ELECTRONICS DIGEST

VOL1 No 3
£1.50

DATA BOOK

PIN OUTS • CHARACTERISTICS • INSTRUCTION SETS • GLOSSARY
SUBSCRIPT DICTIONARY • DATA SHEETS • COMPONENTS EXPLAINED
EQUIVALENTS • TRUTH TABLES • CIRCUITS

100 Pages of invaluable info. for the electronics and computing enthusiast.

INTRODUCTION

Since we began publishing magazines in this country, over eight years ago, Modmags' aim has been to inform people who are interested in the ever-expanding field of electronics. Our first title, **Electronics Today International,** with its vast range of constructional projects and up-to-date reports on the latest developments in technology, was an incredible success. This led to the launching of two more magazines – **Hobby Electronics,** for the less experienced constructor and beginner in electronics; and **Computing Today,** for people interested in home computing and small systems.

In all these magazines it has been our aim, not only to provide projects and programs for you to copy, but to help those who are more able and experienced to experiment for themselves. After all, that's half the fun of electronics! Our **Electronic Circuit Design** series covered the theoretical ground – now **Electronics Digest No. 3** provides the information for those who want to get their hands dirty and their soldering irons tinned.

Transistors

The following tables provide all of the basic information that a designer requires when selecting transistors for a specific application. Furthermore, the lead connections for each transistor are given in the table, to make life easier for people building up circuits with only a circuit diagram to work from.

The transistors included in this table are virtually all available from one or more of the major mail order companies. However, should any type prove difficult to obtain (or you need a transistor *now* and the shops are shut) then the information given here can be used as a guide to help you select a substitute. Bear in mind that this can only be an approximate guide, and you substitute at your own risk!

Computing

This section is for the home computer enthusiast. Basic information is given on four of the most popular microprocessors, together with tables of their instruction sets – conveniently laid out for the bewildered programmer. There are also brief surveys of each type of support chip, including RAMs, PROMs, dynamic RAMs and I/O devices. The ASCII set is listed and there is a conversion table for hex to decimal and vice-versa.

General Information

What are the different types of power supply circuit? How do I wire up an op-amp? What is an AND gate? Or an ALU? What does TTL stand for? Why aren't you looking up the answers in the glossaries and pages of data that we've collected together for you?

Components

It may be possible to build projects without knowing anything about resistors and capacitors except that they're the little cylinders with wires sticking out of the ends, but it's not very satisfying. There are four articles in this issue which examine different categories of component and their construction. Performance, cost and application are all considered, so that you can see why certain types are used in our circuits, and which ones you should use in yours.

Logic

There are two main types of IC logic families, TTL and CMOS. They feature extensively in digital circuits and every home constructor should have access to pin-out tables. (Ever seen a circuit design you'd like to build, with no pin numbers marked? Frustrating, isn't it.) The tables also show the internal arrangement of the ICs to help you understand their function.

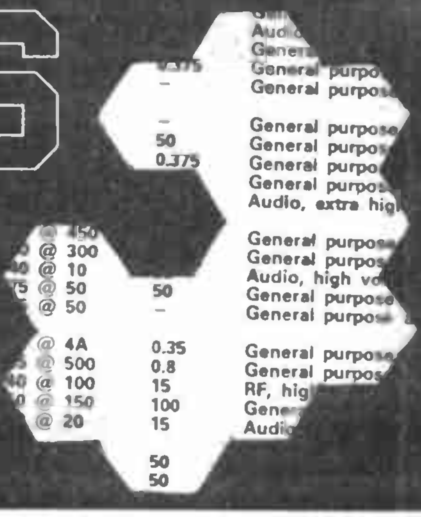
Data Sheet

A selection of articles containing manufacturer's data on some popular ICs. Each IC has application circuits given, to be built as they stand or used as a basis for experiment. We've also included an article explaining the notation used in data sheets, as we've found that quite a lot of confusion exists as to what the data actually means (see the cautionary tale that starts off the article).

Digest No. 3

Whatever your interest in electronics, there's bound to be something in this magazine that you'll need to know sooner or later. If you still haven't decided to buy it, are you sure you're standing at the right rack in the newsagents?

ELECTRONICS DIGEST



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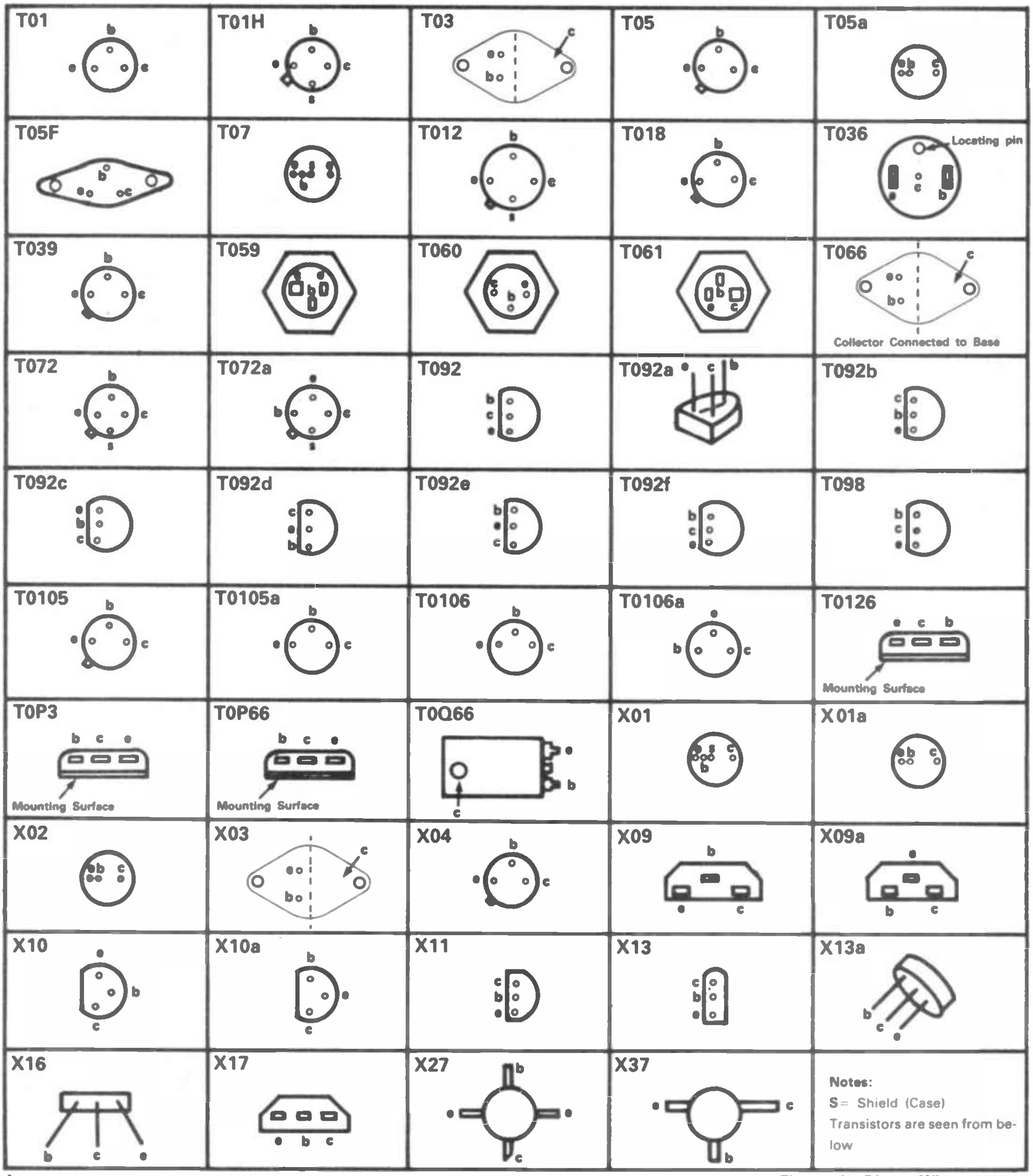
Explanation of Tables

Type Manufacturer's code number.
Pol/Mat Polarity of transistor and semiconductor material used. N is NPN; P is PNP; G is germanium; S is silicon.
Case Style Refers to the lead connections shown below.
V_{CB} (max) Maximum permissible collector-base voltage with the emitter open-circuit.
V_{CE} (max) Maximum permissible collector-emitter voltage with the base open-circuit.
V_{EB} (max) Maximum permissible emitter-base voltage with the collector open-circuit.
I_C (max) Maximum permissible collector current – given in mA unless otherwise stated.
P_{TOT} (max) Maximum power dissipation of the device – given in mW unless otherwise stated.
h_{FE} (min) Minimum current gain of the device. As this depends to a large extent on the collector bias current at which measurements are made, the value is also listed (in mA unless otherwise stated).
f_T (min) Minimum frequency at which the common-emitter current gain will drop to unity – given in MHz.
Application A guide (although necessarily limited) to the typical device application.



Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
AC107	PG	X01	15	15	5	10	80	35 @ 300	1	Audio amplifier
AC117	PG	X04	32	18	10	1A	1W	40 @ 150	0.5	General purpose audio
AC125	PG	T01	32	12	10	100	500	50 @ 2	1	Audio amplifier
AC126	PG	T01	32	12	10	100	500	100 @ 2	1	General purpose audio
AC127	NG	T01	32	12	10	500	340	50 @ 500	1.5	General purpose audio
AC128	PG	T01	32	16	10	1A	267	45 @ 1A	1	General purpose audio
AC141	NG	T01	32	18	10	1.2A	720	40 @ 400	1	General purpose audio
AC141K	NG	X04	32	18	10	1.2A	720	40 @ 400	0.5	General purpose audio
AC142	PG	T01	32	20	10	1.2A	720	40 @ 400	1	General purpose audio
AC142K	PG	X04	32	20	10	1.2A	860	40 @ 400	0.5	General purpose audio
AC151	PG	T01	32	24	10	200	900	30 @ 2	1	Audio amplifier
AC152	PG	T01	32	24	10	500	900	30 @ 100	1	General purpose audio
AC153	PG	T01	32	18	10	2A	1W	50 @ 300	1	General purpose audio
AC176	NG	T01	32	20	10	1A	220	52 @ 500	1	General purpose audio
AC187	NG	T01	25	15	10	2A	225	100 @ 300	1	General purpose audio
AC187K	NG	X04	25	15	10	2A	1W	100 @ 300	1	General purpose audio
AC188	PG	T01	25	15	10	2A	225	100 @ 300	1	General purpose audio
AC188K	PG	X04	25	15	10	2A	1W	100 @ 300	1	General purpose audio
ACY17	PG	T05	70	32	12	500	260	50 @ 300	1	General purpose audio
ACY18	PG	T05	50	30	12	500	260	40 @ 300	1	General purpose audio
ACY19	PG	T05	50	30	12	500	260	80 @ 300	1	General purpose audio
ACY20	PG	T05	40	20	12	500	260	50 @ 50	1	General purpose audio
ACY21	PG	T05	40	20	12	500	260	90 @ 50	1	General purpose audio
ACY22	PG	T05	20	15	12	500	260	30 @ 300	1	General purpose audio
ACY28	PG	T01	40	15	30	200	200	45 @ 1	0.8	RF amplifier
ACY39	PG	T05	110	40	25	500	260	50 @ 300	1	Audio, high voltage
ACY40	PG	T05	32	18	12	500	260	30 @ 300	1	General purpose audio
ACY41	PG	T05	21	18	12	500	260	50 @ 300	1	General purpose audio
ACY44	PG	T05	50	30	12	500	260	40 @ 300	1	General purpose audio
AD140	PG	T03	55	55	10	3A	35W	30 @ 1A	0.2	General purpose audio
AD142	PG	T03	80	50	10	10A	30W	30 @ 1A	0.45	Audio, high voltage
AD149	PG	T03	50	30	20	3.5A	27W	30 @ 1A	0.2	General purpose audio
AD150	PG	T03	32	30	10	3.5A	27W	30 @ 1A	0.45	General purpose audio
AD161	NG	X03	32	20	10	1A	4W	80 @ 500	1	General purpose audio
AD162	PG	X03	32	20	10	1A	6W	50 @ 500	1	General purpose audio
AF106	PG	T072	20	15	0.3	10	60	25 @ 1	100	General purpose FM/VHF
AF109	PG	T072	25	18	0.3	12	60	20 @ 2	100	VHF amplifier
AF114	PG	T07	32	15	2	10	75	50 @ 1	75	RF amplifier
AF118	PG	T07	70	20	2	30	375	–	125	RF amplifier
AF121	PG	T01H	25	25	–	10	140	30 @ 3	270	VHF amplifier
AF124	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF125	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF126	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF127	PG	T072a	32	15	2	10	75	50 @ 1	75	General purpose, RF
AF139	PG	T072	20	15	0.3	10	60	10 @ 1.5	275	UHF amplifier
AF178	PG	T072	20	15	0.3	10	60	10 @ 1.5	275	UHF amplifier
AF180	PG	T012	25	25	–	25	156	10 @ 14	150	VHF amplifier
AF186	PG	T012	25	–	0.5	15	100	20 @ 1	50	FM/VHF/general purpose
AF239	PG	T072	15	15	0.3	10	60	10 @ 2	400	TV/UHF oscillator
AF279	PG	X37	15	15	0.3	10	60	10 @ 2	400	TV/UHF gain controlled amplifier
AFZ11	PG	T072a	20	10	0.5	10	83	20 @ 1	135	VHF amplifier
ASY26	PG	T05	30	15	20	200	150	30 @ 100	4	RF switch
ASY27	PG	T05	25	15	20	200	150	30 @ 100	6	RF switch
ASY50	PG	T01	20	10	20	200	200	15 @ 5	0.4	RF amplifier
ASY76	PG	T05	40	32	10	500	260	26 @ 300	1	General purpose audio
ASZ21	PG	T018	20	15	–	50	120	30 @ 10	300	VHF switch
BC107	NS	T018	50	45	6	100	300	110 @ 2	150	General purpose audio
BC107B	NS	T018	50	45	6	100	300	200 @ 2	150	General purpose audio
BC107C	NS	T018	50	45	6	100	300	450 @ 2	150	
BC108	NS	T018	30	20	5	100	300	120 @ 2	150	General purpose audio
BC108B	NS	T018	30	20	5	100	300	200 @ 2	150	General purpose audio
BC108C	NS	T018	30	20	5	100	300	420 @ 2	150	General purpose audio
BC109	NS	T018	30	20	5	100	300	180 @ 2	150	Audio, low noise
BC109B	NS	T018	30	20	5	100	300	200 @ 2	150	Audio, low noise
BC109C	NS	T018	30	20	5	100	300	420 @ 2	150	Audio, low noise
BC113	NS	T0106	30	25	6	50	200	200 @ 1	60	Audio, low noise
BC114	NS	T0106	30	25	6	50	200	200 @ 1	60	Audio, low noise
BC115	NS	T0105	40	30	5	100	300	80 @ 10	40	General purpose audio
BC116	PS	T0105	45	40	5	100	300	35 @ 10	130	General purpose audio
BC117	NS	T0105	120	120	5	50	300	30 @ 30	60	Audio, high voltage
BC118	NS	T0106	45	45	4	100	200	50 @ 5	200	General purpose audio
BC119	NS	T039	60	30	5	1A	800	40 @ 150	40	General purpose audio
BC123	NS	X16	45	30	5	50	90	25 @ 250μA	20	Audio, low noise
BC132	NS	T0106	30	25	6	200	200	60 @ 10	40	General purpose audio
BC134	NS	T0106	45	45	4	200	200	150 @ 10	200	General purpose audio
BC135	NS	T0106	45	45	5	200	200	50 @ 10	200	General purpose audio
BC136	NS	T0105a	60	40	5	100	300	40 @ 10	60	General purpose audio
BC137	PS	T0105	40	40	4	600	300	40 @ 10	60	General purpose audio
BC139	PS	T039	40	40	5	500	700	40 @ 100	100	General purpose audio
BC140	NS	T039	80	40	7	1A	3.7W	40 @ 100	50	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BC141	NS	T039	100	60	7	1A	3.7W	40 @ 100	50	General purpose audio
BC142	NS	T039	80	60	5	1A	800	20 @ 200	40	General purpose audio
BC143	PS	T039	60	60	5	1A	800	20 @ 300	100	General purpose audio
BC147	NS	X09	50	45	6	200	250	110 @ 2	150	Audio amplifier
BC147B	NS	X09	50	45	6	200	250	200 @ 2	150	Audio amplifier
BC148	NS	X09	30	20	5	200	250	110 @ 2	150	Audio amplifier
BC148B	NS	X09	30	20	5	200	250	200 @ 2	150	Audio amplifier
BC148C	NS	X09	30	20	5	200	250	420 @ 2	150	Audio amplifier
BC149	NS	X09	30	20	5	200	250	200 @ 2	150	Audio, low noise
BC149B	NS	X09	30	20	5	200	250	200 @ 2	150	Audio, low noise
BC149C	NS	X09	30	20	5	200	250	420 @ 2	150	Audio, low noise
BC153	NS	T0106	40	40	5	100	200	50 @ 10	40	General purpose audio
BC154	NS	T0106	40	40	5	100	200	160 @ 10	40	Audio, low noise
BC157	PS	X09	50	45	5	100	300	70 @ 2	130	Audio amplifier
BC158	PS	X09	30	25	5	100	300	70 @ 2	100	Audio amplifier
BC159	PS	X09	25	20	5	100	300	120 @ 2	100	Audio, low noise
BC160	PS	T039	40	40	5	1A	3.2W	40 @ 100	50	General purpose audio
BC161	PS	T039	60	60	5	1A	3.2W	40 @ 100	50	General purpose audio
BC167A	NS	T092	45	45	6	100	300	120 @ 2	85	General purpose audio
BC168C	NS	T092	20	20	5	100	300	380 @ 2	85	General purpose audio
BC169C	NS	T092	20	20	5	100	300	380 @ 2	85	Audio, low noise
BC170	NS	X10	20	20	5	100	300	35 @ 1	60	General purpose audio
BC171	NS	X10	45	45	6	100	300	125 @ 2	100	Audio, low noise
BC172	NS	X10	25	25	5	100	300	125 @ 2	100	General purpose audio
BC173	NS	X10	25	25	5	100	300	125 @ 2	150	Audio, low noise
BC177	PS	T018	45	45	5	100	300	70 @ 2	130	General purpose audio
BC178	PS	T018	30	25	5	200	300	70 @ 2	100	General purpose audio
BC179	PS	T018	25	20	5	50	300	70 @ 2	100	Audio amplifier
BC181	PS	X10a	40	25	5	200	300	60 @ 2	100	General purpose audio
BC182	NS	X10	60	50	5	20	300	120 @ 2	150	General purpose audio
BC182L	NS	T092	60	50	5	200	300	120 @ 2	150	General purpose audio
BC183	NS	X10	45	30	5	200	300	120 @ 2	150	General purpose audio
BC183L	NS	T092	45	30	5	200	300	120 @ 2	150	General purpose audio
BC184	NS	X10	45	30	5	200	300	240 @ 2	150	Audio, low noise
BC184K	NS	X10	45	30	5	200	300	240 @ 2	150	Audio, low noise
BC184L	NS	T092	45	30	5	200	300	240 @ 2	150	Audio, low noise
BC186	PS	T018	40	25	5	100	300	40 @ 2	50	Audio amplifier
BC187	PS	T018	30	25	5	100	300	100 @ 2	50	Audio amplifier
BC205	PS	T0106	20	20	5	100	300	75 @ 2	100	General purpose audio
BC212	PS	X10	60	50	5	200	300	60 @2	200	General purpose audio
BC212L	PS	T092	60	50	5	200	300	50 @ 2	200	General purpose audio
BC213	PS	X10	45	30	5	200	300	80 @ 2	200	Audio, low noise
BC213L	PS	T092	45	30	5	200	300	70 @ 2	200	General purpose audio
BC214	PS	X10	45	30	5	200	300	140 @ 2	200	General purpose audio
BC214L	PS	T092	45	30	5	200	300	125 @ 2	200	Audio, low noise
BC237	NS	X10	50	45	6	100	300	110 @ 2	150	General purpose audio
BC238B	NS	X10	30	20	5	100	300	200 @ 2	150	General purpose audio
BC239	NS	X10	30	20	5	100	300	200 @ 2	150	Audio, low noise
BC250	PS	X10	20	20	5	100	300	35 @ 1	100	General purpose audio
BC251	PS	T092a	45	45	5	100	300	125 @ 1	100	General purpose audio
BC253	PS	T092a	20	20	5	100	300	125 @ 2	80	General purpose audio
BC256	PS	T092a	64	64	5	100	300	125 @ 2	100	General purpose audio
BC258	PS	T092	25	25	5	100	300	70 @ 2	130	General purpose audio
BC260	PS	T018	20	20	5	100	300	35 @ 1	100	Audio amplifier
BC261	PS	T018	45	45	5	100	300	125 @ 2	100	Audio amplifier
BC262	PS	T018	25	25	5	100	300	125 @ 2	100	Audio amplifier
BC266	PS	T018	64	64	5	100	300	125 @ 2	200	Audio amplifier
BC266A	PS	T018	64	64	5	100	.300	125 @ 2	200	Audio amplifier
BC266B	PS	T018	64	64	5	100	300	240 @ 2	200	Audio amplifier
BC301	NS	T039	90	60	7	1A	850	40 @ 150	60	General purpose audio
BC302	NS	T039	80	45	7	1A	850	40 @ 150	60	General purpose audio
BC303	PS	T039	90	65	7	1A	850	40 @ 150	40	General purpose audio
BC304	PS	T039	80	45	7	1A	850	40 @ 150	40	General purpose audio
BC307B	PS	X10	50	45	5	100	300	240 @ 2	130	General purpose audio
BC308	PS	X10	30	25	5	100	300	75 @ 2	100	General purpose audio
BC309	PS	X10	25	20	5	100	300	125 @ 2	100	Audio, low noise
BC317	NS	T092b	50	45	6	150	310	110 @ 2	100	General purpose audio
BC318	NS	T092b	40	30	5	150	310	110 @ 2	100	General purpose audio
BC327	PS	X10	50	45	5	800	500	63 @ 100	60	General purpose audio
BC328	PS	X10	30	25	5	800	500	63 @ 100	60	General purpose audio
BC337	NS	X10	50	45	5	800	360	100 @ 100	60	General purpose audio
BC338	NS	X10	30	20	5	800	360	100 @ 100	60	General purpose audio
BC347	NS	T092b	50	45	5	100	300	40 @ 2	125	General purpose audio
BC350	PS	T092b	50	45	5	100	300	40 @ 2	125	General purpose audio
BC382	NS	X10	50	45	6	100	300	100 @ 2	150	General purpose audio
BC383	NS	X10	45	30	6	100	300	100 @ 2	150	General purpose audio
BC383C	NS	X10	45	30	6	100	450	450 @ 2	150	Audio, low noise
BC384	NS	X10	45	30	6	100	300	250 @ 2	150	Audio, low noise
BC384C	NS	X10	45	30	6	100	300	450 @ 2	150	Audio, low noise
BC414	NS	X10	50	45	5	100	300	180 @ 2	250	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BC415	PS	X10	45	35	5	100	300	120 @ 2	200	General purpose audio
BC416	PS	X10	50	45	5	100	300	120 @ 2	200	Audio, low noise
BC441	NS	T039	75	60	5	2A	1W	40 @ 500	50	General purpose audio
BC447	NS	T092C	80	80	5	200	350	70 @ 10	100	Audio, high voltage
BC461	PS	T039	75	60	5	2A	1W	40 @ 500	50	Audio, high voltage
BC516	PS	X10	40	30	10	400	625	30,000 @ 20	150	Darlington, audio
BC517	NS	X10	40	30	10	400	625	30,000 @ 20	120	Darlington, audio
BC547	NS	T092a	50	45	6	100	500	110 @ 2	200	General purpose audio
BC548	NS	T092a	30	30	6	100	500	110 @ 2	200	General purpose audio
BC549C	NS	T092a	30	30	6	100	500	420 @ 2	200	General purpose audio
BC557B	PS	T092c	50	45	5	100	500	200 @ 2	75	General purpose audio
BC558B	PS	X10	30	25	5	100	500	240 @ 2	75	General purpose audio
BC559C	PS	T092c	30	25	5	100	500	420 @ 2	75	Audio, low noise
BCY30	PS	T05	64	50	45	100	250	10 @ 20	0.25	Audio amplifier
BCY31A	PS	T05	64	64	45	100	600	15 @ 20	–	General purpose audio
BCY32A	PS	T05	64	64	32	100	600	20 @ 20	–	General purpose audio
BCY33A	PS	T05	32	32	32	100	600	10 @ 20	–	General purpose audio
BCY34	PS	T05	32	25	16	100	250	15 @ 20	0.25	Audio amplifier
BCY39	PS	T039	64	60	12	250	410	10 @ 150	0.45	Audio switch
BCY40	PS	T039	32	24	12	250	410	15 @ 150	0.85	Audio switch
BCY42	NS	T018	40	25	5	200	300	45 @ 10	100	General purpose audio
BCY43	NS	T018	40	25	5	200	300	75 @ 10	100	General purpose audio
BCY54	PS	T05	50	50	12	250	410	12 @ 150	0.45	Audio switch
BCY58	NS	T018	32	32	7	200	1W	120 @ 2	125	General purpose audio
BCY59	NS	T018	45	45	7	200	1W	120 @ 2	125	General purpose audio
BCY70	PS	T018	50	40	5	200	350	50 @ 10	250	General purpose audio
BCY71	PS	T018	45	45	5	200	350	100 @ 10	300	Audio, low noise
BCY72	PS	T018	25	25	5	200	350	50 @ 10	200	General purpose audio
BCY78	PS	T018	32	32	5	200	1W	120 @ 2	180	General purpose audio
BCY79	PS	T018	45	45	5	200	1W	120 @ 2	180	General purpose audio
BCZ11	PS	X02	25	25	20	50	250	25 @ 1	0.4	Audio amplifier
BD106A	NS	X03	36	36	5	2.5A	12W	50 @ 500	50	General purpose RF
BD112	NS	T03	80	60	5	12A	20W	50 @ 1A	30	General purpose audio
BD115	NS	T039	245	180	5	150	6W	22 @ 50	80	RF, high voltage
BD116	NS	T03	80	60	5	3A	10W	30 @ 1A	–	General purpose audio
BD121	NS	T03	60	35	6	5A	45W	30 @ 1A	60	General purpose audio
BD123	NS	T03	90	60	8	5A	45W	30 @ 1A	60	General purpose audio
BD124	NS	X03	70	45	–	2A	15W	35 @ 500	60	General purpose VHF
BD131	NS	T0126	70	45	6	3A	11W	40 @ 500	60	General purpose audio
BD132	PS	T0126	45	45	4	3A	11W	40 @ 500	60	General purpose audio
BD133	NS	T0126	90	60	6	3A	11W	40 @ 500	60	Audio, high voltage
BD135	NS	T0126	45	45	5	1A	12W	40 @ 150	50	General purpose audio
BD136	PS	T0126	45	45	5	1A	12W	40 @ 150	50	General purpose audio
BD137	NS	T0126	60	60	5	1A	12W	40 @ 150	50	General purpose audio
BD138	PS	T0126	60	60	5	1A	12W	40 @ 150	50	General purpose audio
BD139	NS	T0126	80	80	5	1A	12W	40 @ 150	50	Audio, high voltage
BD140	PS	T0126	80	80	5	1A	12W	40 @ 150	50	Audio, high voltage
BD144	NS	T03	400	400	5	250	8W	5 @ 5A	6	Audio, extra high voltage
BD153	NS	T0126	70	60	5	3A	25W	30 @ 1A	–	Audio, high voltage
BD158	NS	T0126	325	300	5	500	20W	30 @ 150	–	Audio, extra high voltage
BD160	NS	T03	250	–	–	5A	10W	5 @ 5A	–	TV line output
BD187	NS	T0126	55	45	5	4A	40W	40 @ 500	2	General purpose audio
BD201	NS	T0P66	60	45	5	8A	55W	30 @ 3A	3	General purpose audio
BD203	NS	T0P66	60	60	5	8A	55W	30 @ 2A	3	Audio, high voltage
BD204	PS	T0P66	60	60	5	8A	55W	30 @ 2A	3	Audio, high voltage
BD205	NS	T0P66	55	45	5	10A	90W	30 @ 2A	1.5	General purpose audio
BD206	PS	T0P66	55	45	5	10A	90W	30 @ 2A	1.5	General purpose audio
BD222	NS	T0P66	–	60	–	4A	36W	20 @ 1.5A	0.8	General purpose audio
BD232	NS	T0126	500	300	5	250	11W	25 @ 50	10	Audio, extra high voltage
BD235	NS	T0126	60	60	5	2A	25W	25 @ 1A	3	General purpose audio
BD236	PS	T0126	60	60	5	2A	25W	25 @ 1A	3	General purpose audio
BD239A	NS	T0P66	70	60	5	2A	30W	15 @ 1A	3	General purpose audio
BD239C	NS	T0P66	115	100	5	2A	30W	15 @ 1A	3	General purpose audio
BD240A	PS	T0P66	70	60	5	2A	30W	15 @ 1A	3	General purpose audio
BD240C	PS	T0P66	115	100	5	2A	30W	15 @ 1A	3	General purpose audio
BD241C	NS	T0P66	115	100	5	3A	40W	25 @ 1A	3	General purpose audio
BD242A	PS	T0P66	70	60	5	3A	40W	25 @ 1A	3	General purpose audio
BD242C	PS	T0P66	115	100	5	3A	40W	25 @ 1A	3	General purpose audio
BD243A	NS	T0P66	70	60	5	6A	65W	30 @ 300	3	General purpose audio
BD244A	PS	T0P66	70	60	5	6A	65W	30 @ 300	3	General purpose audio
BD244C	PS	T0P66	115	100	5	6A	65W	30 @ 300	3	General purpose audio
BD245	NS	T0P3	55	45	5	15A	80W	40 @ 1A	–	General purpose audio
BD246A	PS	T0P3	70	60	5	15A	80W	40 @ 1A	–	General purpose audio
BD246C	PS	T0P3	115	100	5	15A	80W	40 @ 1A	–	General purpose audio
BD249A	NS	T0P3	70	60	5	40A	125W	25 @ 1.5A	–	General purpose audio
BD250A	PS	T0P3	70	60	5	40A	125W	25 @ 1.5A	–	General purpose audio
BD250C	PS	T0P3	115	100	5	40A	125W	25 @ 1.5A	–	General purpose audio
BD378	PS	T0126	75	60	5	2A	25W	30 @ 500	–	Audio power amplifier
BD434	PS	T0126	22	22	5	4A	36W	50 @ 2A	3	General purpose audio
BD437	NS	T0126	45	45	5	4A	36W	40 @ 2A	3	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BD441	NS	T0126	80	80	5	4A	36W	15 @ 2A	3	Audio, high voltage
BD535	NS	T0P66	60	60	5	4A	40W	40 @ 500	3	General purpose audio
BD536	PS	T0P66	60	60	5	4A	40W	40 @ 500	3	General purpose audio
BD537	NS	T0P66	80	80	5	4A	40W	40 @ 500	3	General purpose audio
BD538	PS	T0P66	80	80	5	4A	40W	40 @ 500	3	General purpose audio
BD539	NS	T0P66	40	40	5	5A	45W	30 @ 1A	3	General purpose audio
BD540	PS	T0P66	40	40	5	5A	45W	30 @ 1A	3	General purpose audio
BD675	NS	T0126	45	45	5	4A	40W	750 @ 2A	1	Darlington, audio
BD676	PS	T0126	45	45	5	4A	40W	750 @ 2A	1	Darlington, audio
BD695A	NS	T0P66	45	45	5	8A	70W	750 @ 4A	–	Darlington, audio
BD696A	PS	T0P66	45	45	5	8A	70W	750 @ 4A	–	Darlington, audio
BDX18	PS	T03	100	60	7	15A	117W	20 @ 4A	4	Audio, high voltage
BDX32	NS	T03	1700	1700	–	4A	40W	2 @ 3.5A	–	RF, extra high voltage
BDY17	NS	T03	80	60	7	15A	115W	10 @ 10A	1	General purpose audio
BDY18	NS	T03	120	70	7	15A	115W	10 @ 10A	1	Audio, high voltage
BDY24	NS	T03	100	90	10	6A	87W	15 @ 2A	10	RF, high voltage
BDY25	NS	T03	200	140	10	6A	87W	15 @ 2A	10	RF, extra high voltage
BDY38	NS	T03	50	40	–	6A	115W	30 @ 2A	0.5	General purpose audio
BDY54	NS	T03	180	120	7	12A	60W	20 @ 2A	10	RF, extra high voltage
BDY55	NS	T03	100	60	7	15A	115W	20 @ 4A	10	RF, high voltage
BDY56	NS	T03	150	120	7	15A	115W	20 @ 4A	10	RF, high voltage
BDY57	NS	T03	120	80	10	25A	175W	20 @ 10A	10	RF, high voltage
BDY60	NS	T03	120	60	5	10A	30W	45 @ 500	30	General purpose RF
BDY61	NS	T03	100	60	5	10A	30W	45 @ 500	30	General purpose RF
BDY62	NS	T03	60	30	5	10A	30W	45 @ 500	30	General purpose RF
BDY92	NS	T03	80	60	6	15A	40W	30 @ 5A	35	RF, high voltage
BF115	NS	T072a	50	30	5	30	145	45 @ 1	115	FM/AM radio, general purpose
BF118	NS	T05	250	250	5	100	800	25 @ 30	60	Audio, extra high voltage
BF153	NS	T0106	30	12	2	25	200	20 @ 3	300	FM/AM radio, general purpose
BF154	NS	T0106	30	20	4	50	300	25 @ 10	200	TV IF amplifier, gain controlled
BF157	NS	T039	150	150	5	100	800	30 @ 30	30	TV video, extra high voltage
BF158	NS	T0106	30	12	2	50	200	20 @ 4	600	TV IF amplifier
BF160	NS	T0106	30	12	2	50	200	20 @ 3	400	FM/AM radio, general purpose
BF161	NS	T072	50	50	4	20	175	20 @ 3	400	TV, VHF oscillator
BF166	NS	T072	40	40	3	25	175	20 @ 2	400	FM/VHF general purpose
BF167	NS	T072a	40	30	4	25	150	30 @ 4	300	TV IF amplifier, gain controlled
BF170	NS	T05	160	160	–	50	300	15 @ 2	50	TV video, extra high voltage
BF173	NS	T072a	40	25	4	25	260	40 @ 7	350	TV IF amplifier
BF177	NS	T039	100	60	5	50	600	20 @ 10	60	TV video output
BF178	NS	T039	185	115	5	50	600	20 @ 15	60	TV video output
BF179	NS	T039	250	115	5	50	600	20 @ 20	60	TV video output, high voltage
BF180	NS	T072	30	20	3	20	150	13 @ 2	335	TV UHF amplifier, gain controlled
BF181	NS	T072	30	20	3	20	150	13 @ 2	300	TV UHF oscillator
BF182	NS	T072	25	20	3	15	150	10 @ 2	325	TV UHF mixer
BF183	NS	T072	25	20	3	15	150	10 @ 3	400	TV UHF oscillator
BF184	NS	T072a	30	20	5	30	145	75 @ 1	150	FM/AM, general purpose high gain
BF185	NS	T072a	30	20	5	30	145	34 @ 1	110	FM/AM, general purpose medium gain
BF194	NS	X09a	30	20	5	30	250	67 @ 1	130	FM/AM, general purpose high gain
BF195	NS	X09a	30	20	5	30	250	36 @ 1	100	FM/AM, general purpose medium gain
BF196	NS	X09a	40	30	4	25	250	27 @ 4	200	TV IF amplifier, gain controlled
BF197	NS	X09a	40	20	4	25	250	38 @ 7	275	TV IF amplifier
BF198	NS	X10b	40	30	4	25	250	27 @ 4	200	TV IF amplifier, gain controlled
BF199	NS	X10b	40	20	4	25	250	38 @ 7	275	TV IF amplifier
BF200	NS	T072	30	20	3	20	150	15 @ 2	325	FM/VHF general purpose
BF224	NS	X10a	45	30	4	50	360	30 @ 7	300	TV IF amplifier
BF224A	NS	X10	45	30	4	50	360	–	300	TV IF amplifier
BF232	NS	T072a	25	25	4	30	270	30 @ 7	300	TV IF amplifier
BF240B	NS	X13	40	40	–	25	250	110 @ 1	225	RF amplifier
BF250	NS	T018	15	15	3	600	400	75 @ 100μA	20	General purpose RF
BF251	NS	T072a	30	30	4	25	150	30 @ 4	300	TV IF amplifier, gain controlled
BF253	NS	X10a	30	25	–	35	280	50 @ 1	75	RF amplifier
BF254	NS	X10a	30	20	5	30	300	67 @ 1	130	FM/AM, general purpose high gain
BF255	NS	X10a	30	20	5	30	300	36 @ 1	100	FM/AM, general purpose medium gain
BF257	NS	T039	160	160	5	100	500	25 @ 30	55	TV video output, medium voltage
BF258	NS	T039	250	250	5	100	800	25 @ 30	55	TV video output, high voltage
BF259	NS	T039	300	300	5	100	500	25 @ 30	90	VHF, extra high voltage
BF271	NS	T072	30	30	4	50	250	30 @ 10	450	TV IF amplifier
BF274	NS	T0106a	25	25	4	50	200	70 @ 1	400	TV IF amplifier
BF324	PS	X10	30	30	4	25	250	25 @ 4	350	General purpose FM/VHF
BF336	NS	T039	185	180	5	100	800	20 @ 30	80	TV video output, high voltage
BF337	NS	T039	300	225	–	100	800	20 @ 30	80	TV video output, extra high voltage
BF338	NS	T039	250	200	–	100	800	20 @ 30	80	TV video output, high voltage
BF355	NS	T039	300	225	5	100	800	16 @ 160	–	TV video output, high voltage
BF394	NS	T092d	30	30	4	50	310	65 @ 1	80	FM/AM, general purpose high gain
BF451	PS	X10a	40	40	4	25	150	30 @ 1	325	TV IF amplifier
BF457	NS	T0126	160	160	5	100	6W	26 @ 30	40	RF, extra high voltage
BF458	NS	T0126	250	250	5	100	6W	26 @ 30	40	RF, extra high voltage
BF459	NS	T0126	300	300	5	100	6W	26 @ 30	40	RF, extra high voltage
BF594	NS	T092e	30	20	5	30	250	65 @ 1	130	FM/AM, general purpose high gain
BF595	NS	T092e	30	20	5	30	250	35 @ 1	130	FM/AM, general purpose medium gain

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
BF597	NS	T092e	40	25	4	30	360	38 @ 7	275	TV IF amplifier
BFR39	NS	T092	90	80	–	2A	800	50 @ 100	100	Audio, high voltage
BFR40	NS	T092	70	60	–	2A	800	75 @ 100	100	General purpose audio
BFR41	NS	T092	60	50	5	1A	800	100 @ 100	100	General purpose audio
BFR79	PS	T092	90	80	–	2A	800	50 @ 100	100	Audio, high voltage
BFR80	PS	T092f	70	50	–	2A	800	75 @ 100	100	General purpose audio
BFR81	PS	T092	60	50	–	2A	800	100 @ 100	100	General purpose audio
BFR98	NS	T039	40	20	3.5	360	3.5W	10 @ 100	500	General purpose UHF
BFX29	PS	T05	60	60	5	600	600	50 @ 10	100	General purpose RF
BFX81	PS	T05	25	20	10	500	30	–	–	General purpose
BFX84	NS	T05	100	60	6	1A	800	30 @ 150	50	General purpose audio
BFX85	NS	T05	100	60	6	1A	800	70 @ 150	50	Audio, high voltage
BFX86	NS	T05	40	35	6	1A	800	70 @ 150	50	General purpose audio
BFX87	PS	T05	50	50	5	600	600	40 @ 10	100	General purpose audio
BFX88	PS	T05	40	40	5	600	600	40 @ 10	100	General purpose audio
BFY18	NS	T018	60	40	3	100	300	30 @ 10	200	General purpose RF
BFY41	NS	T05	100	60	7	500	500	50 @ 10	60	Audio, high voltage
BFY50	NS	T05	80	35	6	1A	800	30 @ 150	60	General purpose audio
BFY51	NS	T05	60	30	6	1A	800	40 @ 150	50	General purpose audio
BFY52	NS	T05	40	20	6	1A	800	60 @ 150	50	General purpose audio
BFY53	NS	T05	40	20	6	1A	800	30 @ 150	50	General purpose audio
BFY55	NS	T05	80	35	7	1A	800	40 @ 150	60	General purpose audio
BFY56	NS	T039	80	55	7	1A	800	30 @ 150	40	General purpose audio
BFY64	PS	T05	40	40	5	–	700	80 @ 10	200	General purpose RF
BFY80	NS	T018	100	80	7	100	865	30 @ 2	50	Audio, high voltage
BFY90	NS	T072	30	15	2	20	200	25 @ 2	1000	UHF amplifier
BFY90B	NS	T072	28	15	2.5	20	100	20 @ 3	1000	UHF amplifier
BSX19	NS	T018	40	15	5	500	360	20 @ 10	400	UHF switch
BSX20	NS	T018	40	15	5	500	360	40 @ 10	500	UHF switch
BSX26	NS	T018	40	15	4	200	360	30 @ 30	350	UHF switch
BSX29	PS	T018	12	12	4	200	360	30 @ 30	–	VHF switch
BSX78	NS	T018	40	20	5	100	300	80 @ 10	100	RF switch
BSY24	NS	T05	40	20	6	500	600	15 @ 20	40	General purpose audio
BSY25	NS	T05	40	20	6	500	600	30 @ 20	60	General purpose audio
BSY26	NS	T018	20	15	6	100	300	20 @ 10	200	RF switch
BSY28	NS	T018	15	12	3	100	300	20 @ 10	150	RF switch
BSY38	NS	T018	20	15	5	100	300	30 @ 10	300	VHF switch
BSY51	NS	T039	60	25	5	500	800	40 @ 150	100	General purpose audio
BSY52	NS	T039	60	25	5	500	800	100 @ 150	130	RF switch
BSY53	NS	T039	75	30	5	750	800	40 @ 150	100	RF switch
BSY54	NS	T039	75	30	7	750	800	100 @ 150	145	RF switch
BSY68	NS	T05	120	100	5	50	300	10 @ 10	20	Audio, extra high voltage
BSY78	NS	T018	80	64	7	250	300	80 @ 1	90	General purpose audio
BSY80	NS	T018	25	18	5	100	300	200 @ 1	100	Audio, low noise
BSY95A	NS	T018	20	15	5	200	300	50 @ 10	200	VHF switch
BU104	NS	T03	400	–	10	7A	85W	10 @ 5A	5	TV line output, high voltage
BU105	NS	T03	750	500	5	2.5A	10W	1 @ 2A	3	TV line output, extra high voltage
BU109	NS	T03	330	–	10	7A	85W	5 @ 5A	5	TV line output, high voltage
BU126	NS	T03	750	300	–	6A	30W	15 @ 1A	4	RF switch
BU204	NS	T03	1300	600	–	3A	10W	2 @ 2A	4	TV line output, extra high voltage
BU205	NS	T03	1500	700	–	3A	10W	2 @ 2A	4	TV line output, extra high voltage
BU206	NS	T03	1700	800	–	3A	10W	2 @ 2A	4	TV line output, extra high voltage
BU208	NS	T03	1500	700	–	7.5A	12W	2 @ 4.5A	3	TV line output, extra high voltage
ME1120	NS	T0106	130	120	4	200	200	20 @ 10	30	Audio, high voltage
ME4101	NS	T0106	60	45	5	30	200	70 @ 1	150	Audio, low noise
ME4102	NS	T0106	60	45	5	30	200	200 @ 1	150	Audio, low noise
ME6002	NS	T0106	40	30	5	–	360	75 @ 50	200	General purpose RF
ME8001	NS	T0105	40	30	5	–	400	30 @ 150	100	General purpose audio
MJ400	NS	T066	350	325	5	1A	2.5W	30 @ 50	15	TV video output, extra high voltage
MJ480	NS	T03	40	40	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ481	NS	T03	60	60	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ490	PS	T03	40	40	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ491	PS	T03	60	60	5	4A	87W	10 @ 3A	4	Audio power amplifier
MJ802	NS	T03	100	90	4	30A	200W	25 @ 7.5A	2	Audio power amplifier
MJ901	PS	T03	80	80	5	8A	90W	750 @ 4A	–	Darlington, audio
MJ2500	PS	T03	60	60	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ2501	PS	T03	80	80	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ2955	PS	T03	100	60	7	15A	150W	5 @ 10A	4	General purpose audio
MJ3000	NS	T03	60	60	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ3001	NS	T03	80	80	5	10A	150W	1000 @ 5A	–	Darlington, audio
MJ4502	PS	T03	100	90	4	30A	200W	25 @ 7.5A	2	Audio power amplifier
MJE170	PS	T0126	40	40	7	3A	12W	50 @ 100	50	General purpose audio
MJE180	NS	T0126	40	40	–	3A	12W	50 @ 100	50	General purpose audio
MJE340	NS	T0126	300	300	3	500	20W	30 @ 50	10	Audio, extra high voltage
MJE370	PS	T0126	30	30	4	3A	25W	25 @ 1A	–	General purpose audio
MJE371	PS	T0126	40	40	4	4A	40W	40 @ 1A	–	General purpose audio
MJE520	NS	T0126	30	30	4	3A	25W	25 @ 1A	–	General purpose audio
MJE521	NS	T0126	40	40	4	4A	40W	40 @ 1A	–	General purpose audio
MJE2955	PS	T0P66	70	60	5	10A	90W	20 @ 4A	2	Audio, high voltage
MJE3054	NS	T0P66	90	55	5	4A	40W	25 @ 500	1	Audio, high voltage

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
MJE3055	NS	T0P66	70	60	5	10A	90W	20 @ 4A	2	Audio, high voltage
MPSA05	NS	T096b	60	60	4	500	500	50 @ 10	100	General purpose audio
MPSA06	NS	T092b	80	80	4	500	500	50 @ 10	100	General purpose audio
MPSA10	NS	T092b	40	40	4	100	310	40 @ 5	50	General purpose audio
MPSA12	NS	T092b	20	20	10	300	310	20000 @ 10	125	Audio, low noise
MPSA14	NS	T092b	30	30	10	300	310	10000 @ 10	125	Audio, low noise
MPSA16	NS	T092b	40	40	12	100	350	200 @ 5	100	General purpose audio
MPSA55	PS	T092b	60	60	4	500	625	50 @ 10	50	General purpose audio
MPSA56	PS	T092b	80	80	4	500	625	50 @ 10	50	General purpose audio
MPSA70	PS	T092b	40	40	4	100	310	40 @ 5	125	General purpose audio
MPSA92	PS	T092b	300	300	5	500	625	25 @ 30	50	Audio, extra high voltage
MPSU01	NS	X17	30	30	–	1.5A	8W	50 @ 1A	50	General purpose audio
MPSU02	NS	X17	60	40	5	800	6W	50 @ 150	150	General purpose audio
MPSU05	NS	X17	60	60	4	2A	10W	80 @ 50	75	General purpose audio
MPSU06	NS	X17	80	80	4	2A	10W	80 @ 50	75	General purpose audio
MPSU07	NS	X17	100	100	4	2A	10W	60 @ 50	75	Audio, high voltage
MPSU51	PS	X17	30	30	–	1.5A	8W	50 @ 1A	50	General purpose audio
MPSU52	PS	X17	60	40	5	800	6W	50 @ 50	150	General purpose audio
MPSU55	PS	X17	60	60	4	2A	1W	80 @ 50	50	Audio, high voltage
MPSU56	PS	X17	80	80	4	2A	1W	80 @ 50	50	Audio, high voltage
MPSU57	PS	X17	100	100	4	2A	1W.	60 @ 50	50	Audio, high voltage
OC23	PG	T03	55	24	12	1A	16W	50 @ 1A	2	General purpose RF
OC25	PG	T03	40	40	10	4A	23W	15 @ 1A	0.2	General purpose audio
OC26	PG	T03	32	32	–	3.5A	13W	20 @ 1A	0.2	General purpose audio
OC28	PG	T03	80	60	40	8A	30W	20 @ 1A	0.2	Audio, high voltage
OC35	PG	T03	60	32	20	8A	30W	25 @ 1A	0.2	General purpose audio
OC36	PG	T03	80	32	40	8A	30W	30 @ 1A	0.2	General purpose audio
OC41	PG	X01a	16	15	10	50	50	17 @ 50	4	RF switch
OC42	PG	X01a	16	15	10	50	50	35 @ 50	7	RF switch
OC44	PG	X01a	15	12	12	10	83	50 @ 1	8	RF switch
OC45	PG	X01a	15	15	12	10	83	25 @ 1	4	RF amplifier
OC46	PG	X01a	20	20	15	125	83	40 @ 3	2	RF amplifier
OC70	PG	X01a	20	20	10	10	125	15 @ 5	0.2	General purpose audio
OC71	PG	X01a	20	20	10	10	125	30 @ 5	0.3	General purpose audio
OC72	PG	X02	16	16	10	125	165	30 @ 80	0.25	General purpose audio
OC74	PG	X02	20	20	6	300	550	40 @ 50	0.1	General purpose audio
OC75	PG	X01a	20	20	10	10	125	55 @ 10	0.1	General purpose audio
OC76	PG	X02	32	32	10	125	125	30 @ 80	0.1	General purpose audio
OC77	PG	X02	60	60	10	250	125	45 @ 10	0.25	Audio, high voltage
OC81	PG	X02	32	10	3	200	600	50 @ 100	1	General purpose audio
OC82	PG	X02	16	16	6	200	600	15 @ 3	0.4	General purpose audio
OC83	PG	T01	32	20	3	500	600	40 @ 300	1	General purpose audio
OC84	PG	T01	32	20	3	500	600	50 @ 300	1	General purpose audio
OC170	PG	T07	20	20	1	10	80	75 @ 1	60	RF amplifier
OC171	PG	T07	20	20	1	10	80	75 @ 1	60	RF amplifier
OC200	PS	X02	30	25	20	100	250	15 @ 1	0.45	Audio amplifier
OC202	PS	X02	15	10	10	100	250	40 @ 1	1	Audio amplifier
OC204	PS	X02	32	32	12	250	300	10 @ 150	0.45	Audio amplifier
TIP29	NS	T0P66	40	40	5	1A	30W	40 @ 200	3	General purpose audio
TIP29A	NS	T0P66	60	60	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP29B	NS	T0P66	80	80	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP29C	NS	T0P66	100	100	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP30	PS	T0P66	40	40	5	1A	30W	40 @ 200	3	General purpose audio
TIP30A	PS	T0P66	60	60	5	1A	30W	40 @ 200	3	General purpose audio
TIP30B	PS	T0P66	80	80	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP30C	PS	T0P66	100	100	5	1A	30W	40 @ 200	3	Audio, high voltage
TIP31	NS	T0P66	40	40	5	3A	40W	20 @ 1A	3	General purpose audio
TIP31A	NS	T0P66	60	60	5	3A	40W	20 @ 1A	3	General purpose audio
TIP31B	NS	T0P66	80	80	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP31C	NS	T0P66	100	100	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP32	PS	T0P66	40	40	5	3A	40W	20 @ 1A	3	General purpose audio
TIP32A	PS	T0P66	60	60	5	3A	40W	20 @ 1A	3	General purpose audio
TIP32B	PS	T0P66	80	80	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP32C	PS	T0P66	100	100	5	3A	40W	20 @ 1A	3	Audio, high voltage
TIP33	NS	T0P3	40	40	5	10A	80W	20 @ 3A	3	General purpose audio
TIP33A	NS	T0P3	60	60	5	10A	80W	20 @ 3A	3	General purpose audio
TIP33B	NS	T0P3	80	80	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP33C	NS	T0P3	100	100	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP34	PS	T0P3	40	40	5	10A	80W	20 @ 3A	3	General purpose audio
TIP34A	PS	T0P3	60	60	5	10A	80W	20 @ 3A	3	General purpose audio
TIP34B	PS	T0P3	80	80	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP34C	PS	T0P3	100	100	5	10A	80W	20 @ 3A	3	Audio, high voltage
TIP35	NS	T0P3	40	40	5	25A	90W	10 @ 15A	3	General purpose audio
TIP35A	NS	T0P3	60	60	5	25A	90W	10 @ 15A	3	General purpose audio
TIP35B	NS	T0P3	80	80	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP35C	NS	T0P3	100	100	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP36	PS	T0P3	40	40	5	25A	90W	10 @ 15A	3	General purpose audio
TIP36A	PS	T0P3	60	60	5	25A	90W	10 @ 15A	3	General purpose audio
TIP36B	PS	T0P3	80	80	5	25A	90W	10 @ 15A	3	Audio, high voltage
TIP36C	PS	T0P3	100	100	5	25A	90W	10 @ 15A	3	Audio, high voltage

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Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
TIP41A	NS	T0P66	60	60	5	6A	2W	15 @ 3A	3	General purpose audio
TIP41B	NS	T0P66	80	80	5	6A	2W	15 @ 3A	3	Audio, high voltage
TIP41C	NS	T0P66	100	100	5	6A	2W	15 @ 3A	3	Audio, high voltage
TIP42A	PS	T0P66	60	60	5	6A	2W	15 @ 3A	3	General purpose audio
TIP42B	PS	T0P66	80	80	5	6A	2W	15 @ 3A	3	Audio, high voltage
TIP120	NS	T0P66	60	60	5	5A	60W	1000 @ 3A	–	Darlington, audio
TIP121	NS	T0P66	80	80	5	5A	60W	1000 @ 3A	–	Darlington, audio
TIP122	NS	T0P66	100	100	5	5A	60W	1000 @ 3A	–	Darlington, audio
TIP141	NS	T0P3	80	80	5	10A	125W	500 @ 10A	–	Darlington, audio
TIP142	NS	T0P3	100	100	5	10A	125W	500 @ 10A	–	Darlington, audio
TIP147	PS	T0P3	100	100	5	10A	125W	500 @ 10A	–	Darlington, audio
TIP2955	PS	T0P3	100	60	7	15A	90W	20 @ 4A	3	Audio, high voltage
TIP3055	NS	T0P3	100	70	7	15A	90W	20 @ 4A	3	Audio, high voltage
TIS44	NS	T092	25	–	3	50	250	20 @ 10	200	VHF switch
TIS45	NS	T092	40	15	5	200	250	30 @ 10	300	RF switch
TIS46	NS	T092	40	15	5	200	250	30 @ 10	300	RF switch
TIS48	NS	T092	40	15	4.5	200	250	40 @ 10	500	VHF switch
TIS49	NS	T092	40	15	4.5	200	250	40 @ 10	500	VHF switch
TIS50	PS	T092	12	12	4	200	250	40 @ 30	400	VHF switch
TIS60	NS	T092	40	25	5	400	300	100 @ 50	–	General purpose audio
TIS90	NS	T092	40	40	5	400	625	100 @ 50	–	General purpose audio
TIS91	PS	T092	40	40	5	400	625	100 @ 50	–	General purpose audio
TIS93	PS	X10	40	40	5	400	625	100 @ 50	–	General purpose audio
ZTX107	NS	X11	60	45	5	100	300	125 @ 2	150	General purpose audio
ZTX108	NS	X11	45	30	5	100	300	125 @ 2	150	General purpose audio
ZTX109	NS	X11	45	30	5	100	300	240 @ 2	150	Audio, low noise
ZTX212	PS	X11	60	50	5	200	500	60 @ 2	200	General purpose audio
ZTX300	NS	X11	25	25	5	500	300	50 @ 10	150	General purpose audio
ZTX301	NS	X11	35	35	5	500	300	50 @ 10	150	General purpose audio
ZTX302	NS	X11	35	35	5	500	300	100 @ 10	150	General purpose audio
ZTX303	NS	X11	45	45	5	500	300	50 @ 10	150	General purpose audio
ZTX304	NS	X11	70	70	5	500	300	50 @ 10	150	Audio, high voltage
ZTX311	NS	X11	20	15	5	200	300	50 @ 10	200	RF switch
ZTX314	NS	X11	40	15	5	200	300	40 @ 10	500	VHF switch
ZTX320	NS	X11	30	15	3	50	250	20 @ 3	600	VHF amplifier
ZTX326	NS	X11	30	15	2	50	200	25 @ 2	1000	UHF amplifier
ZTX341	NS	X11	100	100	5	100	300	30 @ 2	50	Audio, high voltage
ZTX500	PS	X11	25	25	5	500	300	50 @ 10	150	General purpose audio
ZTX501	PS	X11	35	35	5	500	300	50 @ 10	150	General purpose audio
ZTX502	PS	X11	35	35	5	500	300	100 @ 10	150	General purpose audio
ZTX503	PS	X11	45	45	5	500	300	50 @ 10	150	General purpose audio
ZTX504	PS	X11	70	70	5	500	300	50 @ 10	150	Audio, high voltage
ZTX531	PS	X11	45	45	5	500	300	40 @ 100μA	30	Audio, low noise
2N388	NG	T05	25	20	15	200	150	60 @ 30	7	RF switch
2N441	PG	T036	40	25	20	4A	50W	20 @ 5A	–	General purpose audio
2N526	PG	T05	45	30	15	500	225	32 @ 1	1	General purpose audio
2N696	NS	T05	60	40	5	500	600	20 @ 150	40	General purpose audio
2N697	NS	T05	60	40	5	500	600	40 @ 150	50	General purpose audio
2N698	NS	T05	120	60	7	500	800	20 @ 150	40	General purpose audio
2N699	NS	T05	120	80	5	500	600	40 @ 150	50	Audio, high voltage
2N706A	NS	T018	25	15	5	200	300	20 @ 10	200	RF switch
2N707	NS	T018	56	25	4	200	300	9 @ 10	200	General purpose RF
2N708	NS	T018	40	15	5	200	300	30 @ 10	300	RF switch
2N718	NS	T018	60	28	5	500	400	40 @ 150	50	General purpose audio
2N753	NS	T018	25	15	5	200	300	40 @ 10	200	RF switch
2N914	NS	T018	40	15	5	200	360	30 @ 10	300	RF switch
2N916	NS	T018	45	25	5	100	360	50 @ 10	300	General purpose RF
2N918	NS	T072	30	15	3	50	200	20 @ 3	600	VHF amplifier
2N919	NS	T018	25	15	5	220	360	20 @ 10	200	RF switch
2N920	NS	T018	25	15	5	220	360	40 @ 10	200	RF switch
2N930	NS	T018	45	45	5	30	300	100 @ 10μA	30	Audio, low noise
2N961	PG	T018	12	12	2	100	150	20 @ 10	300	VHF switch
2N987	PG	T072a	40	40	1	10	86	40 @ 1	50	RF amplifier
2N1091	NG	T05	25	15	20	400	120	40 @ 20	6	RF switch
2N1131	PS	T05	50	35	5	600	600	20 @ 150	50	General purpose audio
2N1132	PS	T039	50	35	5	600	600	30 @ 150	60	General purpose audio
2N1302	NG	T05	25	25	25	300	150	20 @ 10	1	RF switch
2N1303	PG	T05	30	25	25	300	150	20 @ 10	1	RF switch
2N1304	NG	T05	25	20	25	300	150	40 @ 10	4	RF switch
2N1305	PG	T05	30	20	25	300	150	40 @ 10	4	RF switch
2N1306	NG	T05	25	15	25	300	150	60 @ 10	8	RF switch
2N1307	PG	T05	30	15	25	300	150	60 @ 10	8	RF switch
2N1308	NG	T05	25	15	25	300	150	80 @ 10	12	RF switch
2N1309	PG	T05	30	15	25	300	150	80 @ 10	12	RF switch
2N1507	NS	T05	60	30	5	1A	600	100 @ 150	50	General purpose audio
2N1613	NS	T05	75	50	7	600	800	40 @ 150	80	General purpose audio
2N1637	PG	T05	–	34	1.5	10	80	40 @ 1	20	General purpose RF
2N1638	PG	T01	34	–	1	10	80	37 @ 1	20	General purpose RF
2N1711	NS	T05	75	50	7	600	800	100 @ 150	70	General purpose audio
2N1893	NS	T05	120	80	7	500	800	40 @ 150	50	Audio, high voltage

