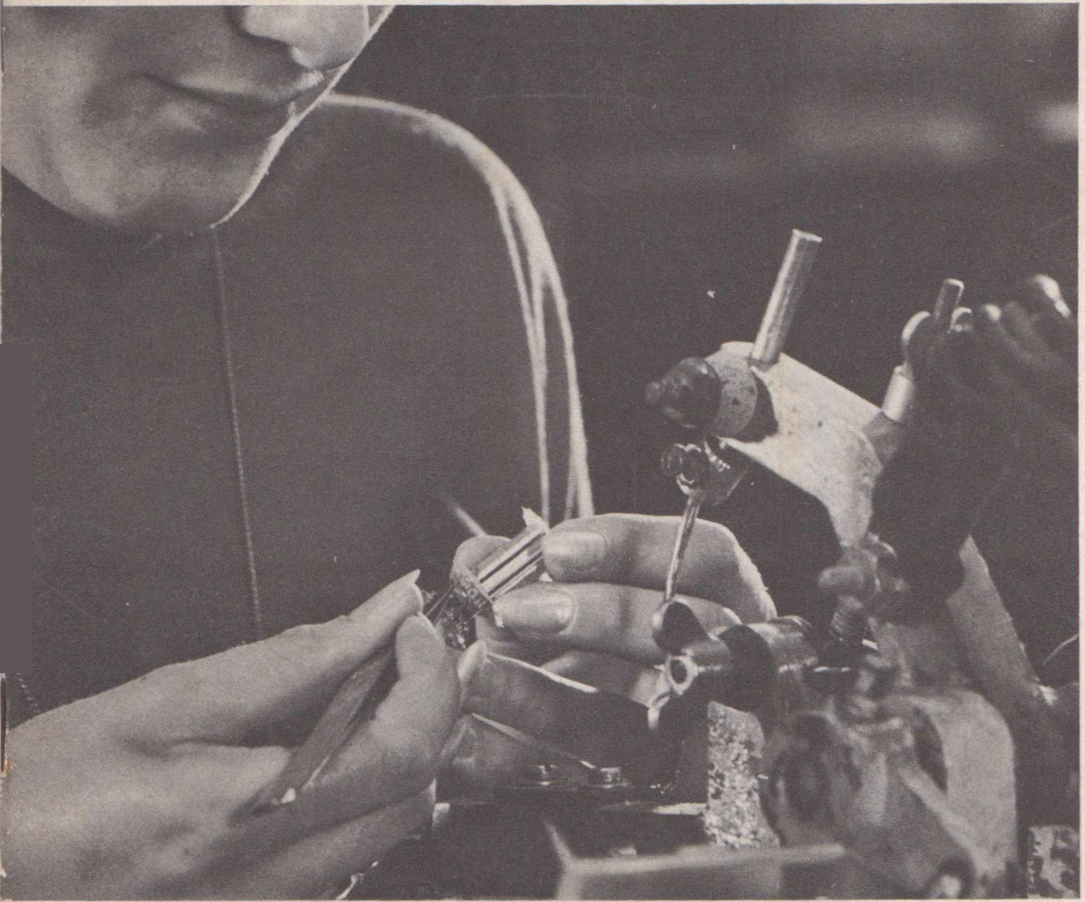
RADIOTRONICS



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AN AWV PUBLICATION

REGISTERED IN AUSTRALIA FOR TRANSMISSION BY POST AS A PERIODICAL

2 WATT COMPLEMENTARY OUTPUT AUDIO AMPLIFIER

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This article describes an interesting 2 Watt, transistorized, complementary symmetry output, audio amplifier which is ideally suited for use in mains operated record-players and radio-grams. By duplicating the amplifier, and using the simple power supply described, a very stable efficient, and relatively low cost stereo unit is produced.

Description

Figure 1 shows the circuit for one complete channel of the amplifier. The circuit uses five directly coupled transistors. The complementary output transistors are A.W.V. types AS128 and AS204, the driver is A.W.V. type 2N217S and the preamplifiers are A.W.V. types AS148 and AS149.

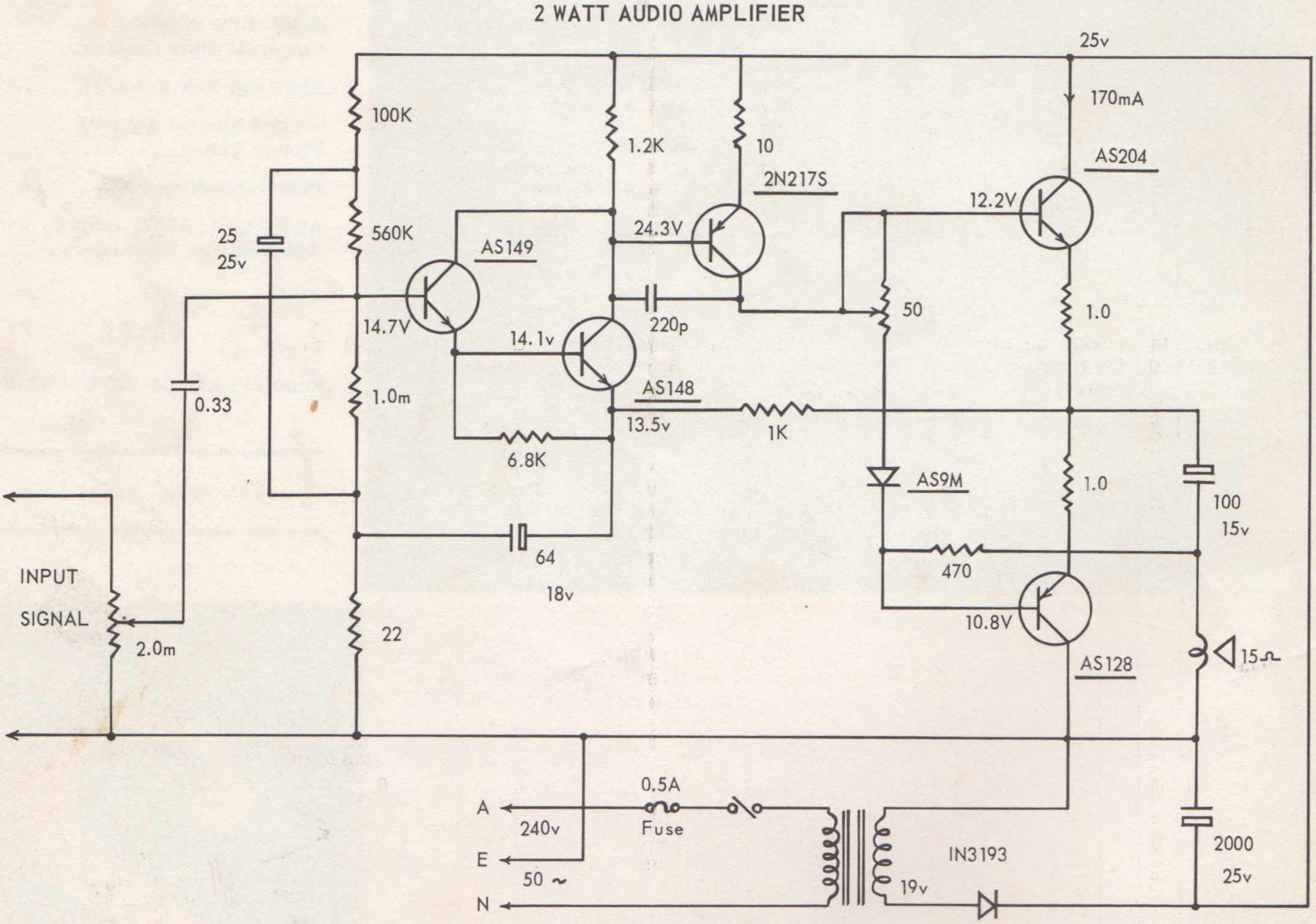

Figure 1.

The circuit, with the volume control at the input, is designed to be driven by a ceramic pickup. If required a simple treble cut tone control could be added to the input circuit.

The class B complementary output stage has been "bootstrapped" from the output load to improve the linearity of the last two stages. The compensating diode AS9M, which forms the major part of the bias network of the output stage, has a two-fold function: - firstly it controls the temperature characteristics of the stage and secondly helps minimize quiescent current variations, due to mains voltage fluctuations.

The input stage incorporates a pair of NPN transistors "Darlington" coupled and directly connected to the driver stage.

The resistor connected between the base and emitter of the second transistor provides a higher collector current for the first transistor. In this way noise is reduced and the gain of the combination increased.

In order to provide an input impedance suitable for the ceramic pick the normal relatively high input impedance of the "Darlington" input system has to be increased. This is achieved by applying negative feedback to the emitter of the second transistor whilst the input transistor base circuit is "bootstrapped" with the feedback signal.

The feedback decreases the gain and increases the input impedance by a factor approximately equal to the square of the gain reduction ratio. In this case the input impedance at the base of the input amplifier is in the order of 2.5 MΩ.

The use of direct coupling in this amplifier has produced a design which is extremely tolerant to variations in component values and the spread of transistor parameters. As a result the tolerances of resistors are not critical, and wide variations in transistor characteristics will have very little effect on overall results, and it is unnecessary to match the output transistors.

The power supply consists of a double wound transformer without taps, a half wave rectifier and a 2000 µf reservoir filter capacitor.

The circuit has been designed in such a manner that the total output noise power with the input short circuited is approximately 50 nanowatts. This has been achieved as follows:-

(1) Any supply voltage with a ripple component has been applied only to the high impedance collector circuits of the transistors.

