		$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$			65	240	mV
		$T_J = 25^\circ\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$			45		mV
Output Voltage		$-30\text{ V} < V_{IN} < -17.5\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		-15.75		-14.25	V
Quiescent Current		$T_J = 25^\circ\text{C}$			1.5	3.0	mA
Quiescent Current Change		with line				0.4	mA
		with load		$5\text{ mA} < I_{OUT} < 350\text{ mA}$			0.4
Output Noise Voltage		$T_A = 25^\circ\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			375		$\mu\text{V}$
Ripple Rejection		$-28.5\text{ V} < V_{IN} < -18.5\text{ V}$ , $I_{OUT} = 100\text{ mA}$		50			dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^\circ\text{C}$		54	59		dB
Dropout Voltage		$T_J = 25^\circ\text{C}$			1.1		V
Short Circuit Current		$T_J = 25^\circ\text{C}$ , $V_{IN} = -30\text{ V}$			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$			-1.0		$\text{mV}/^\circ\text{C}$

\* $P_D < 4\text{ W}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M20HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -29$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-20.8	-20	-19.2	V
Line Regulation		$T_J = 25^{\circ}\text{C}$		12	80	mV
		$-35\text{ V} < V_{IN} < -23\text{ V}$		10	70	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		75	300	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		50		mV
Output Voltage		$-35\text{ V} < V_{IN} < -23\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$	-21		-19	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.5	mA
Quiescent Current Change		with line			0.4	mA
		with load			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$-34\text{ V} < V_{IN} < -24\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	58		dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -35\text{ V}$			0.6	A
Peak Output Current			0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}$ $/V_{OUT}$

## $\mu$ A79M20AHC AND $\mu$ A79M20AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -29$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-20.8	-20	-19.2	V
Line Regulation		$T_J = 25^{\circ}\text{C}$		12	80	mV
		$-35\text{ V} < V_{IN} < -23\text{ V}$		10	70	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		75	300	mV
		$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		50		mV
Output Voltage		$-35\text{ V} < V_{IN} < -23\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	-21		-19	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.5	mA
Quiescent Current Change		with line			0.4	mA
		with load			0.4	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		500		$\mu\text{V}$
Ripple Rejection		$-34\text{ V} < V_{IN} < -24\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB
		$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	58		dB
Dropout Voltage		$T_J = 25^{\circ}\text{C}$		1.1		V
Short Circuit Current		$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -30$		140		mA
Peak Output Current				650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$		-1.0		$\text{mV}/^{\circ}\text{C}$

\* $P_D < 4$  W

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A79M00 SERIES

## $\mu$ A79M24HM

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -33$  V,  $I_{OUT} = 350$  mA,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$	-25	-24	-23	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$-38\text{ V} < V_{IN} < -27\text{ V}$	12	80	mV
		$-38\text{ V} < V_{IN} < -28\text{ V}$	12	70	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		75	300	mV
	$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		50		mV
Output Voltage	$-38\text{ V} < V_{IN} < -27\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}^*$	-25.2		-22.8	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$		1.5	3.5	mA
Quiescent Current Change	with line	$-38\text{ V} < V_{IN} < -27\text{ V}$		0.4	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$		0.4	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{V}/V_{OUT}$
Ripple Rejection	$-38\text{ V} < V_{IN} < -28\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB
	$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	58		dB
Dropout Voltage	$T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Short Circuit Current	$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -35\text{ V}$			0.6	A
Peak Output Current		0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}$ $/V_{OUT}$

## $\mu$ A79M24AHC AND $\mu$ A79M24AUC

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -33$  V,  $I_{OUT} = 350$  mA,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ ,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F, unless otherwise specified.

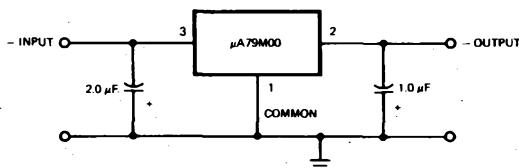
CHARACTERISTICS	CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$	-25	-24	-23	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$-38\text{ V} < V_{IN} < -27\text{ V}$	12	80	mV
		$-38\text{ V} < V_{IN} < -28\text{ V}$	12	70	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$		75	300	mV
	$T_J = 25^{\circ}\text{C}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$		50		mV
Output Voltage	$-38\text{ V} < V_{IN} < -27\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$	-25.2		-22.8	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$		1.5	3.5	mA
Quiescent Current Change	with line	$-38\text{ V} < V_{IN} < -27\text{ V}$		0.4	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$		0.4	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		600		$\mu\text{V}$
Ripple Rejection	$-38\text{ V} < V_{IN} < -28\text{ V}$ , $I_{OUT} = 100\text{ mA}$	50			dB
	$f = 120\text{ Hz}$ , $I_{OUT} = 300\text{ mA}$ , $T_J = 25^{\circ}\text{C}$	54	58		dB
Dropout Voltage	$T_J = 25^{\circ}\text{C}$		1.1		V
Short Circuit Current	$T_J = 25^{\circ}\text{C}$ , $V_{IN} = -30\text{ V}$		140		mA
Peak Output Current			650		mA
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$		-1.0		$\text{mV}/^{\circ}\text{C}$

\* $P_D < 4$  W

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

### DC PARAMETER TEST CIRCUIT



# FAIRCHILD • $\mu$ A79M00 SERIES

## DESIGN CONSIDERATIONS

The  $\mu$ A79M00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

The safe area protection network may cause the device to latch-up if the output is shorted and the regulator is operating with high input voltages. This mode of operation will not damage the device. However, power (input voltage or the load) must be interrupted momentarily for the device to recover from the latched condition.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 79M00, 125°C for 79M00AC and 79M00C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP	MAX	TYP	MAX
	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JA}$	$\theta_{JA}$
TO-39	18.0	25	120	185
TO-220	3.0	5.0	62	70
Power Tab (TO-202 Equiv.)	6.0	8.0	75	80

$$P_D(\text{MAX}) = \frac{T_J(\text{MAX}) - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_J(\text{MAX}) - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

$$\text{Solving for } T_J: T_J = T_A + P_D(\theta_{JC} + \theta_{CA}) \text{ or } T_A + P_D \theta_{JA} \text{ (Without a heat sink)}$$

Where  $T_J$  = Junction Temperature

$T_A$  = Ambient Temperature

$P_D$  = Power Dissipation

$\theta_{JC}$  = Junction to case thermal resistance

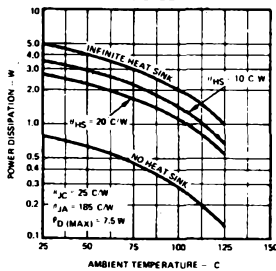
$\theta_{CA}$  = Case to ambient thermal resistance

$\theta_{CS}$  = Case to heat sink thermal resistance

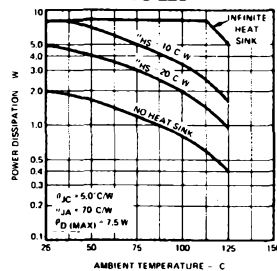
$\theta_{SA}$  = Heat sink to ambient thermal resistance

$\theta_{JA}$  = Junction to ambient thermal resistance

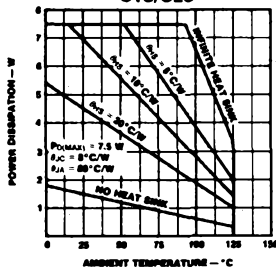
**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
TO-39**



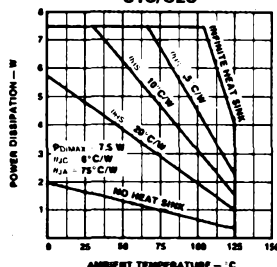
**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
TO-220**



**WORST CASE POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
U1C/U2C**

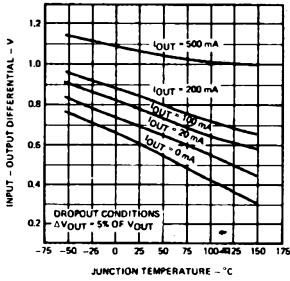


**TYPICAL POWER DISSIPATION  
VERSUS AMBIENT TEMPERATURE  
U1C/U2C**

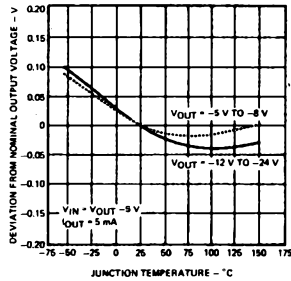


TYPICAL PERFORMANCE CURVES

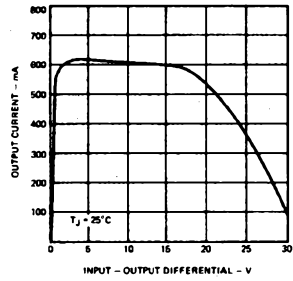
**DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE**



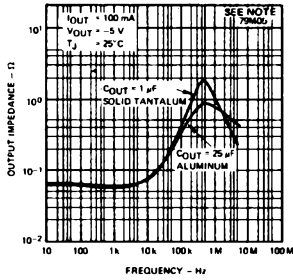
**OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE**



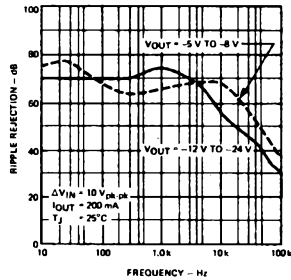
**PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE**



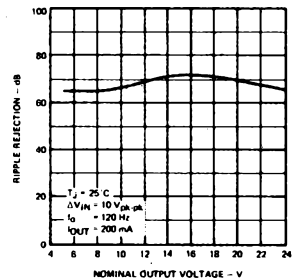
**OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY**



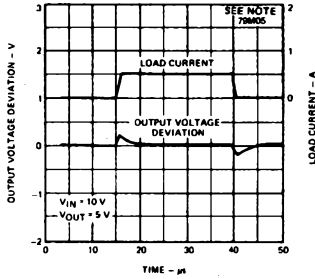
**RIPPLE REJECTION AS A FUNCTION OF FREQUENCY**



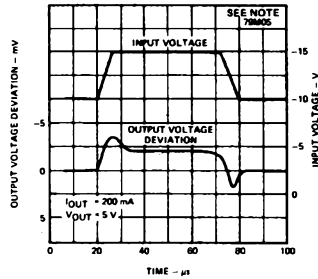
**RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGES**



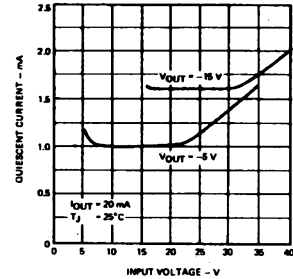
**LOAD TRANSIENT RESPONSE**



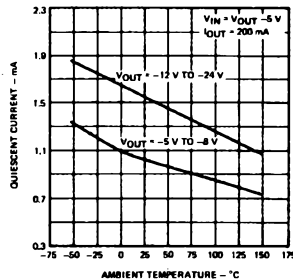
**LINE TRANSIENT RESPONSE**



**QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE**



**QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE**

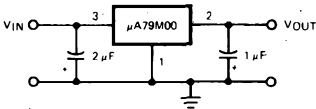


NOTE: The other  $\mu A79M00$  voltage series devices have similar performance curves.

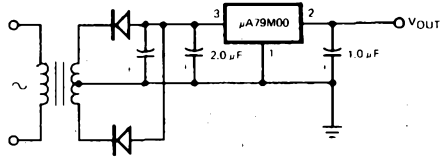
TYPICAL APPLICATIONS

Bypass capacitors are recommended for stable operation of the 79M00 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

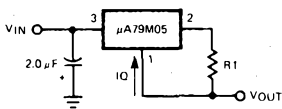
The bypass capacitors, (2  $\mu$ F on the input, 1  $\mu$ F on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10  $\mu$ F or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.



FIXED OUTPUT REGULATOR

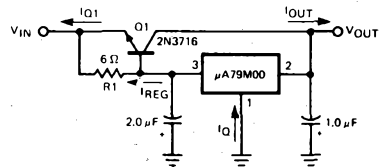


NEGATIVE OUTPUT VOLTAGE CIRCUIT



$$\text{OUTPUT CURRENT} = \frac{5.0 \text{ V}}{R1} + I_Q$$

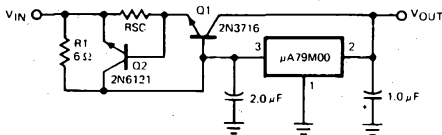
BASIC CURRENT REGULATOR



$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

$$I_{Q1} = \beta(Q1) I_{REG}$$

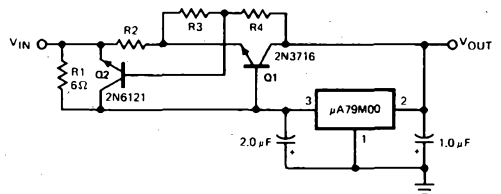
HIGH CURRENT VOLTAGE REGULATOR



$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

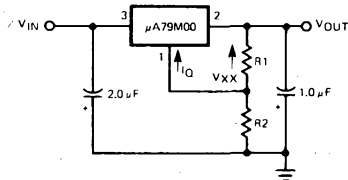
$$R_{SC} = \frac{V_{BE}(Q2)}{I_{SC}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



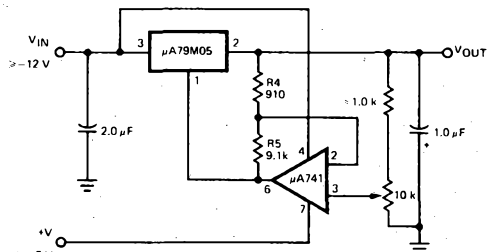
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ}(\text{MAX}) (\beta + 1) - I_{OUT}(\text{MAX})}$$

HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED



$$|V_{OUT}| = V_{XX} \left( 1 + \frac{R2}{R1} \right) + I_Q R2$$

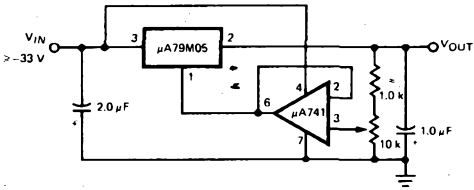
VARIABLE OUTPUT VOLTAGE REGULATOR



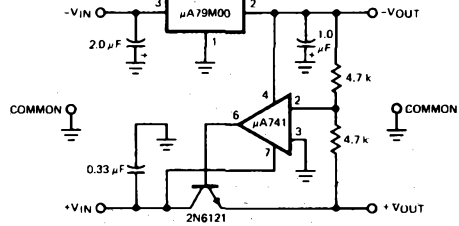
VARIABLE OUTPUT VOLTAGE, -0.5 V TO -10 V



TYPICAL APPLICATIONS (Cont'd)

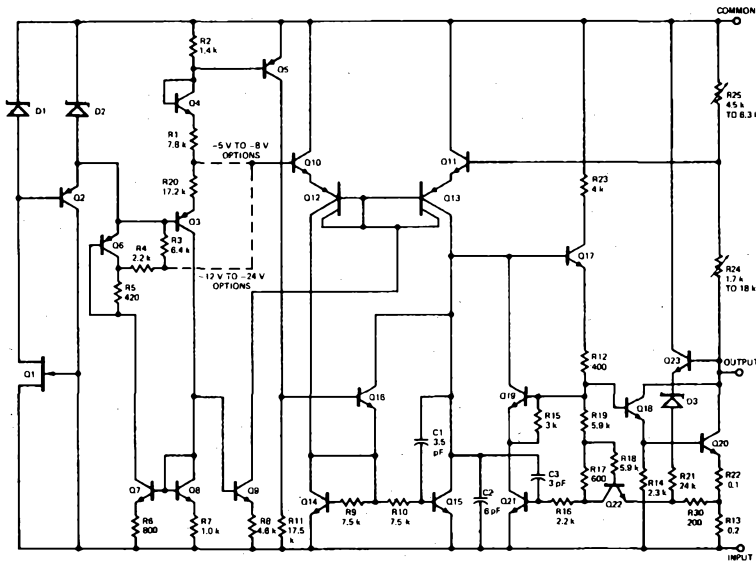


VARIABLE OUTPUT VOLTAGE, -30 V TO -7 V



POSITIVE AND NEGATIVE TRACKING VOLTAGE REGULATOR

EQUIVALENT CIRCUIT



# μA7900 SERIES

## 3-TERMINAL NEGATIVE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

**GENERAL DESCRIPTION** - The μA7900 series of monolithic 3-Terminal Negative Regulators is manufactured using the Fairchild Planar® epitaxial process. These negative regulators are intended as complements to the popular μA7800 series of positive voltage regulators, and they are available in the same voltage options from -5 to -24 V. The 7900s employ internal current limiting, safe-area protection, and thermal shutdown, making them virtually indestructible.

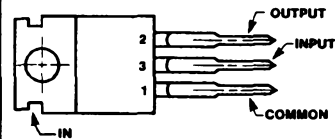
- OUTPUT CURRENT IN EXCESS OF 1 A
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- OUTPUT TRANSISTOR SAFE AREA COMPENSATION
- AVAILABLE IN THE TO-220 AND THE TO-3 PACKAGE
- OUTPUT VOLTAGES ARE 5, 6, 8, 12, 15, 18 AND 24 V

**ABSOLUTE MAXIMUM RATINGS**

Input Voltage		
(5 V through 18 V)		-35 V
(24 V)		-40 V
Internal Power Dissipation		Internally Limited
Storage Temperature Range		
TO-3 (Al. or Steel)		-65° C to +150° C
TO-220		-55° C to +150° C
Operating Junction Temperature Range		
Military (μA7900)		-55° C to +150° C
Commercial (μA7900C)		0° C to +150° C
Lead Temperature		
TO-3 (Soldering, 60 s)		300° C
TO-220 (Soldering, 10 s)		230° C

NOTE: The convention for Negative Regulators is the Algebraic value, thus -15 is less than -10 V.

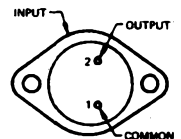
**CONNECTION DIAGRAMS**  
**TO-220 PACKAGE**  
**(TOP VIEW)**



**ORDER INFORMATION**

OUTPUT VOLTAGE	TYPE	PART NO.
-5V	μA7905C	μA7905UC
-6V	μA7906C	μA7906UC
-8V	μA7908C	μA7908UC
-12V	μA7912C	μA7912UC
-15V	μA7915C	μA7915UC
-18V	μA7918C	μA7918UC
-24V	μA7924C	μA7924UC

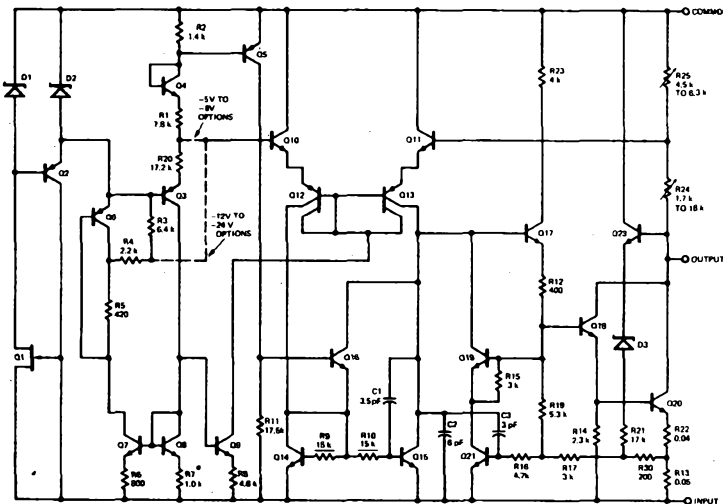
**TO-3 PACKAGE**  
**(TOP VIEW)**



**ORDER INFORMATION**

OUTPUT VOLTAGE	TYPE	PART NO.
-5V	μA7905	μA7905KM
-6V	μA7906	μA7906KM
-8V	μA7908	μA7908KM
-12V	μA7912	μA7912KM
-15V	μA7915	μA7915KM
-18V	μA7918	μA7918KM
-24V	μA7924	μA7924KM
-5V	μA7905C	μA7905KC
-6V	μA7906C	μA7906KC
-8V	μA7908C	μA7908KC
-12V	μA7912C	μA7912KC
-15V	μA7915C	μA7915KC
-18V	μA7918C	μA7918KC
-24V	μA7924C	μA7924KC

**EQUIVALENT CIRCUIT**



\*Planar is a patented Fairchild process.

# FAIRCHILD • $\mu$ A7900 SERIES

## $\mu$ A7908

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -14$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}$  C  $< T_J < 150^{\circ}$  C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}$ C	-7.7	-8.0	-8.3	V	
Line Regulation		$T_J = 25^{\circ}$ C	$-10.5$ V $< V_{IN} < -25$ V		6.0	80	mV
			$-11$ V $< V_{IN} < -17$ V		2.0	40	mV
Load Regulation		$T_J = 25^{\circ}$ C	$5$ mA $< I_{OUT} < 1.5$ A		12	80	mV
			$250$ mA $< I_{OUT} < 750$ mA		4.0	40	mV
Output Voltage		$-11.5$ V $< V_{IN} < -23$ V $5$ mA $< I_{OUT} < 1.0$ A $p < 15$ W	-7.6		-8.4	V	
Quiescent Current		$T_J = 25^{\circ}$ C		1.0	2.0	mA	
Quiescent Current Change		with line			1.0	mA	
		with load			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}$ C, $10$ Hz $< f < 100$ kHz		25	80	$\mu$ V/ $V_{OUT}$	
Ripple Rejection		$f = 120$ Hz, $-11.5$ V $< V_{IN} < -21.5$ V	54	60		dB	
Dropout Voltage		$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}$ C		1.1	2.3	V	
Peak Output Current		$T_J = 25^{\circ}$ C	1.3	2.1	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55^{\circ}$ C $< T_J < 150^{\circ}$ C			0.3	$mV/^{\circ}$ C/ $V_{OUT}$	
Short Circuit Current		$V_{IN} = -35$ V, $T_J = 25^{\circ}$ C			1.2	A	

## $\mu$ A7908C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -14$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}$  C  $< T_J < 125^{\circ}$  C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}$ C	-7.7	-8.0	-8.3	V	
Line Regulation		$T_J = 25^{\circ}$ C	$-10.5$ V $< V_{IN} < -25$ V		6.0	160	mV
			$-11$ V $< V_{IN} < -17$ V		2.0	80	mV
Load Regulation		$T_J = 25^{\circ}$ C	$5$ mA $< I_{OUT} < 1.5$ A		12	160	mV
			$250$ mA $< I_{OUT} < 750$ mA		4.0	80	mV
Output Voltage		$-10.5$ V $< V_{IN} < -23$ V $5$ mA $< I_{OUT} < 1.0$ A $p < 15$ W	-7.6		-8.4	V	
Quiescent Current		$T_J = 25^{\circ}$ C		1.0	2.0	mA	
Quiescent Current Change		with line			1.0	mA	
		with load			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}$ C, $10$ Hz, $< f < 100$ kHz		200		$\mu$ V	
Ripple Rejection		$f = 120$ Hz, $-11.5$ V $< V_{IN} < -21.5$ V	54	60		dB	
Dropout Voltage		$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}$ C		1.1		V	
Peak Output Current		$T_J = 25^{\circ}$ C		2.1		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $0^{\circ}$ C $< T_J < 125^{\circ}$ C		-0.6		$mV/^{\circ}$ C	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## FAIRCHILD • $\mu$ A7900 SERIES

### $\mu$ A7912

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -19$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-11.5	-12.0	-12.5	V
Line Regulation		$T_J = 25^{\circ}\text{C}$		10	120	mV
				3.0	60	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$		12	120	mV
				4.0	60	mV
Output Voltage		$-15.5$ V $< V_{IN} < -27$ V $5$ mA $< I_{OUT} < 1.0$ A $p < 15$ W	-11.4		-12.6	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.0	mA
Quiescent Current Change	with line	$-15$ V $< V_{IN} < -30$ V			1.0	mA
	with load	$5$ mA $< I_{OUT} < 1.0$ A			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10$ Hz $< f < 100$ kHz		.25	80	$\mu\text{V}/V_{OUT}$
Ripple Rejection		$f = 120$ Hz, $-15$ V $< V_{IN} < -25$ V	54	60		dB
Dropout Voltage		$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}/V_{OUT}$
Short Circuit Current		$V_{IN} = -35$ V, $T_J = 25^{\circ}\text{C}$			1.2	A

### $\mu$ A7912C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -19$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-11.5	-12.0	-12.5	V
Line Regulation		$T_J = 25^{\circ}\text{C}$		10	240	mV
				3.0	120	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$		12	240	mV
				4.0	120	mV
Output Voltage		$-14.5$ V $< V_{IN} < -27$ V $5$ mA $< I_{OUT} < 1.0$ A $p < 15$ W	-11.4		-12.6	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.0	mA
Quiescent Current Change	with line	$-14.5$ V $< V_{IN} < -30$ V			1.0	mA
	with load	$5$ mA $< I_{OUT} < 1.0$ A			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10$ Hz $< f < 100$ kHz		300		$\mu\text{V}$
Ripple Rejection		$f = 120$ Hz, $-15$ V $< V_{IN} < -25$ V	54	60		dB
Dropout Voltage		$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}\text{C}$		1.1		V
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$			-0.8	$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7900 SERIES

## $\mu$ A7905

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -10$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-4.8	-5.0	-5.2	V
Line Regulation		$T_J = 25^{\circ}\text{C}$	$-7\text{ V} < V_{IN} < -25\text{ V}$		3	50 mV
			$-8\text{ V} < V_{IN} < -12\text{ V}$		1	25 mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		15	50 mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		5	25 mV
Output Voltage		$-8.0\text{ V} < V_{IN} < -20\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $p < 15\text{ W}$	-4.70		-5.30	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA
Quiescent Current Change	with line	$-8\text{ V} < V_{IN} < -25\text{ V}$			1.3	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{V}/\sqrt{I_{OUT}}$
Ripple Rejection		$f = 120\text{ Hz}$ , $-8\text{ V} < V_{IN} < -18\text{ V}$	54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		1.1	2.3	V
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$			0.3	$\text{mV}/^{\circ}\text{C}$ $/I_{OUT}$
Short Circuit Current		$V_{IN} = -35\text{ V}$ , $T_J = 25^{\circ}\text{C}$			1.2	A

## $\mu$ A7905C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -10$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25^{\circ}\text{C}$	-4.8	-5.0	-5.2	V
Line Regulation		$T_J = 25^{\circ}\text{C}$	$-7\text{ V} < V_{IN} < -25\text{ V}$		3.0	100 mV
			$-8\text{ V} < V_{IN} < -12\text{ V}$		1.0	50 mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		15	100 mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		5.0	50 mV
Output Voltage		$-7\text{ V} < V_{IN} < -20\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $p < 15\text{ W}$	-4.75		-5.25	V
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.0	2.0	mA
Quiescent Current Change	with line	$-7\text{ V} < V_{IN} < -25\text{ V}$			1.3	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		125		$\mu\text{V}$
Ripple Rejection		$f = 120\text{ Hz}$ , $-8\text{ V} < V_{IN} < -18\text{ V}$	54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		1.1		V
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$		-0.4		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7900 SERIES

## $\mu$ A7906

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -11$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		-5.75	-6.0	-6.25	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$-8\text{ V} < V_{IN} < -25\text{ V}$		5.0	60	mV
		$-9\text{ V} < V_{IN} < -13\text{ V}$		1.5	30	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		14	60	mV
		$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	30	mV
Output Voltage	$-9\text{ V} < V_{IN} < -21\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $\rho < 15\text{ W}$		-5.65		-6.35	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			1.0	2.0	mA
Quiescent Current Change <sup>a</sup>	with line	$-9\text{ V} < V_{IN} < -25\text{ V}$			1.3	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			25	80	$\mu\text{V}/\sqrt{\text{V}_{OUT}}$
Ripple Rejection	$f = 120\text{ Hz}$ , $-9\text{ V} < V_{IN} < -19\text{ V}$		54	60		dB
Dropout Voltage	$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$			1.1	2.3	V
Peak Output Current	$T_J = 25^{\circ}\text{C}$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < +150^{\circ}\text{C}$				0.3	$\text{mV}/^{\circ}\text{C}/\text{V}_{OUT}$
Short Circuit Current	$V_{IN} = -35\text{ V}$ , $T_J = 25^{\circ}\text{C}$				1.2	A

## $\mu$ A7906C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -11$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}\text{C}$		-5.75	-6.0	-6.25	V
Line Regulation	$T_J = 25^{\circ}\text{C}$	$-8\text{ V} < V_{IN} < -25\text{ V}$		5.0	120	-mV
		$-9\text{ V} < V_{IN} < -13\text{ V}$		1.5	60	mV
Load Regulation	$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		14	120	mV
		$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	60	mV
Output Voltage	$-8\text{ V} < V_{IN} < -21\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $\rho < 15\text{ W}$		-5.7		-6.3	V
Quiescent Current	$T_J = 25^{\circ}\text{C}$			1.0	2.0	mA
Quiescent Current Change	with line	$-8\text{ V} < V_{IN} < -25\text{ V}$			1.3	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$			150		$\mu\text{V}$
Ripple Rejection	$f = 120\text{ Hz}$ , $-9\text{ V} < V_{IN} < -19\text{ V}$		54	60		dB
Dropout Voltage	$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$			1.1		V
Peak Output Current	$T_J = 25^{\circ}\text{C}$			2.1		A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < V_{IN} < 125^{\circ}\text{C}$			-0.4		$\text{mV}/^{\circ}\text{C}$

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

## FAIRCHILD • $\mu$ A7900 SERIES

### $\mu$ A7915

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -23$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	-14.4	-15.0	-15.6	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$-17.5\text{ V} < V_{IN} < -30\text{ V}$		11	150	mV
			$-20\text{ V} < V_{IN} < -26\text{ V}$		3.0	75	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	150	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	75	mV
Output Voltage		$-18.5\text{ V} < V_{IN} < -30\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $p < 15\text{ W}$	-14.25		-15.75	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.0	mA	
Quiescent Current Change	with line	$-18.5\text{ V} < V_{IN} < -30\text{ V}$			1.0	mA	
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		25	80	$\mu\text{A}/V_{OUT}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $-18.5\text{ V} < V_{IN} < -28.5\text{ V}$	54	60		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		1.1	2.3	V	
Peak Output Current		$T_J = 25^{\circ}\text{C}$	1.3	2.1	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $-55^{\circ}\text{C} < T_J < 150^{\circ}\text{C}$		-1.0	1.3	$\text{mV}^{\circ}\text{C}/V_{OUT}$	
Short Circuit Current		$V_{IN} = -35\text{ V}$ , $T_J = 25^{\circ}\text{C}$			1.2	A	

### $\mu$ A7915C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -23$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$ , unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}\text{C}$	-14.4	-15.0	-15.6	V	
Line Regulation		$T_J = 25^{\circ}\text{C}$	$-17.5\text{ V} < V_{IN} < -30\text{ V}$		11	300	mV
			$-20\text{ V} < V_{IN} < -26\text{ V}$		3.0	150	mV
Load Regulation		$T_J = 25^{\circ}\text{C}$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	300	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	150	mV
Output Voltage		$-17.5\text{ V} < V_{IN} < -30\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $p < 15\text{ W}$	-14.25		-15.75	V	
Quiescent Current		$T_J = 25^{\circ}\text{C}$		1.5	3.0	mA	
Quiescent Current Change	with line	$-17.5\text{ V} < V_{IN} < -30\text{ V}$			1.0	mA	
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$			0.5	mA	
Output Noise Voltage		$T_A = 25^{\circ}\text{C}$ , $10\text{ Hz} < f < 100\text{ kHz}$		375		$\mu\text{V}$	
Ripple Rejection		$f = 120\text{ Hz}$ , $-18.5\text{ V} < V_{IN} < -28.5\text{ V}$	54	60		dB	
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$ , $T_J = 25^{\circ}\text{C}$		1.1		V	
Peak Output Current		$T_J = 25^{\circ}\text{C}$		2.1		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$ , $0^{\circ}\text{C} < T_J < 125^{\circ}\text{C}$		-1.0		$\text{mV}^{\circ}\text{C}$	

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7900 SERIES

## $\mu$ A7918

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -27$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}$  C  $\leq T_J \leq 150^{\circ}$  C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}$ C		-17.3	-18.0	-18.7	V	
Line Regulation		$T_J = 25^{\circ}$ C		$-21$ V $\leq V_{IN} \leq -33$ V		15	180	mV
				$-24$ V $\leq V_{IN} \leq -30$ V		5.0	90	mV
Load Regulation		$T_J = 25^{\circ}$ C		$5$ mA $\leq I_{OUT} \leq 1.5$ A		12	180	mV
				$250$ mA $\leq I_{OUT} \leq 750$ mA		4.0	90	mV
Output Voltage		$-22$ V $\leq V_{IN} \leq -33$ V $5$ mA $\leq I_{OUT} \leq 1.0$ A $p \leq 15$ W		-17.1		-18.9	V	
Quiescent Current		$T_J = 25^{\circ}$ C			1.5	3.0	mA	
Quiescent Current Change		with line		$-22$ V $\leq V_{IN} \leq -33$ V			1.0	mA
		with load		$5$ mA $\leq I_{OUT} \leq 1.0$ A			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}$ C, $10$ Hz $\leq f \leq 100$ kHz			25	80	$\mu$ V/ $V_{OUT}$	
Ripple Rejection		$f = 120$ Hz, $-22$ V $\leq V_{IN} \leq -32$ V		54	60		dB	
Dropout Voltage		$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}$ C			1.1	2.3	V	
Peak Output Current		$T_J = 25^{\circ}$ C		1.3	2.1	3.3	A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $0^{\circ}$ C $\leq T_J \leq 150^{\circ}$ C				0.3	mV/ $^{\circ}$ C/ $V_{OUT}$	
Short Circuit Current		$V_{IN} = -35$ V, $T_J = 25^{\circ}$ C				1.2	A	

## $\mu$ A7918C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -27$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}$  C  $\leq T_J \leq 125^{\circ}$  C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS	
Output Voltage		$T_J = 25^{\circ}$ C		-17.3	-18.0	-18.7	V	
Line Regulation		$T_J = 25^{\circ}$ C		$-21$ V $\leq V_{IN} \leq -33$ V		15	360	mV
				$-24$ V $\leq V_{IN} \leq -30$ V		5.0	180	mV
Load Regulation		$T_J = 25^{\circ}$ C		$5$ mA $\leq I_{OUT} \leq 1.5$ A		12	360	mV
				$250$ mA $\leq I_{OUT} \leq 750$ mA		4.0	180	mV
Output Voltage		$-21$ V $\leq V_{IN} \leq -33$ V $5$ mA $\leq I_{OUT} \leq 1.0$ A $p \leq 15$ W		-17.1		-18.9	V	
Quiescent Current		$T_J = 25^{\circ}$ C			1.5	3.0	mA	
Quiescent Current Change		with line		$-21$ V $\leq V_{IN} \leq -33$ V			1.0	mA
		with load		$5$ mA $\leq I_{OUT} \leq 1.0$ A			0.5	mA
Output Noise Voltage		$T_A = 25^{\circ}$ C, $10$ Hz $\leq f \leq 100$ kHz			450		$\mu$ V	
Ripple Rejection		$f = 120$ Hz, $-22$ V $\leq V_{IN} \leq -32$ V		54	60		dB	
Dropout Voltage		$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}$ C			1.1		V	
Peak Output Current		$T_J = 25^{\circ}$ C			2.1		A	
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $0^{\circ}$ C $\leq T_J \leq 125^{\circ}$ C			-1.0		mV/ $^{\circ}$ C	

**NOTE:**

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.