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N1986	NS	T05	50	25	5	1A	600	60 @ 150	40	General purpose audio
2N1990	NS	T05	100	60	3	1A	600	20 @ 30	40	Audio, high voltage
2N1991	PS	T05	30	20	5	1A	600	15 @ 150	40	General purpose audio
2N2100	PG	T05	40	20	4	500	300	200 @ 400	1000	UHF switch
2N2102	NS	T05	120	60	7	1A	1W	40 @ 10	60	Audio, high voltage
2N2193	NS	T05	80	50	8	1A	800	40 @ 150	50	General purpose audio
2N2193A	NS	T05	80	50	8	1A	800	40 @ 150	50	General purpose audio
2N2194	NS	T05	60	40	5	1A	800	20 @ 150	50	General purpose audio
2N2217	NS	T05	60	30	5	800	800	20 @ 150	250	RF switch
2N2218	NS	T05	60	30	5	800	800	40 @ 150	250	General purpose RF
2N2218A	NS	T05	75	40	6	800	800	40 @ 150	250	General purpose RF
2N2219A	NS	T05	75	50	6	800	800	100 @ 150	300	General purpose RF
2N2220A	NS	T018	75	40	6	800	500	20 @ 150	250	RF switch
2N2221	NS	T018	60	30	5	800	500	40 @ 150	250	General purpose RF
2N2221A	NS	T018	75	40	6	800	500	40 @ 150	250	General purpose RF
2N2222	NS	T018	60	30	5	800	500	100 @ 150	250	General purpose RF
2N2222A	NS	T018	75	40	6	800	500	100 @ 150	300	General purpose RF
2N2297	NS	T05	80	35	7	1A	800	40 @ 150	60	General purpose audio
2N2303	PS	T05	50	35	5	500	600	75 @ 150	60	General purpose audio
2N2368	NS	T018	40	15	4	500	360	–	400	UHF switch
2N2369A	NS	T018	40	15	4	500	360	40 @ 10	500	UHF switch
2N2411	PS	T018	25	20	5	100	300	20 @ 10	140	General purpose audio
2N2476	NS	T05	60	20	5	500	600	20 @ 150	250	RF switch
2N2483	NS	T018	60	60	6	50	360	40 @ 10μA	50	Audio, low noise
2N2484	NS	T018	60	60	6	50	360	100 @ 10μA	50	Audio, low noise
2N2714	NS	T098	18	18	5	100	200	80 @ 2	–	General purpose audio
2N2846	NS	T05	60	30	5	500	800	30 @ 150	250	RF switch
2N2848	NS	T05	60	20	5	500	800	40 @ 150	250	RF switch
2N2891	NS	T039	100	800	5	2A	800	50 @ 1A	30	General purpose audio
2N2892	NS	T059	100	80	–	5A	30W	30 @ 1A	30	RF, high voltage
2N2894	PS	T018	12	12	4	200	360	30 @ 30	400	VHF switch
2N2904A	PS	T05	60	60	5	600	600	40 @ 150	200	General purpose audio
2N2905	PS	T05	60	40	5	600	600	100 @ 150	200	General purpose audio
2N2905A	PS	T05	60	60	5	600	600	100 @ 150	200	General purpose audio
2N2906A	PS	T018	60	40	5	600	400	40 @ 150	200	General purpose audio
2N2907	PS	T018	60	40	5	600	400	100 @ 150	200	General purpose audio
2N2907A	PS	T018	60	60	5	600	400	100 @ 150	200	General purpose audio
2N2922	NS	T098	25	25	5	100	360	55 @ 2	100	General purpose audio
2N2923	NS	T098	25	25	5	100	360	90 @ 2	100	General purpose audio
2N2926R	NS	T098	25	25	5	100	200	55 @ 2	100	General purpose audio
2N2926O	NS	T098	25	25	5	100	200	90 @ 2	100	General purpose audio
2N2926Y	NS	T098	25	25	5	100	200	150 @ 2	100	General purpose audio
2N2926G	NS	T098	25	25	5	100	200	235 @ 2	100	Audio, low noise
2N2959	NS	T05	60	20	5	600	600	100 @ 150	250	General purpose RF
2N3011	NS	T018	30	12	5	200	360	30 @ 10	400	VHF switch
2N3019	NS	T05	140	80	7	1A	800	100 @ 150	100	Audio, high voltage
2N3020	NS	T05	140	80	7	1A	800	40 @ 150	80	Audio, high voltage
2N3053	NS	T05	60	40	5	700	1W	50 @ 150	100	General purpose audio
2N3054	NS	T066	90	60	7	4A	25W	25 @ 500	0.75	General purpose audio
2N3055	NS	T03	100	60	7	15A	115W	20 @ 4A	0.2	Audio, high voltage
2N3107	NS	T05	100	60	7	1A	800	100 @ 150	70	Audio, high voltage
2N3108	NS	T05	100	60	7	1A	800	40 @ 150	60	Audio, high voltage
2N3109	NS	T05	80	40	7	1A	800	100 @ 150	70	General purpose audio
2N3121	PS	T018	45	45	4	500	360	30 @ 50	130	General purpose audio
2N3133	PS	T05	50	35	4	600	600	40 @ 150	200	General purpose audio
2N3135	PS	T018	50	35	4	600	400	40 @ 150	200	General purpose RF
2N3232	NS	T03	60	60	6	7A	117W	18 @ 3A	1	General purpose audio
2N3250	PS	T018	50	40	5	200	360	50 @ 10	250	General purpose RF
2N3251	PS	T018	50	40	5	200	360	100 @ 10	300	General purpose RF
2N3252	NS	T05	60	30	5	1A	1W	30 @ 500	200	RF switch
2N3295	NS	T05	60	–	5	250	800	20 @ 10	200	VHF power amplifier
2N3302	NS	T018	60	30	5	500	360	100 @ 150	250	General purpose RF
2N3392	NS	T098	25	25	5	100	200	150 @ 2	70	Audio, low noise
2N3393	NS	T098	25	25	5	100	200	90 @ 2	70	General purpose audio
2N3394	NS	T098	25	25	5	100	200	55 @ 2	70	General purpose audio
2N3397	NS	T098	25	25	5	100	200	55 @ 2	60	General purpose audio
2N3415	NS	T098	25	25	5	500	360	180 @ 2	60	General purpose audio
2N3420	NS	T05	85	60	8	3A	1W	40 @ 1A	40	General purpose audio
2N3439	NS	T05	450	350	7	1A	1W	40 @ 40	15	Audio, extra high voltage
2N3440	NS	T05	300	250	7	1A	1W	40 @ 40	15	Audio, extra high voltage
2N3441	NS	T066	160	140	7	3A	25W	25 @ 500	0.2	Audio, high voltage
2N3442	NS	T03	160	140	7	10A	117W	20 @ 3A	0.5	Audio, high voltage
2N3478	NS	T072	30	15	2	50	200	25 @ 2	750	VHF amplifier
2N3487	NS	T061	80	60	10	7A	117W	20 @ 3A	10	General purpose RF
2N3553	NS	T039	65	40	4	1A	7W	10 @ 250	250	UHF power amplifier
2N3563	NS	T0106	30	12	2	50	200	30 @ 1	600	VHF amplifier
2N3565	NS	T0106	30	25	6	50	200	70 @ 100μA	40	Audio, low noise
2N3566	NS	T0105	40	30	5	200	300	150 @ 10	40	General purpose audio
2N3567	NS	T0105	80	40	5	500	300	40 @ 150	60	General purpose audio
2N3568	NS	T0105	80	60	5	500	300	40 @ 150	60	General purpose audio

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N3569	NS	T0105	80	40	5	500	300	100 @ 150	60	General purpose audio
2N3570	NS	T072	30	15	3	50	200	20 @ 5	1500	UHF amplifer
2N3571	NS	T072	25	15	3	50	200	20 @ 5	1200	UHF amplifier
2N3572	NS	T072	25	13	3	50	200	20 @ 2	1000	UHF amplifier
2N3606	NS	T098	18	14	5	200	200	30 @ 10	300	VHF switch
2N3607	NS	T098	18	14	5	200	200	30 @ 10	300	VHF switch
2N3614	PG	T03	60	35	30	15A	77W	60 @ 3A	0.3	General purpose audio
2N3615	PG	T03	80	50	40	15A	77W	30 @ 3A	0.3	Audio, high voltage
2N3638	PS	T0105	25	25	4	500	300	30 @ 50	100	General purpose audio
2N3638A	PS	T0105	25	25	4	500	300	100 @ 10	150	General purpose RF
2N3642	NS	T0105	60	45	5	500	350	40 @ 150	150	General purpose audio
2N3643	NS	T0105	60	30	5	500	350	100 @ 150	250	General purpose RF
2N3646	NS	T0106	40	15	5	200	200	30 @ 30	350	RF switch
2N3663	NS	T098	30	12	3	25	200	20 @ 8	700	VHF amplifer
2N3702	PS	T092	40	25	5	200	360	60 @ 50	100	General purpose audio
2N3703	PS	T092	50	30	5	200	360	30 @ 50	100	General purpose audio
2N3704	NS	T092	50	30	5	800	360	300 @ 50	100	General purpose audio
2N3705	NS	T092	50	30	5	800	625	150 @ 50	100	General purpose audio
2N3706	NS	T092	40	20	5	800	625	600 @ 50	100	General purpose audio
2N3707	NS	T092	30	30	6	30	360	100 @ 100μA	100	Audio, low noise
2N3708	NS	T092	30	30	6	30	360	45 @ 1	100	Audio, low noise
2N3709	NS	T092	30	30	6	30	360	45 @ 1	100	General purpose audio
2N3710	NS	T092	30	30	6	30	360	90 @ 1	100	Audio, low noise
2N3711	NS	T092	30	30	6	30	360	180 @ 1	100	Audio, low noise
2N3713	NS	T03	80	60	7	10A	150W	25 @ 1A	4	General purpose RF
2N3714	NS	T03	100	80	7	10A	150W	25 @ 1A	4	General purpose RF
2N3715	NS	T03	80	60	7	10A	150W	50 @ 1A	4	General purpose RF
2N3716	NS	T03	100	80	7	10A	150W	50 @ 1A	4	General purpose RF
2N3732	PG	T03	100	160	0.5	3A	3W	35 @ 700	1	Audio, high voltage
2N3740	PS	T066	60	60	7	10A	25W	30 @ 250	4	General purpose RF
2N3741	PS	T066	80	80	7	10A	25W	30 @ 250	4	RF, high voltage
2N3771	NS	T03	50	40	5	30A	150W	15 @ 10A	0.2	Audio, high voltage
2N3772	NS	T03	100	60	7	30A	150W	15 @ 10A	0.2	Audio, high voltage
2N3773	NS	T03	160	140	7	30A	150W	15 @ 8A	0.2	Audio, high voltage
2N3789	PS	T03	60	60	7	10A	150W	25 @ 1A	4	General purpose RF
2N3790	PS	T03	80	80	7	10A	150W	25 @ 1A	4	RF, high voltage
2N3791	PS	T03	60	60	7	10A	150W	50 @ 1A	4	General purpose RF
2N3792	PS	T03	80	80	7	10A	150W	50 @ 1A	4	RF, high voltage
2N3794	NS	X13	40	20	5	500	250	35 @ 1	100	General purpose audio
2N3854A	NS	T098	30	30	4	100	200	35 @ 2	100	FM/AM, general purpose medium gain
2N3856A	NS	T098	30	30	4	100	200	100 @ 2	140	FM/AM, general purpose high gain
2N3866	NS	T039	55	30	3.5	400	5W	10 @ 50	500	UHF power amplifier
2N3879	NS	T066	120	75	7	7A	35W	20 @ 4A	40	RF switch
2N3902	NS	T03	700	325	5	3.5A	100W	30 @ 1A	2.8	General purpose RF
2N3903	NS	T092b	60	40	6	200	310	50 @ 10	250	General purpose audio
2N3904	NS	T092b	60	40	6	200	310	100 @ 10	250	Audio, low noise
2N3905	PS	T092b	40	40	5	200	310	50 @ 10	200	General purpose audio
2N3906	PS	T092b	40	40	5	200	310	100 @ 10	250	General purpose audio
2N3962	PS	T018	60	60	6	200	360	60 @ 1μA	40	Audio, low noise
2N4031	PS	T05	80	80	5	1A	800	40 @ 100	100	General purpose audio
2N4036	PS	T05	90	65	7	1A	1W	40 @ 150	60	Audio, high voltage
2N4037	PS	T05	60	40	7	1A	1W	50 @ 150	60	General purpose audio
2N4041	NS	X27	65	40	4	500	18W	10 @ 100	400	VHF power amplifier
2N4058	PS	T092	30	30	6	30	360	100 @ 100μA	–	Audio, low noise
2N4059	PS	T092	30	30	6	30	360	45 @ 1	–	General purpose audio
2N4060	PS	T092	30	30	6	30	360	45 @ 1	–	General purpose audio
2N4061	PS	T092	30	30	6	30	360	90 @ 1	–	General purpose audio
2N4062	PS	T092	30	30	6	30	360	180 @ 1	–	Audio, low noise
2N4064	NS	T05F	300	250	7	1A	10W	40 @ 20	15	RF, extra high voltage
2N4123	NS	T092b	40	30	5	200	310	50 @ 2	250	General purpose audio
2N4126	PS	T092b	25	25	4	200	310	120 @ 2	250	General purpose audio
2N4234	PS	T05	40	40	7	3A	1W	30 @ 250	3	General purpose RF
2N4236	PS	T05	80	80	7	3A	1W	30 @ 250	3	RF, high voltage
2N4237	NS	T05	50	40	6	1A	5W	15 @ 1A	80	General purpose audio
2N4249	PS	T0106	60	60	5	100	200	100 @ 1	100	General purpose audio
2N4250	PS	T0106	40	40	5	100	200	250 @ 1	100	Audio, low noise
2N4264	NS	T092b	30	15	6	200	310	40 @ 10	300	VHF switch
2N4284	PS	X13a	25	25	35	50	250	35 @ 1	7	Audio amplifier
2N4286	NS	X13	30	25	6	100	250	150 @ 1	40	Audio, low noise
2N4288	PS	X13	30	25	6	100	250	100 @ 100μA	40	Audio, low noise
2N4289	PS	X13	60	45	7	–	250	100 @ 100μA	40	Audio, low noise
2N4313	PS	T0106	12	12	4	100	200	30 @ 10	700	VHF switch
2N4314	PS	T039	90	65	7	–	1W	50 @ 150	60	General purpose audio
2N4400	NS	T092b	60	40	6	600	310	50 @ 150	200	General purpose audio
2N4401	NS	T092b	60	40	6	600	310	100 @ 150	250	General purpose audio
2N4410	NS	T092b	120	80	5	250	310	60 @ 1	60	Audio, high voltage
2N4427	NS	T039	40	20	2	400	1W	10 @ 100	500	VHF power amplifier
2N4428	NS	T039	55	35	3.5	425	3.5W	20 @ 50	700	UHF power amplifer
2N4896	NS	T039	120	60	6	5A	7W	100 @ 2A	80	General purpose audio
2N4898	PS	T066	40	40	5	4A	25W	20 @ 500	3	General purpose RF

Type	Pol/Mat	Case Style	V_{CB} (max) V	V_{CE} (max) V	V_{EB} (max) V	I_C (max) mA	P_{TOT} (max) mW	h_{FE} (min) @ I_C (mA)	f_T (min) MHz	Application
2N4901	PS	T03	40	40	5	5A	87W	20 @ 1A	4	General purpose RF
2N4903	PS	T03	80	80	5	5A	87W	20 @ 1A	4	RF, high voltage
2N4904	PS	T03	40	40	5	5A	87W	25 @ 2.5A	4	General purpose RF
2N4905	PS	T03	60	60	5	5A	87W	25 @ 2.5A	4	RF, high voltage
2N4906	PS	T03	80	80	5	5A	87W	25 @ 2.5A	4	RF, high voltage
2N4907	PS	T03	40	40	5	10A	150W	20 @ 4A	2	General purpose audio
2N4908	PS	T03	60	60	5	10A	150W	20 @ 4A	2	General purpose audio
2N4909	PS	T03	80	80	5	10A	150W	20 @ 4A	2	General purpose audio
2N4913	NS	T03	40	40	5	5A	87W	25 @ 2.5A	4	General purpose RF
2N4915	NS	T03	80	80	5	5A	87W	25 @ 2.5A	4	RF, high voltage
2N4920	PS	T0126	80	80	5	3A	30W	20 @ 500	3	Audio, high voltage
2N4921	NS	T0126	40	40	5	3A	30W	20 @ 500	3	General purpose audio
2N4922	NS	T0126	60	60	5	3A	30W	20 @ 500	3	General purpose audio
2N4923	NS	T0126	80	80	5	3A	30W	20 @ 500	3	Audio, high voltage
2N5030	NS	T098	30	12	4	200	320	30 @ 10	400	VHF switch
2N5039	NS	T03	120	75	7	20A	140W	30 @ 2A	60	General purpose audio
2N5088	NS	T092b	35	30	3	50	310	300 @ 100µA	–	Audio, low noise
2N5089	NS	T092b	30	25	3	50	310	400 @ 100µA	–	Audio, low noise
2N5102	NS	T060	90	50	4	3.3A	70W	10 @ 500	150	VHF power amplifier
2N5129	NS	T0106	15	12	3	500	300	35 @ 50	150	General purpose audio
2N5135	NS	T0105	30	25	4	200	300	50 @ 10	40	General purpose audio
2N5136	NS	T0105	30	20	3	500	220	20 @ 150	40	General purpose audio
2N5137	NS	T0106	30	20	3	500	300	20 @ 150	40	General purpose audio
2N5138	PS	T0106	30	30	5	100	200	50 @ 100µA	40	Audio, low noise
2N5172	NS	T098	25	25	5	100	200	100 @ 10	–	General purpose audio
2N5179	NS	T072	20	12	2.5	50	200	25 @ 3	900	UHF amplifier
2N5180	NS	T072	30	15	2	50	180	20 @ 2	650	UHF amplifier
2N5189	NS	T039	60	35	5	2A	1W	15 @ 1A	250	General purpose VHF
2N5191	NS	T0126	60	60	4	4A	40W	25 @ 1.5A	2	Audio, high voltage
2N5192	NS	T0126	80	80	4	4A	40W	20 @ 1.5A	2	Audio, high voltage
2N5194	PS	T0126	60	60	4	4A	40W	25 @ 1.5W	2	Audio, high voltage
2N5209	NS	T092b	50	50	4	50	310	150 @ 1	30	General purpose audio
2N5220	NS	T092b	15	15	3	500	310	30 @ 50	100	General purpose audio
2N5222	NS	T092d	20	15	2	50	310	20 @ 4	450	UHF amplifier
2N5223	NS	T092b	25	20	3	100	310	50 @ 2	150	General purpose audio
2N5293	NS	T0Q66	80	75	7	4A	36W	30 @ 500	0.8	Audio, high voltage
2N5294	NS	T0P66	80	75	7	4A	36W	30 @ 500	0.8	Audio, high voltage
2N5296	NS	T0P66	60	50	5	4A	36W	30 @ 1A	0.8	General purpose audio
2N5298	NS	T0P66	80	70	5	4A	36W	20 @ 1.5A	0.8	General purpose audio
2N5301	NS	T03	40	40	5	30A	200W	15 @ 15A	2	General purpose audio
2N5303	NS	T03	80	80	5	20A	200W	15 @ 10A	2	Audio, high voltage
2N5305	NS	T098	25	25	12	300	400	2000 @ 2	60	Darlington, audio
2N5306	NS	T098	25	25	12	300	400	7000 @ 2	60	Darlington, audio
2N5308	NS	T098	40	40	12	300	400	7000 @ 2	60	Darlington, audio
2N5365	PS	X13	40	40	4	500	360	40 @ 50	–	General purpose audio
2N5401	PS	T092b	160	150	5	600	310	60 @ 10	100	RF, extra high voltage
2N5416	PS	T039	350	300	6	1A	10W	30 @ 50	15	RF, extra high voltage
2N5448	PS	X10	50	30	5	200	360	30 @ 50	100	General purpose audio
2N5451	NS	X10	40	20	5	800	360	30 @ 50	100	General purpose audio
2N5490	NS	T0P66	60	50	5	7A	50W	20 @ 2A	–	General purpose audio
2N5492	NS	T0P66	75	65	5	7A	50W	20 @ 2.5A	–	Audio, high voltage
2N5494	NS	T0P66	60	50	5	7A	50W	20 @ 3A	–	General purpose audio
2N5496	NS	T0P66	90	80	5	7A	50W	20 @ 3.5A	–	Audio, high voltage
2N5661	NS	T0P66	400	300	6	1A	20W	25 @ 500	20	Audio, extra high voltage
2N5758	NS	T03	100	100	7	10A	150W	25 @ 3A	1	Audio, high voltage
2N5879	PS	T03	60	60	5	15A	160W	20 @ 6A	4	General purpose audio
2N5885	NS	T03	60	60	5	25A	200W	20 @ 10A	4	General purpose RF
2N6099	NS	T0P66	70	60	8	10A	75W	20 @ 4A	–	Audio, high voltage
2N6109	PS	T0P66	60	50	5	7A	40W	30 @ 2A	0.5	General purpose audio
2N6121	NS	T0P66	45	45	5	4A	40W	25 @ 1.5A	2	General purpose audio
2N6122	NS	T0P66	60	60	5	4A	40W	25 @ 1.5A	2	Audio, high voltage
2N6123	NS	T0P66	80	80	5	4A	40W	20 @ 1.5A	2	Audio, high voltage
2N6124	PS	T0P66	45	45	5	4A	40W	25 @ 1.5A	2	General purpose audio
2N6125	PS	T0P66	60	60	5	4A	40W	25 @ 1.5A	2	Audio, high voltage
2N6126	PS	T0P66	80	80	5	4A	40W	20 @ 1.5A	2	Audio, high voltage
2N6129	NS	T0P66	40	40	5	7A	50W	20 @ 2.5A	2	General purpose audio
2N6130	NS	T0P66	60	60	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6131	NS	T0P66	80	80	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6133	PS	T0P66	60	60	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6134	PS	T0P66	80	80	5	7A	50W	20 @ 2.5A	2	Audio, high voltage
2N6230	PS	T03	120	120	7	10A	150W	20 @ 3A	1	Audio, high voltage
2N6253	NS	T03	55	40	5	15A	115W	20 @ 3A	0.8	General purpose audio
2N6258	NS	T03	100	80	7	30A	250W	20 @ 15A	0.2	Audio, high voltage
2N6288	NS	T0P66	40	40	5	7A	40W	30 @ 3A	0.5	General purpose audio
2N6388	NS	T0P66	80	80	5	10A	40W	1000 @ 5A	20	Darlington, RF
2SD234	NS	T0P66	60	50	10	3A	25W	40 @ 500	0.5	General purpose audio
40251	NS	T03	50	40	5	15A	117W	15 @ 8A	–	General purpose audio
40254	PG	T03	32	–	5	5A	12W	38 @ 1A	0.15	General purpose audio
40310	NS	T066	–	35	2.5	4A	29W	20 @ 1A	–	General purpose audio
40311	NS	T05	–	30	2.5	700	1W	75 @ 50	50	General purpose audio

COMMON ABBREVIATIONS

A	Ampere or Anode
AC	Alternating Current
ACC	Automatic Chroma Control
Ae	Aerial
AF	Audio Frequency
AFC	Automatic Frequency Control
ALC	Automatic Level Control
AM	Amplitude Modulation
ANL	Automatic Noise Limiter
ATU	Aerial Tuning Unit
AVC	Automatic Volume Control
b	Base of transistor
B&S	Wire Gauge (US)
BCD	Binary Coded Decimal
C	Capacitor
c	Collector
CCD	Charge Coupled Device
CCTV	Closed Circuit Television
cgs	Centimetre-Gramme-Second
Ck	Clock
CMOS	Complementary Metal Oxide Semiconductor
CPU	Central Processing Unit
CW	Continuous Wave
D	Diode
d	Drain of FET
dB	Decibel
DC	Direct Current
DF	Direction Finding
DIL	Dual In Line
DIN	German Standards Institute
DNL	Dynamic Noise Limiter
DPDT	Double Pole Double Throw
DPST	Double Pole Single Throw
DTL	Diode Transistor Logic
DX	Long Distance
E	Voltage
ECL	Emitter Coupled Logic
EHT	Extra High Tension
EMF	Electro-Motive Force
ERP	Effective Radiated Power
F	Farad or Farenheit
f	Frequency
FET	Field Effect Transistor
FM	Frequency Modulation
G	Giga (10^9)
g	Grid or Gate
Gnd	Ground
H	Henry
HF	High Frequency
hfe	Transistor gain
HT	High Tension
Hz	Hertz
I	Current
Ib	Base Current (Transistor)
Ic	Collector current
IC	Integrated Circuit
IF	Intermediate Frequency
I^2L	Integrated Injection Logic
I/p	Input
ips	Inches per Second
K	Kilo (10^3) or Cathode
L	Inductance
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LF	Low Frequency
Lin	Linear
Log	Logarithmic
mA	Milliamp
mH	Millihenry
MHz	Megahertz
MOSFET	Metal Oxide Semiconductor FET
MPU	Microprocessing Unit
MSI	Medium Scale Integration
MOST	Metal Oxide Semiconductor Transistor
LS	Loudspeaker
LSI	Large Scale Integration
M	Mega (10^6)
m	Milli (10^{-3})
MPX	Multiplex
mV	Millivolt
mW	Milliwatt
n	Nano (10^{-9})
Ni-Cad	Nickel Cadmium
NR	Noise Reduction
NTSC	National Television Standards Committee
o/c	Open Circuit
o/p	Output
Op-Amp	Operational Amplifier
p	Pico (10^{-12})
PA	Power Amplifier or Public Address
PAL	Phase Alternate Line
PCB	Printed Circuit Board
pd	Potential Difference
PIL	Precision In Line
PIV	Peak Inverse Voltage
PLL	Phase Locked Loop
PROM	Programmable Read Only Memory
Ptot	Total Power Dissipation
PU	Pick Up
PUJT	Programmable Unijunction Transistor
Q	Factor of Tuned Circuit
R	Resistance
RAM	Random Access Memory
ROM	Read Only Memory
RF	Radio Frequency
RFC	Radio Frequency Choke
RMS	Root Mean Square
RTL	Resistor Transistor Logic
RX	Receiver
s	Source (FET)
s/c	Short Circuit
SCR	Silicon Controlled Rectifier
SHF	Super High Frequency
SPDT	Single Pole Double Throw
SPST	Single Pole Single Throw
SSB	Single Side Band
SSI	Small Scale Integration
SWG	Standard Wire Gauge
SWL	Short Wave Listener
SWR	Standing Wave Ratio
TRF	Tuned Radio Frequency
TTL	Transistor Transistor Logic
TVI	Television Interference
Tx	Transmitter
uF	Micro Farad
UHF	Ultra High Frequency
UJT	Unijunction Transistor
V	Volt
VA	Volt Amperes
Vcc	Supply Voltage (TTL)
VCO	Voltage Controlled Oscillator
Vdd	Supply Voltage (CMOS)
VDR	Voltage Dependent Resistor
VDU	Video Display Unit
VHF	Very High Frequency
VLF	Very Low Frequency
VMOS	Vertical Metal Oxide Semiconductor
W	Watts
X	Reactance
Xtal	Crystal
Z	Impedance

PROBLEMS?

SUFFIXES 'k', 'm', 'M' etc after component values indicate a numerical multiplier or divider – thus

Multipliers

k = X 1000
M = X 1000 000
G = X 1000 000 000
T = X 1000 000 000 000

Dividers

m = ÷ 1000
u = ÷ 1000 000
n = ÷ 1000 000 000
p = ÷ 1000 000 000 000

Where the numerical value includes a decimal point the traditional way of showing it was, for example, 4.7k. Experience showed that printing errors occurred due to accidental marks being mistaken for decimal points. The Standard now calls for the ex-suffix to be used in place of the decimal point. Thus a 4.7 k resistor is now shown as 4k7. A 2.2 uF capacitor is now shown as 2u2 etc.

Some confusion still exists with capacitor markings. Capacitors used to be marked with multiples or sub-multiples of microfarads – thus 0.001 uF, 470 uF etc. Markings are now generally in sub-multiples of a Farad. Thus –

1 microfad (1u) $=1\times10^{-6}$F
1 nanofarad (1n) = 1×10^{-12}F
1 picofarad (1p) = 1×10^{-12}F

0V on our circuits means the same as –ve (an abbreviation for 'negative').

Unless otherwise specified all components in our drawings are shown as seen from above – note however that component manufacturers often show them as seen looking *into* the pins.

Pin numbering of ICs – with the IC held so that the pins are facing away from you and with the small cut-out downwards pins are numbered anti-clockwise starting with pin number 1 at bottom right.

The thin line on a battery schematic drawing is positive – (+ve or just +).

If a circuit won't work the most probable causes of trouble in the most probable order of occurrence are:–

(a) Components inserted the wrong way round or in the wrong places.
(b) Faulty soldering.
(c) Bridges of solder between tracks (particularly with Veroboard) – breaks in Veroboard omitted – and/or whiskers of material bridging across Veroboard breaks.
(d) Faulty components.

RESISTORS

RESISTORS MUST BE THE MOST commonly used of electronic components — to the point where they tend to be taken for granted.

Resistors are, however, made in a variety of ways either for general use or because their particular characteristics suit certain areas of application. Modern resistors can be classified into four broad groups:

(a) composition resistors
(b) film resistors
(c) wirewound resistors
(d) semiconductor resistors

There is a variety of construction styles in each group, each style having particular characteristics, advantages and disadvantages.

General Characteristics — Resistors are not quite the passive components they are usually taken to be. All the resistors vary in value with variations in temperature. They also change value with applied voltage and with frequency. All resistors generate noise, and thus certain types are better suited to applications requiring low noise components, such as audio amplifier input circuits. Knowing what the various characteristics of a resistor mean in different situations enables you to make a proper selection for a particular application — or to make substitutes without introducing problems. There is a generally agreed convention on how the various resistor characteristics are expressed and these are explained below.

Temperature coefficient — With many resistors, the change in value of resistance is fairly linear across a large range of temperature. With such resistors the temperature coefficient is usually expressed in 'parts per million per degrees centigrade' or ppm/^{o}C. It is also sometimes expressed in percent of value per degrees centigrade, or %/^{o}C. Some resistors have a nonlinear temperature coefficient and this characteristic is usually referred to as the 'resistance-temperature' characteristic. Some types of resistor, particularly those in the semiconductor group, are manufactured to have a large, controlled resistance-temperature characteristic. They are usually used for temperature sensing, compensation, or in measurement applications.

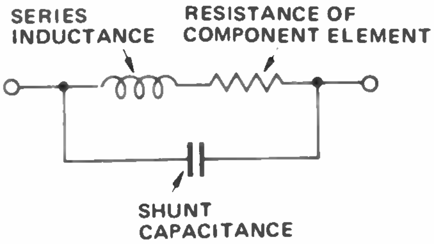


Fig.1. Equivalent circuit of practical resistor.

Voltage Coefficient — The nominal value of a resistance is not independent of the applied voltage, usually decreasing with increase in applied voltage. The voltage coefficient is usually expressed as a percentage of the change in resistance against variation in applied voltage from 10% of maximum working voltage to maximum working voltage. This is a characteristic that is only of importance with carbon composition resistors and some types of semiconductor resistors (i.e. voltage dependant resistors).

Frequency Effects — All resistors have an inherent small amount of inductance and capacitance and this affects the way they behave at high frequencies and above. The length of the actual resistance path in the resistor and the length of the leads contributes inductance in series with the apparent dc resistance. Capacitance, which may be distributed along the resistor body or through the resistance path, contributes capacitance which is effectively in parallel with the apparent dc resistance. This changes what should look like an ordinary resistor into a circuit like that in Fig. 1. The actual amount of series inductance and shunt capacitance depends largely on the type of resistor and its construction. Some styles of resistor are constructed to minimise these effects.

Carbon composition and wirewound resistors are the most affected of any group. Generally, for values above 100 ohms or so, the apparent resistance will decrease as the frequency is increased. Thus low value resistors exhibit the least variation with increasing frequency while the apparent resistance of high value resistors (i.e. about 100 k and above), rapidly decreases as the frequency increases.

Noise — All resistors generate 'noise' in the form of tiny voltage fluctuations which originate in the resistive element. Further noise is generated in the lead connections. The total noise voltage is contributed from a number of different sources. One form of noise that is present in *all* resistors is called 'Johnson Noise' and the magnitude of this depends on the temperature and the value of the resistor. Some resistors (particularly carbon composition types) produce extra noise caused by the current flowing through the component. Faults in the component also cause noise, i.e. for solid body types, minute cracks may add to the noise. Some styles of construction can contribute to noise, for example, those constructed with end caps connecting to the resistive element may become noisy (more noisy) when the end caps are subjected to tension and become slightly loose. For adjustable resistors, added noise may be caused by imperfect contact between the moving contact and the resistive element. The noise is worsened during the time the contact is moving.

To obtain the lowest noise from a resistor it should be operated well below its wattage rating.

Carbon Resistors

Carbon composition resistors have been used extensively in the manufacture of radio and television sets since the valve era but are being rapidly replaced in production by film resistors. These have superior characteristics and are becoming increasingly cost competitive.

Carbon resistors are manufactured in wattage ratings ranging from 0.1 watt to 2 watts and resistance values ranging from 10 ohms to 100 M. They are made to tolerances of ± 5% (E24 series, ± 10% (E12 series) and ± 20% (E6 series), although the latter is the more usual and least expensive.

There are three basic types of carbon composition resistor:

(a) uninsulated
(b) insulated
(c) filament or filament-coated

Uninsulated type: In this type, the resistive element consists of fine carbon particles mixed with a refractory filling, which is non-conducting, bonded together by a resin binder. The proportion of carbon particles to filler determines the resistance value. The mixture is compressed into shape, usually cylindrical, and fired in a kiln. The end connections are made by any one of a variety of methods. These are illustrated in Fig. 2. In the first method, Fig. 2(a), the ends of the composition rod are sprayed with metal, and wire leads soldered on to provide radial connections. The resistor is then painted and colour coded. This method was extensively used with 1 W and 2 W resistors. A second method, much more widely used now, involves enlarging the ends of the connecting leads and moulding them directly into the carbon composition rod – Fig. 2(b). This method is used extensively as it is adaptable to all wattage ratings and sizes of the resistor body. A third method is also employed. Pressed metal caps, usually having integral leads, are forced onto the ends of the carbon rod – Fig. 2(c). These caps have radial leads and are particularly suited to printed circuit board mounting as they may be plugged straight into mounting holes on the board without the necessity of preforming the leads as is required with axial lead components. These are also known as 'pluggable' types. Film resistors are also made in this style.

Uninsulated carbon composition resistors are generally smaller than the insulated types for a given wattage as their open construction permits good heat dissipation. There is the danger however, that short circuits may occur to adjacent components, and for this reason, the insulated type is preferred.

Insulated Type: This type has the composition element made in the same manner as just described, but it is then encapsulated in either a silicon lacquer, a thermoplastic moulding or epoxied into a ceramic tube. The first two generally employ a resistance element having embedded connections, as illustrated in Fig. 3(a). The type having the element sealed in a ceramic tube generally have an element constructed as shown in Fig. 3(b). The ends of the element are sprayed with metal and an end-cap having an integral lead is force-fitted over them. This assembly is then put inside the ceramic tube and the ends sealed with an epoxy or other compound.

Filament or Filament-coated Type: With this type, carbon granules are dispersed, along with a filler, in a varnish which is then applied to the surface of a continuous glass or ceramic filament which is then baked. The resistance value depends on the length and mixture, the filament is cut into appropriate lengths and leads applied by one of the methods detailed above. It is usually encapsulated in an insulating compound as per the insulated style of resistor.

Carbon composition resistors have a large voltage coefficient. The value of this coefficient varies with the resistance of the component (being highest for high value resistors) and the size of the resistance element. Small resistors of a given value have less insulating filler in their composition and will have a lower voltage coefficient. Commonly available composition resistors have quoted voltage coefficient between 0.02 and 0.035 for values up to 1M. Values above this have a coefficient of typically 0.05. These values may cause a maximum change in resistance of 2% when used within their ratings. The voltage coefficient of the other types of resistors is considerably smaller than for composition types – typically 0.002% or less.

A large negative temperature coefficient is one of the disadvantages of composition resistors. It is typically

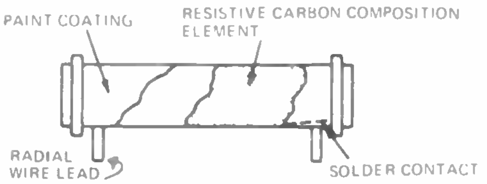


Fig.2(a). Carbon composition resistor with the end connections made by spraying the ends with metal and the leads soldered.

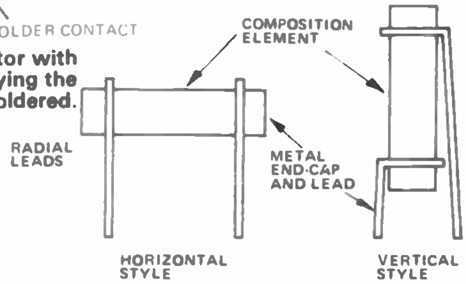


Fig.2(c). Carbon composition resistor with pressed metal end-cap and lead connections for plugging into p.c. boards – the 'plug-gable' style. The end-caps are forced over the ends of the composition rod element.

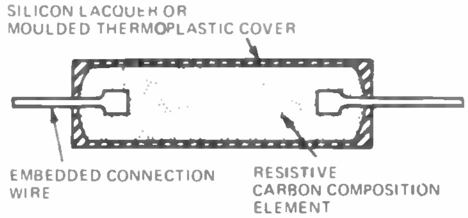


Fig.3(a). Insulated carbon composition resistor construction.

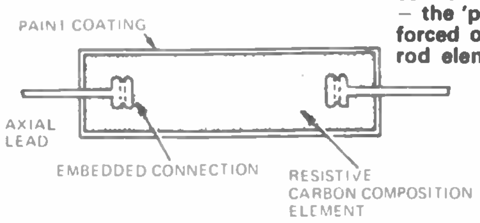


Fig.2(b). Carbon composition resistor with the connections made by embedding leads in the element.

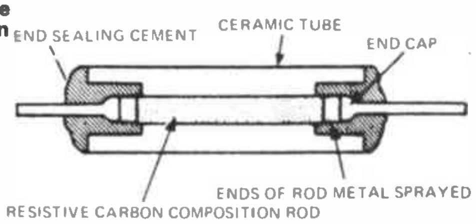


Fig.3(b). Assembly of a ceramic tube type insulated carbon composition resistance.

between 0.1% and 0.15% per ^{o}C (i.e. 1000 ppm per ^{o}C or greater), across the whole resistance range. This means that a 1 M resistor will change its value by 1 k or more for each ^{o}C change in temperature. The curve of percentage resistance change versus temperature is not linear and may be positive over one portion of the temperature range and negative over another.

The amount of noise generated by carbon composition resistors is a function of the materials used in the composition mix. Generally, the noise generated increases with increasing voltage, increasing resistance, and decreasing size, for a given mix of materials. The noise due to current flowing through the resistor is generated by random changes in the material of the element, caused by the current flow. This noise decreases with increasing frequency and Johnson noise, which is frequency independent, becomes dominant above about 1 kHz. The current noise generated by composition resistors is a major limitation against using them at dc and low frequencies. They are not recommended for use in amplifier input stages or DC amplifiers for this reason. Microphony is also noticeable, caused by modulation of the noise voltage generated by the component. Composition resistors having values above about 1 M Johnson noise makes them unsuitable for use in high impedance amplifier inputs or other critical applications.

When subjected to overload, carbon composition resistors usually decrease in value owing to their large negative temperature coefficient. This causes the temperature to rise until the hotspot temperature is exceeded and failure occurs, usually by fracturing.

Film Resistors

Film Resistors are manufactured by forming a deposit of an appropriate resistive material, usually carbon, carbon-boron or some metallic oxide, on a ceramic former, usually a tube or rod. A helical groove is then cut in the film coating. The groove forms the resistive coating into a long continuous path resulting in a compact resistor that can have a value up to 100 megohms. Terminations are made in a variety of ways. Metal end caps may be forced over the ends of the ceramic rod, contacting the deposited film. Leads are attached to the caps by soldering or spot-welding. In some types, the ends of the coated ceramic rod are metallized and leads are wrapped around the metallized portions and soldered. The component is then coated in a suitable lacquer for protection.

Typical construction of a film resistor is illustrated in Figure 4.

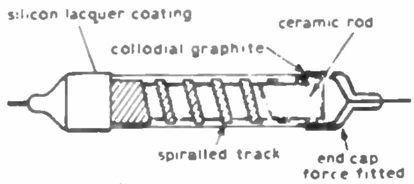


Fig.4. Typical construction of a film resistor

Thick-film resistors are a special type of film resistor. They are generally constructed by depositing the resistive material on a ceramic or aluminium-oxide substrate. A portion of the film coating is then removed, according to a predetermined pattern, to provide a long resistive path between the resistor terminals. Typical construction of one style of thick-film resistor is illustrated in Figure 5. This style is obtainable as a 'fusible' resistor. When overloaded, the substrate cracks, ensuring an open circuit which reduces the possibility of further circuit damage, physical or electronic. These thick-film resistors occupy a minimum of space on a printed circuit board and can dissipate considerable power owing to their large surface area and high hot-spot temperature (150^{o}C).

Thick film resistors are also made in appropriate groupings on a small substrate and encapsulated in a standard DIL IC package. Certain values of resistance are standard in digital circuitry and this style is used in such applications (for example, as the 'weighting' resistor network in a digital-to-analogue converter). Another application is for 'pull-up' resistors for open-collector logic gates.

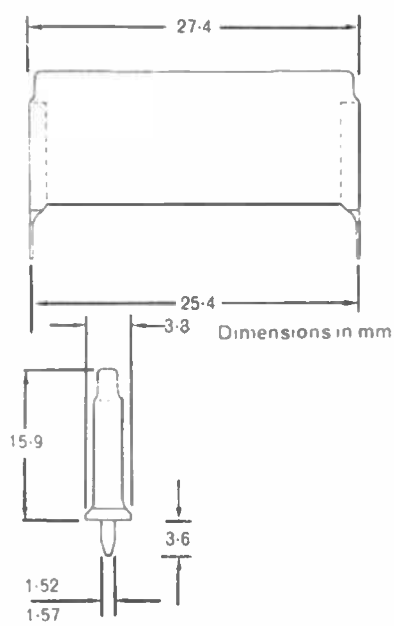


Fig.5. Example of fusible-type of thick-film resistor.

Thin film resistors are constructed in a similar fashion but on a considerably smaller scale. They are primarily used in IC manufacture. Some thin film resistor networks are available in standard DIL integrated circuit packages and these find application in digital circuitry.

There are four basic types of film resistor: –

(a) Carbon Film
(b) Metal Film
(c) Metal Oxide Film
(d) Metal Glaze (Cermet)

Carbon Film Resistors

These resistors are manufactured by a 'cracking' or pyrolytic process where a hydrocarbon vapour at high temperature is decomposed onto a special ceramic rod, producing a thin carbon film on the surface. These are sometimes referred to as 'deposited-carbon' film resistors. Some types use a boron-carbon film; a boron containing gas is introduced during the cracking process. This results in a resistor that has a superior temperature coefficient over a limited range of values than the plain carbon film type.

Terminations may consist of metal end-caps forced over the ends of the element, and then axial or radial leads are attached. Some manufacturers metallize the ends of the element and solder leads to them. Sometimes a combination of the two techniques is used to improve reliability.

Protection for the element is provided in a number of ways. Numerous layers of varnish may be applied followed by a final paint coating. Some modern types are completely sealed in a silicone resin base which is impervious to moisture as well as providing excellent mechanical and thermal protection. Other types may be encased in a plastic moulding or sealed in a ceramic or glass tube. The varnished types afford the least protection against mechanical damage (through handling etc) and moisture.

The voltage coefficient of carbon film resistors is very much less than that of carbon composition types, being usually less than 100 ppm/V and this rarely needs to be considered.

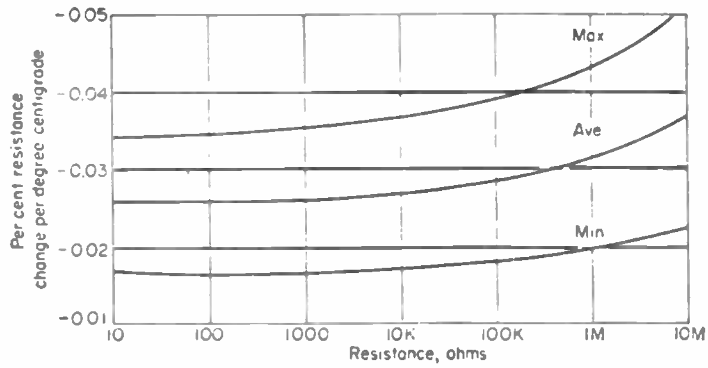


Fig.6. Typical temperature-coefficient spread for deposited-carbon resistors.

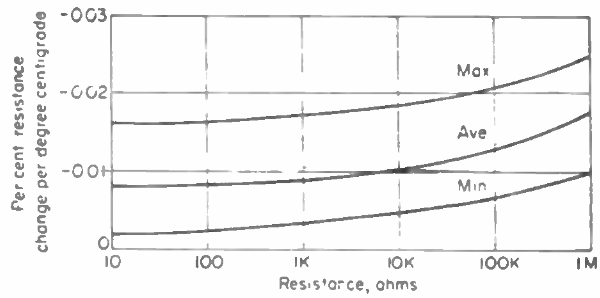


Fig.7. Typical temperature-coefficient spread for boron-carbon resistors.

Getting Heated

Carbon film resistors exhibit temperature characteristics which are superior to composition resistors, but not as good as metal film or wirewound types. Nevertheless, the temperature coefficient of carbon film resistors is quite acceptable for a wide variety of applications. Only those applications requiring a very good temperature characteristic warrant the use of the other, usually more expensive, film resistors.

As mentioned just previously, the temperature coefficient of boron-carbon film resistors is somewhat better than the deposited-carbon types. The latter may have a temperature coefficient between +350 and −550 ppm/^{o}C for values under 100k, and between +350 and −800 ppm/^{o}C for values under 100k. Generally though, the TC will be negative. The variation of TC with resistance value and the sort of 'spread' that can be expected for a particular batch of components is illustrated in Figure 6 for deposited carbon resistors. The temperature coefficient of boron-carbon resistors is typically between +100 and −200 ppm/^{o}C for values under 100k, and between −50 and −400 ppm/^{o}C for values over 100k. The variation of TC with resistance value and the spread that might be expected is illustrated in **Figure 7.**

The TC of carbon film resistors is also dependant on the wattage rating due to the thickness of the carbon film used in its construction.

Growing Old

All resistors change their value permanently with age and use. Carbon composition resistors are the worst in this regard and may be expected to change as much as 20%. Film and wirewound resistors are considerably better. Carbon film resistors have a stability of better than 1% which is usually more than adequate for all but the most stringent applications.

The high frequency characteristic of carbon film resistors is one of its advantages. Coated types are somewhat better than equivalent moulded or encased units. Generally speaking, the apparent value of the resistor decreases at high frequencies. Values below 1k will maintain their resistive value well beyond 500 MHz. Even relatively high values will not show a decrease of more than 10% until well into the VHF region. This is illustrated for typical coated ½W deposited-carbon film resistors in **Figure 8.**

Noise

The noise generated by carbon film resistors is a function of the applied voltage, the thickness of the film and the length of the spiral track. Consequently, the lower value, higher wattage units generate the least noise. For values below 10k it is typically between .08 and .5 µV/V, and for values between 10k and 100k it may be as low as 0.2 µV/V and up to 1.0 µV/V. For values above 100k, the noise ranges from 0.5 µV/V to 1.5 µV/V.

Carbon film resistors are available in ratings from 0.1W to 2W and in values that range from 10 ohms to 15M for commonly available units and up to 100M on special order. They are manufactured to tolerances of ± 0.5% (E192 series), ± 1% (E96 series), ± 2% (E48 series) and ± 5% (E 24 series).

Carbon film resistors will withstand a short-term overload of twice to 2.5 times the rated maximum working voltage. Failure is more common in the high value resistors. Irregularities in the spiral track and extremely thin film contribute to the failure of the component. The resistor may burst into flame when it fails due to a prolonged overload.

The excellent stability and low cost of carbon film resistors, along with other desirable features such as low noise, small TC and good high frequency characteristics have contributed to their increasing use in a wide range of electronic applications.

Metal Film Resistors

These resistors are much the same in appearance and size to deposited-carbon resistors. The resistive film is deposited on a ceramic or glass former by evaporating a metal or alloy in a vacuum, the metal condenses on the surface of the former, forming a hard, dense film. Nickel-chrome alloys are most commonly used. Some manufacturers use a chemical deposition process to coat a former with a nickel alloy. Packaging and protection for metal film resistors is similar to carbon film resistors.

The temperature coefficient of these resistors is superior to most other types with the exception of precision wirewound resistors. The TC is typically ± 100 ppm/^{o}C but they are available with a TC as low as ± 20 ppm/^{o}C. The construction of these resistors makes it possible to supply them in controlled values of temperature coefficient over a wide range of values. Typical TC ranges

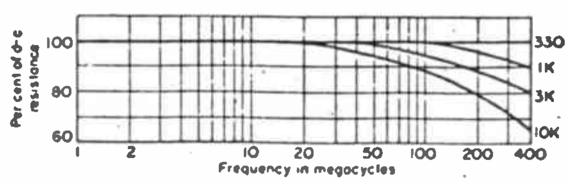


Fig.8. Approximate frequency characteristics for ½-watt deposited-carbon resistor.

for such types are as follows:—

0 ± 50 (ppm/°C)	0 + 50 (ppm/°C)
0 ± 100 "	0 + 100 "
0 ± 150 "	0 – 50 "
0 ± 200 "	0 – 100 "

The thickness of the film establishes the resultant temperature coefficient. This is positive for thick films; the magnitude decreasing with decreasing film thickness, passing through zero and then turns negative for thin films.

The noise level of metal film resistors is very low, being typically 0.015 μV/V which is only rivalled by metal-glaze resistors. However, wirewound resistors are superior to all the others.

Stability of these resistors under ordinary use is generally better than 0.2% which is only bettered by precision wirewound resistors. As a consequence, metal film resistors are available in tolerances as low as ± 0.25% and ± 0.5%. Generally they are available in tolerances of ± 1%, ± 2% and ± 5%.

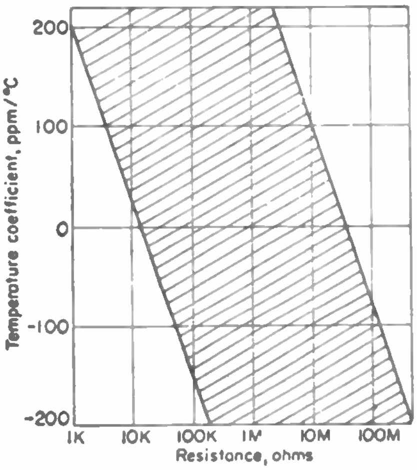


Fig.9. Range of temperature coefficients available for various values of metal film resistors having controlled TC characteristics.

Stable Companion

In general, metal film resistors offer all the advantages of deposited-carbon film resistors as well as exhibiting much superior stability and temperature coefficient characteristics. They generate much lower noise in operation than most other types of resistors. Frequency characteristics are much the same as for carbon film resistors, the construction being largely the same. Metal film resistors are available in wattage ratings from 0.1W to 1W, generally, but higher power types are available.

Metal film resistors are mostly used in applications where reliability, close tolerance and high stability are required or where controlled temperature characteristics are called for. They are generally somewhat more expensive than composition or deposited carbon film resistors but the price differential is decreasing as their use becomes more widespread.

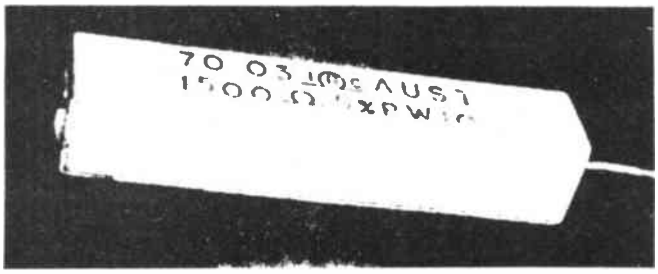


Fig.10. Square section, 'ceramic boat' style medium power film.

Metal Oxide Film Resistors

In this class of film resistor conducting oxides of tin and antimony are formed on a glass or ceramic rod which is at red heat. The chemical reaction produces hard, glass-like oxide on the surface of the former. The oxide film is conductive and is inert to common chemicals. The resistance value required is obtained by cutting a helical groove in the film, along the former, as explained in the last section. General construction and terminations are similar to the other film resistors. The resistive element is usually coated with a flame-proof epoxy material.

The noise and temperature coefficient characteristics do not vary widely with resistance value, these resistors being superior in this respect than deposited-carbon film resistors. The noise is generally around 0.03 μV/V and may be as low as 0.02 μV/V. The TC of common types is generally ± 250 ppm/°C but may be as low as ± 50 ppm/°C. As the film is of a semiconductive nature, the TC may be either positive or negative. The limits of precision in controlling the composition of the film produces resistors which have a positive TC over a certain range of values, and a negative TC over a different range of values.

Stability of metal oxide film resistors is better than 0.5% which is better than composition or carbon film resistors but not quite as good as metal film resistors. However, this is better than most commercial grade wirewound resistors. With a stability of the order quoted, metal oxide film resistors are available in tolerances of ± 1%, ± 2%, and ± 5%

The general characteristics of metal oxide resistors are similar to deposited carbon film and metal film resistors.

Wirewound Resistors

These resistors are made by winding a length of resistance wire on a bobbin (usually of ceramic or fibreglass), the ends being anchored to terminations on the ends of the bobbin. Bobbins are usually cylindrical-shaped or flat. The bobbin and element are generally encapsulated in an impervious coat of vitreous enamel — some styles have the whole bobbin encapsulated in a square ceramic boat, having either axial or radial leads. These are generally the lower power types, up to 20 W.

There are two general types of coating applied to wirewound resistors. One is called Pyrosil D-Coat and consists of a combination of silicone resins and refactory material (which prevents oxidation) of the wire element) and is designed for high temperature operation. It is capable of withstanding temperatures corresponding to five times rated load. The other encapsulation material is known as Tropical C-Coat, another silicone compound and is designed to protect the element under extreme environmental conditions (particularly humidity). The power rating is different for similar resistors coated with different coatings. Resistors coated with tropical C-Coat can only operate at half the power of similar resistors encapsulated with Pyrosil D-Coat.

Terminations for wirewound resistors come in a wide variety of styles. The smaller, low power, types (particularly the completely encapsulated types, often have radial or axial leads and sometimes terminal lugs. High power types may have ferrules on each end — and are plugged into large clips; alternatively they may have terminal lugs, Edison screw threads or flying leads.

The resistance element usually consists of nickel — chromium alloy wire (nichrome). Precision wirewound resistors are usually wound with Eureka wire.

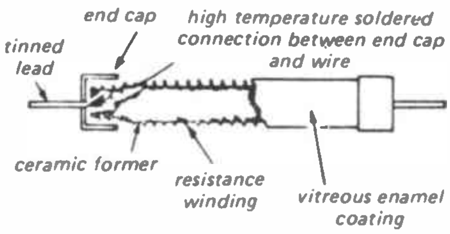


Fig.11. Typical construction of small, cylindrical style wirewound resistor.

Very high power types and some very low resistance types are sometimes wound with flat-tape element instead of wire. It is usually wound edge-on to the bobbin to improve heat dissipation from the element.

Wirewound resistors are made in wattage ratings to 250 W, commonly, and up to 1 kW or more for special applications. There are three basic construction styles: cylindrical, flat and encapsulated ceramic-boat style. The first two are also available as adjustable resistors, having portion of the element exposed and a moveable terminal in contact with it.

Temperature

Wirewound resistors can have excellent temperature characteristics — as low as 5 ppm/°C, but generally less than 200 ppm/°C for the common types.

These resistors exhibit good stability, usually better than 2%, precision types having stabilities better than 0.05%. Common types are available in tolerances of ±5% and ±10% depending on construction style. Tolerance down to 1% can be obtained in precision types.

The noise level and voltage coefficient of wirewound resistors is negligible.

Owing to their construction, wirewound resistors are quite inductive and are generally only useful at low frequencies. Their inherent inductance can be decreased with special winding techniques — occasionally found in precision resistors, but as most wirewound resistors are predominantly used in dc and/or low-frequency circuits where their high power rating is required, this does not present much of a problem.

Mounting & Surrounding

Care must be taken in the mounting of wirewound resistors to prevent the high operating temperature affecting surrounding components. The cylindrical types usually have a hole through the middle through which heat may escape by convection. Mounting these vertically where possible is recommended to keep their operating temperature down. The flat style are mounted using formed 'leaves' which fit into the ends of the former (see Figure 12) — which is hollow, these conducting heat away through the mounting bolts. They are designed for either vertical or horizontal mounting, either singly or in stacks. This style is most suited to applications requiring a high power resistor to be mounted in a limited space.

It is a wise precaution with the axial or radial-lead types to mount them so that they are clear of any other components, chassis, pc board, etc by at least their diameter or width, to provide sufficient ventilation and to prevent damage to other components.

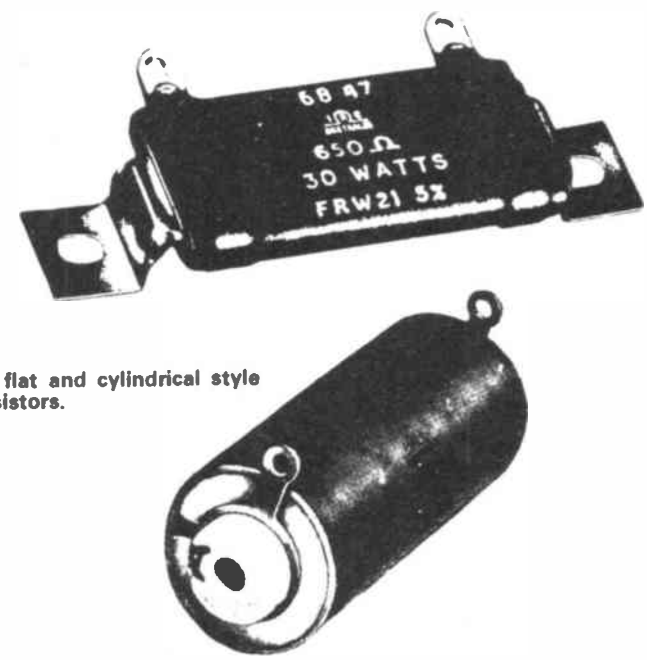


Fig.12. Typical flat and cylindrical style wirewound resistors.

Failure

Wirewound resistors fail occasionally. This may be due to one of the following reasons. In high value types, the resistance wire is very thin. The slightest blemish creates a weak point which may eventually cause the wire to break. In the coated types, expansion differences between the ceramic bobbin and the enamel coating may cause cracking of either the coating or the bobbin allowing moisture to penetrate and attack the resistance wire. The wire may corrode under constant dc load conditions due to chemical action in the enamel coating of the component. This latter problem is rare.

Precision wirewound resistors are wound on special bobbins, generally using Manganin wire, and encapsulated or covered in an insulating coating. They are sometimes epoxy-moulded. Other styles are hermetically sealed in a ceramic container. Wire leads or solder lugs are used as terminations. Precision wirewound resistors are not generally designed to dissipate power. Power types are available however, generally consisting of a conventionally constructed wirewound resistor wound to a tight tolerance or selected, and mounted in an extruded aluminium case. This assists heatsinking, allowing precision resistors to be rated up to powers of 200 W.

Cermet Resistors

These resistors are made by fusing a suspension of metal and glass particles to a ceramic rod at temperatures between 750C and 930C. This forms a thick resistive film, fused with the surface of the ceramic former, resulting in a resistance element that is virtually impervious to environmental extremes of moisture, temperature, shock and vibration.

The fusion of the metal resistive material and the ceramic rod gives rise to the common name 'CERMET' resistor.

The construction of cermet resistors is generally the same as for film resistors: the desired resistance is obtained by spiralling the resistive element. Owing to the high firing temperatures, these resistors may be rated for higher temperatures and loads than similar sized film resistors. Conduction of heat away from the resistance element is superior, owing to the better thermal contact possible between the resistance element on the rod and the metal end-caps. Body temperature rise is lower than for comparably-sized resistors of other types having similar ratings. As a result of these characteristics, cermet resistors are generally smaller than other resistors of the same rating.

The temperature coefficient of cermet resistors is generally comparable with most metal-film and metal-oxide resistors, common types having a TC of ± 100 ppm/°C. Some types exhibit a TC of +50 ppm/°C and may be as low as ±25 ppm/°C. This characteristic shows little variation with the value of the resistor.

Noise level for these resistors is generally higher than for other types, typically ranging from 0.4 μV/V to 1.0 μV/V, which is worse than other types but far below the level of carbon composition resistors. This level of noise is rarely a problem.

The voltage coefficient is generally better than 100 ppm/V, similar to most other film resistors and is not a consideration in the majority of applications. Generally, the voltage coefficient is only a consideration with carbon composition resistors.

As the construction of cermet resistors is similar to the other types of film resistors they have similar frequency characteristics. Values below 10k show little variation in value well into the UHF region.

Cermet resistors have excellent stability owing to body temperature being low for the amount of power dissipated. Figures of 0.5 – 1.0% are common. Generally, cermet resistors are manufactured in standard tolerances of ± 2% and ± 5%. Tolerances of ±1% are available on special order.

Cermet resistors are generally available in ratings from 0.1 W to 0.5 W, and some less common types up to 5 W. Cost is comparable to most types of film resistors which makes them very attractive where their small size and high power rating is required or in applications where they are likely to experience moisture and temperature extremes, etc. Trimpots are manufactured having cermet resistance elements to take advantage of the ruggedness and resistance to environmental extremes that this type of element offers.

Thermistors

Thermistors belong to a group of resistors made from semiconductor materials and are thermally sensitive, having a controlled temperature coefficient that may be positive (PTC thermistors) or negative (NTC thermistors).

Thermistors are widely used for temperature measurement and control, temperature stabilisation, current surge suppression, and a wide variety of other applications. They are non-reactive and non-polarised and are therefore suitable for use in either ac or dc circuits.

The resistive element consists of barium titanate in PTC thermistors and various metal oxides in NTC thermistors. The compounds are sintered into special shapes, depending on the required application. They are formed into small elements in a variety of shapes – generally discs, rods, blocks or tubes. They may be encapsulated simply with a varnish or epoxy or inside a glass or metal tube. Some types are not encapsulated at all.

PTC thermistors are available in two basic characteristics. The 'A' characteristic type exhibits linear change of logarithmic resistance values against temperature. The 'B' characteristic exhibits abrupt increase of resistance when the temperature increases above a specified value, showing only small change in resistance below this temperature.

Some typical PTC thermistors are illustrated in Figure 13. Individual characteristics are best obtained from manufacturers' literature.

NTC thermistors are available covering a wide range of values and temperature ranges.

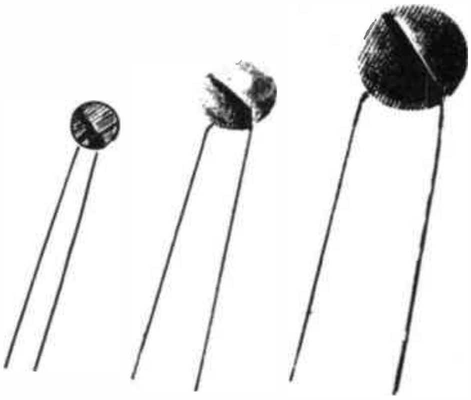


Fig.13. Typical PTC thermistors (actual size).

Voltage Dependent Resistors

These resistors are generally known as 'Varistors' and are another type of semiconductor resistor. They are principally used as voltage surge suppressors, some types being used in voltage stabiliser applications.

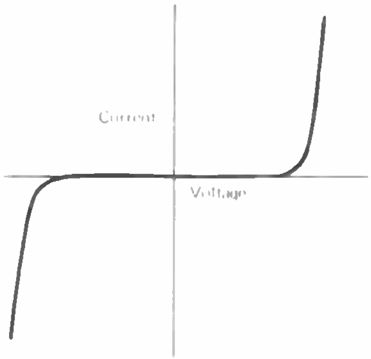


Fig.14. Varistor voltage-current characteristics.

