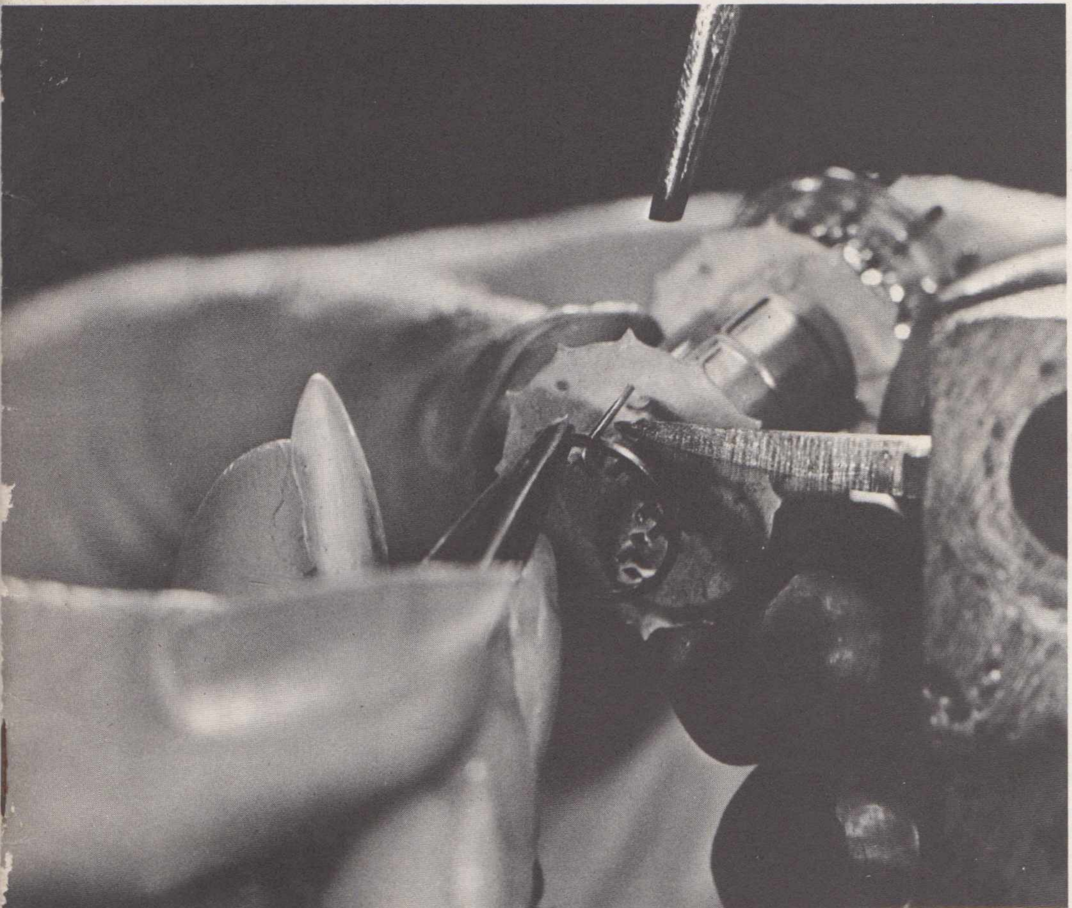
RADIOTRONICS



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COVER

Spot welding the Getter Ring to an AWV Receiving Valve.

Vol. 34, No. 1, February 1969

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NEW GENERATION AUDIO AMPLIFIERS

W.R. EASON,
A.S.T.C., A.M.I.E.(AUST.) M.I.R.E.E.
A.W.V. APPLICATIONS LABORATORY,
RYDALMERE, N.S.W.

In the May 1967 edition of Radiotronics, a series of articles was commenced on a number of high quality audio amplifiers and associated pre-amplifier circuits. The current availability of new types of transistors has enabled the circuits of the earlier amplifier designs to be updated, to give a better performance at a lower cost, and capable of being tailored to suit individual requirements.

As the most sought after amplifiers for normal applications are in the 10-25 watt power output range, the new arrangement has been designed to provide an output which can be varied within that range by variation of the output load and supply voltages. A common printed circuit board has been designed for use with any of the designs selected.

The following points are given to show features which can be obtained by modifications to the basic circuit and using the same board.

1. The input impedance can cover the range from a few thousand ohms to several megohms.

2. The input sensitivity can be from a few millivolts to several volts.

3. Circuits can be developed which will optimise the cost for a given distortion.

4. The frequency response can be tailored to suit individual requirements within the range of a few hertz to near 50 kilohertz. It can be extended above 50 kilohertz by appropriate selection of the output transistors.

5. Noise level, within certain practical limits, can be adjusted to suit the expense allowed.

6. Low frequency boost can be provided if required.

In addition to the above, the design has many other inherent qualities and applications, some of which

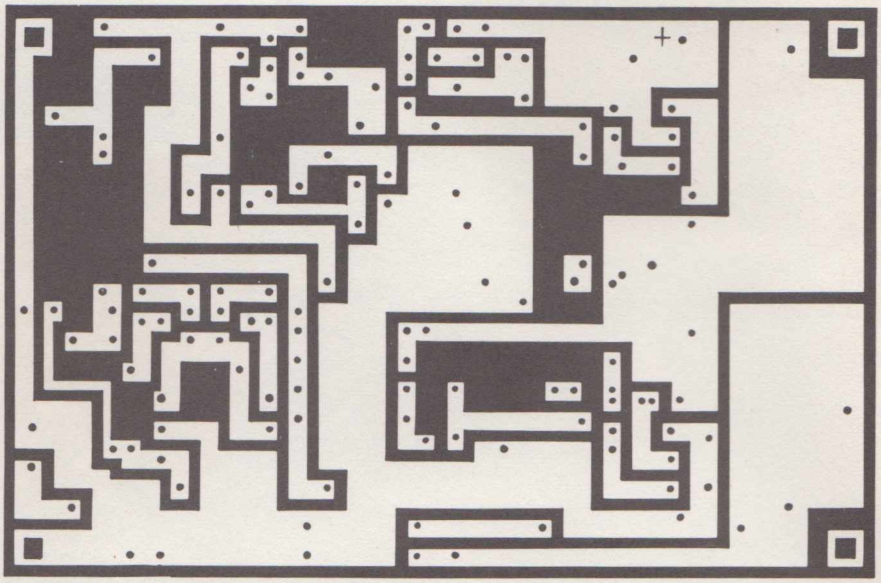


Figure 1. Full size template of the copper side of board.

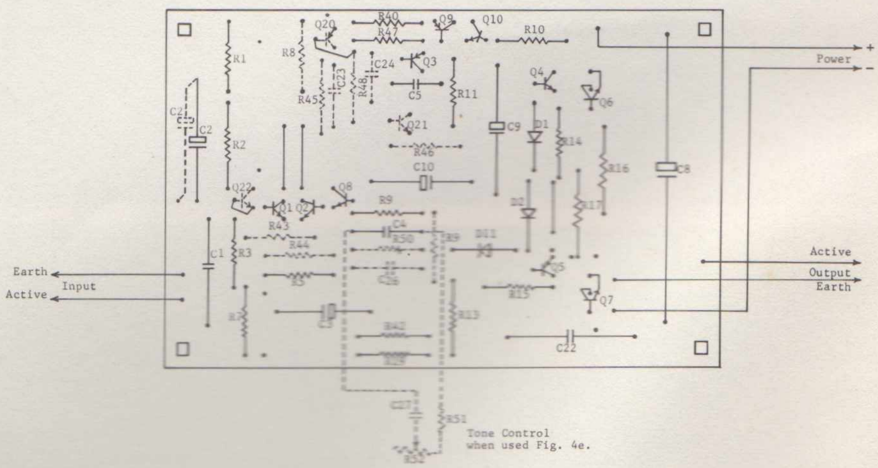


Figure 2. Component layout on top of board.