# FAIRCHILD • $\mu$ A7900 SERIES

## $\mu$ A7924

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -33$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $-55^{\circ}$ C  $\leq T_J \leq 150^{\circ}$ C, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}$ C		-23.0	-24.0	-25.0	V
Line Regulation	$T_J = 25^{\circ}$ C	$-27$ V $\leq V_{IN} \leq -38$ V		18	240	mV
		$-30$ V $\leq V_{IN} \leq -36$ V		6.0	120	mV
Load Regulation	$T_J = 25^{\circ}$ C	$5$ mA $\leq I_{OUT} \leq 1.5$ A		12	240	mV
		$250$ mA $\leq I_{OUT} \leq 750$ mA		4.0	120	mV
Output Voltage	$-28$ V $\leq V_{IN} \leq -38$ V $5$ mA $\leq I_{OUT} \leq 1.0$ A $p \leq 15$ W		-22.8		-25.2	V
Quiescent Current	$T_J = 25^{\circ}$ C			1.5	3.0	mA
Quiescent Current Change	with line	$-28$ V $\leq V_{IN} \leq -38$ V			1.0	mA
	with load	$5$ mA $\leq I_{OUT} \leq 1.0$ A			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}$ C, $10$ Hz $\leq f \leq 100$ kHz			25	80	$\mu$ V/V <sub>OUT</sub>
Ripple Rejection	$f = 120$ Hz, $-28$ V $\leq V_{IN} \leq -38$ V		54	60		dB
Dropout Voltage	$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}$ C			1.1	2.3	V
Peak Output Current	$T_J = 25^{\circ}$ C		1.3	2.1	2.3	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5$ mA, $0^{\circ}$ C $\leq T_J \leq 150^{\circ}$ C				0.3	mV/ $^{\circ}$ C/V <sub>OUT</sub>
Short Circuit Current	$V_{IN} = -35$ V, $T_J = 25^{\circ}$ C				1.2	A

## $\mu$ A7924C

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -33$  V,  $I_{OUT} = 500$  mA,  $C_{IN} = 2$   $\mu$ F,  $C_{OUT} = 1$   $\mu$ F,  $0^{\circ}$ C  $\leq T_J \leq 150^{\circ}$ C, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25^{\circ}$ C		-23.0	-24.0	-25.0	V
Line Regulation	$T_J = 25^{\circ}$ C	$-27$ V $\leq V_{IN} \leq -38$ V		18	480	mV
		$-30$ V $\leq V_{IN} \leq -36$ V		6.0	240	mV
Load Regulation	$T_J = 25^{\circ}$ C	$5$ mA $\leq I_{OUT} \leq 1.5$ A		12	480	mV
		$250$ mA $\leq I_{OUT} \leq 750$ mA		4.0	240	mV
Output Voltage	$-27$ V $\leq V_{IN} \leq -38$ V $5$ mA $\leq I_{OUT} \leq 1.0$ A $p \leq 15$ W		-22.8		-25.2	V
Quiescent Current	$T_J = 25^{\circ}$ C			1.5	3.0	mA
Quiescent Current Change	with line	$-27$ V $\leq V_{IN} \leq -38$ V			1.0	mA
	with load	$5$ mA $\leq I_{OUT} \leq 1.0$ A			0.5	mA
Output Noise Voltage	$T_A = 25^{\circ}$ C, $10$ Hz $\leq f \leq 100$ kHz			600		$\mu$ V
Ripple Rejection	$f = 120$ Hz, $-28$ V $\leq V_{IN} \leq -38$ V		54	60		dB
Dropout Voltage	$I_{OUT} = 1.0$ A, $T_J = 25^{\circ}$ C			1.1		V
Peak Output Current	$T_J = 25^{\circ}$ C			2.1		A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5$ mA, $0^{\circ}$ C $\leq T_J \leq 125^{\circ}$ C			-1.0		mV/ $^{\circ}$ C

**NOTE:**

- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10$  ms, duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

# FAIRCHILD • $\mu$ A7900 SERIES

## DESIGN CONSIDERATIONS

The  $\mu$ A7900 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 7900, 125°C for 7900C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	TYP	MAX	TYP	MAX
	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JA}$
TO-3	3.5°C/W	5.5°C/W	40°C/W	45°C/W
TO-220	3.0°C/W	5.0°C/W	60°C/W	65°C/W

$$P_D (\text{MAX}) = \frac{T_J (\text{MAX}) - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_J (\text{MAX}) - T_A}{\theta_{JA}} \quad (\text{Without a heat sink})$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

$$\text{Solving for } T_J: T_J = T_A + P_D (\theta_{JC} + \theta_{CA}) \quad \text{or} \quad T_A + P_D \theta_{JA} \quad (\text{Without heat sink})$$

Where  $T_J$  = Junction Temperature

$T_A$  = Ambient Temperature

$P_D$  = Power Dissipation

$\theta_{JA}$  = Junction to Ambient Thermal Resistance

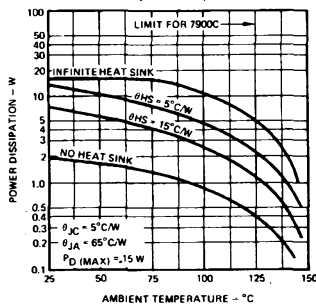
$\theta_{JC}$  = Junction to Case Thermal Resistance

$\theta_{CA}$  = Case to Ambient Thermal Resistance

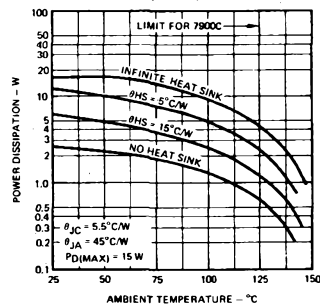
$\theta_{CS}$  = Case to Heat Sink Thermal Resistance

$\theta_{SA}$  = Heat Sink to Ambient Thermal Resistance

**WORST CASE POWER DISSIPATION  
AS A FUNCTION OF  
AMBIENT TEMPERATURE  
(TO-220)**

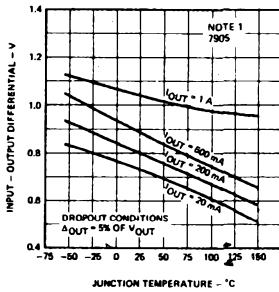


**WORST CASE POWER DISSIPATION  
AS A FUNCTION OF  
AMBIENT TEMPERATURE  
(TO-3)**

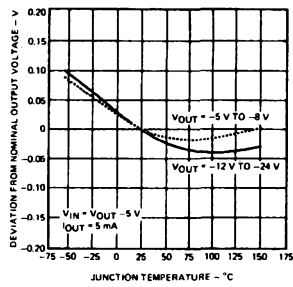


TYPICAL PERFORMANCE CURVES

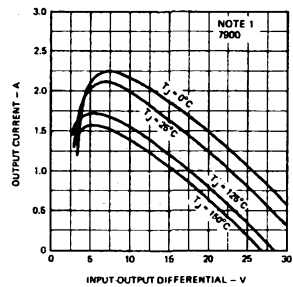
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



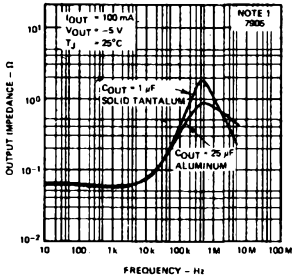
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



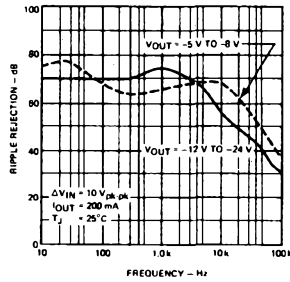
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



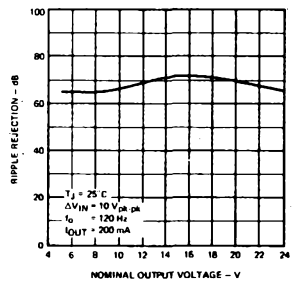
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



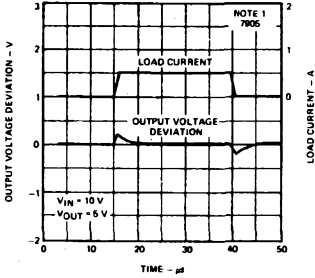
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



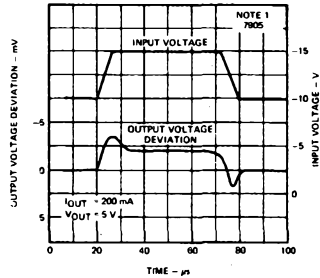
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGES



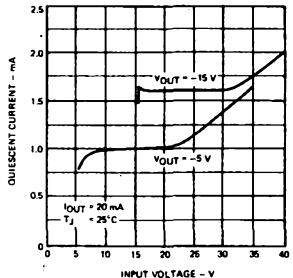
LOAD TRANSIENT RESPONSE



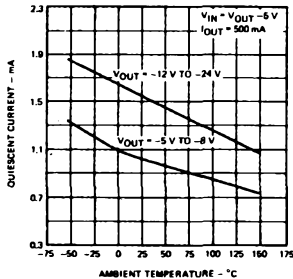
LINE TRANSIENT RESPONSE



QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

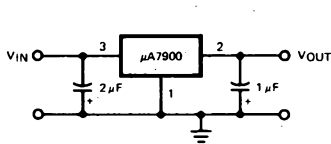


NOTE 1: The other  $\mu$ A7900 series devices have similar performance curves.

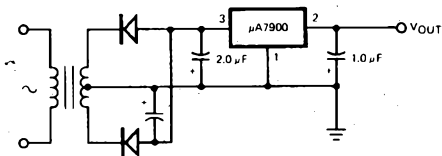
## TYPICAL APPLICATIONS

Bypass capacitors are recommended for stable operation of the  $\mu$ A7900 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

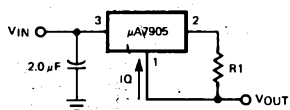
The bypass capacitors, ( $2\ \mu\text{F}$  on the input,  $1\ \mu\text{F}$  on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be  $10\ \mu\text{F}$  or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.



**FIXED-OUTPUT REGULATOR**

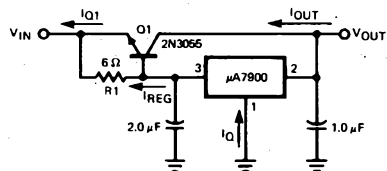


**NEGATIVE OUTPUT VOLTAGE CIRCUIT**



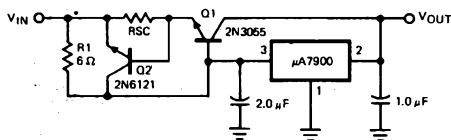
$$\text{OUTPUT CURRENT} = \frac{5.0\ \text{V}}{R1} + I_Q$$

**BASIC CURRENT REGULATOR**



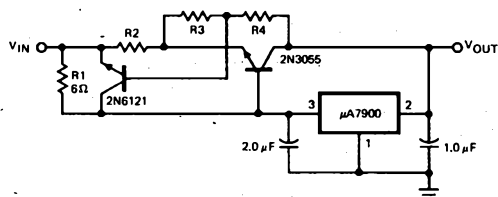
$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} \quad I_{Q1} = (\beta(Q1))I_{REG}$$

**HIGH CURRENT VOLTAGE REGULATOR**

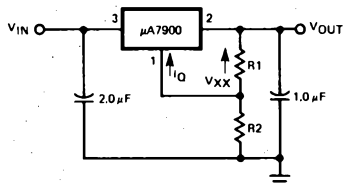


$$R_{SC} = \frac{V_{BE}(Q2)}{I_{SC}}$$

**HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED**

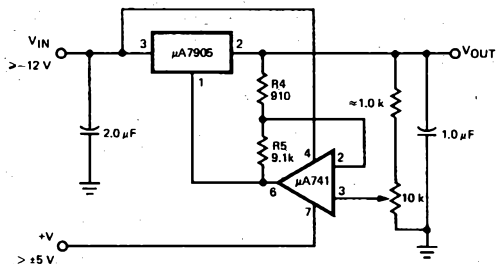


**HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED**



$$|V_{OUT}| = V_{XX} \left(1 + \frac{R2}{R1}\right) + I_Q R2$$

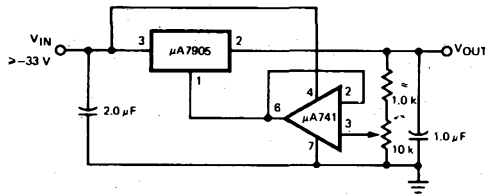
**VARIABLE OUTPUT VOLTAGE REGULATOR**



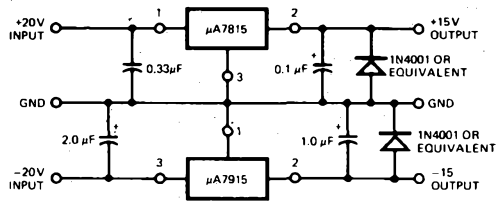
**VARIABLE OUTPUT VOLTAGE, -0.5 V TO -10 V**

TYPICAL APPLICATIONS (Cont'd)

VARIABLE OUTPUT VOLTAGE, -30 V TO -7 V



OPERATIONAL AMPLIFIER SUPPLY ( $\pm 15$  V @ 1.0 A)



# μA78G • μA79G

## 4-TERMINAL POSITIVE AND NEGATIVE ADJUSTABLE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

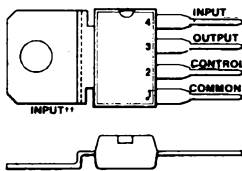
**GENERAL DESCRIPTION** — The μA78G and μA79G are 4-Terminal Adjustable Voltage Regulators. They are designed to deliver continuous load currents of up to 1.0 A with a maximum input voltage of 40 V for the positive regulator 78G and -40 V for the negative regulator 79G. Output current capability can be increased to greater than 1.0 A through use of one or more external transistors. The output voltage range of the 78G positive voltage regulator is 5 V to 30 V and the output voltage range of the negative 79G is -30 V to -2.2 V. For systems requiring both a positive and negative, the 78G and 79G are excellent for use as a dual tracking regulator with appropriate external circuitry. These 4-terminal voltage regulators are constructed using the Fairchild Planar\* process.

- OUTPUT CURRENT IN EXCESS OF 1A
- μA78G POSITIVE OUTPUT VOLTAGE 5 TO 30 V
- μA79G NEGATIVE OUTPUT VOLTAGE -30 TO -2.2 V
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT PROTECTION
- OUTPUT TRANSISTOR SAFE AREA PROTECTION
- MILITARY AND COMMERCIAL VERSIONS AVAILABLE
- AVAILABLE IN 4-PIN TO-202 TYPE AND 4-PIN TO-3

#### ABSOLUTE MAXIMUM RATINGS

Input Voltage		40 V
μA78G, μA78GC		-40 V
μA79G, μA79GC		
Control Pin Voltage		$0 < V < V_{OUT}$
μA78G, μA78GC		$-V_{OUT} < -V < 0$
μA79G, μA79GC		Internally Limited
Power Dissipation		
Operating Junction Temperature Range		
Military (μA78G, μA79G)		-55°C to 150°C
Commercial (μA78GC, μA79GC)		0°C to 150°C
Storage Temperature Range		
4-Pin Power Watt (U1)		-55°C to +150°C
4-Pin TO-3 (K)		-65°C to +150°C
Lead Temperature		
4-Pin Power Watt (U1) (Soldering, 10 s)		230°C
4-Pin TO-3 (K) (Soldering, 60 s)		300°C

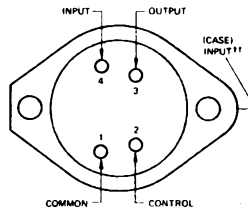
#### μA79G CONNECTION DIAGRAMS POWER WATT PACKAGE



<b>ORDER INFORMATION</b>	
<b>TYPE</b>	<b>PART NO.</b>
μA79GC	μA79GU1C

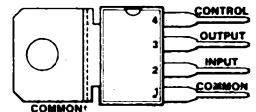
††NOTE:  
Heat sink tabs connected to input through device substrate. Not recommended for direct electrical connection.

#### TO-3 PACKAGE (TOP VIEW)



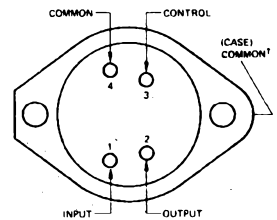
<b>ORDER INFORMATION</b>	
<b>TYPE</b>	<b>PART NO.</b>
μA79G	μA79GKM
μA79GC	μA79GKC

#### μA78G POWER WATT PACKAGE CONNECTION DIAGRAMS



<b>ORDER INFORMATION</b>	
<b>TYPE</b>	<b>PART NO.</b>
μA78GC	μA78GU1C

#### TO-3 PACKAGE (TOP VIEW)

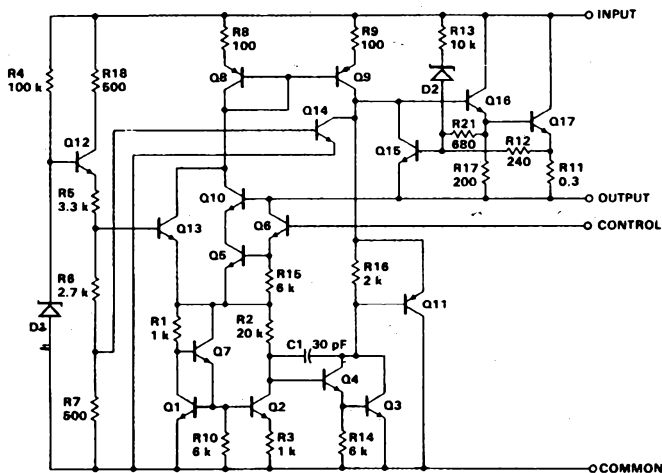


<b>ORDER INFORMATION</b>	
<b>TYPE</b>	<b>PART NO.</b>
μA78G	μA78GKM
μA78GC	μA78GKC

†NOTE:  
Heat sink tabs connected to common through device substrate.

\*Planar is a patented Fairchild process.

$\mu$ A78G EQUIVALENT CIRCUIT



$\mu$ A78G,  $\mu$ A78GC

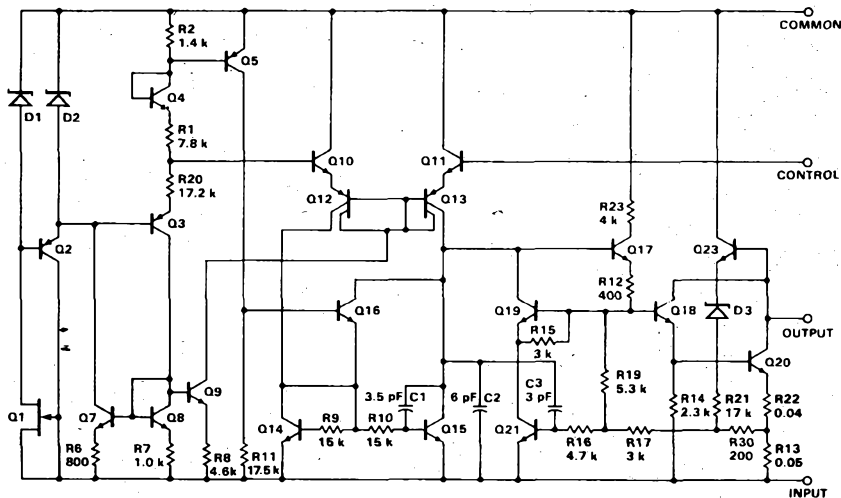
ELECTRICAL CHARACTERISTICS:  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$  for 78GC,  $C_{IN} = 0.33 \mu\text{F}$ ,  $C_{OUT} = 0.1 \mu\text{F}$  and  $-55^\circ\text{C} \leq T_J \leq 150^\circ\text{C}$  for 78G,  $V_{IN} = 10 \text{ V}$ ,  $I_{OUT} = 500 \text{ mA}$ , Test Circuit 1, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Notes 1 & 3)		MIN	TYP	MAX	UNITS	
Input Voltage Range	$T_J = 25^\circ\text{C}$		7.5		40	V	
Output Voltage Range	$V_{IN} = V_{OUT} + 5 \text{ V}$		5.0		30	V	
Output Voltage Tolerance	$V_{OUT} + 3 \text{ V} < V_{IN} < V_{OUT} + 15 \text{ V}$ , $5 \text{ mA} < I_{OUT} < 1.0 \text{ A}$ $P_D < 15 \text{ W}$ , $V_{IN(\text{MAX})} = 38 \text{ V}$	$T_J = 25^\circ\text{C}$			4.0	%( $V_{OUT}$ )	
					5.0	%( $V_{OUT}$ )	
Line Regulation	$T_J = 25^\circ\text{C}$ , $V_{OUT} \leq 10 \text{ V}$ $(V_{OUT} + 2.5 \text{ V}) < V_{IN} < (V_{OUT} + 20 \text{ V})$				1.0	%( $V_{OUT}$ )	
	$T_J = 25^\circ\text{C}$ , $V_{OUT} > 10 \text{ V}$ $(V_{OUT} + 3 \text{ V}) < V_{IN} < (V_{OUT} + 15 \text{ V})$ $(V_{OUT} + 3 \text{ V}) < V_{IN} < (V_{OUT} + 7 \text{ V})$				0.75 0.67	%( $V_{OUT}$ )	
Load Regulation	$T_J = 25^\circ\text{C}$	$250 \text{ mA} < I_{OUT} < 750 \text{ mA}$			1.0	%( $V_{OUT}$ )	
	$V_{IN} = V_{OUT} + 5 \text{ V}$	$5 \text{ mA} < I_{OUT} < 1.5 \text{ A}$			2.0		
Control Pin Current	$T_J = 25^\circ\text{C}$			1.0	5.0	$\mu\text{A}$	
					8.0	$\mu\text{A}$	
Quiescent Current	$T_J = 25^\circ\text{C}$			3.2	5.0	mA	
					6.0	mA	
Ripple Rejection	$8 \text{ V} < V_{IN} < 18 \text{ V}$ , $f = 120 \text{ Hz}$ $V_{OUT} = 5 \text{ V}$	$\mu\text{A78G}$	68	78		dB	
		$\mu\text{A78GC}$	62	78		dB	
Output Noise Voltage	$T_J = 25^\circ\text{C}$ , $10 \text{ Hz} < f < 100 \text{ kHz}$ , $V_{OUT} = 5 \text{ V}$ , $I_{OUT} = 5 \text{ mA}$			8	40	$\mu\text{V}/\text{V}_{OUT}$	
Dropout Voltage	Note 2		$\mu\text{A78G}$		2	2.5	V
			$\mu\text{A78GC}$			2.5	V
Short Circuit Current	$T_J = 25^\circ\text{C}$ , $V_{IN} = 30 \text{ V}$			.750	1.2	A	
Peak Output Current	$T_J = 25^\circ\text{C}$		1.3	2.2	3.3	A	
Average Temperature Coefficient of Output Voltage	$V_{OUT} = 5 \text{ V}$ , $I_{OUT} = 5 \text{ mA}$		$T_J = -55^\circ\text{C}$ to $+25^\circ\text{C}$		.4	mV/ $^\circ\text{C}/V_{OUT}$	
			$T_J = +25^\circ\text{C}$ to $+150^\circ\text{C}$		.3		
Control Pin Voltage (Reference)	$T_J = 25^\circ\text{C}$		4.8	5.0	5.2	V	
			4.75		5.25	V	

NOTES:

- $V_{OUT}$  is defined for the 78GC as  $V_{OUT} = \frac{R1 + R2}{R2} (6.0)$ ; The 79GC as  $V_{OUT} = \frac{R1 + R2}{R2} (-2.23)$ .
- Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.
- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10 \text{ ms}$ , duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

79G EQUIVALENT CIRCUIT



$\mu$ A79G,  $\mu$ A79GC

ELECTRICAL CHARACTERISTICS:  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$  for 79GC and  $-55^\circ\text{C} \leq T_J \leq 150^\circ\text{C}$  for 79G,  $V_{IN} = -10\text{ V}$ ,  $I_{OUT} = 500\text{ mA}$ ,  $C_{IN} = 2\ \mu\text{F}$ ,  $C_{OUT} = 1\ \mu\text{F}$ , Test Circuit 2 and Note 3 unless otherwise specified.