(2) Care has been taken in the design to ensure that the supply ripple is not applied to the base-emitter junctions of any transistors.

Table 1 gives the performance specification of the amplifier. To enable safe operation of the amplifier up to 55°C the output transistors AS204 must be fitted with a flag type heat sink, whilst the AS128 must be fitted with a similar flag radiator mounted on a 4 square inch piece of 16 gauge aluminium or its equivalent.

TABLE 1

Performance Specifications of the Amplifier	
Output Load Impedance	15
Power output at clipping	2.5 W
Power output for 10% distortion	3.5 W
Distortion before clipping	1.5 %
Sensitivity for full unclipped output	150 mV
Sensitivity for 50mW	25 mV
Overall input impedance	1.0 m
Noise level with input matched	54 dB
Noise level with input short circuited	76 dB
Low frequency at – 3dB	150 Hz
High frequency at – 3dB	15 KHz
Maximum allowable ambient temperature	55 °C
Test Conditions for above results	
Supply Mains 240V @ 50Hz	
Unloaded supply rail voltage	25
Test frequency	1 KHz
Reference power output	2 W
Input capacity to simulate source	600 pf
AS204 total thermal resistance	200 °C/W
AS128 total thermal resistance	90 °C/W

Conclusion

The ceramic pickup amplifier and output system just described is ideal for mains operated radiograms and small record players where size, efficiency and reliability are of prime consideration. It is comparable in cost with other units but requires little power and has excellent electrical performance characteristics.

Details of a printed circuit board to suit this amplifier will be published in the August issue. Preliminary information on the board is available on request.

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AS60, AS61, AS62, AS63

AWV CONTROLLED-AVALANCHE DIFFUSED JUNCTION SILICON POWER RECTIFIERS

The AS60, AS61, AS62, AS63 are diffused-junction silicon power rectifiers of the controlled avalanche type. The avalanche effect and how it is controlled can be described as follows:-

Under reverse bias, high electric fields are set up in a semiconductor diode. At a critical value of field, dependent on several factors, field-induced current multiplication results in flow of (reverse) current up to values limited essentially only by the external circuit. Called avalanche breakdown, this is not in itself destructive of the device.

In most silicon diodes, as the reverse bias is increased beyond rated maximum, the critical field is reached in small volumes of material around the pellet perimeter. Even with small total avalanche power, the V.I. heating in these tiny volumes may so raise their temperature that the diode is permanently damaged.

A controlled avalanche diode is designed so that the critical field is reached uniformly throughout the bulk of the pellet. As a result it can handle considerable avalanche power with low - and predictable - temperature rise. In the face of a high reverse voltage transient, such a diode is self-protected, transient energy from the voltage source being harmlessly 'dumped' in the diode as heat - provided that this energy does not exceed the diode's avalanche rating.

Absolute Maximum Ratings

	AS60	AS61	AS62	AS63
Working Reverse Voltage V_{RWM} (crest and continuous)	400	600	800	1000
Reverse Power	See Rating Chart			

Forward Current at 25°C

Average	← 750 mA →
Peak Recurrent	← 6 A →
Surge, for 2 msec. max.	← 35 A →

Thermal Ratings

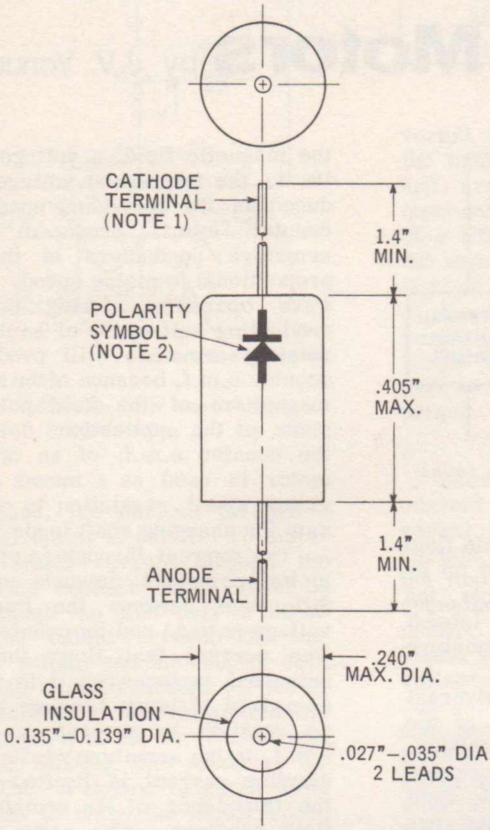
Operating Free-air Temperature	-65 to +100° C.
Storage Temperature	-65 to +175° C.

During soldering lead temperature must not exceed 255° C for 10 seconds max. within ¼" of case.

ELECTRICAL CHARACTERISTICS AT 25°C

SYMBOL	CHARACTERISTICS	CONDITIONS		MIN.	TYP.	MAX.	UNITS
V_F	Forward Volts	$I_F = 0.5A$		-	0.9	1.2	V
I_R	Reverse Current	$V_R = V_{RWM}$, $I_F = 0$		-	1	5	µA
		$V_R = V_{RWM}$, $I_F = 750$ mA		-	10	200	µA
V_{RA}	Avalanche Voltage	$I_R = 30$ µA	AS60	440	-	2000	V
			AS61	660	-	2000	
			AS62	880	-	2000	
			AS63	1100	-	2000	

DIMENSIONAL OUTLINE



NOTE 1: Connected to Metal Shell
NOTE 2: Arrow indicates direction of forward (easy) Current Flow as indicated by D.C. Ammeter.

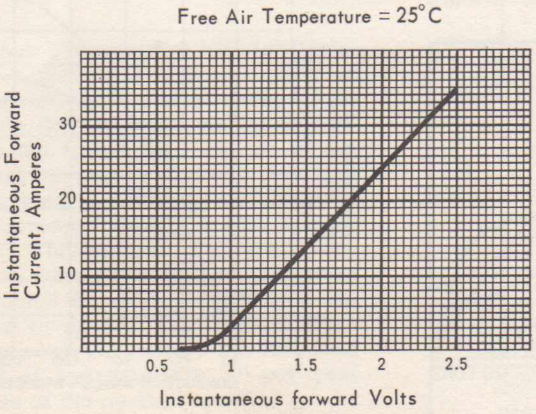


Fig. 2 Typical Forward Characteristics of AS60, AS61, AS62, AS63.

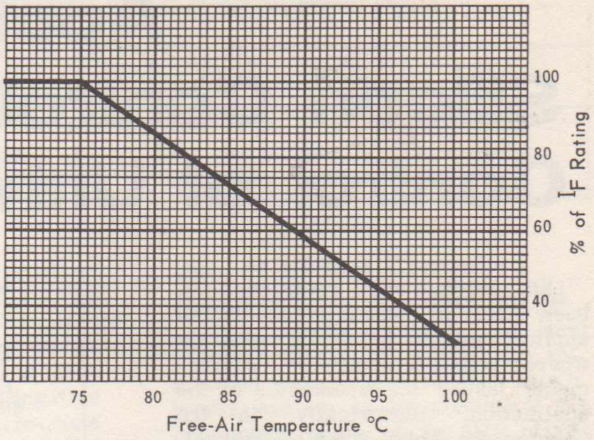


Fig. 1 Rating Chart for AS60, AS61, AS62, AS63.
100% of rating applies for free-air temperatures from − 65°C to +75°C

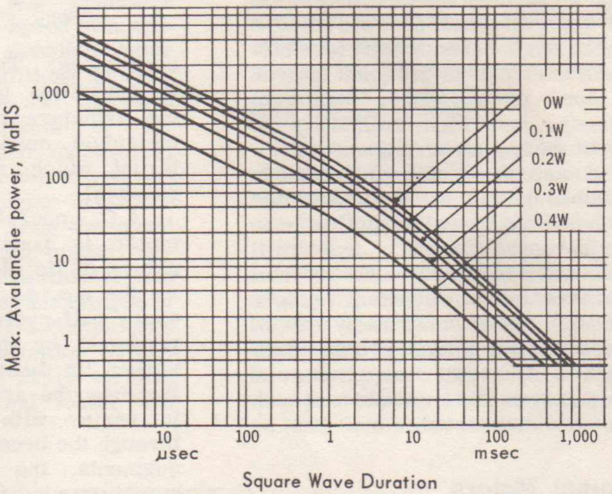


Fig. 3 Avalanche Power Rating At 25°C

Use curve corresponding to average diode dissipation when transient occurs.

The maximum permissible peak avalanche power is shown as a function of duration of the transient. The duration shown is that of an equivalent square wave of the same peak power and total energy as the actual transient. For simple and conservative estimation the actual duration of the transient may be used.

For free-air temperature (T_{FA}) above 25°C derate linearly to zero power at T_{FA} = 100°C

NOTE: *When employing a capacitive load with these units, care should be taken to avoid exceeding their forward current ratings.*

Application of Silicon Controlled Rectifiers to the Control of Universal Motors

by J.V. Yonushka

Silicon controlled rectifiers have been widely accepted in power-control applications in industrial systems where high-performance requirements justify the economics of the application. Historically, in the commercial high-volume market, economic considerations have precluded the use of the SCR. However, with the development of a family of SCR's by RCA designed specifically for mass-produced economy and rated for 240-volt line operation, the use of these devices in controls for many types of small electric motors has been made economically feasible. The controls can be designed to provide good performance, maximum efficiency, and high reliability in compact packaging arrangements.