10 – 25 WATT AUDIO AMPLIFIER

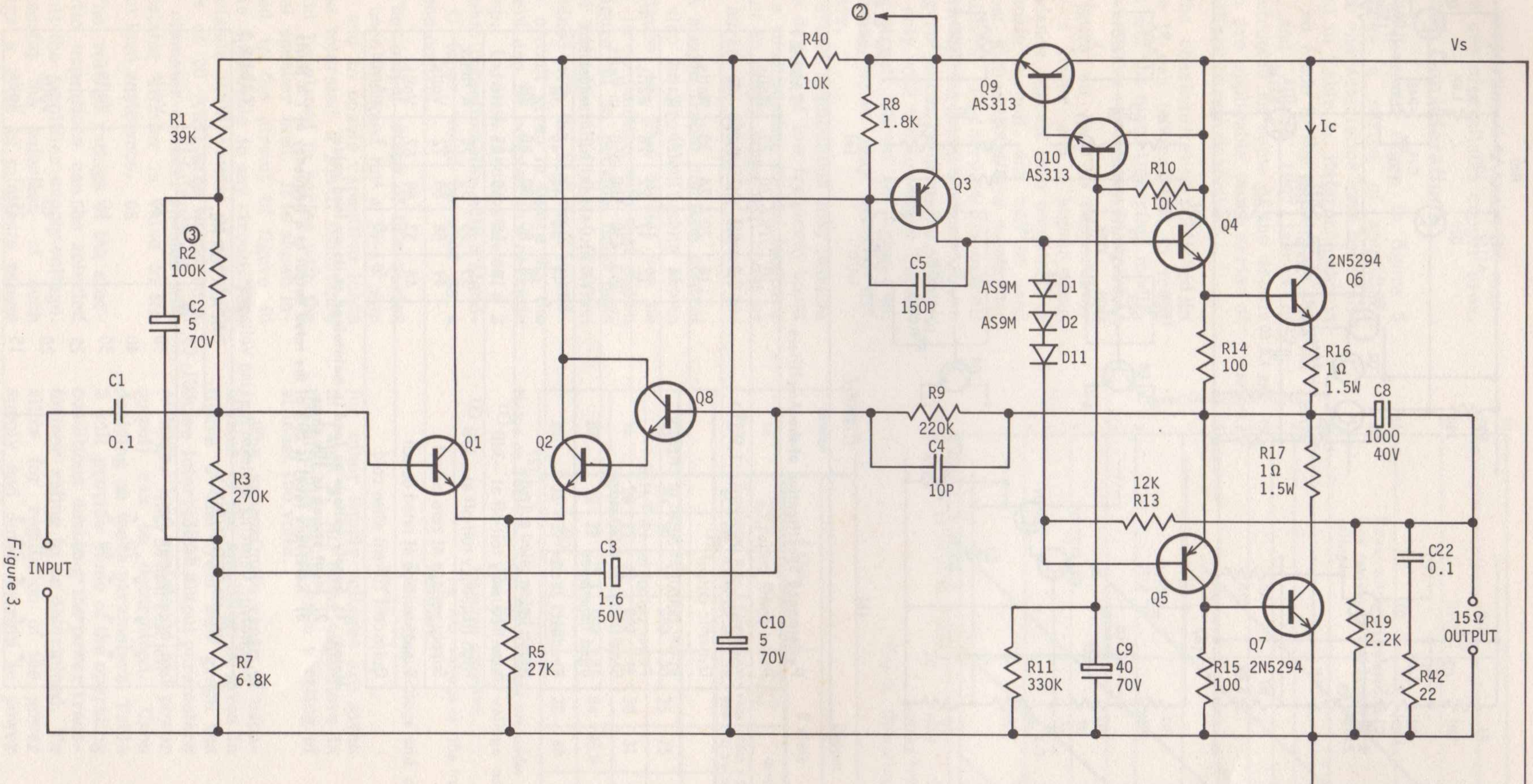
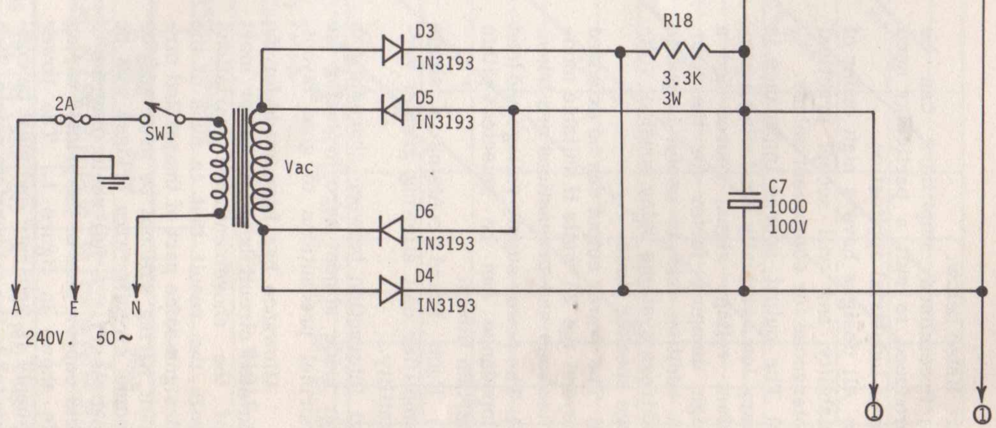


Figure 3.



NOTES: ① Connections to other channel
② To input amplifiers etc.
③ R2 may be adjusted for equal clipping.

CIRCUIT CONDITION FOR 15 OHM LOAD.

Watts	Supply Volts Vs.*	Current Ic mA DC	Voltage Vac. RMS	SEMICONDUCTORS Q3	Q4	Q5	D11	Q1, Q2, Q8
10	41	340	33	AS157	AS147	AS157	AS9M	AS148
15	50	430	40	2N4036	2N2102	2N4036	AS9M	AS147
20	56	490	46	2N4036	2N2102	2N4036	DELETE	AS147
25	63	550	50	2N5322	2N2102	2N5322	DELETE	AS147

* This is the precise value for equal clipping

are listed below:

a) Specialised amplifiers can be produced to suit a particular need in an industrial application.

b) All designs have a high order of stability and will accept practical tolerances for component values.

c) The output source impedance is very low, virtually producing a constant voltage signal source and a high damping factor for the load. In addition this is useful in public address systems using constant voltage speaker lines.

d) The power output can be extended beyond the 25 watts if suitable modifications and precautions are taken.

e) The power supply voltage and load impedance can be selected within certain limits.

f) Each board contains a single amplifier unit allowing greater versatility.

g) Interaction between channels can be made almost zero by taking the normal precautions of good layout.

Allowance has been made for the printed circuit board to cover most of the abovementioned variations with the result that in each of the designs some part of the printed circuit wiring will not be used and for some circuits wire bridges will be necessary. A full scale diagram of the copper side of the printed wiring is shown in figure 1. The power supply is separate and must be connected to the appropriate points. Two of these amplifier units are used for a stereo system and would be fed from a common power supply. With a suitable increase in the power supply ratings any number of channels can be used in a system for special applications.

Figure 2 is a layout of the component side of the board for a series of amplifiers having a 15-16 ohm load and output powers of 10, 15, 20 and 25 watts. The circuit of this series is shown in figure 3 and to obtain characteristics to suit a particular application it can be modified as indicated later.

The printed circuit itself has been laid out in a rectangular form on a 0.050" grid which enables a degree of component compactness to be used that is satisfactory for this application. The layout has been designed to keep all sections of the circuit in their respective position and so reduce interaction between components. The width to length relationship of the copper tracks that conduct the higher currents have

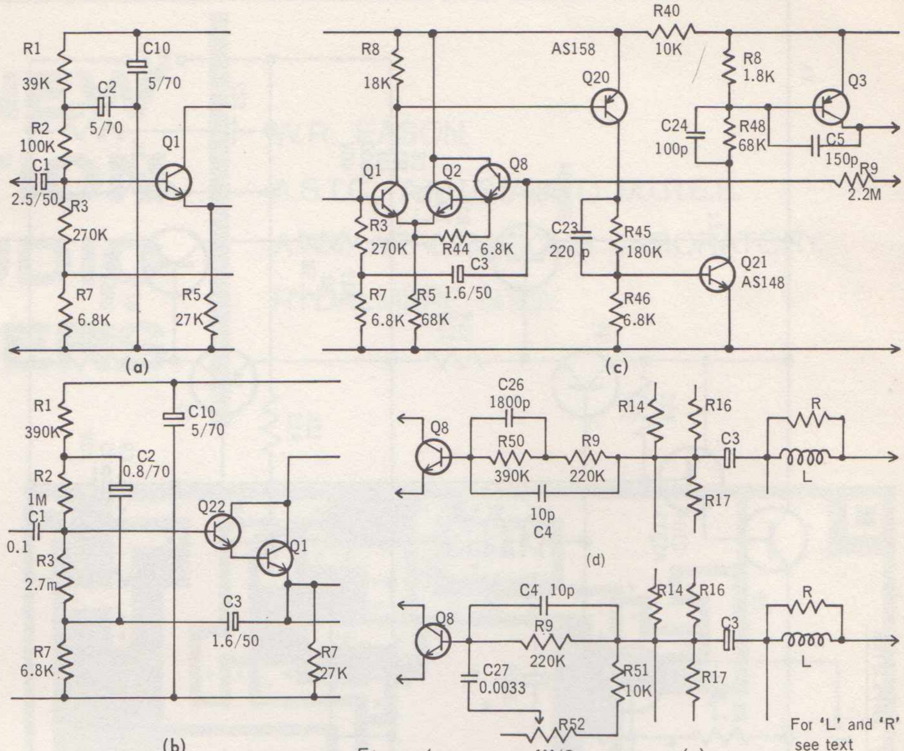


Figure 4.