The element generally consists of a sintered ceramic material, the most common types zinc oxide as the main ingredient. Other types employ elements containing titanate ceramic (sometimes known as 'variatite') or silicon carbide (SiC varistors). The common types are often referred to as ZNR varistors from Zinc Oxide Nonlinear Resistor.

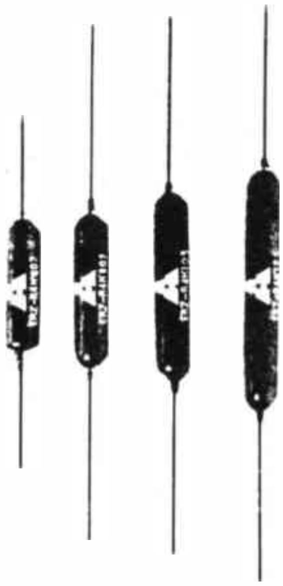


Fig.15. Various types of varistor encapsulations for different applications.

The general characteristics of varistors is illustrated in Figure 14. They are available in a wide variety of encapsulations, some are illustrated in Figure 15. They are often found as 'spike' suppressors in solid state TV sets, as back-emf suppressors across relays, and in rectifier circuits protecting rectifiers from voltage surges.

Resistor Codes

The value and tolerance, and other pertinent characteristics, of resistors may be marked on the body of the component in one of three ways. Viz:

(1) By marking directly on the body.

(2) By using a standard colour code – coloured bands or dots, etc, read in sequence.

(3) By using an appropriate typographic code, consisting of letters and numerals arranged according to a convention.

Which method is used depends on the type and physical size of the component to a large extent and also according to the manufacturer's preference. The larger components, such as power resistors (particularly wire-wound types), usually have the value, tolerance and wattage rating marked directly on the body. Most common low power resistors, from 0.05 W to 2 W, use the standard resistor colour code. Some manufacturers use a typographic code on their resistors, physical size allowing (usually radial-lead types having wattage ratings between 0.25 W and 10 WS The special resistors (PTC, NTC thermistors and Varistors) also may be marked with a colour code or typographic code to indicate their value and characteristics.

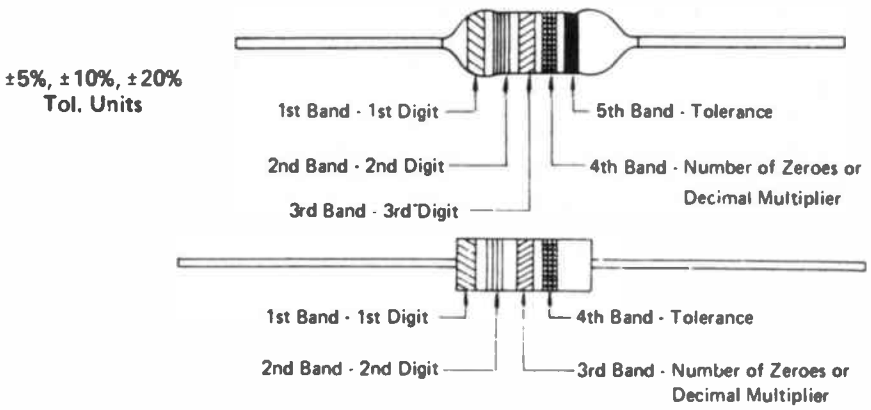


Fig.16. The standard resistor colour code marking.

TABLE 1. STANDARD RESISTOR COLOUR CODE

COLOUR	DIGIT VALUE	MULTIPLIER (No. of zeroes)	TOLERANCE ±%
BLACK	0	1	
BROWN	1	10	1
RED	2	10^2 or 100	2
ORANGE	3	10^3 or 1k	
YELLOW	4	10^4 or 10k	
GREEN	5	10^5 or 100k	
BLUE	6	10^6 or 1M	
VIOLET	7	10^7 or 10M	
GREY	8	10^8 or 100M	
WHITE	9	10^9 or 1000M	
GOLD	–	0.1 or 10^{-1}	5
SILVER	–	0.01 or 10^{-2}	10
none	–	– – – – – –	20

* High Stability (grade 1) resistors are distinguished by a salmon-pink fifth ring or body colour.

The Standard Colour Code

The common axial-lead, composition and film-type resistors are marked with a series of coloured bands, as shown in Figure 16, which are read according to the standard colour code table in Table 1. The standard E24 (5%), E12 (10%) and E6 (20%) series components are marked with either three or four bands. Components below 10 ohms in the E6 series may have only two bands indicating the value. Resistor values in the E48 (2%) and E96 (1%) series are marked with five bands.

The bands are located on the component towards one end. If the resistor is oriented with that end towards the left, the bands are read from left to right as shown. The extreme left (or first) band colour indicates the value of the first digit of the component value; the next, or second, band indicates the second digit of the value and so on. If the bands are not clearly oriented towards one end of the resistor it is best sorted out by trying to locate the tolerance band first. As the most commonly used resistors these days are either E12 or E24 series, the tolerance band is either silver or gold respectively. If still in doubt – resort to an ohmmeter.

The body colour of modern resistors is also used to indicate the resistor type. Carbon film resistors have a very light tan body, and carbon composition resistors have a medium tan body – somewhat darker than the carbon film body colour. Metal film resistors have a brown body colour – quite distinguishable from composition resistors and metal-glazed film resistors have a light blue body colour.

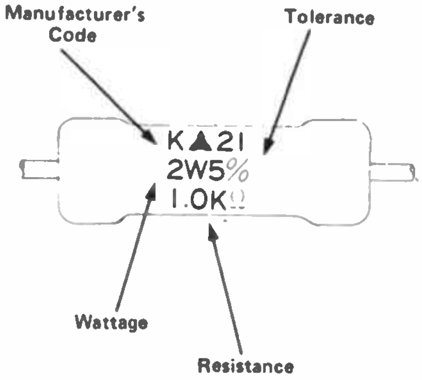
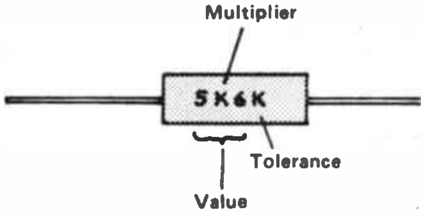


Fig.17. Resistor with characteristics and value marked directly on the body.

High stability resistors (E48, E96, E192 series) are distinguished by salmon-pink 5th band or body colour.



MULTIPLIER	TOLERANCE
R = x1	F = ±1%
K = x1000	G = ±2%
M = x1 000 000	J = ±5%
	K = ±10%
	M = ±20%

**Position of the multiplier indicates the position of the decimal point in the value.*

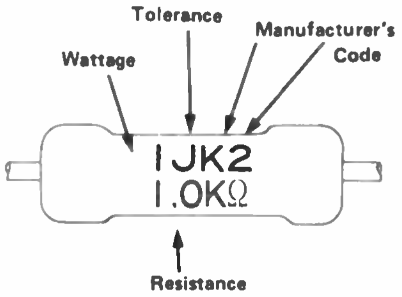
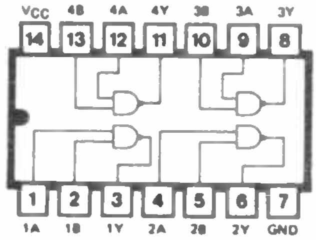


Fig.18. Typographic codes used on resistors.

TTL PINOUTS

7400



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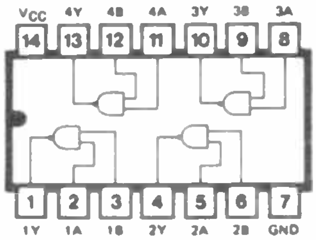

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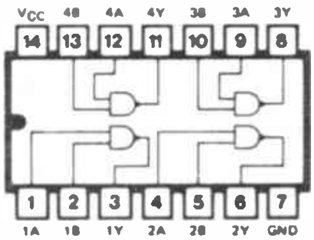

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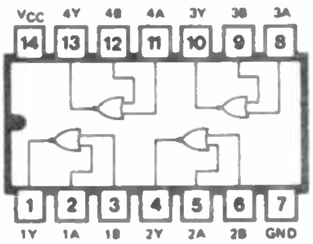

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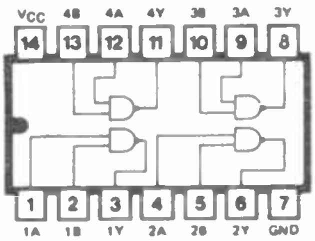

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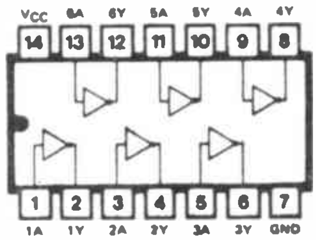

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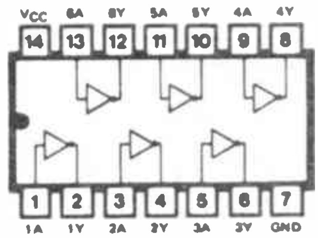

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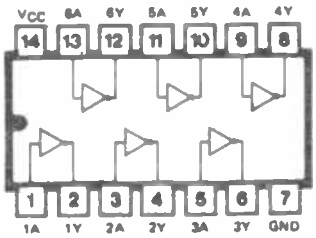

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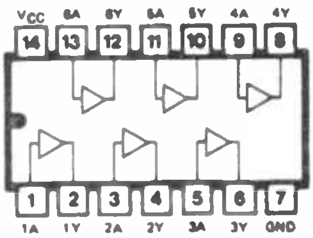

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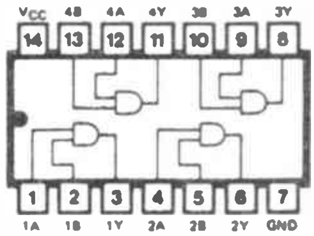

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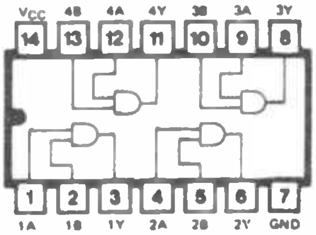

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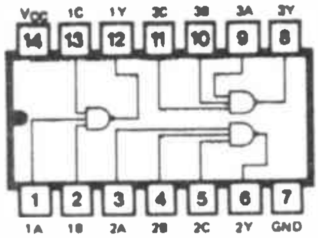

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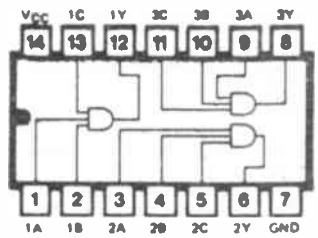

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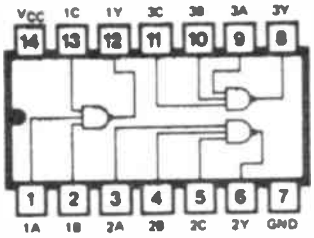

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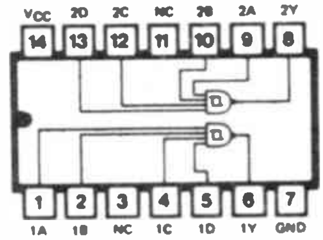

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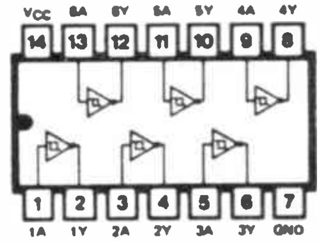

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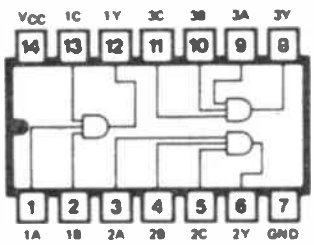

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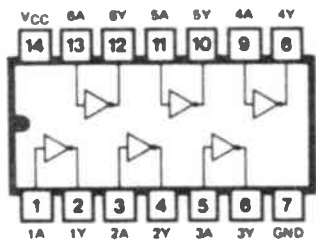

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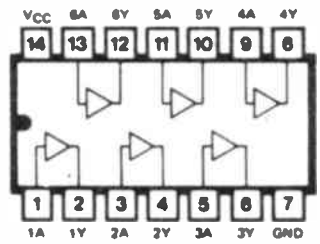

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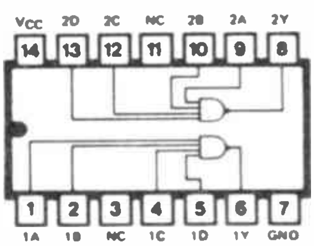

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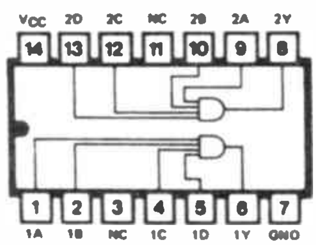

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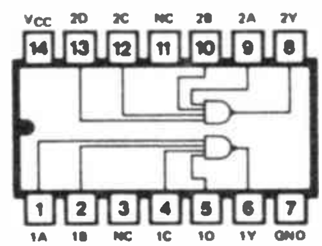

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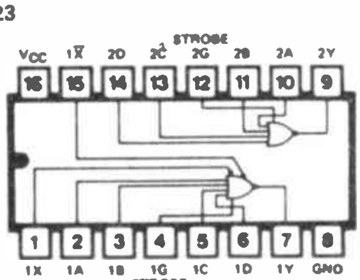

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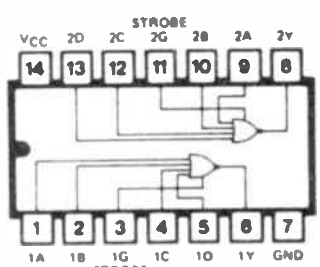

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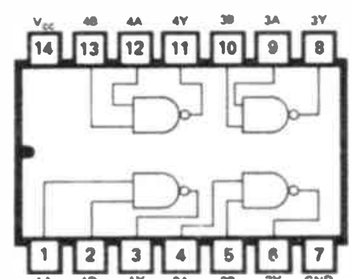

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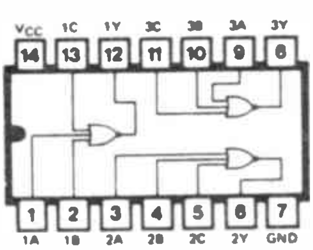

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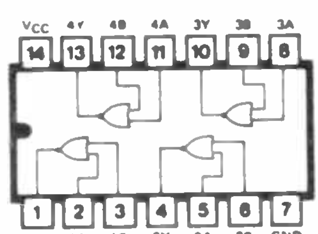

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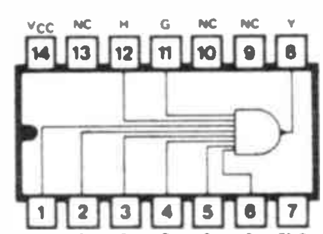

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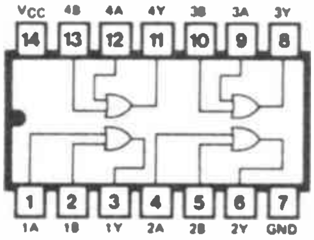

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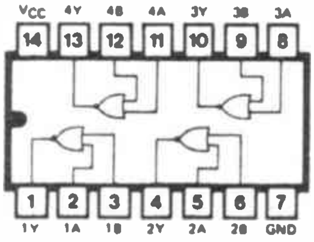

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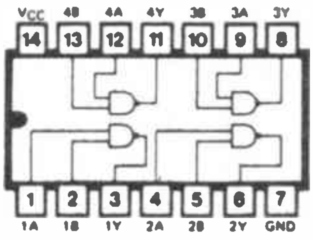

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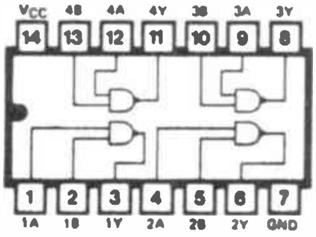

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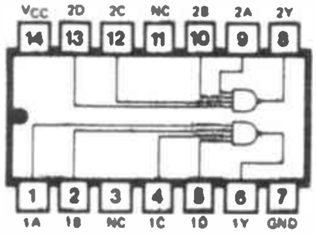

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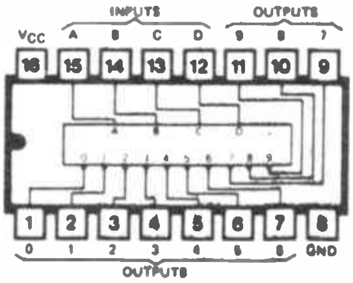

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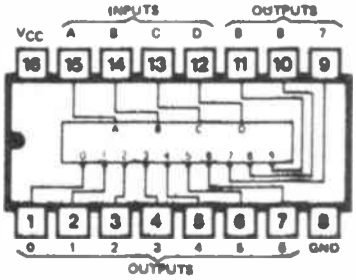

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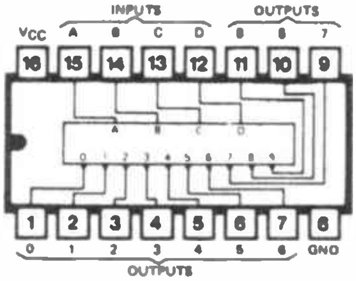

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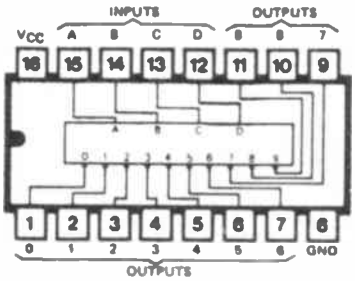

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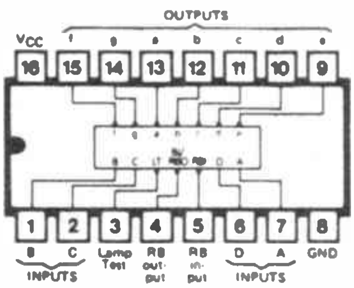

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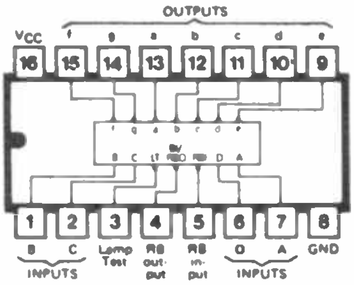

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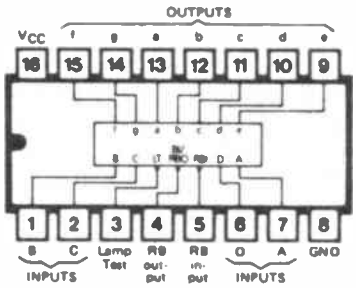

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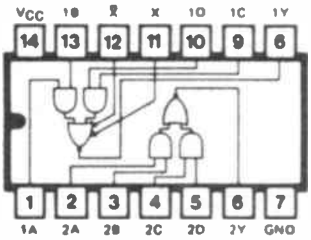

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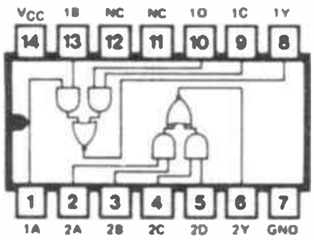

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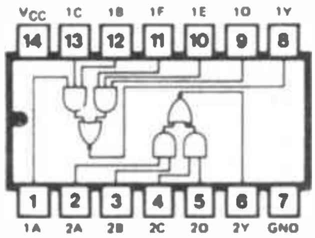

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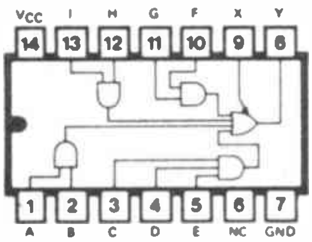

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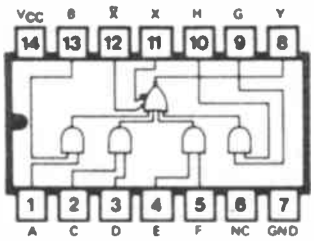

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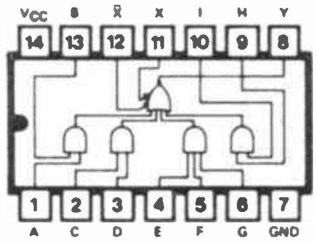

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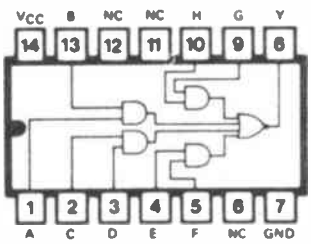

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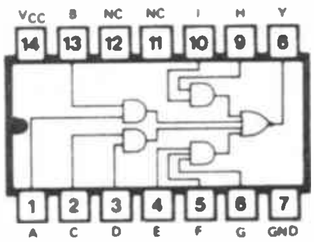

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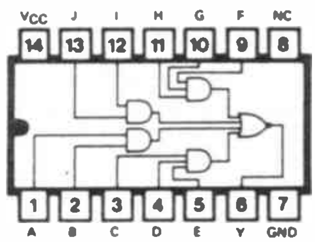

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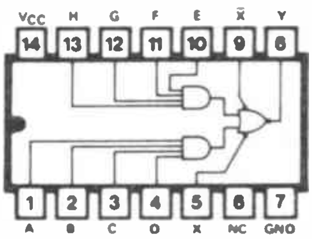

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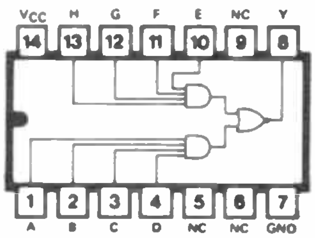

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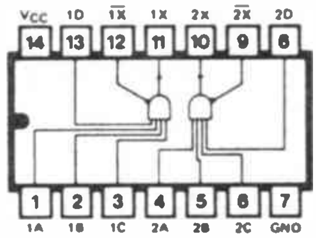

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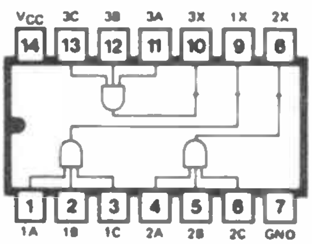

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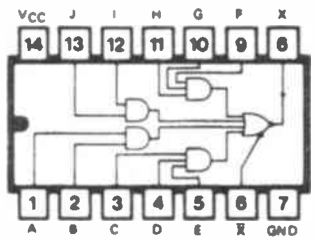

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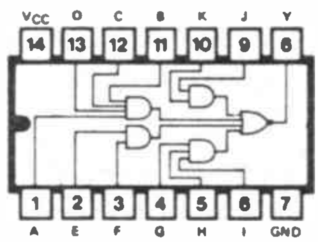

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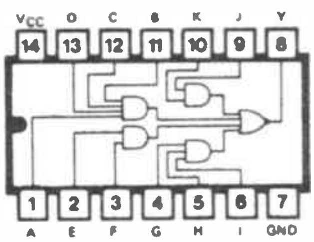

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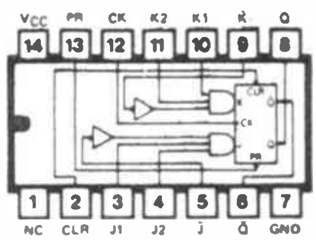

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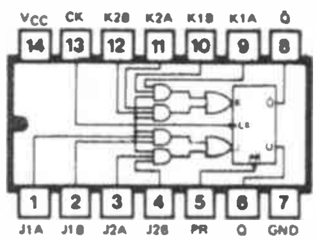

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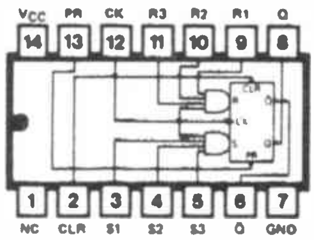

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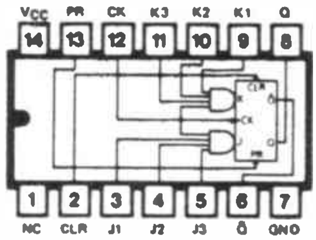

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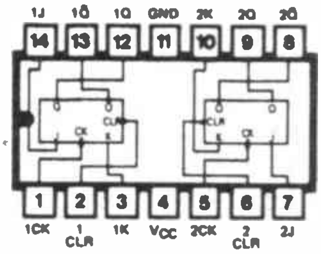

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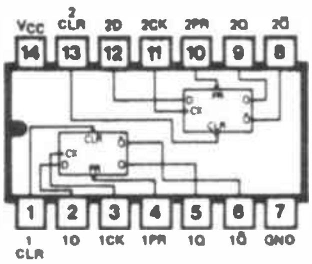

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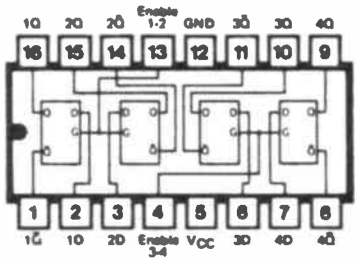

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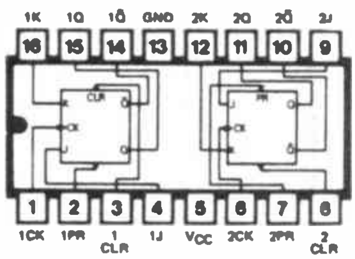

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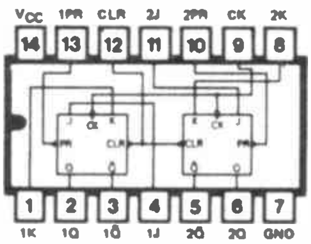

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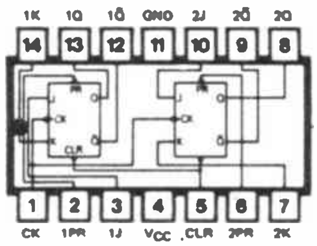

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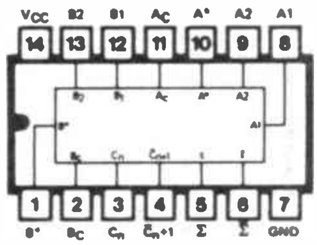

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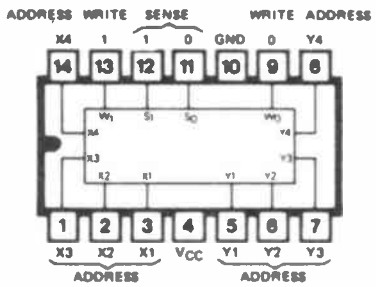

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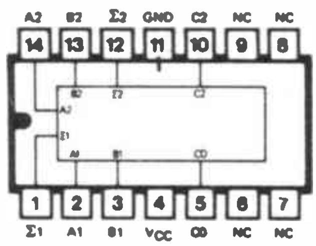

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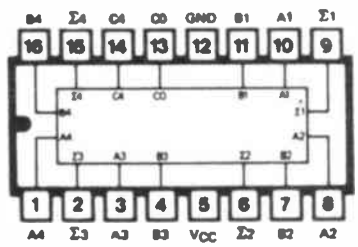

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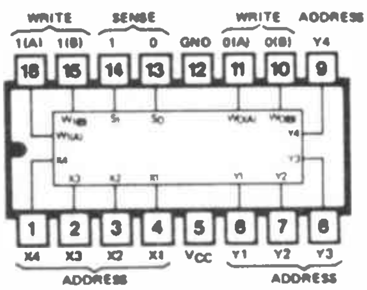

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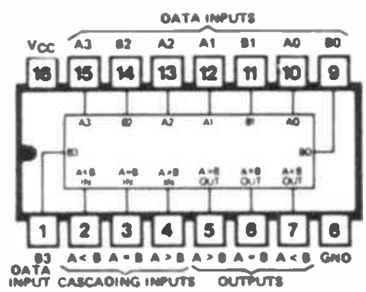

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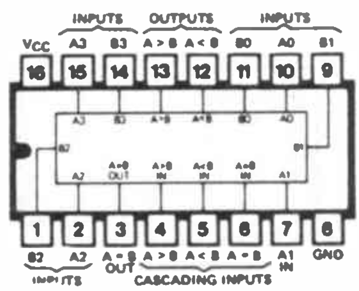

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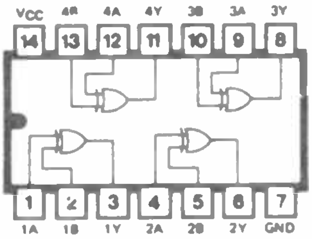

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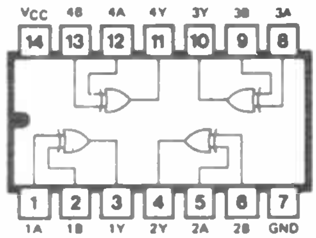

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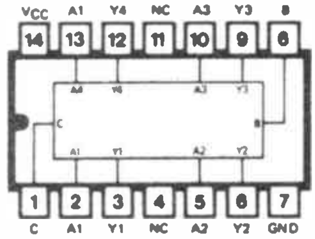

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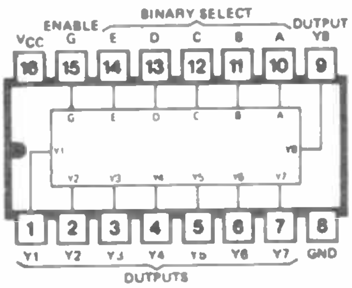

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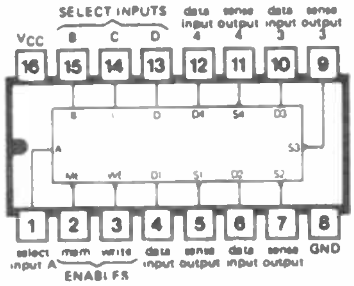

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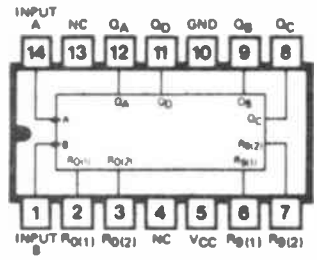

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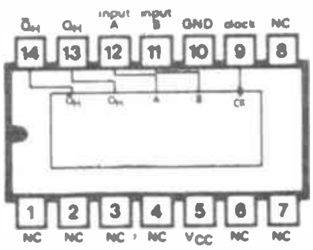

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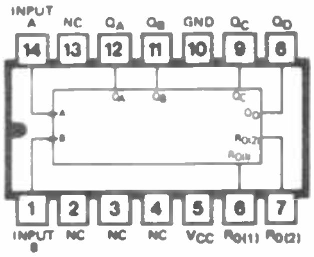

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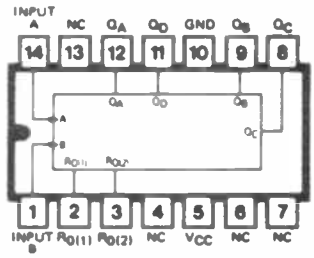

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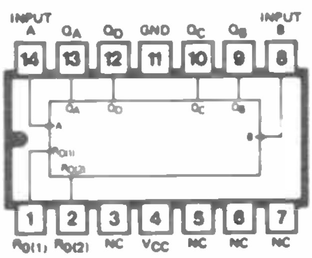

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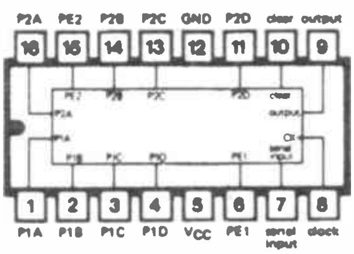

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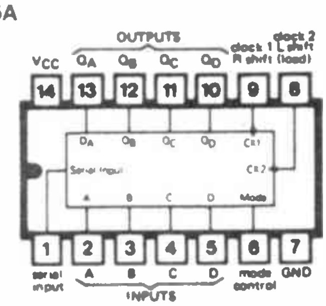

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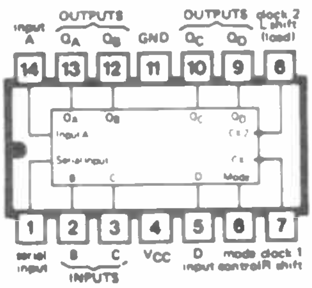

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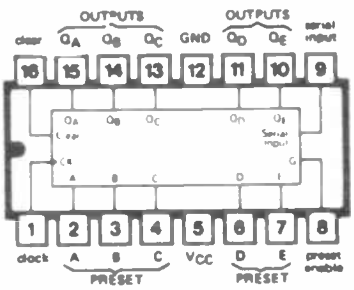

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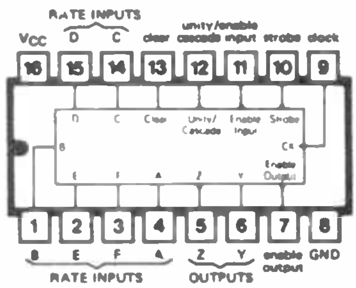

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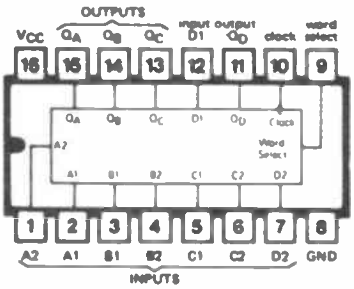

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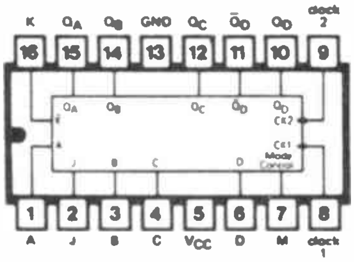

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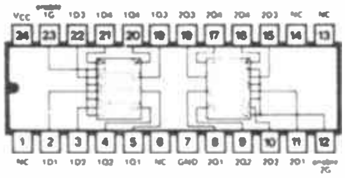

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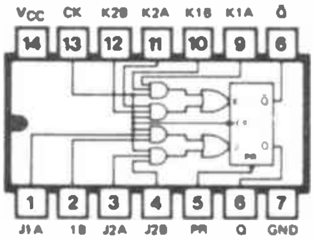

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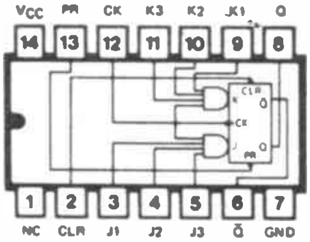

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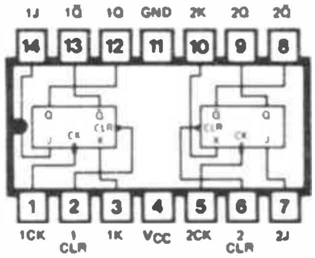

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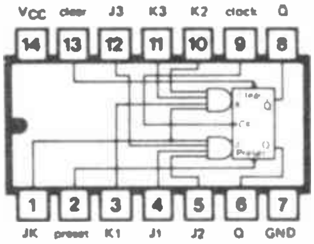

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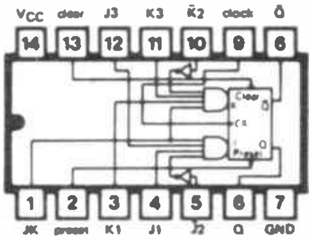

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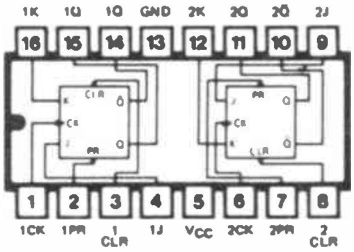

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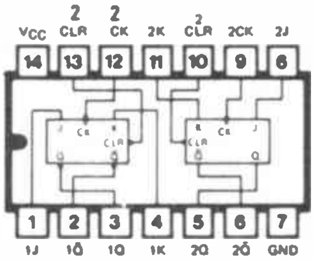

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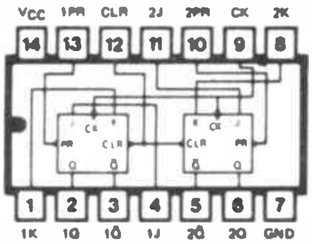

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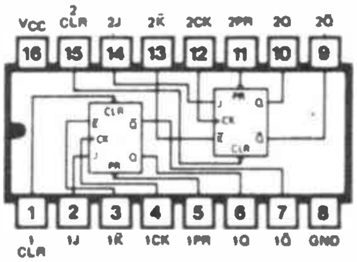

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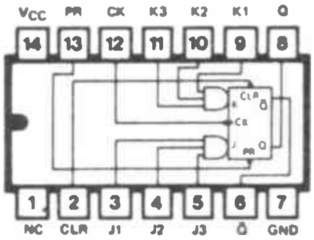

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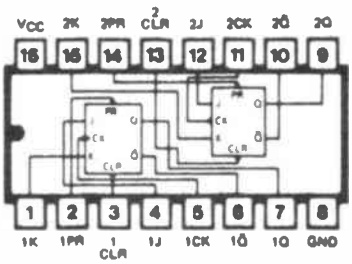

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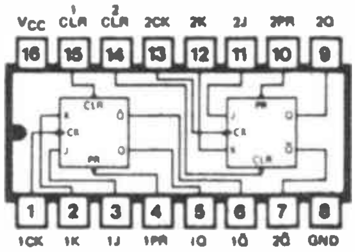

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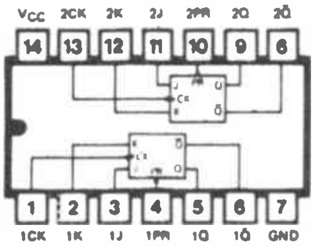

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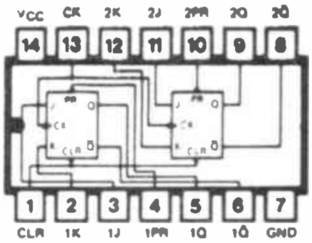

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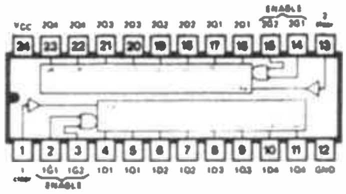

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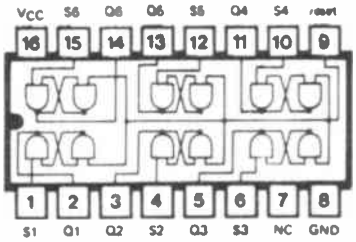

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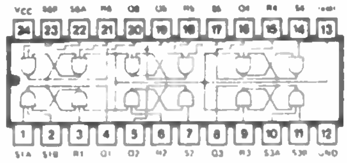

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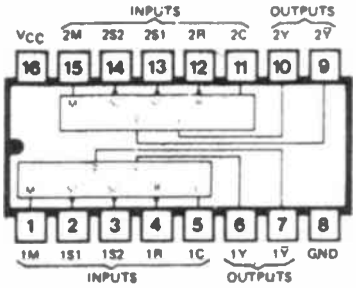

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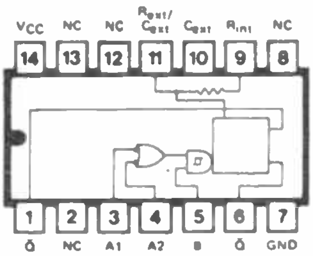

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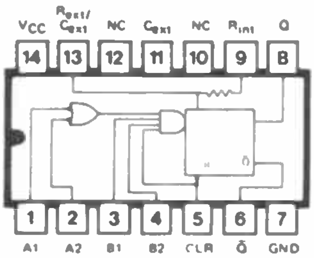

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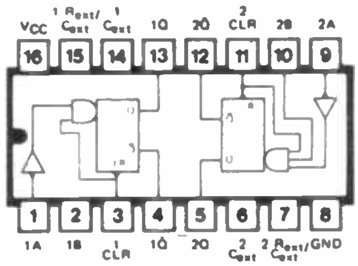

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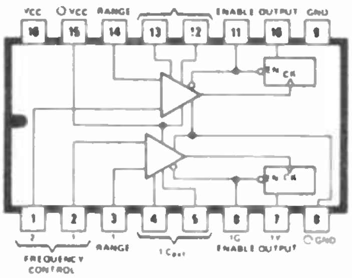

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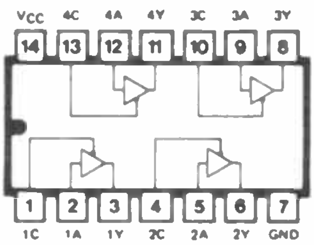

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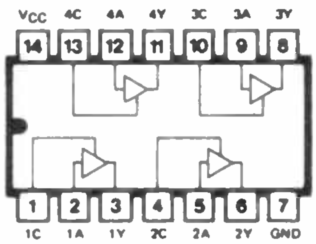

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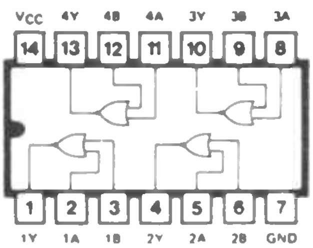

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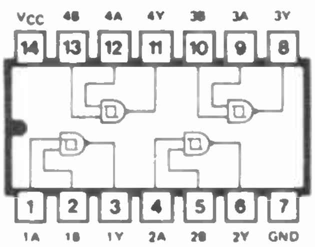

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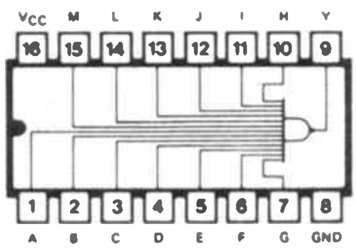

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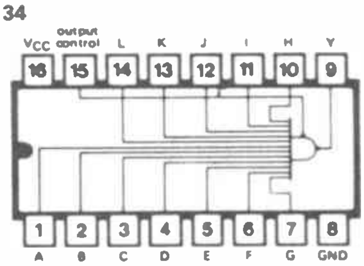

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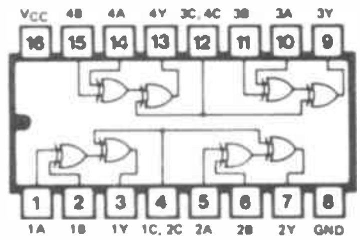

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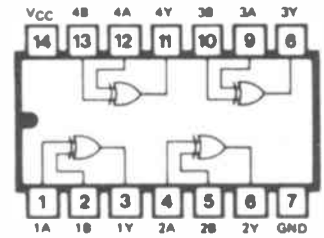

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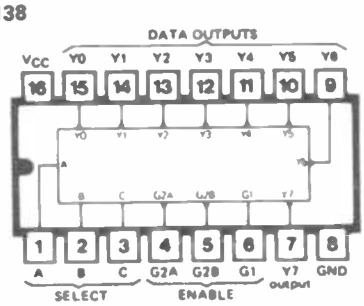

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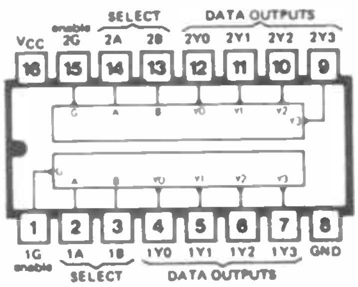

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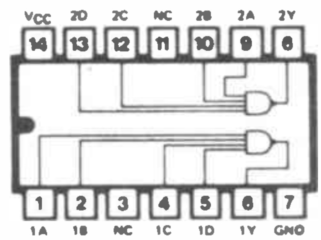

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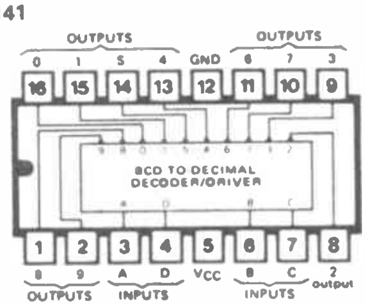

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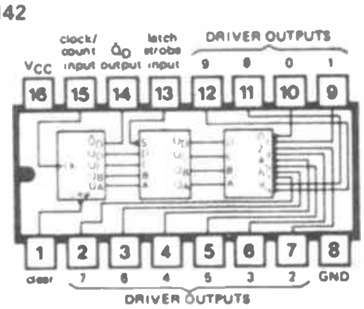

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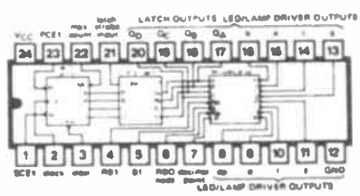

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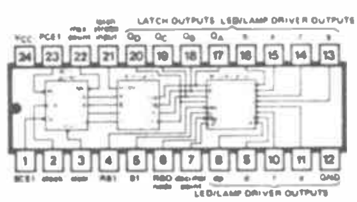

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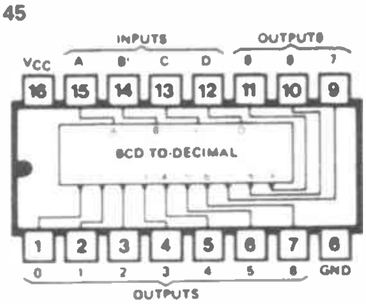

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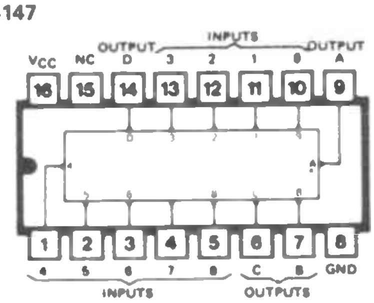

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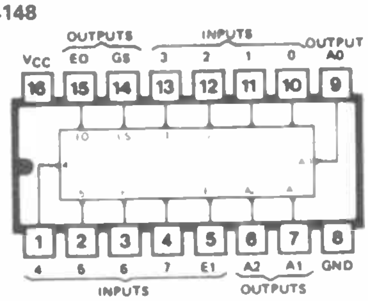

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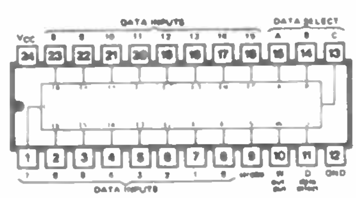

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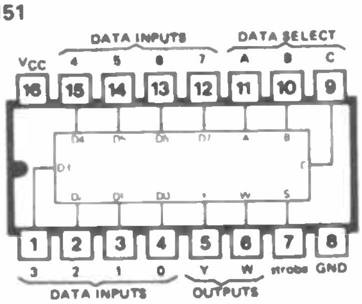

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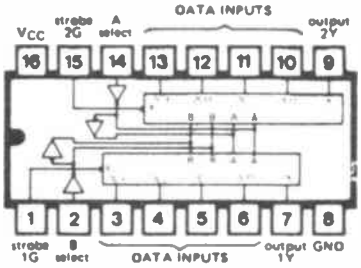

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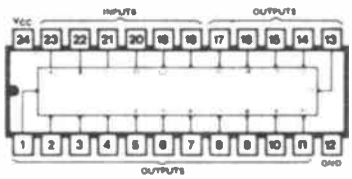

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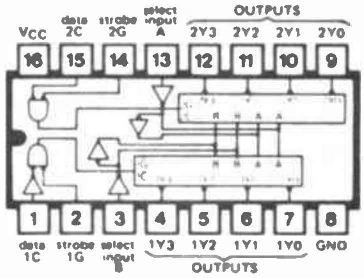

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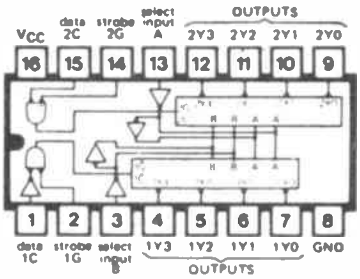

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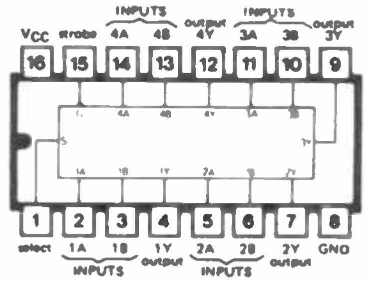

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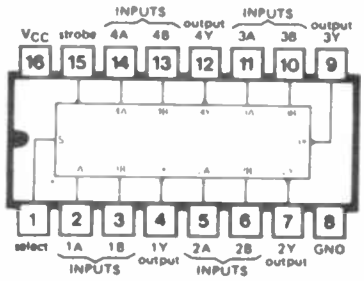

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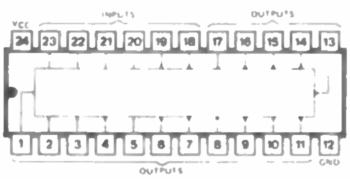

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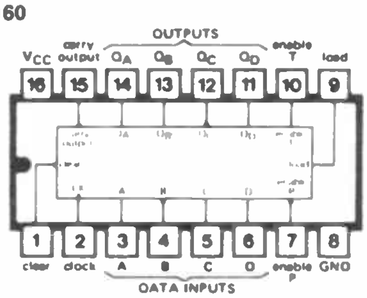

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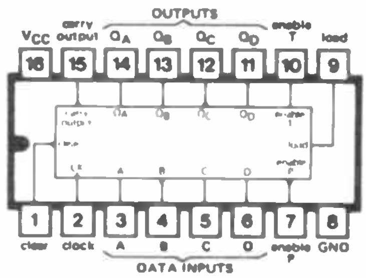

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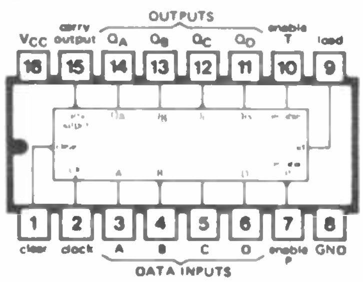

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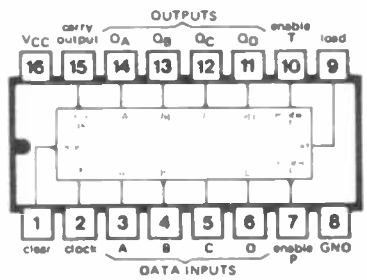

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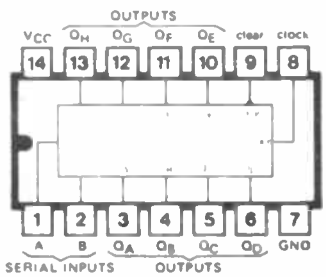

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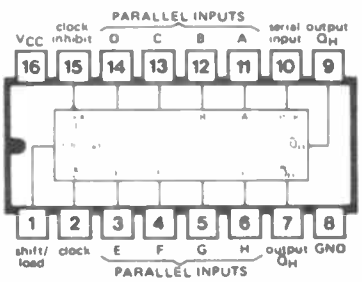

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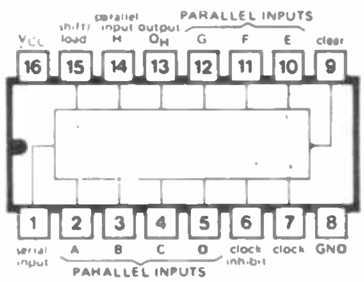

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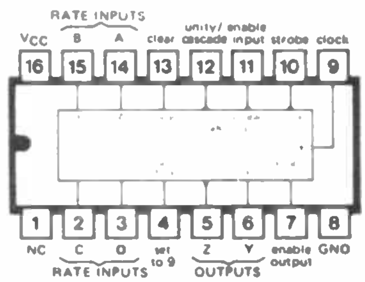

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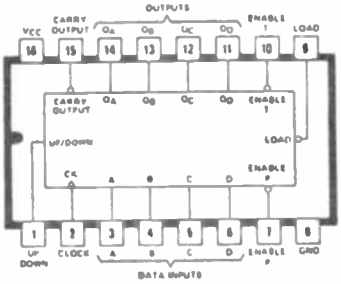

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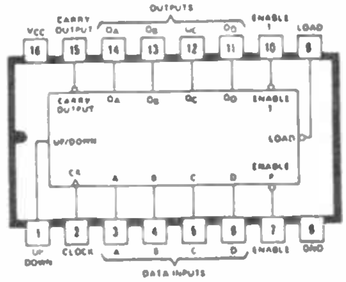

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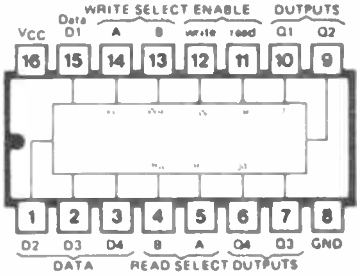

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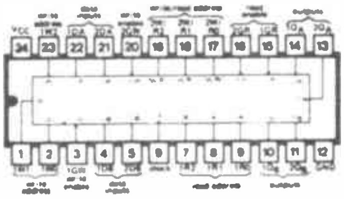

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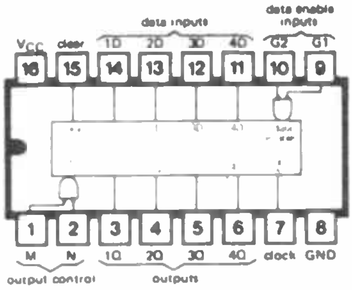

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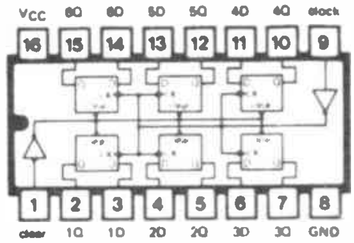

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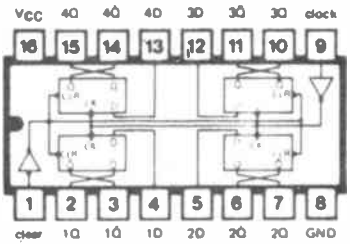

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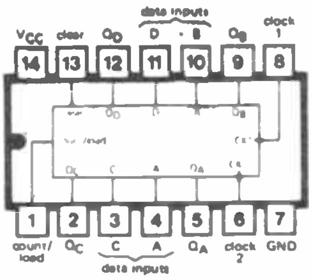

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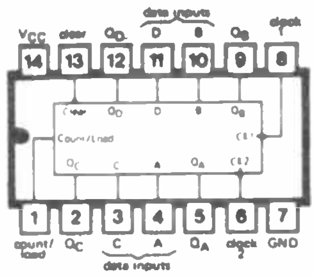

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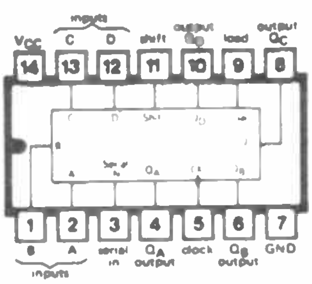

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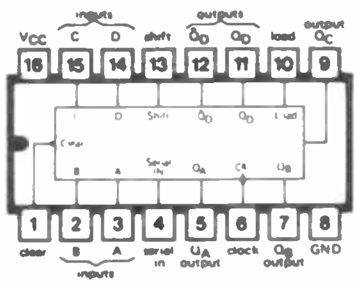

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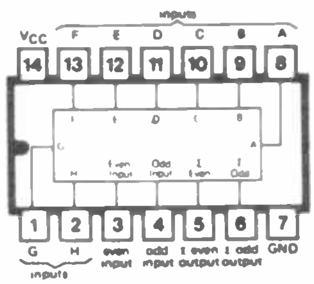

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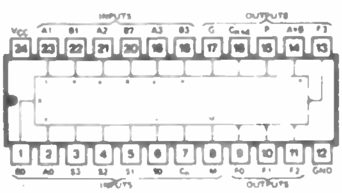

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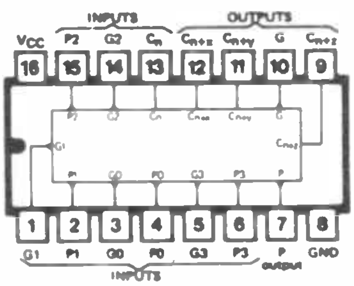

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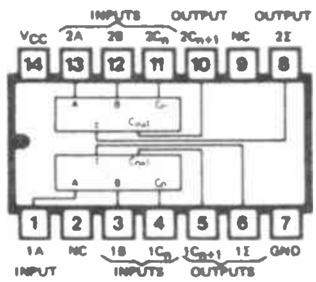

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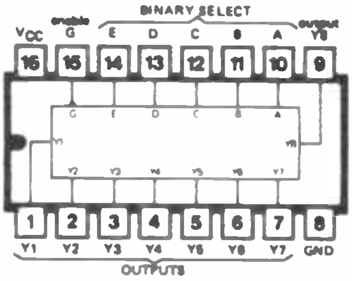

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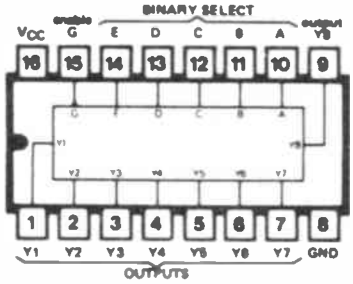

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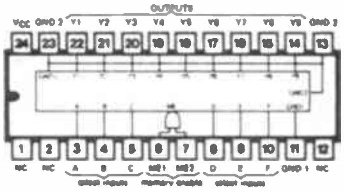

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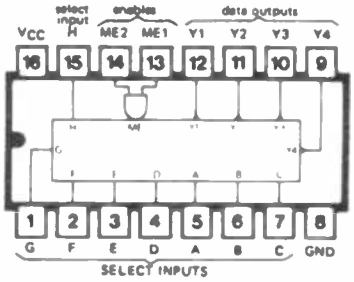

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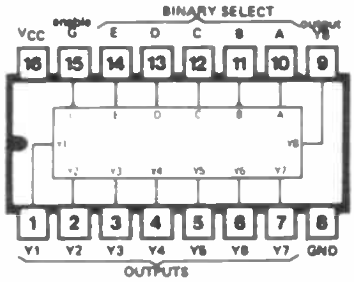

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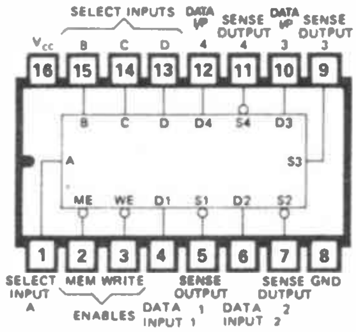

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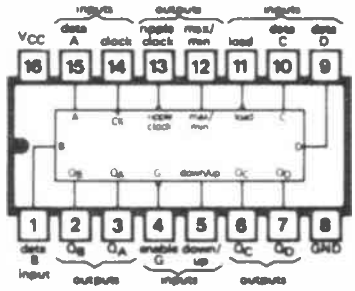

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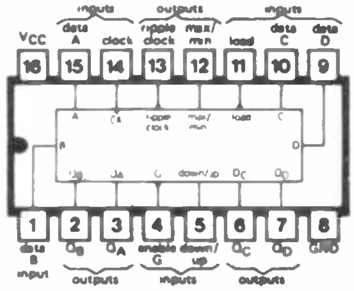

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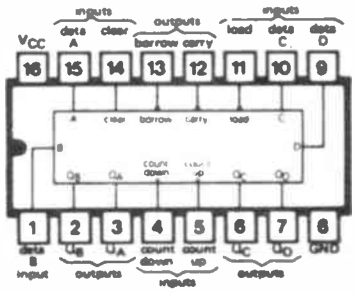

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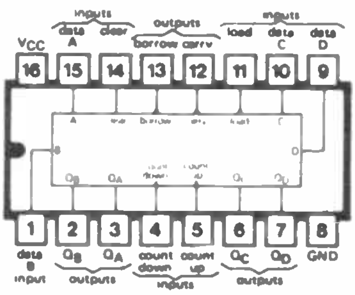

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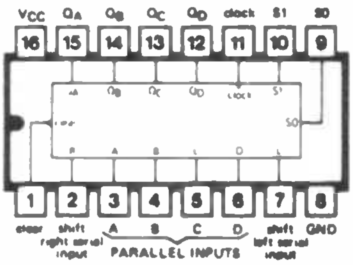

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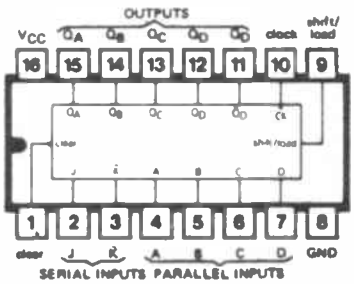

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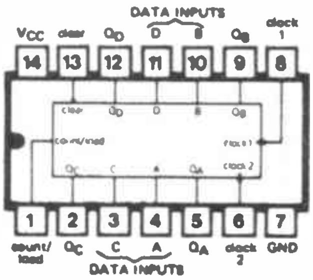

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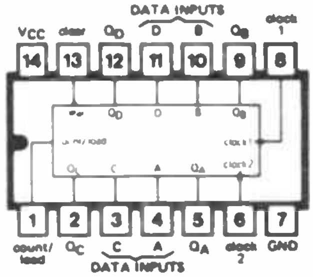

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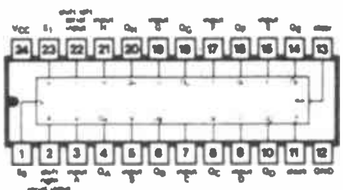

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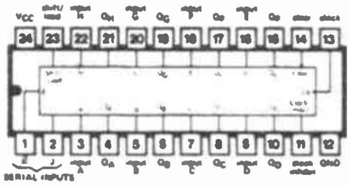

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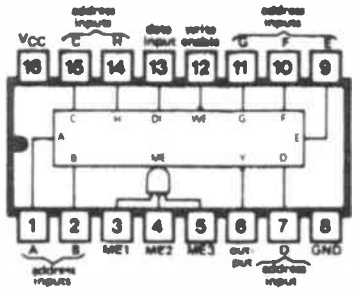

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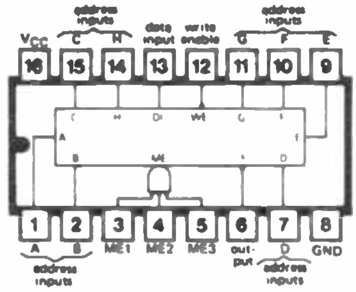

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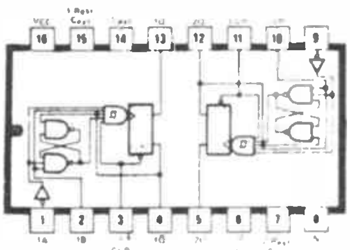