The control circuits discussed in the following text are typical of the many possible circuits applicable to electric motor control. A general description including the typical characteristics of universal motors is given. Speed control by use of phase-angle variations is discussed; schematic diagrams are given, and the advantages and limitations of each circuit are contrasted.

Universal Motors

Many fractional horsepower motors are series-wound "universal" motors, so named because of their ability to operate directly from either a.c. or d.c. power sources. Fig. 1 is a schematic of this type of motor operated from an a.c. supply. Because most domestic applications today require 50-hertz power, universal motors are usually designed to have optimum performance characteristics at this frequency. Most universal motors run faster at a given d.c. voltage than at the same 50-hertz a.c. voltage.

The field winding of a universal motor, whether distributed or lumped (salient pole), is in series with the armature and external circuit, as shown in Fig. 1. The current through the field winding produces a magnetic field which cuts across the armature conductors. The action of this field in opposition to the field set up by the armature current subjects the individual conductors to a lateral thrust which results in armature rotation.

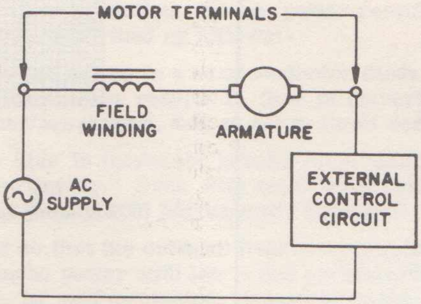


Fig. 1 - Schematic diagram for a series-wound universal motor.

A.C. operation of a universal motor is possible because of the nature of its electrical connections. As the a.c. source voltage reverses every half-cycle, the magnetic field produced by the field winding reverses its direction simultaneously. Because the armature windings are in series with the field windings through the brushes and commutating segments, the current through the armature winding also reverses. Because both the magnetic field and armature current are reversed, the direction of the lateral thrust on the armature windings remains constant.

As the armature rotates through the magnetic field, a voltage opposite to the impressed voltage is induced in the individual conductors. counter e.m.f. produced in the armature conductors is therefore proportional to motor speed. In half-wave operation, during the non-conducting half-cycle of an SCR, the rotating armature still produces a counter e.m.f. because of the residual magnetism of the field poles. In some of the applications described, the counter e.m.f. of an operating motor is used as a means of providing speed regulation to compensate for changing shaft loads.

The current through an operating motor armature depends upon the difference between the impressed voltage (e.m.f.) and the counter e.m.f. The current that flows through a universal motor when it is initially energized is large because there is no rotation to generate a counter e.m.f. in the armature windings. The starting current is limited only by the impedance of the armature and field windings. The ratio of peak starting current to peak running current can be as high as 10:1.

The speed of a series motor automatically adjusts itself so that the difference between the impressed voltage and the counter e.m.f. is sufficient to permit enough current to flow to develop the torque required by the load. At very light loads, or

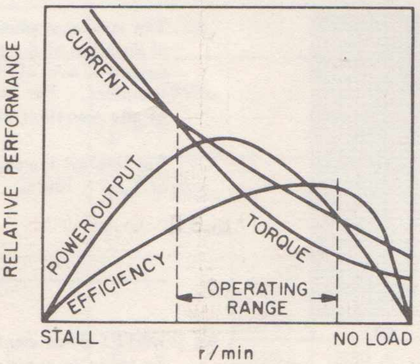


Fig. 2 - Typical performance curves for a universal motor.

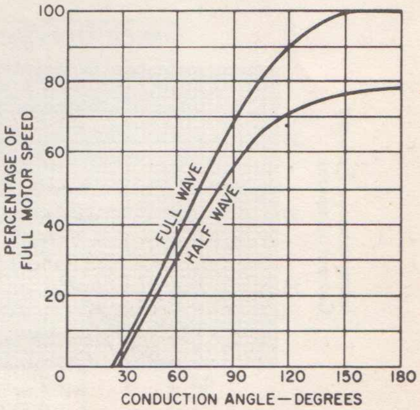
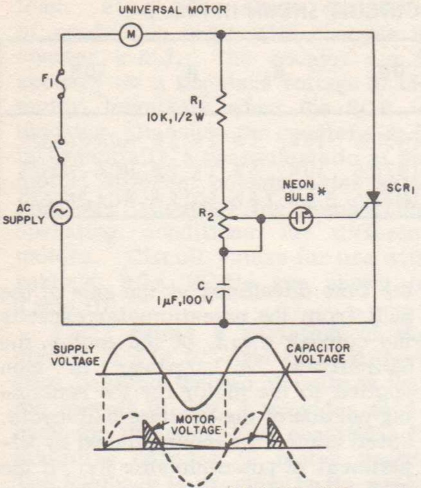


Fig. 3 - Typical performance curves for a universal motor with phase-angle control.



*NE-83, 5AH, A057B, or equiv.

Fig. 4 - Half-wave motor control with no regulation.

at no load, the current through a universal motor is small. To maintain a small current through the motor, the counter e.m.f. must be high enough so that only a small difference exists between the impressed voltage and the counter emf. The small current through the motor also results in a weak magnetic-field flux because it is the current through the field winding that produces the flux. The weakened magnetic-field flux tends to make the motor speed increase even further to produce the high counter e.m.f. required to maintain a small motor current. It would appear, then, that universal motors should tend to "run away" at no load. This run-away does not occur, however, because motors of this type usually offer enough friction and windage loss to limit the maximum attainable no-load speed to a safe value.

When a mechanical load is attached to a universal motor, the current through the motor must increase to provide the increased torque required by the load. An increase in the current through the motor requires an increase in the difference between the impressed voltage and the counter e.m.f. This increased difference can only be brought about by a reduction in counter e.m.f. derived from a decrease in speed. For an uncompensated universal motor, the full-load speed is approximately 60 per cent or less of the no-load speed.

TABLE I - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 4

AC SUPPLY	AC CURRENT	F_1	CR_1	R_1	SCR_1
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	150 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3670

The torque developed by a universal motor is a direct result of the magnitude of magnetic-field flux and armature current. For fixed mechanical loads, the starting torque of a universal motor is high because the armature current at starting time is high; at "stall" conditions, because of the large armature current, the torque is again high. The stall torque of a series motor can be as high as 10 times the continuous rated torque.

Because torque and armature current influence the speed of a universal motor, it is possible under certain operating conditions to vary the impressed voltage and influence operating characteristics of the motor. For increased mechanical loads, an increase in the impressed voltage produces a larger armature current and tends to keep the speed constant. High starting torque, adjustable speed characteristics, and small size are distinct advantages of a universal motor over a comparably rated single-phase induction motor. Typical performance characteristic curves for a universal motor are shown in Fig. 2.

Use of Silicon Controlled Rectifiers for Motor Control

One of the simplest and most efficient means of varying the impressed voltage to a load on an a.c. power system is by control of the conduction angle of an SCR placed in series with the load. Typical curves showing the variation of motor speed with SCR conduction angle for both half-wave and full-wave impressed motor voltages are illustrated in Fig. 3. If desired, a switch may be installed in the half-wave circuits so that the SCR and its related control circuit can be bypassed for full-power operation.

Half-Wave Control

There are many good circuits available for half-wave control of universal motors; their attributes and limitations are described in detail below. The circuits are divided into two classes; regulating and nonregulating. Regulation in this instance implies load sensing and compensation of the system to prevent changes in motor speed. The type of regulation provided by each circuit is stated and compared to other circuits.

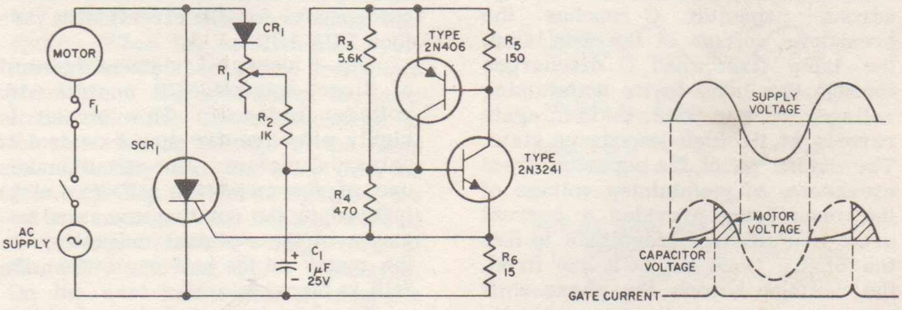
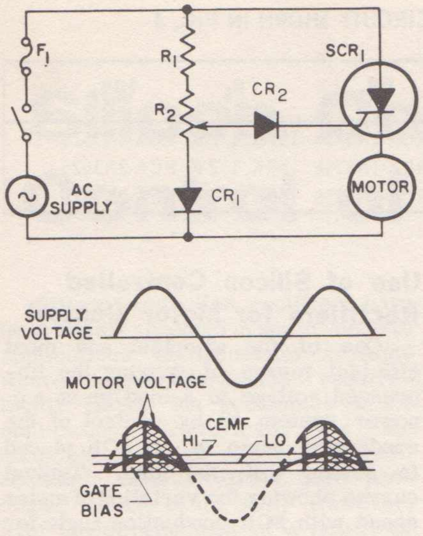


Fig. 5 - Half-wave motor control with no regulation.

TABLE II - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 5

AC SUPPLY	AC CURRENT	F_1	CR_1	R_2	SCR_1
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	150 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3A	RCA-1N3756	150 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3670



Fig, 6 - Half-wave motor control with regulation.