Performance Specification of the Amplifiers **TABLE 1**

Rated power output	10	15	20	25	Watts
Total harmonic distortion (T.H.D.)	0.2	0.2	0.25	0.25	%
Dynamic output (1)	14	20	24	30	Watts
Power output at onset of clipping	11	16	21	27	Watts
Power output for 1% T.H.D.	12	17	22	28	Watts
Sensitivity for rated output	350	430	500	550	m Volts
Input impedance	1.0	1.0	1.0	1.0	megohms
Feedback factor (2)	44	44	44	44	dB
Noise below rated output (2)	78	80	80	80	dB
Low frequency roll-off at −3dB (3)	15	15	15	15	Hertz
High frequency roll-off at −3dB (3)	35	35	35	35	K Hertz
Supply voltage at zero output	49	58	64	72	Volts
Supply voltage at rated output	44	53	59	67	Volts
Quiescent current when cold	5	5	1	1	mAmps

Notes 1) Supply voltage on load is maintained at its no load value.
2) Input source is 10k ohms.
3) Reference level is 50% of the rated output at a frequency of 1 K Hertz.

Electrolytic Capacitor Minimum Working Voltages **TABLE 2**

UNLOADED SUPPLY VOLTAGE	CAPACITOR No.		
	C1, C3, C8	C2, C7, C9, C10	
Not less than 80 volts	50	85	Volts
" " " 70 "	40	80	Volts
" " " 50 "	30	60	Volts
" " " 40 "	25	50	Volts
" " " 30 "	20	40	Volts
" " " 20 "	15	25	Volts

been proportioned to make the maximum use of available copper area.

Circuit Considerations

The circuit shown in figure 3 produces a series of amplifiers whose characteristics have been tabulated in Table 1. Reference should also be made to the articles in the May and August 1967 issues of Radiotronics as some of the details given are applicable to the series of amplifiers herein described.

The characteristics published in Table 1 can be modified in many ways and the more important modifications have been shown in figure 4.

Figure 4a and 4b respectively show a lower and a higher input impedance circuit than contained in the main circuit, and can be used without difficulty on low sensitivity amplifiers. To increase the overall sensitivity the modifications shown in figure 4c can be used, but preferably only with the low input impedance circuit shown in figure 4a, otherwise noise may become excessive.

Certain applications may require some degree of low frequency boost and a modification to the feedback circuit to obtain some 6dB boost at 100 hertz is shown in figure 4d.

A simple treble cut tone control can also be provided and is shown in figure 4e. This circuit can be used in conjunction with that shown in figure 4d to provide fixed bass boost and adjustable treble cut. When combined with the high input impedance circuit given in figure 4b, the system can be coupled to a ceramic pickup. In such circumstances a 2 megohm potentiometer with a standard C taper would be used as a volume control.

The output stage of this series has been designed for a 15-16 ohm load and to enable capacitive loads to be tolerated a small inductance should be placed in series with the actual speaker lead. It is shown included in the circuit of figure 4d but is applicable to any circuit. This inductance could consist of about 20 turns of 20 AWG wire wound on a 3/8" diameter former, shunted with a resistor similar in value to the output load resistance.

The voltage ratings of the electrolytic capacitors can be selected to suit the amplifier supply voltage. To assist the selection of such ratings a table of minimum values for other supply voltages are given in Table 2. All other capacitors in the circuits should have a rating of at least 100 volts.

The approximate range of capabilities of the amplifier is given in figure 5 and from this graph the three interrelated output parameters (voltage, load resistance and power output) can be determined. Upon deciding on these parameters, Table 3 will provide some of the operating conditions enabling the power transformer rating to be determined. To allow for regulation of the power supply and some margin in power output, the power transformer* secondary voltage should now be increased by up to 10% before being specified.

Table 4 gives the heat sink characteristics for continuous as well as normal programme operating conditions. The normal programme material is music where the peaks may be equal to the amplifiers maximum dynamic unclipped power, whereas the continuous rating allows for operation at maximum dissipation continuously. In normal use on a typical programme of music the amplifier will operate well below

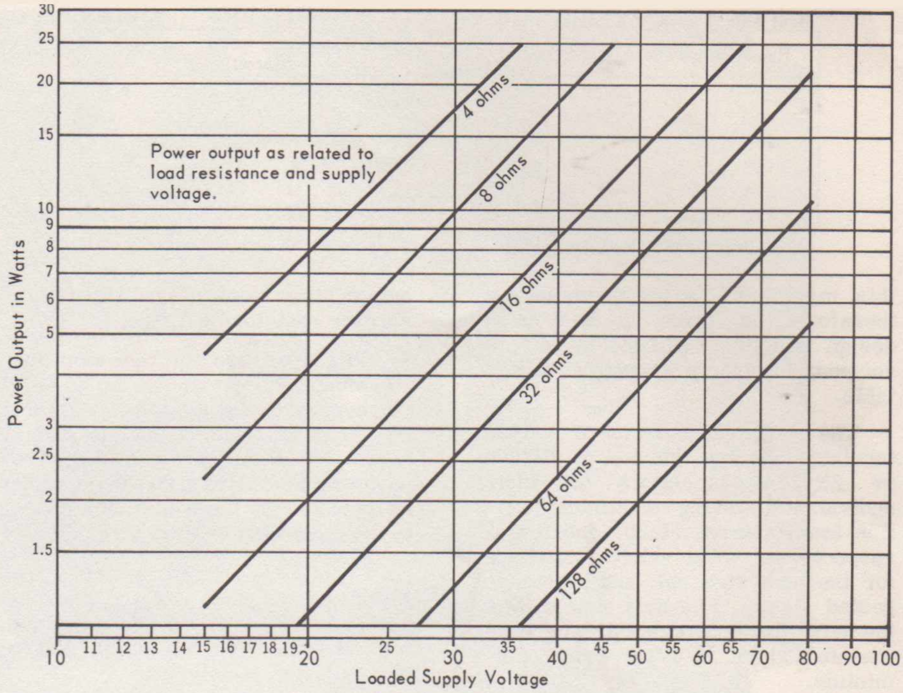


Fig. 5. Operating Characteristics

TABLE 3

Output power in Watts	Output Load Impedance															
	4 ohms				8 ohms				16 ohms				32 ohms			
	Supply Volts		Output		Supply Volts		Output		Supply Volts		Output		Supply Volts		Output	
	Volts DC	Volts RMS	Volts AC p-p	Current mA. DC.	Volts DC	Volts RMS	Volts AC p-p	Current mA. DC.	Volts DC	Volts RMS	Volts AC p-p	Current mA. DC.	Volts DC	Volts RMS	Volts AC p-p	Current mA. DC.
10	24	20	18	680	30	25	25	500	41	33	35.8	340	56	44	50.5	245
15	28	25	22	850	37	30	31	610	50	40	44	430	68	53	62	305
20	32	29	25.3	990	41	34	35.8	700	56	46	50.6	490				
25	36	32	28.2	1100	47	38	40	790	63	50	56.5	550				

Notes on Table 3. All measurments are under loaded conditions.
The DC supply voltage assumes a bridge rectifier followed by a 1000μF reservoir capacitor.
The AC voltage is the transformed mains voltage supplied to the bridge rectifiers.
The output voltage and current are the power components of the output power.

*Suitable transformers are available from: Electronic Transformers Pty. Ltd. 43 Mitchell Road, Brookvale, 2100, N.S.W. 93 4478

Heat Sink Thermal Characteristics **TABLE 4**

Power Output	Program Type Continuous		Normal		
Junction Temperature	150	200	150	200	°C
10W	22 (12)	38 (–)	37 (–)	65 (–)	°C/W
15W	16 (16)	26 (10)	29 (8)	48 (–)	°C/W
20W	9 (28)	15 (18)	16 (16)	26 (10)	°C/W
25W	7 (35)	12 (22)	14 (20)	23 (12)	°C/W

Bracketed values are total heat sink surface area, in square inches.

this maximum. A compromise can therefore be made in heat sink design and this has been taken into account in the preparation of the table.

The thermal resistance values tabulated assume the use of 2N3054 or 2N5294 transistors or their equivalents, having maximum junction temperatures at 200 and 150° C respectively. The values stated are for the heat sink only and lists suggested sizes. The heat sink area is the total for both sides of a vertical mounted sheet of 1/16" bright aluminium.

It is possible to reduce the heat sink areas by approximately 1/3rd if radiating surfaces are finished in matt black.

The output transistors have emitter resistors for temperature stability up to approximately 65° C and can be deleted, if desired, when the equipment is to be operated at ambient temperatures of 45° C or lower. This will provide a small increase in power output since the total load that must be driven by the output stage does not now contain an emitter resistor section.

For operation of the amplifier at ambient temperatures up to 45°C the compensating diodes D_1, D_2 and D_{11} may be mounted on the circuit board. If a higher operating temperature is desired, the diodes must be mounted on the heat sink adjacent to the output transistors.

From the original article a relationship between voltage gain and resistors R_7 and R_9 was provided, and knowing that the output voltage e_o is related as follows:

$$e_o = \sqrt{P\ R_L}$$

where P is the power output

R_L is the load resistance.

The peak to peak output voltage is 2.8 e_o, as listed in Table 3. The input sensitivity, e_i is given by:

$$e_i = \frac{R7\sqrt{P\ R_L}}{R7 + R9}$$

The distortion will be related to the feedback and provided the feedback is above 20dB, the distortion will be less than 1%, with further reductions as the feedback is increased. The frequency response can be tailored to suit, with limitations only determined by stability and noise, by selecting the values of the capacitors C_3 and C_4. The high frequency roll-off is 3dB down when the reactance of C_4 is equal to R_9 and similarly for the low frequency limit, when the reactance of C_3 is equal to R_7. Figure 6 shows the frequency response of the amplifier circuit of figure 3.