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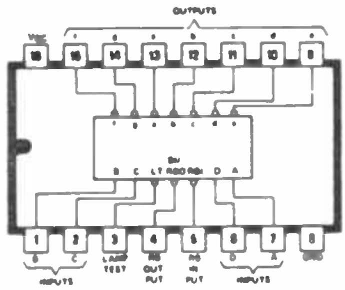

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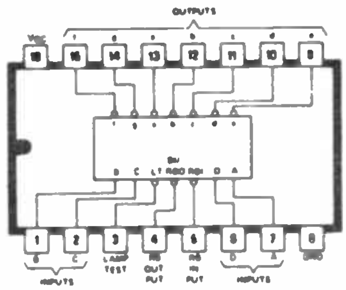

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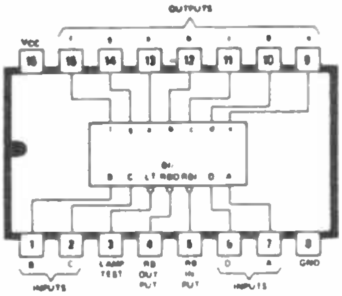

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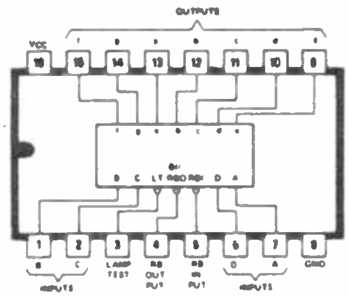

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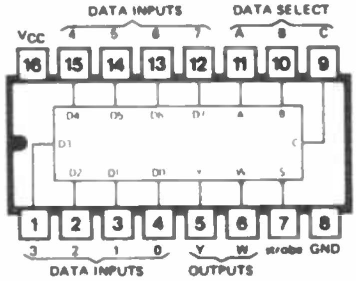

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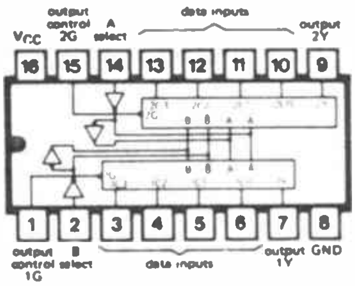

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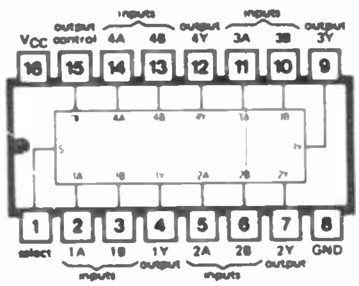

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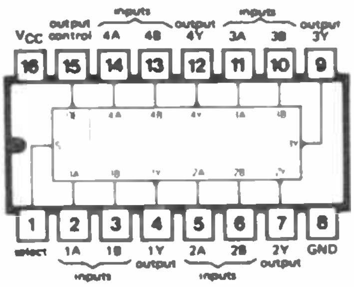

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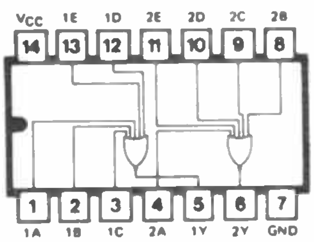

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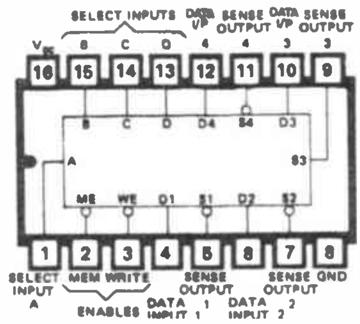

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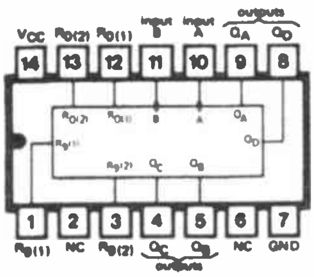

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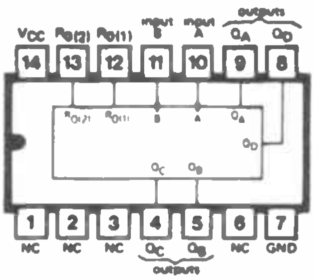

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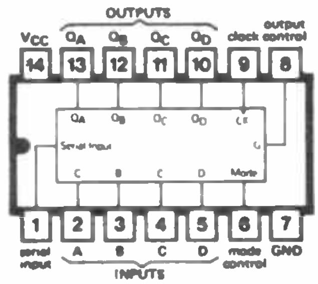

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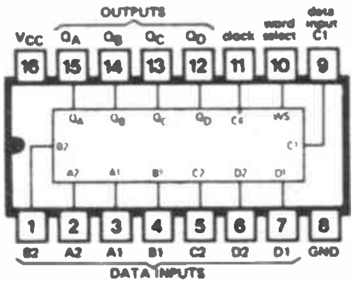

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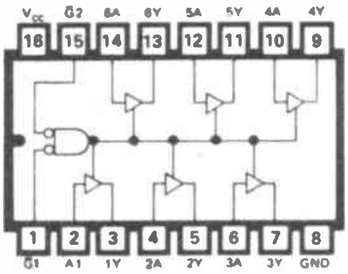

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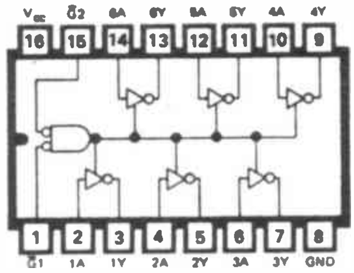

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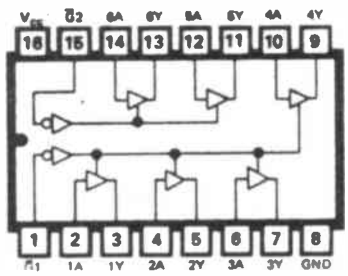

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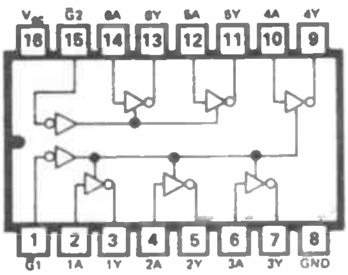

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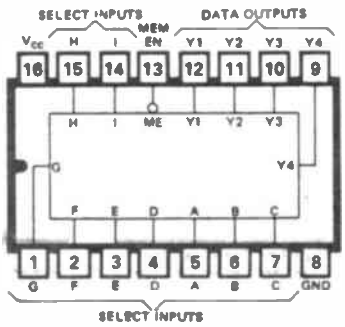

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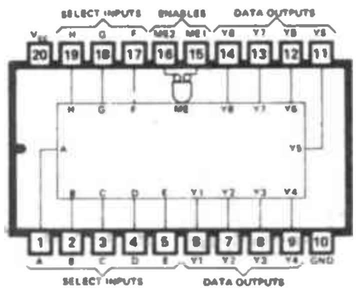

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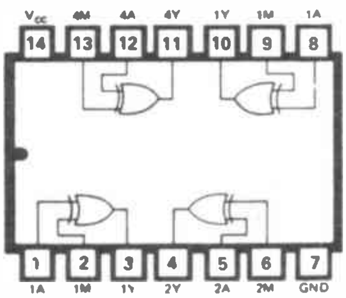

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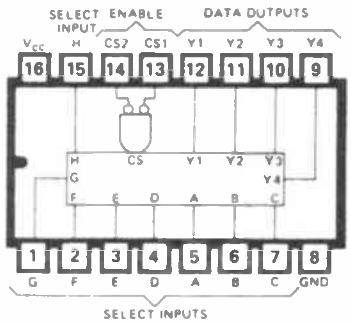

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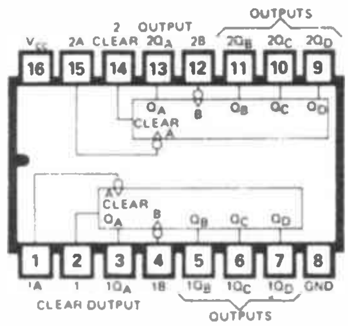

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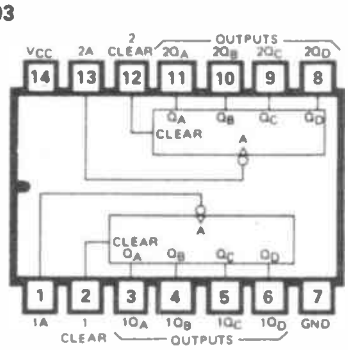

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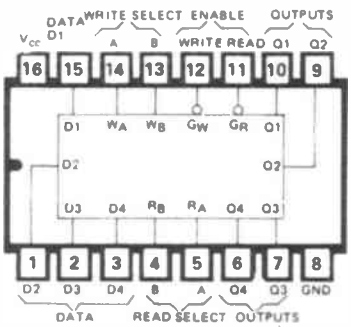

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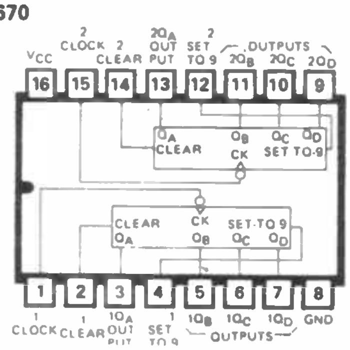
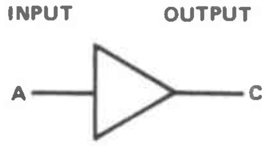


BASIC TRUTH TABLES

BUFFER



A	C
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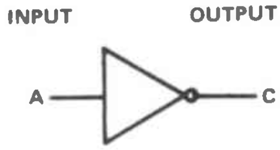
1	1

INVERTER



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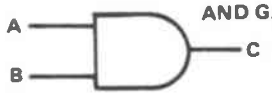
AND GATE



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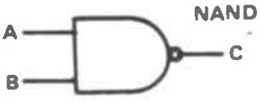
NAND GATE



A	B	C
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0	1	1
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EXCLUSIVE NOR GATE

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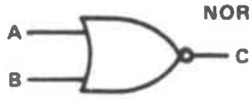
0	1	0
1	1	1

NOR GATE



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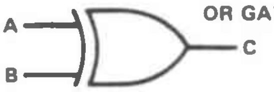
EXCLUSIVE OR GATE



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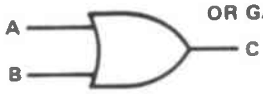
OR GATE



A	B	C
0	0	0
1	0	1
0	1	1
1	1	1

LAWS OF BOOLEAN ALGEBRA

$A + 0 = A$	$A.A = A$
$A + 1 = 1$	$A + \bar{A} = 1$
$A.0 = 0$	$A.\bar{A} = 0$
$A + A = A$	$A.1 = A$

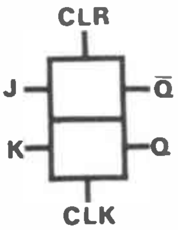
$A.B + A.C = A(B + C)$

$A + B.C = (A + B)(A + C)$

$\overline{A.B.C} = \bar{A} + \bar{B} + \bar{C}$

$\bar{A}.\bar{B}.\bar{C}. = \overline{A + B + C}$

J.K. Flip Flop



INPUTS			OUTPUTS		
CLR	CLK	J	K	Q	$\bar{Q}$
0	X	X	X	0	1
1	⎍	0	0	Q_o	$\bar{Q_o}$
1	⎍	1	0	1	0
1	⎍	0	1	0	1
1	⎍	1	1	TOGGLE	

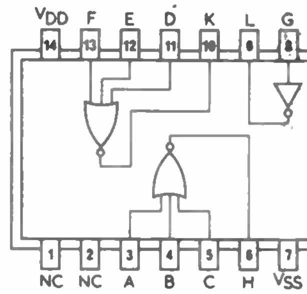
⎍ —HIGH LEVEL PULSE, DATA IS TRANSFERRED ON FALLING EDGE OF PULSE.

Q_o —THE LEVEL OF Q BEFORE INDICATED INPUT CONDITIONS WHERE ESTABLISHED.

TOGGLE —EACH OUTPUT CHANGES TO ITS COMPLEMENT ON EACH ACTIVE TRANSIENT (PULSE OF CLOCK).

CMOS PINOUTS

4000



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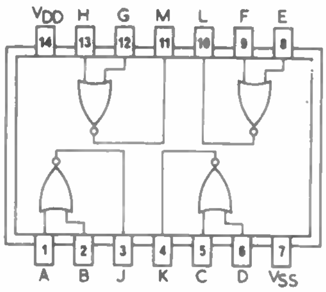

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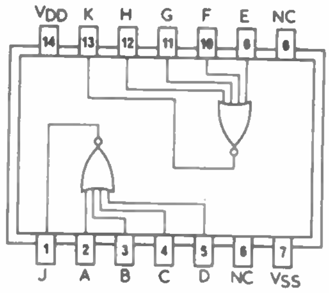

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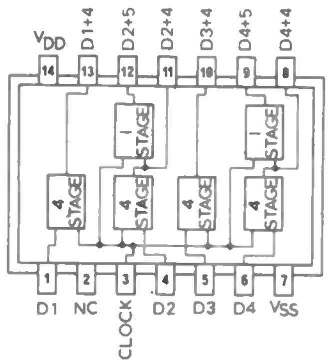

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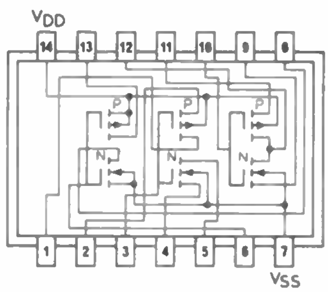

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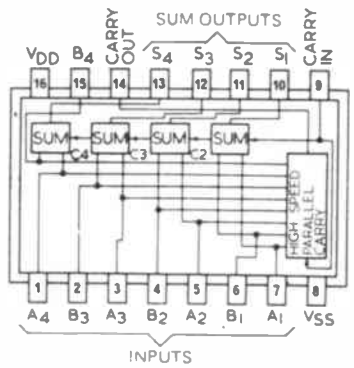

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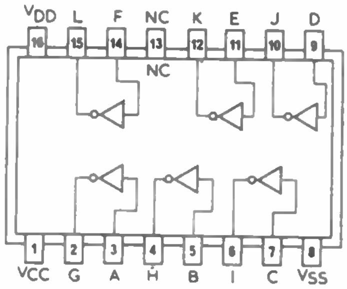

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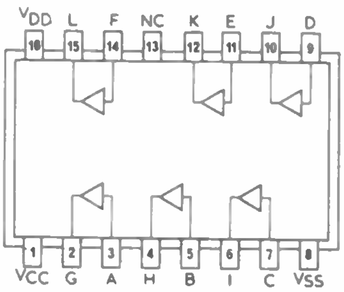

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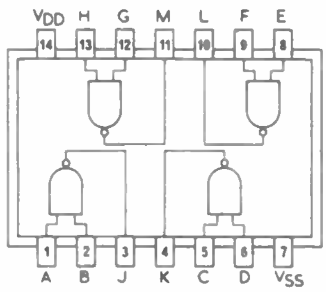

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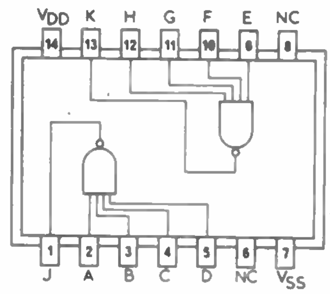

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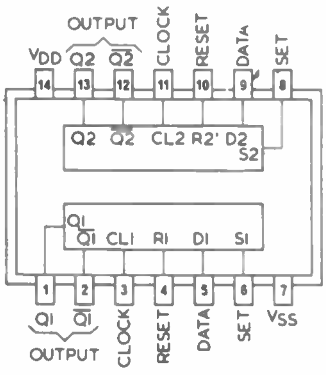

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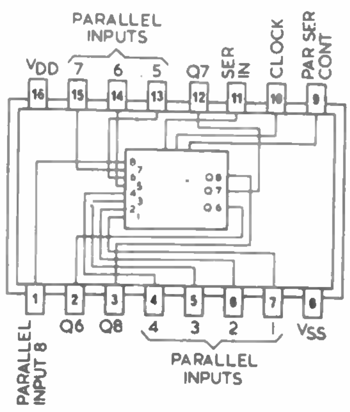

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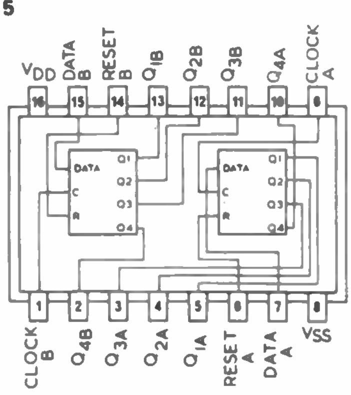

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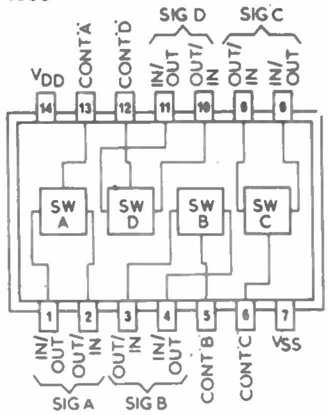

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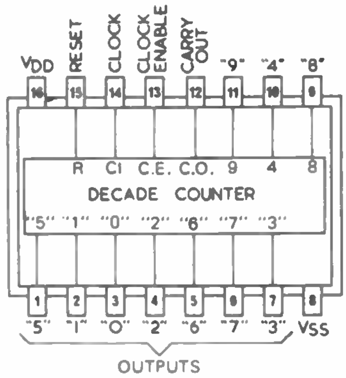

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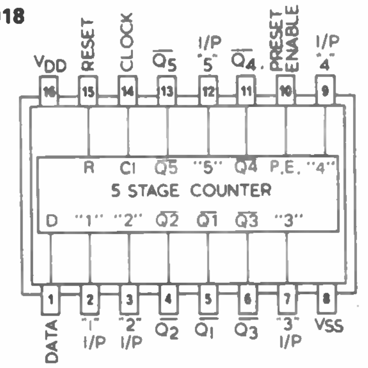

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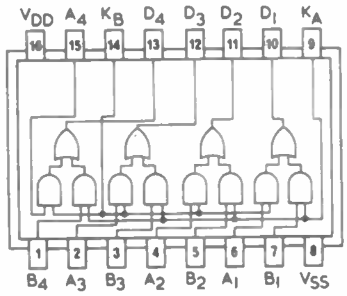

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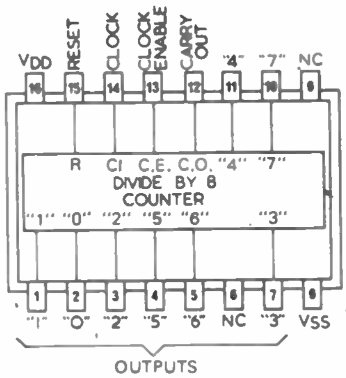

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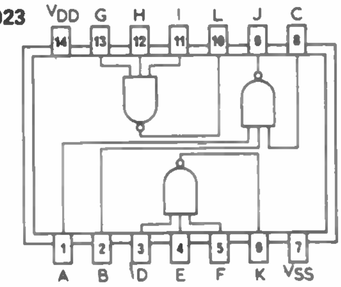

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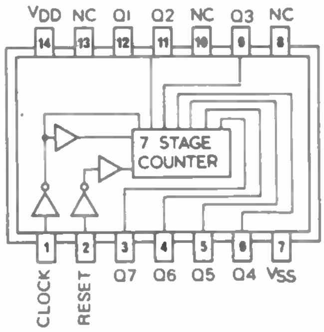

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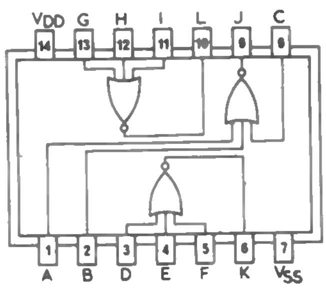

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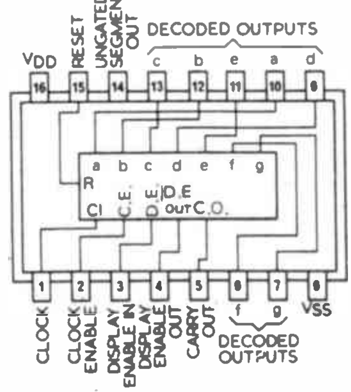

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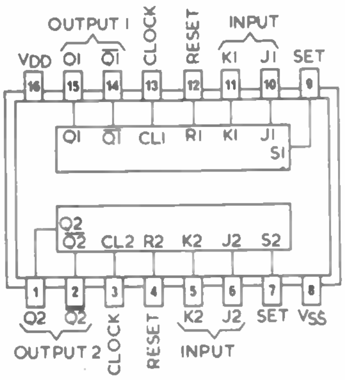

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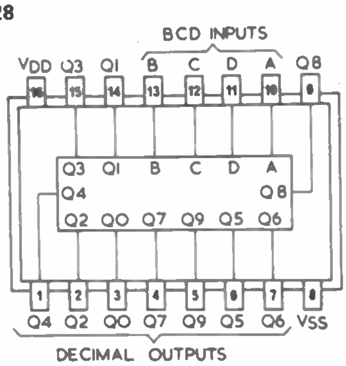

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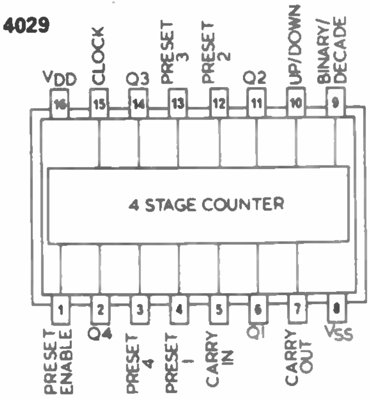

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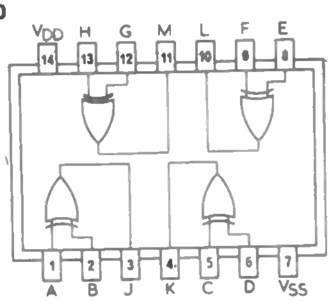

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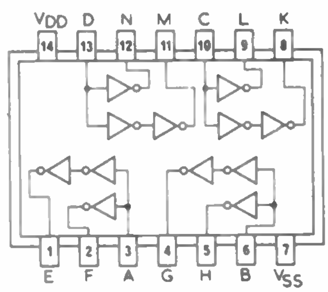

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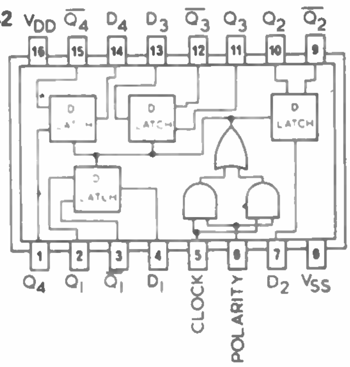

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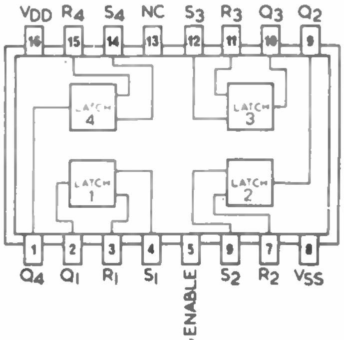

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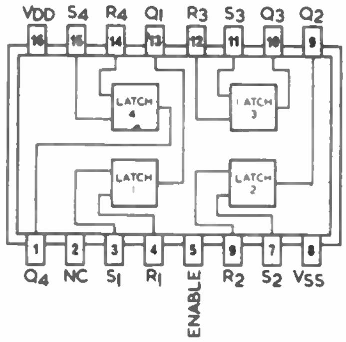

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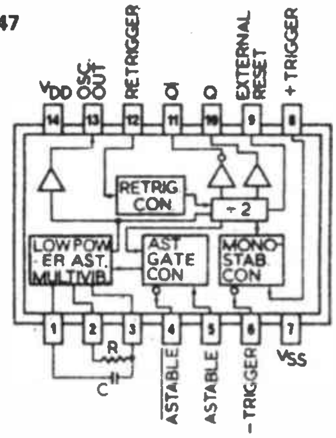

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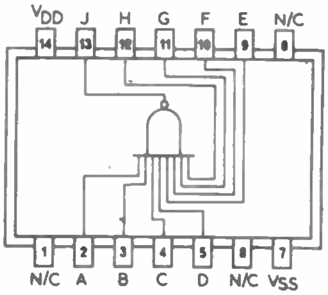

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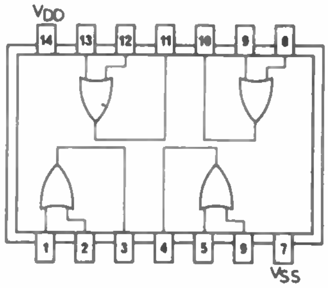

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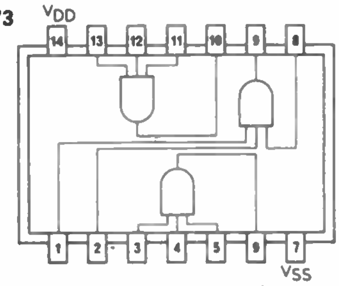

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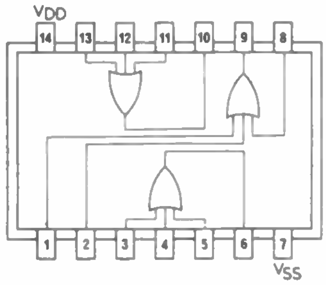

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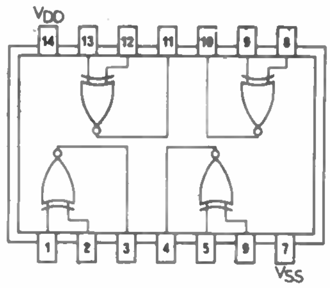

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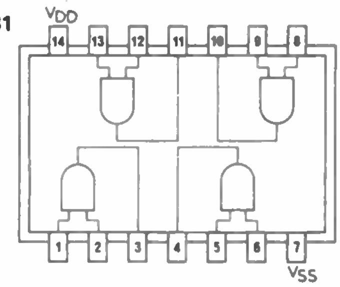

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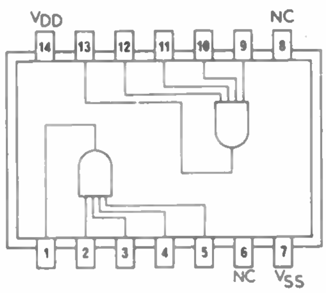

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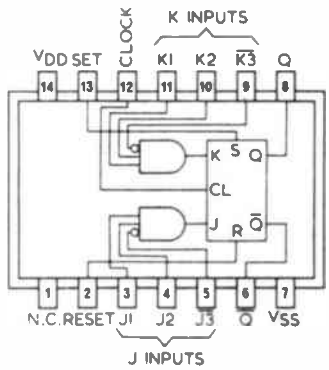

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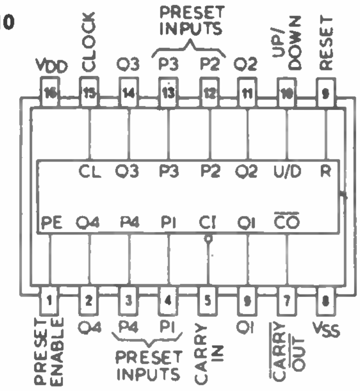

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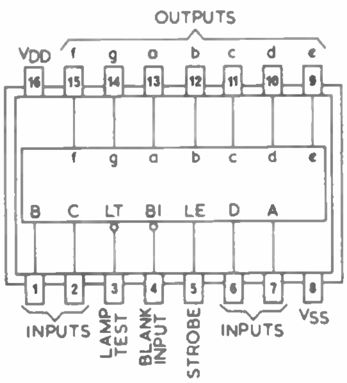

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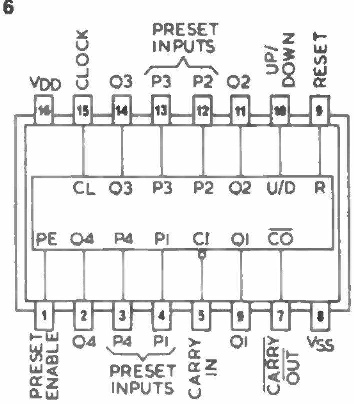

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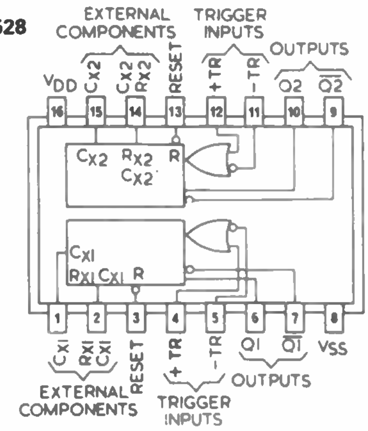


POTENTIOMETERS

POTENTIOMETERS ARE MADE in such a bewildering array of sizes, shapes, styles, and combinations that it is difficult to sort out what best suits a particular situation and what alternatives there may be. Apart from that, they come in a variety of wattage ratings, voltage ratings, resistance variation 'laws', etc — and how are you going to sort through that lot?

Potentiometers perform some control function by varying a resistance element or by tapping off a voltage from a fixed resistance. The variable resistor may need to be varied continuously so that some control function is performed, or it may be a 'preset' control which is only required for some calibrating or 'trimming' function. Preset potentiometers are generally called 'trimpots'.

Types

There are five basic types of potentiometer, classified according to the type of resistance element employed.

Carbon composition pots have a composition element moulded to the required size and shape and generally employ a metallic spring-wiper. They are generally quite inexpensive but have the disadvantage that they become noisy after use. Carbon film pots consist of a resistive film that is sprayed or screened onto a phenolic former of the required size and shape. A metallic spring-wiper is also generally used in this type of pot, and the element will withstand many more rotations than a composition type before noise problems. Carbon film pots are also inexpensive and are the commonest types in use, along with Hot Moulded Carbon types. Carbon film pots have a good degree of resolution whereas the composition types are poor in this respect.

Hot Moulded Carbon potentiometers are manufactured by a process wherein the resistive element, insulating base, and terminations are moulded into one integral part. A carbon wiper contact is usually employed. They have a high wattage rating on a size-to-size basis and a high degree of conformity between units. This factor, together with their very high resolution, has led them to be increasingly used as precision controls. They exhibit low noise levels in operation compared with carbon film and wirewound types.

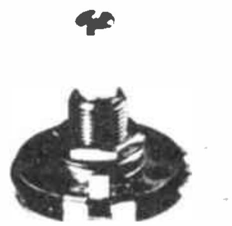


Fig. 1. The common, basic style of potentiometer. It has a threaded bushing and nut for panel mounting through a single hole and standard solder lug terminals.

Cermet potentiometers find wide application in precision controls, as trimpots and in many stringent applications (the element is rugged, exhibits low noise levels in use, and has good resolution). Wattage ratings are similar to those for hot moulded carbon pots of a similar size. They are generally somewhat more expensive. A metallic wiper is usually employed.

Wirewound potentiometers consist of a resistance wire would on a former with a metallic wiper, although a graphite wiper contact is sometimes used on low value, high wattage types. They have the disadvantage of being noisy, the resistance changes in small 'steps' as the wiper passes over the turns of wire, and they are usually more bulky than other types of equivalent value. However, they can be made in very low resistance values and they are able to dissipate much more power than other types of equivalent value.

Styles

The most common, basic style of potentiometer is illustrated in Figure 1.

In some applications, 'Tandem' or 'Ganged' potentiometers are required (for example for stereo tone and balance controls). They consist of several potentiometers all connected to the one shaft and stacked one behind the other, as illustrated in Figure 2. 'Dual-Concentric' potentiometers appear similar to the dual-ganged pot on the left in Figure 2. However, in this case, each pot is separately controlled by means of two concentric shafts. Dual-concentric pots are often used where there is limited space (e.g., for the RF and audio gain controls on a communications receiver).

Switches are often mounted on the rear of potentiometer assemblies and connected (mechanically) to the control shaft so that the one control knob may serve several functions. There are three basic types of switches generally used: the rotary type, the push-pull type and push-push type. A rotary style of switch is often employed as a mains-power switch on a control, such as a volume control. It has the advantage that when the switch is moved to the ON position the control is at minimum. But, it has the disadvantage that anything up to the first 15% or 20% of the control cannot be used. On many controls this is of little consequence. Push-Push and push-pull switches have the advantage that the control may be left in a certain position and switch operation does not disturb it. With a volume control however, this may be disastrous as the equipment may be turned on while the volume control is at a high setting, or worse still, full on!

While solder-lug terminals are commonly found, potentiometers are also manufactured with terminals suitable for printed circuit board mounting,

Power Ratings

With the exception of wirewound types the majority of standard potentiometers are obtainable in ratings of 0.1, 0.2, 0.25, 0.5 and 1 watt. Potentiometers are derated in much the same manner as fixed resistors. If this information is desired it is best to consult the manufacturer's literature.

Wirewound potentiometers are obtainable in ratings up to 100 watts (!!) but more usually they are available in ratings (depending somewhat on their resistance value) of 0.5, 1, 2, 5, 10, 15 and 20 watts. The higher power ones are usually quite bulky. Cermet and hot moulded carbon types are generally the smallest size for a given rating.

Resistance Law

The resistance 'law' of a potentiometer refers to the manner in which the resistance changes (as measured between as end terminal and the wiper terminal) with rotation of the shaft. There are a considerable number of different 'laws' in common use. The main ones however are: linear, logarithmic, and 'S' law. These are illustrated in Figure 3. Note that various log laws are used, the 20% log law is the more common one however. The laws for both clockwise (CW)

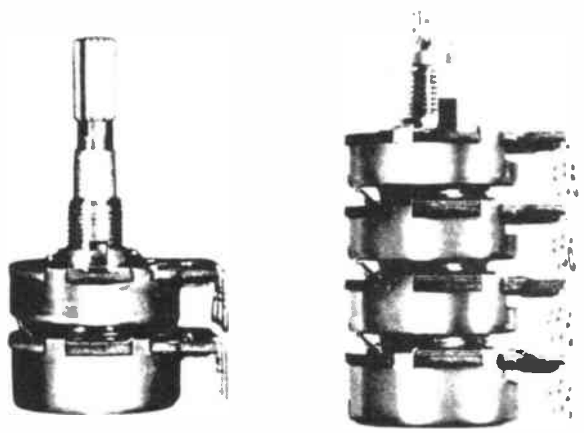


Fig. 2. 'Tandem' or 'ganged' potentiometers consist of several potentiometers controlled by one shaft. 'Dual-concentric' types are similar to the one on the left except that they are separately controlled by concentric shafts one inside the other – the inner shaft controlling the 'back' pot and the outer shaft controlling the 'front' pot.

and counter-clockwise (CCW) log are illustrated, as the potentiometer may be connected to operate in reverse fashion if desired. The various common laws are given a letter code which is stamped or marked on the body of the assembly along with the resistance value. The code is quite straightforward, as follows:

- A = linear law
- B = logarithmic law
- C = reverse logarithmic (or anti-log)
- S = 'S' law.

A pot may be marked 25kA, which is a 25k ohm, linear law potentiometer. Another may be marked 1M/C, which is a one megohm, reverse logarithmic pot.

The linear law control varies resistance in direct proportion to the rotation of the shaft. This type of pot is commonly used in voltage control applications, on tone controls and other applications which require a straightforward resistance variation.

With a log law control, the resistance increases very gradually during the initial rotation of the shaft, most of the resistance change occurring in the last 20-30% of the rotation. This type of law approximates the natural sensation of loudness as our ears follow a logarithmic law in their sensitivity to sound amplitude. Consequently, such controls are frequently used as volume controls so that they produce an apparent linear increase in sound output as the shaft is rotated. If a linear control were used, the greatest change in perceived volume would occur within the first 10-20° of shaft rotation.

Anti-log laws provide the reverse the greatest change in resistance takes place in the early portion of the shaft rotation, the least change occurs in the last 30-40% of shaft rotation.

The 'S' law provides only a small change in resistance for the initial and final 20% of shaft rotation and provides a linear variation between these extremes.

Other laws include semi-log and linear-tapered. These have curves that lie between the log and linear curves on the graph in Figure 4.. The semi-log law provides a somewhat greater change of resistance-versus rotation over the first 40% of shaft rotation than with the log curve. The linear-taper provides a nearly logarithmic variation over the first 50% of shaft rotation and a linear variation thereafter.

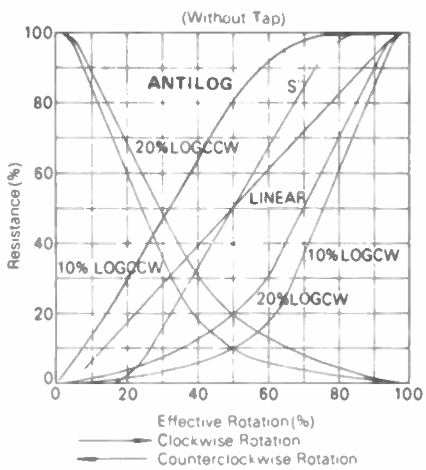


Fig. 3. The common resistance-versus-rotation 'laws' as 'tapers' for potentiometers.

Resistance Ranges

Most types of carbon element potentiometers are made in values ranging from 50 ohms up to 2 M. Some older types were made in values as high as 500 M. Cermet potentiometers are made in values ranging from 10 ohms to 10 M.

Some manufacturers make their pots to values in the standard E6 (20%) series (i.e.: 47 ohms to 2 M for carbon types). However, many pots are made with values according to the following decade series: 10,15,20,25,50 & 100. i.e: 2 k5, 5 k, 10 k, 15 k, 20 k, 25 k, 50 k, 100 k etc . . .
Some (typically of US make) include 75 in the value range.

Wirewound potentiometers are made in values ranging from 10 Ω to 100 k.

Slide Pots

These are pots having a linear element rather than a circular element as in standard pots. They are available generally with a carbon element having slider ranges of typically 50 mm, 75 mm, and 100 mm in the various laws as previously illustrated.

Slide pots have particular advantages of their own. One being that it is easier to see the proportional position of the control at a glance than with standard potentiometers. In some circumstances the slide pot provides a much more convenient form of control, for example in multi-channel audio mixer applications.

Trimpots

Trimpots are usually 'preset' controls. That is, they are only adjusted occasionally to set certain circuit parameters or conditions, for calibration purposes etc. Consequently they are generally adjustable by means of a screwdriver slot on the control shaft, although some have an integral knob to allow finger adjustment.

Trimpots are made in a wide variety of styles and sizes, as illustrated in Figure 4. Some types are enclosed to prevent the ingress of dust etc which can cause the control to become noisy in operation. Many types are only single-turn controls with the wiper covering only 180° in some cases, while others cover the more conventional 270-280° of rotation. Other trimpots are made for more critical applications and have a multi-turn control which allows a much finer and more accurate adjustment.

Manufacturers make trimpots in values ranging from 50 ohms to 5 M for carbon element types, and typically up to 30 M for Cermet types.

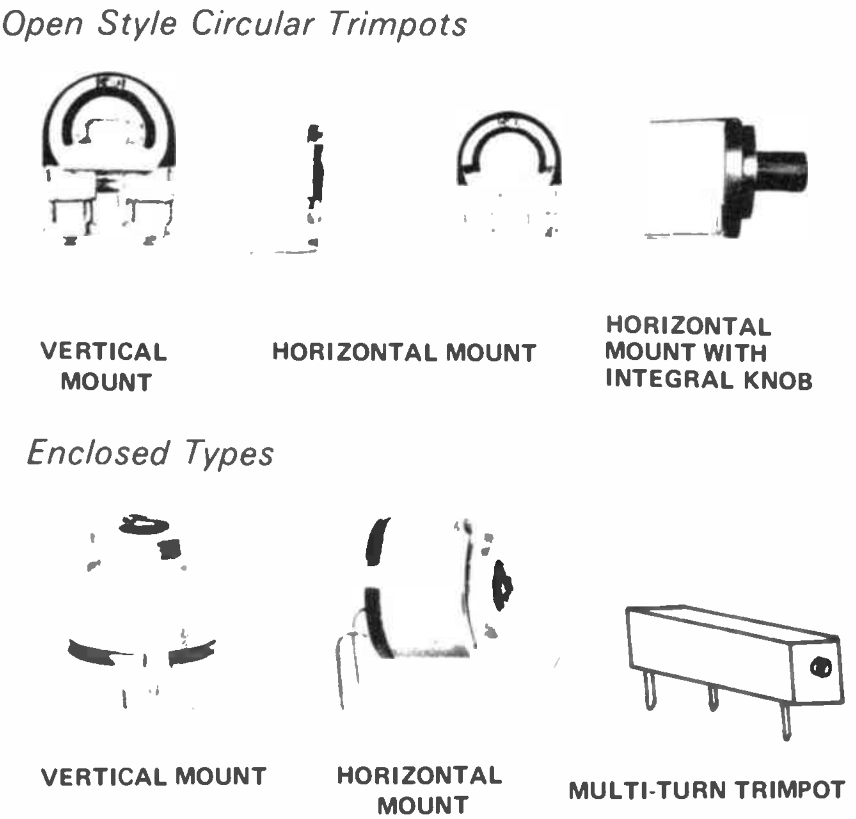


Fig. 4. Examples of various styles of trimpots.

Wirewound types are made in values typically ranging from 100 ohms to 5 k. Wattage ratings for the various types are typically 0.1, 0.2, 0.25, 0.5 up to 1 W. Trimpots are available in the same range of laws as are standard potentiometers, although most common styles have a linear law. Other characteristics are the same as for the type of element employed.

Connecting Potentiometers

One thing that baffles electronic project constructors is the 'correct' way to connect a potentiometer.

The best way to illustrate how to do it is by example. The most common application of a potentiometer is that where it is required to vary a quantity (signal, voltage, etc) so that an increase occurs when the control shaft is rotated *clockwise*. The best example of this is a volume control.

In Figure 5 a pot is illustrated typically as you would see it when you come to make the connections. The arrow indicates the direction in which the control shaft will be turned to increase the output. THE TERMINAL IN THE CENTRE IS ALWAYS THE WIPER CONNECTION. So, terminal 1 (on the left as you view it to wire it up), connects to 'ground' or minimum. Terminal 2 (the wiper) connects to the output (in some cases it can also be the input terminal; operation of the pot still remains the same). Terminal 3 (the one on the right) connects to the input (or the output if the input is connected to the wiper).

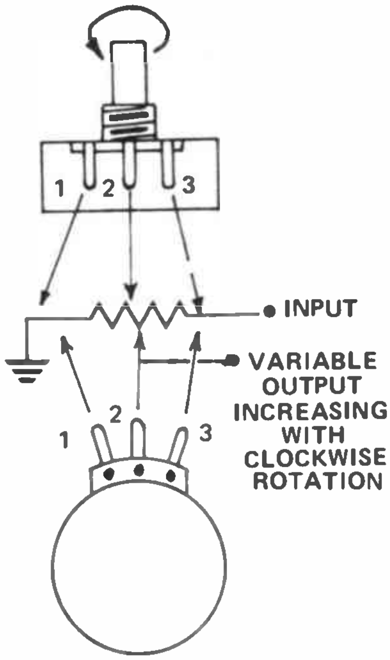


Fig. 5. Connecting a pot as a simple 'increase clockwise' control (e.g. volume).

Fig. 6. Pots in some applications require only a variation in resistance. Which terminals are connected together depends on the circuit effect.

Try it out for yourself. Get a 1 k (linear is best) pot and a battery (anything from 1.5 V to 9 V will do), hook up the battery with the positive to terminal 3, and the negative, to terminal 1. Connect a voltmeter with the negative to terminal 1 and the positive lead to terminal 2. Commence with the control shaft at the fully anti-clockwise position (hard left!). As you slowly rotate the shaft clockwise, the reading on the voltmeter will rise. True! It's easier to do it than it is to read about it. The wiper, in this case, commences at terminal 1 and moves towards terminal 3.

Some applications require the pot to work in the reverse fashion. For example, as a frequency or pulse rate control in an oscillator or multivibrator. In such cases, an increasing effect occurs as the wiper traverses towards the 'minimum resistance' end of the control. The pot is simply connected so that terminal 1 is the 'maximum resistance' end of the control and terminal 3 the minimum.

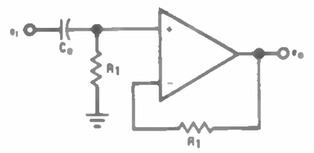
In some applications the circuit shows that the wiper is shorted to one of the 'end' terminals. But which one? Terminal 1, or 3? In such cases it depends on whether the 'maximum effect' occurs at minimum or maximum resistance. Look at Figure 6. The circuit shows that as the wiper traverses the element it shorts out the section of the track it has just traversed, decreasing the resistance as it moves towards the terminal which is not connected to the wiper. Leaving one 'end' terminal unconnected achieves the same purpose.

If the *maximum* effect (from the circuit in which the pot is to be connected) occurs at *minimum* resistance then terminals 1 and 2 are connected together. Maximum resistance (and thus minimum effect) occur at fully anti-clockwise rotation (hard left!). The effect increases as the control is rotated clockwise.

On the other hand, if the *maximum* effect occurs at *maximum* resistance then terminals 2 and 3 are connected together. Thus, as the control is rotated clockwise from the fully anti-clockwise position the resistance, and thus the effect, increases. ●

OP AMP CIRCUITS

Non-Inverting Buffer



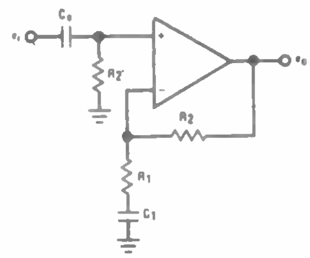
$A_v = 1$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_o}$

Definitions
Av = Closed loop AC Gain
fo = Low frequency −3dB corner
Rin = Input impedance

Non-Inverting AC Amplifier

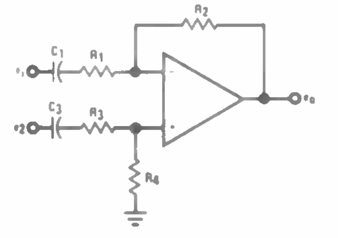


$A_v = 1 + \frac{R_2}{R_1}$

$R_{in} = R_2$

$f_o = \frac{1}{2\pi R_2 C_o} = \frac{1}{2\pi R_1 C_1}$

Difference Amplifier



$e_o = \left(\frac{R_1 + R_2}{R_3 + R_4}\right)\frac{R_4}{R_1} e_2 - \frac{R_2}{R_1} e_1$

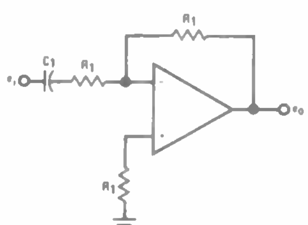
IF $R_1 = R_3$ AND $R_2 = R_4$ THEN

$e_o = \frac{R_2}{R_1}(e_2 - e_1)$

$f_o = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi (R_3 + R_4) C_3}$

$R_2 = R_4$ FOR MINIMAL OFFSET ERROR

Inverting Buffer

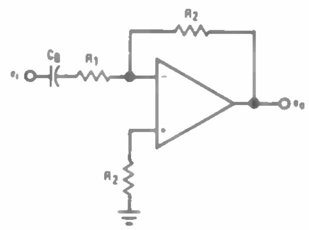


$A_v = -1$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_1}$

Inverting AC Amplifier

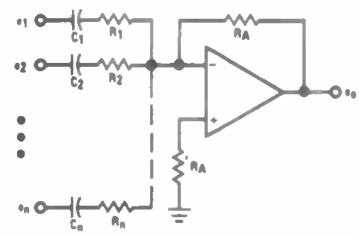


$A_v = -\frac{R_2}{R_1}$

$R_{in} = R_1$

$f_o = \frac{1}{2\pi R_1 C_o}$

Inverting Summing Amplifier



$e_o = -R_A\left(\frac{e_1}{R_1} + \frac{e_2}{R_2} + \ldots + \frac{e_n}{R_N}\right)$

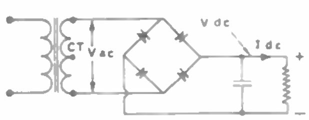
IF $R_1 = R_2 = \ldots = R_N$ THEN

$e_o = -\frac{R_A}{R_1}(e_1 + e_2 + \ldots + e_n)$

THE SUPPLY CONNECTIONS HAVE BEEN OMITTED IN THE ABOVE CONFIGURATIONS FOR THE SAKE OF CLARITY.

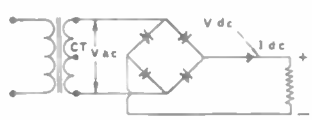
PSU CIRCUITS

FULL-WAVE BRIDGE – CAPACITIVE INPUT FILTER



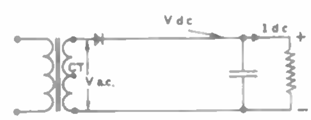
Vdc = 1.41 × Vac
Idc = 0.62 × Iac

FULL-WAVE BRIDGE – RESISTIVE LOAD



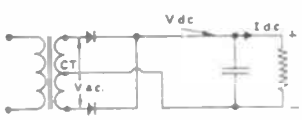
Vdc = 0.90 × Vac
Idc = 0.90 × Iac

HALF-WAVE – CAPACITIVE INPUT FILTER



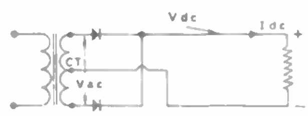
Vdc = 1.41 × Vac
Idc = 0.28 × Iac

FULL-WAVE – CAPACITIVE INPUT FILTER



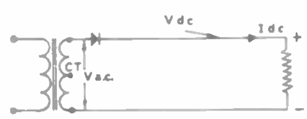
Vdc = 0.71 × Vac
Idc = 1.0 × Iac

FULL-WAVE – RESISTIVE LOAD



Vdc = 0.45 × Vac
Idc = 1.27 × Iac

HALF-WAVE – RESISTIVE LOAD



Vdc = 0.45 × Vac
Idc = 0.64 × Iac

IC SURVEY

THERE ARE VERY many ICs available on the market today, and new devices seem to appear daily (probably hourly). This barrage of technology can be rather daunting, particularly to the newcomer to electronics. The following article tries to untangle some of the confusion by surveying IC technology in four groups of devices; Op Amps, audio amplifiers, multipliers, and oscillators.

Operational Amplifiers (Op Amps)

There are many different types of OP Amp and they are manufactured by several different companies. Most of these companies produce standard Op Amp devices but they put their own part number on them.

In recent years, the trend has been to develop IC's with more than one Op Amp inside. This has resulted in a range of dual and quad Op Amp packages. Texas have brought out a range of Bifet Op Amps. These are pin for pin compatible with standard types, but they are different in that they have FET inputs, giving them a very high input impedance.

Chart 1 shows comparative performance for several standard Op Amp types. The parameters chosen are the most important ones when selecting Op Amps.

Audio Amplifiers

Several manufacturers produce monolithic medium power amplifiers for audio use. This makes the design of small audio amplifier sections relatively easy. There are some pitfalls to watch out for. IC amplifiers can easily destroy themselves if the power rails are high or if insufficient heat sinking is provided. There are now quite a wide range of devices, some of which are shown in Chart 2.

Multipliers

The range of multiplier ICs has never been very large, but recently a few more have been added to the list partly inspired by the needs of telephone companion systems. These systems produce a better signal to noise ratio over the line. Another and very common noise reducer (a special multiplier) is the Dolby B chip. This unfortunately is only obtainable under license.

Oscillators

There are many oscillator ICs that can provide waveforms with periods of several hours to tens of nano seconds. For high frequency work there is the SN74S124 at 85 MHz and the LM375 at 200 MHz. These are TTL devices, they are not linear and are intended for use in feedback circuits. The Teledyne 9400 is a well known linear VCO. Teledyne also make a wide range of VCO modules. The NM5837 and the S2688 are the same device. They are both pseudo random oscillators, that is, they oscillate but the waveform is so complex that the resultant output just sounds like noise. Chart 3 details the most common types.

CHART 1 OP AMP — ABRIDGED PERFORMANCE *S = Single D = Dual Q = Quad*

Op amp type	Input offset voltage mV	Input bias current nA	Type of input structure	Band-width MHz	Slew rate V/NS	Voltage gain gain dB	Maximum supply voltage V	CMRR dB	Qty	Comments
709	2	300	NPN	1	0.25	90	±18	90	S	*Needs frequency compensation*
307	2	70	NPN	1	0.25	100	±18	90	S	*Internal frequency compensation*
301	2	70	NPN	10	0.5	100	±18	90	S	*Needs frequency compensation*
741	2	80	NPN	1	0.5	106	±18	90	S	*Internal frequency compensation*
748	1	120	NPN	10	0.5	103	±22	90	S	*A decompensated 741*
308	2	1.5	NPN	3	0.5	110	±18	100	S	*Low supply current drain 0.3mA Needs frequency compensation Very low differential input voltage range*
318	4	150	NPN	15	50	106	±20	100	S	*Very low differential input voltage range. Sometimes needs frequency compensation*
747	2	80	NPN	1	0.5	106	±18	90	D	*Internal frequency compensation*
1458	1	80	NPN	1	0.8	103	±18	90	D	*Internal frequency compensation*
4136	0.5	40	PNP	3	1.0	110	±18	100	D	*Low noise*
3900 **3401**	Current inputs	30	Current sinks	2.5	0.5 20	70	±18	—	Q	*Current balancing amplifier*
324	2	45	PNP	1	0.5	100	+30	70	Q	*Ground sensing inputs Output voltage can go to ground Low power. 0.8mA drain per IC*
3403	2	150	PNP	1	1.2	100	+36	90	Q	*Ground sensing inputs Class AB output Output voltage can go to ground Low power 3mA drain per IC*
348	1	30	NPN	1	0.5	103	±18	90	Q	*Low power 2.4mA drain per IC Class AB output*

CHART 2
MONOLITHIC PREAMPLIFIER AND POWER AMPLIFIER SURVEY

Part Number	
FAIRCHILD	
nA 739	Low noise stereo preamplifier
nA 706	5 watt audio amplifier Low voltage
MOTOROLA	
MC 1306	0 5 watt audio amplifier 12V operation
NATIONAL SEMICONDUCTOR	
LM 370	AGC/squelch amplifier
LM 377	Dual 2 watt amplifier
LM 378	Dual 4 watt amplifier
LM 379	Dual 6 watt amplifier
LM 380	2 5 watt mono amplifier
LM 381	Dual low noise preamplifier
LM 382	Dual low noise preamplifier
LM 384	5 watt mono amplifier
LM 386	
LM 387	Low noise dual preamplifier
LM 388	1 5 watt mono amplifier
LM 389	0 35 watt mono amplifier plus npn transistor array
LM 390	1 0 watt low voltage amplifier
LM 1303	Stereo preamplifier
RAYTHEON	
RC 4136	Quad low noise op amp
RC 4739	Low noise stereo preamplifier
SIGNETICS	
NE 540	Power drive op amp
NE 542	Dual low noise preamp
RCA	
CA 3052	Stereo preamp
CA 3134	TV sound IF and audio output (3 watts)

CHART 3 OSCILLATOR SURVEY

Manufacturer	Part No.	Description	Package	Frequency range	
TEXAS	745124	Dual VCO	16 pin DIL	0 12Hz to 85MHz	TTL
EXAR	XR2209	LIN VCO (low cost)	8 pin DIL	0 01Hz to 1MHz 1000 1 sweep range	and
Teledyne	9400	LIN VCO	14 pin DIL	10Hz to 100kHz	Pulse and
EXAR	XR2206C	LIN ICO + AM + FSK	16 pin DIL	2000 1 sweep range 0 01Hz to 1MHz	Low distortion or Plus
EXAR	XR2205C	LIN ICO + AM	16 pin DIL	7 1 sweep up to 4MHz	
EXAR	XR2207C	ICO	14 pin DIL	1000 1 sweep range 0 01Hz to 1MHz	
EXAR	XR2209C	LIN VCO	8 pin DIL	1000 1 sweep range 0 01Hz to 1MHz	
Raytheon	RC4151	LIN VCO	8 pin DIL	0 -10kHz	Pulse
Intersil	8038	VCO	14 pin DIL	0 01 to 1MHz	
Signetics	NE555	Timer/Oscillator	8 pin DIL	Up to 100kHz	
Signetics	NE556	Dual 555	14 pin DIL	Up to 100kHz	
Signetics	NE566	LIN VCO	8 pin DIL	10 1 sweep 1MHz max	
National Semi Conductor	LM3909	Led Flasher	8 pin DIL	Up to 1kHz	LED or Loudspeaker drive
National Semi Conductor	LM375	VCO + TTL Buffer	14 Pin DIL	Up to 200MHz	TTL
National Semi Conductor	NM5837	Pseudo Random Oscillator	8 pin DIL		Pseudo random NOISE
AMI	S2688	Pseudo Random Oscillator	8 pin DIL		random NOISE
Motorola	MC14412	FSK Modem	16 pin DIL		Synthesised sinewave
Motorola	MC14410	2 out of 8 tone ENCODER	16 pin DIL	Audio	Telephone 2 tone sinewaves
Motorola	MC14450	OSC + 2^{16} divider	6 pin	For fixed frequency operation — as in watches	
Motorola	MC14451	OSC + 2^{11} to 2^{19} dividers			
Motorola	MC1451	Programmable Oscillator	16 pin DIL	Up to 100kHz	

ABBREVIATIONS
LIN—Linear
VCO—Voltage Controlled Oscillator
ICO Current Controlled Oscillator
AM—Amplitude Modulation
FSK—Frequency Shift Keying
DIL—Dual In Line

OP AMP — ABRIDGED PERFORMANCE

Op amp type	offset voltage mV	Input bias current nA	Type of input structure	Bandwidth MHz	Slew rate V/uS	Voltage gain gain dB	Maximum supply voltage V	CMRR dB	Qty/IC	Comments	Pin for pin replacement for
RC4739	2	40	PNP	3	1	110	±18	100	D	***Raytheon device only Low noise audio amplifier***	
uA739	1	300	NPN	10	1	86	±18	90	D	***Fairchild device only Low noise audio amplifier Needs frequency compensation***	
LM381	**Not applicable**	**Not applicable**	NPN	15	—	112	±20	—	D	***Low noise amplifier Internally compensated***	
CA3130	8	0.005	MOSFET	15	10	110	+16	90	S	***Ground sensing inputs Very high input impedance Needs frequency compensation***	
CA3140	8	0.010	MOSFET	4.5	9	100	+36	90	S	***Ground sensing inputs Very high input impedence***	
CA3160	6	0.005	MOSFET	4	10	110	+15	90	S	***Ground sensing inputs Very high / input impedence***	
NE531 RC4531	2	400	NPN	10	35	96	±22	100	S	***Very fast op amp Needs frequency compensation***	
CA3080	0.4	IABC 100	NPN	2	50	—	±18	110	S	***OTA device Programmable gain Current output***	
CA3094	0.4	IABC 300	NPN	30	50	—	±12	110	S	***OTA device Programmable power switch/ amplifier***	
TL080	15	0.4	JFET	3	13	83	±18	70	S	***JFET input op amps, with fast slew rate and wide bandwidth [TEXAS]***	***748***
TL081	15	0.4	JFET	3	13	83	±18	70	S		***741***
TL082	15	0.4	JFET	3	13	83	±18	70	D		***1458***
TL083	15	0.4	JFET	3	13	83	±18	70	D		***747***
TL084	15	0.4	JFET	3	13	83	±18	70	Q		***324***

TL080 OP-AMP FAMILY

The TL080 family of BIFET operational amplifiers, provides an ideal combination of high-impedance JFET inputs with a low-distortion bipolar output circuit. Quality performance in the TL080 family is achieved without complex circuitry.

TL080 family circuit description

The following sections should be read in conjunction with Fig 1, the basic schematic for one channel.

Bias circuits

FET Q16, zener D2, transistors Q14/Q15 and resistor R6 establish the bias currents for the input differential amplifier and the second gain stage. Epitaxial FET Q16 provides a fixed current to D2 establishing 5.2V on the base of Q15. The resulting 317uA collector current of Q15 flows through Q14 and sets the current levels in Q1 and Q9.

Resistor R1 causes 196uA current in Q1 that is divided between the input stage JFETs Q2 and Q3. The second-gain-stage bias current, about 600uA, is derived from Q9.

Input circuit

Input JFETs Q2 and Q3 operate into the active load circuit consisting of Q4, Q6, and Q7. Current imbalance and input offset voltages may be adjusted on the TL081 and TL083 through connections to the emitters of Q6 and Q7. External offset controls for the TL080 connect to the collectors of Q6 and Q7. The C1 compensation capacitor is internal on the TL080, TL082 and TL083, and TL084. For the TL080 connections for external compensation are provided which allow user adjustment of AC characteristics.

Ion-implanted input devices provide very high input impedance, controlled pinch-off voltage for maximum common-mode input range, and matched characteristics for control of the input offset voltage. JFET inputs also allow adequate drive to the second stage resulting in maximum output peak-to-peak capability and wide power band widths.

Output stage

Q10 and Q11 provide Class AB bias to the output transistors Q12 and Q13. This allows near zero crossover distortion and produces a low total harmonic distortion at the output. The simplicity of the output circuit results in minimum silicon area requirements keeping manufacturing cost down while maintaining quality performance. R2, R3 and R4 form the output short-circuit protection network.