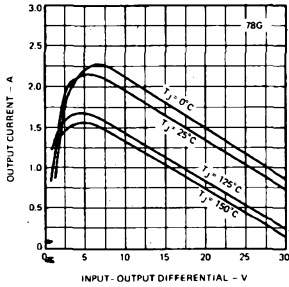
CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Input Voltage Range	$T_J = 25^\circ\text{C}$		-40		-7.0	V
Nominal Output Voltage Range	$V_{IN} = V_{OUT} - 5\text{ V}$		-30		-2.23	V
Output Voltage Tolerance	$V_{OUT} - 15\text{ V} \leq V_{IN} \leq V_{OUT} - 3\text{ V}$ , $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$			$T_J = 25^\circ\text{C}$	4.0	%( $V_{OUT}$ )
	$P_D \leq 15\text{ W}$ , $V_{IN(\text{MAX})} = -38\text{ V}$				5.0	%( $V_{OUT}$ )
Line Regulation	$T_J = 25^\circ\text{C}$ , $V_{OUT} \geq -10\text{ V}$ $(V_{OUT} - 20\text{ V}) \leq V_{IN} \leq (V_{OUT} - 2.5\text{ V})$				1.0	%( $V_{OUT}$ )
	$T_J = 25^\circ\text{C}$ , $V_{OUT} < -10\text{ V}$ $(V_{OUT} - 15\text{ V}) \leq V_{IN} \leq (V_{OUT} - 3\text{ V})$				0.75	%( $V_{OUT}$ )
	$(V_{OUT} - 7\text{ V}) \leq V_{IN} \leq (V_{OUT} - 3\text{ V})$				0.67	%( $V_{OUT}$ )
Load Regulation	$T_J = 25^\circ\text{C}$	$250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$			1.0	%( $V_{OUT}$ )
	$V_{IN} = V_{OUT} - 5\text{ V}$ , $5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$				2.0	%( $V_{OUT}$ )
Control Pin Current	$T_J = 25^\circ\text{C}$			0.4	2.0	$\mu\text{A}$
					3.0	$\mu\text{A}$
Quiescent Current	$T_J = 25^\circ\text{C}$			0.5	1.5	mA
					2.0	mA
Ripple Rejection	$-18\text{ V} \leq V_{IN} < -8\text{ V}$	$\mu$ A79G	50	60		dB
	$V_{OUT} = -5\text{ V}$ , $f = 120\text{ Hz}$	$\mu$ A79GC	50	60		dB
Output Noise Voltage	$T_J = 25^\circ\text{C}$ , $10\text{ Hz} \leq f \leq 100\text{ kHz}$ , $V_{OUT} = -5\text{ V}$ , $I_{OUT} = 5\text{ mA}$			25	80	$\mu\text{V}/V_{OUT}$
Dropout Voltage	Note 2			1.1	2.3	V
					2.3	V
Short Circuit Current	$T_J = 25^\circ\text{C}$ , $V_{IN} = -30\text{ V}$			0.25	1.2	A
Peak Output Current	$T_J = 25^\circ\text{C}$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage	$V_{OUT} = -5\text{ V}$ , $I_{OUT} = 5\text{ mA}$		$T_J = -55^\circ\text{C}$ to $+25^\circ\text{C}$		0.3	$\text{mV}/^\circ\text{C}/V_{OUT}$
			$T_J = +25^\circ\text{C}$ to $+150^\circ\text{C}$		0.3	
Control Pin Voltage (Reference)	$T_J = 25^\circ\text{C}$		-2.32	-2.23	-2.14	V
			-2.35		-2.11	V

- NOTES: 1.  $V_{OUT}$  is defined for the 78GC as  $V_{OUT} = \frac{R1 + R2}{R2} (5.0)$ ; The 79GC as  $V_{OUT} = \frac{R1 + R2}{R2} (-2.23)$ .
2. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.
3. The convention for negative regulators is the algebraic value, thus -15 is less than -10V.
4. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

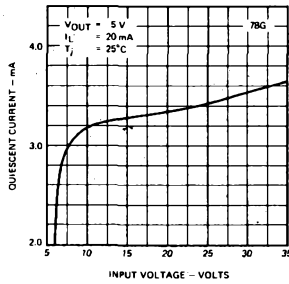


TYPICAL PERFORMANCE CURVES FOR  $\mu$ A78G

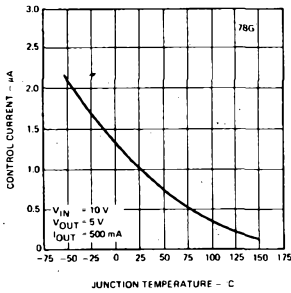
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



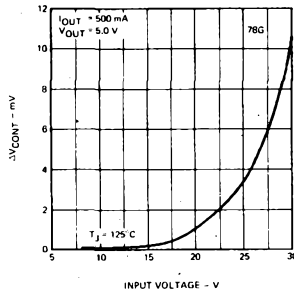
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



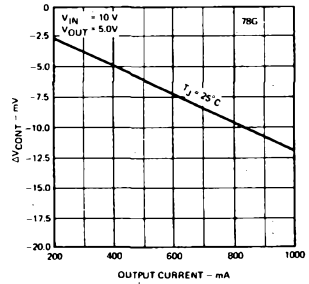
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



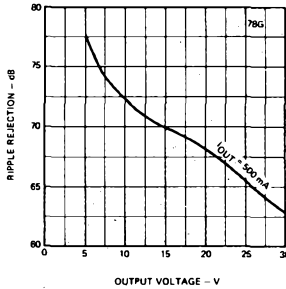
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



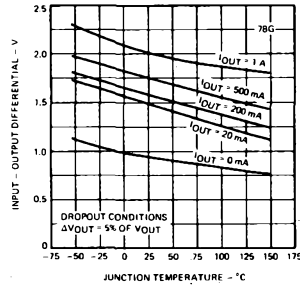
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



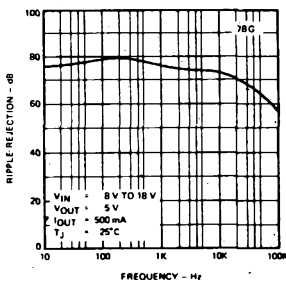
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



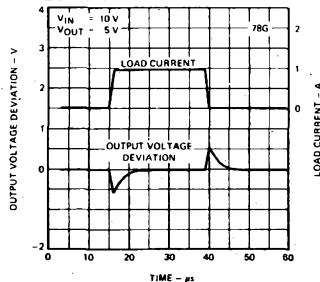
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



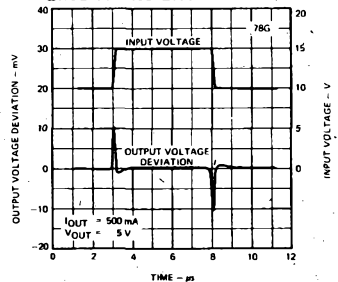
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE

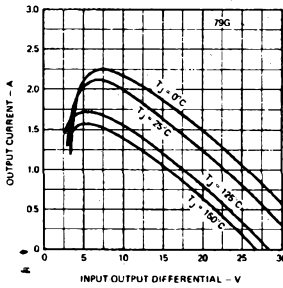


LINE TRANSIENT RESPONSE

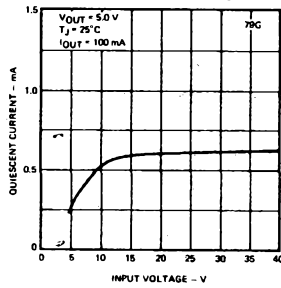


TYPICAL PERFORMANCE CURVES FOR  $\mu$ A79G

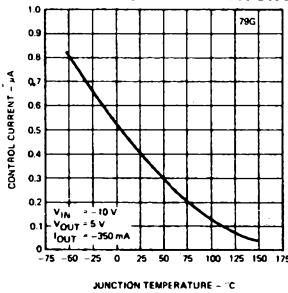
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



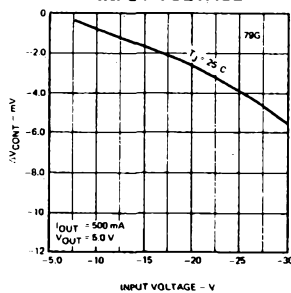
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



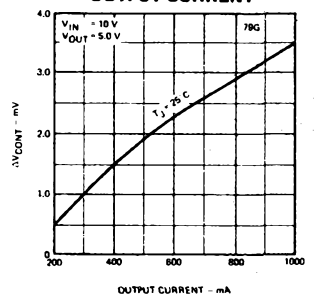
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



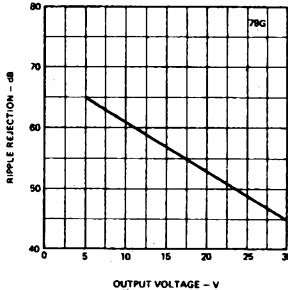
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



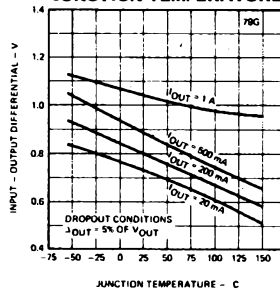
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



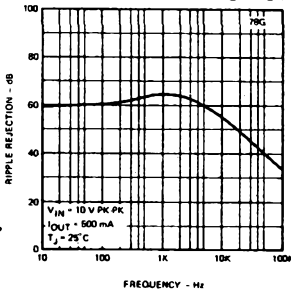
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



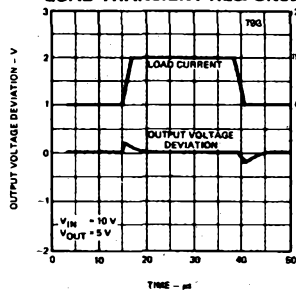
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



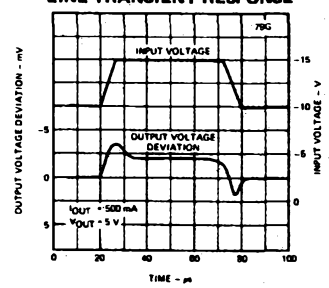
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE



LINE TRANSIENT RESPONSE



**DESIGN CONSIDERATIONS** — The 78G and 79G adjustable voltage regulators have an output voltage which varies from  $V_{CONTROL}$  to typically  $V_{IN} - 2 V$  by  $V_{OUT} = V_{CONTROL} \frac{(R1 + R2)}{R2}$ . The nominal reference in the 78G is 5.0 V and 79G is -2.23 V. If we allow 1.0 mA to flow in the control string to eliminate bias current effects, we can make  $R2 = 5 k\Omega$  in the 78G. The output voltage is then:  $V_{OUT} = (R1 + R2) V$ , where  $R1$  and  $R2$  are in  $k\Omega$ s.

Example: If  $R2 = 5 k\Omega$  and  $R1 = 10 k\Omega$  then  $V_{OUT} = 15 V$  nominal, for the 78G;  
 If  $R2 = 2.2 k\Omega$  and  $R1 = 12.8 k\Omega$  then  $V_{OUT} = -15.2 V$  nominal, for the 79G.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

Both 78G and 79G regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	TYP	MAX	TYP	MAX
	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JA}$	$\theta_{JA}$
POWER WATT	7.5°C/W	11°C/W	75°C/W	80°C/W
TO-3	4.0°C/W	6°C/W	44°C/W	47°C/W

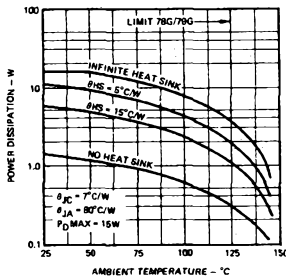
$$P_D (MAX) = \frac{T_J (MAX) - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_J (MAX) - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

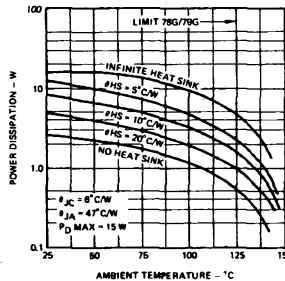
$$\text{Solving for } T_J: T_J = T_A + P_D (\theta_{JC} + \theta_{CA}) \text{ or } T_A + P_D \theta_{JA} \text{ (Without heat sink)}$$

- Where  $T_J$  = Junction Temperature  $\theta_{JC}$  = Junction to case thermal resistance  
 $T_A$  = Ambient Temperature  $\theta_{CA}$  = Case to Ambient thermal resistance  
 $P_D$  = Power Dissipation  $\theta_{CS}$  = Case to heat sink resistance  
 $\theta_{JA}$  = Junction to ambient thermal resistance  $\theta_{SA}$  = Heat sink to ambient thermal resistance

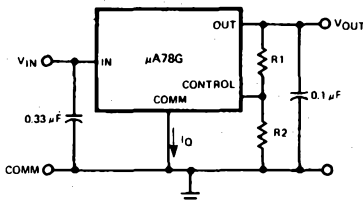
$\mu$ A78G AND  $\mu$ A79G  
 POWER TAB (U1) PACKAGE  
 WORST CASE POWER DISSIPATION  
 AS A FUNCTION OF  
 AMBIENT TEMPERATURE



$\mu$ A78G AND  $\mu$ A79G  
 TO-3 PACKAGE  
 WORST CASE POWER DISSIPATION  
 VERSUS  
 AMBIENT TEMPERATURE



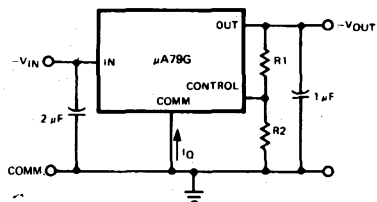
$\mu$ A78G TEST CIRCUIT 1



$$V_{OUT} = \left( \frac{R1 + R2}{R2} \right) V_{CONTROL}$$

$V_{CONTROL}$  Nominal = 5 V

$\mu$ A79G TEST CIRCUIT 2



$$V_{OUT} = \left( \frac{R1 + R2}{R2} \right) V_{CONTROL}$$

$V_{CONTROL}$  Nominal = -2.23 V

Recommended R2 current  $\approx$  1 mA

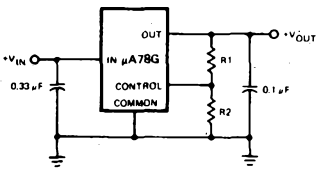
$\therefore R2 = 5 \text{ k}\Omega$  (781G)

$R2 = 2.2 \text{ k}\Omega$  (79G)

TYPICAL APPLICATIONS FOR  $\mu$ A78G

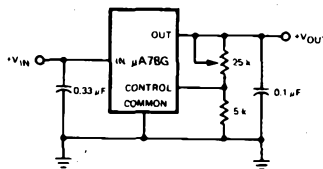
In many  $\mu$ A78G applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33  $\mu$ F and 0.1  $\mu$ F, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

BASIC POSITIVE REGULATOR

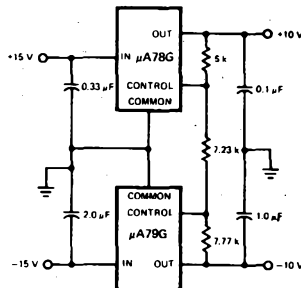


$$V_{OUT} = V_{CONT} \left( \frac{R1 + R2}{R2} \right)$$

POSITIVE 5 TO 30 V  
ADJUSTABLE REGULATOR

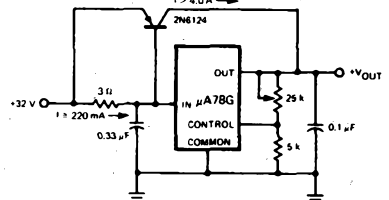


$\pm 10 \text{ V}, 1.0 \text{ A}$   
DUAL TRACKING REGULATOR



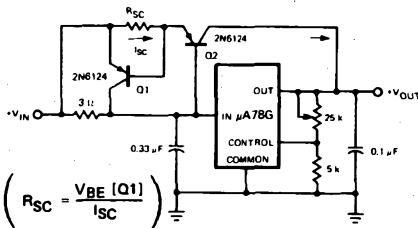
If load is not ground referenced, connect reverse biased diodes from outputs to ground.

POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR  
 $I_{OUT} > 5.0 \text{ A}$

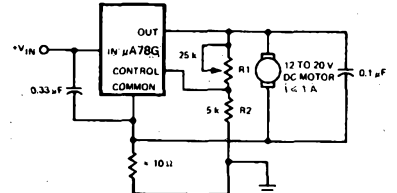


NOTE: External series pass device is not short circuit protected.

POSITIVE HIGH CURRENT SHORT CIRCUIT  
PROTECTED REGULATOR

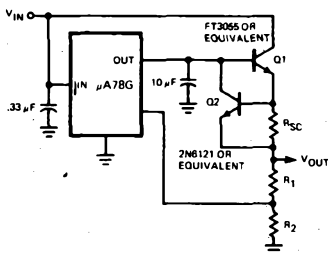


MOTOR SPEED CONTROL

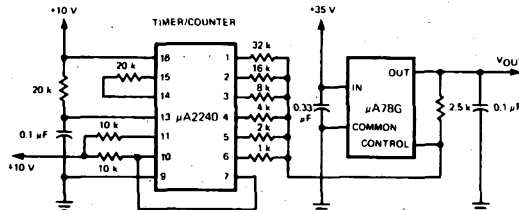


Use flyback diode across motor if necessary.

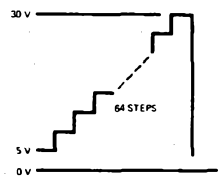
POSITIVE HIGH CURRENT  
SHORT CIRCUIT  
PROTECTED REGULATOR



PROGRAMMABLE SUPPLY



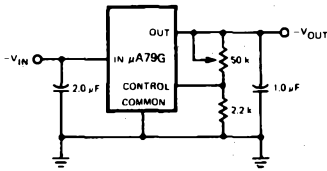
OUTPUT WAVEFORM



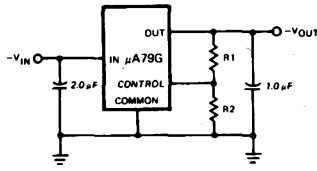
TYPICAL APPLICATIONS FOR  $\mu$ A79G

All  $\mu$ A78G applications apply to the  $\mu$ A79G under the following conditions; R2 values are 2.2 k $\Omega$ , all external transistors and diodes reverse polarity.

-30 V TO -2.2 V  
ADJUSTABLE REGULATOR

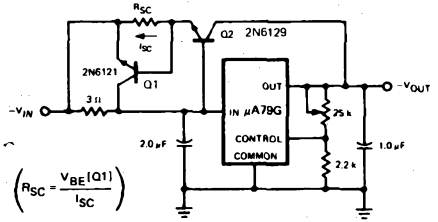


BASIC  
NEGATIVE REGULATOR



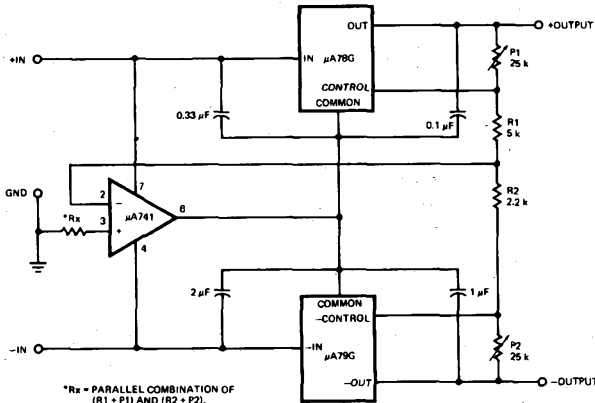
$$V_{OUT} = -V_{CONT} \left( \frac{R1 + R2}{R2} \right)$$

NEGATIVE HIGH CURRENT SHORT CIRCUIT  
PROTECTED REGULATOR



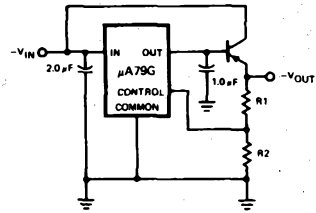
$$\left( R_{SC} = \frac{V_{BE}(Q1)}{I_{SC}} \right)$$

ADJUSTABLE DUAL TRACKING REGULATOR



\*Rx = PARALLEL COMBINATION OF (R1 + P1) AND (R2 + P2).

NEGATIVE HIGH CURRENT VOLTAGE REGULATOR  
EXTERNAL SERIES PASS



**NOTE:**  
Bypass capacitors are recommended for stable operation of the  $\mu$ A79G series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, ( 2  $\mu$ F on the input, 1  $\mu$ F on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10  $\mu$ F or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

# $\mu$ A79HG

## 5 AMP NEGATIVE ADJUSTABLE VOLTAGE REGULATOR FAIRCHILD HYBRID PRODUCTS

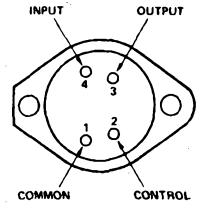
**GENERAL DESCRIPTION** — The  $\mu$ A79HG is an adjustable 4-terminal negative voltage regulator capable of supplying in excess of -5 A over a -24 V to -2.2 V output range. The  $\mu$ A79HG hybrid voltage regulator has been designed with all the inherent characteristics of the monolithic 4-terminal regulator; i.e., full thermal overload and short-circuit protection. The  $\mu$ A79HG is packaged in a hermetically-sealed 4-pin TO-3 package providing 50 W power dissipation. The regulator consists of a monolithic chip providing a discrete-series pass element and short-circuit detection transistors.

- -5 A OUTPUT CURRENT
- INTERNAL CURRENT AND THERMAL LIMITING
- INTERNAL SHORT-CIRCUIT CURRENT LIMIT
- LOW DROP-OUT VOLTAGE
- 50 W POWER DISSIPATION
- ELECTRICALLY NEUTRAL CASE

### ABSOLUTE MAXIMUM RATINGS

Input Voltage	-40 V
Internal Power Dissipation	50 W @ 25°C Case
Maximum Input-to-Output Voltage Differential	-20 V
Operating Junction Temperature Range	-0°C to 150°C
Storage Temperature Range	-55°C to 150°C
Lead Temperature (Soldering, 60 s)	300°C

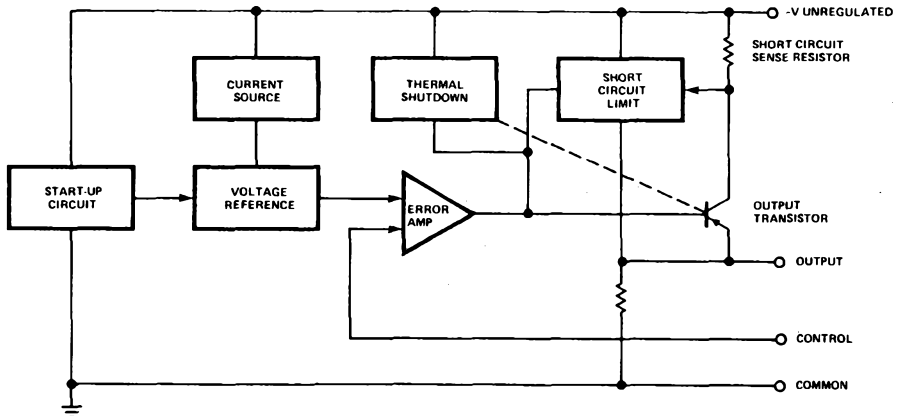
### CONNECTION DIAGRAM TO-3 PACKAGE (TOP VIEW)



### ORDER INFORMATION

TYPE	PART NO.
79HG	$\mu$ A79HGKC

### BLOCK DIAGRAM



# FAIRCHILD • $\mu$ A79HG

**ELECTRICAL CHARACTERISTICS:**  $T_J = 25^\circ\text{C}$ ,  $I_{OUT} = -2.0\text{ A}$  unless otherwise specified.

CHARACTERISTIC	CONDITION	MIN	TYP	MAX	UNITS
Input Voltage Range		-40		-7.0	V
Nominal Output Voltage Range	$V_{IN} = V_{OUT} - 5V$	-24		-2.23	V
Output Voltage Tolerance	$-40\text{ V} \leq V_{IN} \leq -7\text{ V}$			4%	%(V <sub>OUT</sub> )
Line Regulation	$-40 \leq V_{IN} \leq -7\text{ V}$		0.4	1.0	%(V <sub>OUT</sub> )
Load Regulation	$V_{IN} = V_{OUT} - 10\text{ V}$ , $-10\text{ mA} \leq I_{OUT} \leq -5.0\text{ A}$		0.7	1.0	%(V <sub>OUT</sub> )
Control Pin Current				3.0	$\mu\text{A}$
Quiescent Current	$V_{IN} = -10\text{ V}$			-5.0	mA
Ripple Rejection	$-18\text{ V} \leq V_{IN} \leq -8.5\text{ V}$ $V_{OUT} = -5\text{ V}$ , $f = 120\text{ Hz}$		50		dB
Output Noise Voltage	$10\text{ Hz} \leq f \leq 100\text{ kHz}$ , $V_{OUT} = -5.0\text{ V}$		200		$\mu\text{V}$
Dropout Voltage	$I_{OUT} = -5\text{ A}$		-2.0		V
Peak Output Current	$V_{IN} = -10\text{ V}$		-8		A
Control Pin Voltage (Reference)	$V_{IN} = -10\text{ V}$	-2.35		-2.11	V

**DESIGN CONSIDERATIONS** — The nominal reference in the  $\mu$ A79HG is -2.23 V. If we allow -1.0 mA to flow in the control string to eliminate bias current effects, we can make  $R_2 = 2.2\text{ k}\Omega$  in the  $\mu$ A79HG. The output voltage is then:  $V_{OUT} = (R_1 + R_2)$  Volts, where  $R_1$  and  $R_2$  are in  $\text{k}\Omega$ .

Example:  $R_2 = 2.2\text{ k}\Omega$  and  $R_1 = 12.8\text{ k}\Omega$ , then  $V_{OUT} = -15.2\text{ V}$  nominal.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

The  $\mu$ A79HG regulator has thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature ( $150^\circ\text{C}$ ) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYPICAL	TYPICAL
	$\theta_{JC}$	$\theta_{JA}$
TO-3	3.0	$\frac{33}{\text{(Without heat sink)}}$

$$P_D (\text{MAX}) = \frac{T_J (\text{MAX}) - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_J (\text{MAX}) - T_A}{\theta_{JA}}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

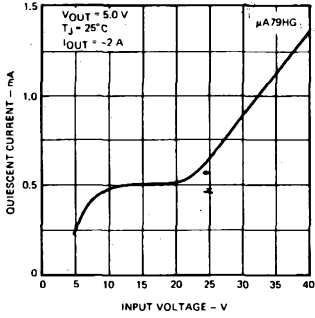
$$\text{Solving for } T_J: \quad T_J = T_A + P_D (\theta_{JC} + \theta_{CA}) \quad \text{or} \quad T_A + P_D \theta_{JA} \quad (\text{Without heat sink})$$

Where  $T_J$  = Junction Temperature  
 $T_A$  = Ambient Temperature  
 $P_D$  = Power Dissipation

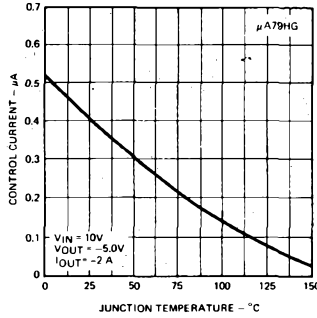
$\theta_{JC}$  = Junction to case thermal resistance  
 $\theta_{CA}$  = Case to ambient thermal resistance  
 $\theta_{CS}$  = Case to heat sink thermal resistance  
 $\theta_{SA}$  = Heat sink to ambient thermal resistance  
 $\theta_{JA}$  = Junction to ambient thermal resistance

TYPICAL PERFORMANCE CURVES

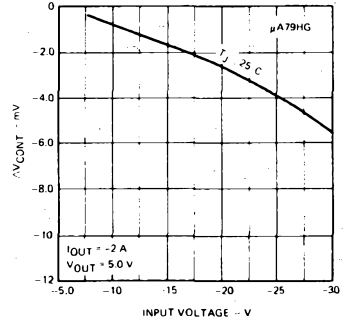
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



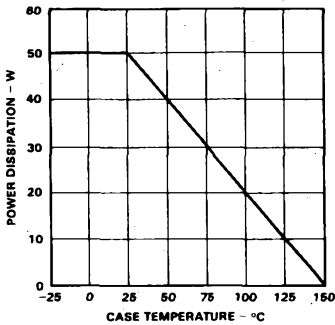
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



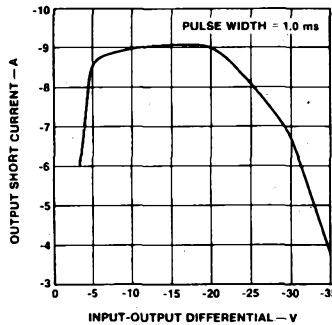
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



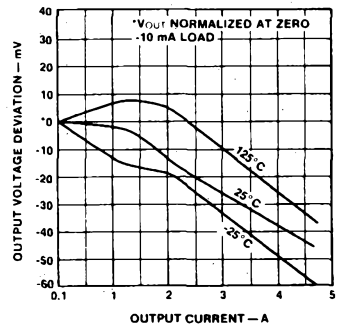
MAXIMUM POWER DISSIPATION



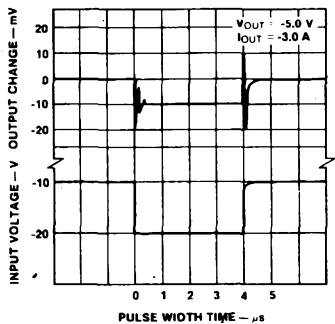
OUTPUT SHORT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



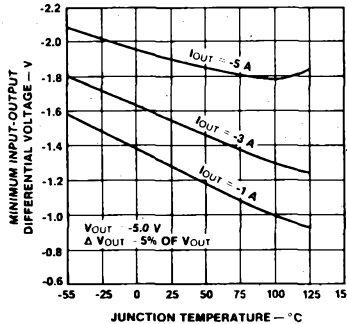
LOAD REGULATION AS A FUNCTION OF OUTPUT CURRENT



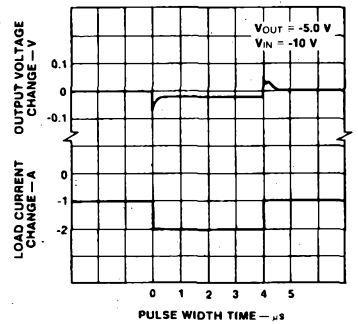
LINE TRANSIENT RESPONSE



DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



LOAD TRANSIENT RESPONSE

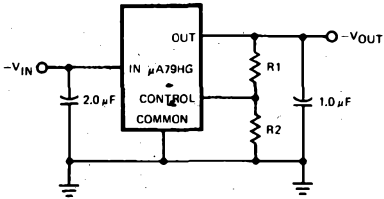




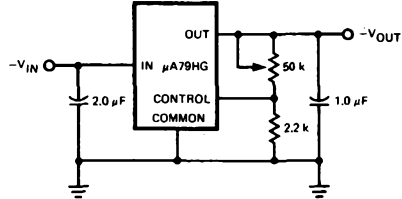
TYPICAL APPLICATIONS FOR 79HG

Bypass capacitors are recommended for stable operation of the  $\mu$ A79HG over all input voltage and output current ranges. The bypass capacitors, ( $2 \mu\text{F}$  on the input,  $1 \mu\text{F}$  on the output) should be solid tantalum which have good high frequency characteristics. The bypass capacitors should be mounted with the shortest possible leads, and directly across the regulator terminals.

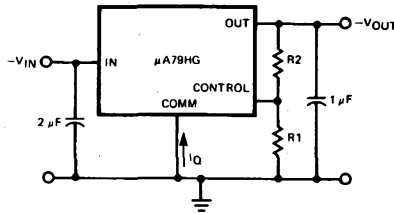
BASIC NEGATIVE REGULATOR



-30 V TO -2.2 V  
ADJUSTABLE REGULATOR



$\mu$ A79HG TEST CIRCUIT 2



# μA78MG • μA79MG

## 4-TERMINAL POSITIVE AND NEGATIVE ADJUSTABLE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

**GENERAL DESCRIPTION** — The μA78MG and μA79MG are 4-Terminal Adjustable Voltage Regulators. They are designed to deliver continuous load currents of up to 500 mA with a maximum input voltage of 40 V for the positive regulator 78MG and -40 V for the negative regulator 79MG. Output current capability can be increased to greater than 10 A through use of one or more external transistors. The output voltage range of the 78MG positive voltage regulator is 5 V to 30 V and the output voltage range of the negative 79MG is -30 V to -2.2 V. For systems requiring both a positive and negative, the 78MG and 79MG are excellent for use as a dual tracking regulator. These 4-terminal voltage regulators are constructed using the Fairchild Planar<sup>†</sup> process.