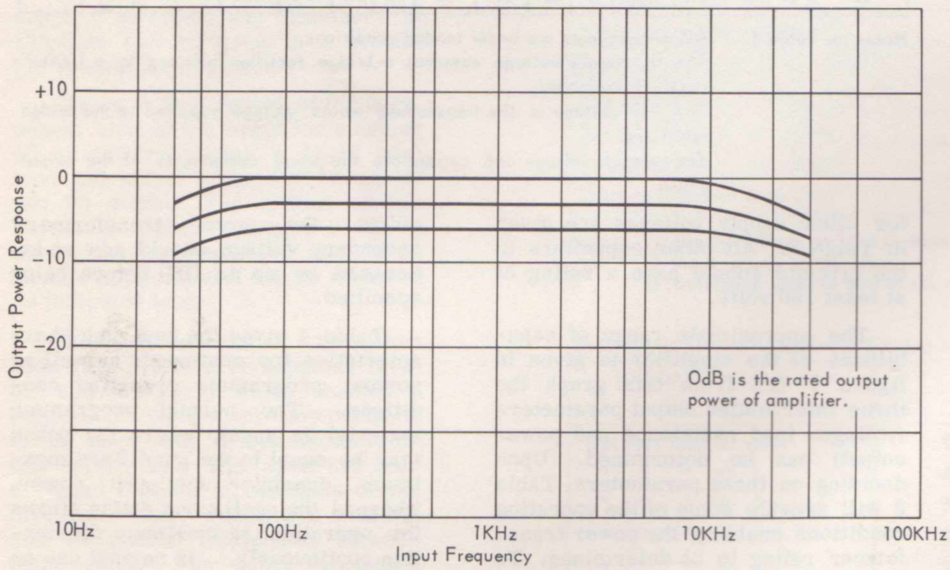


Fig. 6. Frequency Response Curve

Construction

The 2N5294 type of transistor used for the output stage features a simple type of insulated mounting capable of being mounted inside the main unit and so obviating the problems associated with the flange type of mounting. The printed board has been designed to accept the output transistor terminals directly into the board or alternatively leads can be extended from the board to the output transistors. Leads will be necessary if a type of output transistor such as 2N3054 is used. In this case an aluminium chassis should be used and the transistors mounted on the outside.

It is suggested that the printed boards for each channel be mounted on a suitable piece of 1/16" aluminium which may be used to mount each assembly vertically on the main chassis with the power transformer behind. The same constructional comments as given previously are relevant to this unit with the advantage that the power transformer need not be spaced above the chassis if the above mounting details for the printed board are used.

Conclusion

The amplifiers just described are a logical step in the design of modern audio amplifiers and they can be readily adapted to many other applications where their unique characteristics would be advantageous. Some of the possible designs that can be assembled with the printed board shown, have been indicated but the range is too extensive for this article and other designs can readily be developed to suit specified applications.

All the silicon preamplifier tone controls etc. that have recently been published can be coupled to this series and new designs and applications are proposed for future publication.

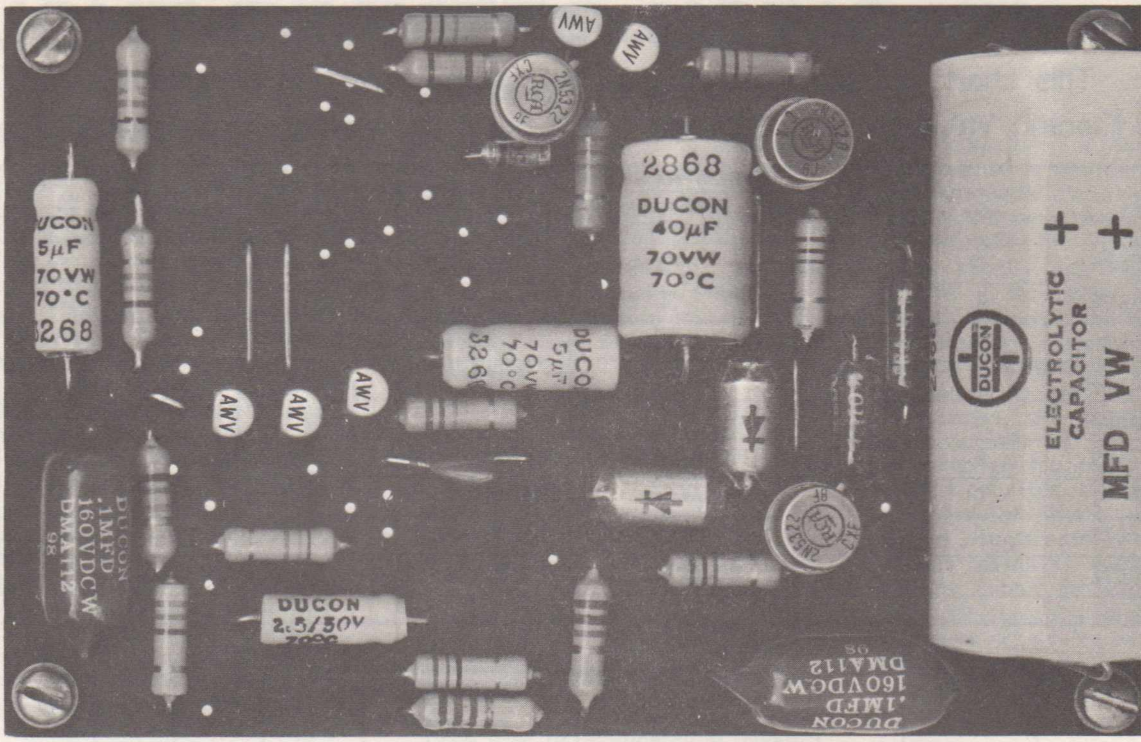


Figure 7. Photograph of component side of board wired for the basic circuit

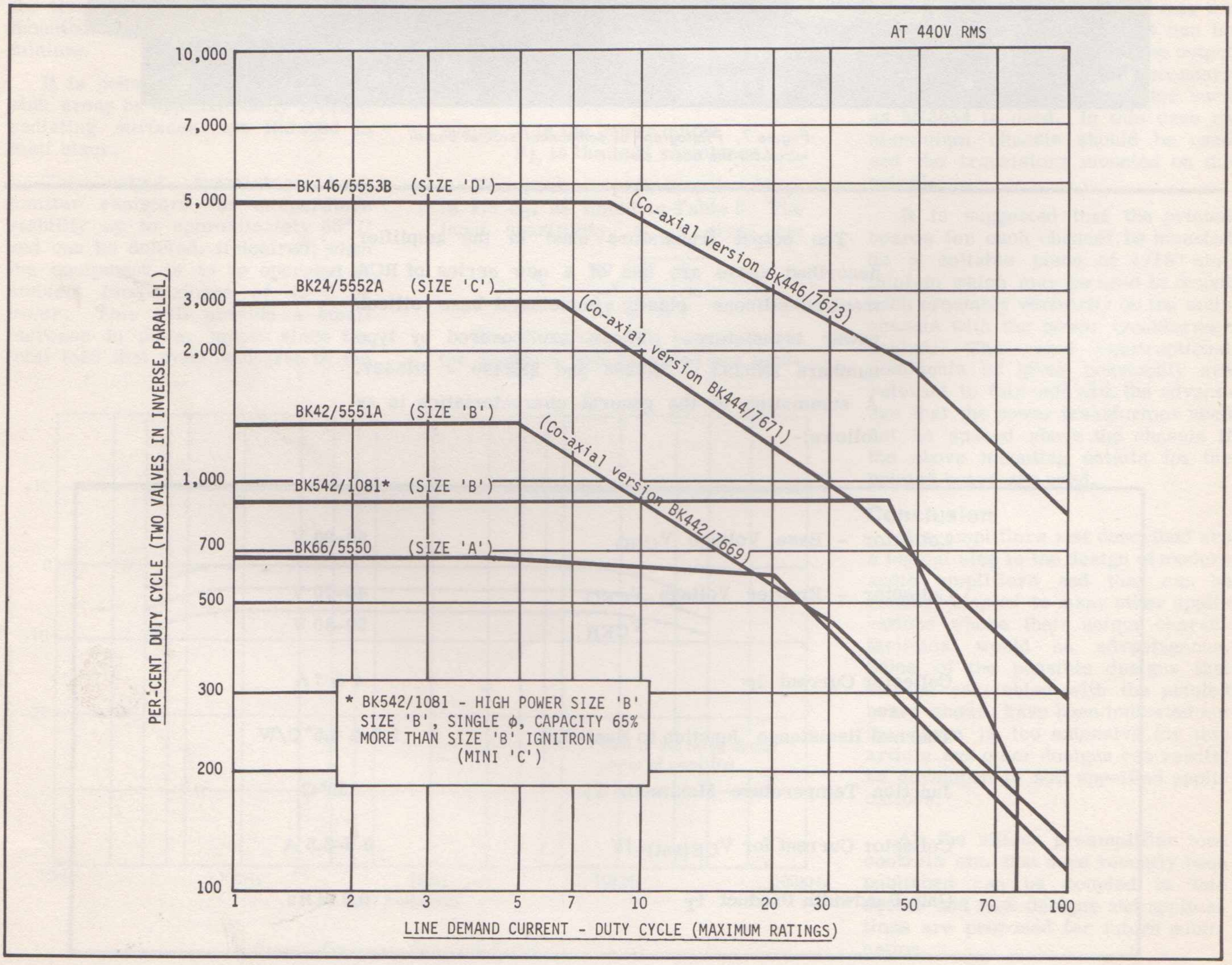
The output transistors used in the amplifier described above are one of a new series of RCA moulded-silicone plastic hometaxial-base silicon power transistors. These are covered by type numbers 2N5293 – 2N5298 and 2N5490 – 2N5497. A summation of the general characteristics is as follows:-