TABLE III - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 6

AC SUPPLY	AC CURRENT	F_1	CR_1, CR_2	R_1	R_2	SCR_1
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	10 K, 5 W	1 K, 2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	10 K, 5 W	1 K, 2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	5.6 K, 7.5 W	500, 2 W	RCA-2N3670

The half-wave proportional control circuit shown in Fig. 4 is a non-regulating circuit whose function depends upon an RC relay network for gate phase-lag control. This circuit is better than simple resistance firing circuits because the phase-shifting characteristics of the RC network permit the firing of the SCR beyond the peak of the impressed voltage, resulting in small conduction angles and very slow speed.

The control circuit shown in Fig. 4 uses the breakdown voltage of a neon lamp as a threshold setting for firing the SCR. The neon lamp is specifically designed for handling the high-current pulses required to trigger SCR's. When the voltage across capacitor C reaches the breakdown voltage of the neon lamp, the lamp fires, and C discharges through the lamp to its maintaining voltage. At this point, the lamp again reverts to its high-impedance state. The discharge of the capacitor from breakdown to maintaining voltage of the neon lamp provides a current pulse of sufficient magnitude to fire the SCR. Once the SCR has fired, the voltage across the phase-shift network reduces to the forward voltage drop of the SCR for the remainder of the half-cycle. The range of conduction angles of this circuit is approximately 30 to 150 degrees. The high breakdown voltage of the neon lamp improves noise rejection and prevents erratic firing of the SCR because of brush noises on the voltage supply lines. Table I shows components for the circuit of Fig. 4.

The circuit shown in Fig. 5 reduces spread in gate turn-on characteristics. This circuit depends upon the fast switching characteristics of transistors such as those used in the two-transistor regenerative trigger network shown. The phase-shift characteristics are still retained to provide conduction angles less than 90 degrees through the RC network of R_1, R_2, and C_1. Resistor R_3 provides turn-on current to the base of Q_1 when the voltage across C_1 becomes large enough during the positive half-cycle. The base current in Q_1 turns on this transistor. Transistor Q_1 then supplies base current to Q_2. When Q_2 turns on, it supplies more base current to Q_1. This regenerative action leads to the rapid saturation of transistors Q_1 and Q_2. Capacitor C_1 discharges through the saturated transistors into the gate of the SCR. When the SCR fires, the remaining portion of the positive half-cycle of a.c. power is applied to the motor. Speed control is accomplished by adjustment of potentiometer R_1. With component values as shown on the schematic diagram in Fig. 5, the threshold voltage for firing the circuit is approximately 8 volts; the maximum conduction angle is approximately 170 degress. Table II shows components for the circuit with various RCA SCR's.

Fig. 6 shows a fundamental circuit of direct-coupled SCR control with voltage feedback. This circuit is highly effective for speed control of universal motors. The circuit makes use of the counter e.m.f. (c.e.m.f.) induced in the rotating armature because of the residual magnetism in the motor on the half-cycle when the SCR is blocking.

The counter e.m.f. is a function of speed and, therefore, can be used as an induction of speed changes as mechanical load varies. The gate-firing circuit is a resistance network consisting of R_1 and R_2. During the positive half-cycle of the source voltage, a fraction of the voltage is developed at the centre-tap of the potentiometer and is compared with the counter e.m.f. developed in the rotating armature of the motor. When the bias developed at the gate of the SCR from the potentiometer exceeds the counter e.m.f. of the motor, the SCR fires. A.C. power is then applied to the motor for the remaining portion of the positive half-cycle. Speed control is accomplished by adjustment of potentiometer R_1. If the SCR is fired early in the cycle, the motor operates at high speed because essentially the full rated line voltage is applied to the motor. If the SCR is fired later in the cycle, the average value of voltage applied to the motor is reduced, and a corresponding reduction in motor speed occurs. On the negative half-cycle, the SCR blocks voltage to the motor. The voltage applied to the gate of the SCR is a sine wave because it is derived from the sine-wave line voltage. The minimum conduction angle occurs at the peak of the sine wave and is restricted to 90 degrees. Increasing conduction angles occur when the gate bias to the SCR is increased to allow firing at voltage values which are less than the peak value.

At no load and at the low-speed control setting, "skip-cycling" operation occurs, and motor speeds are erratic. Because no counter e.m.f. is induced in the armature when the motor is standing still, the SCR fires at low bias settings. The motor is then accelerated to a point at which counter e.m.f. induced in the rotating armature exceeds the gate-firing bias of the SCR and prevents the SCR from firing. The SCR is not able to fire again until the speed of the motor is reduced (because of friction and windage losses) to a value for which the induced voltage in the rotating armature is less than the gate bias. At this time the SCR fires again. The motor deceleration occurs over a number of cycles when there is no voltage applied to the motor, (hence the term "skip cycling").

When a load is applied to the motor, the motor speed decreases and thus reduces the counter e.m.f. induced in the rotating armature. With a reduced counter e.m.f., the SCR fires earlier in the cycle and provides increased motor torque to the

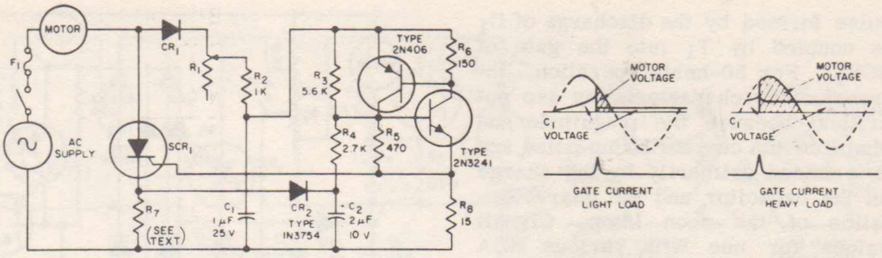


Fig. 7 - Half-wave motor control using two-transistor regenerative triggering with regulation.

TABLE IV - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 7

AC SUPPLY	AC CURRENT	F_1	CR_1	R_1	SCR_1
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N3756	150 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-1N3756	150 K, 1/2 W	RCA-2N3670

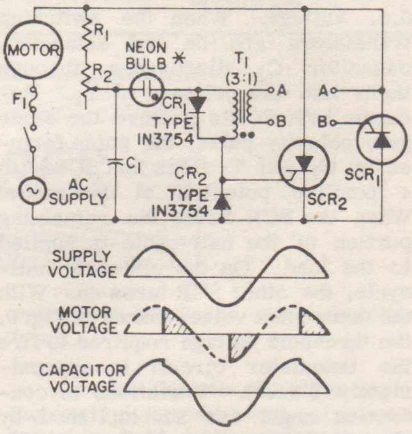
load. Fig. 6 also shows variations of conduction angle with changes in counter e.m.f. The counter e.m.f. appears as a constant voltage at the motor terminals when the SCR is blocking. Because the counter e.m.f. is essentially a characteristic of the motor, different potentiometer settings are required for comparable operating conditions for different motors. Circuit values for use with various RCA SCR's are shown in Table III.

Fig. 7 shows a variation of the circuit in Fig. 5. The basic difference between the two circuits is that the circuit in Fig. 7 provides feedback for changing load conditions to minimize changes in motor speed. The feedback is provided by R_7, which is in series with the motor. A voltage proportional to the peak current through the motor is developed across the resistor. This voltage is stored on capacitor C_2 through diode CR_2, and is of a polarity that causes the bias on the resistance network of R_3 and R_4 to change in accordance with the load on the motor. With an increasing motor load, the speed tends to decrease. This decrease in motor speed causes more current to flow through the motor armature and field windings. When the current flowing through R_7 increases, the voltage stored on capacitor C_2 increases in the positive direction. This increase in capacitor voltage causes the transistors to conduct earlier in the cycle, to fire the SCR, and to provide a greater portion of the power cycle to the motor. With a decreasing load, the motor current decreases and the voltage stored by capacitor C_2 decreases. The transistors and SCR then conduct later in the cycle. The resultant reduction in the average power supplied to the motor causes a reduced torque to the smaller load. Because motor current is a function of the motor itself, resistor R_7 has to be matched with the motor rating to provide optimum feedback for load compensation. Resistor R_7 may range from 0.1 ohm for larger-sized universal motors to 1.0 ohm for smaller types. Circuit values for use with various RCA SCR's are shown in Table IV.

Full-Wave Control

This section discusses the application of SCR's to full-wave motor control. Two SCR's are usually required to provide full-wave control.

The very simple SCR full-wave proportional control circuit is shown in Fig. 8. Again, a.c. phase shifting and neon triggering are used to provide gate phase-angle control; a small pulse transformer is utilized for isolation. The circuit provides a symmetrical output for both halves of the a.c. input voltage because the same electrical components are used in the phasing network for both SCR gates. Because of SCR gate circuits are completely isolated from each other, the cross-talk problem usually associated with gate firing circuits using transformer coupling and bidirectional trigger devices is avoided. There is a hysteresis effect associated with this circuit because C_1 charges to alternate positive and negative values. As R_2 decreases from its maximum value, C_1 charges to a higher voltage on each half cycle. When the positive half-cycle voltage on C_1 reaches the breakdown potential of the neon lamp, the lamp fires, allowing C_1 to discharge to the maintaining voltage of the lamp through CR_1 and the lamp into the gate of SCR_2. When SCR_2 fires, the voltage across the control circuit drops to the forward voltage value of the SCR, allowing C_1 to discharge. On the next half-cycle, C_1 charges from a lower positive potential and allows the neon lamp to fire earlier in the cycle. If the potentiometer resistance R_2 is increased, the SCR's fire at a reduced conduction angle and the hysteresis effect is produced. On the negative half-cycle, when the charge on C_1 has reached the breakdown potential of the neon lamp, the capacitor discharges through CR_2, the lamp, and the primary of transformer T_1 to the maintaining voltage of the neon lamp. The current



*NE-83, 5AH, A057B, or equiv.
T_1 - Better Coil and Transformer Co. Type 99A16, or equiv.