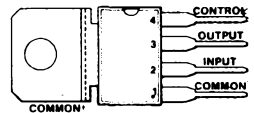
- OUTPUT CURRENT IN EXCESS OF 0.5 A
- μA78MG POSITIVE OUTPUT VOLTAGE 5 TO 30 V
- μA79MG NEGATIVE OUTPUT VOLTAGE -30 V TO -2.2 V
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT PROTECTION
- OUTPUT TRANSISTOR SAFE AREA PROTECTION
- POWER MINI DUAL IN-LINE PACKAGE

**ABSOLUTE MAXIMUM RATINGS**

<b>Input Voltage</b>	
μA78MG, μA79MGC	40V
μA79MG, μA79MGC	-40V
<b>Control Pin Voltage</b>	
μA78MG, μA78MGC	$0 < V < V_{OUT}$
μA79MG, μA79MGC	$-V_{OUT} < -V < 0$
<b>Power Dissipation</b>	
Internally Limited	
<b>Operating Junction Temperature Range (Note 1)</b>	
Military (μA78MG, μA79MG)	-55°C to 150°C
Commercial (μA78MGC, μA79MGC)	0°C to 150°C
<b>Storage Temperature Range</b>	
4-Pin TO-39	-65°C to +150°C
Power Mini DIP and Power Watt	-55°C to +150°C
<b>Lead Temperature</b>	
Power Watt and Power Mini DIP (Soldering, 10 s)	230°C
4-Pin TO-39(Soldering, 60 s)	300°C

**μA78MG  
CONNECTION DIAGRAMS**

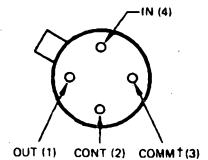
**POWER WATT**



**ORDER INFORMATION**  

TYPE	PART NO.
μA78MGC	μA78MGU1C

**4-PIN TO-39  
(TOP VIEW)**



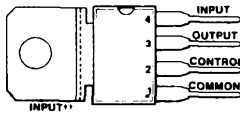
**ORDER INFORMATION**  

TYPE	PART NO.
μA78MG	μA78MGHM
μA78MGC	μA78MGHC

†NOTE:  
Heat sink tabs connected to common through device substrate.

**μA79MG  
CONNECTION DIAGRAMS**

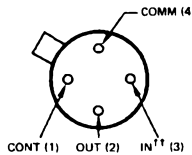
**POWER WATT**



**ORDER INFORMATION**  

TYPE	PART NO.
μA79MG	μA79MGU1C

**4-PIN TO-39  
(TOP VIEW)**

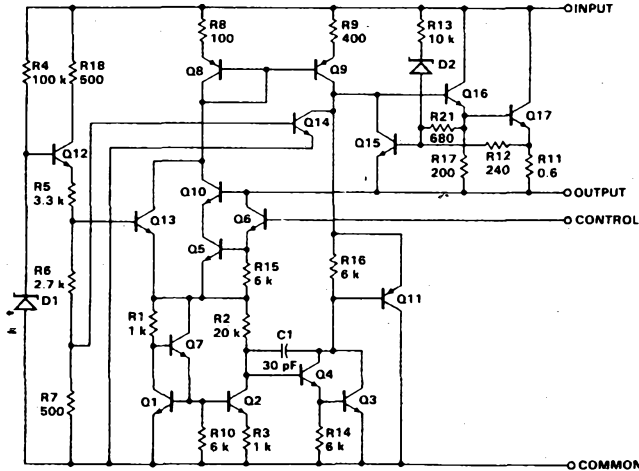


**ORDER INFORMATION**  

TYPE	PART NO.
μA79MG	μA79MGHM
μA79MGC	μA79MGHC

††NOTE:  
Heat sink tabs connected to input through device substrate. Not recommended for direct electrical connection.

78MG EQUIVALENT CIRCUIT



Resistor values in  $\Omega$  unless otherwise noted.

$\mu$ A78MG (C, HC, HM)

ELECTRICAL CHARACTERISTICS:  $0^\circ\text{C} < T_J \leq 125^\circ\text{C}$  for  $\mu$ A78MGHC and  $\mu$ A78MGC,  $-55^\circ\text{C} < T_J \leq 150^\circ\text{C}$  for  $\mu$ A78MGHM,  $V_{IN} = 10\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $C_{IN} = 0.33\mu\text{F}$ ,  $C_{OUT} = 0.1\mu\text{F}$ , Test Circuit 1, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (1 and 3)	MIN	TYP	MAX	UNITS
Input Voltage Range	$T_J = 25^\circ\text{C}$	7.5		40	V
Output Voltage Range	$V_{IN} = V_{OUT} + 5\text{ V}$	5.0		30	V
Output Voltage Tolerance	$V_{OUT} + 3\text{ V} < V_{IN} < V_{OUT} + 15\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$ $P_D < 5\text{ W}$ , $V_{INMAX} = 38\text{ V}$	$T_J = 25^\circ\text{C}$		4.0	%( $V_{OUT}$ )
				5.0	%( $V_{OUT}$ )
Line Regulation	$T_J = 25^\circ\text{C}$ , $I_{OUT} = 200\text{ mA}$ , $V_{OUT} < 10\text{ V}$ $(V_{OUT} + 2.5\text{ V}) \leq V_{IN} \leq (V_{OUT} + 20\text{ V})$			1.0	%( $V_{OUT}$ )
	$T_J = 25^\circ\text{C}$ , $I_{OUT} = 200\text{ mA}$ , $V_{OUT} \geq 10\text{ V}$ $(V_{OUT} + 3\text{ V}) < V_{IN} < (V_{OUT} + 15\text{ V})$			0.75	%( $V_{OUT}$ )
	$(V_{OUT} + 3\text{ V}) < V_{IN} < (V_{OUT} + 7\text{ V})$			0.67	%( $V_{OUT}$ )
Load Regulation	$T_J = 25^\circ\text{C}$ $5\text{ mA} < I_{OUT} \leq 500\text{ mA}$ , $V_{IN} = V_{OUT} + 7\text{ V}$			1.0	%( $V_{OUT}$ )
Control Pin Current	$T_J = 25^\circ\text{C}$		1.0	5.0	$\mu\text{A}$
				8.0	$\mu\text{A}$
Quiescent Current	$T_J = 25^\circ\text{C}$		2.8	4.0	mA
				5.0	mA
Ripple Rejection	$8\text{ V} < V_{IN} < 18\text{ V}$	$I_{OUT} = 300\text{ mA}$ , $T_J = 25^\circ\text{C}$	62	80	dB
	$V_{OUT} = 5\text{ V}$ , $f = 120\text{ Hz}$		$I_{OUT} = 100\text{ mA}$	62	
Output Noise Voltage	$10\text{ Hz} \leq f < 100\text{ kHz}$ , $V_{OUT} = 5\text{ V}$		8	40	$\mu\text{V}/V_{OUT}$
Dropout Voltage	(Note 2)	$\mu$ A78MGHM	2	2.5	V
		$\mu$ A78MG(HC and C)		2.5	
Short Circuit Current	$V_{IN} = 35\text{ V}$ , $T_J = 25^\circ\text{C}$			600	mA
Peak Output Current	$T_J = 25^\circ\text{C}$	0.4	0.8	1.4	A
Average Temperature Coefficient of Output Voltage	$V_{OUT} = 5\text{ V}$ $I_{OUT} = 5\text{ mA}$	$T_J = -55^\circ\text{C}$ to $+25^\circ\text{C}$		0.4	$\text{mV}/^\circ\text{C}/V_{OUT}$
		$T_J = +25^\circ\text{C}$ to $+150^\circ\text{C}$		0.3	
Control Pin Voltage (Reference)	$T_J = 25^\circ\text{C}$		4.8	5.0	V
			4.75	5.25	V

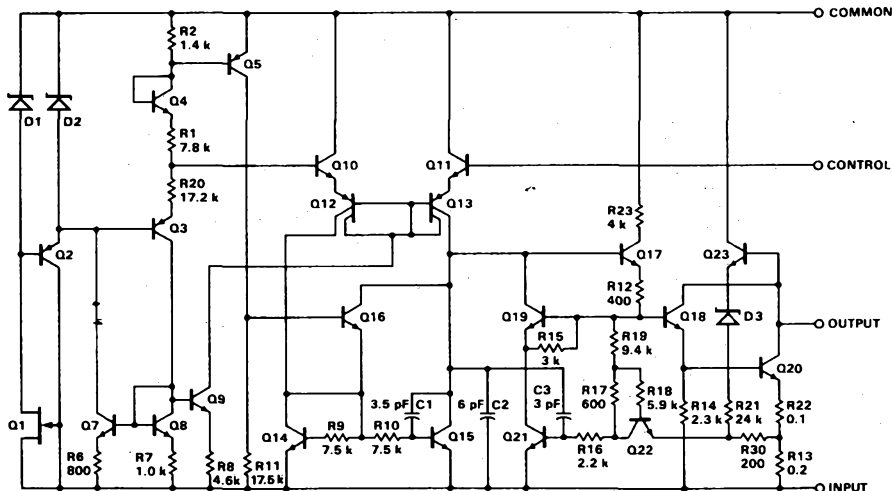
NOTES:

1.  $V_{OUT}$  is defined for the 78MGC as  $V_{OUT} = \frac{R1 + R2}{R2} (5.0)$ ; The 79MGC as  $V_{OUT} = \frac{R1 + R2}{R2} (-2.23)$ .

2. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.

3. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w < 10\text{ ms}$ , duty cycle  $< 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

79MG EQUIVALENT CIRCUIT



Resistor values in  $\Omega$  unless otherwise noted.

$\mu$ A79MG (C, HC, HM)

ELECTRICAL CHARACTERISTICS:  $0^\circ\text{C} < T_J < 125^\circ\text{C}$  for  $\mu$ A79MGHC and  $\mu$ A79MGC,  $-55^\circ\text{C} < T_J < 150^\circ\text{C}$  for  $\mu$ A79MGHM,

$V_{IN} = -10\text{ V}$ ,  $I_{OUT} = 350\text{ mA}$ ,  $C_{IN} = 2.0\ \mu\text{F}$ ,  $C_{OUT} = 1.0\ \mu\text{F}$ , Test Circuit 2, unless otherwise specified.

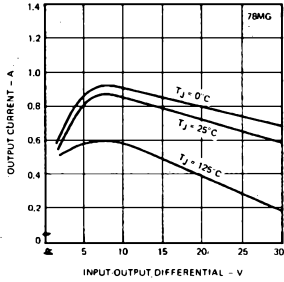
CHARACTERISTICS	CONDITIONS (1 and 2)	MIN	TYP	MAX	UNITS
Input Voltage Range	$T_J = 25^\circ\text{C}$	-40		-7.0	V
Output Voltage Range	$V_{IN} = V_{OUT} - 5\text{ V}$	-30		-2.23	V
Output Voltage Tolerance	$V_{OUT} - 15\text{ V} < V_{IN} < V_{OUT} - 3\text{ V}$ , $5\text{ mA} < I_{OUT} < 350\text{ mA}$ , $P_D < 5\text{ W}$ , $V_{INMAX} = -38\text{ V}$		$T_J = 25^\circ\text{C}$	4.0	$\%(V_{OUT})$
Line Regulation	$T_J = 25^\circ\text{C}$ , $I_{OUT} = 200\text{ mA}$ , $V_{OUT} > -10\text{ V}$ $(V_{OUT} - 20\text{ V}) < V_{IN} < (V_{OUT} - 2.5\text{ V})$			1.0	$\%(V_{OUT})$
	$T_J = 25^\circ\text{C}$ , $I_{OUT} = 200\text{ mA}$ , $V_{OUT} < -10\text{ V}$ $(V_{OUT} - 15\text{ V}) < V_{IN} < (V_{OUT} - 3\text{ V})$ $(V_{OUT} - 7\text{ V}) < V_{IN} < (V_{OUT} - 3\text{ V})$			0.75 0.67	$\%(V_{OUT})$ $\%(V_{OUT})$
Load Regulation	$V_{IN} = V_{OUT} - 7\text{ V}$ , $5\text{ mA} < I_{OUT} < 500\text{ mA}$ $T_J = 25^\circ\text{C}$			1.0	$\%(V_{OUT})$
Control Pin Current	$T_J = 25^\circ\text{C}$			3.0	$\mu\text{A}$
				2.0	$\mu\text{A}$
Quiescent Current	$T_J = 25^\circ\text{C}$			0.5	mA
				2.5	mA
Ripple Rejection	$-18\text{ V} < V_{IN} < -8\text{ V}$ , $T_J = 25^\circ\text{C}$ , $I_{OUT} = 300\text{ mA}$	54	65		dB
	$V_{OUT} = -5\text{ V}$ , $f = 120\text{ Hz}$ , $I_{OUT} = 100\text{ mA}$	50			dB
Output Noise Voltage	$10\text{ Hz} < f < 100\text{ kHz}$ , $V_{OUT} = -5\text{ V}$		25	80	$\mu\text{V}/V_{OUT}$
Dropout Voltage	(Note 2)	$\mu$ A79MGHM	1.1	2.3	V
		$\mu$ A79MG (HC and C)		2.3	
Short Circuit Current	$V_{IN} = -35\text{ V}$			600	mA
Peak Output Current		0.4	.65	1.4	mA
Average Temperature Coefficient of Output Voltage	$V_{OUT} = -5\text{ V}$ , $I_{OUT} = 5\text{ mA}$	$T_J = -55^\circ\text{C}$ to $+25^\circ\text{C}$		0.3	mV/ $^\circ\text{C}$ / V <sub>OUT</sub>
		$T_J = +25^\circ\text{C}$ to $+150^\circ\text{C}$		0.3	
Control Pin Voltage (Reference)	$T_J = 25^\circ\text{C}$	-2.32	-2.23	-2.14	V
		-2.35		-2.11	V

NOTES:

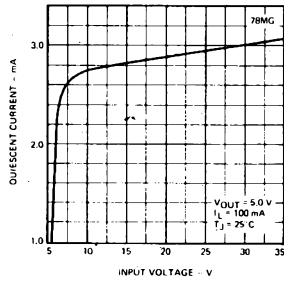
- The convention for Negative Regulators is the Algebraic value, thus -15 is less than -10 V.
- All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ( $t_w \leq 10\text{ ms}$ , duty cycle  $\leq 5\%$ ). Output voltage changes due to changes in internal temperature must be taken into account separately.

TYPICAL PERFORMANCE CURVES FOR  $\mu$ A78MG

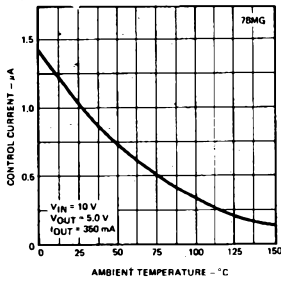
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



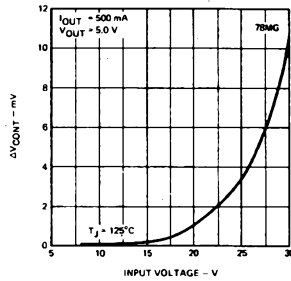
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



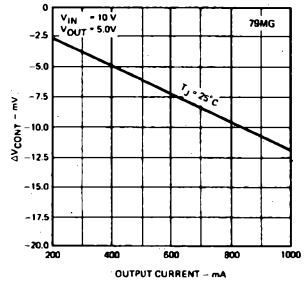
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



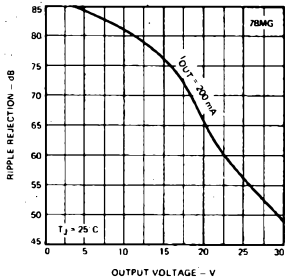
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



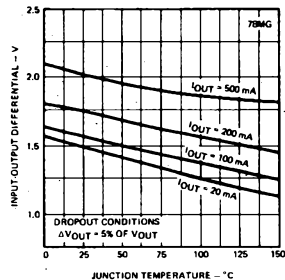
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



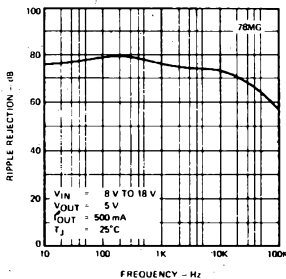
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



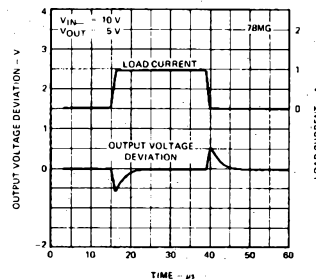
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



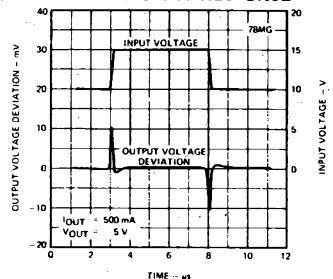
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE

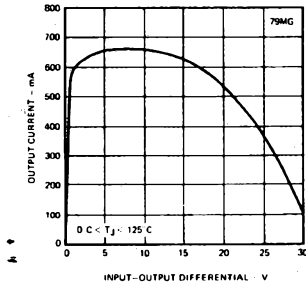


LINE TRANSIENT RESPONSE

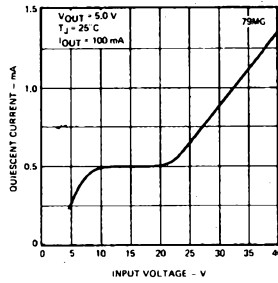


TYPICAL PERFORMANCE CURVES FOR  $\mu$ A79MG

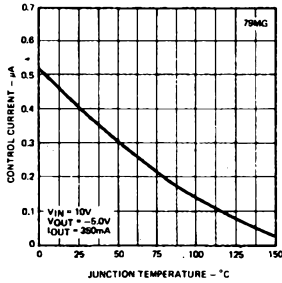
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



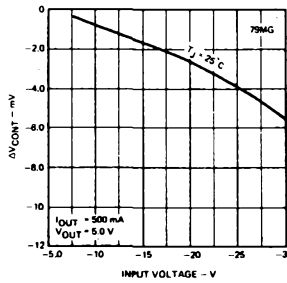
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



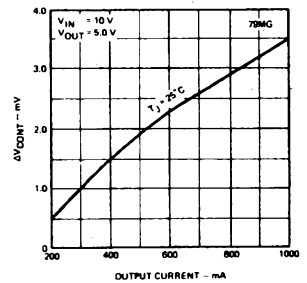
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



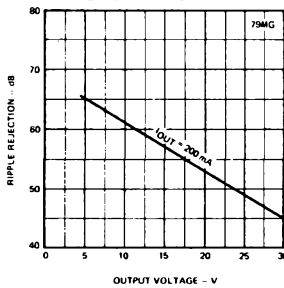
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



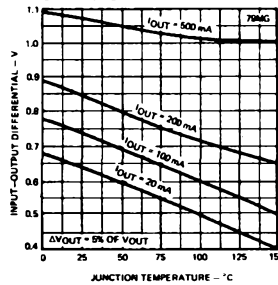
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



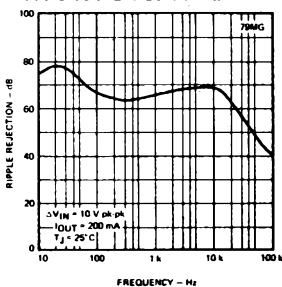
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



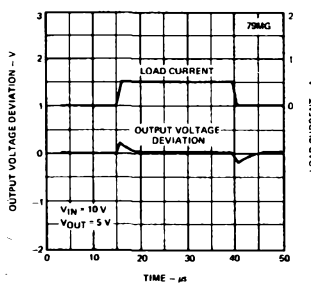
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



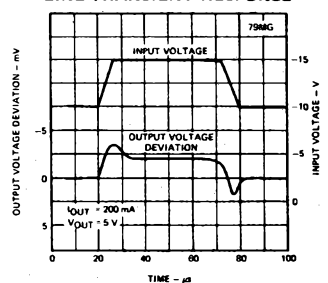
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE



LINE TRANSIENT RESPONSE



**DESIGN CONSIDERATIONS** – The 78MG and 79MG variable voltage regulators have an output voltage which varies from  $V_{CONTROL}$  to typically  $V_{IN} - 2V$  by  $V_{OUT} = V_{CONTROL} \frac{(R1 + R2)}{R2}$ . The nominal reference in the 78MG is 5.0 V and 79MG is -2.23 V. If we allow 1.0 mA to flow in the control string to eliminate bias current effects, we can make  $R2 = 5 k\Omega$  in the 78MG. The output voltage is then:  $V_{OUT} = (R1 + R2)$  Volts, where  $R1$  and  $R2$  are in  $k\Omega$ s.

Example: If  $R2 = 5 k\Omega$  and  $R1 = 10 k\Omega$  then  $V_{OUT} = 15 V$  nominal, for the 78MG;  
 $R2 = 2.2 k\Omega$  and  $R1 = 12.8 k\Omega$  then  $V_{OUT} = -15.2 V$  nominal, for the 79MG.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

Both 78MG and 79MG regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYPICAL	MAX	TYPICAL	MAX
	$\theta_{JC}$	$\theta_{JC}$	$\theta_{JA}$	$\theta_{JA}$
Power Mini DIP (T2)	7.5	11.0	75	80
Power Watt	8.0	12.0	75	80
TO-39	18.0	25.0	125	185

$$P_D (MAX) = \frac{T_J (MAX) - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_J (MAX) - T_A}{\theta_{JA}} \quad (\text{Without a heat sink})$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

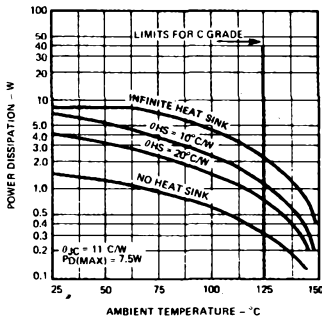
$$\text{Solving for } T_J: \quad T_J = T_A + P_D (\theta_{JC} + \theta_{CA}) \quad \text{or} \quad T_A + P_D \theta_{JA} \quad (\text{Without heat sink})$$

Where  $T_J$  = Junction Temperature  
 $T_A$  = Ambient Temperature  
 $P_D$  = Power Dissipation

$\theta_{JC}$  = Junction to case thermal resistance  
 $\theta_{CA}$  = Case to ambient thermal resistance  
 $\theta_{CS}$  = Case to ambient thermal resistance  
 $\theta_{SA}$  = Heat sink to ambient thermal resistance  
 $\theta_{JA}$  = Junction to ambient thermal resistance

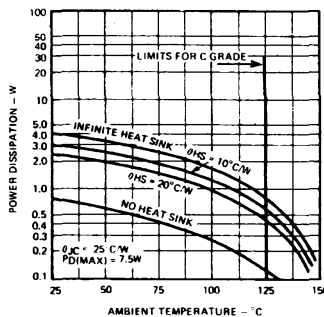
$\mu$ A78MG AND  $\mu$ A79MG  
POWER MINI DIP (T2)

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



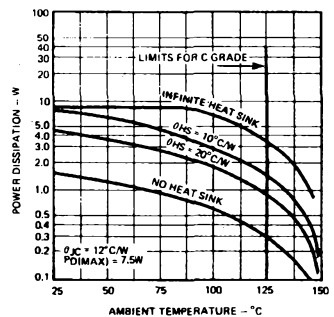
$\mu$ A78MG AND  $\mu$ A79MG  
TO-39

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



$\mu$ A78MG AND  $\mu$ A79MG  
POWER WATT (U1)

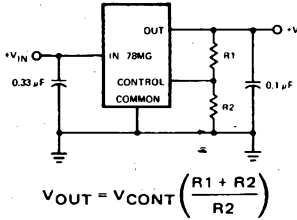
WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



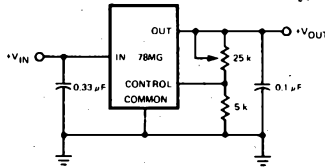
TYPICAL APPLICATIONS FOR  $\mu A78MG$

In many  $\mu A78MG$  applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33  $\mu F$  and 0.1  $\mu F$ , respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

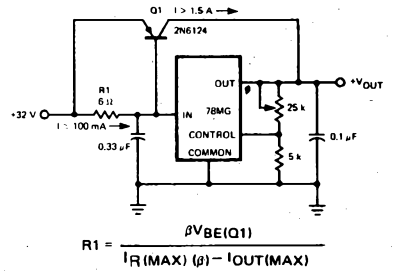
**BASIC POSITIVE REGULATOR**



**POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR**

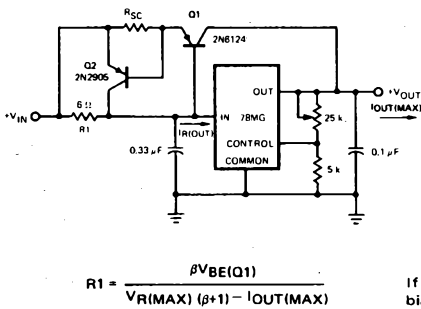


**POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR**  
**I<sub>OUT</sub> > 1.5 A**

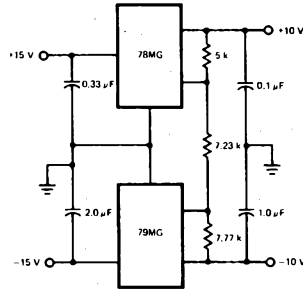


NOTE: External series pass device is not short circuit protected.

**POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR**

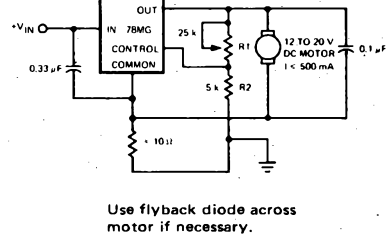


**± 10 V, 500 mA DUAL TRACKING REGULATOR**

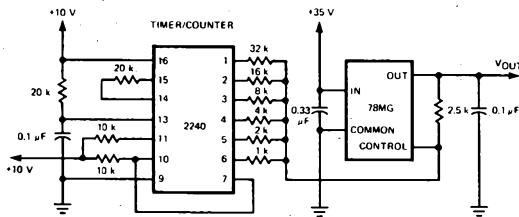


If load is not ground referenced, connect reverse biased diodes from outputs to ground.

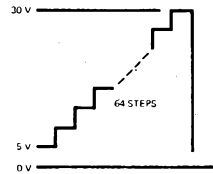
**MOTOR SPEED CONTROL**



**PROGRAMMABLE SUPPLY**

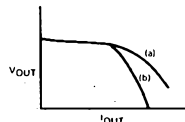
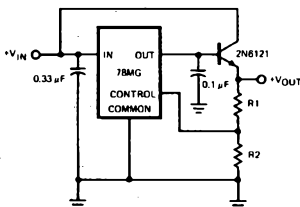


**OUTPUT WAVEFORM**

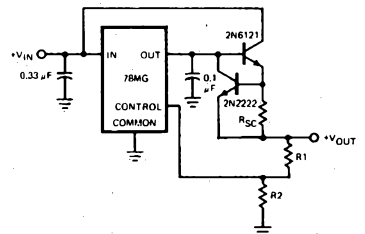


**POSITIVE HIGH CURRENT VOLTAGE REGULATOR**

**EXTERNAL SERIES PASS (a)**



**SHORT CIRCUIT LIMIT (b)**



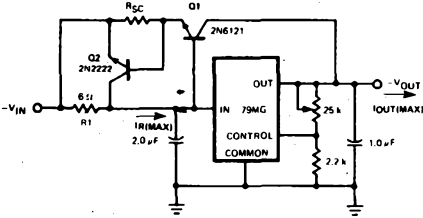


TYPICAL APPLICATIONS FOR 79MG

Bypass capacitors are recommended for stable operation of the  $\mu$ A79MG over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

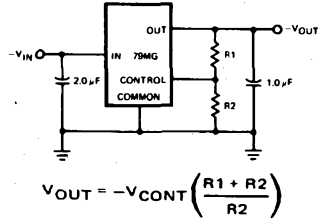
The bypass capacitors, (2  $\mu$ F on the input, 1  $\mu$ F on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10  $\mu$ F or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

**NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR**



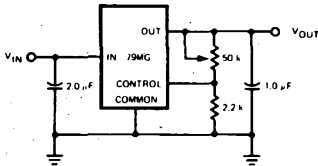
$$R1 = \frac{\beta V_{BE}(Q1)}{I_R(\text{MAX}) (\beta) - I_{OUT}(\text{MAX})}$$

**BASIC NEGATIVE REGULATOR**

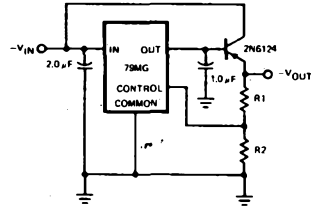


$$V_{OUT} = -V_{CONT} \left( \frac{R1 + R2}{R2} \right)$$

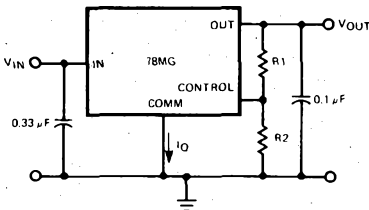
**-30 V TO -2.2 V ADJUSTABLE REGULATOR**



**NEGATIVE HIGH CURRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS**



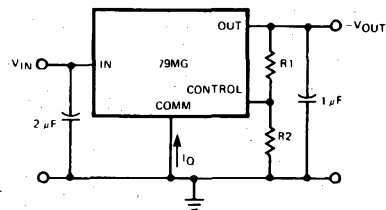
**78MG TEST CIRCUIT 1**



$$V_{OUT} = \left( \frac{R1 + R2}{R2} \right) V_{CONTROL}$$

$V_{CONTROL}$  Nominally = 5 V

**79MG TEST CIRCUIT 2**



$$V_{OUT} = \left( \frac{R1 + R2}{R2} \right) V_{CONTROL}$$

$V_{CONTROL}$  Nominally = -2.23 V

Recommended R2 current  $\approx$  1 mA  
 $\therefore R2 = 5 \text{ k}\Omega$  (78MG)  
 $R2 = 2.2 \text{ k}\Omega$  (79MG)

# μA723

## PRECISION VOLTAGE REGULATOR

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

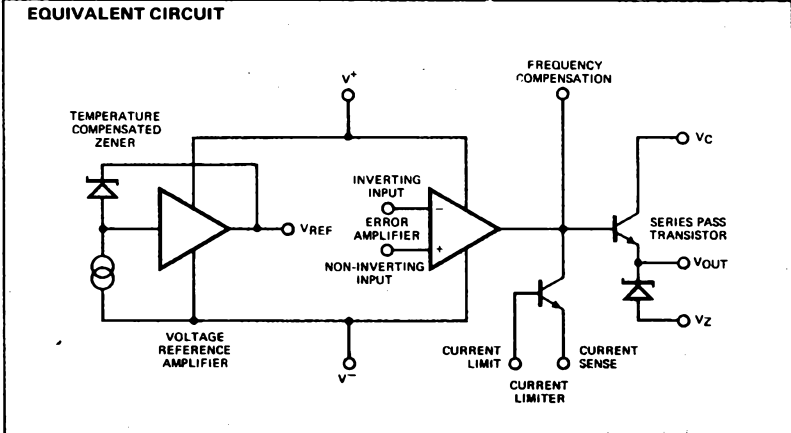
**GENERAL DESCRIPTION** — The μA723 is a monolithic Voltage Regulator constructed using the Fairchild Planar\* epitaxial process. The device consists of a temperature compensated reference amplifier, error amplifier, power series pass transistor and current limit circuitry. Additional NPN or PNP pass elements may be used when output currents exceeding 150 mA are required. Provisions are made for adjustable current limiting and remote shutdown. In addition to the above, the device features low standby current drain, low temperature drift and high ripple rejection. The μA723 is intended for use with positive or negative supplies as a series, shunt, switching or floating regulator. Applications include laboratory power supplies, isolation regulators for low level data amplifiers, logic card regulators, small instrument power supplies, airborne systems and other power supplies for digital and linear circuits.