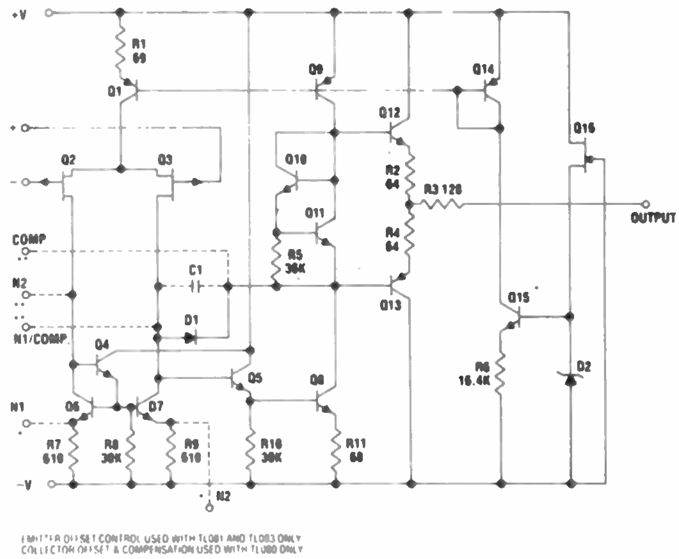
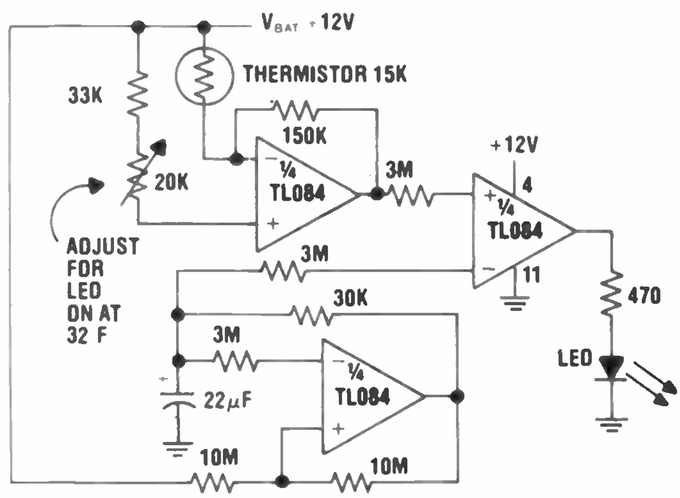


Fig 1. Schematic diagram for TL080 family.

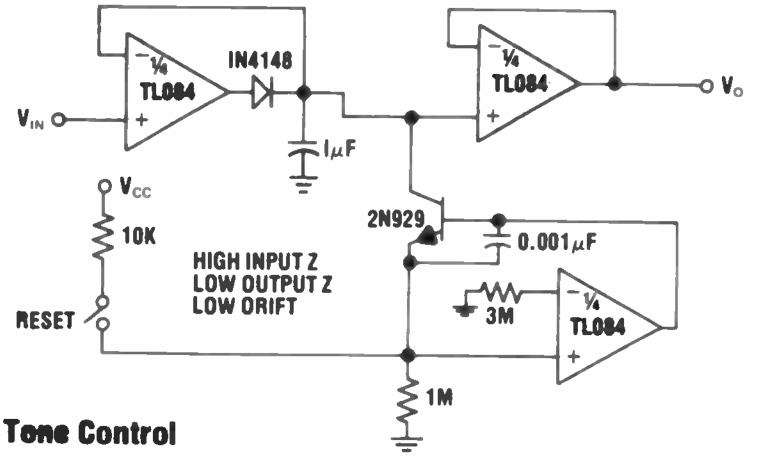
Second stage

Drive from the input stage is single-ended from the collector of Q7. D1 provides a clamping action across Q5 and Q8 preventing saturation of Q8 and excessive current in Q5. Q5 and Q8 form the high-gain second stage. The second stage output, collector of Q8, drives the output stage consisting of bias transistors Q10 and Q11, and output drivers Q12 and Q13.

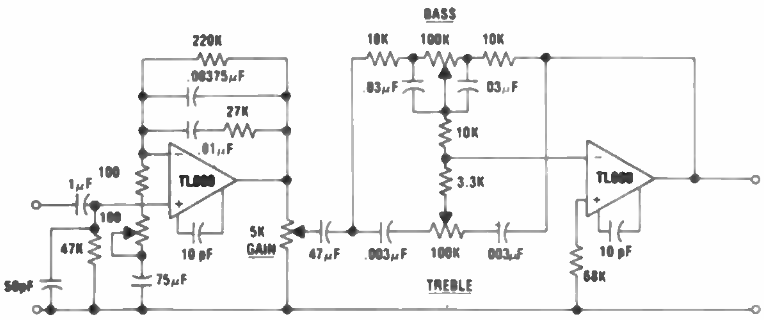
Icy Road Warning Indicator



Peak Detector

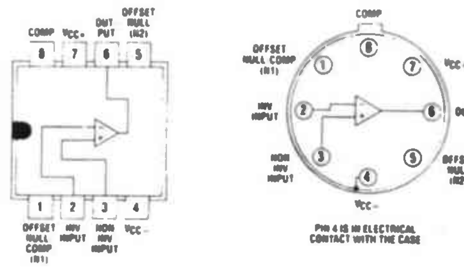


Tone Control

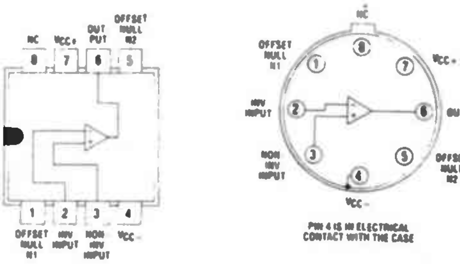


PIN OUTS

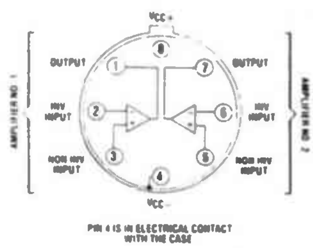
TL080



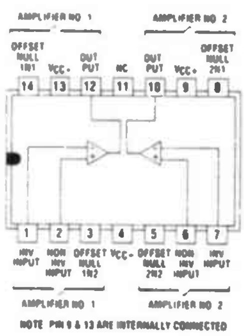
TL081



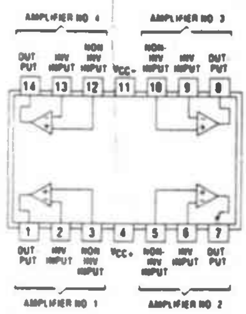
The TL082



The TL083



The TL084



FEATURES	ADVANTAGES
● HIGH INPUT IMPEDANCE	Minimum loading effects allow efficient use with high impedance transducers.
● HIGH SLEW RATE	Provides the desired response characteristics required in audio frequency active filters and quality sound systems.
● LOW DISTORTION	Minimized crossover distortion yields very low total harmonic distortion for maximum performance in critical music systems.
● CONTINUOUS SHORT CIRCUIT PROTECTION	No damage resulting from accidental shorts or operation into low impedance loads.
● LOW POWER CONSUMPTION	Only 2.8 mA per operational amplifier. Less system power required and battery operation is practicable.

absolute maximum ratings		TL08_C TL08_AC TL08_BC
Supply voltage, V_{CC} (see Note 1)		18 V
Supply voltage, V_{CC} (see Note 1)		−18 V
Differential input voltage (see Note 2)		±30 V
Input voltage (see Notes 1 and 3)		±15 V
Duration of output short circuit (see Note 4)		Unlimited
Continuous total dissipation at 25°C free-air temperature	J,JG,N, or P Package	680 mW
	L Package	625 mW
Operating free-air temperature range		0 to 70°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

SN76477

THE SN76477 is a bipolar/I²L device that provides a noise source, VCO, low frequency oscillator, envelope generator, plus various mixing and control logic on a single 28 pin DIL package. By the connection of appropriate external components and application of logic level control signals a wide variety of complex sounds can be synthesized. The design of the SN76477 allows for maximum user flexibility and the device should prove useful in applications requiring audio feedback to an operator (home video games, toys, timers, alarms, etc.).

SLF (Super Low Frequency Oscillator)

The SLF can be operated in the range 0.1-30 Hz, the specific frequency is determined by a control resistor connected to pin 20, and a capacitor connected to pin 21. The frequency being given by the following equation

$$F_{SLF} = \frac{0.64}{R_{SLF} C_{SLF}} \text{Hz}$$

VCO (Voltage Controlled Oscillator)

The VCO provides an output whose frequency is dependent upon a voltage fed to its input, the higher the voltage the lower the frequency. The control voltage may be either the SLF output, or an external voltage applied to pin 16, the SLF output being selected when the voltage applied to pin 22 is a logic '1', and the external source when pin 22 is at logic '0'.

The "range" of the VCO is internally set at a ratio of 10:1. The minimum VCO frequency is determined by a control resistor connected to pin 18 and a capacitor to pin 17. This minimum frequency is given by the equation

$$F_{MIN\ VCO} = \frac{0.64}{R_{VCO} C_{VCO}} \text{Hz}$$

The "pitch" of the VCO's output is changed by varying the duty cycle of the output. This is achieved by adjusting the ratio of the voltages at pins 16 and 19. The duty cycle is given by the following equation:

$$\text{VCO Duty Cycle} = 0.5 \left[\frac{V\ \text{pin } 16}{V\ \text{pin } 19} \right] \%$$

leaving pin 19 high produces an output with 50% duty cycle.

Noise Oscillator

The "noise oscillator" supplies random frequencies for the "noise generator". The noise oscillator requires a 43 k resistor to ground at pin 4. The "noise oscillator" controls the rate of the "noise generator". An external noise oscillator may be used to provide this control. The external source is applied to pin 3 and provides an automatic override of pin 4.

Noise Generator/Filter

The output of the "noise generator" feeds an internal noise filter. This "rounds off" the generator's output, reducing the HF content of the noise. The upper 3 dB point is given by

$$F_{UPPER} = \frac{1.28}{R_{NF} C_{NF}}$$

where R_{NF} and C_{NF} are external components connected to pins 5 and 6 respectively.

Mixer

The "mixer" logic selects one, or a combination, of the inputs from the SLF, VCO, and noise generator. Selection is according to Table 1.

System Enable Logic

The "system enable" input provides an enable/inhibit for the system output. The output is inhibited when the voltage at pin 9 is a logic '1', and enabled when logic '0'.

One Shot Logic

The "one shot" logic can be used to provide sounds of a short duration. The duration of the "one-shot" is given by the following equation

MIXER SELECT C	MIXER SELECT B	MIXER SELECT A	MIXER OUTPUT
PIN 27	PIN 25	PIN 26	
0	0	0	VCO
0	0	1	SLF
0	1	0	NOISE
0	1	1	VCO/NOISE
1	0	0	SLF/NOISE
1	0	1	SLF/VCO/NOISE
1	1	0	SLF/VCO
1	1	1	INHIBIT

TABLE 1

ABSOLUTE MAXIMUM RATINGS AT T_A = 25°C (Unless otherwise specified)

SUPPLY VOLTAGE, Vcc (1), PIN 15 .... 6.0V
SUPPLY VOLTAGE, Vcc (2), PIN 14 .... 12.0V
INPUT VOLTAGE APPLIED TO ANY DEVICE TERMINAL 6.0V
STORAGE TEMPERATURE .... −65°C to +150°C
OPERATING TEMPERATURE RANGE . −55°C to +120°C
LEAD TEMPERATURE 1/16 INCH FROM CASE FOR 10 SECONDS . +260°C

RECOMMENDED OPERATING CONDITIONS

	MIN	TYP	MAX	UNITS
SUPPLY VOLTAGE, Vcc1, PIN 15	4.5	5.0	5.5	V
SUPPLY VOLTAGE, Vcc2, PIN 14	5.7		9.0	V
OPERATING FREE-AIR TEMPERATURE	0	25	70	°C

OPERATING CHARACTERISTICS AT T_A=25°C AND Vcc1=5.0V

Fig. 1. Showing the various envelopes that the SN 76477 circuitry can produce.

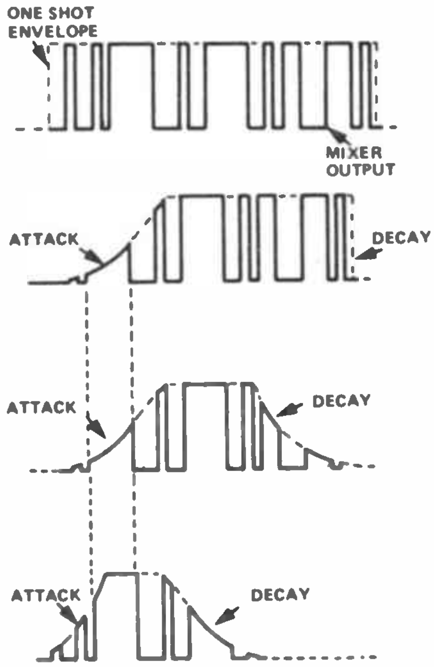


Fig. 2. Block diagram

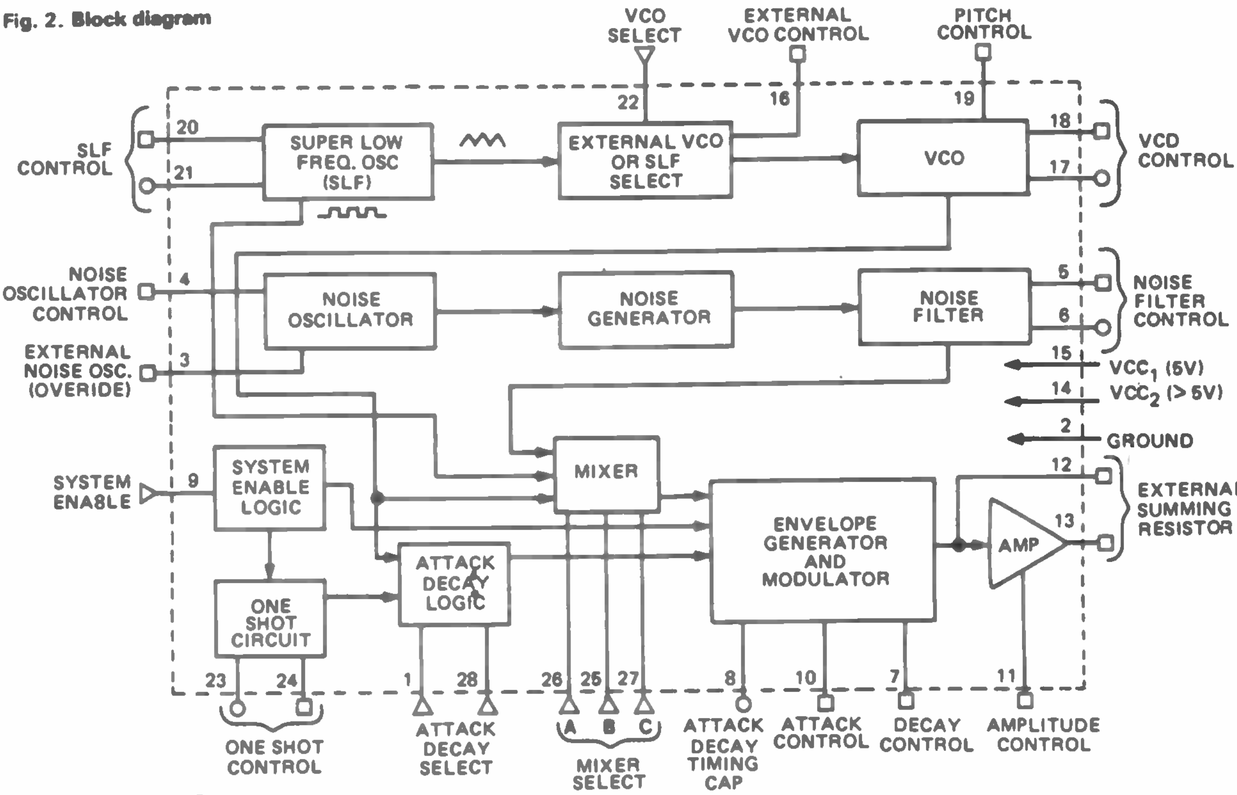


TABLE 2

AOL SELECT 1	AOL SELECT 2	OUTPUT
PIN 1	PIN 28	
0	0	VCO
0	1	MIXER ONLY
1	0	ONE–SHOT
1	1	VCO WITH FLIP–FLOP

$T_{OS} = 0.8\ R_{OS}\ C_{OS}$

where R_{OS} and C_{OS} are external components connected to pins 24 and 23 respectively. The maximum duration of the "one-shot" is about two seconds.

The "one-shot" logic is triggered by the trailing edge of the system enable logic control signal.

ADL (Attack/Decay Logic)

The ADL determines the envelope for the mixer's output. The envelope selected is determined by the ADL control inputs to pins 1 and 28, the output selected being shown in Table 2.

Envelope Generator and Modulator

The attack/delay characteristics of the output are determined by the components connected to pins 7, 8 and 10.

The attack and delay times are given by the following:

$T_{ATTACK} = R_A\ C_{A/D}$ secs

$T_{DELAY} = R_D\ C_{A/D}$ secs

where $C_{A/D}$ is the attack delay capacitor connected to pin 8, and R_A and R_D are resistors connected to pins 7 and 10.

Output Amplifier

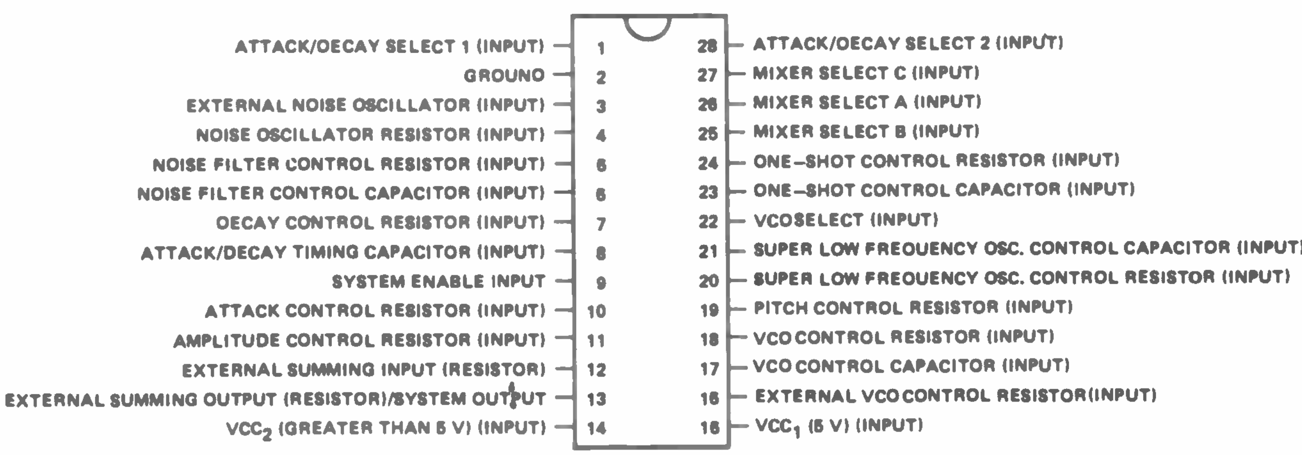
The output amplifier provides a low impedance output. The peak output voltage is determined by the following equation:

$$V_{OUT} = \frac{3.4\ R_S}{R_G}$$

where R_S is a summing resistor connected to pins 12 and 13 (set equal to 10 k) and R_G is a gain resistor connected to pin 11.

Notes:

1. Supplies greater than 5VO may be used, in which case they should be connected to pin 14 to allow the internal regulator to supply the internal circuit requirements.
2. For dedicated sound logic inputs (pins 1, 9, 22, 25, 26, 27 and 28) may be hard-wired to high or low logic levels.



DATA SHEETS EXPLAINED

The data sheets which we publish regularly are very popular, but from time to time we receive requests for a fairly simple explanation of the terms and abbreviations which one finds in semiconductor device data sheets, and so here it is!

THE INFORMATION contained in semiconductor device data sheets is often grossly misunderstood. Great care must be taken to ensure that the exact meaning of a term or abbreviation is clear. As an example, we can quote the following conversation which actually occurred between two people who should both have known better.

A representative of a semiconductor distributor was showing data on a new power device to a lecturer. The lecturer said that the device data was wrong, since the maximum collector current was quoted as 12A and the maximum collector-emitter voltage (V_{CEO}) as 80V; this is a power level of $12 \times 80 = 960W$, but the maximum permissible dissipation quoted in the data sheet is only 90W. The representative could provide no answer!

The data was, of course, perfectly correct. The problem arose because neither of the people concerned had appreciated the exact meaning of V_{CEO} which signifies the collector-emitter voltage *with the base open circuited*. Under these conditions (with zero base current) the collector current will be very small and the power dissipation in the transistor will also be quite small. Thus there is a great deal of difference between V_{CE} (the collector-emitter voltage under any conditions) and V_{CEO} (the collector-emitter voltage with the base open circuited). If still more information is required, one must look into the SOAR (Safe Operating ARea) graph to ascertain the regions of the collector voltage/collector current curve where the device can be safely operated for limited or unlimited times.

This is a very simple example of the pitfalls one can encounter if one does not really understand the *exact* meanings of the terms and abbreviations used in data sheets. Such misunderstandings are very common, but not (we hope!) amongst the devices covered in our data sheets, since it is equally important that our readers understand the exact meanings of abbreviations used in data sheets on relatively simple devices such as ordinary diodes and transistors.

Letter Symbols

Three of the most important symbols used in semi-conductor device data sheets are V, I and P for voltage, current and power respectively. Various subscripts are added to these three letters to indicate the electrode(s) to which the symbol is being applied and possibly certain circuit conditions. Some of the most commonly used subscripts are listed below

A	anode
AV	average
B.	base
BO	breakover
BR	breakdown
C	collector
D	drain or delay
E	emitter
F	forward
G	gate
H	holding
I	input
J	junction
K	cathode
M	peak value of a quantity
O	open circuit or output
R	reverse or repetitive
S	source, short circuit, series or shield
T	in the on state (that is, triggered)
W	working
X	specified circuit
Z	impedance

Order of subscripts

In most cases more than one subscript is needed; the subscripts are usually placed in a definite order governed by the following rules

The first subscript indicates the electrode at which the current or voltage is measured.

The second subscript denotes the reference terminal or circuit mode. (This subscript is often omitted if it is felt no ambiguity will arise.)

Thus i_E is the instantaneous value of the total emitter current, i_e the instantaneous value of the alternating component of the emitter current, and $I_{E(AV)}$ the average (DC) value of the total emitter current. Other subscripts can be used in a similar way, I_F being the forward DC current with no signal, i_F the instantaneous forward current and I_{FM} the peak forward current.

The letter O may be used as a third subscript to show that the electrode not indicated by any previous subscript is open circuited. Similarly the letter S can be used as a third subscript to show the third electrode is shorted to the reference electrode of the second subscript, whilst the letter R as a third subscript indicates that a specified resistance is connected between the third electrode and the reference electrode.

The supply voltage to a collector is indicated as V_{CC}, the second suffix being a repetition of the first in the case of supply voltages. Similarly, one often meets the symbol V_{DD} for the positive supply to a CMOS (or COS/MOS) device, this being the supply to the drain. The negative supply to CMOS devices is normally represented by the symbol V_{SS}.

It should now be clear why V_{CEO} is the steady collector emitter voltage with the base open circuited. Similarly I_{CER} is the collector cut off current with a specified resistance between the base and emitter. It is current with the base and emitter joined, since either the base or emitter can be used as the reference electrode without any change when they are joined.

The parameters of individual devices vary from one device to another of the same type number. The typical value of a parameter such as transistor current gain is often quoted in data sheets by the abbreviation 'typ' after the quantity, but minimum and maximum values are also often quoted. In economical devices no maximum and minimum values may be quoted. In the case of breakdown voltages the minimum value applicable to any device of that type number is usually quoted so that the circuit designer knows that he can apply that value of voltage without danger of the device junction breaking down.

The above discussion gives the general principles of the way in which the symbols for various parameters are chosen. It is not complete, since we have not yet covered such items as current gain of a transistor or thermal characteristics of a device. However, these and other quantities will be covered in the following tables.

Thermal characteristics

The symbols used for the following thermal quantities apply to all types of semiconductor device.

- P_{tot} total power dissipated within the device
- T_{amb} ambient temperature
- T_c temperature of the case of the device
- T_j temperature of the junction in the semiconductor material
- T_{mb} temperature of the mounting base of the device ($= T_c$)

- T_{stg} storage temperature
- θ_h thermal resistance of heat sink. (Units. C/W)
- θ_i contact thermal resistance between the case of the device and the heat sink
- θ_{j-amb} junction to ambient thermal resistance
- θ_{j-c} junction to case thermal resistance

Symbols used mainly with diodes

- C_d diode capacitance with reverse bias
- C_f diode capacitance with forward bias
- C_j capacitance of the junction itself
- C_{min} minimum capacitance (which occurs at the rated breakdown voltage)
- C_o diode capacitance at zero bias
- f_{co} cut off frequency of a varactor diode
- I_F total dc forward current
- i_F instantaneous forward current
- $I_{F(AV)}$ average forward current
- I_{FM} peak forward current
- I_{FRM} repetitive peak forward current
- I_{FSM} non-repetitive peak forward current occurring under surge conditions
- I_R continuous reverse leakage current
- i_R instantaneous reverse leakage current
- I_{RRM} repetitive peak reverse current
- I_{RSM} non-repetitive peak reverse current
- I_Z zener diode continuous operating current
- I_{ZM} zener diode peak current
- t_{on} turn on time
- t_{off} turn off time
- t_r rise time
- t_{rr} reverse recovery time
- t_s storage time
- V_F steady forward voltage
- v_F instantaneous forward voltage
- V_R steady reverse voltage
- v_R instantaneous value of the reverse voltage
- V_{RM} peak reverse voltage
- V_{RRM} repetitive peak reverse voltage
- V_{RSM} non-repetitive peak reverse voltage (on surges)
- V_Z zener diode working voltage

Symbols used mainly with transistors

- C_{ob} transistor output capacitance in the grounded base circuit
- C_{oe} transistor output capacitance in the grounded emitter circuit
- f_T transition frequency or gain-bandwidth product in common emitter circuit
- h_{FE} (h_{FB}, h_{FC}) current gain in the grounded emitter circuit (or in the grounded base or grounded collector circuit)
- h_{fe} the increase in collector current divided by the small increase in the base current which produces it. (Small signal current gain)
- I_B, I_C or I_E the steady base, collector or emitter current
- $I_{B(AV)}$, $I_{C(AV)}$ or $I_{E(AV)}$ the average value of the base, collector or emitter current
- I_{CEX} collector cut-off current in a specified circuit
- I_{CM}, I_{BM} or I_{EM} peak value of collector, base or emitter current
- I_b, I_c or I_e rms value of the alternating component of the current
- I_{bm}, I_{cm}m or I_{em} peak value of the alternating component of the current
- i_C, i_B or i_E instantaneous value of the total current
- i_c, i_b or i_e instantaneous value of the alternating component of the current
- I_{CBO} collector cut off current with the emitter open circuited
- I_{CBS} or I_{CES} collector cut off current with emitter shorted to the base
- i_{CEO} collector cut off current with the base open circuited
- I_{CER} collector cut off current with a specified value of resistance between the base and the emitter
- I_{EBO} emitter cut off current with the collector open circuited
- $V_{BE(SAT)}$ base-emitter saturation voltage
- $V_{(BR)}$ breakdown voltage
- $V_{BR)CBO}$ collector to base breakdown voltage with emitter open circuited
- $V_{(BR)CEO}$ collector to emitter breakdown voltage with base open circuited
- V_{CB} collector-base voltage
- V_{CBO} collector to base voltage with emitter open circuited
- V_{CC} collector supply voltage
- V_{CE} collector to emitter voltage
- V_{CEO} collector to emitter voltage with base open circuited
- V_{ce} collector to emitter rms voltage
- $V_{CE(SAT)}$ collector to emitter saturation voltage
- V_{EB} emitter-base voltage
- V_{EBO} emitter-base voltage with collector open circuited
- V_{eb} emitter-base rms voltage

Symbols used mainly with FETS

- I_D steady value of the drain current
- I_{DSS} steady value of the drain current with the gate connected to the source
- I_m peak drain current
- I_G steady gate current
- I_S steady source current
- r_{DS} drain to source (or channel) resistance
- V_{DS} steady drain to source voltage
- V_{GS} steady gate to source voltage

Symbols used mainly with thyristors

- I_{FRM} repetitive peak forward current.
- I_{FSM} non-repetitive peak (surge) current
- I_{GD} gate current which does not trigger the device
- I_{GT} gate trigger current
- I_{GO} gate turn off current
- I_H holding current required to maintain conduction
- I_R steady reverse leakage current
- I_{RG} reverse gate current
- I_{RRM} repetitive peak reverse current
- I_{RSM} non-repetitive peak reverse current (in surge conditions)
- I_T steady anode-cathode 'ON' state current
- P_G gate power
- t_{gt} gate controlled turn-on time
- t_{gq} gate controlled turn-off time
- $V_{(BO)}$ breakover voltage
- V_D continuous off state voltage
- V_{FG} forward gate voltage
- V_{GT} gate trigger voltage
- V_R steady reverse voltage

Operational amplifier terms

Bandwidth, Δf. The frequency at which the gain falls by a factor of 0.7 relative to the gain at low frequencies

Common mode rejection ratio, CMMR. The gain when a signal is applied to one of the inputs of the amplifier divided by the gain when the signal is applied to both the inverting and non-inverting inputs. It is usually expressed in dB.

Frequency compensation. An operational amplifier requires a capacitor to enable it to be used in circuits which are stable over a wide frequency range. Internally compensated operational amplifiers have this capacitor fabricated on the silicon chip but an external capacitor must be used with other types of operational amplifier which do not contain an internal capacitor.
Input bias current, I_{BIAS}. The mean value of the currents at the two inputs of an operational amplifier.
Input offset current, I_{OS}. The difference in the two currents to the inputs of an operational amplifier. Normally much smaller than the input bias current.
Input offset voltage, V_{OS}. The voltage which must be applied between the two input terminals to obtain zero voltage at the output.
Open loop voltage gain, A_{VOL}. The amplifier gain with no feedback applied.
Output resistance, R_O. The small signal resistance seen at the output when the output voltage is near zero.

Voltage regulator terms

Dropout voltage, V_{DO}. When the difference between the input and output voltages falls down below the dropout voltage, the device ceases to provide regulation.
Foldback current limiting. In regulators with foldback current limiting, the current will 'fold back' to a fairly small value when the output is shorted.
Line regulation. The change in the output voltage for a specified change in the input voltage.
Load regulation. The change in output voltage for a change in the load current at a constant chip temperature.
Quiescent current, I_Q. The current taken by the regulator device when it is not delivering any output current.
Ripple rejection. The ratio of the peak-to-peak ripple at the input of the regulator to that at the output. Normally expressed in dB.

Monolithic timer terms

Comparator input current. The mean current flowing in the comparator input connection during a timing cycle.
Timing capacitor, C_t. This capacitor is normally connected between the comparator input and ground. The time taken for it to charge controls the delay time.
Timing resistor, R_t. This is the resistor through which the timing capacitor charges.
Trigger current. The current flowing in the trigger input connection, at the specified trigger voltage.
Trigger voltage. The voltage required at the trigger pin to initiate a timing cycle.

Conclusions

Data sheets must be used intelligently and with much thought. Information on the conditions under which an entry in the data sheet is applicable is often stated in small print, but is of great importance. Data should always be thoroughly studied before a device is used for the first time, only then will you be able to fully understand the potential applications of the device.

ICM7217/7227

The ICM 7217 and ICM 7227 are four digit, presetable up/down counters with an onboard presetable register continuously compared to the counter. The ICM 7217 versions are intended for use in hardwired applications where thumbwheel switches are used for loading data and simple SPDT switches are used for chip control. The ICM 7227 versions are intended for use in processor-based systems where presetting and control functions are performed under processor control.

These circuits provide multiplexed seven segment LED display outputs, with common anode or common cathode configurations available. Digit and segment drivers are provided to dirrectly drive displays of up to 250mm character height at a 25% duty cycle. The frequency of the onboard oscillator (and thus the multiplex frequency) may be controlled with a single capacitor, or the oscillator may be allowed to free run. Leading zeroes are blanked, and the display drivers may be disabled allowing the display to be used for other purposes. The data appearing at the seven segment and BCD outputs is latched; the content of the counter is transferred into the latches under external control by means of the Store pin.

The ICM7217/7227 (common anode) and ICM1721A/7227A (common cathode) versions are decade counters, providing a maximum count of 9999, while the ICM 7217B, 7227B (common anode) and ICM7217C/7227C (common cathode) are intended for timing purposes, providing a maximum count of 5959.

These circuits provide three main outputs; a carry/borrow output which allows for direct cascading of counters, a zero output which indicates when the count is zero, and an equal output which indicates when the count is equal to the value contained in the register. Data is multiplexed into and out of the device by means of a tri-state BCD I/O port, which acts as a high impedence input when loading, and provides a multiplexed BCD output. The carry/borrow, equal, and zero outputs, and the BCD port functioning as an output, will drive one standard TTL load.

In order to permit operation in noisly environments and to prevent multiple triggering with slowly changing inputs, the count input is provided with a Schmitt trigger.

The carry/borrow output is a positive going signal occurring typically 500nS after the positive going edge of the count input advancing the counter from 9999 to 0000 counting up and from 0000 to 9999 counting down. This output allows direct cascading of counters.

The equal output assumes a negative level when the contents of the counter and register are equal (i.e., for the duration of one period of the count input until the count is changed by a positive going edge on the count input).

The zero output assumes a negative level when the content of the counter is 0000.

The digit and segment drivers provide a decoded seven segment display system, capable of directly driving common anode LED displays at typical peak currents of 40mA per seg. This corresponds to average current of 10mA/seg with the 25% multiplex duty cycle. For the common cathode versions peak segment currents are 12.5mA, corresponding to average segment currents of 3.1mA. The display control pin controls the display output using three level logic. The pin is self-biased to a voltage approximately half way between rails which corresponds to normal operation. When this pin is connected to V+, the segments are inhibited, thus disabling the display and reducing power. When this pin is connected to V the leading zero blanking feature is inhibited. For normal operation (display on with leading zero blanking) the pin may be left open. The display may be controlled with a 3 position SPDT switch as in the test circuits.

The BCD input/output port provides a means of transferring data into and out of the device in BCD format. The ICl 7217 versions self-multiplex data into the counter or register via thumbwheel switches in response to inputs at the load counter or load register pins, while in the ICl 7227 versions input/output control and timing must be provided externally. When functioning as outputs, the BCD I/O pins will also drive one standard TTL load.

The onboard multiplex scan oscillator has a nominal free-running frequency of 10kHz. This may be reduced by the addition of a single capacitor between the Scan pin and the positive supply, or the oscillator may be directly overdriven to about 20kHz.

FEATURES

Four decade, presetable up-down counter with parallel zero detect.

Setable register with contents continuously compared to counter.

Directly drives multiplexed seven segment common anode or common cathode LED displays.

On-board multiplex scan oscillator.

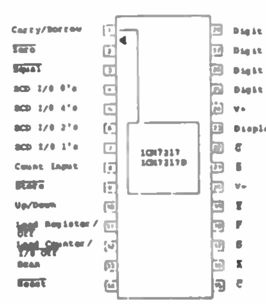
Schmitt trigger on count input.

TTL compatible BCD I/O port, carry/borrow, equal and zero outputs.

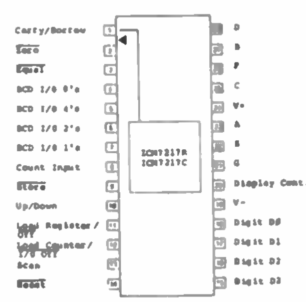
Display blank control for low power operation; quiescent power dissipation less than 5mW.

Display off control to allow use of display for other purposes.

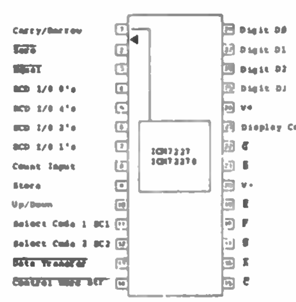
7217 numbers refer to hardwired control versions of the device, while 7227 numbers refer to the processor control versions.

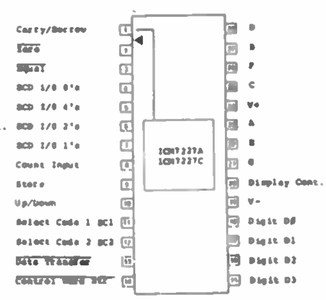


COMMON ANODE



COMMON CATHODE





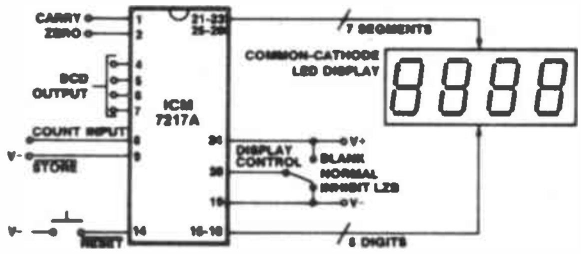
The Store pin of the 7217 will allow the output latches to be updated only if it is held low. The device will count up if the Up/Down pin is high and down if low. The Reset pin will allow normal operation when high, resetting the device when taken low. The Load Counter pin has three states. When high the counter is loaded with BCD data, when floating normal operation is selected and when the pin is low the BCD port is forced to a high impedance. The Load Register pin also has three states. High loads the register with BCD data, floating allows normal operation while low disables the display drivers. The three state Display Control disables the segment drivers when high, allows normal operation when floating and inhibits the leading zero blanking when low.

The 7227 pin configurations are somewhat different. The Data Transfer pin will allow normal operation when high, and when pulsed low will cause a transfer of data as directed by the select code set up on pins Select Code Bits 1 and 2. If these are set to 00 there will be no data transfer, 01 will latch the output data, 10 will preset the counter while 11 will preset the register. The Control Word Stobe will allow normal operation when high and when pulsed low will cause the control word set up on the Store and Up/Down pins to be written to the control latches. The Store pin will update the latches if high during CWS's active period, not allowing updates if low. The counter will count up if Up/Down is high, down if low. The display control is a three state input, blanking if low and allowing normal operation if left floating.
blanking if low and allowing normal operation of left floating.

The ICM 7217/7227 series provides in one easy to interface circuit (1) a high speed four decade up/down counter with carry out and parallel zero detect) (2) setable register and comparator; (3) output latches for (4) a multiplexed LED display decoder/driver system and (5) multiplexed (or directly addressed in the ICM7227) BCD outputs. These five subsystems can be used together or separately to provide a large number of circuit configurations.

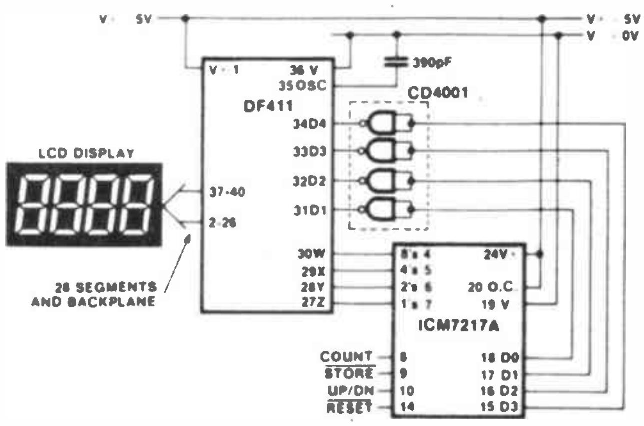
A few possible applications are shown below.

TIMER	DISPLAY	COUNTER/
ICM7217	Common Anode	Decade/9999
ICM7217A	Common Cathode	Decade/9999
ICM7217B	Common Anode	Timer/5959
ICM7217C	Common Cathode	Timer/5959
ICM7227	Common Anode	Decade/9999
ICM7227A	Common Cathode	Decade/9999
ICM7227B	Common Anode	Timer/5959
ICM7227C	Common Cathode	Timer/5959



UNIT COUNTER WITH BCD OUTPUT

The simplest application of the ICM217 is as a four digit unit counter. All that is required is an ICM7217, a power supply and a four digit display. Add a momentary switch for reset and an SPDT centre-off switch to blank the display or view leading zeroes. One more SPDT gives up/down.



LCD DISPLAY INTERFACE

The low-power operation of the ICM7217 makes an LCD interface desirable. The Siliconix DF411 four digit BCD to LCD display driver easily interfaces to the ICM7217A with one CD4000-series package to provide a total system power consumption of less than 5mW. The common-cathode devices should be used since in these versions the digit drivers are CMOS, while in the common-anode devices the digit drivers are NPN devices and will not provide full logic swing.

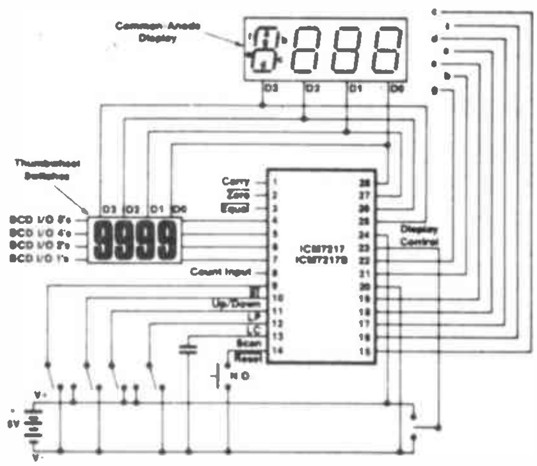


Fig. 1. The 7217 (common anode) version. The display and power connections are the same for the 7217B, 7227 and 7227B.

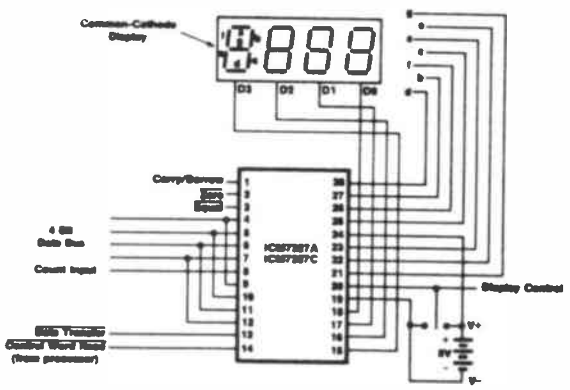
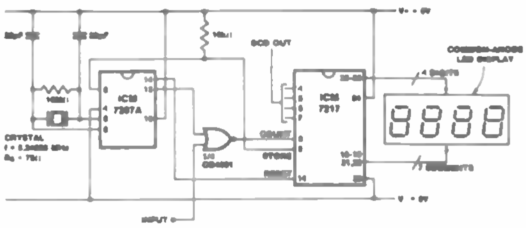


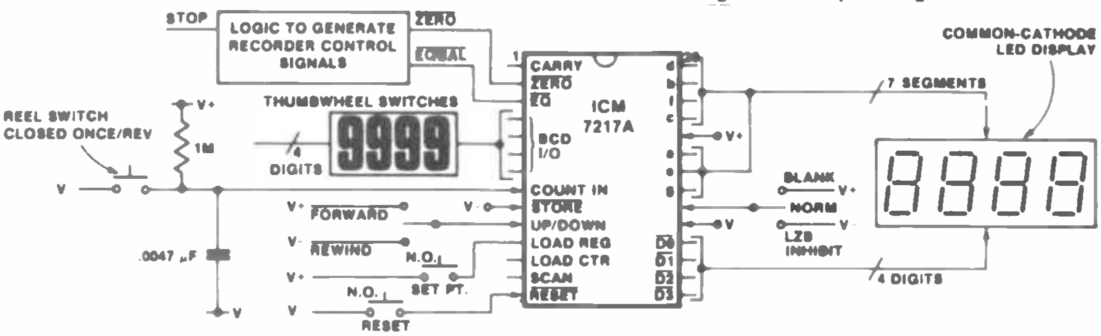
Fig. 2. The 7227A (common cathode) version. The display and power connections are the same for the 7227C, 7217A and 7217C.



PRECISION FREQUENCY COUNTER/TACHOMETER

This circuit is a simple implementation of a four digit frequency counter, using an ICM7207A to provide the one second gating window and the store and reset signals. In this configuration, the display reads hertz directly. With Pin 11 of the ICM7207A connected to V⁺, the gating time will be 0.1 second which will give tens of hertz in the least significant digit. For shorter gating times an ICM7207 may be used (with a 6.5536 MHZ crystal), giving a 0.01 second gating with Pin 11 connected to V⁺ and a 0.1 second gating with Pin 11 open.

To implement a four digit tachometer, the ICM7207A with a one second gating should be used. In order to get the display to read directly in RPM, the rotational frequency of the object to be measured must be multiplied by 60 (or 600 using a 0.1 second gating for faster update). This can be done electronically using a phase-locked loop or mechanically by using a disc rotating with the object with the appropriate number of holes drilled around its edge to interrupt the light from an LED to a photo-dector.



TAPE RECORDER POSITION INDICATOR/CONTROLLER

This circuit shows an application which uses the up down counting feature of the ICM7217 to keep track of tape position on a tape recorder. This circuit is representative of the many applications of up/down counting in monitoring dimensional position.

In the tape recorder application, the preset register, equal and zero outputs can be used to control the recorder. To make the recorder stop at a particular point on the tape, the register can be set with the stop point and the equal output used to stop the recorder (either on fast forward, play or rewind).

TDA 1008

Introduction

The TDA1008 integrated circuit provides frequency-dividing and gating functions for tone signal generation in electronic organs and other electronic musical instruments. An increasing variety of electronic organs has become available in recent years, their popularity having been enhanced by the rapid expansion of the home entertainments market. To provide effects such as sustain, percussion, and fifth coupling, the organ designer has usually needed to add special electronic circuits to the basic organ design, increasing overall cost. However, in a system based on TDA1008 ICs, these and many other effects can be easily provided without significantly adding to circuit complexity. The reduction in component count and number of key contacts compared with conventional systems results in a significant saving in cost, greater reliability, and easier servicing. With simplified circuits and fewer components, organ designs using TDA1008 ICs are also ideal for the home constructor.

The main features of the TDA1008 are given below.

The IC is a monolithic bipolar device using I^2L logic, and therefore requires no special handling techniques.

Only a single set of contacts is required for each key, because the TDA1008 provides five octave-related output signals when each of five key inputs is activated. Thus, in a typical system, only one busbar is required for each manual.

An outstanding feature of the TDA1008 is that the tone-output signals are symmetrical about a fixed DC level, and so no DC jump occurs in the outputs when the keys are operated. Thus 'plopping and scratching' sounds are eliminated from the audio output without the need for the usual additional suppression components.

The amplitudes of the five output signals from the IC are proportional to the DC voltage applied to each key input, and because the nominal impedance of these inputs is high, sustain and percussion effects can be added by using simple RC networks in conjunction with the key circuits.

The rate of attack and decay can be adjusted simply by varying a DC voltage applied to a 'sustain control' pin on the IC.

Description of TDA1008

The circuit of the TDA1008 IC with basic peripheral components is shown in Fig. 1. The IC comprises eight divide-by-two circuits and a matrix of gate circuits.

As shown in Fig. 1, the TDA1008 can be driven directly from a top-octave synthesiser, because only one input signal applied to pin 15 is required to produce nine octave-related notes within the IC. The minimum impedance at pin 15 is 28 k ohm.

Up to five keys can be connected to pins 8 to 12. When a DC voltage is applied to one of these inputs, five of the nine octave-related notes are routed by the matrix circuit to the five tone outputs, as shown in the truth table. Although the maximum input frequency of the TDA1008 is 100 kHz, as can be seen from the truth table the frequency chosen would normally be within the audio range to give the full range of audible tones. If more than one key input is activated, then the signal from each tone output will comprise the sum of all the tones for the activated inputs.

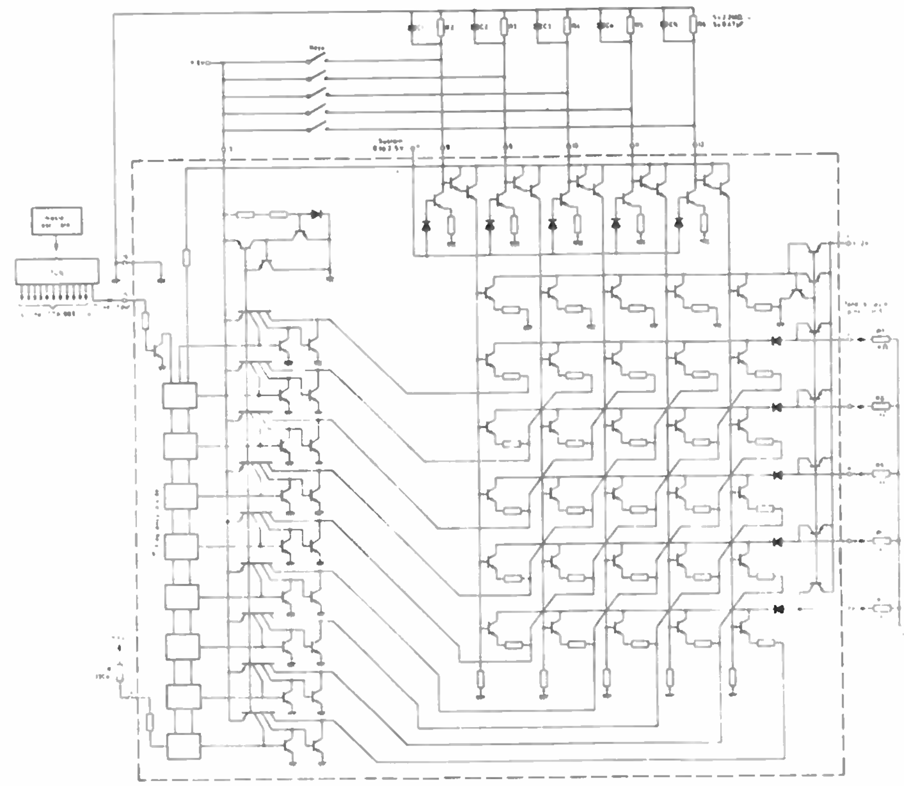


Fig. 1. TDA1008 and basic peripheral circuit.

The signal amplitude at each tone output (pins 2 to 6) is proportional to the DC voltage applied to each key input. Sustain and percussion effects can, therefore, be obtained by connecting simple RC networks to the key inputs. Some practical networks are described later. The networks shown in Fig. 1 (resistors R_2 to R_6 and capacitors C_1 to C_5) provide a simple sustain effect. The impedance of the key inputs, and hence the rate of discharge of C_1 to C_5, is determined by the DC voltage applied to pin 7 of the IC. With pin 7 at 0 V, the impedance of each key input is greater than 8 M ohms. When this voltage is increased towards 2.5 V DC, the impedance of each input falls accordingly. Thus the decay of the output waveforms at pins 2 to 6 can be adjusted continuously by simply varying the sustain control voltage at pin 7. The impedance of the tone outputs is determined mainly by the values of the load resistors R_7 to R_{11} (1 k ohms in the circuit shown).

The ungated output from the last divider stage is provided at pin 14. This output is used when the IC is tested during manufacture, but it can also be used by the organ manufacturer for a quick operational check of each TDA1008. (An output signal from pin 14 when an input signal is applied to pin 15 indicates that all the divider stages are operating correctly.) During normal operation, pin 14 should be connected through a resistor to the +6 V supply so that a current of 20 μA is drawn. In a practical circuit, this can be achieved by connecting a 330 k ohms resistor (R_1 in Fig. 4) between pins 14 and 13.

It is possible to derive a low-frequency output signal for a pedal board from pin 14. Provided that the current drain of 20 μA is maintained, a transistor can be used to amplify the low-frequency signal from this pin.

Practical Circuits for Organs Using TDA1008 ICs

The number of TDA1008 ICs required for a particular system depends on the number of octaves required by the organ designer. Normally, a minimum of twelve of these ICs would be required for subdivision of the twelve top-octave notes. For example, a master oscillator, a top-octave synthesiser IC, and twelve TDA1008 ICs would be required for a five-octave single-manual organ. All the ICs, together with the peripheral components, can be mounted on a single compact printed-wiring board.

A brief description of a variety of practical circuits for use with TDA1008 ICs is given below. The five-octave organ has been chosen as a practical example of a system using these circuits.

Master oscillator

The Hartley oscillator is a popular choice for electronic organs because of its inherent high stability. The sinewave output signal from this oscillator must be shaped by a Schmitt trigger to provide a squarewave with the correct slew rate for driving the TOS, as shown in Fig. 2. For TOS circuits that require two input signals of opposite phase, these can be provided as shown.

However, because the TDA1008 IC requires a stabilised supply, use can be made of this supply to simplify the oscillator circuit greatly, as shown in Fig. 3. Only four NAND gates contained in a single HEF4011P IC, three resistors (one variable), and a capacitor, are required to produce an output signal of the correct shape for the TOS. One of the gates can be used as shown to provide an output signal of opposite phase.

Switching and envelope-shaping circuits

The TDA1008 IC can be connected as shown in Fig. 4, and will provide five octave-related tones at pins 2 to 6 by operation of a single key contact connected to each key input (pins 8 to 12). The signal obtained from each output, relative to the three supply voltages, is shown in Fig. 5. The amplitude of this signal is dependent on the voltage applied to the key inputs. If any of the output pins remain unused, these pins should be connected to the +9 V supply to avoid intermodulation between the output signals.

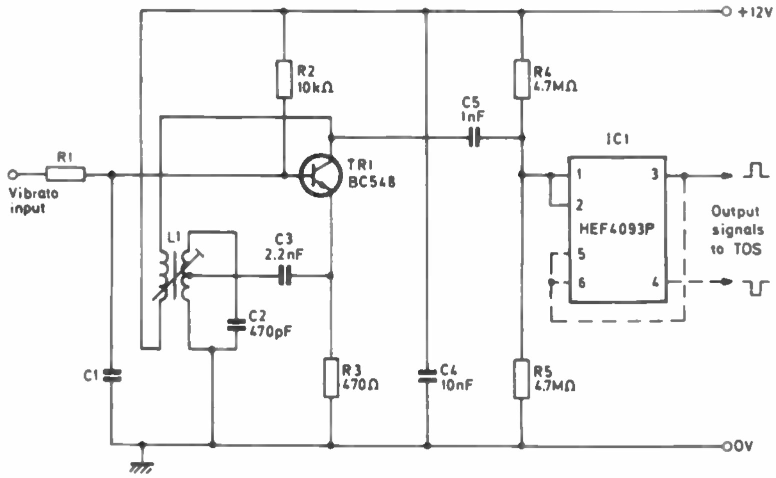


Fig. 2. Hartley oscillator and Wave- Shaping circuit.

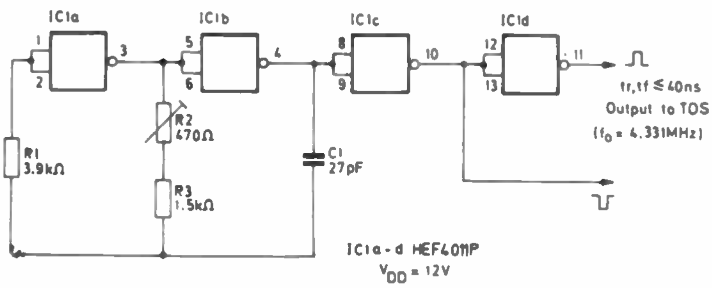


Fig. 3. Master oscillator using NAND gates.

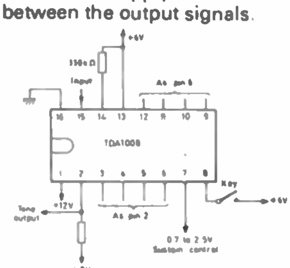


Fig. 4. Simplified connection diagram for TDA1008.

Sustain

The sustain effect, the continuation of a note or notes for a predetermined period after a key has been released, can be easily obtained in an organ system using TDA1008 ICs.

To apply sustain to the five tone-output signals simultaneously, it is only necessary to connect a capacitor between each key input of the TDA1008 and earth, as shown in Fig. 6. With pin 7 either open-circuit or at a low DC voltage, the impedance of each key input is high (≥8M ohms). This impedance, combined with capacitor C_1, provides a time-constant which gives the maximum sustain period (about 4s with the value shown for C_1). Resistor R_2 is included to reduce this maximum period to a practical value, determined mainly by the time-constant of R_2 and C_1. The time-constant is given by:

$$t = C_1 R_2,$$

where t is in seconds.

For more details of the device contact Mullard Ltd, at: Mullard House, Torrington Place, London WC1E 7HD.

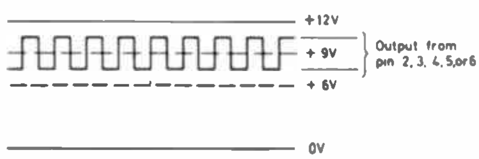


Fig. 5. Output signal from pin 2, 3, 4, 5 or 6.

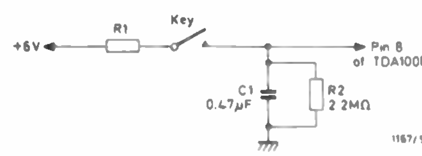


Fig. 6. Sustain circuit.

Tone output pin	Key input pin 8	9	10	11	12
2	f_{in}	$f_{in}/2$	$f_{in}/4$	$f_{in}/8$	$f_{in}/16$
3	$f_{in}/2$	$f_{in}/4$	$f_{in}/8$	$f_{in}/16$	$f_{in}/32$
4	$f_{in}/4$	$f_{in}/8$	$f_{in}/16$	$f_{in}/32$	$f_{in}/64$
5	$f_{in}/8$	$f_{in}/16$	$f_{in}/32$	$f_{in}/64$	$f_{in}/128$
6	$f_{in}/16$	$f_{in}/32$	$f_{in}/64$	$f_{in}/128$	$f_{in}/256$

TDA1008 Truth Table.

ICL 7106/7107

THE ICL7106 and 7107 are high performance, low power, CMOS 3½ digit A/D converters that contain all the necessary active devices on a single monolithic IC. Each has parallel seven-segment outputs which are ideal for use in a digital panel meter. The ICL7106 will directly drive a liquid crystal display including the backplane drive. The ICL7107 will directly drive instrument size LEDs without buffering. With seven passive components, display and power supply, the system forms a complete digital voltmeter with automatic zero connection and polarity. (see figs. 1 and 3).

Both ICs use the time-proven dual slope integration technique with all its advantages, i.e. non-critical components, high noise rejection, non-critical clock frequency and almost perfect differential linearity. Both the ICL7106 and 7107 can be used not only with its internal reference, but true ratiometric reading applications may also be accomplished over a full scale input range of 199.9 mV to 1.999 V.

The accuracy of conversion is guaranteed to plus or minus 1 count over the entire plus or minus 2000 counts and the auto-zero facility provides a guaranteed zero reading for 0 volts input. However, the chip does provide a true polarity output at low voltages for null detection. Both chips have an on-board clock and reference circuitry, as well as overrange detection.

The Clock

The chip carries the active parts of an RC oscillator which runs at about 48 kHz and is divided by 4 for use as the system clock. The integration period (1000 clock pulses) is therefore 83.3 ms. Each conversion requires 4,000 clock pulses, i.e. 3 readings per second. For optimum 50 Hz line frequency rejection, the clock should be set to a multiple of 50 Hz, e.g. 50 kHz.

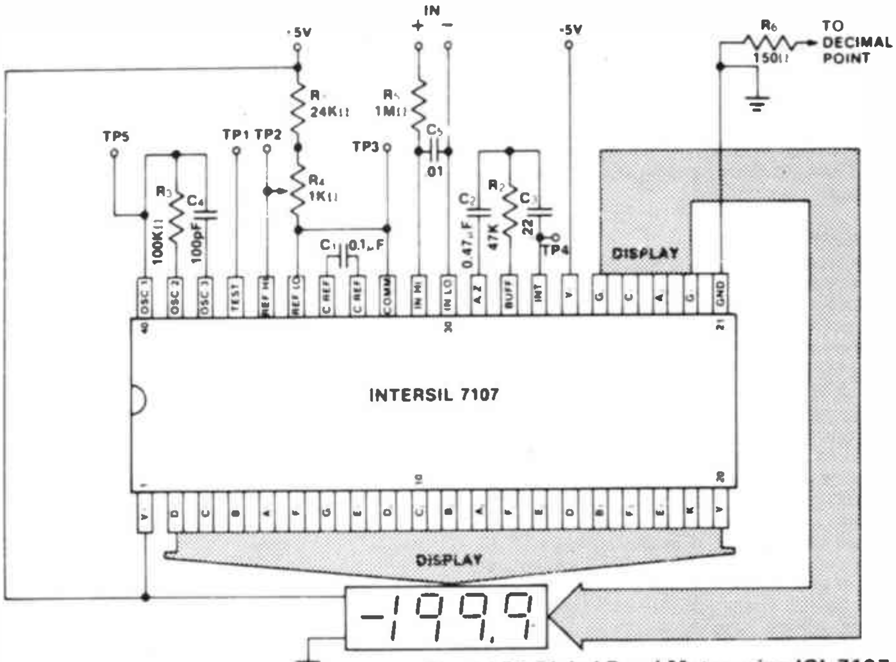


Fig. 1 LED Digital Panel Meter using ICL 7107

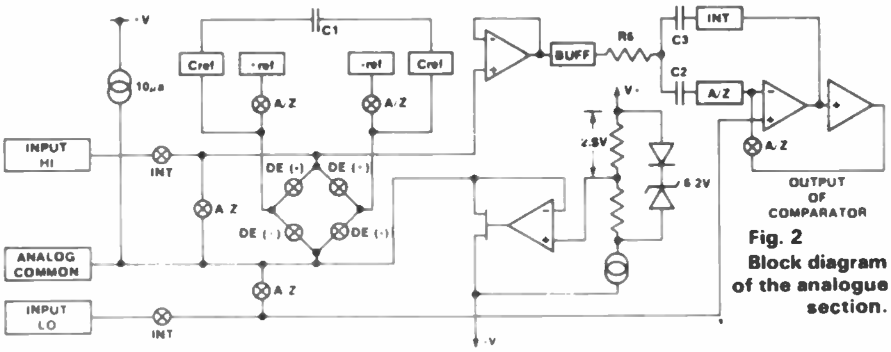


Fig. 2 Block diagram of the analogue section.