Fig. 8 - Full-wave motor control with no regulation.

TABLE V - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 8

AC SUPPLY	AC CURRENT	F_1	R_1	R_2	C_1	SCR_1, SCR_2
240 V	1.5 A	3 AG, 2 A, Quick Act	1 K, 1 W	50 K, 2 W	0.22 F, 100 V	RCA-2N3529
240 V	5 A	3 AB, 5 A	1 K, 1 W	50 K, 2 W	0.22 F, 100 V	RCA-2N3525
240 V	10 A	3 AB, 10 A	1 K, 1 W	25 K, 4 W	0.47 F, 100 V	RCA-2N3670

pulse formed by the discharge of C_1 is coupled by T_1 into the gate of SCR_1. For 50-hertz operation, the transformer characteristics are not critical because the magnitude and shape of the current firing pulse are determined primarily by the charge on the capacitor and the characteristics of the neon lamp. Circuit values for use with various RCA SCR's are shown in Table V. Conduction angles obtained with this circuit vary from 30 to 150 degrees; at the maximum conduction angle, the voltage impressed upon the load (universal motor) is approximately 95 per cent of the input rms voltage.

Fig. 9 shows a full-wave control circuit that has increased conduction-angle capability. Table VI shows the component chart for use of the circuit with various SCR's. The threshold point of the transistor circuit can be changed by varying the value of R_3. The phase-shift network composed of R_1, R_2, and C_1 permits the variation of conduction angles from minimum to maximum. An a.c. potential impressed upon this phase-shifting network eliminates skip-cycling at low conduction angles. The bridge network of CR_1, CR_2, CR_3, and CR_4 rectifies the a.c. voltage developed across CR_1 and provides the switching transistors with d.c. voltage. When the switching transistors are on and saturated, capacitor C_1 discharges through them into the primary of T_1. Because both SCR's receive the same gate polarity pulse, the pulse formed by C_1 and T_1 fires that SCR with a positive potential at the anode. When the SCR fires, the remaining portion of the half-cycle is applied to the load. On the alternate half-cycle, the other SCR turns on. With the component values shown in Fig. 9, the threshold voltage required to fire the transistor circuit is approximately 8 volts. Variations in conduction angle are accomplished by changing the setting of R_2. In this circuit, the conduction angles may be varied from 5 to 170 degrees; this larger range is more desirable when higher power is to be controlled.

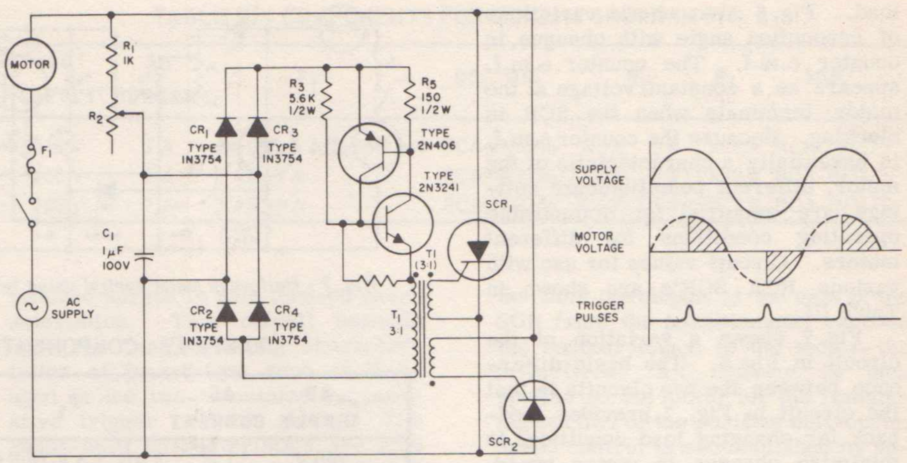


Fig. 9 - Full-wave motor control with no regulation in which the conduction angle can be varied from 5 to 180 degrees.

TABLE VI - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 9

AC SUPPLY	AC CURRENT	F_1	R_2	SCR_1, SCR_2
240 V	1.5 A	3 AG, 2 A, Quick Act	150 K, 1/2 W	RCA-2N3529
240 V	5 A	3 AB, 5 A	150 K, 1/2 W	RCA-2N3525
240 V	10 A	3 AB, 10 A	150 K, 1/2 W	RCA-2N3670

An SCR full-wave circuit designed for applications requiring feedback for compensation of load changes is shown in Fig. 10. Operation is similar to that of the circuits discussed previously except that this circuit has full-wave conduction with proportional control. Again, as in the circuit of Fig. 7, R_7 must be matched with the motor rating to provide optimum feedback for load compensation. Resistor R_7 may range from 0.1 ohm for larger-size universal motors to 1.0 ohm for smaller types. Table VII gives a component list for use of this circuit with various SCR's.

Ratings and Limitations

Package size and environment limit the voltage and current capabilities and, consequently, the power-dissipation abilities of an SCR. Maximum temperature ratings usually depend on the use of a heat sink of a particular size at a prescribed ambient or case temperature.

The main cause of heat within an SCR operating at 50 hertz is the forward current and voltage drop during conduction. Under steady-state conditions, the heat generated within the device must be balanced by the flow of heat to the heat sink and the ambient air. If more heat is generated within the SCR than can be dissipated by the case and the heat sink, the junction temperature increases and forward blocking capabilities are lost. Under these conditions the SCR may break down thermally in the reverse direction, causing damage to the SCR pellet. An increase in heat-sink size to maintain the balance between heat generated and heat dissipated assures reliable performance of the SCR.

The current ratings for the circuits using the 2N3529 SCR are based upon measurements made with this device mounted by its electrical leads with the package in free air. The current ratings for the circuit using the other SCR types are based upon measurements made with the SCR's mounted on an aluminium heat sink having an equivalent dimension of 3 by 3 by 1/16 inches.

The SCR can be mounted on a single-plate heat sink or on a metal chassis. In chassis mounting the package housing and heat sink can be insulated from the chassis by a mica washer. The use of silicone grease or other similar material between the SCR housing and the heat sink provides a better thermal contact and more efficient heat dissipation. If heat dissipation is critical, a finned heat sink should be used. Heat-sink size may be reduced in any application if moving air can be provided at the SCR mounting site.

If a universal motor is operated at low speed under a heavy mechanical load, it may stall and cause heavy current flow through the SCR. For this reason, low-speed heavy-load conditions should be allowed to exist for only a few seconds to prevent possible circuit damage. In any case, fuse ratings should be carefully observed and limited to the types and values indicated in the tables accompanying the circuits in this Note.

Practical heat sinks, packaging, available fuse characteristics, and motor overload and stall performance have been considered and are reflected in the current ratings shown for the circuit in this Note; these current values should not be exceeded.

Nameplate data for some universal motors are given in developed horsepower to the load. This mechanical designation can be converted into its electrical current equivalent through the following procedure.

Internal motor losses are taken into consideration by assigning a figure of merit. This figure, 0.5, represents motor operation at 50-per-cent efficiency, and indicates that the power input to the motor is twice the power delivered to the load. With this figure of merit and the input voltage V_{ac}, the rms input current to the motor can be calculated as follows:

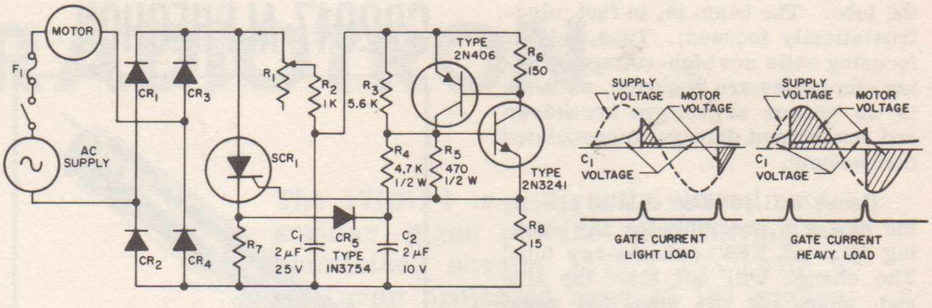


Fig. 10 - Full-wave motor control with regulation.

TABLE VII - COMPONENTS FOR CIRCUIT SHOWN IN FIG. 10

AC SUPPLY	AC CURRENT	F_1	CR_1, CR_2 CR_3, CR_4	R_1	SCR_1
240 V	1 A	3 AG, 1.5 A, Quick Act	RCA-1N2862	100 K, 1/2 W	RCA-2N3529
240 V	3 A	3 AB, 3 A	RCA-40112	100 K, 1/2 W	RCA-2N3525
240 V	7 A	3 AB, 7 A	RCA-40112	100 K, 1/2 W	RCA-2N3670

$$\text{rms current} = \frac{\text{mechanical horsepower} \times 746}{0.5\ V_{ac}}$$

For an input voltage of 240 volts, the rms input current becomes:

$$\text{rms current} = \text{horsepower} \times 6.2$$

The circuits in this Note should not be used with universal motors that have calculated rms current exceeding the values given in the tables. The circuits will accommodate universal motors with ratings up to 1-1/2 horsepower at 240 volts input.