- POSITIVE OR NEGATIVE SUPPLY OPERATION
- SERIES, SHUNT, SWITCHING OR FLOATING OPERATION
- 0.01% LINE AND LOAD REGULATION
- OUTPUT VOLTAGE ADJUSTABLE FROM 2 TO 37 VOLTS
- OUTPUT CURRENT TO 150 mA WITHOUT EXTERNAL PASS TRANSISTOR

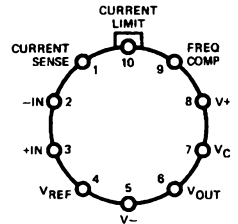
**ABSOLUTE MAXIMUM RATINGS**

Pulse Voltage from $V_+$ to $V_-$ , (50 ms) (μA723)	50 V
Continuous Voltage from $V_+$ to $V_-$	40 V
Input/Output Voltage Differential	40 V
Differential Input Voltage	±5 V
Voltage Between Non-Inverting Input and $V_-$	+8 V
Current from $V_Z$	25 mA
Current from $V_{REF}$	15 mA
Internal Power Dissipation (Note 1)	
Metal Can	800 mW
DIP	1000 mW
Storage Temperature Range	-65°C to +150°C
Operating Temperature Range	
Military (μA723)	-55°C to +125°C
Commercial (μA723C)	0°C to +70°C
Lead Temperature (Soldering, 60 s)	300°C

**EQUIVALENT CIRCUIT**



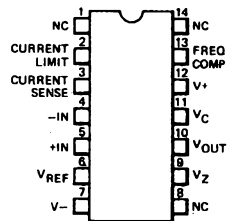
**CONNECTION DIAGRAMS**  
**10-LEAD METAL CAN**  
 (TOP VIEW)



Note: Pin 5 connected to case.

ORDER INFORMATION	
TYPE	PART NO.
μA723	μA723HM
μA723C	μA723HC

**14-LEAD DIP**  
 (TOP VIEW)



ORDER INFORMATION	
TYPE	PART NO.
μA723	μA723DM
μA723C	μA723DC
μA723C	μA723PC

Notes on following pages.

\*Planar is a patented Fairchild process

# FAIRCHILD • $\mu A723$

## $\mu A723$

**ELECTRICAL CHARACTERISTICS:**  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = V^+ = V_C = 12\text{V}$ ,  $V^- = 0$ ,  $V_{OUT} = 5\text{V}$ ,  $I_L = 1\text{mA}$ ,  $R_{SC} = 0$ ,  $C_1 = \text{pF}$ ,  $C_{REF} = 0$ , unless otherwise specified. Divider impedance as seen by error amplifier  $\leq 10\text{ k}\Omega$  connected shown in Fig. 1. Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Line Regulation	$V_{IN} = 12\text{V to } V_{IN} = 15\text{V}$		0.01	0.1	$\%V_O$
	$V_{IN} = 12\text{V to } V_{IN} = 40\text{V}$		0.02	0.2	$\%V_O$
	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ , $V_{IN} = 12\text{V to } V_{IN} = 15\text{V}$			0.3	$\%V_O$
Load Regulation	$I_L = 1\text{mA to } I_L = 50\text{mA}$		0.03	0.15	$\%V_O$
	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ , $I_L = 1\text{mA to } I_L = 50\text{mA}$			0.6	$\%V_O$
Ripple Rejection	$f = 50\text{ Hz to } 10\text{ kHz}$		74		dB
	$f = 50\text{ Hz to } 10\text{ kHz}$ , $C_{REF} = 5\text{ }\mu\text{F}$		86		dB
Average Temperature Coefficient of Output Voltage	$-55^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.002	0.015	$\%/^\circ\text{C}$
Short Circuit Current Limit	$R_{SC} = 10\text{ }\Omega$ , $V_O = 0$		65		mA
Reference Voltage		6.95	7.15	7.35	V
Output Noise Voltage	$BW = 100\text{ Hz to } 10\text{ kHz}$ , $C_{REF} = 0$		20		$\mu\text{V}_{\text{rms}}$
	$BW = 100\text{ Hz to } 10\text{ kHz}$ , $C_{REF} = 5\text{ }\mu\text{F}$		2.5		$\mu\text{V}_{\text{rms}}$
Long Term Stability			0.1		$\%/1000\text{ hrs}$
Standby Current Drain	$I_L = 0$ , $V_{IN} = 30\text{V}$		2.3	3.5	mA
Input Voltage Range		9.5		40	V
Output Voltage Range		2.0		37	V
Input/Output Voltage Differential		3.0		38	V

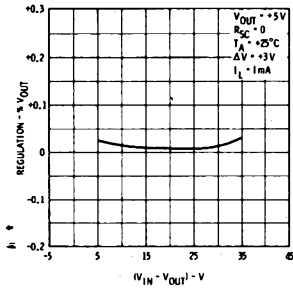
## $\mu A723C$

**ELECTRICAL CHARACTERISTICS:**  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = V^+ = V_C = 12\text{V}$ ,  $V^- = 0$ ,  $V_{OUT} = 5\text{V}$ ,  $I_L = 1\text{mA}$ ,  $R_{SC} = 0$ ,  $C_1 = 100\text{ pF}$ ,  $C_{REF} = 0$ , unless otherwise specified. Divider impedance as seen by error amplifier  $\leq 10\text{ k}\Omega$  connected as shown in Fig. 1. Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

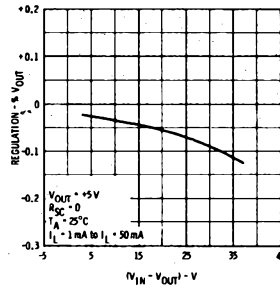
CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Line Regulation	$V_{IN} = 12\text{V to } V_{IN} = 15\text{V}$		0.01	0.1	$\%V_O$
	$V_{IN} = 12\text{V to } V_{IN} = 40\text{V}$		0.1	0.5	$\%V_O$
	$0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ , $V_{IN} = 12\text{V to } V_{IN} = 15\text{V}$			0.3	$\%V_O$
Load Regulation	$I_L = 1\text{mA to } I_L = 50\text{mA}$		0.03	0.2	$\%V_O$
	$0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ , $I_L = 1\text{mA to } I_L = 50\text{mA}$			0.6	$\%V_O$
Ripple Rejection	$f = 50\text{ Hz to } 10\text{ kHz}$		74		dB
	$f = 50\text{ Hz to } 10\text{ kHz}$ , $C_{REF} = 5\text{ }\mu\text{F}$		86		dB
Average Temperature Coefficient of Output Voltage	$0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$		0.003	0.015	$\%/^\circ\text{C}$
Short Circuit Current Limit	$R_{SC} = 10\text{ }\Omega$ , $V_O = 0$		65		mA
Reference Voltage		6.80	7.15	7.50	V
Output Noise Voltage	$BW = 100\text{ Hz to } 10\text{ kHz}$ , $C_{REF} = 0$		20		$\mu\text{V}_{\text{rms}}$
	$BW = 100\text{ Hz to } 10\text{ kHz}$ , $C_{REF} = 5\text{ }\mu\text{F}$		2.5		$\mu\text{V}_{\text{rms}}$
Long Term Stability			0.1		$\%/1000\text{ hrs}$
Standby Current Drain	$I_L = 0$ , $V_{IN} = 30\text{V}$		2.3	4.0	mA
Input Voltage Range		9.5		40	V
Output Voltage Range		2.0		37	V
Input/Output Voltage Differential		3.0		38	V

TYPICAL PERFORMANCE CURVES FOR  $\mu A723$  AND  $\mu A723C$

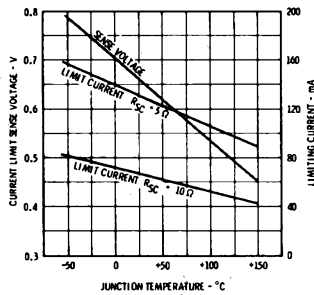
LINE REGULATION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



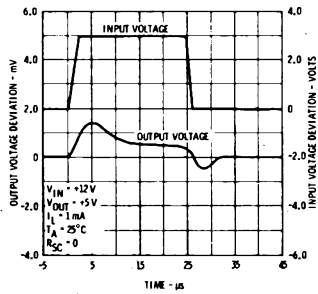
LOAD REGULATION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



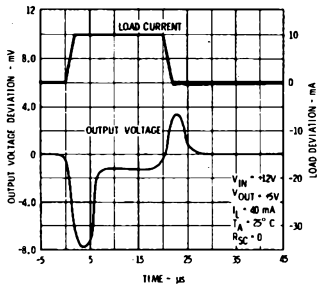
CURRENT LIMITING CHARACTERISTICS AS A FUNCTION OF JUNCTION TEMPERATURE



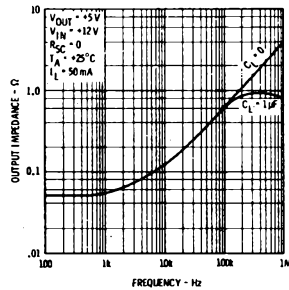
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE



OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



NOTES:

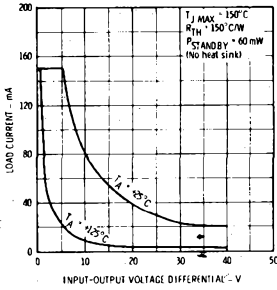
1. Rating applies to ambient temperatures up to  $25^\circ C$ . Above  $25^\circ C$  ambient derate based on the following thermal resistance values:

	$\theta_{JA}$	
	TYP	MAX
TO-5	150	190
Plastic DIP	150	190
Ceramic DIP	125	160

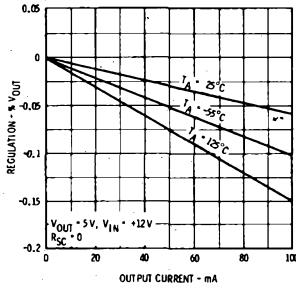
- $L_1$  is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009" air gap.
- Figures in parentheses may be used if  $R_1/R_2$  divider is placed on opposite side of error amp.
- Replace  $R_1/R_2$  in figures with divider shown in figure 13.
- $V^+$  must be connected to a +3 V or greater supply.
- For metal can applications where  $V_Z$  is required, an external 6.2 volt zener diode should be connected in series with  $V_{OUT}$ .

TYPICAL PERFORMANCE CURVES FOR  $\mu A723$

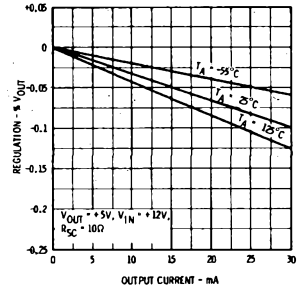
MAXIMUM LOAD CURRENT AS A FUNCTION OF INPUT-OUTPUT VOLTAGE DIFFERENTIAL



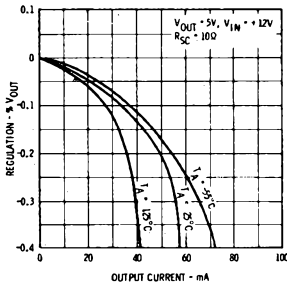
LOAD REGULATION CHARACTERISTICS WITHOUT CURRENT LIMITING



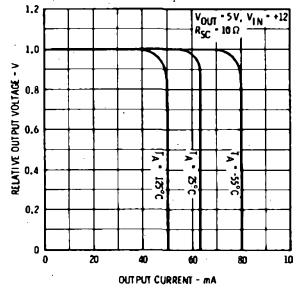
LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING



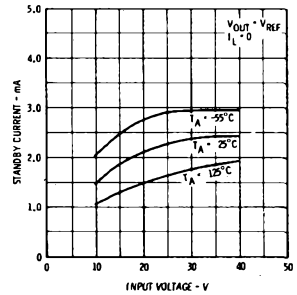
LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING



CURRENT LIMITING CHARACTERISTICS

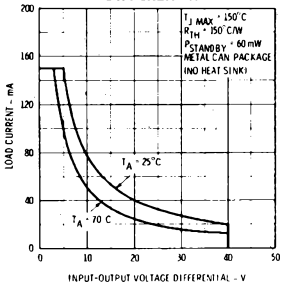


STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE

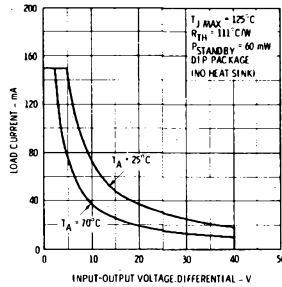


TYPICAL PERFORMANCE CURVES FOR  $\mu A723C$

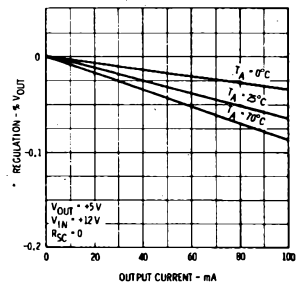
MAXIMUM LOAD CURRENT AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



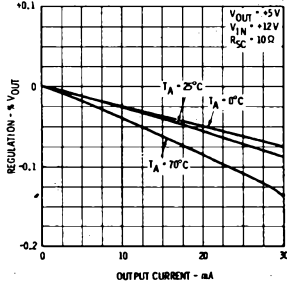
MAXIMUM LOAD CURRENT AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



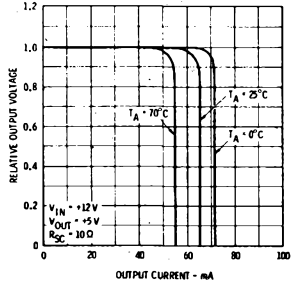
LOAD REGULATION CHARACTERISTICS WITHOUT CURRENT LIMITING



LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING



CURRENT LIMITING CHARACTERISTICS



STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE

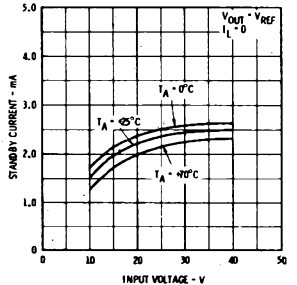


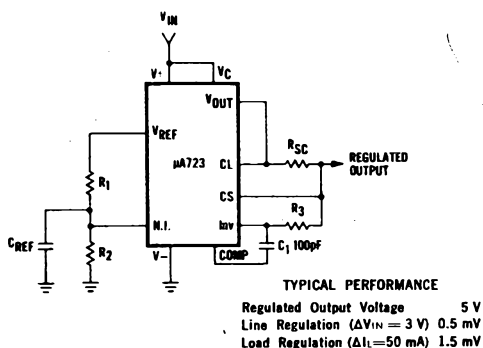
TABLE I  
RESISTOR VALUES (k $\Omega$ ) FOR STANDARD OUTPUT VOLTAGES

POSITIVE OUTPUT VOLTAGE	APPLICABLE FIGURES (Note 3)	FIXED OUTPUT $\pm 5\%$		OUTPUT ADJUSTABLE $\pm 10\%$ (Note 4)			NEGATIVE OUTPUT VOLTAGE	APPLICABLE FIGURES	FIXED OUTPUT $\pm 5\%$		5% OUTPUT ADJUSTABLE $\pm 10\%$		
		R <sub>1</sub>	R <sub>2</sub>	R <sub>1</sub>	P <sub>1</sub>	R <sub>2</sub>			R <sub>1</sub>	R <sub>2</sub>	R <sub>1</sub>	P <sub>1</sub>	R <sub>2</sub>
+3.0	1, 5, 6, 9, 12 (4)	4.12	3.01	1.8	0.5	1.2	+100	7	3.57	102	2.2	10	91
+3.6	1, 5, 6, 9, 12 (4)	3.57	3.65	1.5	0.5	1.5	+250	7	3.57	255	2.2	10	240
+5.0	1, 5, 6, 9, 12 (4)	2.15	4.99	.75	0.5	2.2	-6 (Note 5)	3, (10)	3.57	2.43	1.2	0.5	.75
+6.0	1, 5, 6, 9, 12 (4)	1.15	6.04	0.5	0.5	2.7	-9	3, 10	3.48	5.36	1.2	0.5	2.0
+9.0	2, 4, (5, 6, 12, 9)	1.87	7.15	.75	1.0	2.7	-12	3, 10	3.57	8.45	1.2	0.5	3.3
+12	2, 4, (5, 6, 9, 12)	4.87	7.15	2.0	1.0	3.0	-15	3, 10	3.65	11.5	1.2	0.5	4.3
+15	2, 4, (5, 6, 9, 12)	7.87	7.15	3.3	1.0	3.0	-28	3, 10	3.57	24.3	1.2	0.5	10
+28	2, 4, (5, 6, 9, 12)	21.0	7.15	5.6	1.0	2.0	-45	8	3.57	41.2	2.2	10	33
+45	7	3.57	48.7	2.2	10	39	-100	8	3.57	97.6	2.2	10	91
+75	7	3.57	78.7	2.2	10	68	-250	8	3.57	249	2.2	10	240

TABLE II  
FORMULAE FOR INTERMEDIATE OUTPUT VOLTAGES

Outputs from +2 to +7 volts [Figures 1, 5, 6, 9, 12, (4)] $V_{OUT} = [V_{REF} \times \frac{R_2}{R_1 + R_2}]$	Outputs from +4 to +250 volts [Figure 7] $V_{OUT} = [ \frac{V_{REF}}{2} \times \frac{R_2 - R_1}{R_1} ]; R_3 = R_4$	Current Limiting $I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}}$
Outputs from +7 to +37 volts [Figures 2, 4, (5, 6, 9, 12)] $V_{OUT} = [V_{REF} \times \frac{R_1 + R_2}{R_2}]$	Outputs from -6 to -250 volts [Figures 3, 8, 10] $V_{OUT} = [ \frac{V_{REF}}{2} \times \frac{R_1 + R_2}{R_1} ]; R_3 = R_4$	Foldback Current Limiting $I_{KNEE} = [ \frac{V_{OUT} R_3}{R_{SC} R_4} + \frac{V_{SENSE} (R_3 + R_4)}{R_{SC} R_4} ]$ $I_{SHORT\ CKT} = [ \frac{V_{SENSE}}{R_{SC}} \times \frac{R_3 + R_4}{R_4} ]$

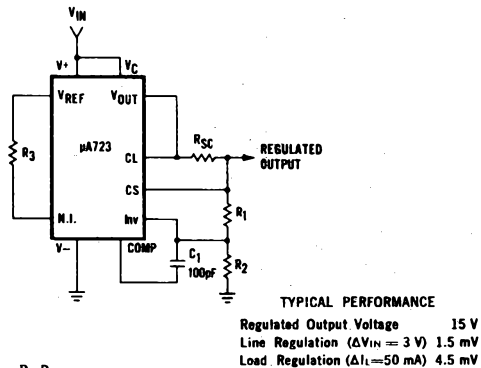
BASIC LOW VOLTAGE REGULATOR  
(V<sub>OUT</sub> = 2 to 7 V)



Note:  $R_3 = \frac{R_1 R_2}{R_1 + R_2}$  for minimum temperature drift.

Fig. 1

BASIC HIGH VOLTAGE REGULATOR  
(V<sub>OUT</sub> = 7 to 37 V)

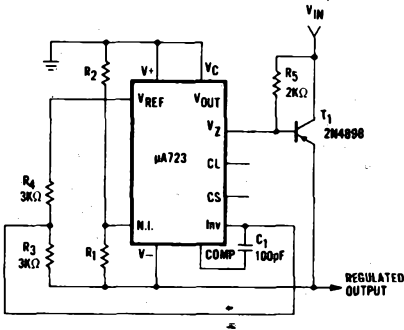


Note:  $R_3 = \frac{R_1 R_2}{R_1 + R_2}$  for minimum temperature drift.

R<sub>3</sub> may be eliminated for minimum component count.

Fig. 2

**NEGATIVE VOLTAGE REGULATOR**

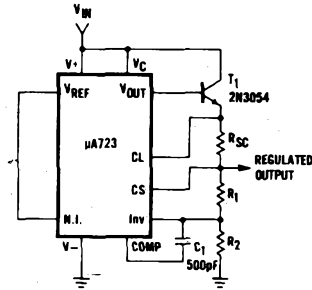


**TYPICAL PERFORMANCE**

Regulated Output Voltage  $-15\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )  $1\text{ mV}$   
 Load Regulation ( $\Delta I_L = 100\text{ mA}$ )  $2\text{ mV}$

Fig. 3

**POSITIVE VOLTAGE REGULATOR  
(External NPN Pass Transistor)**

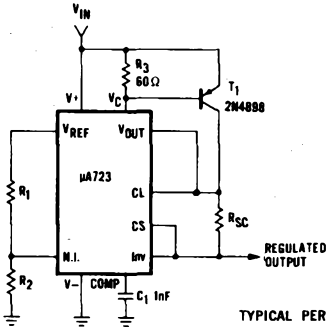


**TYPICAL PERFORMANCE**

Regulated Output Voltage  $+15\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )  $1.5\text{ mV}$   
 Load Regulation ( $\Delta I_L = 1\text{ A}$ )  $15\text{ mV}$

Fig. 4

**POSITIVE VOLTAGE REGULATOR  
(External PNP Pass Transistor)**

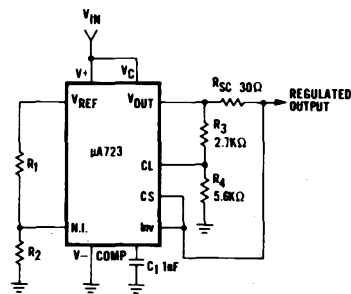


**TYPICAL PERFORMANCE**

Regulated Output Voltage  $+5\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )  $0.5\text{ mV}$   
 Load Regulation ( $\Delta I_L = 1\text{ A}$ )  $5\text{ mV}$

Fig. 5

**FOLDBACK CURRENT LIMITING**

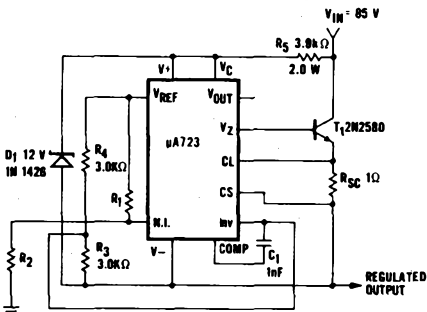


**TYPICAL PERFORMANCE**

Regulated Output Voltage  $+5\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 3\text{ V}$ )  $0.5\text{ mV}$   
 Load Regulation ( $\Delta I_L = 10\text{ mA}$ )  $1\text{ mV}$   
 Short Circuit Current  $20\text{ mA}$

Fig. 6

**POSITIVE FLOATING REGULATOR**

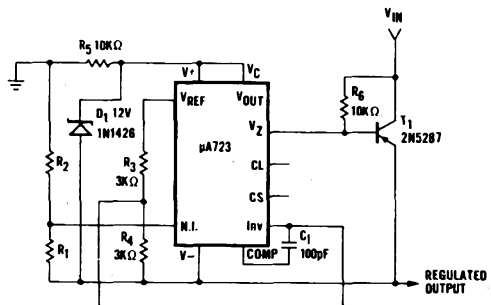


**TYPICAL PERFORMANCE**

Regulated Output Voltage  $+50\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 20\text{ V}$ )  $15\text{ mV}$   
 Load Regulation ( $\Delta I_L = 50\text{ mA}$ )  $20\text{ mV}$

Fig. 7

**NEGATIVE FLOATING REGULATOR**



**TYPICAL PERFORMANCE**

Regulated Output Voltage  $-100\text{ V}$   
 Line Regulation ( $\Delta V_{IN} = 20\text{ V}$ )  $30\text{ mV}$   
 Load Regulation ( $\Delta I_L = 100\text{ mA}$ )  $20\text{ mV}$

Fig. 8

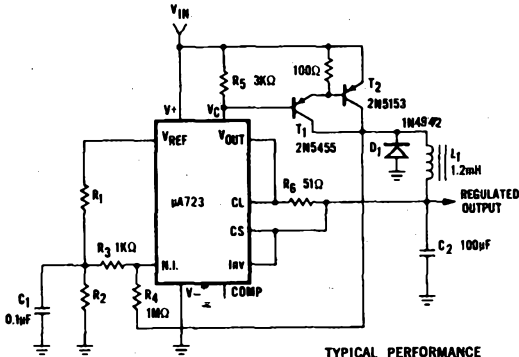
Note 6

Note 6

Note 6

7

**POSITIVE SWITCHING REGULATOR**



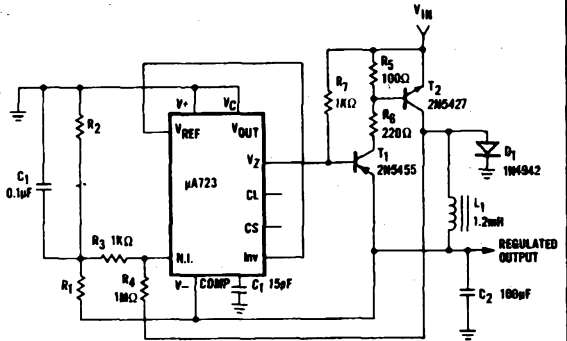
**TYPICAL PERFORMANCE**

Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 30$  V) 10 mV  
 Load Regulation ( $\Delta I_L = 2$  A) 80 mV

Note 2

Fig. 9

**NEGATIVE SWITCHING REGULATOR**



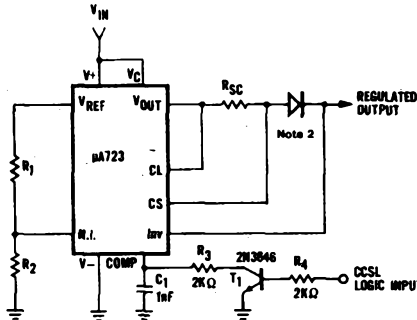
**TYPICAL PERFORMANCE**

Regulated Output Voltage -15 V  
 Line Regulation ( $\Delta V_{IN} = 20$  V) 8 mV  
 Load Regulation ( $\Delta I_L = 2$  A) 6 mV

Notes 2, 6

Fig. 10

**REMOTE SHUTDOWN REGULATOR WITH CURRENT LIMITING**



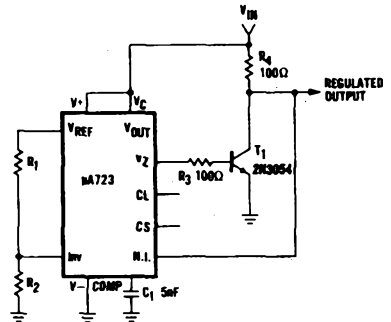
**TYPICAL PERFORMANCE**

Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 3$  V) 0.5 mV  
 Load Regulation ( $\Delta I_L = 50$  mA) 1.5 mV

Note 1: Current limit transistor may be used for shutdown if current limiting is not required.  
 2: Add if  $V_{out} > 10$  V

Fig. 11

**SHUNT REGULATOR**



**TYPICAL PERFORMANCE**

Regulated Output Voltage +5 V  
 Line Regulation ( $\Delta V_{IN} = 10$  V) 0.5 mV  
 Load Regulation ( $\Delta I_L = 100$  mA) 1.5 mV

Note 6

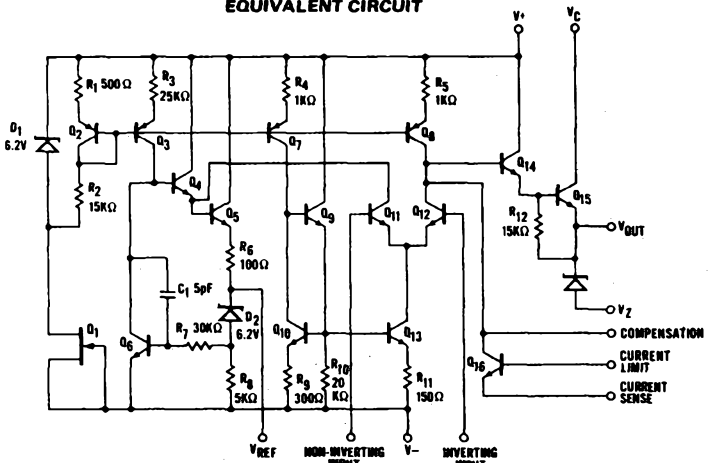
Fig. 12

**OUTPUT VOLTAGE ADJUST**



Fig. 13

**EQUIVALENT CIRCUIT**





# $\mu$ A105 • $\mu$ A305 • $\mu$ A305A • $\mu$ A376

## VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

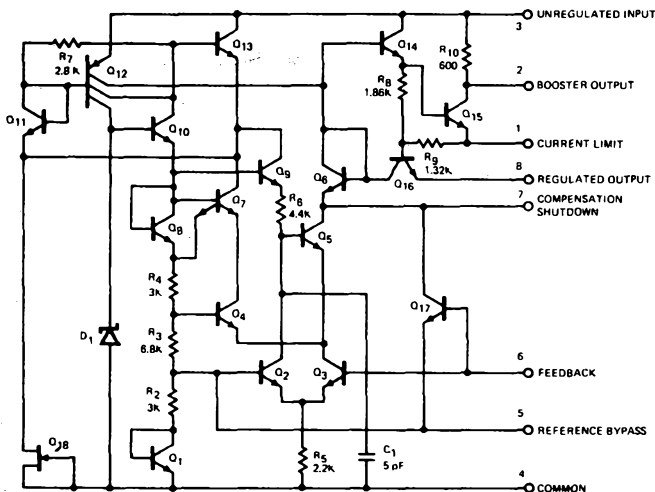
**GENERAL DESCRIPTION** — The 105/305/305A/376 are monolithic Positive Voltage Regulators constructed using the Fairchild Planar<sup>®</sup> epitaxial process. Applications for these devices include both linear and switching regulator circuits with output voltages greater than 4.5 V. These devices will not oscillate when confronted with varying resistive and reactive loads and will start reliably regardless of the load within the ratings of the circuit. They also feature fast response to both load and line transients. Used independently, the 105/305 will supply 12 mA, the 305A, 45 mA and 376, 25 mA. The 105 is specified for the military temperature range ( $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ) and the 305/376/305A are specified for  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  operation. The 105/305/305A are in an 8-lead TO-5 package and the 376 is available in the space and cost saving mini DIP.