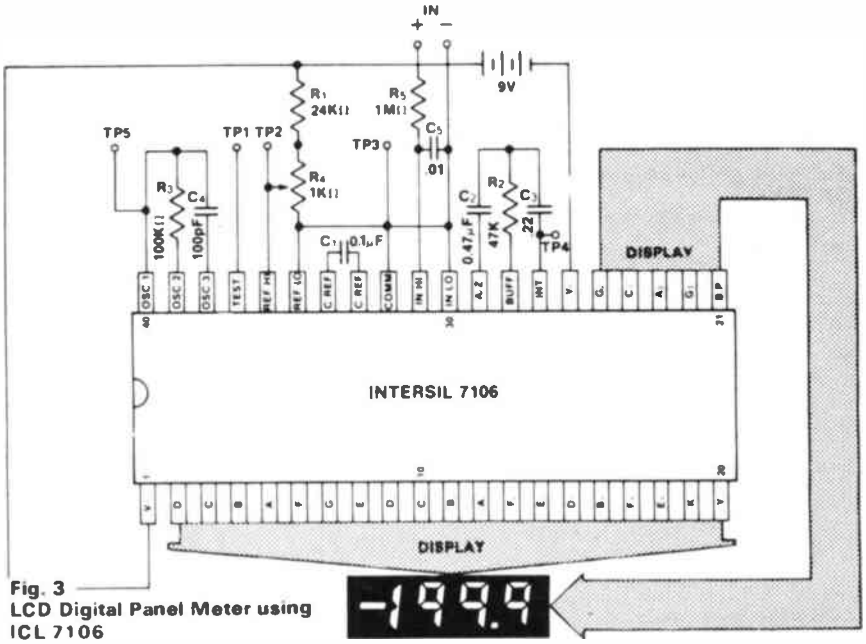
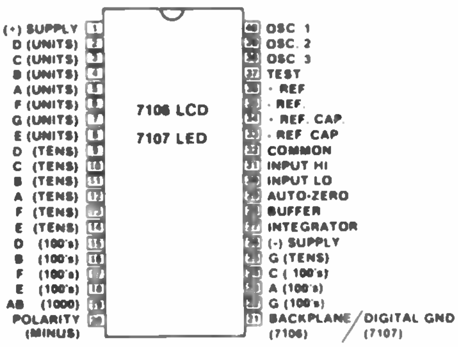


Fig. 3 LCD Digital Panel Meter using ICL 7106

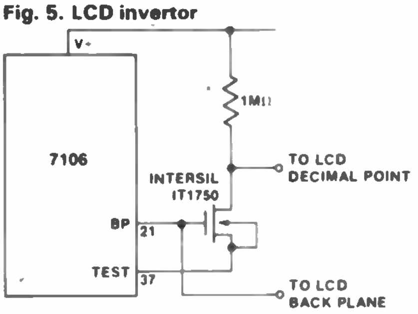
Fig. 4. Pinouts



Displays and DPs

The additional components required to build a DPM are a display (either LCD or LED), 4 resistors, 4 capacitors, and an input filter if required. Liquid crystal displays become polarised and damaged if a DC voltage is continuously applied to them, so they must be driven with an AC signal. To turn on a segment, a waveform 180 degrees out of phase with the backplane drive (but of equal amplitude) is applied to that segment. The 7106 generates the segment drive waveform for all digits internally, but does not generate segment drive for the decimal point. This must be done using an inverter or exclusive-OR logic (see fig. 5 below). For use with LED displays the 7107 pull-down FETs will sink about 8 mA per segment, which produces a bright display suitable for almost any indoor application. A fixed decimal point can be turned on by tying the appropriate cathode to ground through a 150 ohm resistor.

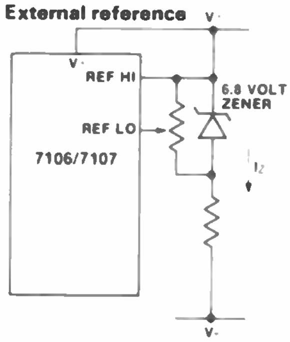
Fig. 5. LCD invertor



The Reference

For 200.0 mV full scale, the voltage applied between REF Hi and REF Lo should be set at 100.0 mV. For 2.000 V full scale, this should be 1.000 V. The reference inputs are floating, and the only restriction on the applied voltage is that it should lie in the range V– to V+.

Fig. 6. External reference



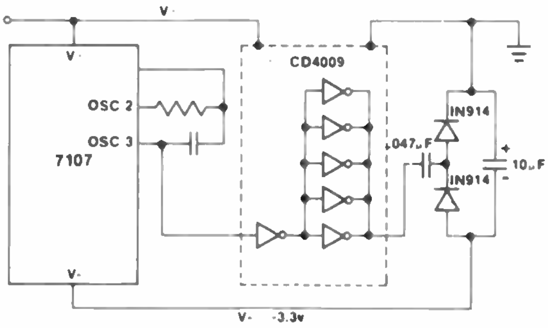
(a)

For many applications, the internal reference of 2.8 V between V+ and COMMON is adequate, but power dissipation in the 7107 LED version can wreck this. However, an external reference can be added as shown in Fig.6.

Electrical Specifications @ +25 C unless otherwise specified

Full Scale Voltage Range	±200mv (5.0V min V+ to V–) ±2.0V (6.0V min V+ to V–)
Full Scale Digital Range	±2000 Counts
Common Mode Voltage Range	V+ minus 0.5V to V–, plus 1V
Accuracy 10 C to 50 C with external reference	<1/2 Count
Noise referred to Input	15μV typical
Zero width	0–1 transition at .7 to .9 counts
Turnover	< 1 Count
Input circuit	Differential
Input Bias Current	2pA
Input Impedance	> 10¹² ohm
Polarity	Automatic with neg sign displayed
Reference (Internal)	Internal 2.8V, referenced to V+ Temperature Coefficient 100ppm/ C typical.
Reference (External)	External reference must be in the range V+ to V–
Recommended External Components	
200mV Full Scale	2V Full Scale
C = Int Cap 220n	C = Int Cap 220n
C = AZ Cap 470n	C + AZ Cap 47n
C = Ref Cap 100n	C = Ref Cap 100n
C = Clock Cap 100p	C = Clock Cap 100p
R = Int Res 47k	R = Int Res 470k
R = Clock Res 100k	R = Clock Res 100k
R = Short	R = Short
Clock Frequency	48kHz divided by 4 An internal divide by 4 counter is provided to count external oscillators down to 12kHz, the internal dual slope clock.
Display Outputs (LED ICL7107)	22 Current limited segment drives plus one current limited neg sign drive plus LED common Note The 2 die in the 1k bit are in parallel
Display Outputs (LCD ICL7106)	22 segment drives plus one neg sign drive plus LCD back plane drive
LED (7107) current @ +5.0V	5.5 to 8.0ma
Power Requirements	LCD 1ma @ 4.5 – 6V LED 1ma @ 4.5 – 6V, plus LED current
Power supply configuration (7107)	Dual +4.5 to +6V and –3 to –6V @ 1ma Note for inputs that remain within the CM voltage range only a single supply is required
Digital input Signals (7106)	Test Single 5 to 12V A high on the test input turns on all segments and the minus sign.
Read Rate	3 Readings per second with 12kHz internal clock (48kHz external clock) Accurate from 1 to 15 reading per second

Fig. 7. Deriving a negative supply



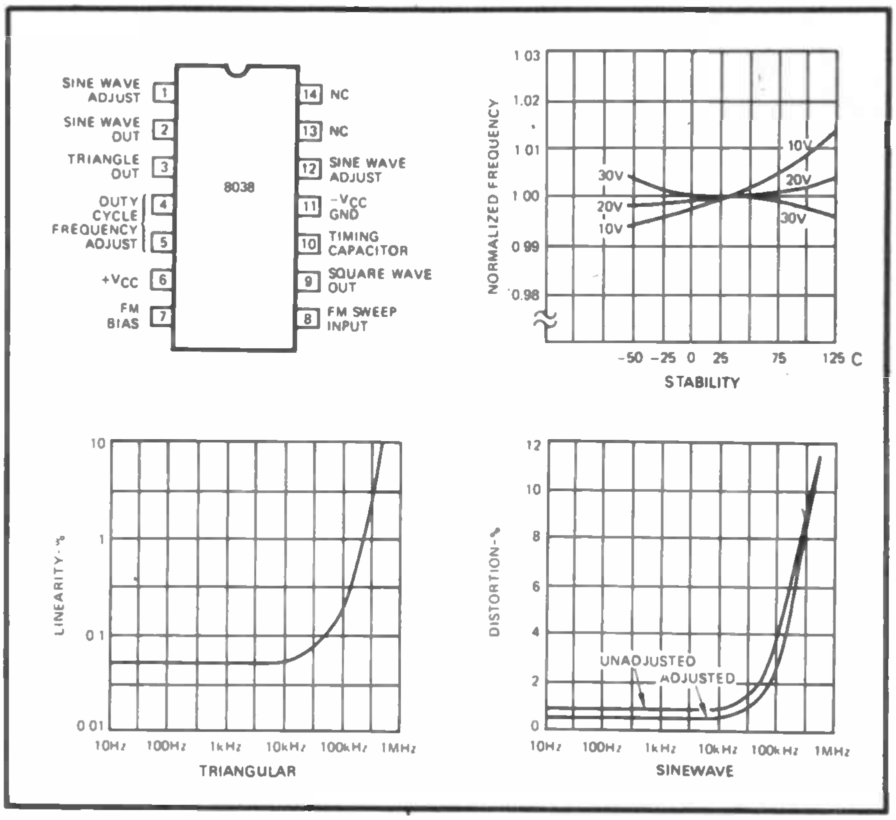
Power Supplies

The 7106 will run from a single 5 to 12 V supply. If INPUT Lo is shorted to COMMON, this will cause V+ to sit 2.8 V positive with respect to INPUT Lo, and V– at 6.2 V negative with respect to INPUT Lo.

The 7107 requires dual supplies, +4.5 to +6 V and –3 to –6 V at 1 mA. A negative supply may be derived from +5 V using the circuit given in Fig 7.

ICL8038

The 8038 has been around for about 5 years — which is a long time in electronics. In fact it has reached the position of becoming an 'Industry Standard' on a par with the 741. An inherently versatile device it has its drawbacks like most chips — but overall has a lot going for it. Intersil even produced a very honest application bulletin (A013) called 'Everything you always wanted to know about the 8038', which explained how to get the best out of this device and admitted its defects — an uncommon event with most manufacturers! Some of the data from A013 has been included in this data sheet.



Description

The 8038 Waveform Generator is a monolithic integrated circuit, capable of producing sine, square, triangular, sawtooth and pulse waveforms of high accuracy. The frequency (or repetition rate) can be selected externally over a range of less than 1/1000 Hz to more than 1 MHz and is highly stable over a wide temperature and supply voltage range. Frequency modulation and sweeping can be accomplished with an external voltage and the frequency can be programmed digitally through the use of either resistors or capacitors. The Waveform Generator utilizes advanced monolithic technology, such as thin film resistors and Schottky-barrier diodes.

Theory of operation

A block-diagram of the waveform generator is shown in Figure 1. An external capacitor C is charged and discharged by two current sources. Current source #2 is switched on and off by a flip-flop, while current source #1 is on continuously. Assuming that the flip-flop is in a state such that current source #2 is off, then the capacitor is charged with a current I. Thus the voltage across the capacitor rises linearly with time. When this voltage reaches the level of comparator #1 (set at 2/3 of the supply voltage), the flip-flop is triggered, changes states, and releases current source #2. This current source normally carries a current 2I, thus the capacitor is discharged with a net-current I and the voltage across it drops linearly with time. When it has reached the level of comparator #2 (set at 1/3 of the supply voltage), the flip-flop is triggered into its original state and the cycle starts anew.

Four waveforms are readily obtainable from this basic generator circuit. With the current sources set at I and 2I respectively, the charge and discharge times are equal. Thus a triangle waveform is created across the capacitor and the flip-flop produces a square-wave. Both waveforms are fed to

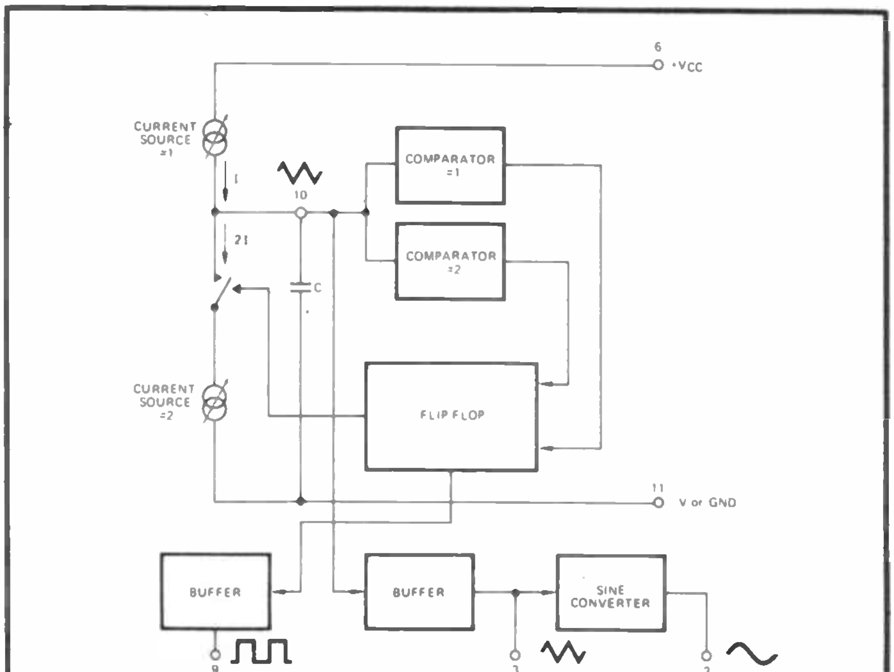


fig 1. BLOCK-DIAGRAM OF WAVEFORM GENERATOR.

buffer stages and are available at pins 3 and 9.

The levels of the current sources can, however, be selected over a wide range with two external resistors. Therefore, with the two currents set at values different from I and 2I, an asymmetrical sawtooth appears at terminal 3 and pulses with a duty cycle from less than 1% to greater than 99% are available at terminal 9.

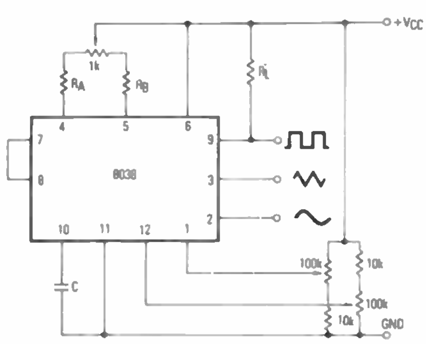
The sine-wave is created by feeding the triangle-wave into a non-linear network (sine-converter). This network provides a decreasing shunt-impedance as the potential of the triangle moves toward the two extremes.

Power Supply

The waveform generator can be operated either from a single power supply (10 to 30 Volts) or a dual power supply (±5 to ±15 Volts). With a single power supply the average levels of the triangle and sine-wave are at exactly one-half of the supply voltage, while the square wave alternates between +V and ground. A split power supply has the advantage that all waveforms move symmetrically about ground.

Also notice that the square wave output is not committed. The load resistor can be connected to a different power supply, as long as the applied voltage remains within the breakdown capability of the waveform generator (30 V). In this way, for example, the square-wave output be made TTL compatible (load resistor connected to +5 Volts) while the waveform generator itself is powered from a much higher voltage.

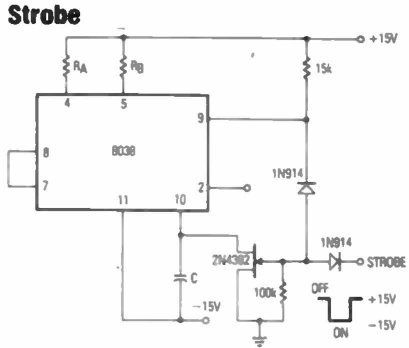
Purity



The symmetry of all waveforms can be adjusted with the external timing resistors. To minimize sine-wave distortion the resistors between pins 11 and 12 are best made variable ones. With this arrangement distortion of less than 1% is achievable. To reduce this even further, two potentiometers can be connected as shown. This configuration allows a reduction of sinewave distortion close to 0.5%.

Both the sine-wave and triangular outputs, are only useful up to about 20kHz if a reasonably pure signal is required. A perusal of the graphs will show why.

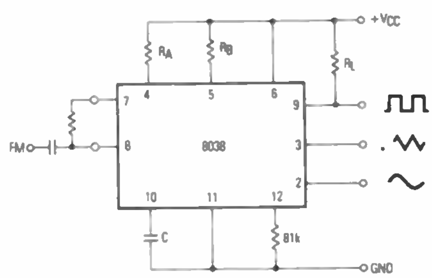
Strobe



With a dual supply voltage (e.g., ±15V) the external capacitor (pin 10) can be shorted to ground so that the sine wave and triangle wave always begin at a zero crossing point. Random switching has a 50/50 chance of starting on a positive or negative slope. A simple AND gate using pin 9 will allow the strobe to act only on one slope or the other.

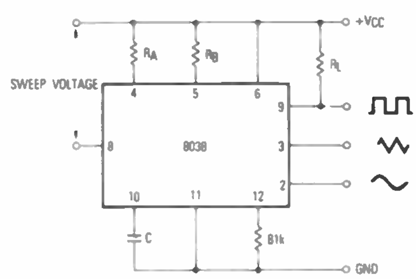
Using only a single supply, the capacitor (pin 10) can be switched to either V+ or ground to force the comparator to set in either the charge or discharge mode. The disadvantage of this technique is that the beginning cycle of the next burst will be 30% longer than the normal cycle.

F.M. and Sweeping



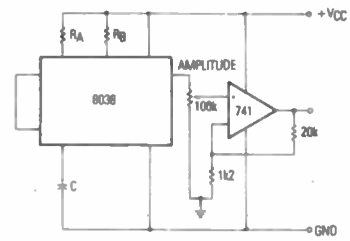
The frequency of the waveform generator is a direct function of the DC voltage at terminal 8 (measured from +VCC). Thus by altering this voltage, frequency modulation is achieved.

For small deviations (i.e. ±10%) the modulating signal can be applied directly to pin 8, merely providing dc decoupling with a capacitor. An external resistor between pins 7 and 8 is not necessary, but it can be used to increase input impedance. Without it (i.e. terminals 7 and 8 connected together), the input impedance is 8k, with it, this impedance increases to (R+8k).



For larger FM deviations or for frequency sweeping, the modulating signal is applied between the positive supply voltage and pin 8. In this way the entire bias for the current sources is created by the modulating signal and a very large (e.g. 1000:1) sweep range is created (f = 0 at V_{sweep} = 0). Care must be taken, however, to regulate the supply voltage; in this configuration the charge current is no longer a function of the supply voltage (yet the trigger thresholds still are) and thus the frequency becomes dependent on the supply voltage. The potential on pin 8 may be swept from V_{CC} to about 2/3 V_{CC}.

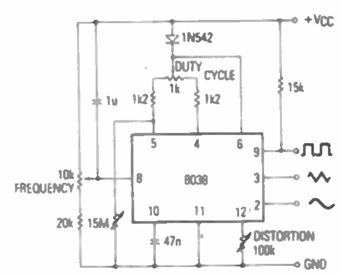
Buffering



The sine wave output has a relatively high output impedance (1K Typ). The circuit provides buffering, gain and amplitude adjustment. A simple op amp follower could also be used.

If the available outputs are all fed through a buffer, extra resistors can be inserted in series with the signal before a switch. Values of 47k (square wave), 15k (triangular) and 10k (sine wave) will ensure equal amplitude signals.

Audio Oscillator



To obtain a 1000:1 Sweep Range on the 8038 the voltage across external resistors RA and RB must decrease to nearly zero. This requires that the highest voltage on control Pin 8 exceed the voltage at the top of RA and RB by a few hundred millivolts.

The Circuit achieves this by using a diode to lower the effective supply voltage on the 8038. The large resistor on pin 5 helps reduce duty cycle variations with sweep. The range of this circuit is 20Hz to 20 kHz, output buffer can be added to make a general purpose bench unit.

Points to Note!

The 8038 runs hot to touch, this is normal, and is due to the resistive nature of the sinewave shaping network.

The optimum supply voltage, for minimum temperature drift is 20V, this can be seen in the stability graph.

CAPACITORS

MODERN FIXED CAPACITORS can be placed in three general classes according to the characteristics of their dielectric.

(A) Low loss, high stability e.g. mica, low-K ceramic, polystyrene.
(B) Medium loss, medium stability e.g. paper, plastic film, high-K ceramic.
(C) Polarised capacitors e.g. electrolytic, tantalum.

Mica Capacitors

Mica capacitors have low RF losses right through to UHF and very good capacitance stability. They are suitable for use in RF circuits up to 500 MHz and are recommended for use in oscillators and filters where their stability characteristics are almost unrivalled. Mica capacitors of appropriate size can handle large RF currents and high voltages and are often used in transmitting applications.

Moulded Mica or "Postage Stamp" – the most common form is the "Postage stamp" style, so named because of its size and shape. Often cheaper than real postage stamps and taste better when licked! General purpose mica capacitors have good stability and can be obtained with high voltage and high RF current ratings. They are constructed of layers of foil interleaved with mica (referred to as "stacked mica") or layers of metallized mica. Obtainable in values between 10 pF and 0.1 μF. They may be marked 'M.S.' to indicate Stacked Mica.

Silvered Mica – usually labelled with an S.M. marking, not to be confused with Stacked Mica capacitors. These have very high stability and are recommended for use in oscillators, filters and other critical applications requiring highly stable capacitance. Tolerance is also very good, usually specified to ± 5% but in practice often better. Generally obtainable in values from 4.7 pF to 3300 pF.

Metal-Clad Mica – a square or rectangular-shaped capacitor having a metal clamp holding the stack of interleaved plates of foil and mica. This form of construction has low lead inductance and can handle high RF currents. It is used for dc blocking and bypassing in RF circuits.

Button Mica – named after their shape. Very good RF bypasses. Made in standoff and feedthrough styles. They have very low inductance connections and are used for RF bypass, filter, and tuned circuit applications up to UHF. The feedthrough style provides a bypassed connection through a chassis while the standoff style provides a direct bypass or bypassed tie point. Obtainable in values between 5 pF and 10 000 pF.

Dipped Mica – this style is encapsulated by dipping in resinous material below atmospheric pressure. They have improved electrical characteristics and higher reliability than moulded types. Obtainable in values from 10 pF to 0.1 μF.

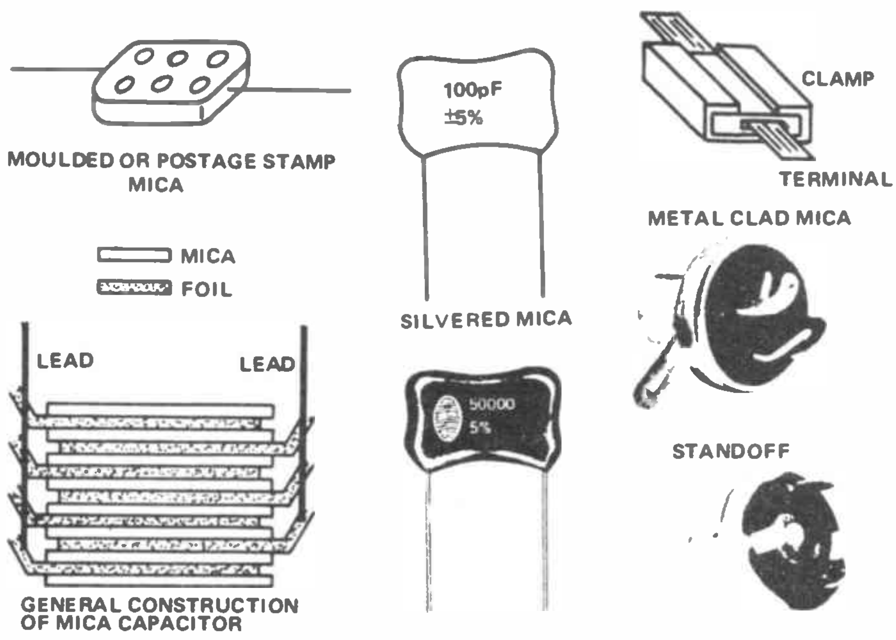


Fig. 1. Typical mica capacitors

Ceramic Capacitors

There are two basic types of ceramic capacitors – low permittivity ("Low-K") and high permittivity ("High-K"). They have widely different characteristics.

Low-K ceramics have low loss and exhibit small, linear changes of capacitance with temperature. They are useful up to 1000 MHz and are made for both low voltage and high voltage applications.

High-K ceramics provide large capacitance values in small space. Their losses are dependent on applied ac and dc fields. They exhibit large, non-linear changes in capacitance against temperature. As a consequence they find application as decoupling and bypass capacitors (discussed later).

Low-K Ceramic Capacitors. Low-K ceramic capacitors are manufactured in a range of temperature characteristics. They are sometimes referred to as "temperature compensating" capacitors as they can be used to compensate for temperature changes in other circuit components. This property is particularly useful in RF oscillators and filters.

The temperature characteristic or coefficient, is quoted in parts per million per ^{o}C (ppm/^{o}C), either positive or negative e.g. a capacitor marked 100 pF/P100 will *increase* its capacitance by 100 ppm for each degree centigrade increase in temperature. For a temperature rise of 10^{o}C it will increase its capacitance by 0.1 pF. As a further example, a 1000 pF capacitor

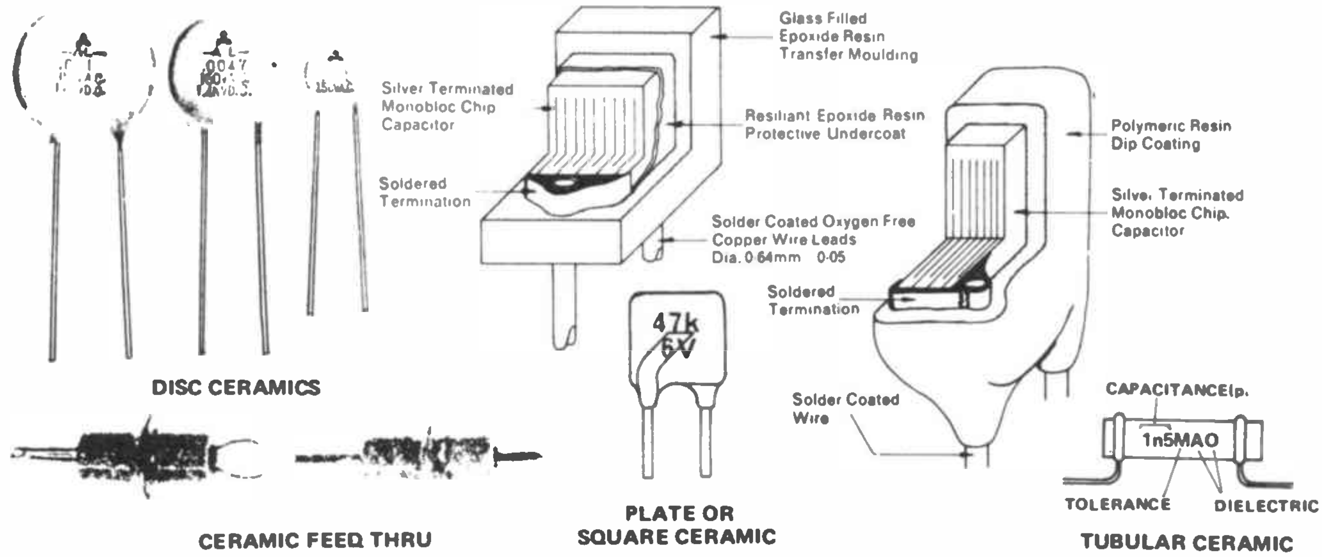


Fig. 2. Ceramic capacitors.

will *decrease* its capacitance by 1500 ppm for each degree centigrade rise in temperature. For a temperature rise of 10°C, its capacitance will drop by 15 pF.

Low-K capacitors are also produced having an extremely small temperature characteristic. These are known as NPO ceramics ("Negative-Positive Zero"). Their stability rivals that of silvered mica capacitors.

The graphs in Fig. 3 indicate the range of standard characteristics manufactured. The nominal value of ceramic capacitors is specified at 25°C. It should be noted that the change in capacitance is not strictly linear, having a small curvature, at low temperatures it becomes more negative. The tolerance on the temperature characteristic ranges from ± 30 ppm for NPO capacitors, to ± 1000 ppm for N5600. Below values of 10 pF stray capacitances begin to have a marked effect on the temperature characteristic and the tolerances are widened.

The temperature coefficient of silvered mica capacitors is usually about +20 ppm/°C but may be as low as +5 ppm/°C which is somewhat better than NPO ceramics.

Low-K ceramic capacitors are made in disc, square and tubular forms. They are obtainable in a range of working voltages from 50 V to 15 kV. They are useful in RF circuits up to three or four hundred megahertz. Above this frequency, leadless unencapsulated "chip" capacitors are used.

Polystyrene Capacitors

Polystrene capacitors are one type of plastic film capacitor. They are constructed usually by interleaving strips of foil and polystyrene film, the alternate strips of foil being staggered to provide connections. The assembly is then rolled up to form a tubular shaped capacitor. See Fig. 4. They exhibit low loss and good stability and are manufactured in a range of working

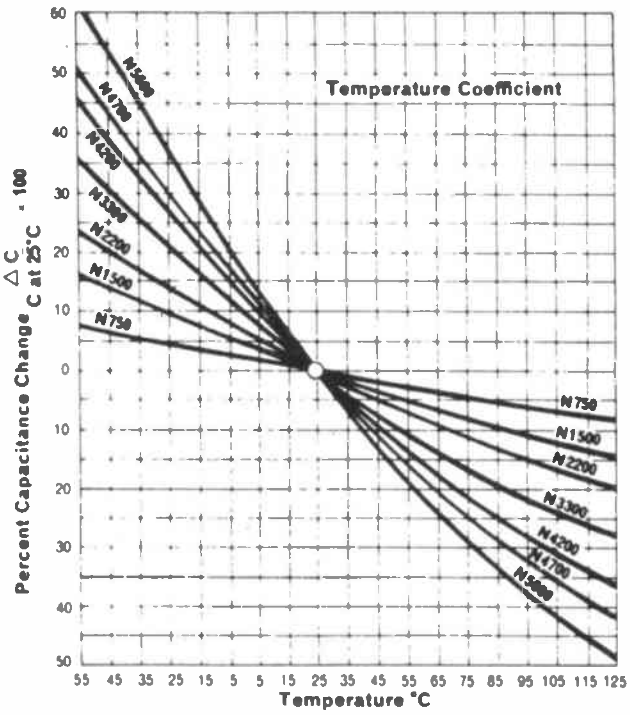
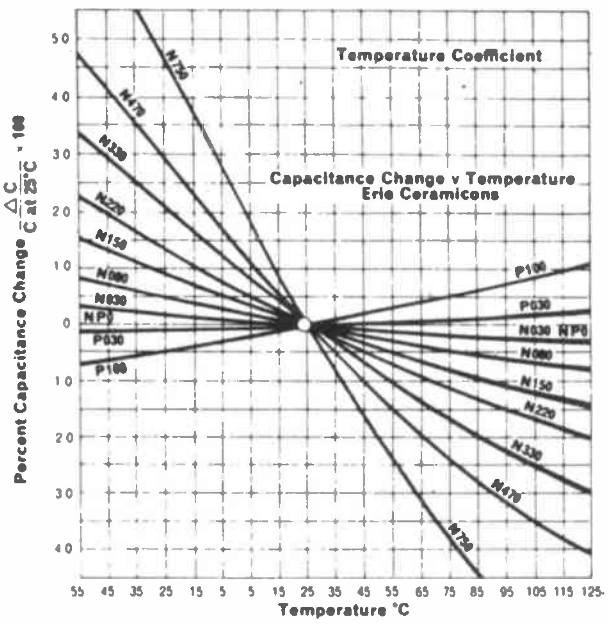


Fig. 3. Characteristics of ceramic capacitors



	Paper		Polyester		Polycarbonate		Polypropylene		Polystyrene	Ceramic		Mica	Electrolytic		
	metalized	film/foil	metalised	film/foil	metalised	film/foil	metalized	film/foil		disc/tube	monolithic		aluminium foil	foil	tantalum solid & wet
Insulation resistance (in megohms)	3×10[illegible]	7×10^{4}	5×10^{4}	10[illegible]	5×10^{4}	10[illegible]	10[illegible]	5×10^{4}	10[illegible]	10[illegible]	10^{4}	10^{5}	← variable →		
Tolerance	10	5%	5%	5%	5%	2%	5%	2%	0.625%	10%	20%	0.5%	10%	10	5
Temperature range (°C)	30 to 100	30 to 100	55 to 125	55 to 125	55 to 125	55 to 125	40 to 85	40 to 100	40 to 70	-55 to 125	-55 to 125	-55 to 125	20 to 80	40 to 125	40 to 150
Size per CV*	small	large	small	small	small	small	small	small	large	small	small	small	very small	small	
Stability	fair	fair	fair	fair	fair	fair	fair	excellent	excellent	fair	fair	excellent	fair	very good	excellent
Capacitance range (µF unless indicated)	0.01 to 100	0.001 to 100	0.001 to 10	100 pF to 0.01 µF	0.001 to 100	5 pF to 0.01 µF	0.001 to 100	100 pF to 0.47 µF	100 pF to 0.6 µF	5 pF to 1µF	0.001 to 10	5 pF to 0.01 µF	typically 1 22 000	1 1000	3500 max
Voltage (ac) (dc)	250 630 500 5000	250 630	63 400 100 1500	90 160 160 400	40 250 63 1000	63 160 100 400	250 440 750 1000	63 500 100 1500	63 1000	63 250 63 10 000	63-450	63-630	6.3 500	6.3 300	1 50
Temperature coefficient PPM °C	300	300	400	400 (non linear)	150	50 to 100	170	120	150	non linear positive to 1000 neg		100	1500	1000 (non linear)	200 - 1000
Appr. resonance MHz	0.1	0.1	0.1	1	0.1	1	0.1	1	1	10	100	10	0.05	0.1	0.1

*CV product of capacitance and voltage

Capacitor Comparison Chart.

voltages from 100 volts to 630 volts. They exhibit a small negative temperature characteristic of about 150 ppm/°C and are sometimes used as temperature compensating capacitors. Their main application is in tuned circuits and as coupling capacitors up to about 100 MHz. The higher values (0.01 µF and above) are sometimes used in bypass and decoupling applications.

Polystyrene capacitors are affected by heat, greases and solvents. Care must be taken when using them to keep them away from heat sources (e.g. power resistors). Exercise care when soldering. Flux solvents and other chemical solvents will dissolve the capacitor, with disastrous effects.

Paper Capacitors

Paper capacitors are medium loss, medium stability capacitors that were once widely used. They have been largely replaced by plastic film types for most purposes but are unsurpassed in high voltage dc and low frequency ac power applications.

There are two basic types of construction, the metal foil type and the metallized type. The metal foil type is constructed by winding together interleaved layers of foil and impregnated paper similar to plastic film capacitors, see Fig. 4. This type is best for high voltage and high current applications, a common form being the paper "block" capacitor. See Fig. 5. They are available in voltage ratings up to 4000 V and will withstand considerable charge-discharge currents. The metalized type has the impregnated paper dielectric coated with a thin layer of aluminium or zinc. This form of construction results in a capacitor of relatively smaller physical size.

The paper dielectric is impregnated with another dielectric substance to replace the water content inherent in paper and to prevent the absorption of

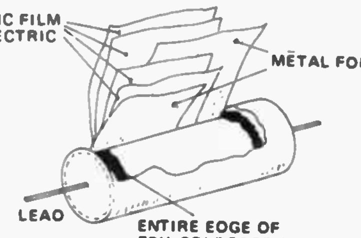


Fig. 4. How polystyrene capacitors are made

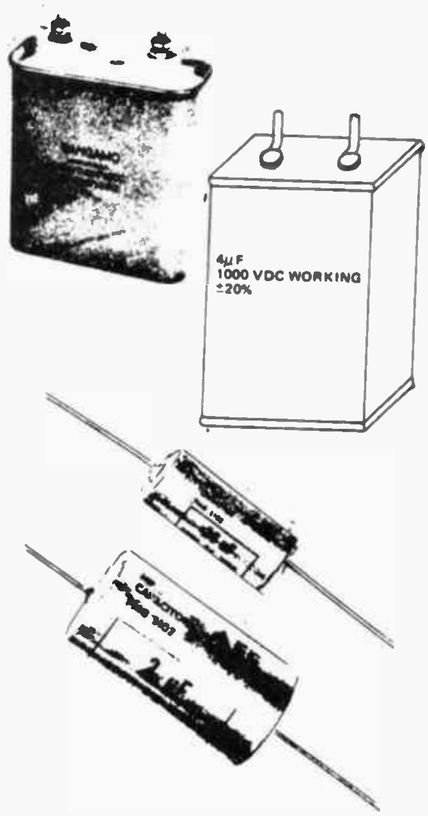


Fig. 5. Paper block capacitors

moisture. A variety of natural oils or waxes, or synthetic chemicals, is used.

Encapsulation of the capacitor assembly is usually by moulding in resin or encasing in hermatically sealed metal cans as is done with block capacitors.

Plastic Film Capacitors

Plastic films are widely used in capacitor manufacture due to their high reliability and low cost. They have medium loss and medium stability characteristics except for polystyrene capacitors which have already been discussed. Many types of plastic film are used but these fall into three general groups:— polystyrene, polyester and polycarbonate.

The common form of construction uses strips of aluminium foil interleaved with the plastic film dielectric, alternate layers of foil being staggered to provide

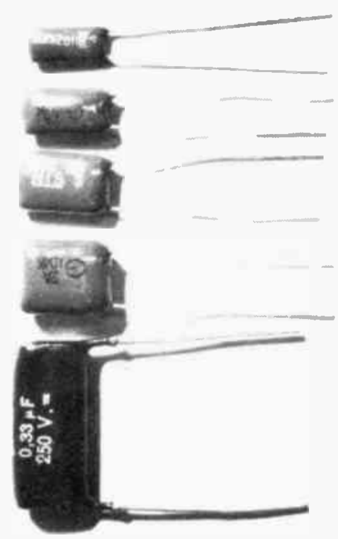


Fig. 6. Resin dipped polyester capacitors.

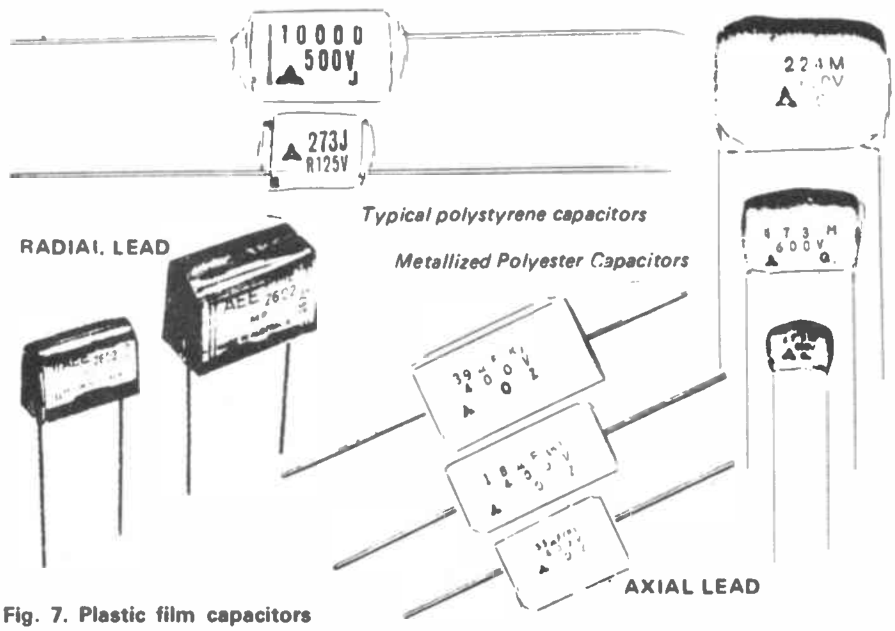


Fig. 7. Plastic film capacitors

lead connections. The assembly is then rolled-up to form a tubular-shaped capacitor. Some types are wound flat to form a flat rectangular-shaped capacitor which enables it to be packed more densely on a printed circuit board. They are referred to as 'flat film' capacitors.

Metallized film construction is also extensively used with plastic film capacitors, resulting in physically small dimensions. These capacitors have largely replaced paper capacitors in most low voltage applications owing to their superior electrical characteristics and considerably smaller size.

Plastic film capacitors are generally encapsulated in a tough, impervious plastic or resin or in a metal case.

The polyester films used are generally of the polyethylene type (Mylar, Melinex etc) or polypropylene, and for most purposes they have similar properties to polycarbonate films. The latter though, has less loss and exhibits less change in capacitance with temperature. Polyester capacitors are available in ratings up to 100 Vdc (or 250 V rms ac), Polycarbonate capacitors are usually only available in ratings up to 400 Vdc.

A small defect, such as a hole, in the dielectric of a capacitor will allow an arc between the electrodes when a sufficiently high voltage is present. In foil capacitors, the arc usually destroys more of the surrounding dielectric, resulting in catastrophic failure – usually a short circuit.

This disadvantage does not occur in metallized capacitors. The heat generated by the arc rapidly vaporizes the electrode section, clearing the short. A very short pulse of current occurs and the voltage across the capacitor drops and then rises again in a few microseconds. Usually, no further damage results. The process is illustrated in Fig. 8.

High-K Ceramic Capacitors

High-K ceramic capacitors provide large values of capacitance in a very small space. Owing to their method of manufacture they have appreciable loss and show large non-linear changes in capacitance with temperature. Primarily for these reasons they largely find application in bypassing and dc blocking. They change capacitance with applied dc and ac voltage, showing a decrease in capacitance with increasing dc voltage which ranges from 14% for the relatively low permittivity high-K ceramics to 80% for the higher permittivity ceramics. Ac voltage effects are the reverse of dc, giving an increase in capacitance with increasing voltage. This may be only 2% for the lower permittivity ceramic or up to 80% with the higher permittivity types.

High-K ceramic capacitors also change capacitance with frequency. The change is primarily dependent on the particular ceramic used, rather than high or low permittivity. They decrease in capacitance with increasing frequency. Most high-K capacitors only show a decrease of 5% between 1 kHz and 10 MHz, but others can drop 20% over the same range. These characteristics are usually of little consequence in most applications. However, care should be exercised in using them as bypass and decoupling capacitors around oscillator circuits. Plastic film capacitors or low-k disc ceramics are to be preferred.

In general, high-K ceramic capacitors have less internal inductance than plastic film or paper capacitors, as well as smaller size and are preferred in bypass applications. Disc or plate style ceramic capacitors are suitable for bypass applications from 10 MHz to 100 MHz. High-K ceramic capacitors are also made in button feedthrough and bypass styles for bypass applications to 1000 MHz. The tubular style is suitable in bypass applications to 50 MHz while the ceramic feedthrough is useful to 500 MHz. See Fig. 2 for illustrations. The large value (1000 pF – 0.47 μF) 'chip' or 'block' style, which has very low lead inductance, is very useful for bypassing in digital circuitry.

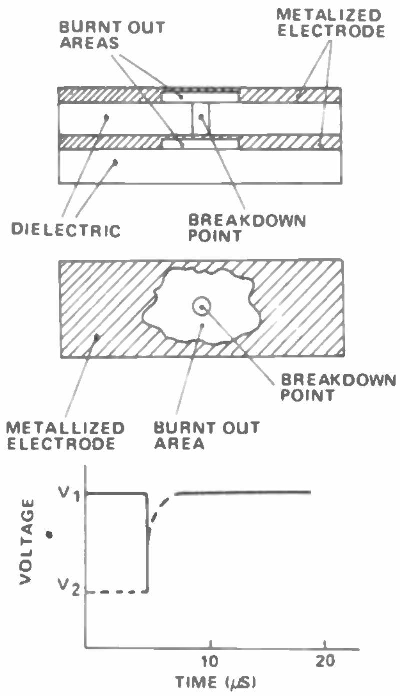


Fig. 8. Process of self healing of a metalized dielectric capacitor. The voltage trace is typical during the process.

Electrolytic Capacitors

Electrolytic capacitors consist basically of two aluminium foils interleaved with an absorbent paper and wound tightly into a cylinder. Contacts are provided by tabs of aluminium attached to the foils. The winding is impregnated with electrolyte and housed in a suitable container, usually an aluminium can, which is hermetically sealed (Fig. 9).

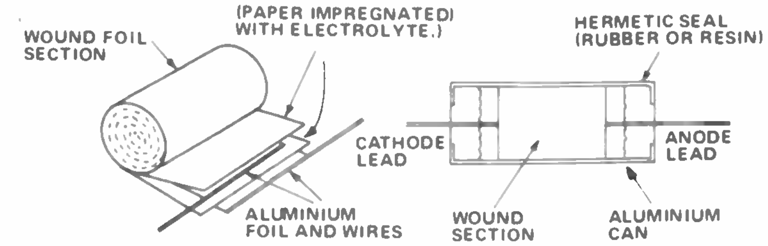


Fig. 9. Construction of typical electrolytic capacitor.

A dielectric layer of aluminium oxide is 'formed' electrolytically on the surface of one aluminium foil which acts as the positive plate, or anode, of the capacitor. The electrolyte serves as the second plate of the capacitor and also to repair any flaws in the oxide film when the electrolyte is polarised. The second foil, usually called the cathode foil, provides contact to the electrolyte. Since this film will have a thin oxide film, due to natural oxidation, it will also possess very high capacitance. The thinness of the oxide films, and their high breakdown potential, is responsible for the very high capictance values per unit volume and high working voltages of electrolytic capacitors.

As a result of their construction, these capacitors are polarised and require the anode terminal to be at a positive potential to the cathode terminal. Most types will only withstand a reverse voltage of 1 V or 2 V for short periods and about 1.5 V peak-to-peak ac without a depolarising voltage.

There are two types of electrolytic capacitor, the plain foil type and the etched foil type. The plain foil construction is described above. The etched foil type is constructed similarly to the plain foil except that the aluminium oxide on the anode and cathode foils has been chemically etched to increase its surface area and permittivity. It results in a capacitor which is physically smaller than a plain foil type of equivalent value but has the disadvantage of not being able to withstand high ac currents, compared with the plain foil type.

Etched foil electrolytics are best used in coupling, dc blocking and bypass applications. Plain foil types are better suited as reservoir capacitors in power supplies.

Tolerances

Electrolytic capacitors are usually manufactured to a tolerance of −20 +100% or −50 +100% (they really are!).

The capacitance value and leakage current both increase with temperature. The leakage current increases with applied dc voltage, this increase becoming more rapid at voltages in excess of the rated working value. This can lead to increased heat dissipation in the capacitor which will, in turn, increase the leakage current, leading ultimately to destruction

Most electrolytics are rated to withstand a short voltage surge about 15–20% greater than the rated working voltage. e.g: a capacitor rated at 450 V may be marked 450 VWdc (volts, working, dc), 525 V surge.

Electrolytics can be used below their rated voltage. There may be a slight increase of capacitance with time. Leakage current is usually considerably reduced, resulting in an increased service life.

In manufacture, the internal negative connection may be taken directly to the case or to a tag on the insulated end disc. In this case the capacitor winding is inserted in the case without surrounding insulation so that, even though the negative tag is not directly connected to the case, it is not deliberately insulated from it and leakage current can flow between the case and negative terminal. These capacitors are usually covered in shrunk-on plastic sleeve to insulate the can.

Electrolytic capacitors are made in a range of voltage ratings from 10 V to 600 V.

Non-Polarised Electrolytics

These capacitors are constructed using several foils in one winding and connected 'back-to-back'. They are usually larger than polarised capacitors of equivalent value. Since double the foil area than is normally required is used they have increased leakage current. Ac voltage without a dc polarising voltage is permissible, the value depending on ripple current ratings and the frequency.

These capacitors are used as speaker coupling and crossover network capacitors. They are obtainable in values from 1 μF to 100 μF.

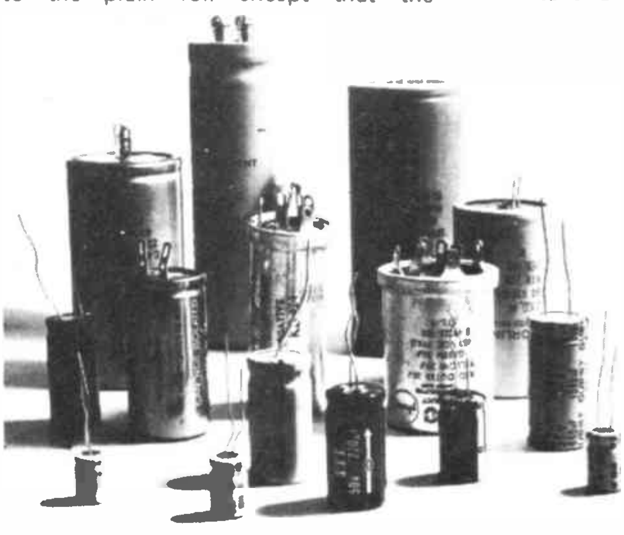


Fig. 10. A selection of electrolytic capacitors.

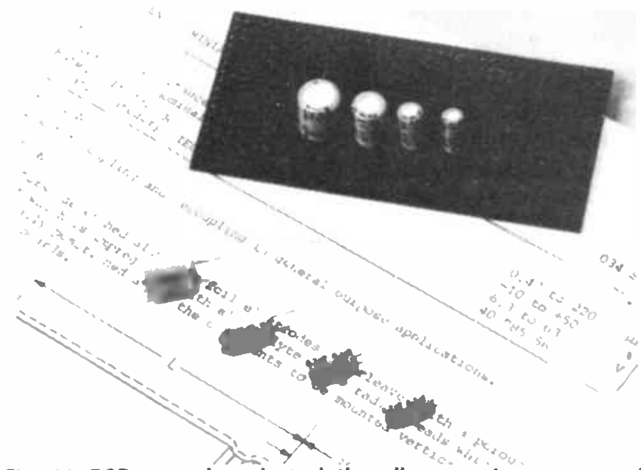


Fig. 11. PCB-mounting electrolytics allow greater component density.

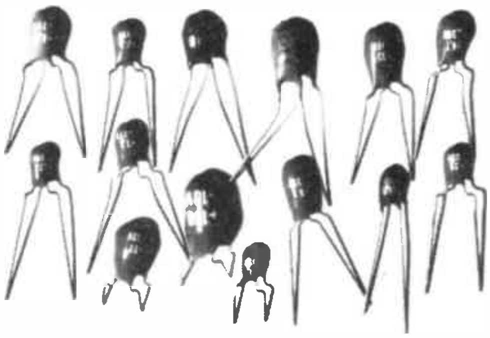


Fig. 12. Miniature tantalum capacitors have a small size and large capacity, but usually have a low working voltage.

Tantalum Capacitors

These capacitors use tantalum oxide as a dielectric. This has a much greater permittivity than aluminium oxide resulting in high value capacitance in relatively small space. Owing to their construction, they are also used as polarised capacitors.

There are three different types of tantalum capacitors, each having different construction. These are the tantalum foil type, the solid tantalum, and the wet-sintered tantalum. The tantalum foil type is similar in construction to electrolytic capacitors but the electrolyte and anode and cathode terminals use different materials.

Solid tantalum capacitors use solid maganese dioxide (which is a semiconductor) as the electrolyte, and a tantalum anode. The cathode connection is formed by coating the electrolyte with graphite and silver. These capacitors may be encapsulated in capacitors may be encapsulated in epoxy resin, polyester sleeve with epoxy seals, or a can with epoxy seals.

Tantalum capacitors are rated at much lower voltages than electrolytic capacitors. Their small size makes them very suitable for use in transistor circuits. Low leakage current and better capacitance stability than electrolytics are two features which make them suitable for timing applications.

Tantalum capacitors are generally available in values between 0.1 µF and 100 µF. Tolerance is usually +50% −20%. Solid tantalum capacitors are available in voltage ratings from 3 V to 100 V. Wet sintered tantalums are available up to 125 V rating and foil tantalums up to 450 V.

Variable Capacitors

Variable capacitors can be divided into two basic groups: continuously variable types, generally called tuning capacitors, and preset types, generally called trimmers.

Tuning capacitors have a set of fixed plates and a set of moving plates that mesh with the fixed plates. The position of the moving plates with respect to the fixed plates determines the capacitance. Capacitance is maximum when the plates are fully meshed. The dielectric may be air, mica or plastic film. Various tuning capacitors are shown in Fig. 1.3. Most tuning capacitors have air as the dielectric. Miniature tuning capacitors such as those used in portable transistor radios, have a plastic film dielectric. As this has a greater permittivity than air, a considerable reduction in size is achieved. Precision tuning capacitors such as those used in instruments and communications receivers have precision ball-race bearings at each end of the shaft and a heavy, rigid frame to provide stability and reset accuracy.

Tuning capacitors are available in various sizes and values for different applications. Those for receiver applications generally have small, closely-spaced plates, several units being "ganged" together in one frame so that several circuits may be tuned simultaneously. Two and three gang capacitors are quite common. The plates are often semi-circular or specially shaped to produce the desired tuning scale or "law". This is done to obtain linear or logarithmic dial calibrations for example.

There are four basic tuning characteristics.

Linear Capacitance For each degree of rotation there is an equal change in capacitance. For example, a capacitor may change by 2 pF for each degree of rotation. This produces a square-law dial scale.

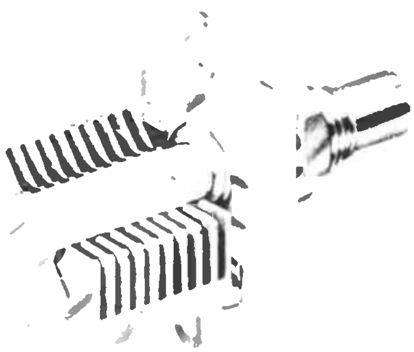
Linear Frequency Each degree of rotation causes an equal change in frequency. This produces a linear dial scale. This characterisation is very useful in tuners and communication receivers.

Log Frequency Each degree of rotation produces a constant percentage change in frequency, e.g. a 1% change in frequency for each degree of rotation. This produces a logarithmic dial scale which is sometimes seen on AM tuners and broadcast receivers. It is often used in measuring instruments and signal generators.

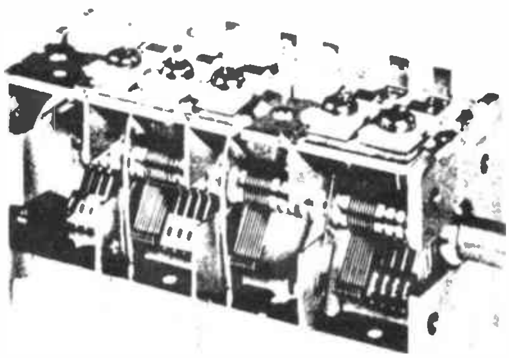
Square Law The variation in capacitance is proportional to the square of the angle of rotation. This is also used in measuring instruments. Typical dial calibrations and capacitor tuning law curves are shown in Fig. 15.

Multiple-gang capacitors are commonly used in superhet receivers, particularly AM and FM broadcast receivers, where the RF, mixer and

Fig. 13. Different types of variable capacitor used where the circuit requires continual readjustment.



Low capacitance, single section air dielectric variable capacitor.



Combined tuning gang for AM/FM receiver.

oscillator circuits are ganged to tune a range of frequencies. Usually, each section of a gang covers the same capacitance range and has the same tuning law. As the oscillator circuit covers a different frequency range from the RF and mixer, one section of a gang may have less plates and thus a different capacitance range or a slightly different tuning law. This is done so that the oscillator can correctly "track" the RF and mixer circuit with an almost constant frequency difference (the intermediate frequency).

Maximum and minimum capacitance values used for tuning the AM broadcast band and in general coverage HF receivers are:—

3 – 120 pF
10 – 240 pF
4 – 250 pF
6 – 340 pF
10 – 365 pF
11 – 415 pF

For the 88-108 MHz FM broadcast band, common values are:—

0.9 – 19 pF
1 – 22 pF
2 – 32 pF
7 – 40 pF

Some gangs may have each section fitted with trimmers so that the effect of stray capacitance may be compensated for and to provide alignment for the high frequency end of the tuning range.

Tuning capacitors for use in transmitters usually have large, widely-spaced plates to withstand high voltages, and special connections to reduce inductance and to conduct high RF currents. Semi-circular plates are commonly used. For push-pull tuned circuits, requiring two sets of fixed plates and common moving plates, 'butterfly' capacitors are used. See Fig. 14. The construction permits 90° rotation only. 'Split-Stator' capacitors are also used in this application: these have two sets of semi-circular rotor plates on opposite sides of a common shaft and two sets of stator plates with separate connections. These turn a full 180°.

Trimmers

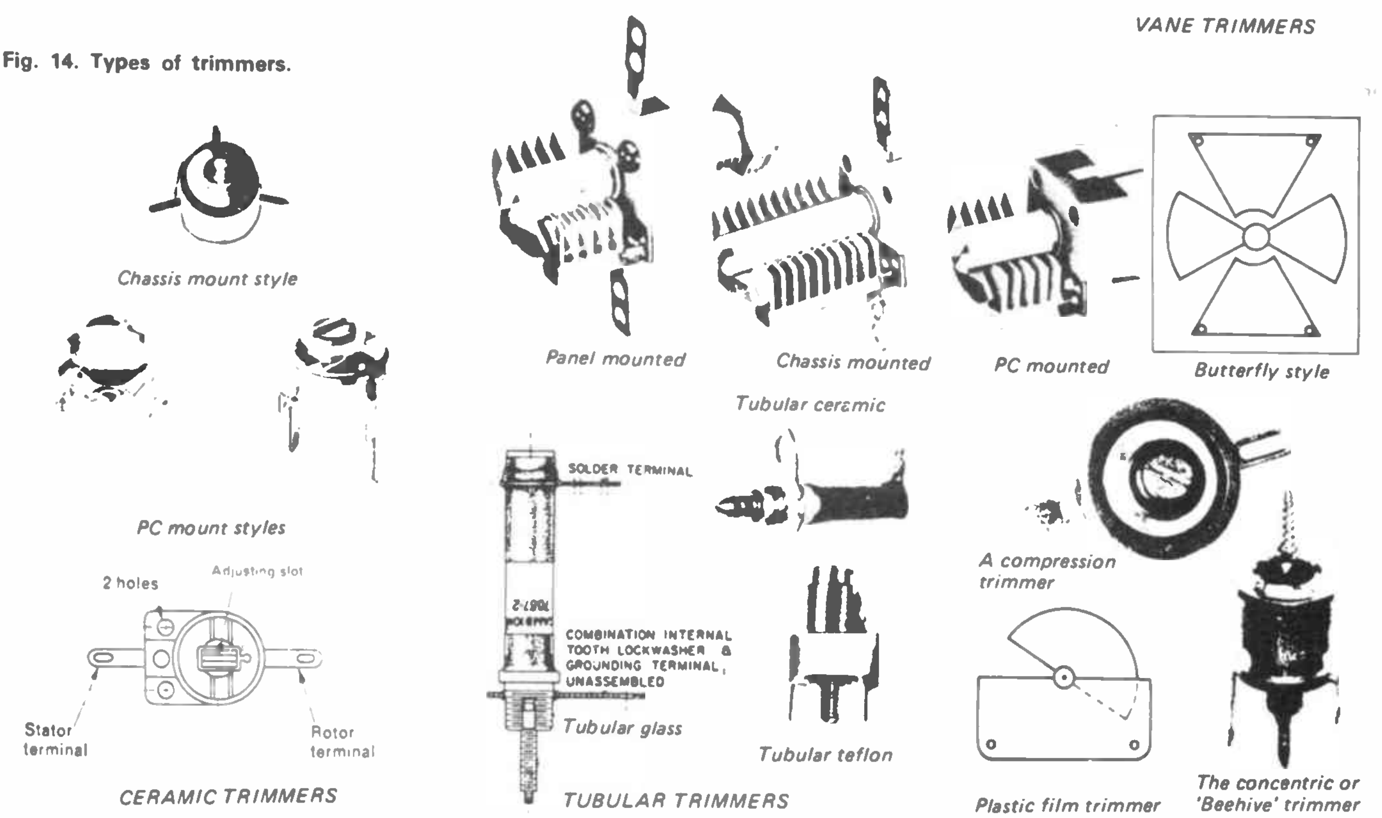
Trimming capacitors are available in a wide variety of constructions and adjustment methods. The most common dielectrics are air, mica and ceramic, although glass and quartz are also used for their superior temperature stability. A representative selection is illustrated in Fig. 14.

Vane Trimmers These trimmers have solid metal plates that may be silver-soldered to a rigid frame or the plates and frame milled from a single piece of specially shaped metal. The latter have better mechanical and electrical stability. The capacitor assembly is usually fixed to a ceramic mounting plate. This type of trimmer is usually more costly than other types but has superior electrical characteristics. Vane trimmers are available in a wide variety of values and sizes, with breakdown voltage ratings from 100 V to 1500 V, depending on the air gap between the fixed and moving plates. Butterfly and split-stator types can also be obtained.

Concentric or 'Beehive' Trimmers The fixed and moving plates of these trimmers are constructed from short sections of different diameter aluminium cylinders, nested inside each other and mounted concentrically around a central shaft. The diameters of the moving plates are such that they mesh between the fixed plates with a small air gap. The central shaft is threaded and a hexagonal boss on top of the moving plates enables capacitance to be adjusted by using a simple plastic tool. These trimmers are cheap and have a wide variety of applications. They are made in several values, the most common being 3-30 pF and 5-60 pF. Their breakdown voltage is usually above 250 V, although it is not *recommended* that they be operated at high voltages. The threaded centre shaft imparts a vernier action which makes adjustment easy and accurate.

Compression Trimmers These consist of several thin plates of springy metal interleaved with a mica or plastic film

Fig. 14. Types of trimmers.



dielectric. An insulated screw is passed through the centre of the plates and threaded into a phenolic, plastic or ceramic mounting compressing the springy plates. The further the screw is turned in, the more compression is applied to the plates, thus increasing the capacitance. Trimmers of this type are usually quite inexpensive. Their stability is not very good but is nevertheless adequate for many applications, but they drift appreciably with time necessitating frequent realignment.

Mica compression trimmers are generally constructed on a ceramic mount. They have the best characteristics of all the compression trimmers and find application in solid state transmitters as they can withstand appreciable RF currents. Some types are manufactured especially for this application. The other styles having a phenolic or plastic mount are used mostly in receiver or non-critical instrument applications.