Collector – Base Voltage V_{CBO}	60–90 V
Collector – Emitter Voltage V_{CEO}	40–70 V
V_{CER}	50–80 V
Collector Current I_C	4 & 7 A
Thermal Resistance Junction to Heat-Sink	5.5 & 4.5°C/W
Junction Temperature Maximum Tj	150°C
Collector Current for $V_{CE(sat)}$=IV	0.5–3.5 A
Gain Bandwidth Product f_T	0.8 MHz

IGNITRON SELECTION CHART

This chart has been designed to help in the selection of suitable English Electric Valve Co. Ltd., ignitrons to suit particular welder control applications.

TYPE	INTERNATIONAL LETTER SIZE	SINGLE-PHASE SERVICE			3Ø SERVICE (1500V PEAK)		
		MAX DEMAND KVA	CORRESPONDING AV. ANODE I(A)	MAX. AV. ANODE I(A) REDUCED D'ND	MAX PEAK ANODE I(A)	Corresponding Av. Anode I(A)	MAX AV. ANODE I RED. PEAK (A)
BK24/5552A	C	1200	75.6	140	-	-	-
BK42/5551A	B	600	30.2	56	480	4.0	18
BK66/5550	A	300	12.1	22.4	-	-	-
BK146/5553B	D	2400	192	355	2400	32	112
BK168/5822A	C	-	-	-	1200	16	56
BK442/7669	B		CO-AXIAL	VERSION OF	BK42/5551A		
BK444/7671	C		CO-AXIAL	VERSION OF	BK24/5552A		
BK446/7673	D		CO-AXIAL	VERSION OF	BK146/5553B		
BK468/7672	C		CO-AXIAL	VERSION OF	BK168/5822A		



LIGHT DIMMERS USING TRIACS

by J.M. Neilson

Introduction

A simple, inexpensive light-dimmer circuit contains a diac, triac and RC charge-control network. The diac is a two-terminal ac switch which is changed from the non-conducting state to the conducting state by an appropriate voltage of either polarity. The triac is a three-terminal ac switch which is changed from the non-conducting state to the conducting state when a positive or negative voltage is applied to the gate terminal. This article describes the use of the diac to trigger the triac in light-dimming circuits. The basic light-control circuit is introduced and its operation described. In addition, the various components added to improve circuit performance are discussed. Three complete circuits are shown, with tables showing the component values to be used for 120-volt, 60-Hz operation and 240-volt, 50/60 Hz operation. Mechanical details involved in building the circuits are also discussed and a trouble-shooting chart is included.

Circuit Description

The triac or bidirectional triode thyristor is a three-terminal solid-state switch. The two power electrodes or main terminals are referred to as T_1 and T_2, and the control electrode is referred to as the gate. Fig. 1 shows the voltage-current characteristic observed between the power electrodes. For either polarity of applied voltage, the device is bistable: the triac exhibits either a high impedance (off state) or a low impedance (on state). The device normally assumes the off state when bias is applied, but can be triggered into the on state by a pulse of current, of either polarity, applied between gate and T_1. The device then remains in the on state until current is reduced close to zero by the external circuitry.

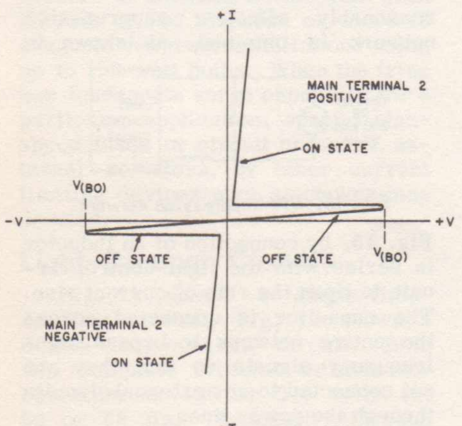


Fig. 1. Voltage-current characteristic of a triac.

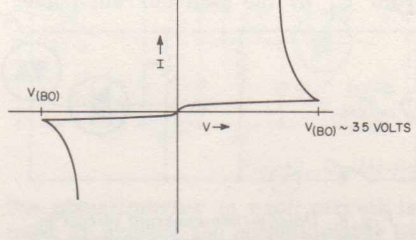


Fig. 2. Voltage-current characteristic of a diac.

The diac or symmetrical trigger diode is a two-terminal bidirectional switch with a voltage-current characteristic as shown in Fig. 2. The device exhibits a high-impedance, low-leakage-current characteristic until the applied voltage reaches the breakover voltage V_{BO}, of the order of 35 volts. Above this voltage the device exhibits a negative resistance, so that voltage decreases as current increases. In light-dimmer circuits a diac is used in conjunction with a capacitor to generate current pulses which trigger the triac into conduction. The voltage on the diac and capacitor increases until it reaches V_{BO}, at which point the diac voltage breaks back and a pulse of current flows as the capacitor discharges.

Fig. 3 shows the basic triac-diac light control circuit with the triac connected in a series with the load. During the beginning of each half cycle the triac is in the off-state. As a result, the entire line voltage appears across the triac, and none appears across the load. Because the triac is in parallel with the potentiometer and capacitor, the voltage across the triac drives current through the potentiometer and charges the capacitor. When the capacitor voltage reaches the breakover voltage V_{BO} of the diac, the capacitor discharges through the triac gate, turning on the triac. At this point, the line voltage is transferred from the triac to the load for the remainder of that half cycle. This sequence of events is repeated for every half cycle of either polarity. If the potentiometer resistance is reduced, the capacitor charges more rapidly and V_{BO} is reached earlier in the cycle, increasing the power applied to the load and hence the intensity of light. If the potentiometer resistance is increased, triggering occurs later, load power is reduced, and the light intensity is decreased.

Although the basic light-control circuit operates with the component arrangement shown in Fig. 3, additional components and sections are usually added to reduce hysteresis effects, extend the effective range of the light-control potentiometer, and suppress radio-frequency interference.

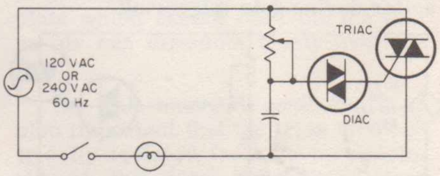


Fig. 3. Basic triac-diac light-control circuit.

Hysteresis

As applied to light controls, the term hysteresis refers to a difference in the control potentiometer setting at which the light initially turns-on and the setting at which it is extinguished. With high hysteresis, the control may have to be turned across 35 per cent of its range before the light turns on at all, after which the control must be turned back to a much lower setting before the light goes completely out.

Besides poor control, hysteresis is undesirable because at low illumination levels, the light may be extinguished by a momentary drop in line voltage. At low illumination levels, the potentiometer is normally turned back beyond the setting at which it initially turned on. When triggering is missed on one half cycle as a result of a momentary drop in line voltage such as that caused by starting a heavy appliance, oil burner, etc., the light may go out and stay out until the control is again turned up to the starting point.

Hysteresis it caused by an abrupt decrease in capacitor voltage when triggering begins. Fig. 4 shows the charging cycle of the capacitor-diac

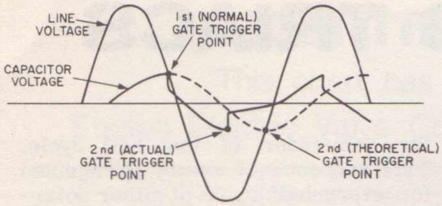


Fig. 4. Charging cycle of the capacitor-diac network in the circuit of Fig. 3

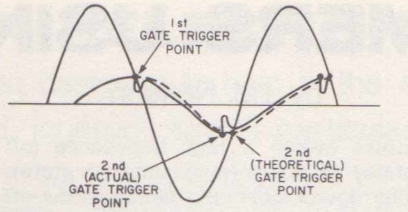


Fig. 7. Charging cycle of the diac network in the circuit of Fig. 6.