- LOW STANDBY CURRENT DRAIN
- ADJUSTABLE OUTPUT VOLTAGE FROM 4.5 V TO 40 V
- HIGH OUTPUT CURRENTS EXCEEDING 10A WITH EXTERNAL COMPONENTS
- LOAD REGULATION BETTER THAN 0.1%, FULL LOAD WITH CURRENT LIMITING
- DC LINE REGULATION GUARANTEED AT 0.03%/V
- RIPPLE REJECTION OF 0.01%/V

### ABSOLUTE MAXIMUM RATINGS

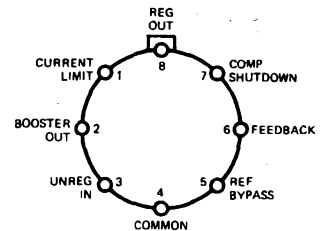
Input Voltage	
$\mu$ A105, $\mu$ A305A	50 V
$\mu$ A305, $\mu$ A376	40 V
Input/Output Voltage Differential	40 V
Integral Power Dissipation (Note 1)	
$\mu$ A105, $\mu$ A305, $\mu$ A305A	500 mW
$\mu$ A376	450 mW
Operating Temperature Range	
Military ( $\mu$ A105)	$-55^{\circ}\text{C}$ to $+125^{\circ}\text{C}$
Commercial ( $\mu$ A305, $\mu$ A305A, $\mu$ A376)	$0^{\circ}\text{C}$ to $+70^{\circ}\text{C}$
Storage Temperature Range	
Metal Can	$-65^{\circ}\text{C}$ to $+150^{\circ}\text{C}$
Mini DIP	$-55^{\circ}\text{C}$ to $+125^{\circ}\text{C}$
Lead Temperature	
Metal Can (Soldering, 60 s)	$300^{\circ}\text{C}$
Mini DIP (Soldering, 10 s)	$260^{\circ}\text{C}$

### EQUIVALENT CIRCUIT



PIN CONNECTIONS SHOWN ARE FOR METAL CAN

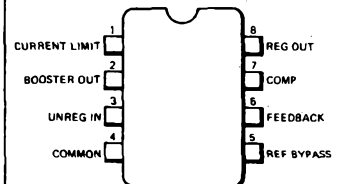
### CONNECTION DIAGRAMS 8-LEAD METAL CAN (TOP VIEW)



### ORDER INFORMATION

TYPE	PART NO.
$\mu$ A105	$\mu$ A105HM
$\mu$ A305	$\mu$ A305HC
$\mu$ A305A	$\mu$ A305AHC

### 8-LEAD MINI DIP (TOP VIEW)



### ORDER INFORMATION

TYPE	PART NO.
$\mu$ A376	$\mu$ A376TC

**FAIRCHILD •  $\mu$ A105 •  $\mu$ A305 •  $\mu$ A305A •  $\mu$ A376**

**$\mu$ A105**

**ELECTRICAL CHARACTERISTICS:**  $T_A = 25^\circ\text{C}$  unless otherwise specified Note 2

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			8.5		50	V
Output Voltage Range			4.5		40	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation (Note 3)	$0 < I_L < 12 \text{ mA}$	$R_{SC} = 10\Omega, T_A = 25^\circ\text{C}$		0.02	0.05	%
		$R_{SC} = 10\Omega, T_A = 125^\circ\text{C}$		0.03	0.1	%
		$R_{SC} = 10\Omega, T_A = -55^\circ\text{C}$		0.03	0.1	%
Line Regulation	$V_{IN} - V_O \leq 5 \text{ V}$			0.025	0.06	%/V
	$V_{IN} - V_O > 5 \text{ V}$			0.015	0.03	%/V
Ripple Rejection	$C_{REF} = 10 \mu\text{F}, f = 120 \text{ Hz}$			0.003	0.01	%/V
Temperature Stability (Note 5)	$-55^\circ\text{C} < T_A < 125^\circ\text{C}$			0.3	1.0	%
Feedback Sense Voltage			1.63	1.7	1.81	V
Output Noise Voltage	$10 \text{ Hz} < f < 10 \text{ kHz}$	$C_{REF} = 0$		0.005		%
		$C_{REF} > 0.1 \mu\text{F}$		0.002		%
Current Limit Sense Voltage (Note 4)	$R_{SC} = 10\Omega, T_A = 25^\circ\text{C}, V_O = 0 \text{ V}$		225	300	375	mV
Standby Current Drain	$V_{IN} = 50 \text{ V}$			0.8	2.0	mA
Long Term Stability				0.1	1.0	%

**$\mu$ A305**

**ELECTRICAL CHARACTERISTICS:**  $T_A = 25^\circ\text{C}$  unless otherwise specified Note 2

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			8.5		40	V
Output Voltage Range			4.5		30	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation (Note 3)	$0 < I_L < 12 \text{ mA}$	$R_{SC} = 10\Omega, T_A = 25^\circ\text{C}$		0.02	0.05	%
		$R_{SC} = 15\Omega, T_A = 70^\circ\text{C}$		0.03	0.1	%
		$R_{SC} = 10\Omega, T_A = 0^\circ\text{C}$		0.03	0.1	%
Line Regulation	$V_{IN} - V_O \leq 5 \text{ V}$			0.025	0.06	%/V
	$V_{IN} - V_O > 5 \text{ V}$			0.015	0.03	%/V
Ripple Rejection	$C_{REF} = 10 \mu\text{F}, f = 120 \text{ Hz}$			0.003	0.01	%/V
Temperature Stability (Note 5)	$0^\circ\text{C} < T_A < 70^\circ\text{C}$			0.3	1.0	%
Feedback Sense Voltage			1.63	1.7	1.81	V
Output Noise Voltage	$10 \text{ Hz} < f < 10 \text{ kHz}$	$C_{REF} = 0$		0.005		%
		$C_{REF} > 0.1 \mu\text{F}$		0.002		%
Current Limit Sense Voltage (Note 4)	$R_{SC} = 10\Omega, T_A = 25^\circ\text{C}, V_O = 0 \text{ V}$		225	300	375	mV
Standby Current Drain	$V_{IN} = 40 \text{ V}$			0.8	2.0	mA
Long Term Stability				0.1	1.0	%

**NOTES**

- Rating applies to ambient temperatures up to  $70^\circ\text{C}$ . Above  $70^\circ\text{C}$  ambient derate linearly at  $6.25 \text{ mW}/^\circ\text{C}$  for the metal can and  $5.6 \text{ mW}/^\circ\text{C}$  for the mini Dip.
- These specifications apply for input and output voltages within the ranges given, and for a divider impedance seen by the feedback terminal of  $2 \text{ k}\Omega$ , unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.
- The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.
- With no external pass transistor.
- Temperature Stability is defined as the percentage change in output voltage for a thermal variation from room temperature to either temperature extreme.

**FAIRCHILD •  $\mu$ A105 •  $\mu$ A305 •  $\mu$ A305A •  $\mu$ A376**

**$\mu$ A305A**

**ELECTRICAL CHARACTERISTICS:**  $T_A = 25^\circ\text{C}$  unless otherwise specified Note 2

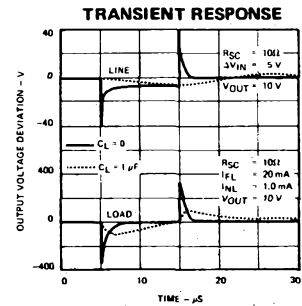
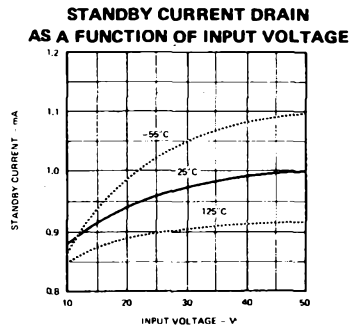
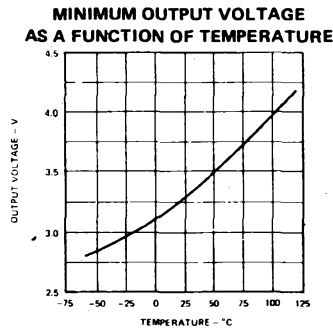
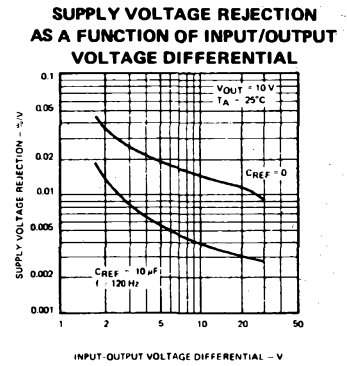
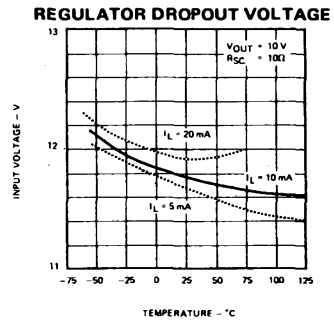
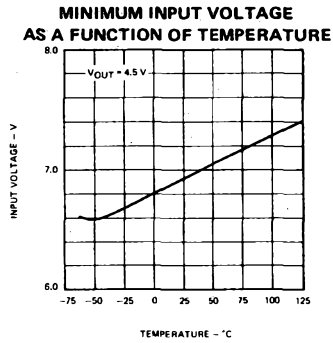
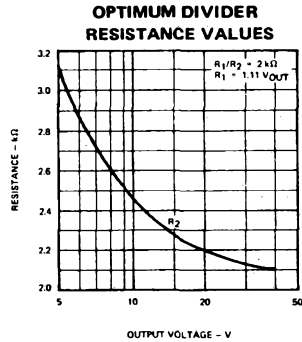
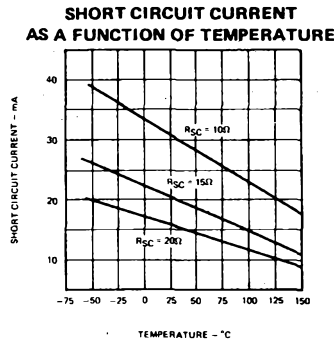
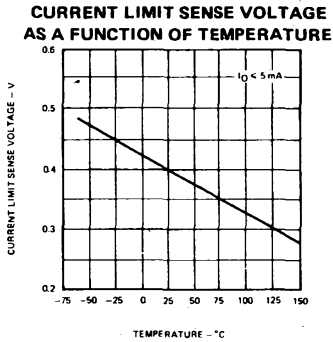
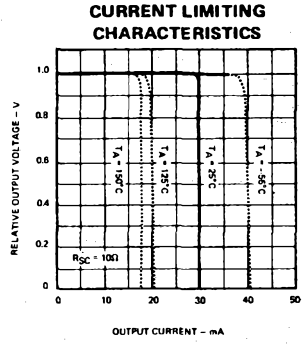
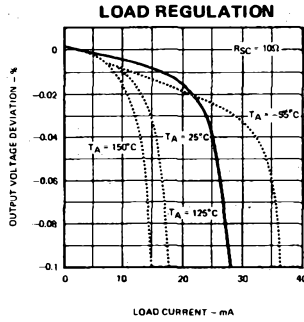
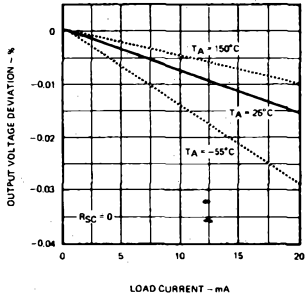
CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			8.5		50	V
Output Voltage Range			4.5		40	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation (Note 3)	$0 < I_L < 45 \text{ mA}$	$R_{SC} = 0\Omega, T_A = 25^\circ\text{C}$		0.02	0.2	%
		$R_{SC} = 0\Omega, T_A = 70^\circ\text{C}$		0.03	0.4	%
		$R_{SC} = 0\Omega, T_A = 0^\circ\text{C}$		0.03	0.4	%
Line Regulation	$V_{IN} - V_O \leq 5 \text{ V}$			0.025	0.06	%/V
	$V_{IN} - V_O > 5 \text{ V}$			0.015	0.03	%/V
Ripple Rejection	$C_{REF} = 10 \mu\text{F}, f = 120 \text{ Hz}$			0.003		%/V
Temperature Stability (Note 5)	$0^\circ\text{C} < T_A < 70^\circ\text{C}$			0.3	1.0	%
Feedback Sense Voltage			1.55	1.7	1.85	V
Output Noise Voltage	$10 \text{ Hz} < f < 10 \text{ kHz}$	$C_{REF} = 0$		0.005		%
		$C_{REF} > 0.1 \mu\text{F}$		0.002		%
Current Limit Sense Voltage (Note 4)	$R_{SC} = 10\Omega, T_A = 25^\circ\text{C}, V_O = 0 \text{ V}$		225	300	375	mV
Standby Current Drain	$V_{IN} = 50 \text{ V}$			0.8	2.0	mA
Long Term Stability				0.1	1.0	%

**$\mu$ A376**

**ELECTRICAL CHARACTERISTICS**  $0^\circ\text{C} < T_A < 70^\circ\text{C}$

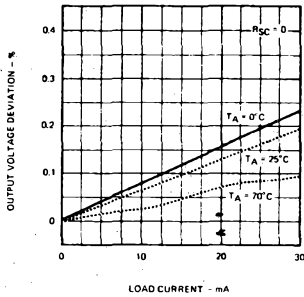
CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			9.0		40	V
Output Voltage Range			5.0		37	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation	$0 < I_L < 25 \text{ mA}$	$R_{SC} = 0\Omega, T_A = 25^\circ\text{C}$			0.2	%
		$R_{SC} = 0\Omega, T_A = 70^\circ\text{C}$			0.5	%
		$R_{SC} = 0\Omega, T_A = 0^\circ\text{C}$				0.5
Line Regulation					0.03	%/V
					0.1	%/V
Ripple Rejection	$f = 120 \text{ Hz}, T_A = 25^\circ\text{C}$				0.1	%/V
Standby Current Drain	$V_{IN} = 30 \text{ V}, T_A = 25^\circ\text{C}$				2.5	mA
Reference Voltage			1.60	1.72	1.80	V
Current Limit Sense Voltage				360		mV

TYPICAL PERFORMANCE CURVES FOR  $\mu A105/\mu A305/\mu A305A$

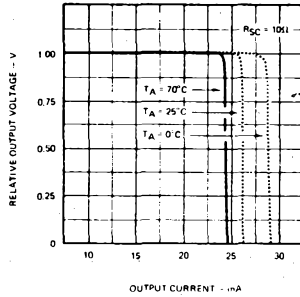


TYPICAL PERFORMANCE CURVES FOR  $\mu A376$

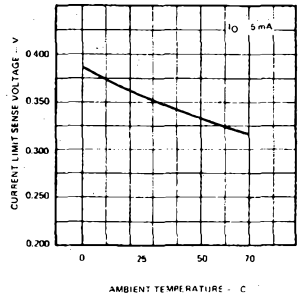
LOAD REGULATION



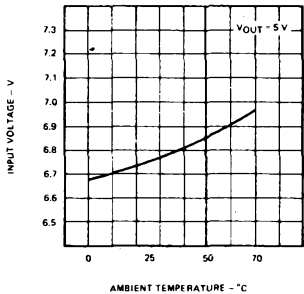
CURRENT LIMITING CHARACTERISTICS



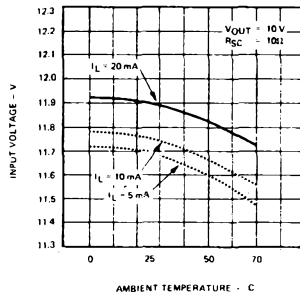
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



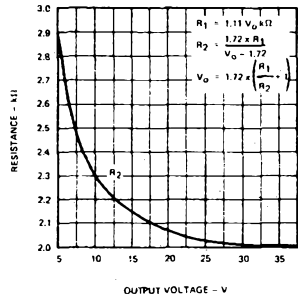
MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE



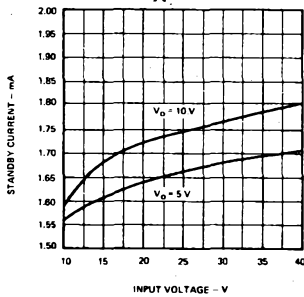
REGULATOR DROPOUT VOLTAGE



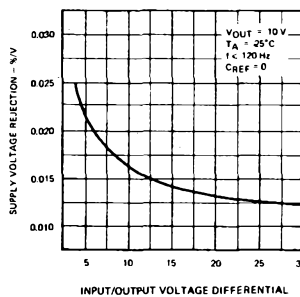
OPTIMUM DIVIDER RESISTANCE



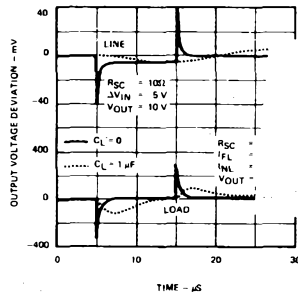
STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE TA = 25°C



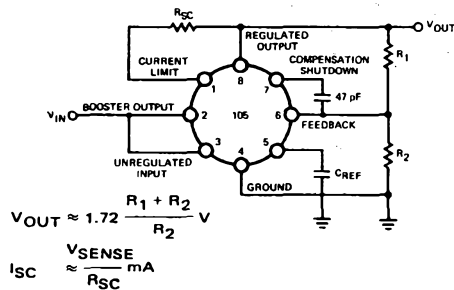
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



TRANSIENT RESPONSE

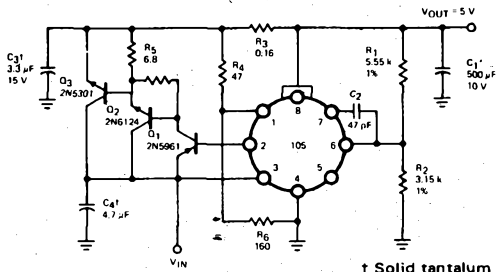


BASIC POSITIVE REGULATOR WITH CURRENT LIMITING



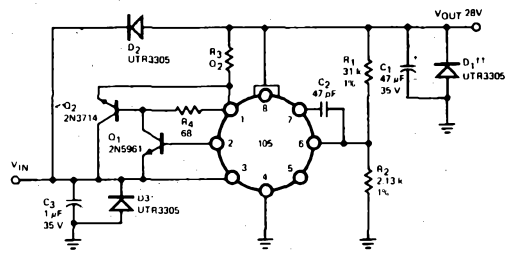
TYPICAL APPLICATIONS

10A REGULATOR WITH FOLDBACK CURRENT LIMITING



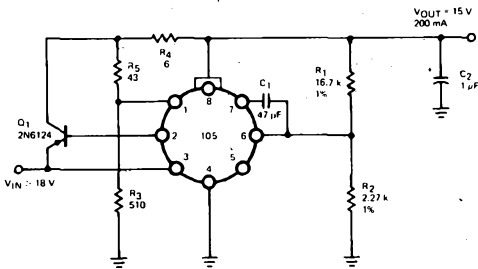
- † Solid tantalum
- Electrolytic

1.0A REGULATOR WITH PROTECTIVE DIODES

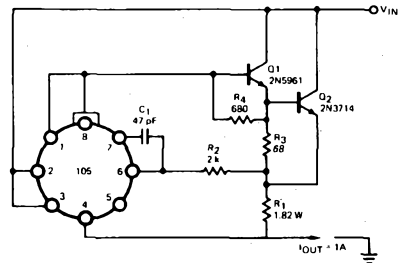


- Protects against input voltage reversal
- †† Protects against output voltage reversal
- † Protects against shorted input or inductive loads on unregulated supply

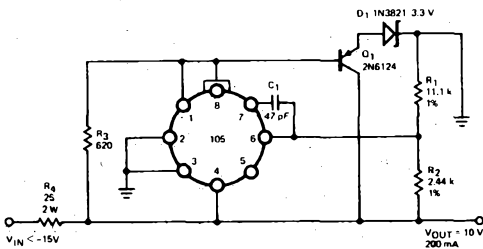
LINEAR REGULATOR WITH FOLDBACK CURRENT LIMITING



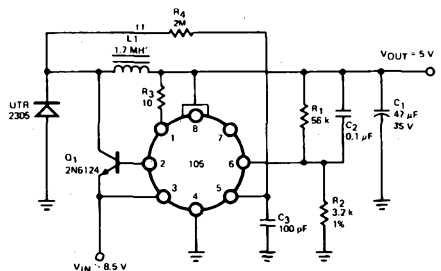
CURRENT REGULATOR



SHUNT REGULATOR



SWITCHING REGULATOR



- † Solid tantalum
- †† 125 turns #22 on Arnold Engineering A262123-2 molybdenum permalloy core.

# μA104 • μA304

## NEGATIVE VOLTAGE REGULATORS

### FAIRCHILD LINEAR INTEGRATED CIRCUITS

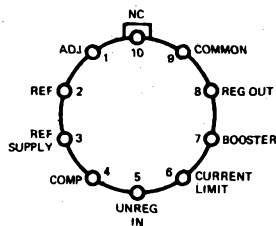
**GENERAL DESCRIPTION** — The 104 family of Precision Negative Voltage Regulators is constructed using the Fairchild Planar\* epitaxial process. This device can be programmed by a single external resistor to supply any voltage from 0 V to 30 V from a single unregulated supply. When used with a separate floating bias supply, the 104/304 can provide 0.01% regulation with the output voltage limited only by the breakdown of external pass transistors. The 104 and 304 provide complementary operation with the 105 positive regulator family. Although primarily designed as a linear series regulator, the 104 family can be used as a current regulator, switching regulator, or in control applications. Without external pass elements, the device can supply currents up to 25 mA; with external pass transistors, the output current is limited only by the capacity of the pass transistors. External resistors establish the output voltage and either constant or fold-back current limiting.

- 1 mV REGULATION WITH FULL LOAD
- 0.01%/V LINE REGULATION
- 0.2 mV/V RIPPLE REJECTION
- 0.3% TEMPERATURE STABILITY OVER FULL TEMPERATURE RANGE

#### ABSOLUTE MAXIMUM RATINGS

Input Voltage	
μA104	50 V
μA304	40 V
Input/Output Voltage Differential	
μA104	50 V
μA304	40 V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	
Military grade (μA104)	-55°C to +125°C
Commercial grade (μA304)	0°C to +70°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 s)	300°C

**CONNECTION DIAGRAM**  
10-LEAD METAL CAN  
(TOP VIEW)

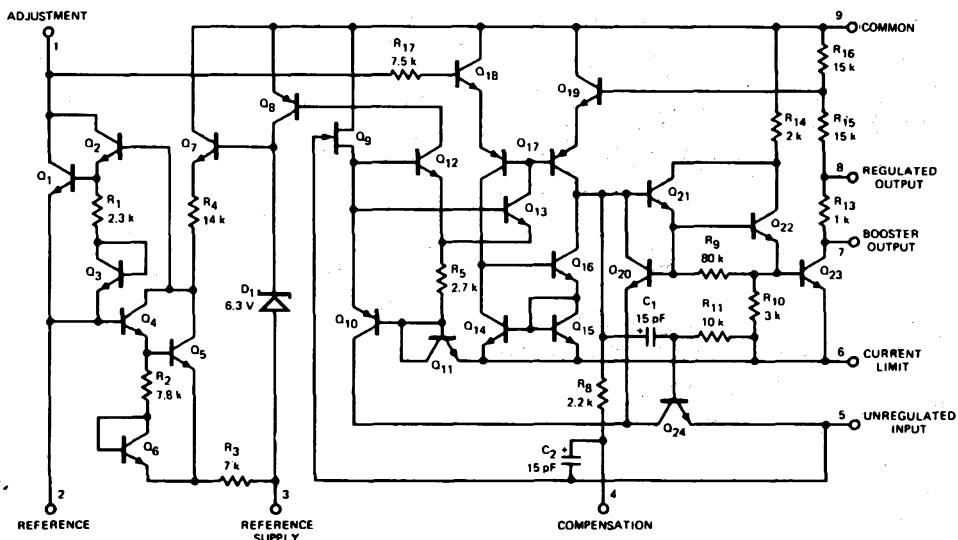


Note: Pin 5 connected to case.

#### ORDER INFORMATION

TYPE	PART NO.
μA104	μA104HM
μA304	μA304HC

#### EQUIVALENT CIRCUIT



# FAIRCHILD • $\mu$ A104 • $\mu$ A304

## $\mu$ A104

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -40$  V to  $-8.0$  V,  $T_A = 0^\circ$  C to  $70^\circ$  C, unless otherwise specified, Note 2

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		-50		-8.0	V
Output Voltage Range		-40		-0.015	V
Output/Input Voltage Differential (Note 3)	$I_L = 20$ mA	2.0		50	V
	$I_L = 5$ mA	0.5		50	V
Load Regulation (Note 4)	$0 \leq I_L \leq 20$ mA, $R_{SC} = 15 \Omega$		1.0	5.0	mV
Line Regulation (Note 5)	$V_O \leq -5$ V, $\Delta V_{IN} = 0.1 V_{IN}$		0.056	0.1	%
Ripple Rejection	$C_2 = 10 \mu$ F, $V_{IN} \geq -15$ V		0.2	0.5	mV/V
	$f = 120$ Hz, $-7$ V $\geq V_{IN} \geq -15$ V		0.5	1.0	mV/V
Output Voltage Scale Factor $V_O/R_2$	$R_1 = 2.4$ k $\Omega$	1.8	2.0	2.2	V/k $\Omega$
Temperature Stability	$V_O \leq -1$ V, $-55^\circ$ C $\leq T_A \leq 125^\circ$ C		0.3	1.0	%
Output Noise Voltage	$10$ Hz $\leq f \leq 10$ kHz, $C_2 = 0$		0.007		%
	$V_O \leq -5$ V, $C_2 = 10 \mu$ F		15		$\mu$ V
Standby Current Drain	$I_L = 5$ mA, $V_O = 0$		1.7	2.5	mA
	$V_O = -40$ V		3.6	5.0	mA
Long Term Stability	$V_O \leq -1$ V		0.1	1.0	%

## $\mu$ A304

**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = -50$  V to  $-8.0$  V,  $T_A = -55^\circ$  C to  $125^\circ$  C, unless otherwise specified, Note 2

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		-40		-8.0	V
Output Voltage Range		-30		-0.035	V
Output/Input Voltage Differential (Note 3)	$I_L = 20$ mA	2.0		40	V
	$I_L = 5$ mA	0.5		40	V
Load Regulation (Note 4)	$0 \leq I_L \leq 20$ mA, $R_{SC} = 15 \Omega$		1.0	5.0	mV
Line Regulation (Note 5)	$V_O \leq -5$ V, $\Delta V_{IN} = 0.1 V_{IN}$		0.056	0.1	%
Ripple Rejection	$C_2 = 10 \mu$ F, $V_{IN} < -15$ V		0.2	0.5	mV/V
	$f = 120$ Hz, $-7$ V $\geq V_{IN} \geq -15$ V		0.5	1.0	mV/V
Output Voltage Scale Factor $V_O/R_2$	$R_1 = 2.4$ k $\Omega$	1.8	2.0	2.2	V/k $\Omega$
Temperature Stability	$V_O \leq -1$ V, $0^\circ$ C $\leq T_A \leq 70^\circ$ C		0.3	1.0	%
Output Noise Voltage	$10$ Hz $\leq f \leq 10$ kHz, $C_2 = 0$		0.007		%
	$V_O \leq -5$ V, $C_2 = 10 \mu$ F		15		$\mu$ V
Standby Current Drain	$I_L = 5$ mA, $V_O = 0$		1.7	2.5	mA
	$V_O = -30$ V		3.6	5.0	mA
Long Term Stability	$V_O \leq -1$ V		0.1	1.0	%

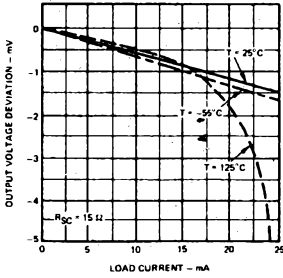
**NOTES:**

- Rating applies to ambient temperatures up to  $70^\circ$  C. Above  $70^\circ$  C ambient derate linearly at 6.3 mW/ $^\circ$  C.
- The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation. See Basic Regulator Circuit.
- When external booster transistors are used, the minimum output-input voltage differential is increased, in the worst case, by approximately 1 V.
- The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.
- With zero output, the dc line regulation is determined from the ripple rejection. Hence, with output voltages between 0 V and  $-5$  V, a dc output variation, determined from the ripple rejection, must be added to find the worst-case line regulation.