● *WITH ACKNOWLEDGEMENT TO R.C.A.*

NEWS & NEW RELEASES

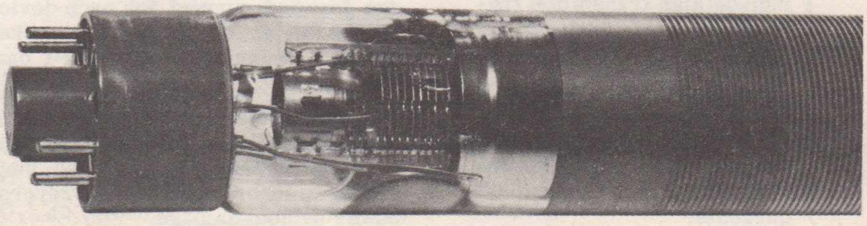
LAMINAR BEAM CRT

English Electric Valve Co. Ltd. has developed a new electron gun for its cathode-ray tubes. Compared with previous designs, this new gun produces an extremely narrow stream of electrons. Hence the name, 'Laminar Beam'.

The cathode and focusing assembly of this new gun have been designed to produce an electron beam with smaller beam angle and therefore much reduced aberrations. This laminar beam has a uniform electron density (rather than the normal Gaussian, or bell-shaped, distribution); it therefore produces a spot which has uniform brightness and a very sharp edge. Moreover, the narrowness of the beam at the point of deflection minimises any deflection defocusing. The spot size may also be varied without defocusing. These advances give the EEV laminar beam CRT a 3 : 2 improvement in resolution compared with conventinal types.

Because the new gun gives such a narrowly divergent beam only a weak focusing field is required, and this can be obtained from a conducting spiral mounted inside the neck of

Close-up view of gun of Laminar Beam CRT.



the tube. The beam is, in fact, electrostatically focused. Thus, neither focusing coils nor high-voltage focusing electrodes are required, so there is no chance of voltage breakdown and consequent damage to associated components.

Users will soon be able to specify the new gun assembly for any existing type of EEV cathode-ray tube. The change will not alter the size and shape of the tube, but some alterations to existing electrical supplies may be needed.

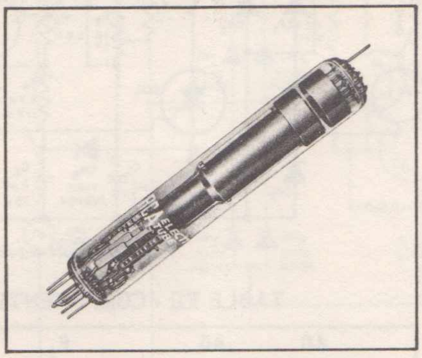
The improvement in resolution will not interest some CRT users who are satisfied with the resolution of the tubes they now use. For such users, EEV's new laminar beam gun offers other important advantages. CRTs fitted with the new EEV laminar beam gun can have a shorter neck or a much greater deflection angle, or both, and still maintain a standard acceptable to these users. Thus the total length of the display tube is reduced, offering further economies in equipment design and compression.

AWV SILICON TRANSISTORS

A further six silicon planar epitaxial transistors have been added to the range of A.W.V. packaged transistors.

AS303	An r.f. amplifier type suitable for use in television and communication receivers. Features of the AS303 include low r.f. noise, high transition frequency and a low cut-off current.
AS304 AS305	These two transistors are v.h.f. types primarily designed for use as mixer and local oscillator respectively in television tuners up to a frequency of 220 MHz. Features of the AS304 and AS305 include high transition frequencies and low cut-off currents.
AS306 AS307 AS308	The AS306, AS307 and AS308 are for use in 36 MHz television r.f. amplifiers features include, high transition frequencies and low cut-off currents.

C22017 ALPHECHON



The RCA Developmental Type C22017 is a small, low-cost, single-ended, non-destructive read-out storage tube. It is useful in systems where computer-generated alphanumeric messages are to be displayed on conventional TV monitors. In the original data-distribution system for which it was designed, messages are coded as TV-type signals at the transmitting unit. At the display terminal, the particular TV frame containing the desired message is selected and written into the Alphechon. The frame of data thus stored can then be continuously read out for display for periods of at least two minutes. At the end of this time, the stored message can be erased in the time period of one TV frame (33 milliseconds) and then a new message can be written (or the same message rewritten) into the C22017. The data link and the computer itself can therefore service a large number of display terminals without the need for "refreshing" the display terminals at a rate high enough to avoid display flicker.

AWV AVALANCHE DIODES

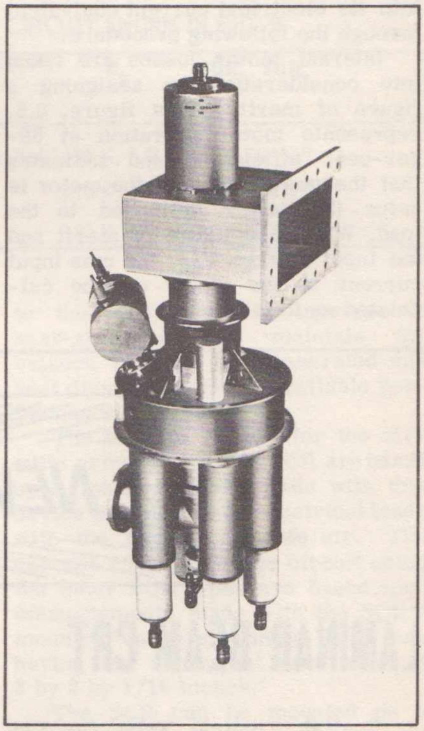
Production has commenced at our Rydalmere plant of a series of four controlled avalanche diodes. The types are AS60, AS61 and AS63, which have a maximum reverse working voltages of 400, 600, 800 and 1000 respectively. The maximum average forward current for each device is 750 mA at 25°. They are packed in the popular axial lead TO-I can.

Because of their special design, they are protected against transient voltages, in excess of their working reverse voltage ratings, by their ability to absorb considerable reverse power without damage.

Complete data on these devices is given elsewhere in this issue.

SUPER-POWER TRIODE COAXITRON

The R.C.A. developmental type No. A1519IB is a liquid-cooled, super-power, triode Coaxitron intended for use as a long pulse UHF amplifier. The Coaxitron construction integrates the complete r.f.-tuned circuits and the associated grid-controlled electronics within a single vacuum envelope to optimize performance and reliability.



The A1519IB features a symmetrical array of unit triode electron-optical systems. Each unit employs a thoriated tungsten filamentary cathode for very high pulse emission, long life and economical operation. The Coaxitron also features a standard 50-ohm UHF coaxial input connector, a standard waveguide output connector, and quick-disconnect coolant connectors.

This device is capable of 1.25 megawatts peak power output at 805 MHz with a pulse width of 500 µ sec. and a duty factor of 0.06.

SUPER RADIOTRON
17ERP4
PICTURE TUBE

The 17ERP4 is a directly viewed rectangular glass picture tube having an aluminised screen 13⅝" x 10⅝" with a minimum projected area of 141 square inches. It employs 114° magnetic deflection and low voltage electrostatic focus. Integral implosion protection is provided by a formed rim band and tension band around the periphery of the tube panel.

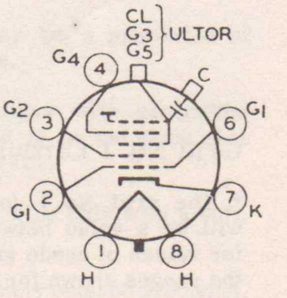
GENERAL

Heater Voltage	6.3 volts
Heater Current	0.6 amp
Direct Interelectrode Capacitances:	
Cathode to all other electrodes	5 pf
Grid 1 to all other electrodes	6 pf
External conductive coating to anode:	
Maximum	1500 pf
Minimum	1000 pf
Faceplate	Filterglass
Light Transmission	50½%
Phosphor	Aluminised P4 Sulphide
Fluorescence	White
Phosphorescence	White
Focusing Method	Electrostatic
Deflection Method	Magnetic
Deflection Angles (approx.):	
Diagonal	114°
Horizontal	102°
Vertical	84°
Tube Dimensions:	
Overall Length	10.945 ±0.250 inches
Greatest Width	14.750 ±0.100 inches
Greatest Height	11.875 ±0.100 inches
Diagonal	17.312 ±0.100 inches
Neck Length	4.125 ±0.125 inches

Screen Dimensions (min.):	
Horizontal	13.625 inches
Vertical	10.625 inches
Diagonal	16.250 inches
Area	141 sq. in.
Electron Gun	Unipotential
Bulb	J137¼A1
Bulb Contact	JEDEC J1-21
Base	JEDEC B7-208

SOCKET CONNECTIONS –8HR

Pin 1 – Heater
Pin 2 – Grid No. 1
Pin 3 – Grid No. 2
Pin 4 – Grid No. 4
Pin 5 – Blank
Pin 6 – Grid No. 1
Pin 7 – Cathode
Pin 8 – Heater
Bulb Contact – Anode



RATINGS, DESIGN MAXIMUM SYSTEM

(Unless otherwise specified, voltage values are positive, and measured with respect to cathode.)

Maximum Anode Voltage	20,000 volts
Minimum Anode Voltage	11,000 volts
Maximum Grid No. 4 Voltage	+1100, -550 volts
Maximum Grid No. 2 Voltage	550 volts
Minimum Grid No. 2 Voltage	200 volts
Grid No. 1 Voltage:	
Maximum Negative Value	-154 volts
Maximum Negative Peak Value	-220 volts
Maximum Positive Value	0 volts
Maximum Positive Peak Value	2 volts
Maximum Heater-Cathode Voltage, Heater Negative with respect to Cathode:	
During Warm-up, 15 secs	450 volts
After Warm-up Period	200 volts
Maximum Heater-Cathode Voltage, Heater Positive with respect to Cathode	200 volts

TYPICAL OPERATION, GRID DRIVE SERVICE

(Unless otherwise specified, all voltage values are positive with respect to cathode.)