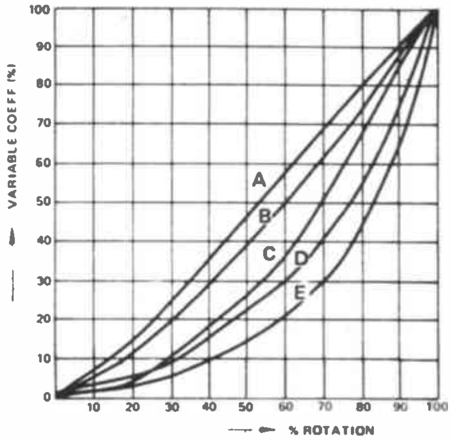
Compression trimmers are capable of quite a wide adjustment range – an advantage over other trimmers, although the adjustment may be coarse and quite non-linear. Typical minimum and maximum values are:–

2 – 25 pF
3 – 30 pF
2.5 – 40 pF
3 – 55 pF
10 – 80 pF
30 – 150 pF
20 – 220 pF

Compression trimmers have a large, and not really predictable temperature co-efficient that varies appreciably over their range. Their breakdown voltage is in the order of 100 V to 300 V.

Plastic Film Trimmers. These are constructed in a way similar to vane trimmers and generally have semi-circular fixed and moving plates with a plastic film dielectric. Consequently they are smaller in size for similar values. These trimmers are relatively inexpensive and are a good alternative to air dielectric trimmers. They generally have a negative temperature coefficient of about 200 ppm/°C (decrease capacitance with increasing temperature). They are generally manufactured for p.c. board mounting although chassis-mounting styles are available. Typical minimum and maximum values are:–

1 – 5 pF
1.8 – 10 pF
2 – 18 pF
1.5 – 20 pF
4 – 40 pF
5 – 60 pF
7 – 100 pF



Capacitance Variation Graph.

A CAPACITANCE LINEAR
B LINEAR FREQUENCY OF FM SECTION
C LOG
D LINEAR FREQUENCY OF AM OSC. SECTION
E LINEAR FREQUENCY OF AM RF SECTION

NOTES
1. CAPACITANCE AT 100% ROT. = 100% VARIABLE COEFF.
2. 180° = 100% ROT

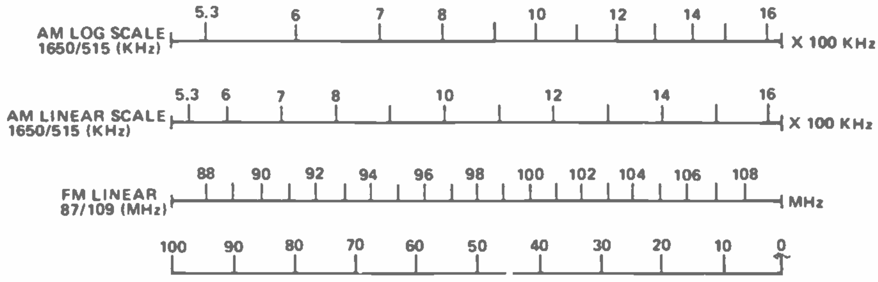


Fig. 15. The standard dial formats.

Film dielectric trimmers generally have a breakdown voltage of 100 V.

Ceramic Trimmers. These consist of a ceramic body with a semi-circular metal film deposited on it as the fixed plate. The moving plate is a ceramic disc with a semi-circular film (the same size as the fixed plate) deposited on it, and pivoted over the fixed plate by a metal screw which is soldered to the metal film. The screw passes through a nut in the ceramic body, the moving plate connection being made to this nut.

Ceramic trimmers are available having a variety of temperature characteristics ranging from P 100 to N 500, the more common values having negative temperature coefficients. Typical maximum and minimum values and temperature coefficients are:–

2 – 4 pF/P100
3 – 9 pF/N033 or N075*
3 – 12 pF/N 470
4 – 20 pF/N 470 or N 750*
7 – 35 pF/N 1500
10 – 60 pF/N 1500

* Characteristic depends on size, the subminiature ones having the smaller coefficient. Ceramic trimmers are obtainable in pc board or chassis mounting styles and may be operated at voltages of at least 200 V or greater.

Tubular Trimmers. Tubular trimmers are also known as 'piston' trimmers. They consist of a tube of dielectric material which has a metal band or metal film around one end forming the fixed plate and a threaded metal cap on the other, through which passes a screw; this latter assembly forms the moving plate. The dielectric material may be ceramic, glass, PTFE (Teflon), polypropylene or quartz. Tubular trimmers are very stable but are used only in VHF/UHF receiver applications (i.e. TV tuners, VHF converters as their particular construction limits the maximum capacitance obtainable. However, ceramic, glass and quartz types can withstand considerable RF currents and voltages, so find some applications in transmitters. Typical working voltages are 250 Vdc to 600 Vdc. Tubular trimmers with a plastic dielectric are generally cheapest, the more costly styles being ceramic, glass and quartz. Typical maximum and minimum values are:–

0.25 – 1.5 pF
0.7 – 3 pF
0.8 – 8.5 pF
1.8 – 10 pF
0.8 – 12 pF
0.8 – 23 pF
0.8 – 38 pF
2 – 60 pF

Both printed circuit and chassis mounting styles are available.

RF CHOKES

RADIO FREQUENCY chokes are used to prevent the passage of radio energy (hence the term 'choke') while allowing direct current or lower-frequency signals (eg, audio) to pass. This sort of application is principally one of decoupling; that is, isolating the RF – carrying portions of a circuit by providing a high RF impedance between two portions of the circuit. The principle also applies in RF interference suppression applications. For example, in reducing RF 'hash' from SCR or Triac motor speed controllers, light dimmers, etc.

RF chokes are also used widely in a variety of filter applications, eg, low-pass and high-pass filters. They are also used in pulse-forming networks and as frequency compensation components in wideband amplifiers (eg, video amplifiers).

RF chokes are also referred to as 'minichokes', 'microchokes' and 'video peaking chokes'.

Construction

The general range of construction styles employed are illustrated in Fig. 1. The different winding styles have particular advantages and characteristics on which we will elaborate shortly. RF chokes are generally made in values according to the preferred series E6, E12, and E24, in tolerances of 5%, 10% and 20%.

Regardless of the form of the winding or the encapsulation, RF chokes are wound on bobbins consisting either of a phenolic or plastic material (non-magnetic), powdered iron or ferrite material. The last two materials, because of their high permeability increase the inductance of the winding effecting a decrease in the number of turns required as well as influencing the other characteristics of the choke.

The bobbin generally has integral pigtail leads moulded into the material to which the winding is terminated. Axial leads are the most common form although radial-lead RF chokes are obtainable – principally intended for printed-circuit mounting.

A form of construction that reduces the external magnetic field of the choke to negligible proportions is illustrated in Fig. 2. This form of construction completely encloses the winding with the result that it has a very weak stray field, reducing 'crosstalk', or coupling, between the choke and adjacent components. In fact, two chokes can be mounted so that they touch each other over the full length of the bobbin – and crosstalk attenuation is quoted as 60 dB.

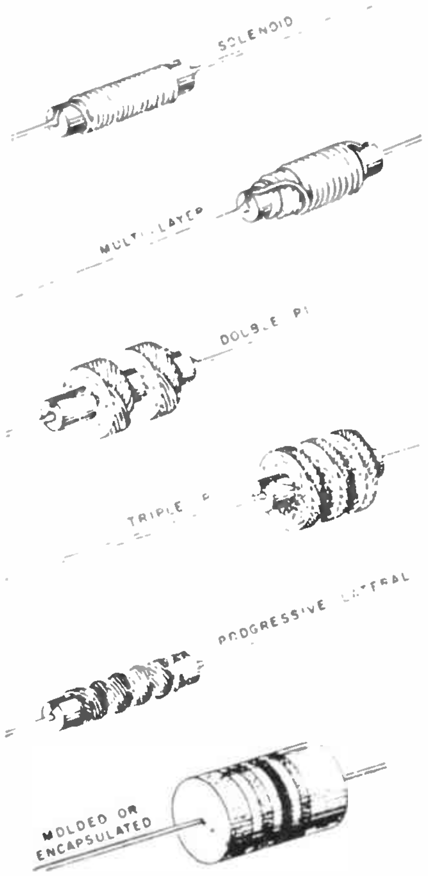


Fig.1. General range of constructor styles of RF chokes. The particular style employed depends on the required or allowable component size, the inductance, the application and the required characteristics.

Low inductance RF chokes are usually 'solenoid' wound, whereby a single layer of wire is closewound on the bobbin. Chokes in the range 0.1 μH to 200 μH are generally solenoid-wound. The very low inductance types below 10 μH are generally wound on a non-magnetic bobbin. Powdered iron bobbins are generally used for chokes between about 5 μH and 100 μH, ferrite for the higher inductances to 200 μH or so.

Higher inductance chokes are obtained by overlapping several closewound layers on the bobbin. There is a limitation to this as the self-capacitance of the winding increases, decreasing the frequency range over which the choke is effective. This is discussed later. Chokes in the range 20 μH to 10 mH are often multilayer wound, generally on powdered iron or ferrite bobbins.

The Philips series of 'micro-chokes' cover the inductance range from 0.1 μH to 100 mH and employ solenoid or multilayer windings on the enclosed ferrite bobbins as illustrated in Fig 2.

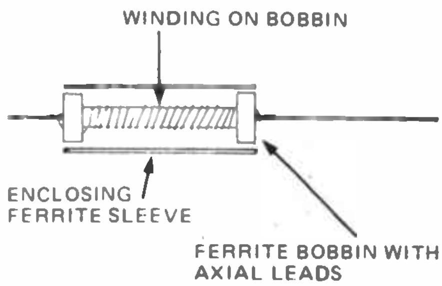


Fig.2. Construction of fully enclosed style of RF choke.

RF chokes from around 47 μH through to 100 mH are often 'pie-wound'. This is a form of winding where the wire is zig-zagged around the circumference of the bobbin and built up in many layers. The individual turns are not colinear – lying alongside the adjacent turns – but the wires cross at an angle due to the zig-zag winding, thus reducing the total self-capacitance of the coil. A multilayer winding wound in this way is termed a 'pie', the method of winding is also referred to as 'universal' winding.

Pie-wound RF chokes may have 1, 2, 3 or as many as 5 or 6, pies making up the inductance. Generally the pies are of the same width, diameter and number of turns but some types for special applications, or where special characteristics are required, are wound with a number of pies, each having a smaller diameter but a greater width than the preceding pie. This achieves a more uniform impedance characteristic over the desired frequency range.

A variation on the pie winding is the 'progressive lateral' type where the zig-zag winding is progressively moved along the bobbin rather than building a high, multilayer pie. This technique reduces the inherent self-capacitance of the winding and provides a more uniform impedance characteristic across the required frequency range.

Encapsulated chokes are generally of solenoid or multilayer construction, and are encapsulated in an epoxy or other suitable material. Pie-wound chokes are sometimes encapsulated although they are more usually wax-impregnated. Heat-shrink tubing is also used to enclose and protect RF chokes.

Characteristics

RF chokes are an inductance that is required to have a high value of impedance over a wide range of frequencies.

In practice, an RF choke has inductance, distributed capacitance, and resistance. At low frequencies, the distributed capacitance has negligible effect and the electrical equivalent of the choke will be as shown in Fig. 3(a). With increasing frequency the effect of the distributed capacitance becomes more evident until at some particular frequency it becomes a parallel resonant circuit. The equivalent circuit at and around this frequency is illustrated in Fig. 3(b). At frequencies beyond this the overall reactance of the choke becomes capacitive and eventually the choke becomes a series resonant circuit, as shown in Fig. 3(c).

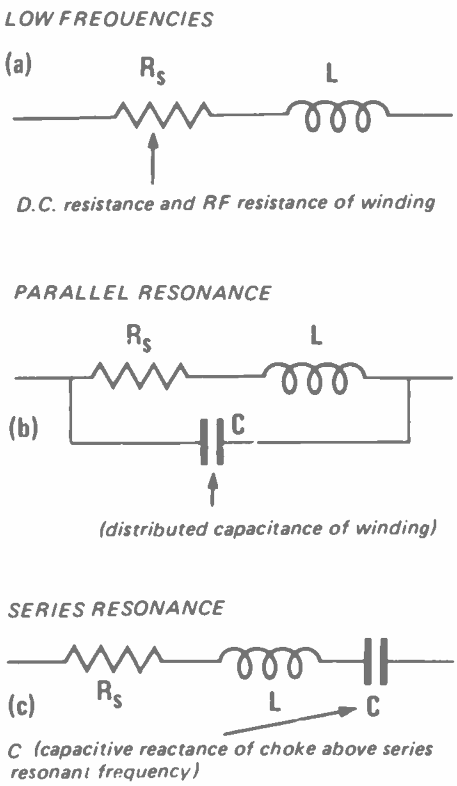


Fig.3. Equivalent circuits of an RF choke over a wide frequency range.

The cycles of parallel resonance-reactance, series resonance, etc, repeat with increasing frequency, the overall impedance of the choke rapidly becoming lower past the initial cycles. This sort of characteristic is illustrated in Fig. 4.

The lower the self capacitance of a particular style of winding, the higher will be the series resonant frequency (also referred to as the self-resonant frequency), thus allowing the choke to operate over a wide frequency range. Special windings, such as the progressive lateral, have extremely low distributed capacitance as well as less variation in impedance across the frequency range, compared to other styles. The variation in self resonant frequency versus choke inductance for three different bobbins and winding styles is illustrated in Fig. 5.

The equivalent series resistance of a choke is made up of the actual dc resistance of the winding plus the RF resistance of the wire used due to 'skin effect'. The actual dc resistance of the choke may need to be taken into account in a circuit, particularly in high current circuits or with high inductance chokes. The latter may have dc resistances up to 500 or 600 ohms.

The equivalent series resistance (also called the 'apparent resistance') varies with frequency, reaching a peak before decreasing due to the shunting effect of the distributed capacitance of the winding. The variation of R_S with frequency for a range of inductances is illustrated in Fig. 6.

Naturally enough, RF chokes have a limit to the amount of dc current they can carry without either overheating or effecting a change in the inductance outside the specified tolerance limits. Manufacturers specify a maximum dc current for their chokes.

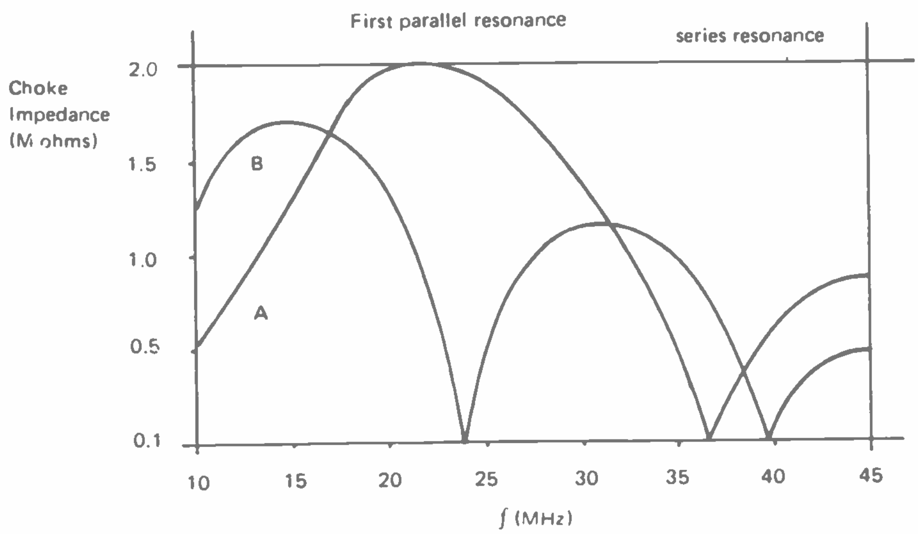


Fig.4. Typical behaviour of two RF chokes (A= around 10 μH, B= around 40 μH) over a range of frequencies.

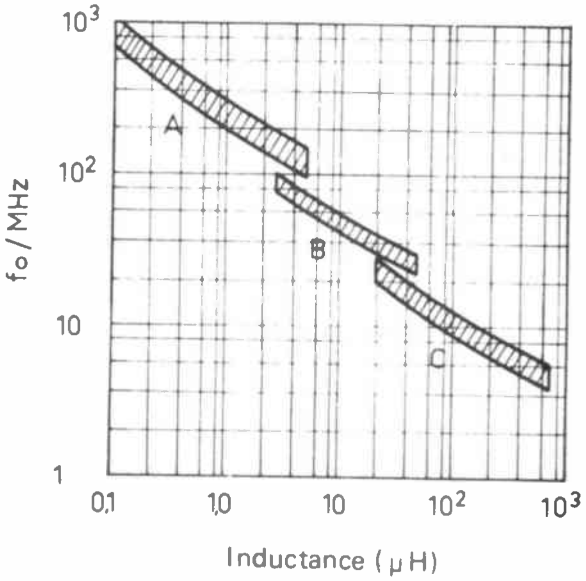


Fig.5. Typical variation of self-resonant (or series-resonant) frequency against choke inductance for three different styles of choke construction.
A = non-magnetic bobbin
B = solenoid wound (single layer) chokes on powdered iron and ferrite bobbins
C = Multilayer choke on powdered iron and ferrite bobbins.

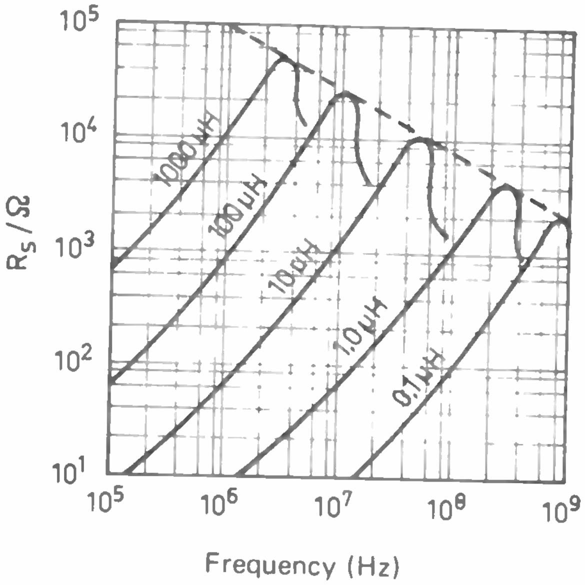


Fig.6. Typical variation or equivalent serves resistance of a range of RF chokes against frequency.

RF chokes are generally low Q components. The actual Q specified by a manufacturer is generally the minimum Q, measured at a particular frequency, generally in the manner illustrated for several values and two sizes in Figure 7.

Markings

RF chokes are marked with their value and tolerance with the standard colour code or typographic code, in much the same way that resistors and some capacitors are marked.

The nominal inductance value is always indicated in microhenries (μH).

Where a typographic code is employed it is generally of a quite simple form, similar to that used on resistors. The nominal inductance value, again, is always expressed in microhenries (μH). The value is identified as follows:–

Nominal inductance values less than 100 μH are identified with three (3) numbers representing the significant figures, the letter R being used to designate the decimal point.

eg,
0.68 μH = R680
4.7 μH = 4R70
33 μH = 33R0

Nominal inductance values of 100 μH and above are identified by a four digit number. The first three (3) digits represent the significant figures of the value and the last digit specifies the number of the following zeroes,

eg,
680 μH = 6800
4700 μH 4701 (4.7 mH)
33000 μH 3302 (33 mH)

In addition, a single letter may be added to indicate the tolerance, as follows:

J = ± 5%
K = ± 10%
M = ± 20%

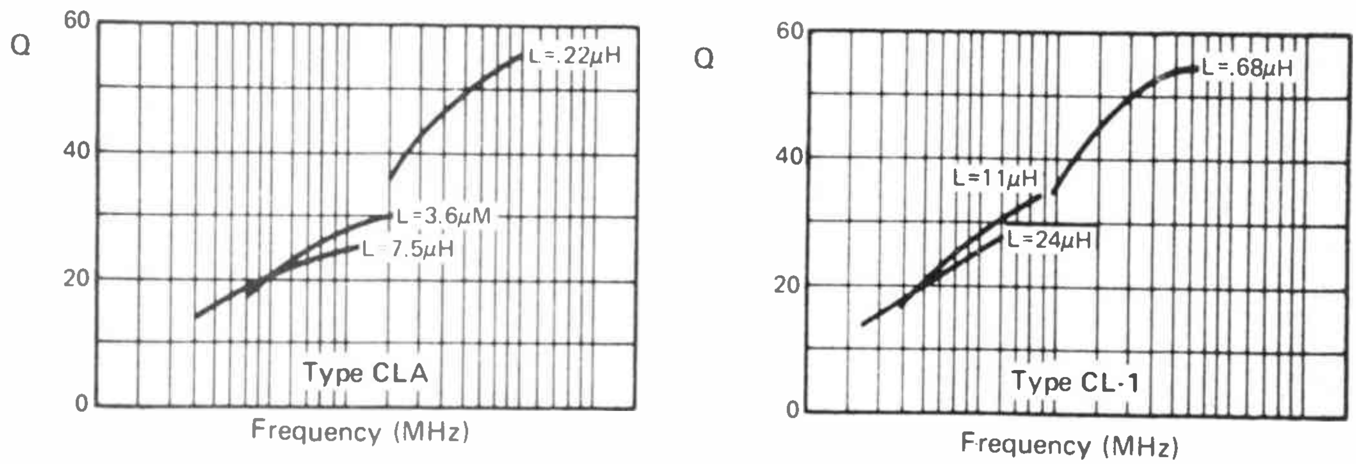


Fig.7. Typical Q values versus frequency for several values of two different sizes of moulded RF chokes (From IRH).
CLA = 6.4 mm dia. x 78 mm long.
CL1 = 6.4 mm dia. x 27 mm long.

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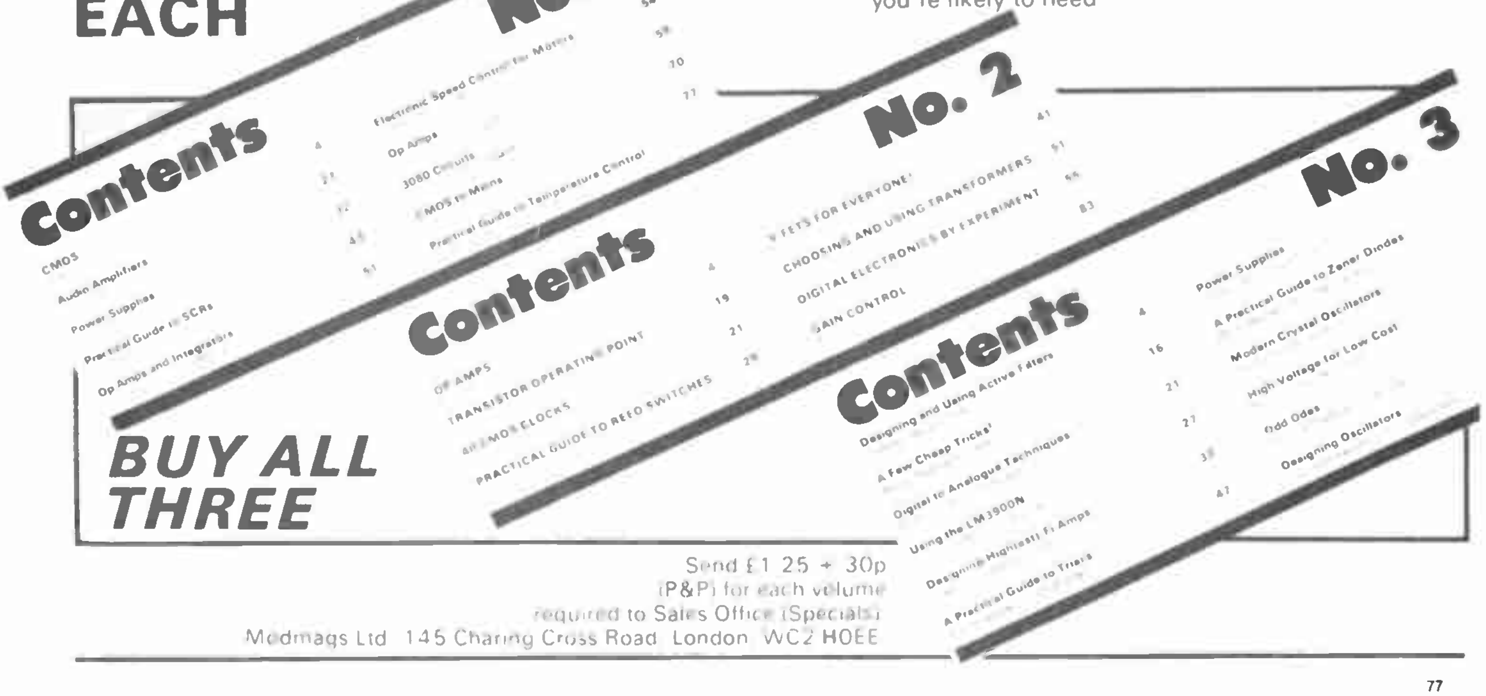

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8080 CPU

The 8080 is a complete 8-bit parallel, central processor unit (CPU) for use in general purpose digital computer systems. It is fabricated on a single LSI chip using the N-channel silicon gate MOS process. The 8080 transfers data and internal state information via an 8-bit, bidirectional 3-state Data Bus (D_0-D_7). Memory and peripheral device addresses are transmitted over a separate 16-bit 3-state Address Bus (A_0-A_{15}). The 8080 has six timing and control outputs (SYNC, DBIN, WAIT, $\overline{WR}$, HLDA and INTE); and four control inputs (READY, HOLD, INT and RESET), four power inputs (+12V, +5V, −5V, and GND) and two clock inputs (ϕ_1 and ϕ_2).

Instructions for the 8080 require from one to five machine cycles for complete execution. The 8080 sends out 8 bits of status information on the data bus at the beginning of each machine cycle (during SYNC time). The following table defines the status information.

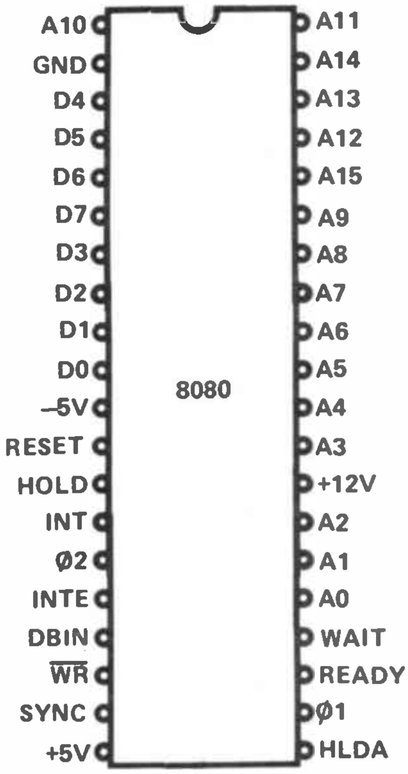


Fig. 1. 8080 microprocessor.

Status Information Definition

Symbols	Data Bus Bit	Definition
INTA*	D_0	Acknowledge signal for INTERRUPT request. Signal should be used to gate a restart instruction onto the data bus when DBIN is active.
$\overline{WO}$	D_1	Indicates that the operation in the current machine cycle will be a WRITE memory or OUTPUT function ($\overline{WO}$ = 0). Otherwise, a READ memory or INPUT operation will be executed.
STACK	D_2	Indicates that the address bus holds the pushdown stack address from the Stack Pointer.
HLTA	D_3	Acknowledge signal for HALT instruction.
OUT	D_4	Indicates that the address bus contains the address of an output device and the data bus will contain the output data when $\overline{WR}$ is active.
M_1	D_5	Provides a signal to indicate that the CPU is in the fetch cycle for the first byte of an instruction.
INP*	D_6	Indicates that the address bus contains the address of an input device and the input data should be placed on the data bus when DBIN is active.
MEMR*	D_7	Designates that the data bus will be used for memory read data.

*These three status bits can be used to control the flow of data onto the 8080 data bus.

The 8080 Instruction Set

The 8080 instruction set contains five different types of instructions:

Data Transfer Group – move data between registers or between memory and registers

Arithmetic Group – add, subtract, increment or decrement data in registers or in memory

Logical Group – AND, OR, EXCLUSIVE-OR, compare, rotate or complement data in registers or in memory

Branch Group – conditional and unconditional jump instructions, subroutine call instructions and return instructions

Stack, I/O and Machine Control Group – includes I/O instructions, as well as instructions for maintaining the stack and internal control flags.

Summary of Processor Instructions In Alphabetical Order

Mnemonic	Description	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Clock (2) Cycles
		Instruction Code (1)								
ACI	Add immediate to A with carry	1	1	0	0	1	1	1	0	7
ADC M	Add memory to A with carry	1	0	0	0	1	1	1	0	7
ADC r	Add register to A with carry	1	0	0	0	1	S	S	S	4
ADD M	Add memory to A	1	0	0	0	0	1	0	1	7
ADD r	Add register to A	1	0	0	0	0	S	S	S	4
ADI	Add immediate to A	1	1	0	0	0	1	1	0	7
ANA M	And memory with A	1	0	1	0	0	1	1	0	7
ANA r	And register with A	1	0	1	0	0	S	S	S	4
ANI	And immediate with A	1	1	1	0	0	1	1	0	7
CALL	Call unconditional	1	1	0	0	1	1	0	1	17
CC	Call on carry	1	1	0	1	1	1	0	0	11/17
CM	Call on minus	1	1	1	1	1	1	0	0	11/17
CMA	Compliment A	0	0	1	0	1	1	1	1	4
CMC	Compliment carry	0	0	1	1	1	1	1	1	4
CMP M	Compare memory with A	1	0	1	1	1	1	1	0	7
CMP r	Compare register with A	1	0	1	1	1	S	S	S	4
CNC	Call on no carry	1	1	0	1	0	1	0	0	11/17
CNZ	Call on no zero	1	1	0	0	0	1	0	0	11/17
CP	Call on positive	1	1	1	1	0	1	0	0	11/17
CPE	Call on parity even	1	1	1	0	1	1	0	0	11/17
CPI	Compare immediate with A	1	1	1	1	1	1	1	0	7
CPO	Call on parity odd	1	1	1	0	0	1	0	0	11/17
CZ	Call on zero	1	1	0	0	1	1	0	0	11/17
DAA	Decimal adjust A	0	0	1	0	0	1	1	1	4
DAD B	Add B & C to H & L	0	0	0	0	1	0	0	1	10
DAD D	Add D & E to H & L	0	0	0	1	1	0	0	1	10
DAD H	Add H & L to H & L	0	0	1	0	1	0	0	1	10
DAD SP	Add stack pointer to H & L	0	0	1	1	1	0	0	1	10
DCR M	Decrement memory	0	0	1	1	0	1	0	1	10
DCR r	Decrement register	0	0	D	D	D	1	0	1	5
DCX B	Decrement B & C	0	0	0	0	1	0	1	1	5
DCX D	Decrement D & E	0	0	0	1	1	0	1	1	5
DCX H	Decrement H & L	0	0	1	0	1	0	1	1	5
DCX SP	Decrement stack pointer	0	0	1	1	1	0	1	1	5
DI	Disable Interrupt	1	1	1	1	0	0	1	1	4
EI	Enable Interrupts	1	1	1	1	1	0	1	1	4
HLT	Halt	0	1	1	1	0	1	1	0	7
IN	Input	1	1	0	1	1	0	1	1	10
INR M	Increment memory	0	0	1	1	0	1	0	0	10
INR r	Increment register	0	0	D	D	D	1	0	0	5
INX B	Increment B & C registers	0	0	0	0	0	0	1	1	5
INX D	Increment D & E registers	0	0	0	1	0	0	1	1	5
INX H	Increment H & L registers	0	0	1	0	0	0	1	1	5
INX SP	Increment stack pointer	0	0	1	1	0	0	1	1	5
JC	Jump on carry	1	1	0	1	1	0	1	0	10
JM	Jump on minus	1	1	1	1	1	0	1	0	10
JMP	Jump unconditional	1	1	0	0	0	0	1	1	10
JNC	Jump on no carry	1	1	0	1	0	0	1	0	10
JNZ	Jump on no zero	1	1	0	0	0	0	1	0	10
JP	Jump on positive	1	1	1	1	0	0	1	0	10
JPE	Jump on parity even	1	1	1	0	1	0	1	0	10
JPO	Jump on parity odd	1	1	1	0	0	0	1	0	10
JZ	Jump on zero	1	1	0	0	1	0	1	0	10
LDA	Load A direct	0	0	1	1	1	0	1	0	13
LDAX B	Load A indirect	0	0	0	0	1	0	1	0	7
LDAX D	Load A indirect	0	0	0	1	1	0	1	0	7
LHLD	Load H & L direct	0	0	1	0	1	0	1	0	16
LXI B	Load immediate register Pair B & C	0	0	0	0	0	0	0	1	10
LXI D	Load immediate register Peir D & E	0	0	0	1	0	0	0	1	10
LXI H	Load immediate register Pair H & L	0	0	1	0	0	0	0	1	10
LXI SP	Load immediate stack pointer	0	0	1	1	0	0	0	1	10
MVI M	Move immediate memory	0	0	1	1	0	1	1	0	10
MVI r	Move immediate register	0	0	D	D	D	1	1	0	7
MOV M,r	Move register to memory	0	1	1	1	0	S	S	S	7
MOV r,M	Move memory to register	0	1	D	D	D	1	1	0	7
MOV r1,r2	Move register to register	0	1	D	D	D	S	S	S	5
NOP	No-operation	0	0	0	0	0	0	0	0	4
ORA M	Or memory with A	1	0	1	1	0	1	1	0	7
ORA r	Or register with A	1	0	1	1	9	S	S	S	4
ORI	Or immediate with A	1	1	1	1	0	1	1	0	7
OUT	Output	1	1	0	1	0	0	1	1	10
PCHL	H & L to program counter	1	1	1	0	1	0	0	1	5
POP B	Pop register pair B & C off stack	1	1	0	0	0	0	0	1	10
POP D	Pop register pair D & E off stack	1	1	0	1	0	0	0	1	10
POP H	Pop register pair H & L off stack	1	1	1	0	0	0	0	1	10
POP PSW	Pop A and Flags off stack	1	1	1	1	0	0	0	1	10
PUSH B	Push register Pair B & C on stack	1	1	0	0	0	1	0	1	11
PUSH D	Push register Pair D & E on stack	1	1	0	1	0	1	0	1	11
PUSH H	Push register Pair H & L on stack	1	1	1	0	0	1	0	1	11
PUSH PSW	Push A and Flags on stack	1	1	1	1	0	1	0	1	11
RAL	Rotate A left through carry	0	0	0	1	0	1	1	1	4
RAR	Rotate A right through carry	0	0	0	1	1	1	1	1	4
RC	Return on carry	1	1	0	1	1	0	0	0	5/11
RET	Return	1	1	0	0	1	0	0	1	10
RLC	Rotate A left	0	0	0	0	0	1	1	1	4
RM	Return on minus	1	1	1	1	1	0	0	0	5/11
RNC	Return on no carry	1	1	0	1	0	0	0	0	5/11
RNZ	Return on no zero	1	1	0	0	0	0	0	0	5/11
RP	Return on positive	1	1	1	1	0	0	0	0	5/11
RPE	Return on parity even	1	1	1	0	1	0	0	0	5/11
RPO	Return on parity odd	1	1	1	0	0	0	0	0	5/11
RRC	Rotate A right	0	0	0	0	1	1	1	1	4
RST	Restart	1	1	A	A	A	1	1	1	11
RZ	Return on zero	1	1	0	0	1	0	0	0	5/11
SBB M	Subtract memory from A with borrow	1	0	0	1	1	1	1	0	7
SBB r	Subtract register from A with borrow	1	0	0	1	1	S	S	S	4
SBI	Subtract immediate from A with borrow	1	1	0	1	1	1	1	0	7
SHLD	Store H & L direct	0	0	1	0	0	0	1	0	16
SPHL	H & L to stack pointer	1	1	1	1	1	0	0	1	5
STA	Store A direct	0	0	1	1	0	0	1	0	13
STAX B	Store A indirect	0	0	0	0	0	0	1	0	7
STAX D	Store A indirect	0	0	0	1	0	0	1	0	7
STC	Set carry	0	0	1	1	0	1	1	1	4
SUB M	Subtract memory from A	1	0	0	1	0	1	1	0	7
SUB r	Subtract register from A	1	0	0	1	0	S	S	S	4
SUI	Subtract immediate from A	1	1	0	1	0	1	1	0	7
XCHG	Exchange D & E, H & L Registers	1	1	1	0	1	0	1	1	4
XRA M	Exclusive Or memory with A	1	0	1	0	1	1	1	0	7
XRA r	Exclusive Or register with A	1	0	1	0	1	S	S	S	4
XRI	Exclusive Or immediate with A	1	1	1	0	1	1	1	0	7
XTHL	Exchange top of stack, H & L	1	1	1	0	0	0	1	1	18

NOTES: 1. DDD (Destination) or SSS (Source); 000 is register B; 001 is register C; 010 is register D; 011 is register E; 100 is register H; 101 is register L; 110 is memory; 111 is register A (accumulator).
2. Where the number of instruction cycles is dependent on the condition flags, two possible cycle times are given.

Table 1. Status word chart for the 8080.

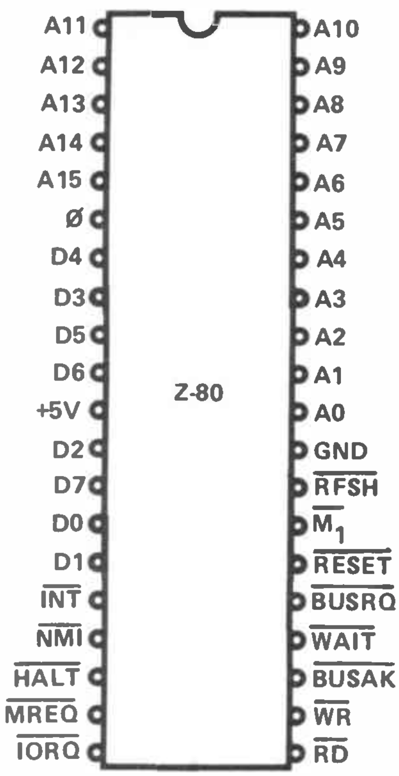
TYPE OF MACHINE CYCLE

Ⓝ STATUS WORD

DATA BUS BIT	STATUS INFORMATION	INSTRUCTION FETCH ①	MEMORY READ ②	MEMORY WRITE ③	STACK READ ④	STACK WRITE ⑤	INPUT READ ⑥	OUTPUT WRITE ⑦	INTERRUPT ACKNOWLEDGE ⑧	HALT ACKNOWLEDGE ⑨	INTERRUPT ACKNOWLEDGE WHILE HALT ⑩
D_0	INTA	0	0	0	0	0	0	0	1	0	1
D_1	$\overline{WO}$	1	1	0	1	0	1	0	1	1	1
D_2	STACK	0	0	0	1	1	0	0	0	0	0
D_3	HLTA	0	0	0	0	0	0	0	0	1	1
D_4	OUT	0	0	0	0	0	0	1	0	0	0
D_5	M_1	1	0	0	0	0	0	0	1	0	1
D_6	INP	0	0	0	0	0	1	0	0	0	0
D_7	MEMR	1	1	0	1	0	0	0	0	1	0

Z-80 CPU

The Z-80 CPU is packaged in an industry standard 40 pin Dual In-Line Package. The functions of the pins are given below:



A_0-A_{15} (Address Bus)

Tri state output, active high. A_0-A_{15} constitute a 16-bit address bus. The address bus provides the address for memory (up to 64 Kbytes) data exchanges and for I/O device data exchanges. I/O addressing uses the eight lower address bits to allow the user to directly select up to 256 input or 256 output ports. A_0 is the least significant address bit. During refresh time, the lower 7 bits contain a valid refresh address.

D_0-D_7 (Data Bus)

Tri-state input/output, active high. D_0-D_7 constitute an 8-bit bidirectional data bus. The data bus is used for data exchanges with memory and I/O devices.

$\overline{M_1}$ (Machine Cycle one)

Output, active low. $\overline{M_1}$ indicates that the current machine cycle is the OP code fetch cycle of an instruction execution. Note that during execution of two-byte op-codes, $\overline{M1}$ is generated as each op code byte is fetched. These two byte op-codes always begin with CBH, DDH, EDH or FDH. $\overline{M1}$ also occurs with $\overline{IORQ}$ to indicate an interrupt acknowledged cycle.

$\overline{MREQ}$ (Memory Request)

Tri-state output, active low. The memory request signal indicates that the address bus holds a valid address for a memory read or memory write operation.

$\overline{IORQ}$ (Input/Output Request)

Tri-state output, active low. The $\overline{IORQ}$ signal indicates that the lower half of the address bus holds a valid I/O address for a I/O read or write operation. An $\overline{IORQ}$ signal is also generated with an $\overline{M1}$ signal when an interrupt is being acknowledged to indicate that an interrupt response vector can be placed on the data bus. Interrupt Acknowledge operations occur during M_1 time while I/O operations never occur during M_1 time.

$\overline{RD}$ (Memory Read)

Tri-state output, active low. $\overline{RD}$ indicates that the CPU wants to read data from memory or an I/O device. The addressed I/O device or memory should use this signal to gate data onto the CPU data bus.

$\overline{WR}$ (Memory Write)

Tri-state output, active low. $\overline{WR}$ indicates that the CPU data bus holds valid data to be stored in the addressed memory or I/O device.

$\overline{RFSH}$ (Refresh)

Output, active low. $\overline{RFSH}$ indicates that the lower seven bits of the address bus contain a refresh address for dynamic memories and the current $\overline{MREQ}$ signal should be used to do a refresh read to all dynamic memories.

$\overline{HALT}$ (Halt state)

Output, active low. $\overline{HALT}$ indicates that the CPU has executed a HALT software instruction and is awaiting either a non-maskable or a maskable interrupt (with the mask enabled) before operation can resume. While halted, the CPU executes NOPs to maintain memory refresh activity.

$\overline{WAIT}$ (Wait)

Input, active low. $\overline{WAIT}$ indicates to the Z-80 CPU that the addressed memory or I/O devices are not ready for a data transfer. The CPU continues to enter wait states for as long as this signal is active. This signal allows memory or I/O devices of any speed to be synchronized to the CPU.

INT (Interrupt Request)

Input, active low. The Interrupt Request signal is generated by I/O devices. A request will be honoured at the end of the current instruction if the internal software controlled interrupt enable flip-flop (IFF) is enabled and if the BUSRQ signal is not active. When the CPU accepts the interrupt, an acknowledge signal (IORQ during M_1 time) is sent out at the beginning of the next instruction cycle. The CPU can respond to an interrupt in three different modes.

NMI (Non Maskable Interrupt)

Input, negative edge triggered. The non-maskable interrupt request line has a higher priority than INT and is always recognized at the end of the current instruction, independent of the status of the interrupt enable flip-flop. NMI automatically forces the Z-80 CPU to restart to location 0066_H. The program counter is automatically saved in the external stack so that the user can return to the program that was interrupted. Note that continuous WAIT cycles can prevent the current instruction from ending, and that a BUSRQ will override a NMI.

RESET

Input, active low. RESET forces the program counter to zero and initializes the CPU. The CPU initialization includes:

1) Disable the interrupt enable flip-flop
2) Set Register I $=_H$
3) Set Register R = 00_H
4) Set Interrupt Mode 0

During reset time, the address bus and data bus go to a high impedance state and all control output signals go to the inactive state.

BUSRQ (Bus Request)

Input, active low. The bus request signal is used to request the CPU address bus, data bus and tri-state output control signals to go to a high impedance state so that other devices can control these buses. When BUSRQ is activated, the CPU will set these buses to a high impedance state as soon as the current CPU machine cycle is terminated.

BUSAK (Bus Acknowledge)

Output, active low. Bus acknowledge is used to indicate to the requesting device that the CPU address bus, data bus and tri-state control bus signals have been set to their high impedance state and the external device can now control these signals.

Φ

Single-phase TTL level clock which requires only a 330R pull-up resistor to +5V to meet all clock requirements.

The Z80 Instruction Set

The following is a summary of the Z80, Z80A instruction set showing the assembly language mnemonic and the symbolic operation performed by the instruction. The instructions are divided into the following 16 categories:

8-bit loads	Miscellaneous Group
16-bit loads	Rotates and Shifts
Exchanges	Bit Set, Reset and Test
Memory Block Moves	Input and Output
Memory Block Searches	Jumps
8-bit arithmetic and logic	Calls
16-bit arithmetic	Restarts
General purpose Accumulator & Flag Operations	Returns

In the table the following terminology is used.

b is a bit number in any 8-bit register or memory location
cc is the flag condition code:
NZ is non zero
Z is zero
NC is non carry
C is carry
PO is Parity odd or no overflow
PE is Parity even or overflow
P is Positive
M is Negative (minus)
d is any 8-bit destination register or memory location
dd is any 16-bit destination register or memory location
e is the 8-bit signed 2's complement displacement used in relative jumps and indexed addressing
L is the 8 special call locations in page zero. In decimal notation these are 0, 8, 16, 24, 32, 40, 48 and 56
n is any 8-bit binary number
nn is any 16-bit binary number
r is any 8-bit general purpose register (A, B, C, D, E, H, or L)
s is any 8-bit source register or memory location
s_b is a bit in a specific 8-bit register or memory location
ss is any 16-bit source register or memory location
subscript "L" means the low order 8 bits of a 16-bit register
subscript "H" means the high order 8 bits of a 16-bit register
() means that the contents within the () are to be used as a pointer to a memory location or I/O port number
8-bit registers are A, B, C, D, E, H, L, I and R
16-bit register pairs are AF, BC, DE and HL
16-bit registers are SP, PC, IX and IY

Addressing Modes implemented include combinations of the following:

Immediate	Index
Immediate extended	Register
Modified Page	
Zero	Implied
Relative	Register Indirect
Extended	Bit

Z-80 Instruction Set

8-BIT LOADS

Mnemonic	Symbolic Operation	Comments
LD r, s	r←s	s is r, n, (HL), (IX+e), (IY+e)
LD d, r	d←r	d is (HL), r (IX+e), (IY+e)
LD d, n	d←n	d is (HL), (IX+e), (IY+e)
LD A, s	A←s	s is (BC), (DE), (nn), I, R
LD d, A	d←A	d is (BC), (DE), (nn), I, R

8-BIT ALU

Mnemonic	Symbolic Operation	Comments
ADD s	A←A+s	
ADC s	A←A+s+CY	CY is the carry flag
SUB s	A←A–s	
SBC s	A←A–s–CY	s is r, n, (HL) (IX+e), (IY+e)
AND s	A←A ∧ s	
OR s	A←A ∨ s	
XOR s	A←A ⊕ s	
CP s	A–s	s is r, n (HL) (IX+e), (IY+e)
INC d	d←d+1	d is r, (HL) (IX+e), (IY+e)
DEC d	d←d–1	

16-BIT LOADS

Mnemonic	Symbolic Operation	Comments
LD dd, nn	dd←nn	dd is BC, DE, HL, SP, IX, IY
LD dd, (nn)	dd←(nn)	dd is BC, DE, HL, SP, IX, IY
LD (nn), ss	(nn)←ss	ss is BC, DE, HL, SP, IX, IY
I D SP, ss	SP←ss	ss is HL, IX, IY
PUSH ss	(SP–1)←ss_H; (SP–2)←ss_L	ss is BC, DE HL, AF, IX, IY
POP dd	dd_L←(SP); dd_H←(SP+1)	dd is BC, DE, HL, AF, IX, IY

16-BIT ARITHMETIC

Mnemonic	Symbolic Operation	Comments
ADD HL, ss	HL←HL+ss	} ss is BC, DE HL, SP
ADC HL, ss	HL←HL+ss+CY	
SBC HL, ss	HL←HL–ss–CY	
ADD IX, ss	IX←IX+ss	ss is BC, DE, IX, SP
ADD IY, ss	IY←IY+ss	ss is BC, DE, IY, SP
INC dd	dd←dd+1	dd is BC, DE, HL, SP, IX, IY
DEC dd	dd←dd–1	dd is BC, DE, HL, SP, IX, IY

EXCHANGES

Mnemonic	Symbolic Operation	Comments
EX DE, HL	DE↔HL	
EX AF, AF'	AF↔AF'	
EXX	(BC DE HL)↔(BC' DE' HL')	
EX (SP), ss	(SP)↔ss_L, (SP+1)↔ss_H	ss is HL, IX, IY

MEMORY BLOCK SEARCHES

Mnemonic	Symbolic Operation	Comments
CPI	A–(HL), HL←HL+1 BC←BC–1	
CPIR	A–(HL), HL←HL+1 BC←BC–1, Repeat until BC=0 or A=(HL)	A–(HL) sets the flags only. A is not affected
CPD	A–(HL), HL←HL–1 BC←BC–1	
CPDR	A–(HL), HL←HL–1 BC←BC–1, Repeat until BC=0 or A=(HL)	

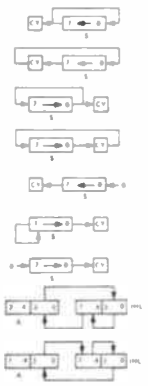
MEMORY BLOCK MOVES

Mnemonic	Symbolic Operation	Comments
LDI	(DE)←(HL), DE←DE+1 HL←HL+1, BC←BC–1	
LDIR	(DE)←(HL), DE←DE+1 HL←HL+1, BC←BC–1 Repeat until BC=0	
LDD	(DE)←(HL), DE←DE–1 HL←HL–1, BC←BC–1	
LDDR	(DE)←(HL), DE←DE–1 HL←HL–1, BC←BC–1 Repeat until BC=0	

GP ACC. & FLAG

Mnemonic	Symbolic Operation	Comments
DAA	Converts A contents into packed BCD following add or subtract.	Operands must be in packed BCD format
CPL	A←$\overline{A}$	
NEG	A←00–A	
CCF	CY←$\overline{CY}$	
SCF	CY←1	

ROTATES AND SHIFTS

Mnemonic	Symbolic Operation	Comments
RLC s		
RL s		
RRC s		
RR s		
SLA s		s is r, (HL) (IX+e), (IY+e)
SRA s		
SRL s		
RLD		
RRD		

BIT S, R, & T

Mnemonic	Symbolic Operation	Comments
BIT b, s	Z←$\overline{s_b}$	Z is zero flag
SET b, s	s_b←1	s is r, (HL)
RES b, s	s_b←0	(IX+e), (IY+e)

INPUT AND OUTPUT

Mnemonic	Symbolic Operation	Comments
IN A, (n)	A←(n)	
IN r, (C)	r←(C)	Set flags
INI	(HL)←(C), HL←HL+1 B←B–1	
INIR	(HL)←(C), HL←HL+1 B←B–1 Repeat until B=0	
IND	(HL)←(C), HL←HL–1 B←B–1	
INDR	(HL)←(C), HL←HL–1 B←B–1 Repeat until B=0	
OUT(n), A	(n)←A	
OUT(C), r	(C)←r	
OUTI	(C)←(HL), HL←HL+1 B←B–1	
OTIR	(C)←(HL), HL←HL+1 B←B–1 Repeat until B=0	
OUTD	(C)←(HL), HL←HL–1 B←B–1	
OTDR	(C)←(HL), HL←HL–1 B←B–1 Repeat until B=0	

MISCELLANEOUS

Mnemonic	Symbolic Operation	Comments
NOP	No operation	
HALT	Halt CPU	
DI	Disable Interrupts	
EI	Enable Interrupts	
IM 0	Set interrupt mode 0	8080A mode
IM 1	Set interrupt mode 1	Call to 0038_H
IM 2	Set interrupt mode 2	Indirect Call

JUMPS

Mnemonic	Symbolic Operation	Comments
JP nn	PC←nn	cc { NZ PO, Z PE, NC P, C M
JP cc, nn	If condition cc is true PC←nn, else continue	
JR e	PC←PC+e	
JR kk, e	If condition kk is true PC←PC+e, else continue	kk { NZ NC, Z C
JP (ss)	PC←ss	ss is HL, IX, IY
DJNZ e	B←B–1, if B=0 continue, else PC PC+e	

CALLS

Mnemonic	Symbolic Operation	Comments
CALL nn	(SP–1)←PC_H (SP–2)←PC_L, PC←nn	cc { NZ PO, Z PE, NC P, C M
CALL cc, nn	If condition cc is false continue, else same as CALL nn	

RESTARTS

Mnemonic	Symbolic Operation	Comments
RST L	(SP–1)←PC_H (SP–2)←PC_L, PC_H←0 PC_L←L	

RETURNS

Mnemonic	Symbolic Operation	Comments
RET	PC_L←(SP), PC_H←(SP+1)	
RET cc	If condition cc is false continue, else same as RET	cc { NZ PO, Z PE, NC P, C M
RETI	Return from interrupt, same as RET	
RETN	Return from non- maskable interrupt	

6800 CPU

The processor is a bi-directional, bus-oriented, 8-bit parallel machine with 16 bits of address. For most systems, depending on inter-connection capacitance, the processor is capable of directly interfacing with eight peripheral devices and one TTL load on the same bus at a 1 MHz minor cycle clock rate. For systems requiring additional peripheral devices, a Data Bus Extender (BEX) is available.

The processor has two 8-bit accumulators which are used to hold operands and results from the Arithmetic Logic Unit (ALU). The 16-bit index register stores 16 bits of memory address for the index mode of memory addressing. The stack pointer is a two byte (8 bits/byte) register that contains the address of the next available location in an external push-down/pop-up stack. This stack is normally a random access read/write memory that may have any location (address) that is convenient. In those applications that require storage of information in the stack when power is lost, the stack must be non-volatile. The program counter is a 16-bit register that contains the program address. A condition code register (flag register) contains six bits of condition codes. The condition codes indicate the results of an ALU operation: Negative (N), Zero (Z), Overflow (V), Carry from bit 7 (C), and Half carry from bit 3 (H). These bits of the Condition Code Register are used as testable conditions for the conditional branch instructions. Bit 4 is the interrupt mask bit (I). The unused bits of the Condition Code Register (B6, B7) are always ones.

Processor control lines include Reset, which automatically restarts the processor, as well as Interrupt Request and Non-Maskable Interrupt to monitor peripheral status. Finally there is a Three-State Control, Data Bus Enable and a Halt control line which can be used for Direct Memory Access (DMA) or multiprocessing.

The 6800 Instruction Set

The MC6800 has a set of 72 different instructions. These include binary and decimal arithmetic, logical, shift, rotate, load, store, conditional or unconditional branch, interrupt and stack manipulation instructions.

LSB / MSB	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0		NOP (INH)					TAP (INH)	TPA (INH)	INX (INH)	DEX (INH)	CLV (INH)	SEV (INH)	CLC (INH)	SEC (INH)	CLI (INH)	SEI (INH)
1	SBA	CBA					TAB (INH)	TBA (INH)		DAA (INH)		ABA (INH)				
2	BRA (REL)		BHI (REL)	BLS (REL)	BCC (REL)	BCS (REL)	BNE (REL)	BEQ (REL)	BVC (REL)	BVS (REL)	BPL (REL)	BMI (REL)	BGE (REL)	BLT (REL)	BGT (REL)	BLE (REL)
3	TSX (INH)	INS (INH)	PUL (A)	PUL (B)	DES (INH)	TXS (INH)	PSH (A)	PSH (B)		RTS (INH)		RTI (INH)			WAI (INH)	SWI (INH)
4	NEG (A)			COM (A)	LSR (A)		ROR (A)	ASR (A)	ASL (A)	ROL (A)	DEC (A)		INC (A)	TST (A)		CLR (A)
5	NEG (B)			COM (B)	LSR (B)		ROR (B)	ASR (B)	ASL (B)	ROL (B)	DEC (B)		INC (B)	TST (B)		CLR (B)
6	NEG (IND)			COM (IND)	LSR (IND)		ROR (IND)	ASR (IND)	ASL (IND)	ROL (IND)	DEC (IND)		INC (IND)	TST (IND)	JMP (IND)	CLR (IND)
7	NEG (EXT)			COM (EXT)	LSR (EXT)		ROR (EXT)	ASR (EXT)	ASL (EXT)	ROL (EXT)	DEC (EXT)		INC (EXT)	TST (EXT)	JMP (EXT)	CLR (EXT)
8	SUB (A) (IMM)	CMP (A) (IMM)	SBC (A) (IMM)		AND (A) (IMM)	BIT (A) (IMM)	LDA (A) (IMM)		EOR (A) (IMM)	ADC (A) (IMM)	ORA (A) (IMM)	ADD (A) (IMM)	CPX (A) (IMM)	BSR (REL)	LDS (IMM)	
9	SUB (A) (DIR)	CMP (A) (DIR)	SBC (A) (DIR)		AND (A) (DIR)	BIT (A) (DIR)	LDA (A) (DIR)	STA (A) (DIR)	EOR (A) (DIR)	ADC (A) (DIR)	ORA (A) (DIR)	ADD (A) (DIR)	CPX (A) (DIR)		LDS (DIR)	STS (DIR)
A	SUB (A) (IND)	CMP (A) (IND)	SBC (A) (IND)		AND (A) (IND)	BIT (A) (IND)	LDA (A) (IND)	STA (A) (IND)	EOR (A) (IND)	ADC (A) (IND)	ORA (A) (IND)	ADD (A) (IND)	CPX (A) (IND)	JSR (IND)	LDS (IND)	STS (IND)
B	SUB (A) (EXT)	CMP (A) (EXT)	SBC (A) (EXT)		AND (A) (EXT)	BIT (A) (EXT)	LDA (A) (EXT)	STA (A) (EXT)	EOR (A) (EXT)	ADC (A) (EXT)	ORA (A) (EXT)	ADD (A) (EXT)	CPX (A) (EXT)	JSR (EXT)	LDS (EXT)	STS (EXT)
C	SUB (B) (IMM)	CMP (B) (IMM)	SBC (B) (IMM)		AND (B) (IMM)	BIT (B) (IMM)	LDA (B) (IMM)		EOR (B) (IMM)	ADC (B) (IMM)	ORA (B) (IMM)	ADD (B) (IMM)			LDX (IMM)	
D	SUB (B) (DIR)	CMP (B) (DIR)	SBC (B) (DIR)		AND (B) (DIR)	BIT (B) (DIR)	LDA (B) (DIR)	STA (B) (DIR)	EOR (B) (DIR)	ADC (B) (DIR)	ORA (B) (DIR)	ADD (B) (DIR)			LDX (B) (DIR)	STX (B) (DIR)
E	SUB (B) (IND)	CMP (B) (IND)	SBC (B) (IND)		AND (B) (IND)	BIT (B) (IND)	LDA (B) (IND)	STA (B) (IND)	EOR (B) (IND)	ADC (B) (IND)	ORA (B) (IND)	ADD (B) (IND)			LDX (IND)	STX (IND)
F	SUB (B) (EXT)	CMP (B) (EXT)	SBC (B) (EXT)		AND (B) (EXT)	BIT (B) (EXT)	LDA (B) (EXT)	STA (B) (EXT)	EOR (B) (EXT)	ADC (B) (EXT)	ORA (B) (EXT)	ADD (B) (EXT)			LDX (EXT)	STX (EXT)

DIR = DIRECT ADDRESSING MODE
EXT = EXTENDED ADDRESSING MODE
IMM = IMMEDIATE ADDRESSING MODE
IND = INDIRECT ADDRESSING MODE
INH = INHERENT ADDRESSING MODE
REL = RELATIVE ADDRESSING MODE
A = ACCUMULATOR A
B = ACCUMULATOR B

Summary of Processor Instructions in Alphabetical Order

ABA Add Accumulators
ADC Add with Carry
ADD Add
AND Logical And
ASL Arithmetic Shift Left
ASR Arithmetic Shift Right

BCC Branch if Carry Clear
BCS Branch if Carry Set
BEQ Branch if Equal to Zero
BGE Branch if Greater or Equal Zero
BGT Branch if Greater than Zero
BHI Branch if Higher
BIT Bit Test
BLE Branch if Less or Equal
BLS Branch if Lower or Same
BLT Branch if Less than Zero
BMI Brnach if Minus
BNE Branch if Not Equal to Zero
BPL Branch if Plus
BRA Branch Always
BSR Branch to Subroutine
BVC Branch if Overflow Clear
BVS Branch if Overflow Set

CBA Compare Accumulators
CLC Clear Carry
CLI Clear Interrupt Mask
CLR Clear
CLV Clear Overflow
CMP Compare
COM Complement
CPX Compare Index Register

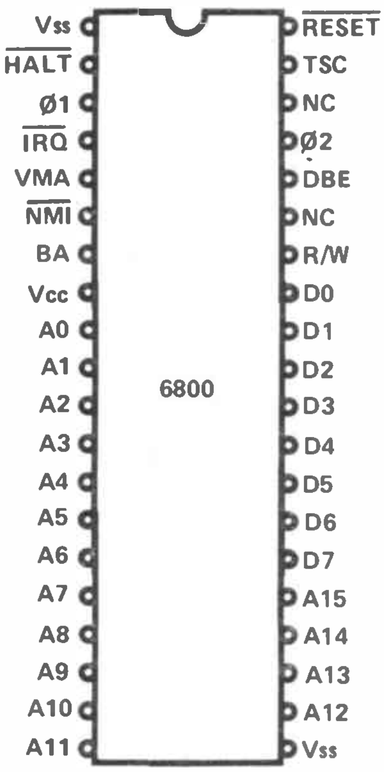
DAA Decimal Adjust
DEC Decrement
DES Decrement Stack Pointer
DEX Decrement Index Register

EOR Exclusive OR

INC Increment
INS Increment Stack Pointer
INX Increment Index Register

JMP Jump
JSR Jump to Subroutine

LDA Load Accumulator
LDS Load Stack Pointer



LDX Load Index Register
LSR Logical Shift Right

NEG Negate
NOP No Operation

ORA Inclusive OR Accumulator

PSH Push Data
PUL Pull Data

ROL Rotate Left
ROR Rotate Right
RTI Return from Interrupt
RTS Return from Subroutine

SBAS Subtract Accumulators
SBC Subtract with Carry
SEC Set Carry
SEI Set Interrupt Mask
SEV Set Overflow
STA Store Accumulator
STS Store Stack Register
STX Store Index Register
SUB Subtract
SWI Software Interrupt

TAB Transfer Accumulators
TAP Transfer Accumulators to Condition Code Reg
TBA Transfer Accumulators
TPA Transfer Condition Code Reg to Accumulator
TST Test
TSX Transfer Stack Pointer to Index Register
TXS Transfer Index Register to Stack Pointer

WAI Wait for Interrupt

6502 CPU

Address Bus (A_0-A_{15})

The address bus buffers on the R6500 family of microprocessors are push/pull type drivers capable of driving at least 130 pf and one standard TTL load.