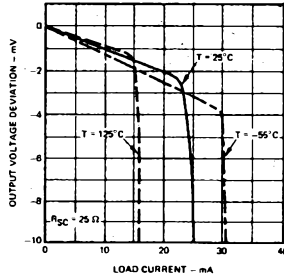


TYPICAL PERFORMANCE CURVES FOR  $\mu A104$

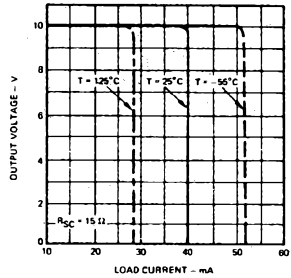
LOAD REGULATION



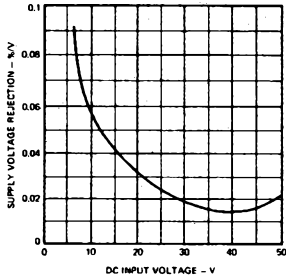
LOAD REGULATION



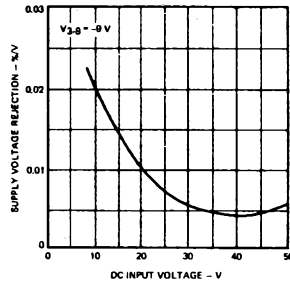
CURRENT LIMITING



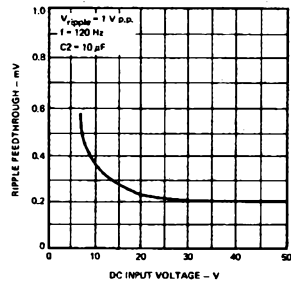
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF DC INPUT VOLTAGE



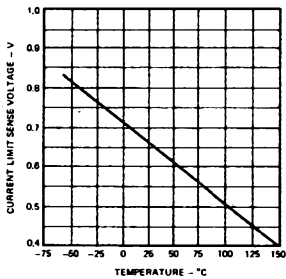
SUPPLY VOLTAGE REJECTION WITH PREREGULATED REFERENCE SUPPLY



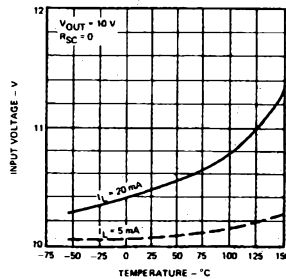
RIPPLE REJECTION



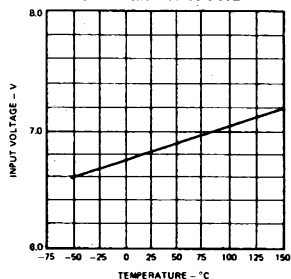
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



REGULATOR DROPOUT VOLTAGE

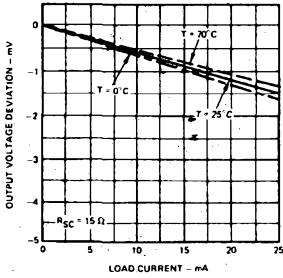


MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE

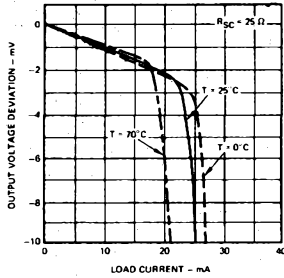


TYPICAL PERFORMANCE CURVES FOR  $\mu A304$

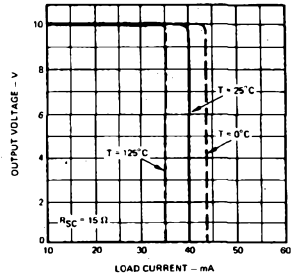
LOAD REGULATION



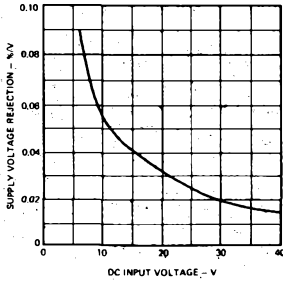
LOAD REGULATION



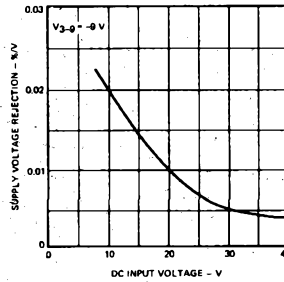
CURRENT LIMITING



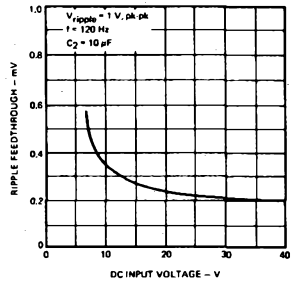
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF DC INPUT VOLTAGE



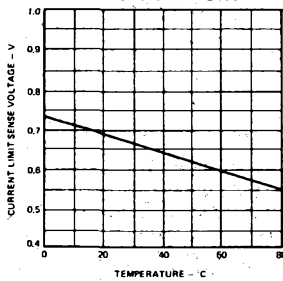
SUPPLY VOLTAGE REJECTION WITH PREREGULATED REFERENCE SUPPLY



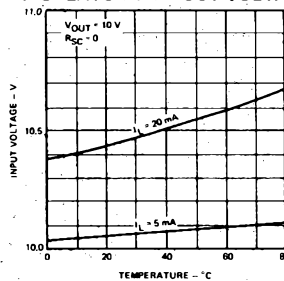
RIPPLE REJECTION



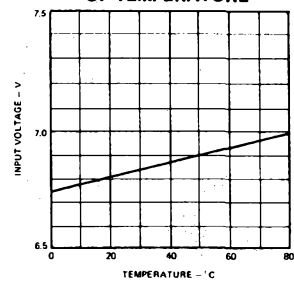
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



REGULATOR DROPOUT VOLTAGE

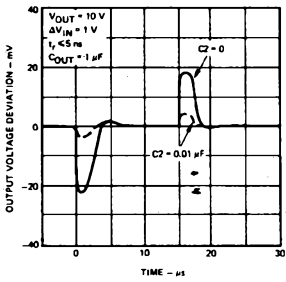


MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE

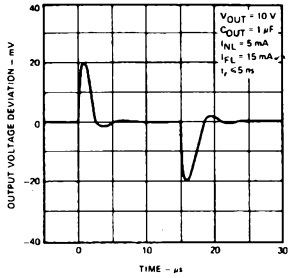


TYPICAL PERFORMANCE CURVES FOR  $\mu A104$  AND  $\mu A304$

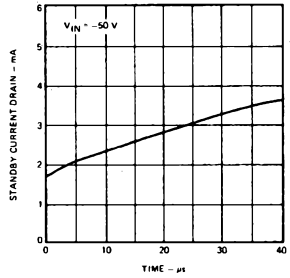
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE

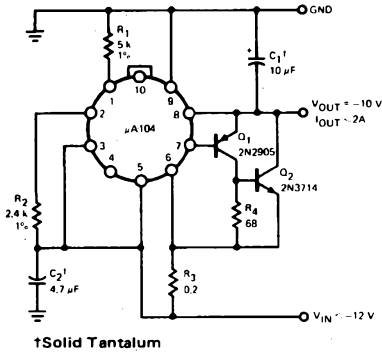


STANDBY CURRENT DRAIN AS A FUNCTION OF TIME

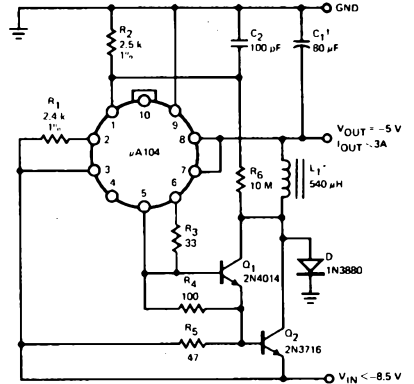


TYPICAL APPLICATIONS

HIGH CURRENT REGULATOR

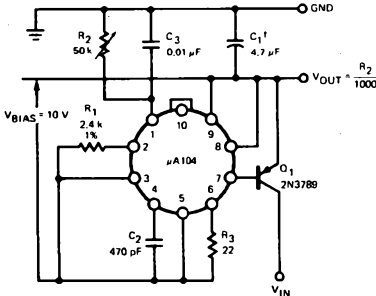


SWITCHING REGULATOR

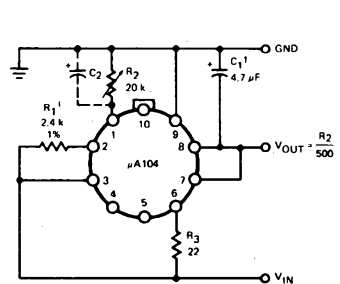


†Solid Tantalum  
\*60 Turns #20  
on Arnold  
Engineering  
A930157-2  
Molybdenum  
Permalloy Core.

OPERATING WITH SEPARATE BIAS SUPPLY



BASIC REGULATOR CIRCUIT



†Solid Tantalum  
†Trim  $R_1$  for exact  
scale factor

NOTE: †Solid Tantalum

A 0.01  $\mu F$  capacitor may be required across the input if long leads are used from the unregulated power source. Line transient response, noise and ripple rejection can be improved by shunting  $R_2$  with a 10  $\mu F$  capacitor  $C_2$ .

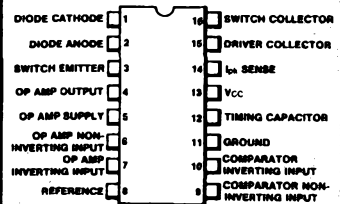
# $\mu$ A78S40

## UNIVERSAL SWITCHING REGULATOR SUBSYSTEM FAIRCHILD LINEAR INTEGRATED CIRCUITS

**GENERAL DESCRIPTION** — The  $\mu$ A78S40 is a Monolithic Regulator Subsystem consisting of all the active building blocks necessary for switching regulator systems. The device consists of a temperature-compensated voltage reference, a duty-cycle controllable oscillator with an active current limit circuit, an error amplifier, high-current, high-voltage output switch, a power diode and an uncommitted operational amplifier. The device can drive external npn or pnp transistors when currents in excess of 1.5 A or voltages in excess of 40 V are required. The device can be used for step down, step up or inverting switching regulators as well as for series pass regulators. It features wide supply voltage range, low standby power dissipation, high efficiency and low drift. It is useful for any stand-alone, low part-count switching system and works extremely well in battery operated systems.

- STEP UP, STEP DOWN OR INVERTING SWITCHING REGULATORS
- OUTPUT ADJUSTABLE FROM 1.3 TO 40 V
- OUTPUT CURRENTS TO 1.5 A WITHOUT EXTERNAL TRANSISTORS
- OPERATION FROM 2.5 TO 40 V INPUT
- LOW STANDBY CURRENT DRAIN
- 80 dB LINE AND LOAD REGULATION
- HIGH GAIN, HIGH CURRENT, INDEPENDENT OP AMP

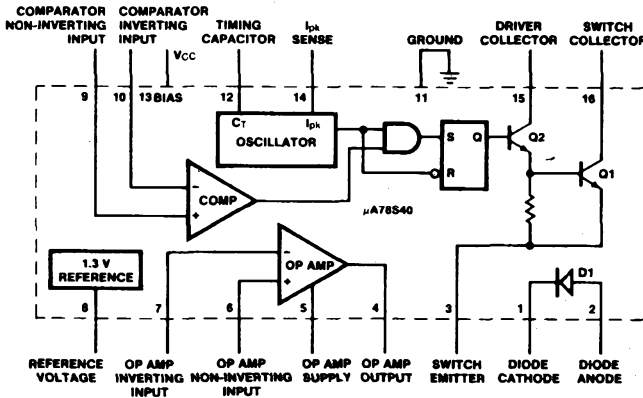
**CONNECTION DIAGRAM**  
16-PIN DIP  
(TOP VIEW)



**ORDER INFORMATION**

TYPE	PART NO.
$\mu$ A78S40	$\mu$ A78S40DM
$\mu$ A78S40	$\mu$ A78S40DC
$\mu$ A78S40	$\mu$ A78S40PC

**BLOCK DIAGRAM**



# FAIRCHILD • $\mu$ A78S40

## ABSOLUTE MAXIMUM RATINGS

Input voltage from $V^+$ to $V^-$	40 V	Current through Power Switch	1.5 A
Input voltage from $V^+$ op amp to $V^-$	40 V	Current through Power Diode	1.5 A
Common mode input range (Error Amplifier and Op Amp)	-0.3 to $V^+$	Internal Power Dissipation (Note 2)	
Differential input voltage (Note 1)	$\pm 30$ V	Plastic DIP	1500 mW
Output Short Circuit Duration (Op Amp)	continuous	Hermetic DIP	1000 mW
Current from $V_{REF}$	10 mA	Storage Temperature Range	-65°C to +150°C
Voltage from Switch Collectors to GND	40 V	Operating Temperature Range	
Voltage from Switch Emitters to GND	40 V	Military ( $\mu$ A78S40M)	-55°C to 125°C
Voltage from Switch Collectors to Emitter	40 V	Commercial ( $\mu$ A78S40C)	0°C to 70°C
Voltage from Power Diode to GND	40 V	Lead Temperature	
Reverse Power Diode Voltage	40 V	Hermetic DIP (Soldering, 60 s)	300°C
		Plastic DIP (Soldering, 10 s)	260°C

### NOTES:

- For supply voltages less than 30 V, the absolute maximum voltage is equal to the supply voltage.
- Ratings apply to 25°C. Above 25°C ambient, derate hermetic DIP at 8 mW/°C and plastic DIP at 14 mW/°C.

### ELECTRICAL CHARACTERISTICS: $V_{IN} = 5.0$ V, $V_{Op\ Amp} = 5.0$ V, $T_A = 25^\circ$ C unless otherwise specified.

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
<b>GENERAL CHARACTERISTICS</b>					
Supply Voltage		2.5		40	V
Supply Current (Op Amp Disconnected)	$V_{IN} = 5.0$ V $V_{IN} = 40$ V		1.8 2.3	2.5 3.5	mA mA
Supply Current Op Amp	$V_{IN} = 5.0$ V $V_{IN} = 40$ V		0.4 0.5	1.0 1.5	
<b>REFERENCE SECTION</b>					
Reference Voltage	$I_{REF} = 1.0$ mA	1.180	1.245	1.310	V
Reference Voltage Temperature Coefficient	$I_{REF} = 1.0$ mA		100		ppm/°C
Reference Voltage Line Regulation	$V_{IN} = 3.0$ V to $V_{IN} = 40$ V, $I_{REF} = 1.0$ mA		0.04	0.2	mV/V
Reference Voltage Load Regulation	$I_{REF} = 1.0$ mA to $I_{REF} = 10$ mA		0.2	0.2	mV/mA
<b>OSCILLATOR SECTION</b>					
Charging Current			25		$\mu$ A
ON Time	$C_T = 0.01$ $\mu$ F		200		$\mu$ s
Discharge Current			225		$\mu$ A
OFF Time	$C_T = 0.01$ $\mu$ F		22		$\mu$ s
Oscillator Voltage Swing			0.5		V
<b>CURRENT LIMIT SECTION</b>					
Current Limit Sense Voltage			330		mV
<b>OUTPUT SWITCH SECTION</b>					
Output Saturation Voltage 1	$I_{SW} = 1.0$ A		1.1	1.3	V
Output Saturation Voltage 2	$I_{SW} = 1.0$ A		0.45	0.7	V
Output Transistor $h_{FE}$	$I_C = 1.0$ A, $V_{CE} = 5.0$ V		70		
Output Leakage Current	$V_{OUT} = 40$ V		10		nA

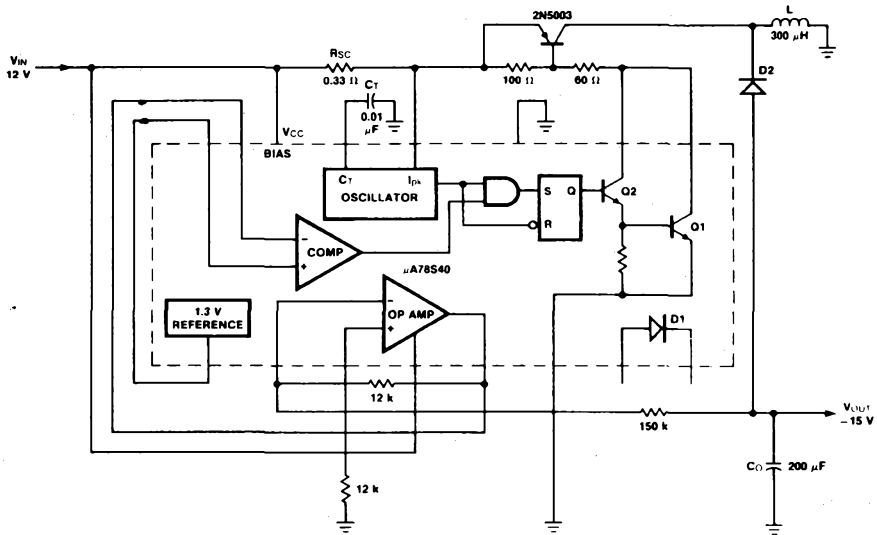
**ELECTRICAL CHARACTERISTICS:**  $V_{IN} = 5.0$  V,  $V_{Op Amp} = 5.0$  V,  $T_A = 25^\circ$  C unless otherwise specified.

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
<b>POWER DIODE</b>					
Forward Voltage Drop	$I_D = 1.0$ A		1.25	1.5	V
Diode Leakage Current	$V_D = 40$ V		10		nA
<b>COMPARATOR</b>					
Input Offset Voltage	$V_{CM} = V_{REF}$		1.5	10	mV
Input Bias Current	$V_{CM} = V_{REF}$		35	200	nA
Input Offset Current	$V_{CM} = V_{REF}$		5.0	75	nA
Common Mode Voltage Range		0		$V^+ - 2$	V
Power Supply Rejection Ratio	$V_{IN} 3.0$ V to 40 V	70	96		dB
<b>OUTPUT OPERATIONAL AMPLIFIER</b>					
Input Offset Voltage	$V_{CM} = 2.5$ V		4.0	10	mV
Input Bias Current	$V_{CM} = 2.5$ V		30	200	nA
Input Offset Current	$V_{CM} = 2.5$ V		5.0	75	nA
Voltage Gain +	$R_L = 2.0$ k to GND; $V_O = 1.0$ to 2.5 V	25 k	250 k		V/V
Voltage Gain -	$R_L = 2.0$ k to $V^+$ Op Amp; $V_O = 1.0$ to 2.5 V	25 k	250 k		V/V
Common Mode Voltage Range		0		$V^+ - 2$	V
Common Mode Rejection Ratio	$V_{CM} = 0$ to 3.0 V	76	100		dB
Power Supply Rejection Ratio	$V^+$ Op Amp = 3.0 to 40 V	76	100		dB
Output Source Current		100	150		mA
Output Sink Current		10	35		mA
Slew Rate			0.6		V/ $\mu$ s
Output Voltage LOW	$I_L = -5.0$ mA			1.0	V
Output Voltage HIGH	$I_L = 50$ mA		$V^+$ Op Amp -2.5 V		V

**DESIGN FORMULAS**

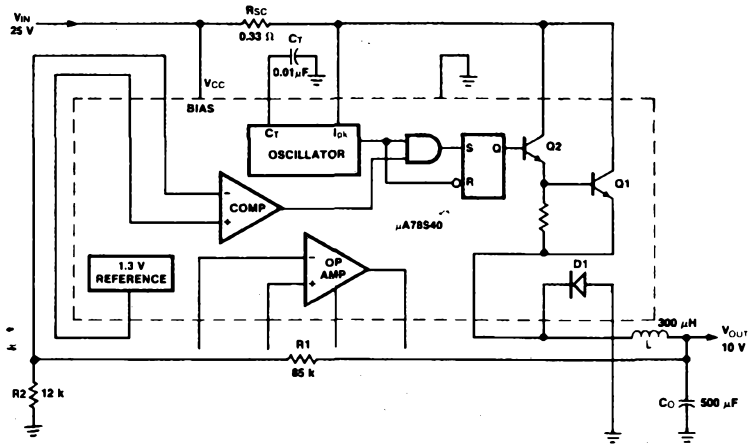
CHARACTERISTIC	STEP DOWN	STEP UP	INVERTING
$I_{pk}$	$2 I_{OUT(max)}$	$2 I_{OUT(max)} \cdot \frac{V_{OUT} + V_D - V_S}{V_{IN} - V_S}$	$2 I_{OUT(max)} \cdot \frac{V_{IN} +  V_{OUT}  + V_D - V_S}{V_{IN} - V_S}$
$R_{SC}^*$	$0.33 V/I_{pk}$	$0.33 V/I_{pk}$	$0.33 V/I_{pk}$
$\frac{t_{on}}{t_{off}}$	$\frac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$	$\frac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$	$\frac{ V_{OUT}  + V_D}{V_{IN} - V_S}$
$L^*$	$\frac{V_{OUT} + V_D}{I_{pk}} \cdot t_{off}$	$\frac{V_{OUT} + V_D - V_{IN}}{I_{pk}} \cdot t_{off}$	$\frac{ V_{OUT}  + V_D}{I_{pk}} \cdot t_{off}$
$t_{off}$	$\frac{I_{pk} \cdot L}{V_{OUT} + V_D}$	$\frac{I_{pk} \cdot L}{V_{OUT} + V_D - V_{IN}}$	$\frac{I_{pk} \cdot L}{ V_{OUT}  + V_D}$
$C_T^*(\mu F)$	$45 \times 10^{-5} t_{off}(\mu s)$	$45 \times 10^{-5} t_{off}(\mu s)$	$45 \times 10^{-5} t_{off}(\mu s)$
$C_O^*$	$\frac{I_{pk} \cdot (t_{on} + t_{off})}{8 V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \cdot t_{off}}{2 I_{pk} \cdot V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \cdot t_{off}}{2 I_{pk} \cdot V_{ripple}}$
Efficiency	$\frac{V_{IN} - V_S + V_D}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D}$	$\frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{V_{OUT}}{V_{OUT} + V_D - V_S}$	$\frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{ V_{OUT} }{ V_{OUT}  + V_D}$
$I_{IN(avo)}$ (Max load condition)	$\frac{I_{pk}}{2} \cdot \frac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$	$\frac{I_{pk}}{2}$	$\frac{I_{pk}}{2} \cdot \frac{ V_{OUT}  + V_D}{V_{IN} +  V_{OUT}  + V_D - V_S}$

\* Denotes Component Values



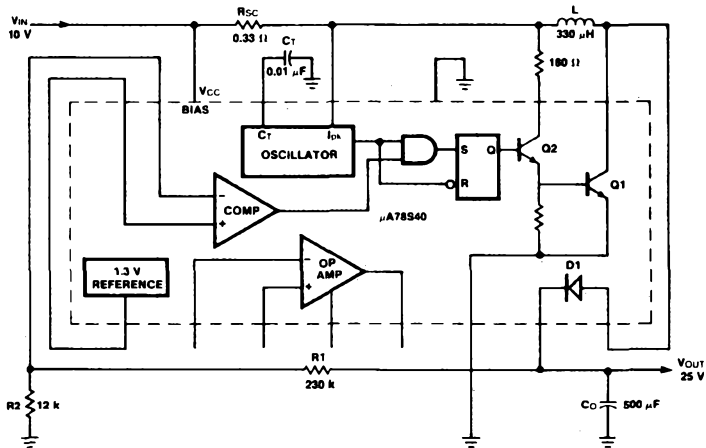
TYPICAL INVERSION OPERATIONAL PERFORMANCE  
 $T_A = 25^\circ$

CHARACTERISTIC	CONDITIONS	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 100 \text{ mA}$	-15 V
LINE REGULATION	$8 \text{ V} \leq V_{IN} \leq 18 \text{ V}$	5.0 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 150 \text{ mA}$	3.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 14.25 \text{ V}$	160 mA
OUTPUT RIPPLE	$I_{OUT} = 100 \text{ mA}$	20 mV
EFFICIENCY	$I_{OUT} = 100 \text{ mA}$	70%
STANDBY CURRENT		2.3 mA



TYPICAL STEP-DOWN PERFORMANCE  
 $T_A = 25^\circ$

CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 200 \text{ mA}$	10 V
LINE REGULATION	$20 \leq V_{IN} \leq 30 \text{ V}$	1.5 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 300 \text{ mA}$	3.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 9.5 \text{ V}$	500 mA
OUTPUT RIPPLE	$I_{OUT} = 200 \text{ mA}$	50 mV
EFFICIENCY	$I_{OUT} = 200 \text{ mA}$	74%
STANDBY CURRENT		2.8 mA



TYPICAL STEP-UP OPERATIONAL PERFORMANCE  
 $T_A = 25^\circ\text{C}$

CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 50 \text{ mA}$	25V
LINE REGULATION	$5 \text{ V} < V_{IN} \leq 15 \text{ V}$	4.0 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 100 \text{ mA}$	2.0 mA
MAX OUTPUT CURRENT	$V_{OUT} = 23.75 \text{ V}$	160 mA
OUTPUT RIPPLE	$I_{OUT} = 50 \text{ mA}$	30 mV
EFFICIENCY	$I_{OUT} = 50 \text{ mA}$	79%
STANDBY CURRENT	$I_{OUT} = 50 \text{ mA}$	2.8 mA





SELECTION GUIDES AND INDUSTRY  
CROSS REFERENCE

VOLTAGE REGULATORS

1

TESTING AND RELIABILITY

2

APPLICATIONS

3

POWER SUPPLY DESIGN

4

POWER TRANSISTORS

5

THERMAL CONSIDERATIONS

6

PRODUCT INFORMATION

7

DEFINITIONS, ORDERING INFORMATION  
AND PACKAGE OUTLINES

8

FAIRCHILD FIELD SALES OFFICES,  
REPRESENTATIVES AND DISTRIBUTORS

9

## DEFINITIONS, ORDERING INFORMATION AND PACKAGE INFORMATION

- Definitions ..... 8-3
- Ordering Information ..... 8-4
- Package Outline Guide ..... 8-5
- Package Outlines ..... 8-7

# DEFINITION OF TERMS

**Average Temperature Coefficient of Output Voltage** – The change in output voltage for a specified change in ambient temperature. ( $\Delta V_{OUT}/\Delta T_A$ ) (mV/°C)

**Dropout Voltage** – The input-output voltage differential that causes the output voltage to decrease by 5% of its initial value. ( $V_{DO}$ ) (V)

**Feedback Sense Voltage** – The voltage measured on the feedback terminal of the regulator, with respect to ground, when the device is operating in regulation. ( $V_{sense}$ ) (V)

**Input Current** – The current flowing into the input with a specified voltage applied to the input. ( $I_{IN}$ )

**Input-Output Voltage Differential** – The voltage range between the unregulated input voltage and the regulated output voltage in which a regulator operates within specifications.

**Input Voltage** – The voltage potential between the input terminal and the device ground reference. ( $V_{IN}$ ) (V)

**Line Regulation** – The change in output voltage for a specified change in input voltage. ( $\Delta V_{OUT}/\Delta V_{IN}$ ) (mV or %)

**Load Regulation** – The change in output voltage for a specified change in load current. ( $\Delta V_{OUT}/\Delta I_L$ ) (mV or %)

**Output Noise Voltage** – The rms value of the noise voltage measured at the output with constant load current and no input ripple. ( $e_{NO}$ ) ( $\mu$ V)

**Output Short Circuit Current** – The output current obtainable with the output shorted to ground or to either supply. ( $I_{SC}$ ) (mA)

**Output Resistance** – The small signal ac resistance seen looking into the output with no feedback applied and the output dc voltage near zero.

**Quiescent Current** – That part of a regulator input current that is not delivered to the load. ( $I_Q$ ) (mA)

**Output Voltage** – The voltage present at the output terminal referred to ground. ( $V_{OUT}$ ) (V)

**Output Voltage Range** – The range of output voltages over which the specifications apply. ( $\Delta V_{OUT}$ ) (V)

**Peak Output Current** – The maximum current delivered by the device for a period too short for thermal protection to be activated. ( $I_{OUT(PK)}$ ) (A)

**Power Dissipation (Max)** – The maximum power that can be dissipated in the device with a given heat sink beyond which the device may not perform to specification. ( $P_{D(MAX)}$ ) (mW)

**Reference (Control) Current** – The current drawn or supplied by the reference (control) terminal. ( $I_{REF}$ ) ( $\mu$ A)

**Reference Voltage** – The output of the reference amplifier measured with respect to the negative supply. ( $V_{REF}$ ) (V)

**Ripple Rejection** – The ratio of the peak-to-peak input ripple voltage to the peak-to-peak output ripple voltage. (dB)

**Short-Circuit Current Limit** – The output current of a regulator with the output shorted to common (ground). ( $I_{SC}$ ) (mA)

**Standby Current Drain** – The supply current drawn by a regulator with no output load and no reference voltage load (see Quiescent Current).

**Temperature Stability** – The percentage change in output voltage over a specified ambient temperature range. ( $\Delta V_{OUT}/\Delta T_A$ ) (V/°C)

## ORDERING INFORMATION

A standard voltage regulator order code includes three basic units of information, the device type, the package type, and the temperature range. Simply combining these three elements specifies exactly what product, package, and temperature range is desired.

The device type is available on the first page of each product data sheet. The package type is specified by a package code from the table in this section. The specific package outlines available for each product are listed in the columns under the type of package and the package ordering code. The temperature ranges available are listed on each product data sheet. There are four grades of commercial or industrial or consumer temperature ranges used, depending upon the product, specified in the ordering code by a C. There are two grades of military temperature ranges used, depending upon the product, specified in the ordering code by an M. An example of a complete ordering code is shown below.

$\mu$ A723	D	C
Device Type	Package Code	Temperature Range

The device type specifies a 723 precision voltage regulator, the D specifies a ceramic DIP according to a 6A outline (from the following table), and the C specifies a commercial temperature range of 0°C to +70°C (from the data sheet).

All packages available for voltage regulators are specified by one of the following codes. The specific package outline can be determined by checking the table overleaf. Details of each package outline are provided following this table.

Package Code	Basic Package Style
D	Ceramic Hermetic Dual In-Line
P	Molded Plastic Dual In-Line
K	Metal Power (TO-3 Outline)
H	Metal Can (TO-39, TO-78, TO-99, TO-100 Outlines)
W	TO-92 Outline
U	Molded Plastic Power (TO-220 Outline)
U1	Power Watt (similar to TO-202)
T	Mini Dual In-Line
T2	Power Mini Dual In-Line

Temperature ranges available are listed below and specified by a suffix C for commercial ranges and a suffix M for military ranges. The specific range within each category is specified on each product data sheet.

Commercial/Industrial/Consumer (Suffix C)	Military (Suffix M)
0°C to +70°C	-55°C to +125°C

Additional processing to Fairchild Unique 38510 specifications is available and indicated by a QB or QC suffix on the order code, depending upon the processing required. Screening to the Fairchild Matrix VI program is indicated by a QM or QR suffix on the order code. For detailed information, consult the OEM price list.