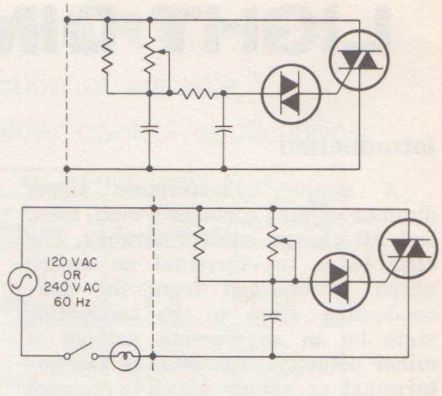


Fig. 9. Light-control circuits incorporating a trimmer resistor across the potentiometer.

circuit. The large ac sine wave represents the line voltage; the smaller ac sine wave represents the normal charging cycle of the capacitor. Gate triggering occurs at the first point of intersection of the two waves. At this point, however, there is an abrupt decrease in the capacitor voltage (dashed line). As a result, the capacitor begins to charge during the next half cycle at a lower voltage and reaches the trigger voltage in the opposite direction earlier in the cycle (2nd [Actual] Gate Trigger Point). Hysteresis is reduced by maintaining some voltage on the capacitor during gate triggering.

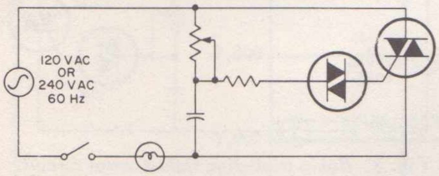


Fig. 5. Light-control circuit incorporating a resistor in series with the diac.

Some improvement is realized when a resistor is connected in series with the diac, as shown in Fig. 5. Although this positive resistance reduces the net amount of negative resistance so the capacitor voltage does not drop as much, it also decreases the magnitude of the gate current pulse, and therefore, a larger-value capacitor may be required. More significant improvement is obtained when a second capacitor is added as shown in Fig. 6, forming a "double-time-constant" circuit.

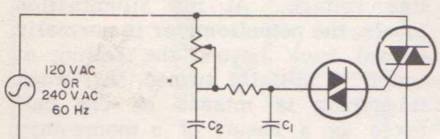


Fig. 6. "Double-time-constant" light-control circuit.

The added capacitor C_2 reduces hysteresis by charging to a higher voltage than C_1, and maintaining some voltage on C_1 after triggering. The effect is illustrated in Fig. 7.

As gate triggering occurs C_1 discharges to form the gate current pulse. However, because of the longer C_2 R time constant, C_2 restores some of the charge removed from C_1 by the gate current pulse.

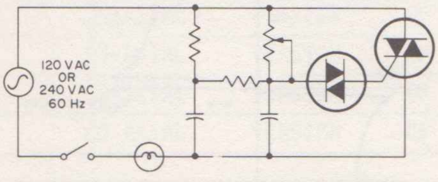


Fig. 8. Double-time-constant circuit in which the potentiometer is connected directly to the diac.

Fig. 8 shows another double-time constant circuit in which a fixed resistor is added and the potentiometer is moved over to connect directly to the diac. Although the maximum attainable conduction angle is increased, the difference in power is less than one per cent.

Range Control

Maximum range of light control is obtained when the lamp begins to light as soon as the potentiometer is turned slightly from the zero-intensity end of the range. After the control circuit is assembled, the point of initial turn-on may be located at 40 per cent across the control range, leaving only 60 per cent effective to control the light intensity. This difference occurs because the interaction of three components (potentiometer, capacitor, and diac) each of which may have values with a tolerance of plus or minus 20 per cent. A trimmer resistor connected across the potentiometer, as shown in Fig. 9, can be used to compensate for component variations and move the initial turn-on point back to the end of the control range. The trimmer can be a variable resistor which is set to the required value after the circuit is assembled, or a fixed resistor of the required value as determined by individually testing the assemblies with a resistor substitution box in place of the trimmer.

The double-time-constant circuit with trimmer resistor provides consisently good hysteresis correction as well as good range control. The use of a high-resistance potentiometer, possibly about twice the resistance of the trimmer, spreads out the low-intensity range for finer control.

RFI Suppression

Because the triac switches from the high-impedance state to the low-impedance state within 1 or 2 microseconds, the current must rise from essentially zero to whatever the load will permit within this period. This rapid rise in current produces radio frequency interference (RFI) extending up into the range of several megahertz. Although the resulting noise does not affect the television and FM radio frequencies, it does affect the short-wave and AM-radio bands. The level of RFI produced by the triacs is well below that produced by most AC-DC brush-type electric motors, but because the light dimmer may be on for long periods of time, some type of RFI suppression network is usually added. A reasonably effective suppresssion network is obtained, as shown in

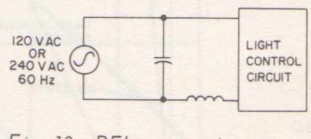


Fig. 10. RFI-suppression network.

Fig. 10, by connection of an inductor in series with the light-control circuit to limit the rate of current rise. The capacitor is connected across the entire network to bypass high-frequency signals so that they are not connected to any external circuits through the power lines.

Overload Considerations

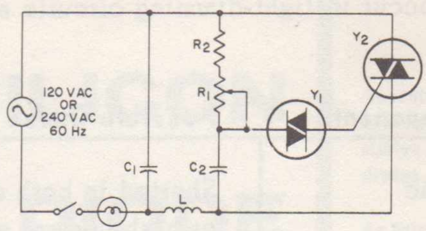
An important consideration in the

choice of a triac is the transient load which results from the initially lower resistance of the cold filament when the lamp is first turned on. The transient load results in a surge or inrush current which can destroy the triac. The worst case occurs when the light is switched on at the peak of the line voltage. The ratio of initial peak current to steady-state current is usually about 10 to 1 and can be as high as 15 to 1 for high-wattage lamps. The triac chosen for a particular lamp, therefore, should have a subcycle capability sufficient to allow repeated passage of this peak current without degradation of the device.

Flashover is another transient condition associated with incandescent loads, and may impose an even greater stress than inrush. Flashover refers to the arc developed between the broken ends of the filament when the light bulb burns out. Ionization within the bulb allows the arc to flow directly between the internal lead-in wires, and current is then limited only by line impedance. Because of the large currents associated with flashover, incandescent light bulbs have fuses built into the stem to open circuit at the bulb without opening the line circuit breaker. On low-wattage bulbs, the arc frequently self-extinguishes as line voltage goes through zero, so the surge duration is less than one half cycle. On higher-wattage bulbs, however, the arc often continues until the bulb fuse opens, and may last for somewhat more than one half cycle. Damage or degradation of the triac can be avoided by selecting of a triac that has surge capability in excess of the flashover currents which can occur. A device capable of handling a one-cycle peak current of 100 amperes or more is adequate for most installations using up to 150-watt bulbs. When the triac has inadequate surge capability for a particular application, special high-speed fuses or circuit breakers, external resistors, or other current limiting devices such as chokes may be used.

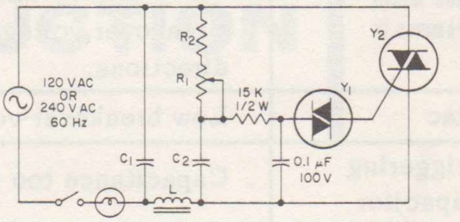
Light–Dimmer Circuits

Fig. 11 shows a single-time-constant circuit; Fig. 12 shows a double-time-constant circuit. Both are complete circuits suitable for operation at 120 or 240 volts ac, 50 or 60 Hz. The chart with each circuit specifies the values of components which change with the line voltage. The resistor in series with



	120 VAC, 60 Hz	240 VAC, 50/60 Hz
R_1	0.25 megohm, ½W	0.25 megohm, 1W
R_2	3300 ohms, ½W	4700 ohms, ½W
C_1	0.05 μF, 100V	0.1 μF, 100V
C_2	0.05 μF, 100V	0.10 μF, 100V (60 Hz) 0.12 μF, 100V (50 Hz)
L	100 μH	200 μH
Y_1	40583 } or 40431	40583 } or 40432
Y_2	40485 }	40486 }

Fig. 11. Single-time-constant light-dimmer circuit.



	120 VAC, 60 Hz	240 VAC, 50/60 Hz
R_1	2200 ohms, ½W	3300 ohms, ½W
R_2	0.1 megohm, ½W	0.2 megohm, 1W (60 Hz) 0.25 megohm, 1W (60 Hz)
C_1, C_2	0.1 μF, 200 V	0.1 μF, 400V
L	100 μH	200 μH
Y_1	40583 } or 40431	40583 } or 40432
Y_2	40485 }	40486 }

Fig. 12. Double-time-constant light-dimmer circuit.

the potentiometer in each circuit is used to protect the potentiometer by limiting the current when the potentiometer is at the low-resistance end of its range. Where space is limited, the diac and triac of each circuit may be replaced by a single integral diac-triac unit: the 40431 for 120-volt operation, or the 40432 for 240-volt operation.