The address is valid 300 ns (at 1 MHz clock rate) into the Ø1 clock pulse and remains stable until the next Ø1 pulse: this specification will change only for processors which are specified to operate at a higher clock rate.

Data Bus (D_0-D_7)

All instructions and data transfers between the processor and memory take place on these lines. The buffers driving the data bus lines have full "three-state" capability. This is necessitated by the fact that the lines are bidirectional.

Each data bus pin is connected to an input and an output buffer, with the output buffer remaining in the "floating" condition except when the processor is transferring data into or out of one of the support chips. All inter-chip data transfers take place during the Phase 2 clock pulse. During Phase 1 the entire data bus is "floating."

The data bus buffer is a push/pull driver capable of driving 130 pf and one standard TTL load at the rated speed. At a 1-MHz clock rate, the date on the data bus must be stable 100 ns before the end of Phase 2. This is true for transfers in either direction.

Read/Write (R/W)

The Read/Write line allows the processor to control the direction of data transfers between the processor and the support chips. This line is high except when the processor is writing to memory or to a peripheral interface device.

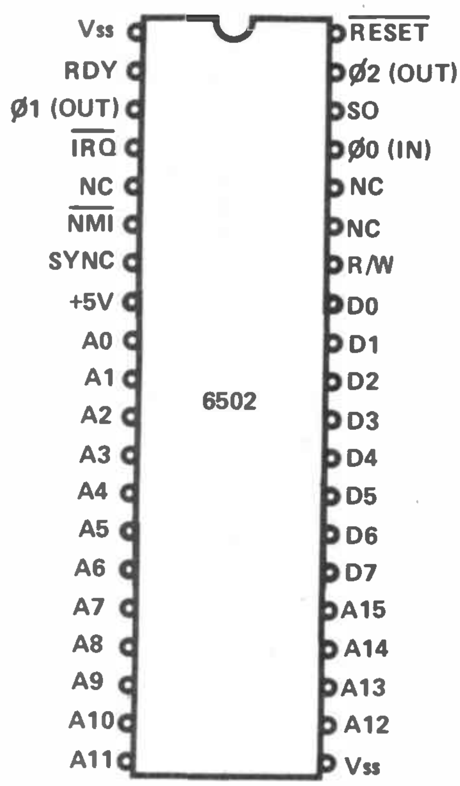
All transitions on this line occur during the Phase 1 clock pulse (concurrent with the address lines). This allows complete control of the data transition which takes place during the Phase 2 clock pulse.

The R/W buffer is similar to the address buffers. They are capable of driving 130 pf and one standard TTL load at the rated speed.

Ready (RDY)

The RDY input delays execution of any cycle during which the RDY line is pulled low. This line should change during the Phase 1 clock pulse. This change is then recognized during the next Phase 2 pulse to enable or disable the execution of the current internal machine cycle. This execution normally occurs during the next Phase 1 clock.

The primary purpose of the RDY line is to delay execution of a program fetch cycle until data are available from memory. this has direct application in prototype systems employing light-erasable PROMs or EAROMs. Both of these devices have relatively slow access times and require implementation of the RDY function if the processor is to operate at full speed. Without the RDY function a reduction in the



frequency of the system clock would be necessary.

The RDY function will not stop the processor in a cycle in which a WRITE operation is being performed. If the RDY line goes from high to low during a WRITE cycle the processor will execute that cycle and will then stop in the next READ cycle (R/W=1).

Non-Maskable Interrupt ($\overline{\text{NMI}}$)

The $\overline{\text{NMI}}$ input, when the interrupted state, always interrupts the processor after it completes the instruction currently being executed. This interrupt is not "maskable" – i.e., there is no way for the processor to prevent recognition of the interrupt.

The $\overline{\text{NMI}}$ input responds to a negative transition. To interrupt the processor, the $\overline{\text{NMI}}$ input must go from high (> +2.4V) to low (> +0.4V). It can then stay low for an indefinite period without affecting the processor operation and without another interrupt. The processor will not detect another interrupt until this line goes high and then back to low. The $\overline{\text{NMI}}$ signal must be low for at least two clock cycles for the interrupt to be recognized, whereupon new program count vectors are fetched.

Interrupt Request ($\overline{\text{IRQ}}$)

The interrupt request ($\overline{\text{IRQ}}$) responds in much the same manner as $\overline{\text{NMI}}$. However, this function can be enabled or disabled by the interrupt inhibit bit in the processor status register. As long as the I flag (interrupt inhibit flag) is a logic 1, the signal on the $\overline{\text{IRQ}}$ pin will not affect the processor.

The $\overline{\text{IRQ}}$ pin is not edge-sensitive. Instead, the processor will be interrupted as long as the I flag is a logic "O" and the signal on the $\overline{\text{IRQ}}$ input is at GND. Because of this, the $\overline{\text{IRQ}}$ signal must be held low until it is recognized, i.e., until the processor completes the instruction currently being executed. If I is set when

IRQ goes low, the interrupt will not be recognized until I is cleared through software control. To assure that the processor will not recognize the interrupt more than once, the I flag is set automatically during the last cycle before the processor begins executing the interrupt software, beginning with the fetch of program count.

The final requirement is that the interrupt input must be cleared before the I flag is reset. If there is more than one active interrupt driving these two lines (OR'ed together), the recommended procedure is to service and clear both interrupts before clearing the I flag. However, if the interrupts are cleared one-at-a-time and the I flag is reset after each, the processor will simply recognize any interrupts still active and will process them properly but more slowly because of the time required to return from one interrupt before recognizing the next. If the procedure recommended above is followed, each interrupt will be recognized and processed only once.

Reset (RES)

The RES line is used to initialize the microprocessor from a power-down condition. During the power-up time this line is held low, and writing from the microprocessor is inhibited. When the line goes high, the microprocessor will delay 6 cycles and then fetch the new program count vectors from specific locations in memory (PCL from location FFFC and PCH from location FFFD). This is the start of the user's code. It should be assumed that any time the reset line has been pulled low and then high, the internal states of the machine are unknown and all registers must be re-initialized during the restart sequence.

Synchronization Signal (SYNC)

A SYNC signal is provided to identify those cycles in which the processor is doing an OP CODE fetch. The SYNC line goes high during Phase 1 of an OP CODE fetch and stays high for the remainder of that cycle. If the RDY line is pulled low during the Phase 1 clock pulse in which the SYNC line went high, the processor will stop in its current state. It remains in that state until the RDY line goes high. In this manner, the SYNC signal can be used to control RDY to cause single-instruction execution.

Set Overflow (S.O.)

This pin sets the overflow flag on a negative transition from TTL one to TTL zero. This is designed to work with a future I/O device and should not be used in normal applications unless the user has programmed for the fact the arithmetic operations also affect the overflow flag.

Power Lines (V_{CC}, V_{SS})

The V_{CC} and V_{SS} pins are the only power supply connections to the chip. The supply voltage is +5.0 V DC ± 5%. The absolute limit on the V_{CC} input is +7.0 V DC.

Φ(Clock Input)

The R6502 can be used with an externally generated time base consisting of either a TTL-level single-phase clock, crystal oscillator, or RC network.

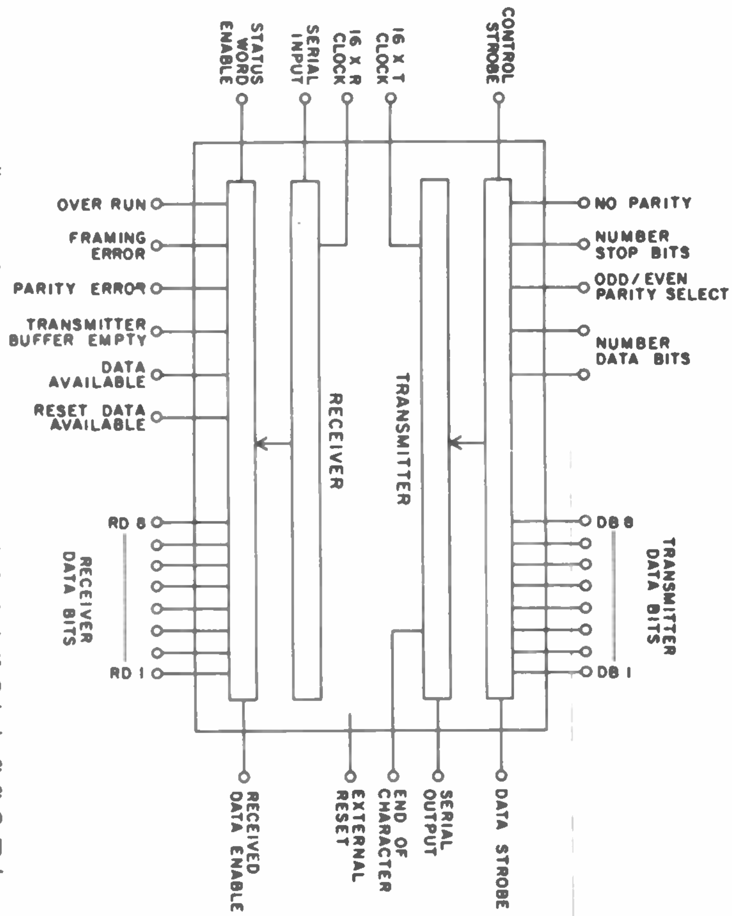
FIRST DIGIT	SECOND DIGIT															
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	BRK	ORD (I,X)				ORA ZERO	ASL ZERO		PHP	ORA IMMED	ASLA			ORA ABSOLUTE	ASL ABSOLUTE	0
1	BPL	ORD (I),Y				ORD Z,X	ASL Z,X		CLC	ORA A,Y				ORA A,X	ASL A,X	1
2	JSR	AND (I,X)			BIT ZERO	AND ZERO	ROL ZERO		PLP	AND IMMED	ROLA		BIT ABSOLUTE	AND ABSOLUTE	ROL ABSOLUTE	2
3	BMI	AND (I),Y				AND Z,X	ROL Z,X		SEC	AND A,Y				AND A,X	ROL A,X	3
4	RTI	EOR (I,X)				EOR ZERO	LSR ZERO		PHA	EOR IMMED	LSRA		JMP ABSOLUTE	EOR ABSOLUTE	LSR ABSOLUTE	4
5	BVC	EOR (I),Y				EOR Z,X	LSR Z,X		CLI	EOR A,Y				EOR A,X	LSR A,X	5
6	RTS	ADC (I,X)				ADC ZERO	FOR ZERO		PLA	ADC IMMED	RORA		JMP INDIRECT	ADC ABSOLUTE	ROR ABSOLUTE	6
7	BVS	ADC (I),Y				ADC Z,X	ROR Z,X			ADC A,Y				ADC A,X	ROR A,X	7
8		STA (I,X)			STY ZERO	STA ZERO	STX ZERO		DEY		TXA		STY ABSOLUTE	STA ABSOLUTE	STX ABSOLUTE	8
9	BCC	STA (I),Y			STY Z,X	STA Z,X	STX Z,Y		TYA	STA A,Y	TXS			STA A,X		9
A	LDY IMMED	LDA (I,X)	LDX IMMED		LDY ZERO	LDA ZERO	LDX ZERO		TAY	LDA IMMED	TAX		LDY ABSOLUTE	LDA ABSOLUTE	LDX ABSOLUTE	A
B	BCS	LDA (I),Y			LDY Z,X	LDA Z,X	LDX Z,Y		CLV	LDA A,Y	TSX		LDY A,X	LDA A,X	LDX A,Y	B
C	CPY IMMED	CMP (I,X)			CPY ZERO	CMP ZERO	DEC ZERO		INY	CMP IMMED	DEX		CPY ABSOLUTE	CMP ABSOLUTE	DEC ABSOLUTE	C
D	BNE	CMP (I),Y				CMP Z,X	DEC Z,X		CLD	CMP A,Y				CMP A,X	DEC A,X	D
E	CPX IMMED	SBC (I,X)			CPX ZERO	SBC ZERO	INC ZERO		INX	SBC IMMED	NOP		CPX ABSOLUTE	SBC ABSOLUTE	INC ABSOLUTE	E
F	BEQ	SBC (I),Y				SBC Z,X	INC Z,X		SED	SBC A,Y				SBC A,X	INC A,X	F

AY-5-1013A

Features

- DTL and TTL Compatible – no interfacing circuits required – drives one TTL load.
- Fully Double Buffered – eliminates need for system synchronisation, facilitates high speed operation.
- Full Duplex Operation – can handle multiple baud rates (receiving-transmitting) simultaneously.
- Start Bit Verification – decreases error rate with centre sampling.
- The receiver will strobe the input bit within ±4% of the theoretical centre.
- External reset of error flags.
- High Speed Operation – greatest through-put; 40k baud.
- Tri-State Outputs – bus structure capability.
- Low Power – minimum power requirements.
- Input Protected – eliminates handling problems.
- Hermetic DIP Package – easy board insertion and mechanical handling.

The Universal Asynchronous Receiver/Transmitter (UART) is an LSI subsystem which accepts binary characters from either a terminal device or a computer and receives/transmits this character with appended control and error detecting bits. All characters contain a start bit, 5 to 8 data bits, one or two stop bits, and either odd/even parity or no parity. In order to make the UART universal, the baud rate, bits per word, parity mode, and the number of stop bits are externally selectable. All inputs and outputs are directly compatible with MTOS/MTNS logic, and also with TTL/DTL logic without the need for interfacing components and with all strobed outputs having tri-state logic.



Description of Pin Functions

Pin No.	Name	Symbol	Function
1	V_{CC} Power Supply	V_{CC}	+5V Supply
2	V_{GG} Power Supply	V_{GG}	−12V Supply
3	Ground	V_{GR}	Ground
4	Received Data Enable	$\overline{RDE}$	A logic 0 on the receiver enable line places the received data on to the output lines.
5-12	Received Data Bits	RD8-RD1	These are the 8 data output lines. Received characters are right justified, the LSB always appears on RD1. These lines have tri-state outputs; i.e., they have the normal TTL output characteristics when RDE is 0 and a high impedance state when RDE is 1. Thus, the data output lines can be bus structure oriented. Unused outputs go to an active 0 when enabled.

13	Receive Parity Error	PE	This line goes to a logic 1 if the received character parity does not agree with the selected parity. Tri-state.
14	Framing Error	FE	This line goes to a logic 1 if the received character has no valid stop bit. Tri-state.
15	Over-Run	OR	This line goes to a logic 1 if the previously received character is not read (DA line not reset) before the present character is transferred to the receiver holding register. Tri-state.
16	Status Word Enable	$\overline{SWE}$	A logic 0 on this line places the status word bits (PE, FE, OR, DA, TBMT) on to the output lines. Tri-state.
17	Receiver Clock	RCP	This line will contain a clock whose frequency is 16 times the desired receiver baud rate.
18	Reset Data Available	$\overline{RDA}$	A logic 0 will reset the DA line. DA FF is only thing that is reset.
19	Receive Data Available	DA	This line goes to a logic 1 when an entire character has been received and transferred to the receiver holding register. Tri-state.
20	Serial Input	SI	This line accepts the serial bit input stream. A Marking (logic 1) to spacing (logic 0) transition is required for initiation of data reception.
21	External Reset	XR	Resets shift registers. Sets SO, EOC, and TBMT to a logic 1. Resets DA, and error flags to 0. Clears input data buffer. Must be tied to logic 0 when not in use.
22	Transmitter Buffer Empty	TBMT	The transmitter buffer empty flag goes to a logic 1 when the data bits holding register may be loaded with another character. Tri-state.
23	Data Strobe	$\overline{DS}$	A strobe on this line will enter the data bits into the data bits holding register. Initial data transmission is initiated by the rising edge of DS. Data must be stable during entire DS.
24	End of Character	EOC	This line goes to a logic 1 each time a full character is transmitted. It remains at this level until the start of transmission of the next character.
25	Serial Output	SO	This line will serially, by bit, provide the entire transmitted character. It will remain at a logic 1 when no data is being transmitted.
26-33	Data Bit Inputs	DB1-DB8	There are up to 8 data bit input lines available.
34	Control Strobe	CS	A logic 1 on this pin will enter the control bits (EPS, NB1, NB2, TSB, NP) into the control bits holding register. This line can be strobed or hard wired to a logic 1 level.
35	No Parity	NP	A logic 1 on this pin will eliminate the parity bit from the transmitted and received character (no PE indication). The stop bit(s) will immediately follow the last data bit. If not used, this lead must be tied to a logic 0.
36	Number of Stop Bits	TSB	This lead will select the number of stop bits, 1 or 2, to be appended immediately after the parity bit. A logic 0 will insert one stop bit and a logic 1 will insert two stop bits.
37-38	Number of Bits/Character	NB2, NB1	These two leads will be internally decoded to select either 5, 6, 7 or 8 data bits/character. NB1 NB2 Bits/Character 0 0 5 1 0 6 0 1 7 1 1 8
39	Odd/Even Parity	EPS	The logic level on this pin selects the type of parity which will be appended immediately after the data bits. It also determines the parity that will be checked by the receiver. A logic 0 will insert odd parity and a logic 1 will insert even parity.
40	Transmitter Clock Line	TCP	This line will contain a clock whose frequency is 16 times the desired transmitter baud rate.

MC14412

THE MC 14412 contains a complete FSK (Frequency-Shift Keying) modulator and demodulator compatible with both CCITT standards and USA low speed (0 to 600 bps) communication networks.

- On Chip Crystal Oscillator
- Echo Suppressor Disable Tone Generator
- Originate and Answer Modes
- Simplex, Half-Duplex, and Full Duplex Operation
- On Chip Sine Wave Generator
- Modern Self Test Mode
- Single Supply
- Selectable Data Rates: 0-200, 0-300, 0-600 bps
- Post Detection Filter
- TTL or CMOS Compatible Inputs and Outputs

The data to be transmitted is presented in serial format to the modulator for conversion to FSK signals for transmission over the telephone network. The modulator output is buffered/amplified before driving the 600 ohm telephone line.

The FSK signal from the remote modem is received via the telephone line and filtered to remove extraneous signals such as the local Transmit Carrier. This filtering can be either a bandpass which passes only the desired band of frequencies or a notch which rejects the known interfering signal. The desired signal is then limited to preserve the axis crossings and fed to the demodulator where the data is recovered from the received FSK carrier.

Type (Pin 14)

The Type input selects either the U.S. or C.C.I.T.T. operational frequencies for both transmitting and receiving data. When the Type input = "1", the U.S. standard is selected and when the Type input = "0", the C.C.I.T.T. standard is selected.

Transmit Data (Tx Data, Pin 11)

Transmit Data is the binary information input. Data entered for transmission is modulated using FSK techniques. When operating in the U.S. standard (Type = "1") a logic "1" input level represents a Mark or when operating in the CCITT standard (Type = "0") a logic "1" input level represents a Mark.

Transmit Carrier (Tx Car, Pin 9)

The Transmit Carrier is a digital-synthesized sine wave derived from a 1.0 MHz oscillator reference. The frequency characteristics are as follows:

United States Standard — Type = "1", Echo = "0"

Mode		Tx Data		Tx Car
Originate	"1"	Mark	"1"	1270 Hz
Originate	"1"	Space	"0"	1070 Hz
Answer	"0"	Mark	"1"	2225 Hz
Answer	"0"	Space	"0"	2025 Hz

C.C.I.T.T. Standard — Type = "0", Echo = "0"

Mode		Tx Data		Tx Car
Channel No. 1	"1"	Mark	"1"	980 Hz
	"1"	Space	"0"	1180 Hz
Channel No. 2	"0"	Mark	"1"	1650 Hz
	"0"	Space	"0"	1850 Hz

Echo Suppressor Disable Tone — Type = "0", Echo = "1"

Mode	Tx Data	Tx Car
Chan. No. 2 "0"	"1"	2100 Hz

Transmit Enable (Tx Enable, Pin 12)

The Transmit Carrier output is enabled when the Tx Enable input = "1". No output tone can be transmitted when Tx Enable = "0".

Mode (Pin 10)

The Mode input selects the pair of transmitting and receive frequencies used during modulation and demodulation. When Mode = "1", the U.S. originate mode is selected (Type input = "1") or the C.C.I.T.T. Channel No. 1 (Type input = "0"). When mode = "0", the U.S. answer mode is selected (Type input = "1") or the C.C.I.T.T. Channel No. 2 (Type input = "0").

Echo (Pin 13)

When the Echo input = "1" (Type = "0", Mode = "0", Tx Data = "1") the modulator will transmit a 2100 Hz tone for disabling line echoe suppressors. During normal data transmission, this input should be low = "0".

Receive Data (Rx Data, Pin 7)

The Receive Data output is the digital data resulting from demodulating the Receive Carrier.

Receive carrier (Rx Car, Pin 1)

The Receive Carrier is the FSK input to the demodlator. This input must have either a CMOS or TTL compatible logic level input (see TTL pull-up disable) at a duty cycle of 50% ± 4%, that is a square wave resulting from a signal limiter.

Receive Data Rate (Rx, Rate, Pin 6)

The demodulator has been optimized for signal to noise performance at 200, 300 and 600-bps.

Data Rate	Rx Rate	Type
0 – 200 bps	"1"	"0"
0 – 300 bps	"1"	"1"
0 – 600 bps	"0"	"1"

Self Test (ST, Pin 2)

When a high level (ST = "1") is placed on this input, the demodulator is switched to the modulator frequency and demodulates the transmitted FSK signal.

Reset (Pin 5)

This input is provided to decrease the test time of the chip. In normal operation, this input may be used to disable the demodulator (Reset = "1") – otherwise it should be tied low = "0".

Crystal (Osc_{in}, Osc_{out}, Pin 4, Pin 3)

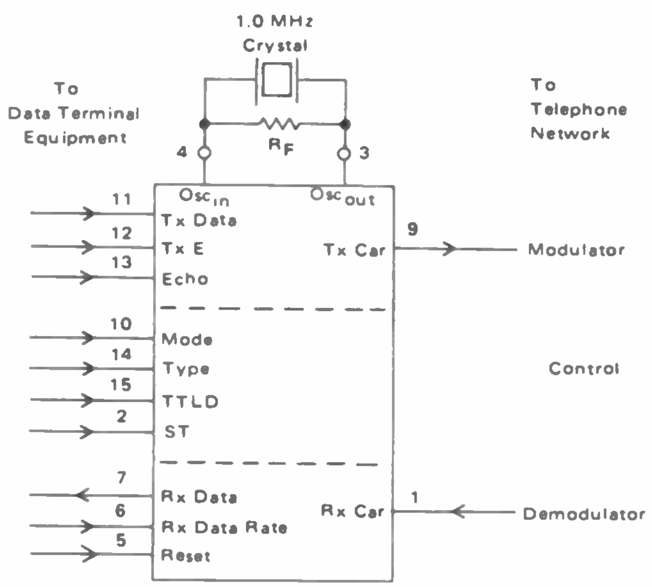
A 1.0 MHz crystal is required to utilize the on chip oscillator. A 1.0 MHz square wave clock can also be applied to the Osc_{in} input to satisfy the clock requirement

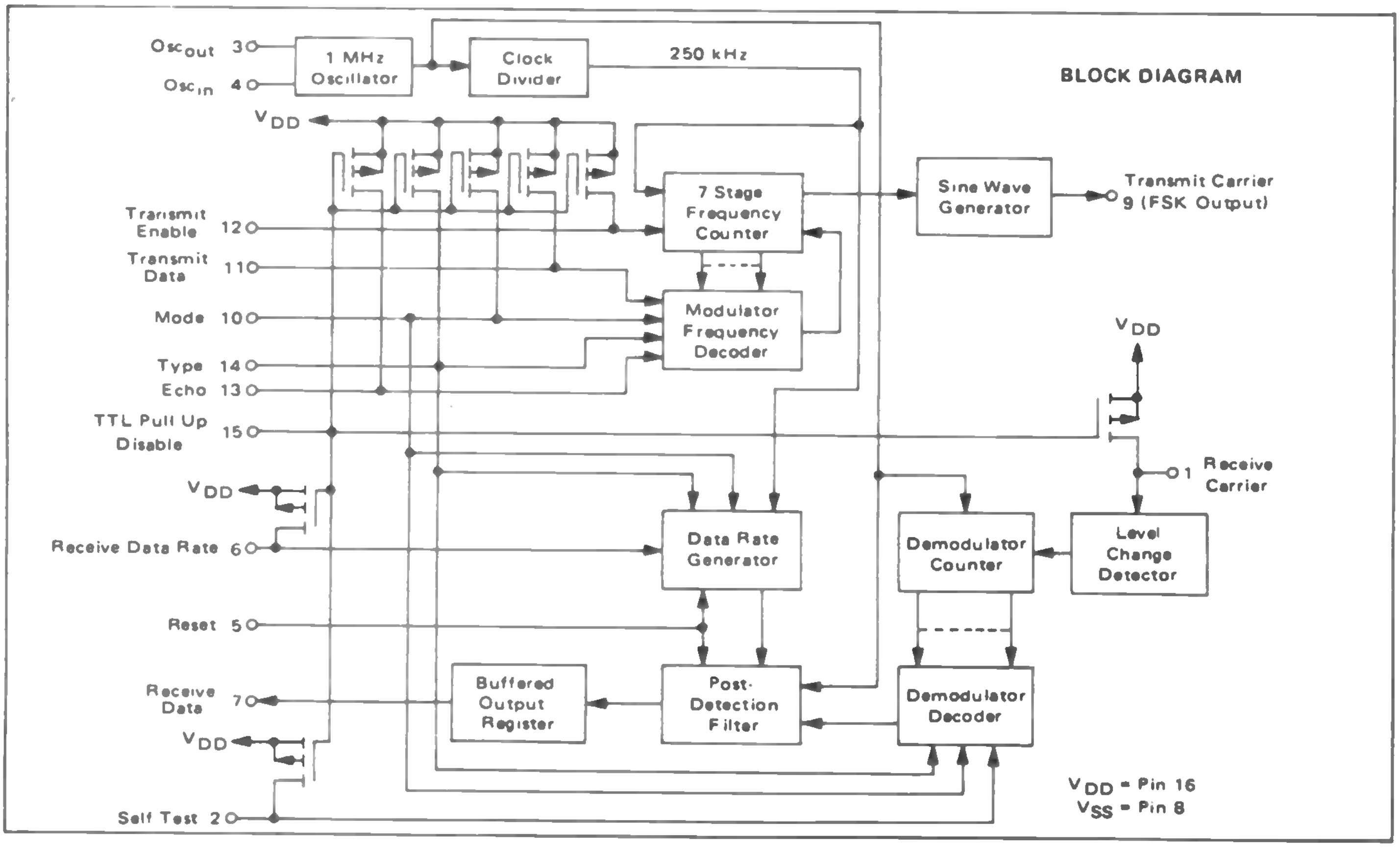
When utilizing the 1.0 MHz crystal, external parasitic capacitance, including crystal shunt capacitance, must be <9pF at the crystal input (pin 4).

TTL Pull-up Disable (TTLD, Pin 15)

To improve TTL interface compatibility, all of the inputs to the MODEM have controllable P-Channel devices which act as pull-up resistors when TTLD input is low ("0"). When the input is taken high ("1") the pull-up is diabled, thus reducing power dissipation when interfacing with CMOS.

MC14412 INPUT/OUTPUT SIGNALS

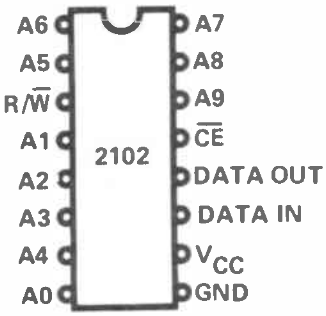




STATIC RAM

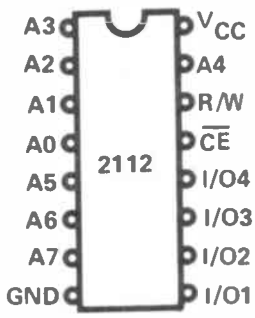
2102

A 1024-bit static random access read/write memory (RAM) organised as 1024×1-bit words. The IC operates from a single 5 V supply at typically 30 mA. Access time is <650 ns. The outputs are 3-state and all inputs and outputs are TTL compatible. Complete address decoding is performed on-chip and the chip-enable allows simple memory expansion.



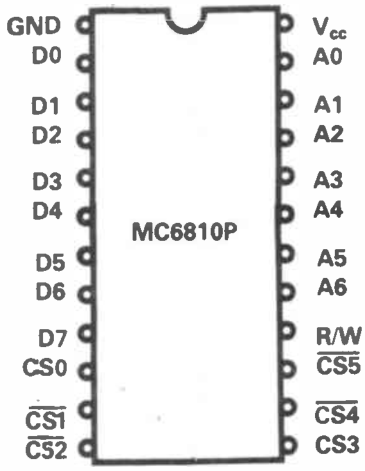
2112

A 1024-bit static random access read/write memory (RAM) organised as 256×4-bit words. The IC operates from a single 5 V supply at typically 30 mA. Access time is <650 ns. The inputs/outputs are 3-state and TTL compatible. Complete address decoding is performed on-chip and the chip-enable allows simple memory expansion.



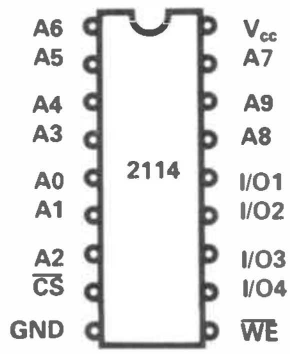
MC6810AP

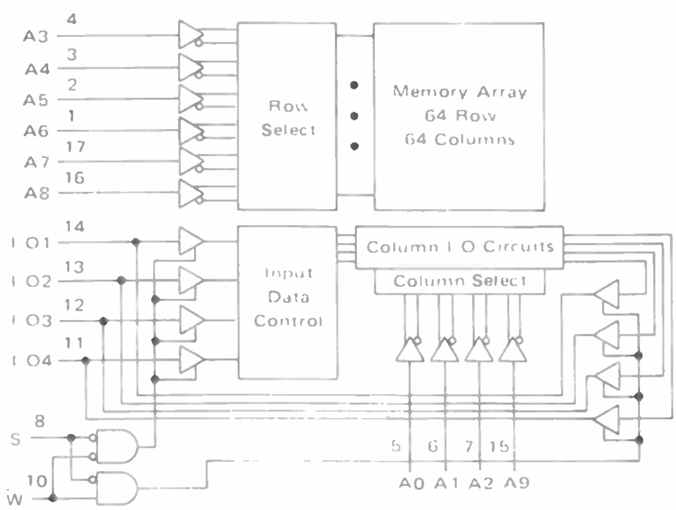
A 1024-bit static random access read/write memory (RAM) organised at 128×8-bit words. The IC operates from a single 5 V supply at typically 40 mA. Access time is <450 ns. The inputs/outputs are 3-state and TTL compatible. Complete address decoding is performed on-chip and there are six chip-enable inputs (four are active-low and two are active-high) for absolute ease of memory expansion.



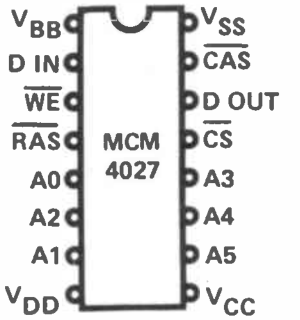
2114

A 4096-bit static random access read/write memory (RAM) organised as 1024×4 bit words. The IC operates from a single 5 V supply at typically 80 mA. Access time is <450 ns. The inputs/outputs are 3-state and TTL compatible. Complete address decoding is performed on-chip and there is a chip-enable input for memory expansion.





DYNAMIC RAM



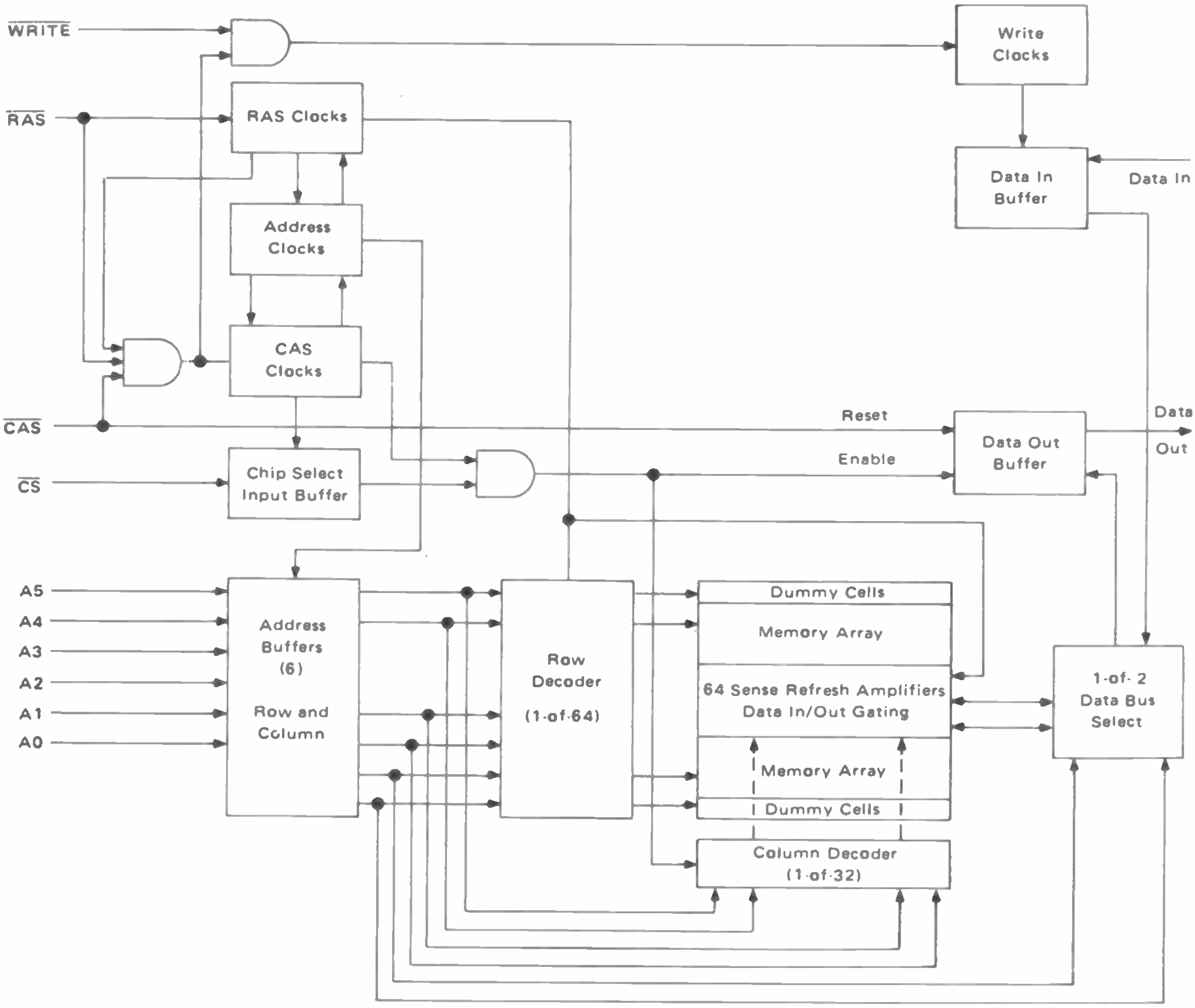
4027

A 4096-bit dynamic random access read/write memory (RAM) organised as 4096 x 1-bit words. The IC operates from three voltage supplies: $V_{DD} = +12$ V (at 35 mA Max), $V_{CC} = +5$ V (The current depends on the output load) and $V_{BB} = -5$ V (at 150 uA max). ($V_{SS} = 0$ V). When the chip is not selected V_{DD} current falls to 2 mA max. Access time is <250 nS, and a refresh cycle is required every 2 mS for each of the 64 row addresses. All inputs are TTL-compatible, and the output is 3-state to enable memory expansion. Complete address decoding is performed on-chip and there are on-chip latches for address, data in and chip-select. The IC has page-mode capability.

Addressing

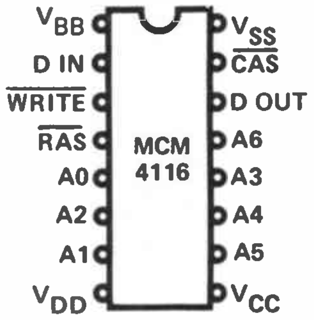
The 4027 has six address inputs (A0–A5) and two clock signals designated Row Address Strobe ($\overline{RAS}$) and Column Address Strobe ($\overline{CAS}$). At the beginning of a memory cycle, the six low order address bits A0 through A5 are strobed into the chip with $\overline{RAS}$ to select one of the 64 rows. The row address strobe also initiates the timing that will enable the 64 column sense amplifiers. After a specified hold time, the row address is removed and the six high high order address bits (A6–A11) are placed on the address pins. This address is then strobed into the chip with $\overline{CAS}$. Two of the 64 column sense amplifiers are selected by A1 through A5. A one of two data bus select is accomplished by A0 to complete the data selection. The Chip Select ($\overline{CS}$) is latched into the port along with the column addresses.

BLOCK DIAGRAM



4116

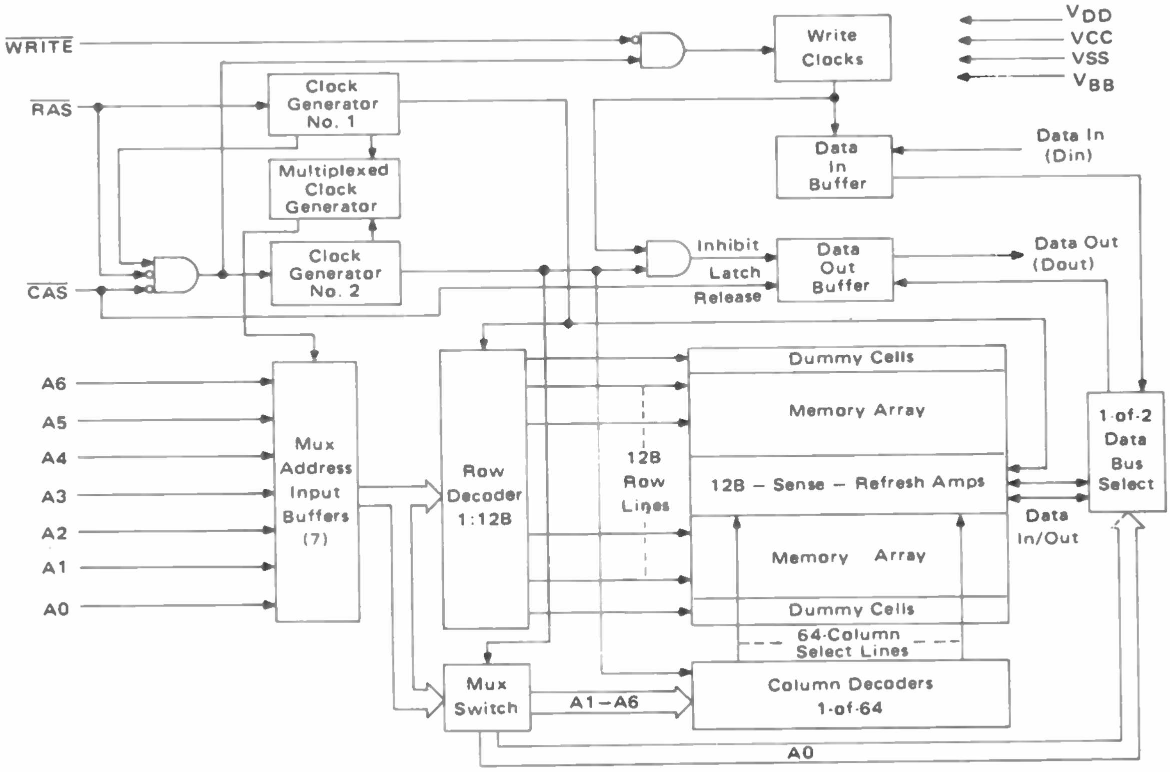
A 16,384-bit dynamic random access read/write memory (RAM) organised as 16,384 x 1-bit words. The IC operates from three voltage supplies: V_{DD} =+12 V (at 35 mA max), V_{CC} =+5 V (the current depends on the output load) and V_{BB} = −5V (at 200 uA max). V_{SS} = 0 V.(. When the chip is not selected V_{DD} current falls to 1.5 mA max. Access time is <300 nS, and a refresh cycle is required every 2 mS for each of the 128 row addresses. All inputs are TTL-compatible, and the output is 3-state to enable memory expansion. The data output is controlled by the column address strobe and remains valid from access time until the column address strobe returns to the high state. Complete address decoding is performed on-chip and there are on-chip latches for address and data in.



Pin Names

A0-A6	Address Inputs
$\overline{CAS}$	Column Address Strobe
D IN	Data In
D OUT	Data Out
$\overline{RAS}$	Row Address Strobe
$\overline{WRITE}$	Read/Write Input
V_{BB}	Power (−5 V)
V_{CC}	Power (+5 V)
V_{DD}	Power (+12 V)
V_{SS}	Ground

BLOCK DIAGRAM



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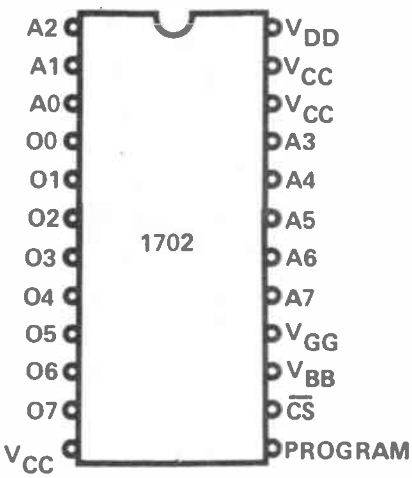
REVIEWS ON: ZENITH Z89 SINCLAIR ZX-80 MICROTAN 65 EXPLORER HP 85 SYM 1
SPECIAL GRAPHICS ISSUE
PASCAL - A FALSE IDOL?

PROMs

1702

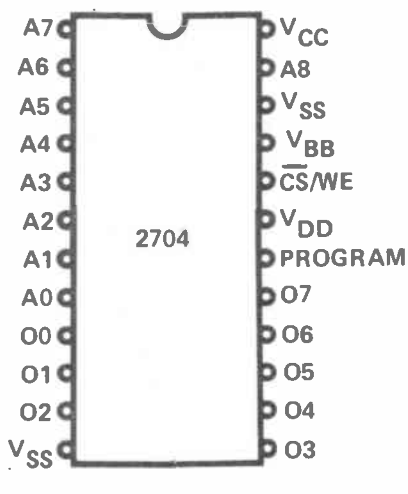
A 2048-bit electrically programmable and ultra-violet erasable read only memory (EPROM) organised as 256×8-bit words. Access time is 1uS and the IC is fully static. The outputs are 3-state and inputs and outputs are TTL-compatible. Complete address decoding is performed on-chip and there is a chip-enable input for memory expansion. A transparent lid on the IC allows the user to erase the bit pattern by exposing the chip to ultraviolet light at 253.7 nm (2537Å) with an incident energy of 6 W-seconds/cm^2. Thus with a 5.5 mW/cm^2 UV tube and the device positioned one inch from it and with no intervening filter or glass the IC will be completely erased in about 20 minutes.
In the unprogrammed state, all data contained in the EPROM are zeros (output low). Programming is accomplished by writing ones (output high) in the proper bit locations. The pin functions of the IC vary according to whether it is in the programming mode or read mode.

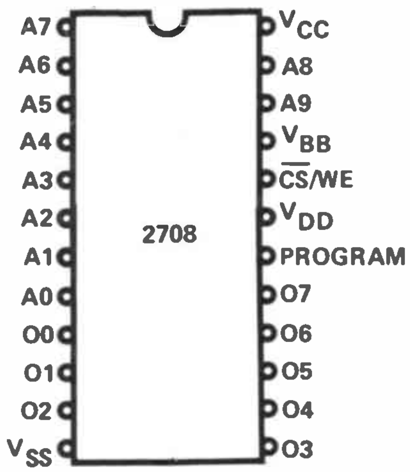


Pin No.	Pin Function: Read Mode	Programming Mode
1	Address Line 2	Address Line 2
2	Address Line 1	Address Line 1
3	Address Line 0	Address Line 0
4	Data Output 1	Data Input 1
5	Data Output 2	Data Input 2
6	Data Output 3	Data Input 3
7	Data Output 4	Data Input 4
8	Data Output 5	Data Input 5
9	Data Output 6	Data Input 6
10	Data Output 7	Data Input 7
11	Data Output 8	Data Input 8
12	+5V	0V
13	+5V	−48V Programme Pulse
14	Chip Select (Low to select)	0V
15	+5V	+12V
16	−9V	−35V Pulse
17	Address Line 7	Address Line 7
18	Address Line 6	Address Line 6
19	Address Line 5	Address Line 5
20	Address Line 4	Address Line 4
21	Address Line 3	Address Line 3
22	+5V	0V
23	+5V	0V
24	−9V	−48V Pulse

2704, 2708

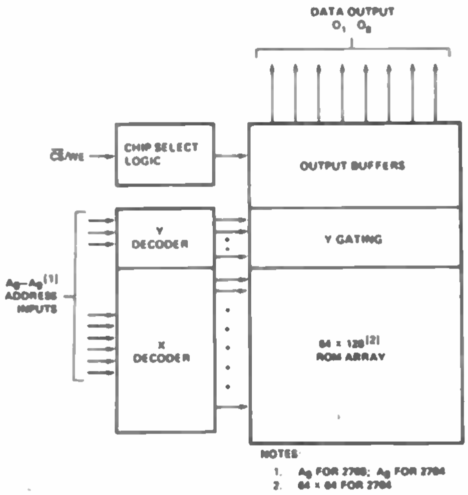
The 2704 is a 4096-bit electrically programmable and ultraviolet erasable read-only memory (EPROM) organised as 512×8-bit words. The 2708 is an 8192-bit EPROM organised as 1024×8-bit words. Access time is 450 ns and the ICs are fully static. The outputs are 3-state and inputs and outputs are TTL-compatible. Complete address decoding is performed on-chip and there is a chip-enable input for memory expansion. A transparent lid on the IC allows the user to erase the bit pattern by exposing the chip to ultraviolet light at 253.7 nm (2537Å) with an incident energy of 15 W-seconds/cm^2. Thus with a 5.5 mW/cm^2 UV tube and the device positioned one inch from it and with no intervening filter or glass the IC will be completely erased in about 50 minutes. The pin functions of the ICs vary according to whether they are in the programming mode or read mode.



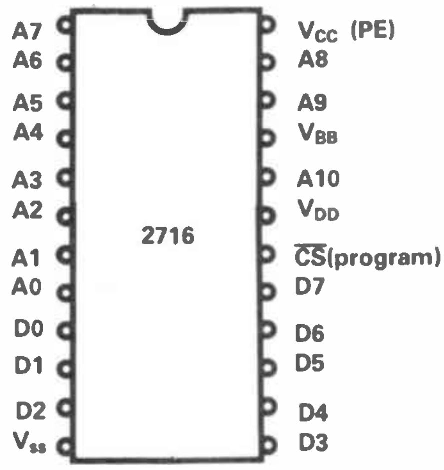


2716

A 16,384-bit electrically programmable and ultra-violet erasable read-only memory (EPROM) organised as 2048×8-bit words. Access time is less than 450 ns and the IC is fully static. The outputs are 3-state and inputs and outputs are TTL-compatible. Complete address decoding is performed on-chip and there is a chip-select input for memory expansion. A transparent lid on the IC allows the user to erase the bit pattern by exposing the chip to ultra-violet light at 253.7 nm (2537Å) with an incident energy of 15 W-seconds/cm^2. In the erased state, all bits are in the one state. Programming is accomplished by writing zeros in the proper bit locations. The pin functions of the IC vary according to whether it is the programming mode or the read mode.



2704/2708 Block Diagram.



Pin No.	Pin Function Read Mode	Programming Mode
1	Address Line 7	Address Line 7
2	Address Line 6	Address Line 6
3	Address Line 5	Address Line 5
4	Address Line 4	Address Line 4
5	Address Line 3	Address Line 3
6	Address Line 2	Address Line 2
7	Address Line 1	Address Line 1
8	Address Line 0	Address Line 0
9	Data Output 0	Data Input 0
10	Data Output 1	Data Input 1
11	Data Output 2	Data Input 2
12	0V	0V
13	Data Output 3	Data Input 3
14	Data Output 4	Data Input 4
15	Data Output 5	Data Input 5
16	Data Output 6	Data Input 6
17	Data Output 7	Data Input 7
18	0V	+26V Programme Pulse
19	+12V	+12V
20	Chip select (low to select)	+12V
21	−5V	−5V
22	Address Line 9	Address Line 9
23	Address Line 8	Address Line 8
24	+5V	+5V

Pin No.	Pin Function Read Mode	Programming Mode
1	Address Line 7	Address Line 7
2	Address Line 6	Address Line 6
3	Address Line 5	Address Line 5
4	Address Line 4	Address Line 4
5	Address Line 3	Address Line 3
6	Address Line 2	Address Line 2
7	Address Line 1	Address Line 1
8	Address Line 0	Address Line 0
9	Data Output 0	Data Input 0
10	Data Output 1	Data Input 1
11	Data Output 2	Data Input 2
12	0V	0V
13	Data Output 3	Data Input 3
14	Data Output 4	Data Input 4
15	Data Output 5	Data Input 5
16	Data Output 6	Data Input 6
17	Data Output 7	Data Input 7
18	Chip Select (low to select)	+26V Programming Pulse
19	+12V	+12V
20	Address Line 10	Address Line 10
21	−5V	−5V
22	Address Line 9	Address Line 9
23	Address Line 8	Address Line 8
24	+5V	0V (or +12V)

HEX CONVERSION

8		7		6		5		4		3		2		1	
Hex	Decimal	Hex	Decimal	Hex	Decimal	Hex	Decimal	Hex	Decimal	Hex	Decimal	Hex	Decimal	Hex	Decimal
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	268,435,456	1	16,777,216	1	1,048,576	1	65,536	1	4 096	1	256	1	16	1	1
2	536,870,912	2	33,554,432	2	2,097,152	2	131,072	2	8 192	2	512	2	32	2	2
3	805,306,368	3	50,331,648	3	3,145,728	3	196,608	3	12,288	3	768	3	48	3	3
4	1,073,741,824	4	67,108,864	4	4,194,304	4	262,144	4	16,384	4	1,024	4	64	4	4
5	1,342,177,280	5	83,886,080	5	5,242,880	5	327,680	5	20 480	5	1,280	5	80	5	5
6	1,610,612,736	6	100,663,296	6	6,291,456	6	393,216	6	24,576	6	1,536	6	96	6	6
7	1,879,048,192	7	117,440,512	7	7,340,032	7	458,752	7	28,672	7	1,792	7	112	7	7
8	2,147,483,648	8	134,217,728	8	8,388,608	8	524,288	8	32,768	8	2,048	8	128	8	8
9	2,415,919,104	9	150,994,944	9	9,437,184	9	589,824	9	36,864	9	2,304	9	144	9	9
A	2,684,354,560	A	167,772,160	A	10,485,760	A	655,360	A	40,960	A	2,560	A	160	A	10
B	2,952,790,016	8	184,549,376	B	11,534,336	B	720,896	B	45,056	B	2,816	B	176	8	11
C	3,221,225,472	C	201,326,592	C	12,582,912	C	786,432	C	49,152	C	3,072	C	192	C	12
D	3,489,660,928	D	218,103,808	D	13,631,488	D	851,968	D	53,248	D	3,328	D	208	D	13
E	3,758,096,384	E	234,881,024	E	14,680,064	E	917,504	E	57,344	E	3,584	E	224	E	14
F	4,026,531,840	F	251,658,240	F	15,728,640	F	983,040	F	61,440	F	3,840	F	240	F	15
8		7		6		5		4		3		2		1	

Hex to Decimal

1 Locate column of decimal numbers corresponding to left-most digit or letter of hexadecimal select from this column and record number that corresponds to position of hexadecimal digit or letter
2 Repeat step 1 for next (second from left) position
3 Repeat step 1 for units (third from left) position
4 Add numbers selected from table to form decimal number

Decimal to Hex

1 (A) select from table highest decimal number that is equal to or less than number to be converted
B) Record hexadecimal of column containing selected number
C) Subtract selected decimal from number to be converted
2 Using remainder from step 1 (C) repeat all of step 1 to develop second position of hexadecimal (and remainder)
3 Using remainder from step 2 repeat all of step 1 to develop units position of hexadecimal
4 Combine terms to form hexadecimal number

ASCII CODE SET

CODE	SYM-BOL	CODE	SYM-BOL	CODE	SYM-BOL	CODE	SYM-BOL	CODE	SYM-BOL	CODE	SYM-BOL	CODE	SYM-BOL	CODE	SYM-BOL
0	NUL	16	DLE	32	SP	48	0	64	@	80	P	96		112	p
1	SOH	17	DC1	33	!	49	1	65	A	81	Q	97	a	113	q
2	STX	18	DC2	34	"	50	2	66	B	82	R	98	b	114	r
3	EXT	19	DC3	35	£	51	3	67	C	83	S	99	c	115	s
4	EOT	20	DC4	36	$	52	4	68	D	84	T	100	d	116	t
5	ENQ	21	NAK	37	%	53	5	69	E	85	U	101	e	117	u
6	ACK	22	SYN	38	&	54	6	70	F	86	V	102	f	118	v
7	BEL	23	ETB	39	'	55	7	71	G	87	W	103	g	119	w
8	BS	24	CAN	40	(	56	8	72	H	88	X	104	h	120	x
9	HT	25	EM	41	)	57	9	73	I	89	Y	105	i	121	y
10	LF	26	SUB	42	*	58	:	74	J	90	Z	106	j	122	z
11	VT	27	ESC	43	+	59	;	75	K	91	[	107	k	123	{
12	FF	28	FS	44	,	60	<	76	L	92	\	108	l	124	¦
13	CR	29	GS	45	—	61	=	77	M	93	]	109	m	125	}
14	SO	30	RS	46	.	62	>	78	N	94	↑	110	n	126	~
15	SI	31	US	47	/	63	?	79	O	95	←	111	o	127	DEL

MPU GLOSSARY

ACCUMULATOR The register where arithmetic or logic results are held Most MPU instructions manipulate or test the accumulator contents

ACCESS TIME Time take for specific byte of storage to become available to processor

ACIA: Asynchronous Communication Interface Adapter. Interface between asynchronous peripheral and an MPU

ALU Arithmetic and Logic Unit The part of the MPU where arithmetic and logic functions are performed

ASCII American Standard Code for Information Interchange Binary code to represent alphanumeric special and control characters

ASSEMBLER Software which converts assembly language statements into machine code and checks for non valid statements or incomplete definitions

ASSEMBLY LANG Means of representing programme statements in mnemonics and conveniently handling memory addressing by use of symbolic terms

ASYNCHRONOUS Operations that initiate a new operation immediately upon completion of current one — not timed by system clock

BASIC: Beginner's All Purpose Symbolic Instruction Code: An easy to learn, widely used high level language.

BAUD Measure of speed of transmission line Number of times a line changes state per second Equal to bits per second if each line state represents logic 0 or 1

BAUDOT CODE 5 bit code used to encode alphanumeric data

BCD Binary Coded Decimal Means of representing decimal numbers where each figure is replaced by a binary equivalent

BENCHMARK A common task for the implementation of which programmes can be written for different MPUs in order to determine the efficiency of the different MPUs in the particular application

BINARY The two base number system The digits are 0 or 1 They are used inside a computer to represent the two states of an electric circuit

BIT A single binary digit

BREAKPOINT Program address at which execution will be halted to allow debugging or data entry

BUFFER Circuit to provide isolation between sensitive parts of a system and the rest of that system

BUG A program error that causes the program to malfunction

BUS The interconnections in a system that carry parallel binary data Several bus users are connected to the bus but generally only one sender and one receiver are active at any one instant

BYTE A group of bits — the most common byte size is eight bits

CLOCK The basic timing for a MPU chip

COMPILER Software which converts high level language statements into either assembly language statements or into machine code

CPU Central processor unit The part of a system which performs calculation and data manipulation functions

CRT Cathode Ray Tube Often taken to mean complete output device

CUTS Computer Users Tape System Definition of system for storing data on cassette tape as series of tones to represent binary 1 s and 0 s

DEBUG The process of checking and correcting any program errors either in writing or in actual function

DIRECT ADDRESSING An addressing mode where the address of the operand is contained in the instruction

DMA Direct Memory Access

DUPLEX Transfer of data in two directions simultaneously

ENVIRONMENT The conditions of all registers flags etc at any instant in program

EPROM Electrically Programmable Read Only Memory Memory that may be erased (usually by ultra violet light) and reprogrammed electrically

EXECUTE To perform a sequence of program steps

EXECUTION TIME The time taken to perform an instruction in terms of clock cycles

FIRMWARE Instructions or data permanently stored in ROM

FLAG A flip flop that may be set or reset under software control

FLIP-FLOP Two state device that changes state when clocked

FLOPPY (DISK) Mass storage which makes use of flexible disks made of a material similar to magnetic tape

FLOW CHART A diagram representing the logic of a computer program

GLITCH Noise pulse

HALF DUPLEX Data transfer in two directions but only one way at a time

HANDSHAKE: System of data transfer between CPU and peripheral whereby CPU asks peripheral if it will accept data and only transfers data if answer is yes

HARD COPY System output that is printed on paper

HARDWARE All the electronic and mechanical components making up a system

HARD WIRE Circuits that are comprised of logic gates wired together the wiring pattern determining the overall logic operation

HEXADECIMAL The base 16 number system Character set is decimal 0 to 9 and letters A to F

HIGH LEVEL LANGUAGE Computer language that is easy to use but which requires compiling into machine code before it can be used by an MPU

HIGHWAY As BUS

IMMEDIATE ADDRESSING Addressing mode which uses part of the instruction itself as the operand data

INDEXED ADDRESSING A form of indirect addressing which uses an Index Register to hold the address of the operand

INDIRECT ADDRESSING Addressing mode where the address of the location where the address of the operand may be found is contained in the instruction

INITIALISE Set up all registers flag etc to defined conditions

INSTRUCTION Bit pattern which must be supplied to an MPU to cause it to perform a particular function

INSTRUCTION REGISTER MPU register which is used to hold instructions fetched from memory

INSTRUCTION SET The repertoire of instructions that a given MPU can perform

INTERFACE Circuit which connects different parts of system together and performs any processing of signals in order to make transfer possible ie serial — parallel conversion)

INTERPRETER An interpreter is a software routine which accepts and executes a high level language program but unlike a compiler does not produce intermediate machine code listing but converts each instruction as received

INTERRUPT A signal to the MPU which will cause it to change from its present task to another

I O Input Output

K: Abbreviation for $2^{10} = 1024$

KANSAS CITY (Format) Definition of a CUTS based cassette interface system

LANGUAGE A systemmatic means of communicating with an MPU

LATCH Retains previous input state until overwritten

LIFO Last In First Out Used to describe data stack

LOOPING Program technique where one section of program the loop) is performed many times over

MACHINE LANG The lowest level of program The only language an MPU can understand without interpreter

MASK Bit pattern used in conjunction with a logic operation to select a particular bit or bits from machine word

MEMORY The part of a system which stores data working data or instruction object code)

MEMORY MAP Chart showing the memory allocation of a system

MEMORY MAPPED I O A technique of implementing I O facilities by addressing I O ports as if they were memory locations

MICRO CYCLE Single program step in an MPUs Micro program The smallest level of machine program step

MICRO PROCESSOR A CPU implemented by use of large scale integrated circuits Frequently implemented on a single chip

MICRO PROGRAM Program inside MPU which controls the MPU chip during its basic fetch execute sequence

MNEMONIC A word or phrase which stands for another longer) phrase and is easier to remember

MODEM Modulator demodulator used to send and receive serial data over an audio link

NON VOLATILE: Memory which will retain data content after power supply is removed e g ROM

OBJECT CODE: Bit patterns that are presented to the MPU as instructions and data

O C Open Collector Means of tieing together O/P s from different devices on the same bus

OCTAL Base 8 number system Character set is decimal 0-7

OP CODE Operation Code A bit pattern which specifies a machine operation in the CPU

OPERAND Data used by machine operations

PARALLEL Transfer of two or more bits at the same time

PARITY Check bit added to data can be odd or even parity In odd parity sum of data 1 s + parity bit is odd

PERIPHERAL: Equipment for inputing to or outputting from the system e g teletype VDU etc)

PIA Peripheral Interface Adapter

POP Operation of removing data word from LIFO stack

PORT A terminal which the MPU uses to communicate with the outside world

PROGRAMS Set of MPU instructions which instruct the MPU to carry out a particular task

PROGRAM COUNTER Register which holds the address of next instruction (or data word) of the program being executed

PROM Programmable read only memory Proms are special form of ROM which can be individually programmed by user

PUSH Operation of putting data to LIFO stack

RAM Random Acce Memory Read write memory Data may be written to or read from any location in this type of memory

REGISTER General purpose MPU storage location that will hold one MPU word

RELATIVE ADDRESSING Mode of addressing whereby address of operand is formed by combining current program count with a displacement value which is part of the instruction

ROM Read Only Memory Memory device which has its data content established as part of manufacture and cannot be changed

SCRATCH PAD Memory that has short access time and is used by system for short term data storage

SERIAL Transfer of data one bit at a time

SIMPLEX Data transmission in one direction only

SOFTWARE Programs stored on any media

SOURCE CODE The list of statements that make up a program

STACK A last in first out store made up of registers or memory locations used for stack

STATUS REGISTER Register that is used to store the condition of the accumulator after an instruction has been performed e g Acc = 0)

SUBROUTINE A sequence of instructions which perform an often required function which can be called from any point in the main program

SYNTAX The grammar of a programming language

TRAP Vector) Pre-defined location in memory which the processor will read as a result of particular condition or operation

TRI STATE Description of logic devices whose outputs may be disabled by placing them in a high impedance state

TTY Teletype

TWO S COMPLEMENT ARITHMETIC System of performing signed arithmetic with binary numbers

UART Universal Asynchronous Receiver Transmitter

VDU: Visual Display Unit.

VECTOR Memory address provided to the processor to direct it to a new area in memory

VOLATILE Memory devices that will lose data content if power supply removed i e RAM)

WORD Parallel collection of binary digits much as byte