Anode Voltage	16,000 volts dc
Grid No. 4 Voltage*	0-400 volts dc
Grid No. 2 Voltage	400 volts dc
Grid No. 1 Voltage	-36 to -94 volts dc

TYPICAL OPERATION, CATHODE DRIVE SERVICE

(Unless otherwise specified, all voltage values are positive with respect to Grid No. 1.)

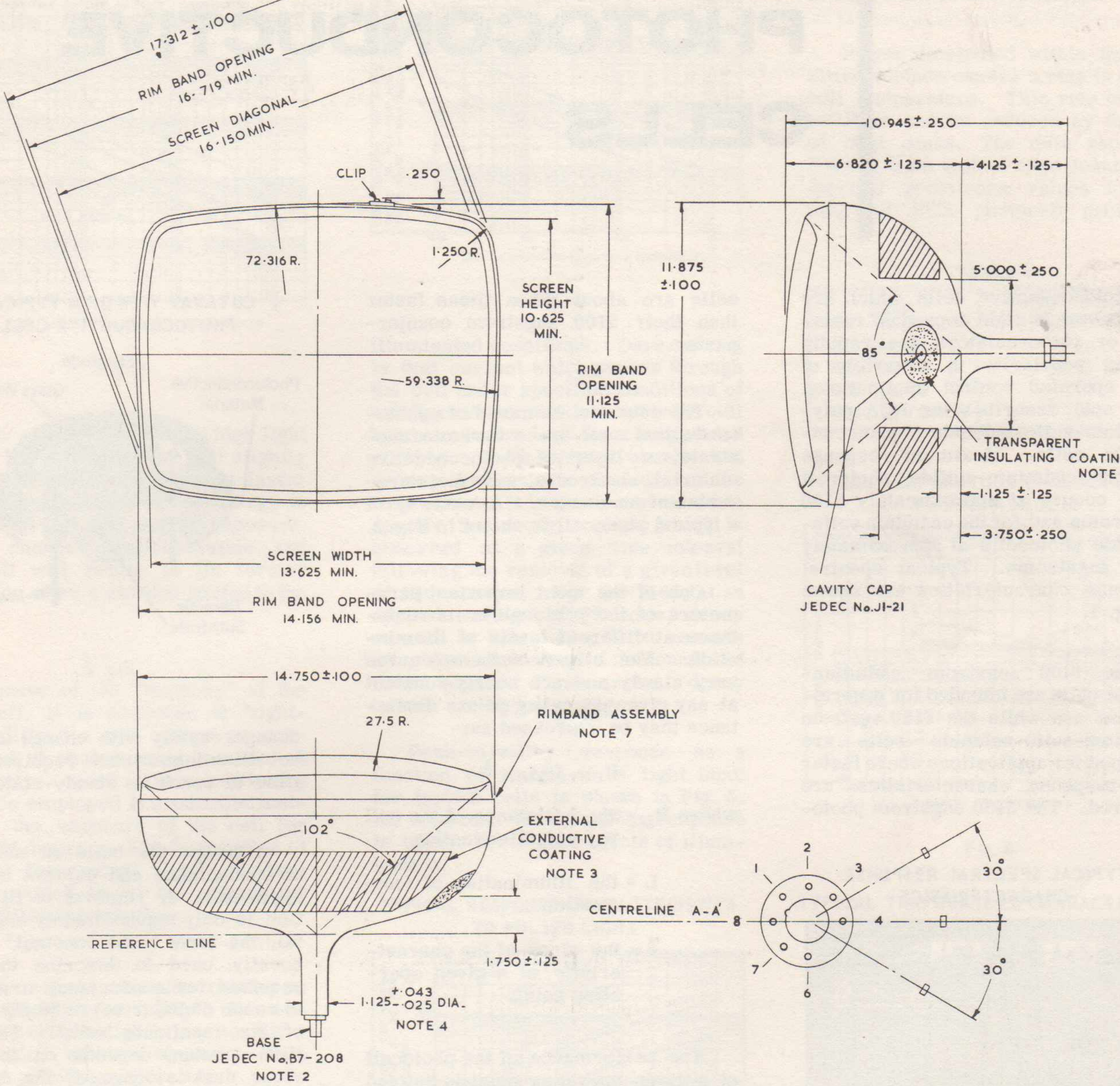
Anode Voltage	16,000 volts dc
Grid No. 4 Voltage*	0-400 volts dc
Grid No. 2 Voltage	400 volts dc
Cathode Voltage	36 to 78 volts dc

MAXIMUM CIRCUIT VALUE

Grid No. 1 Circuit Resistance	1.5 megohms

---

* The grid No. 4 (or grid No. 4 to grid No. 1) voltage required for optimum focus of any individual tube will be a value between 0 and 400 volts independent of anode current. It will remain essentially constant for values of anode (or anode to grid No. 1) voltage and grid No. 2 (or grid No. 2 to grid No. 1) voltage within the ranges shown for these items.



NOTE 1. Yoke Reference Line is determined by plane surface of flared end of JEDEC Reference Line Gauge No. 126 when seated on funnel of tube. With minimum neck length tube, the PM centring magnet should extend no more than 2¼" from Yoke Reference Line.

NOTE 2. Lateral strains on the base pins must be avoided. The socket should have flexible leads permitting movement. The perimeter of the base wafer will be inside a 1¾" diameter circle concentric with the tube axis.

NOTE 3. External conductive coating forms supplementary filter capacitor and must be grounded.

NOTE 4. Neck diameter may be a maximum of 1.168" at the splice.

NOTE 5. Base pin No. 4 aligns with centreline A-A' within 30° and is on the same side as anode contact J1-21.

NOTE 6. To clean this area, wipe only with a soft, dry lintless cloth.

NOTE 7. The Rimband assembly must be grounded.

PHOTOCONDUCTIVE CELLS

Photoconductive cells which are also known as light dependant resistors or photoresistors are rapidly gaining popularity in a variety of light operated control applications. This note describes the RCA poly-cadmium-sulfo-selenide photoconductive cells. Maximum response for the cadmium-sulfide photocell types occurs at approximately 5100 angstroms and for the cadmium sulfo-selenide photocells at approximately 6150 angstroms. Typical spectral response characteristics are shown in Fig. 1.

The 5100 angstrom cadmium-sulfide cells are intended for general-purpose use while the 6150 agstrom cadmium-sulfo-selenide cells are designed for applications where faster time-response characteristics are required. The 6150 angstrom photocells are about three times faster than their 5100 angstrom counterparts.

TYPICAL SPECTRAL RESPONSE CHARACTERISTICS

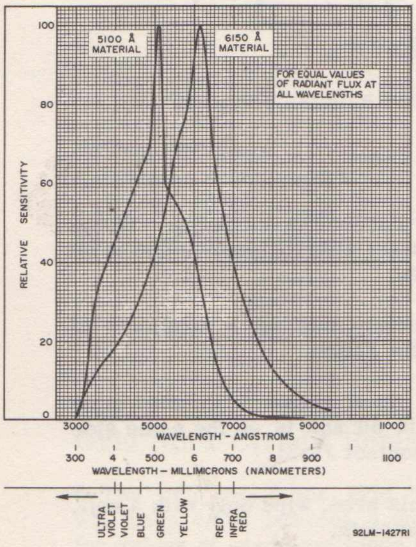


Fig. 1

The essential elements of a photoconductive cell are a ceramic substrate, a layer of photoconductive material, electrodes, and a moisture-resistant enclosure. A cutaway of a typical photocell is shown in Fig. 2.

One of the most important parameters of the photocell is its resistance at different levels of illumination. The slopes of these curves vary slowly and are nearly constant at any given operating point. Resistance may be expressed as:

$$R \approx R_1 L - \gamma$$

where R_1 = the resistance of the cell per unit illumination

L = the illumination of foot-candles

γ = the slope of the characteristic at a given operating point.

The performance of the photocell at a given operating point is defined by specifying R_1 and γ. For a typical cell, RCA-7163, R_1 and γ are 0.03×10^6 ohms and 0.83, respectively at 1 footcandle illumination. The resistance, or conductance, of the cell is often indirectly expressed in terms of the current drawn through the cell at a given voltage and given light level. When a d.c. voltage is applied across the cell, the resistance for a given illumination may be computed by means of Ohm's Law.

CUTAWAY VIEW OF A TYPICAL PHOTOCONDUCTIVE CELL

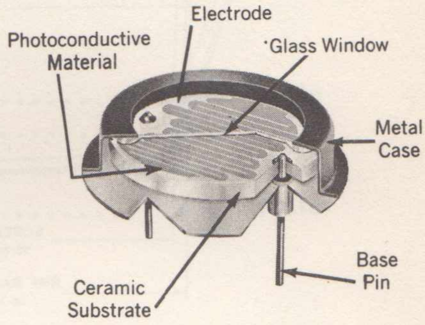


Fig. 2

The conductance (1/resistance) of the photoconductive cell does not change rapidly with change in incident illumination but requires some time to reach its steady-state value.

Although the build-up and decay of conductance and current upon the application or removal of illumination is only approximately exponential, the term "time constant" is frequently used to describe the time required for conductance or current to reach 63.2% (rise) or 36.8% (decay) of its maximum value. The rise time-constant depends on the previous dark storage of the cell and the intensity of the applied illumination. In general, the cell responds more quickly to high illumination levels than to low illumination levels and its rise time is usually longer than its decay time. Typical photocurrent rise curves are shown in Fig. 3.