It is important to remember that a triac in these circuits dissipates power at the rate of about one watt per ampere. Therefore, some means of removing heat must be provided to keep the device within its safe operating-temperature range. On a small light-control circuit such as one built into a lamp socket, the lead-in wire serves as an effective heat sink. Attachment of the triac case directly to one of the lead-in wires provides sufficient heat dissipation for operating currents up to 2 amperes (rms). On wall-mounted controls operating up to 6 amperes, the combination of face plate and wall-box serves as a effective heat sink. For higher-power controls, however, the ordinary face plate and wallbox do not provide sufficient heat-sinking area. In this case, additional area may be obtained by use of a finned face plate that has a cover plate which stands out from the wall so air can circulate freely over the fins.

On wall-mounted controls, it is also important that the triac be electrically isolated from the face plate, but at the same time be in good thermal contact with it. Although the thermal conductivity of most electrical insulators is relatively low when compared with metals, a low-thermal-resistance, electrically isolated bond of triac to face plate can be obtained if the thickness of the insulator is minimized, and the area for heat transfer through the insulator is maximized. Suitable insulating materials are fibreglass tape, ceramic sheet, mica, and polyimide film. Fig. 13 shows two examples of isolated mounting for triacs: in Fig. 13(a), a TO-5 package; in Fig. 13(b), the new plastic package. Electrical insulating tape is first placed over the inside of the face plate. The triac is then mounted to the insulated face plate by use of epoxy-resin cement.

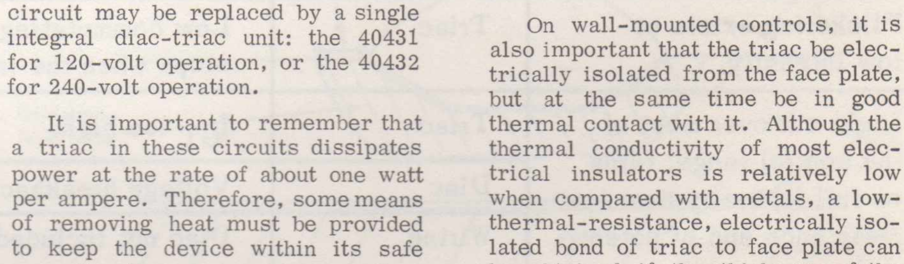


Fig. 13. Examples of isolated mounting of triacs.

Trouble Shooting

Some malfunctions which can occur in light-dimming circuits are listed with their possible causes, as follows:

	Component	Possible Cause
Light remains on full intensity and will not dim.	Triac	Shorted in both directions caused by flashover or high current surge.
	Wiring	Anode-cathode or anode-gate shorted.
Light intensity can be varied but fails to reach zero.	Triac	Breakover voltage reduced in one or both directions.
	Diac	Low breakover voltage.
	Triggering Capacitor	Capacitance too low.
	Potentiometer	Maximum resistance too low.
Discontinuity in brightness at about half intensity.	Triac	I_{GT} too high in one mode.
	Diac	Breakover not symmetrical.
Flickering exists at low intensity.	Triac	Low commutating $dv/_{dt}$ capability. Flickering stops when the inductor is shorted.
Light out over most of the control range; turns on full intensity near low resistance end of potentiometer.	Triac	I_{GT} too high.
	Diac	Voltage breakback too low.
	Wiring	Diac not included or shorted out.
Same effect as preceding, but accompanied by arcing in potentiometer.	Triac	Internal short gate to cathode (very unlikely because such devices are rejected by 100 per cent electrical test).
	Capacitor	Shorted (this condition destroys the potentiometer, but not the triac).
	Wiring	Open anode contact (this condition destroys both the potentiometer and the triac). Cathode to gate short (this condition destroys only the potentiometer).
Light fails to turn on at all.	Triac	Open gate contact (very unlikely due to the 100 per cent electrical test by manufacturer).
	Diac	Open
	Potentiometer	Open
	Wiring	Open circuit at potentiometer, diac, triac gate, or cathode.

• WITH ACKNOWLEDGEMENT TO RCA.

SILICON DIODE CONSTRUCTION

Recently AWV received a request from a lecturer at a large provincial technical college for information on the construction of silicon rectifier diodes.

As this subject is one on which detailed information is not readily available we are publishing the reply by Mr. J. Ziegler of the AWV Semiconductor Section to the request and feel it will be of general interest to our readers.

Dear Sir,

In your recent letter you ask for internal construction details for power rectifier diodes. As you will know, such diodes vary considerably in constructional design.

Design of these devices is dominated by the need, embracing semiconductor element and the electrical and thermal paths of the package, to handle the rated forward power and reverse voltage. In addition, adequate protection from the (basically chemical) effects of the environment has to be provided. With this in mind, we may refer briefly to design principles and construction practices for some typical silicon power rectifier diodes.

1. The Rectification Element: fabrication

Two types are in major use: the older alloy design, still in wide use, and the double diffused type.

(a) The alloy type is usually made from N type silicon, with an aluminium wire alloyed to one side and an ohmic contact alloyed to the other. Fig. 1 is a sketch of the arrangement. The characteristic shape of the butt alloyed region is shown: the thin regrowth zone around it forms a heavily P-doped region. The gold alloyed to the other side (Silicon-Gold eutectic contains some 6% Silicon (Si) and forms at about 370°C) forms an ohmic contact to the header which acts as heat sink.

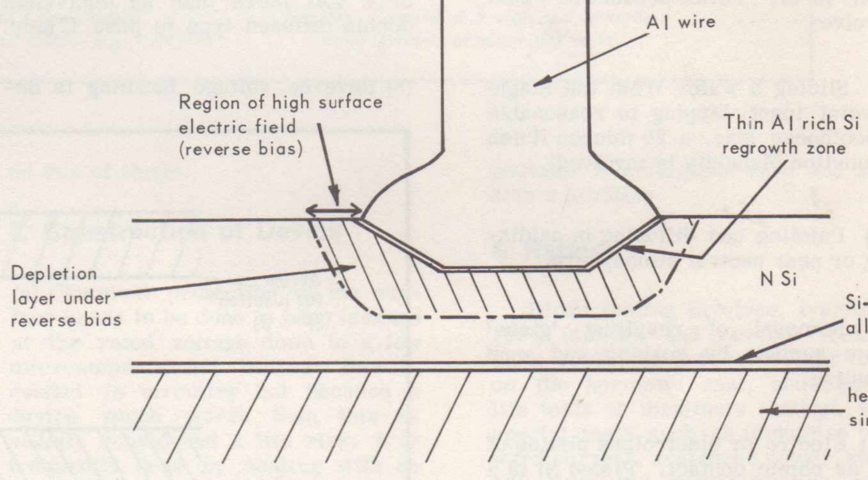


Fig. 1. Typical alloyed diode: rectifying element

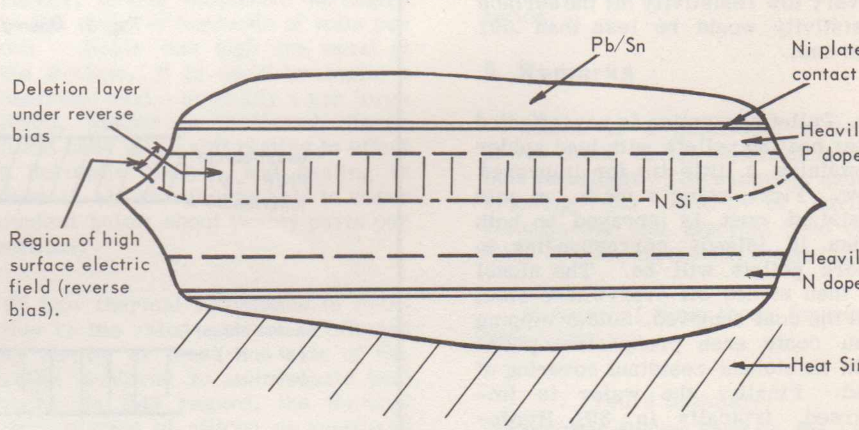


Fig. 2. Typical double diffused diode: rectifying element

The aluminium (Al) is simultaneously alloyed and partly diffused in a hydrogen atmosphere at around 600°C. Preparation of the Si pellet before alloying would typically be done by slicing a wafer from the doped single crystal ingot and after lapping and etching, using a diamond to scribe and, typically, ultrasonic agitation to crack.

(b) The double diffused type is sketched in Fig. 2. It is rather more usually made from N than from P type silicon, and N type is shown here. (Choice is based mostly on minor considerations involving processing methods to achieve minimum surface leakage current.) Dopants are usually boron one side, phosphorus other side, simultaneously diffused from high surface concentration sources - usually a paint containing a non-volatile compound. Typical diffusion schedules would be 10-20 hours at 1200-1300°C., resulting in junction depths of 1 to 2 mils* with surface concentrations to the solid solubility limits of each element in Si. Pellet production would involve:

(i) Slicing a wafer from the single crystal ingot; lapping to reasonable smoothness (say, a 20 micron finish - junction planarity is involved).

(ii) Painting and diffusing in oxidising or near neutral atmosphere.

(iii) Removal of resulting 'glass' from surface by soaking and sand blasting.

(iv) Electro or electroless plating of Ni as ohmic contact. Plated Ni is a satisfactory ohmic contact if made to very low resistivity Si; the surface resistivity would be less than .001 ohm-cm.