# PACKAGE OUTLINE GUIDE

TYPE	CERAMIC DIP	PLASTIC DIP	TO-3	TO-39/78/ 99/100	TO-92	TO-220	POWER WATT	MINI DIP	POWER MINI DIP
ID#	(D)	(P)	(K)	(H)	(W)	(U)	(U1)	(T)	(T2)
4				5F**				9T	
5				5B**					
9			HJ**						
4			HJ**	5F*				9T	
5				5B*				9T	
5A				5B*					
9			HJ*						
6								9T*	
3	6A	9A*		5F					
05			HJ*			GH*	8Y†		
06			HJ			GH*	8Y†		
08			HJ			GH*	8Y†		
12			HJ			GH*	8Y†		
15			HJ			GH*	8Y†		
18			HJ			GH*	8Y†		
24			HJ			GH*	8Y†		
85			HJ			GH*	8Y†		
C08							8Y†		
C10							8Y†		
C12							8Y†		
C15							8Y†		
C17							8Y†		
C18							8Y†		
C20							8Y†		
C22							8Y†		
C24							8Y†		
C82							8Y†		
CB			HJ*			GH*			
G			GK				8Z*		
H05			HJ						
H05A			AW						
H12			HJ*						
H15			HJ*						
HG			HJ						

Commercial Grade Only

\*\*Military Grade Only

†Commercial Grade Only—U1 and U2 Configuration



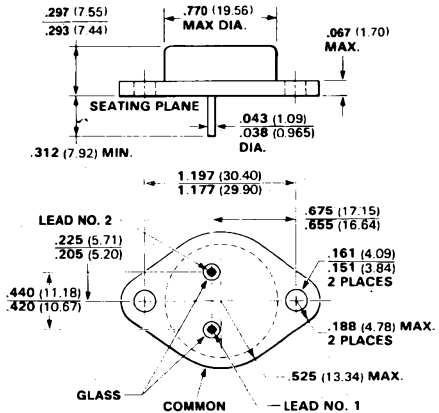
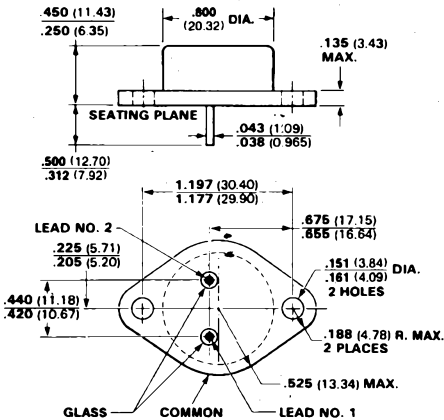
# PACKAGE OUTLINES

In Accordance with  
JEDEC (TO-3) Outline

AW

In Accordance with  
JEDEC (TO-3) Outline

HJ



**NOTES:**

- Leads 1 and 2 electrically-isolated from case
- Case is third electrical connection
- Steel base
- Package weight is 12.27 grams

**NOTES:**

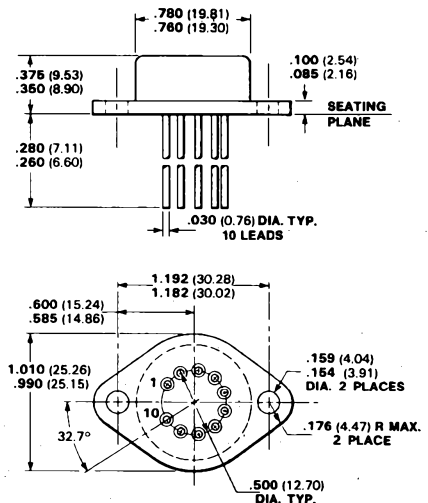
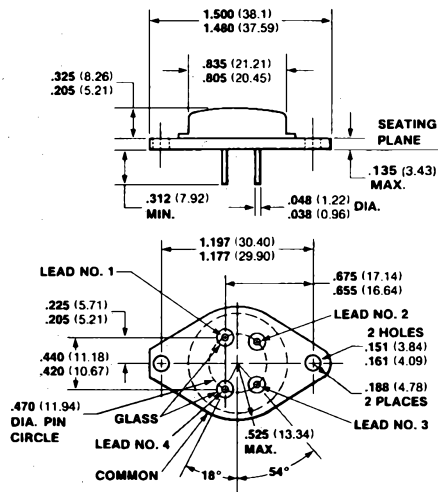
- Leads are nickel plated solder-dipped Alloy 52
- Leads 1 and 2 electrically-isolated from case
- Case is third electrical connection
- Steel package with copper slug, pins are soldered in package weight is 9.2 grams

In Accordance with  
JEDEC (TO-3) Outline

GK

Similar to\*  
JEDEC (TO-3) Outline

5H



**NOTES:**

- Leads are gold-plated or solder dipped Alloy 52
- All leads electrically-isolated from case
- Package weight is 7.4 grams

**NOTES:**

- Package material is nickel-plated CRS 1010
- Lead material is Alloy 52
- Glass material is Corning 9010
- Lead, post and base are gold-plated

\*Except 10 Leads

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

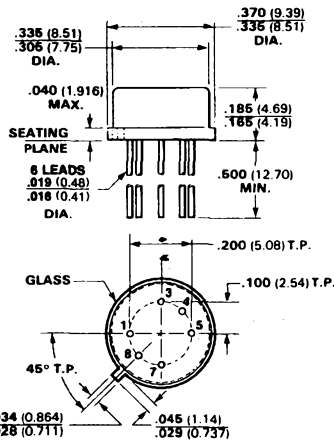




# PACKAGE OUTLINES

## In Accordance with JEDEC (TO-78) Outline

5C

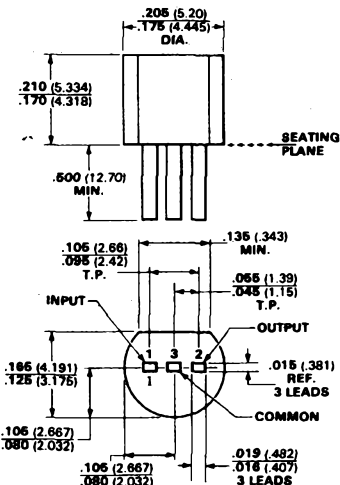


**NOTES:**

- Leads are solder dipped to within .040 of seating plane
- Six leads through
- Leads 2 and 6 are omitted
- Package weight is 0.95 gram

## In Accordance with JEDEC (TO-92) Outline

EI

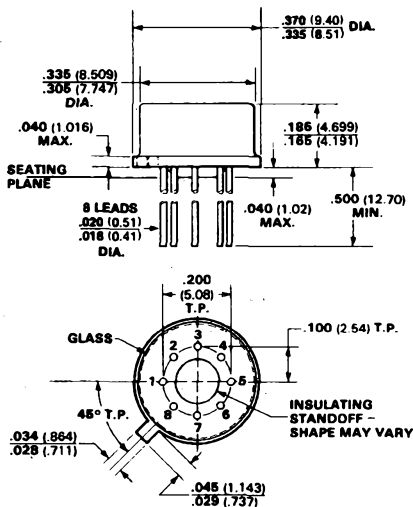


**NOTES:**

- Leads are tin plated copper
- Package material is transfer molded thermosetting plastic
- ECB configuration
- Package weight is 0.25 gram

## In Accordance with JEDEC (TO-99) Outline

5S

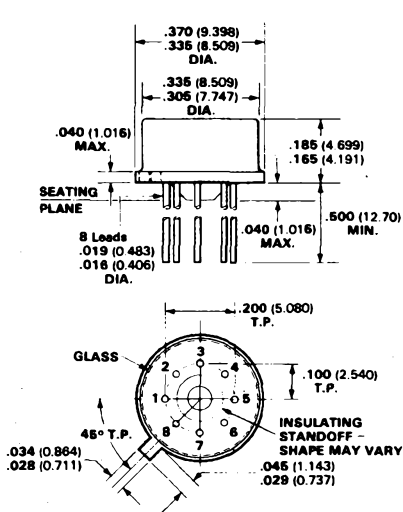


**NOTES:**

- Leads are solder-dipped to seating plane
- Seven leads through, lead 4 connected to case
- Package weight is 1.22 grams

## In Accordance with JEDEC (TO-99) Outline

5B



**NOTES:**

- Leads are gold-plated Kovar
- Seven leads through, lead 4 connected to case
- Package weight is 1.22 grams

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

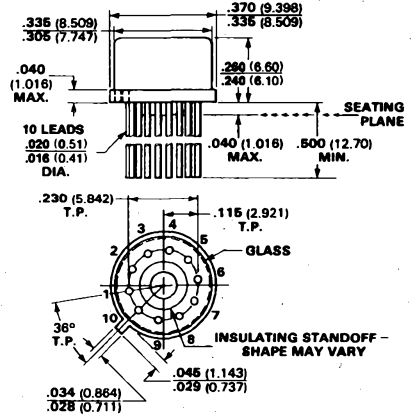
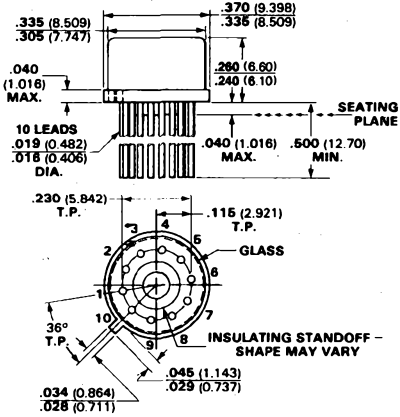
# PACKAGE OUTLINES

In Accordance with  
JEDEC (TO-100) Outline

5F

In Accordance with  
JEDEC (TO-100) Outline

5N



**NOTES:**

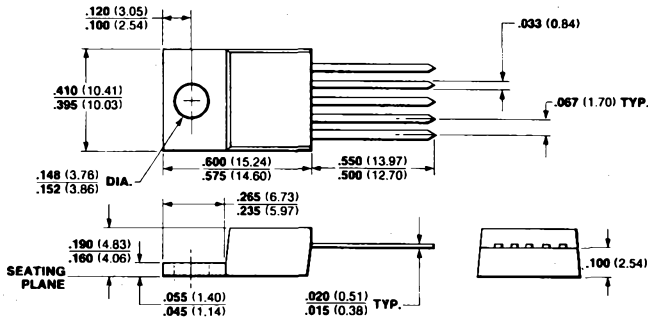
Leads are gold-plated Kovar  
Nine leads through, lead 5 connected to case  
Package weight is 1.32 grams

**NOTES:**

Leads are solder-dipped to the seating plane  
Nine leads through, lead 5 connected to case  
Package weight is 1.32 grams

## TO-220 (5 Leads) Pentawatt

GO



**NOTES:**

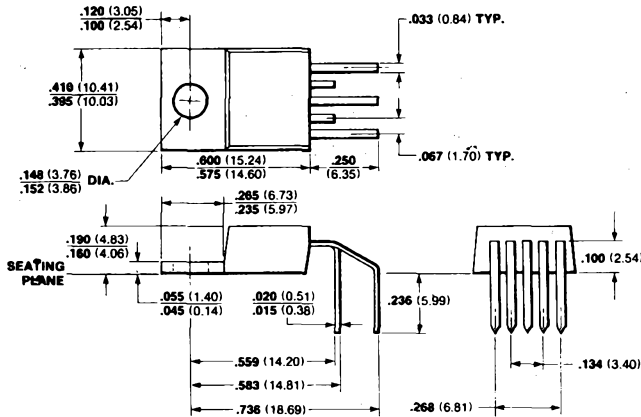
Mounting tab electrically-connected to center lead  
Package is molded over a copper base material with solderable leads  
Package weight is 2.1 grams

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

# PACKAGE OUTLINES

**GO  
(H)**

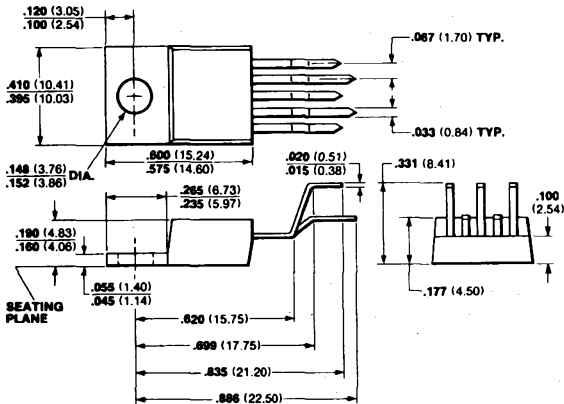
## TO-220 (5 Leads) Pentawatt



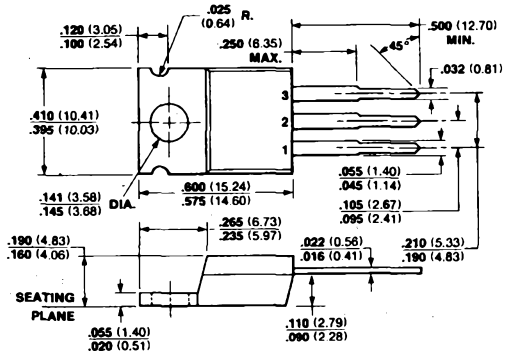
Mounting tab electrically-connected to center lead  
 Package is molded over a copper base material  
 with solderable leads  
 Package weight is 2.1 grams

## TO-220 (5 Leads) Pentawatt **GO (V)**

In Accordance with **GH  
(-3)**  
**JEDEC (TO-220) Outline\***  
**Plastic Power Package**



Mounting tab electrically-connected to center lead  
 Package is molded over a copper base material  
 with solderable leads  
 Package weight is 2.1 grams



**NOTES:**  
 Package is epoxy plastic with plated copper tab  
 and leads  
 Center lead is electrical contact with the  
 mounting tab  
 Package weight is 2.1 grams

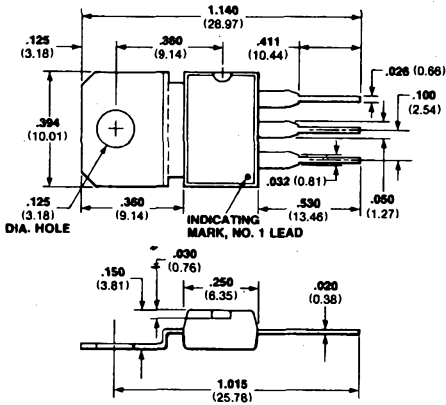
\*Mechanically interchangeable with TO-66

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

8

# PACKAGE OUTLINES

## 3-Lead Single Side Power 8Y Plastic Mini DIP (U-1)



### NOTES:

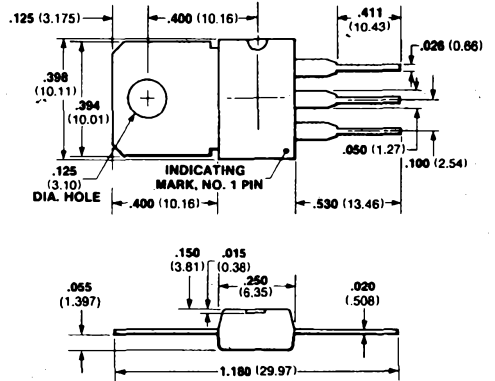
Package is plastic with tin-plated copper leads

Package weight is 0.6 gram

Center lead is electrical contact with mounting tab

This package is intended to be mounted with the tab flush with the top of the PC board or heat sink. A No. 4 screw may be used to secure the package. Thermal compound is recommended

## 3-Lead Single Side Power 8Y Plastic Mini DIP (U-2)



### NOTES:

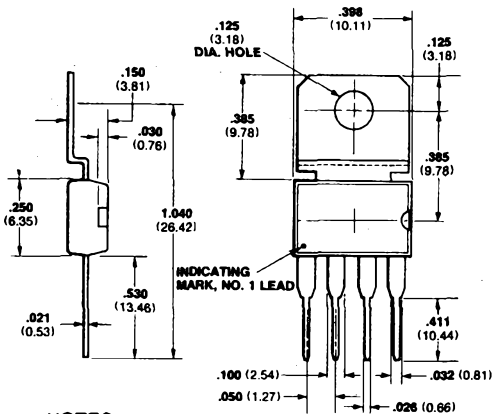
Package is plastic with tin-plated copper leads

Package weight is 0.6 gram

Center lead is electrical contact with mounting tab

For detailed package configuration, refer to FSB-90717

## 4-Lead Single Side Power 8Z Plastic Mini DIP (U-1)



### NOTES:

Package is plastic with tin-plated copper leads

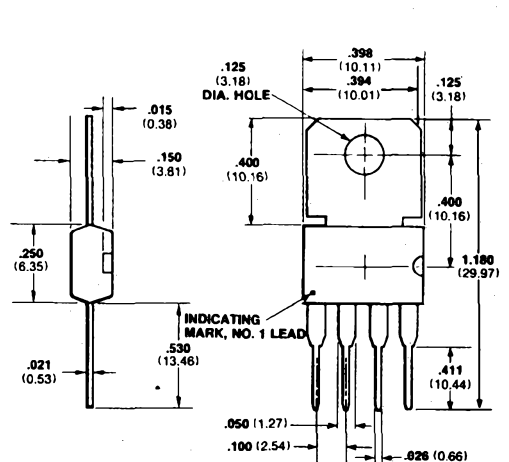
Board-drilling dimensions should equal your practice for .033(0.84) inch diameter leads

Package weight is 0.6 gram

Tab is electrically insulated from leads

This package is intended to be mounted with the tab flush with the top of the PC board or heat sink. A No. 4 screw may be used to secure the package. Thermal compound is recommended

## 4-Lead Single Side Power 8Z Plastic Mini DIP (U-2)



### NOTES:

Package is plastic with tin-plated copper leads

Board-drilling dimensions should equal your practice for .033(0.84) inch diameter lead

Package weight is 0.6 gram

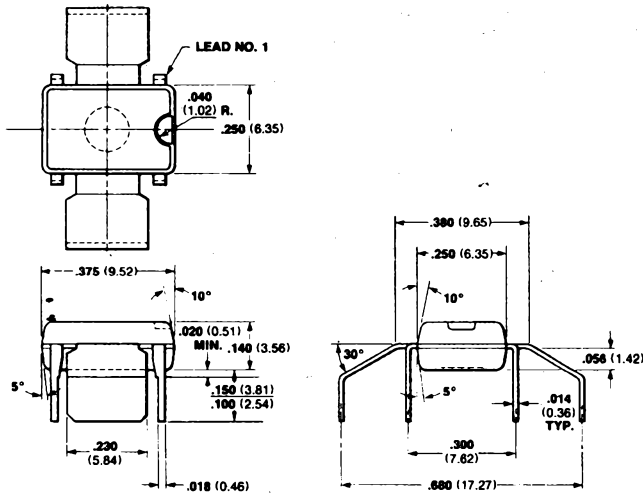
Tab is electrically insulated from leads

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

# PACKAGE OUTLINES

## 4-Lead Power Mini DIP

9V  
(T-1)



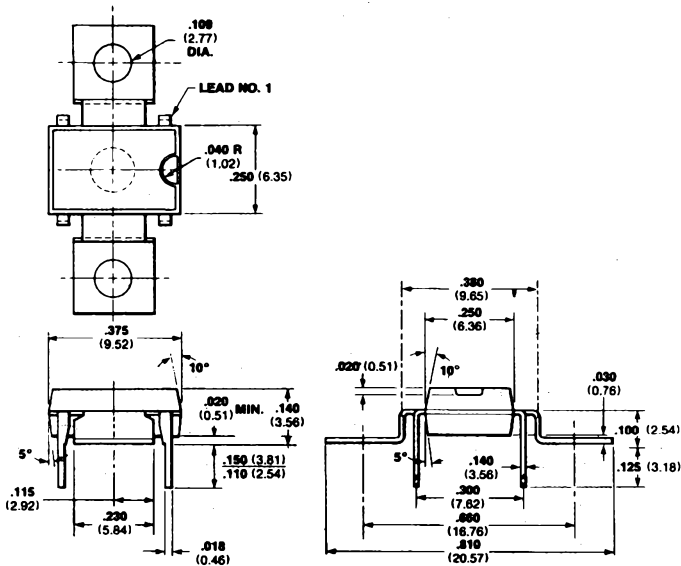
**NOTES:**

Package is plastic with tin-plated copper leads  
For detailed package configuration refer to  
FSD-90669  
Package weight is 0.6 gram

T-1 package can be soldered to the PC board  
through .0230" x .020" (0.584 x 0.51) slots.  
Double or single-sided  
boards may be used.

## 4-Lead Power Mini DIP

9V  
(T-2)



**NOTES:**

Package is plastic with tin-plated copper leads  
and wings  
For detailed package configuration refer to  
FSD-90670  
Package weight is 0.6 gram

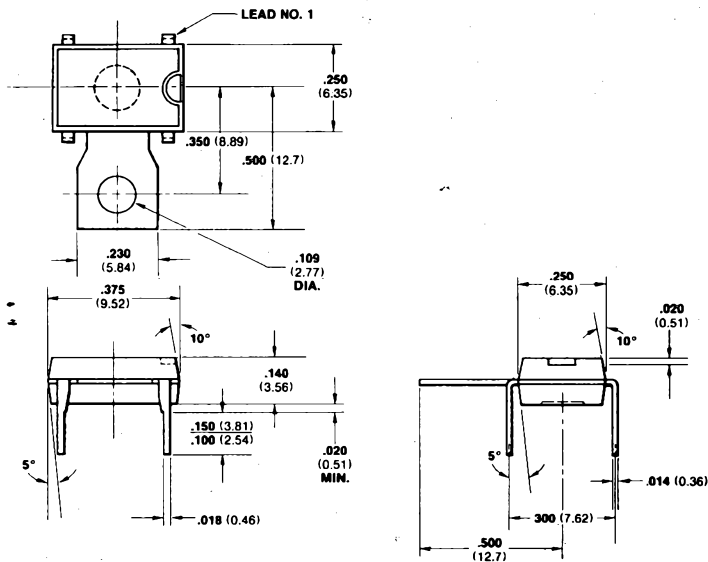
T-2 package is intended to be mounted with the  
tabs flush with the top of the PC board. Either  
No. 2-56 screws or No. 2 rivets may be used to  
secure the package. Single or double-sided  
PC boards can be used. Thermal compound  
is recommended.

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

# PACKAGE OUTLINES

9V  
(T-3)

## 4-Lead Power Mini DIP



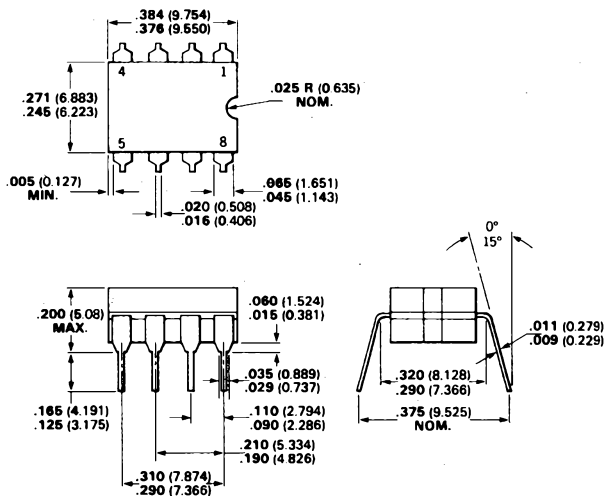
**NOTES:**

Package is plastic with tin-plated copper leads and wings  
Package weight is 0.6 gram

T-3 package is intended for applications with an external heat sink. A No. 2 mounting hole is provided for ease of mounting. The tab may be bent to any convenient angle.

## 8-Lead SSI Dual In-Line

6T



**NOTES:**

Leads are tin-plated Kovar  
Leads are intended for insertion in hole rows on .300" centers (7.62)  
Leads purposely have a "positive" misalignment to facilitate insertion

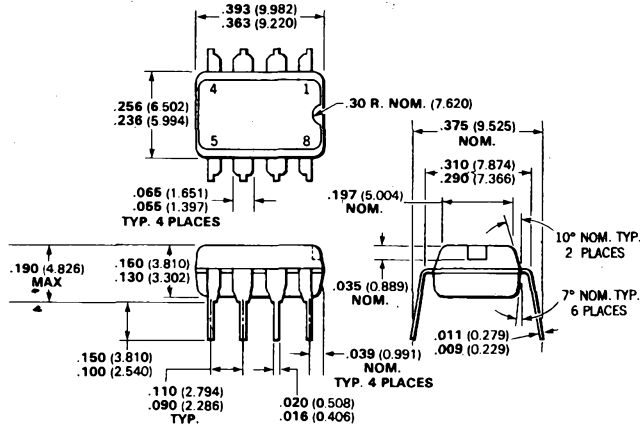
Board-drilling dimensions should equal your practice for .020 (0.51) inch diameter lead  
Hermetically sealed alumina package  
Cavity size is .110 x .140 (2.79 x 3.56)  
Package weight is 1.0 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

# PACKAGE OUTLINES

## 8-Lead Plastic Dual In-Line

9T



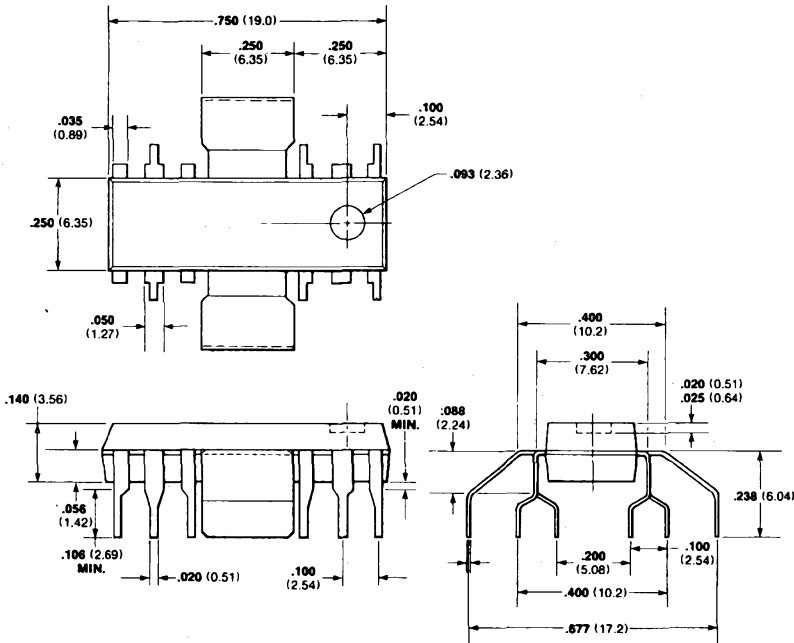
**NOTES:**

Package is plastic with tin or gold-plated Kovar leads  
 Leads are intended for insertion in hole rows on .300" centers (7.62)

Leads purposely have a "positive" misalignment to facilitate insertion  
 Board-drilling dimensions should equal your practice for .020 (0.51) inch diameter lead  
 Package weight is 0.6 gram

## 12-Lead Power Plastic Dual In-Line

9W  
(P-3)



**NOTES:**

Package is plastic with tin plated copper leads and wings

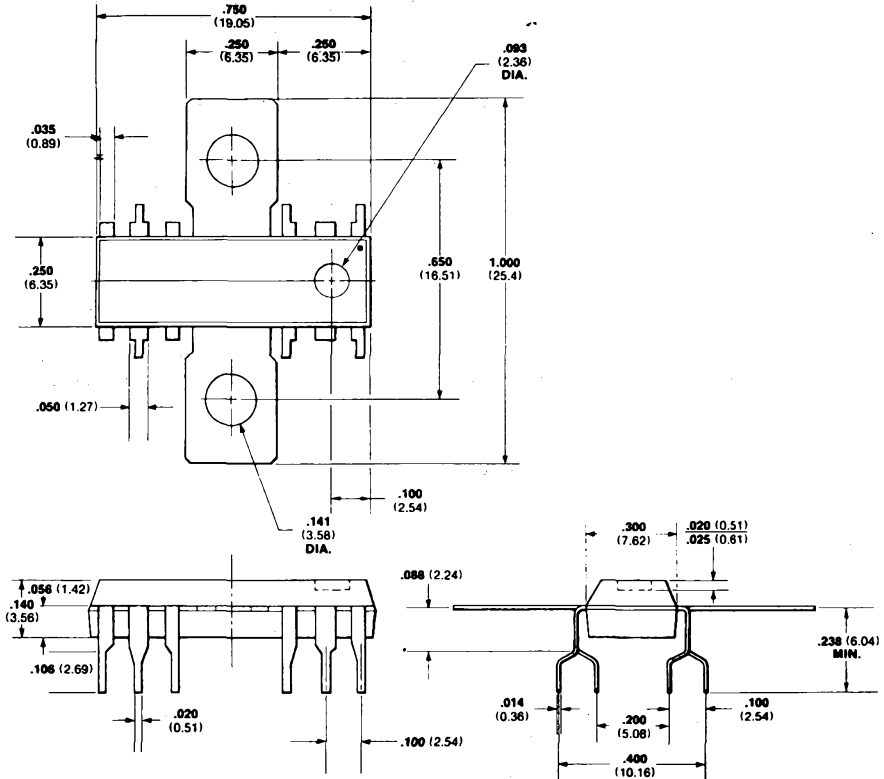
For detailed package configuration refer to FSB-90698  
 Package weight is 0.9 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

# PACKAGE OUTLINES

## 12-Lead Power Plastic Dual In-Line

9W  
(P-4)



### NOTES:

Package is plastic with tin-plated copper leads and wings

For detailed package configuration refer to FSB-90699

Package weight os 0.9 gram

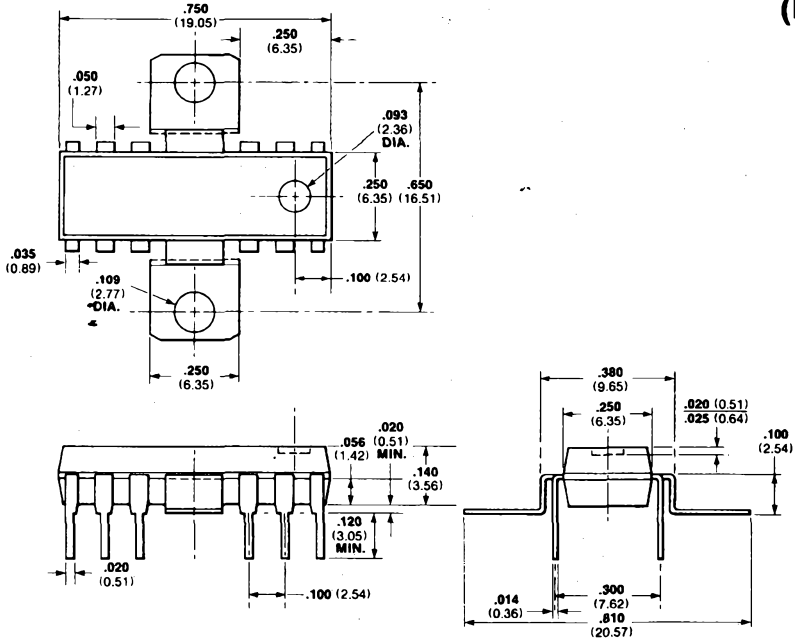
Dimensions nominal, in inches. Parentheses indicate metric dimensions.



# PACKAGE OUTLINES

**9W  
(P-5 CONF)**

## 12-Lead Power Plastic Dual In-Line



**NOTES:**

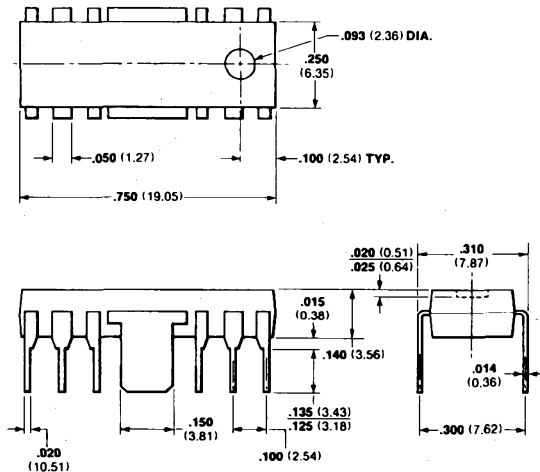
Package is plastic with tin-plated copper leads and wings

For detailed package configuration refer to FSD-90740

Package weight is 0.9 gram

## 12-Lead Power Plastic Dual In-Line

**9W  
(P-6)**



**NOTES:**

Package is plastic with tin-plated copper leads and wings

For detailed package configuration refer to FSB-90126

Package weight is 0.9 gram

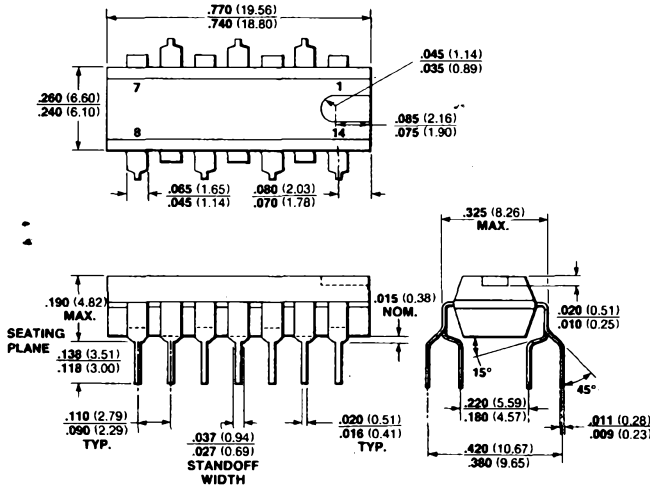
Dimensions nominal, in inches. Parentheses indicate metric dimensions.



# PACKAGE OUTLINES

9C

## Similar to\* JEDEC (TO-116) Outline 14-Lead Epoxy Quad In-Line



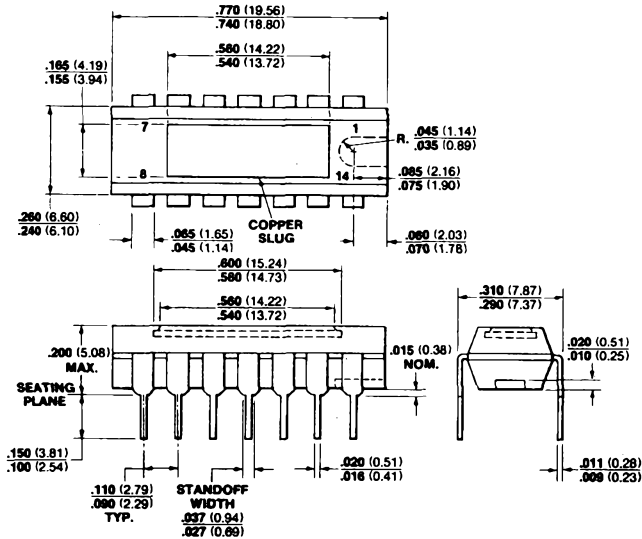
**NOTES:**

Package is epoxy with tin-plated Kovar leads  
Board-drilling dimensions should equal your  
practice for .020 (0.51) inch diameter lead  
Package weight is 0.9 gram

\*This is a 9A package with the leads formed  
in assembly. Only the notched and epoxy  
version is used

## 14-Lead Epoxy Dual In-Line (With Copper Slug)

9H



**NOTES:**

Package material is epoxy with copper slug  
Leads are gold-plated Kovar

Board-drilling dimensions should equal your  
practice for .020 (0.51) inch diameter lead  
Package weight is 0.9 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.





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