In addition to these time effects, there are other time-associated phenomena that take place more slowly. The phenomena can best be described by saying that the cell has some memory of previous light ex-

TYPICAL PHOTOCURRENT RISE CHARACTERISTICS

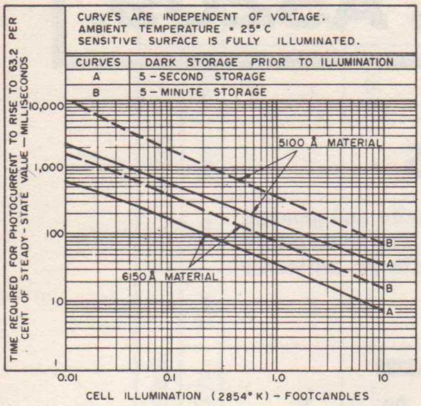


Fig. 3

TYPICAL PHOTOCURRENT DECAY CHARACTERISTICS

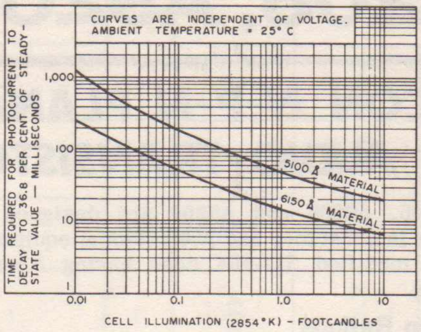


Fig. 4

posure. Long exposure to high light levels tends to make the cell slightly less sensitive and somewhat faster in response whether or not voltage is applied to the cell during exposure. These changes are reversible, and the cell will return to its former condition after a storage period in the dark.

Because of the "memory" of the photocell, it is desirable to "light-precondition" a cell before a measurement of photocurrent is made. A commonly used preconditioning schedule employed in production testing is the exposure of the cell for 16 to 24 hours to 500 footcandles of daylight fluorescent light. Voltage is not applied to the cell during the preconditioning schedule.

Time effects are also related to the application of voltage. For example, a cell is slightly less sensitive under a.c. voltage operation than under d.c. voltage operation.

In most photocell applications, it is important that the conductance of the cell be substantially less when the cell is in the dark than when it is illuminated. The terms dark current and decay current are used to describe cell performance under unilluminated conditions. Dark current is that current which passes through the cell under specified conditions of voltage and temperature after the cell has been in the dark for a long period of time. Dark current usually has a very low value. Because of the time effects, it is more convenient to specify the decay current which is observed at a given time interval following the removal of a given level of illumination. For the 7163, at an applied voltage of 50 volts, decay current is below 40 μA, 10 seconds after the removal of 1 footcandle of illumination. Photocurrent decay curves are shown in Fig. 4.

Peak-to-valley response as a function of square-wave light input for typical cells is shown in Fig. 5. As expected, the frequency response is higher for higher levels of illumination.

TYPICAL RESPONSE CHARACTERISTICS TO PULSED LIGHT

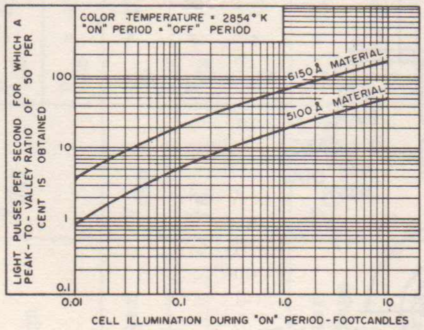


Fig. 5

The effects of ambient temperature on photocell sensitivity is shown in Fig. 6 for 5100 Å material and in Fig. 7 for 6150 Å material.

Power dissipated within the sensitive surface causes a rise in photocell temperature. This rise in temperature can be reduced by the use of heat sinks. The data shown in Table 1 lists typical case-to-ambient thermal resistance values for the different RCA photocell packages.

TABLE 1

CASE	Thermal Resistance (Case to Ambient) °C/W
1" - Diameter	38
Modified TO - 8	95
Modified TO - 5	170
Modified TO - 18	250

TYPICAL TEMPERATURE CHARACTERISTICS
For 6150 Å Material

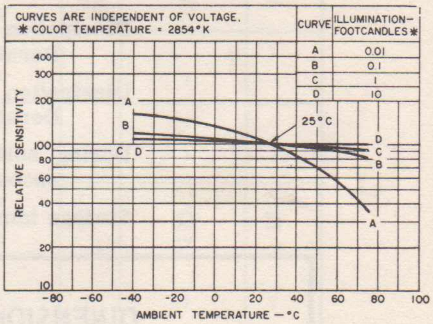


Fig. 6

TYPICAL TEMPERATURE CHARACTERISTICS
For 5100 Å Material

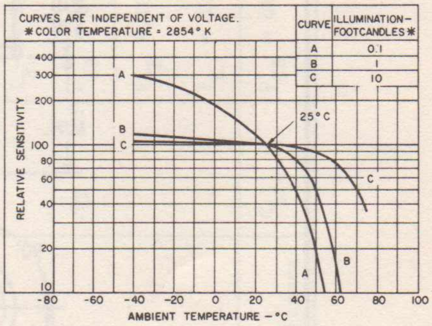


Fig. 7

● *WITH ACKNOWLEDGEMENT TO R.C.A.*

ERRATA: Vol. 34 No. 1

Page 8
Dissipation should be 300mW
V_{EBF} for AS147 should be 1V maximum at V_{CB} = 45V.
Page 9
Unit for I_{CBO} should be μA

AS204, AS205, AS208, AS209,

AWV SILICON N-P-N PLANAR EPITAXIAL AUDIO TRANSISTORS

The AS204, AS205, AS208 and AS209 are designed for audio and general purpose applications in consumer and professional equipment. The transistors are packaged in a modified TO-104 case having 3 leads, with the collector connected to the case.

Absolute Maximum Ratings

	AS204	AS205	AS208	AS209	
Collector-base voltage	40	20	40	20	V
Collector-emitter voltage	40	20	40	20	V
Emitter-base voltage	5	5	5	5	V
Emitter current	350	350	350	350	mA
Base current	30	30	30	30	mA

Thermal Ratings AS204, AS205, AS208, AS209

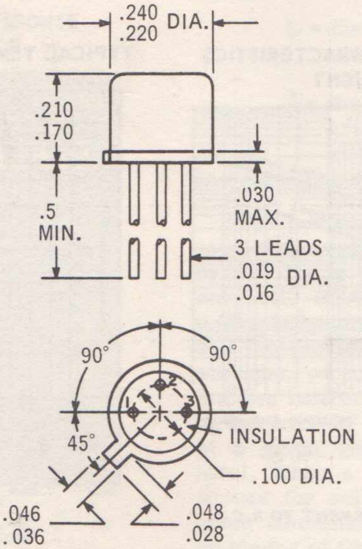
Dissipation at case temperature up to 75°C .... 2W max.
Derate linearly to zero at 175°C.

Dissipation in an ambient temperature up to 25°C ..... 500mW max.
Derate linearly to zero at 175°C.

During soldering lead temperature must not exceed 255°C. for 10 seconds maximum within 1/16" of can.

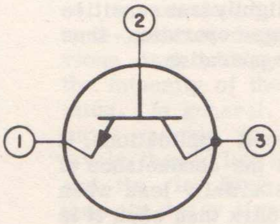
Storage temperature range -65°C. to 175°C.

DIMENSIONAL OUTLINE



Dimensions in Inches

TERMINAL DIAGRAM



Lead 1 – Emitter
Lead 2 – Base
Lead 3 – Collector, Case

ELECTRICAL CHARACTERISTICS AT TA = 25°C

CHARACTERISTICS	SYMBOL	TEST CONDITIONS	AS204			AS205			AS208			AS209			Units.
			Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Collector Cut-off current	I_{CBO}	V_{CB} = 12V	–	–	–	–	–	–	–	–	–	–	–	450	nA
		V_{CB} = 25V	–	–	10	–	–	100	–	–	10	–	–	–	
Emitter-base current	I_{EBO}	V_{EB} = 2.5V	–	–	10	–	–	100	–	–	10	–	–	450	nA
		V_{EB} = 5V	–	–	50	–	–	–	–	–	50	–	–	–	µA
Emitter-base floating voltage	V_{EBF}	V_{CB} = 25V	–	–	–	–	–	1	–	–	–	–	–	1	V
		V_{CB} = 45V	–	–	1	–	–	–	–	–	1	–	–	–	
Collector-emitter voltage	V_{CEO}	I_C = 10mA	40	–	–	20	–	–	40	–	–	20	–	–	V
Base current	I_B	V_{CE} = 10V I_B = 10mA	33	–	133	33	–	167	33	–	133	33	–	167	V
Collector-emitter saturation voltage	$V_{CE\ (SAT)}$	I_C = 100mA I_B = 15mA	–	–	–	–	–	–	–	0.1	0.2	–	0.1	0.2	V
		I_C = 300mA I_B = 5mA	–	0.24	0.3	–	0.24	0.3	–	–	–	–	–	–	
Gain Bandwidth Product	f_T	V_{CB} = 6V, I_E = 1mA	–	50	–	–	–	–	–	50	–	–	–	–	MHz
		V_{CB} = 10V I_E = 10mA	–	175	–	–	175	–	–	175	–	–	175	–	
Collector-base feedback capacitance	$C_{b'c}$	V_{CB} = 6V, I_E = 0	–	12	–	–	12	–	–	12	–	–	12	–	pF

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