(v) Pellet separation is now effected after coating pellets with lead solder containing a little tin for improved flow. First, using a mask, an acid resistant coat is sprayed on both sides in islands corresponding to where pellets will be. The nickel is then etched off everywhere else, and the coat removed. Solder dipping then coats each prospective pellet with an etchant-resistant covering of lead. Finally, the wafer is immersed, typically in 30% Hyrdofluoric acid 70% Nitric acid (these are volumes of commercial, high purity 'concentrated' acids) which separates the pellets out. The rate of Si attack by these would be about 2-3 mils/minute.

2. Design Consideration: rectification element

(a) Forward voltage drop is governed largely by the efficiency of hole and electron injection from the opposite sides of the pellet, assuming that lifetime is sufficiently long in relation to pellet thickness. Resistivity under these conditions does not in itself much influence voltage drop. However, note that junction area must be adequate to avoid either overheating or too high a current density by the intended forward current (the latter will increase the voltage drop). The double diffused type provides high injection efficiency from both sides. The alloyed type suffers from reduced efficiency across the ohmic alloyed contact, and as a result, an alloyed 1 amp diode would require one or two tenths of a volt more than an equivalent double diffused type to pass 1 amp.

(b) Reverse voltage handling is determined by two things: the internal capability of the pellet and the state of the surface (the latter is mentioned later).

Both the alloyed and double diffused types have a highly asymmetric, abrupt PN junction. That is, doping-wise the structures of the given examples are, respectively:

(1) heavily doped P, lightly doped N (usually nowadays called $P^+ - \nu -$ metal) and (2) heavily doped P, lightly doped N, heavily doped N ($P^+ - \nu - N^+$) where 'ν' (Nu) refers to lightly doped N type. See Figs. 3 and 4.

The depletion layer under reverse bias thus extends almost entirely into the ν region of either type: depletion layer penetration into the P^+ region is negligible under most considerations. The standard references describe the electric field and depletion layer width as func-

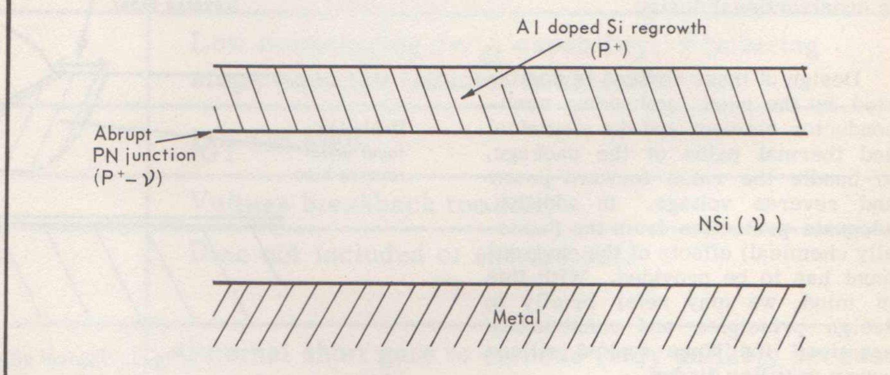


Fig. 3. Doping structure of alloyed type of Fig. 1

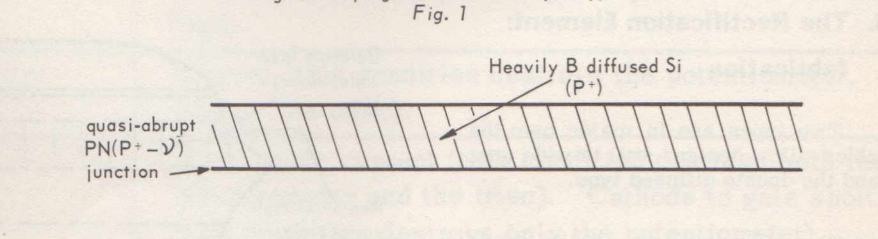


Fig. 4. Doping structure of double diffused Type of Fig. 2.

* i.e.:- thousandths of an inch.

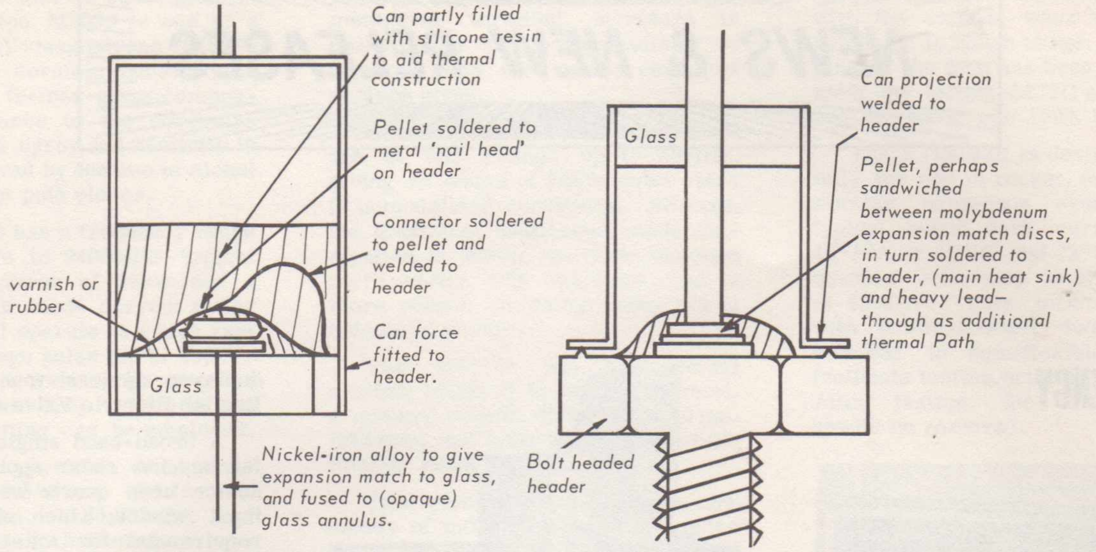


Fig. 5A. Typical of a ½ to 1 amp double diffused design, rated up to 1000V, e.g.:- 1N3194

Fig. 5B. Typical of 5 amp. and upwards, rated upwards of about 100 volts.

tions of voltage and resistivity, the electric field, of course, being at a maximum at the junction.

For a given ν layer width and resistivity, neglecting surface effects, either of two things will happen as the reverse bias is increased: either avalanche occurs before the depletion layer 'punches through' to the opposite boundary (metal or $\nu - N^+$ junction); or punch through occurs before avalanche.

Basically, avalanche voltage sets an upper bound to the diode rating: but if punch through occurs first, field crowding effects on the surface may, in a rather unpredictable way, set a voltage limit considerably below the 'body' theoretical avalanche voltage (see, for example, Miller, Physical Review 105, P.1248, on 'body' avalanche).

In this way, the ν layer width and resistivity are arrived at. It usually turns out that alloyed designs have to be made to give theoretical body avalanche before or near the punch through voltage, whereas double diffused types are often designed, and will frequently operate, near avalanche voltages about twice the punch through voltage. This arises from surface field effects and the influence on this of shape.

3. Construction of Device

(a) Chemical protection of the surface needs to be done to keep leakage at the rated voltage down to a few microamps - not because this is needed in circuitry but because a device much worse than this is usually considered a life risk. It is frequently done by coating with an organo-silicone varnish or a silicone rubber, having dielectric strengths in the order of hundreds of volts per mil - fields this high are usual at the surface. It is usual to employ a hermetic seal - normally a can force fitted, welded or soldered (force fitted cans use a soft plating to effect a hermetic seal) - and sealing is done in air or nitrogen held to water content below about twenty parts per million.

(b) Low thermal resistance in relation to the rated current is effected by having at least one side of the pellet soldered to an adequate heat sink. In this regard, the thermal performance of silicon as measured by thermal diffusivity is considerably better than for steel and nearly as good as for copper.

(c) Electrical insulation through the package is straightforward and seldom a problem.

4. Ratings

Diode testing involves, typically, 100% forward and reverse testing, often 100% high pressure water tests on the hermetic seal, and sample life tests at maximum ratings, with special tests such as impulsive forward current, avalanche power, storage time and stored charge, etc., done as required depending on application.

5. Remarks

There is a good deal more to power diode design and manufacture than mentioned. For example, understanding and control of surface cleanliness, and electric field control, are in themselves large topics.

However, I hope these few notes will assist you.

Yours faithfully,

Amalgamated Wireless Valve Co. Pty. Ltd.

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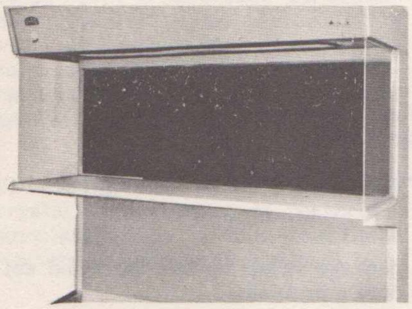
J. ZIEGLER

NEWS & NEW RELEASES

SLEE AGENCY



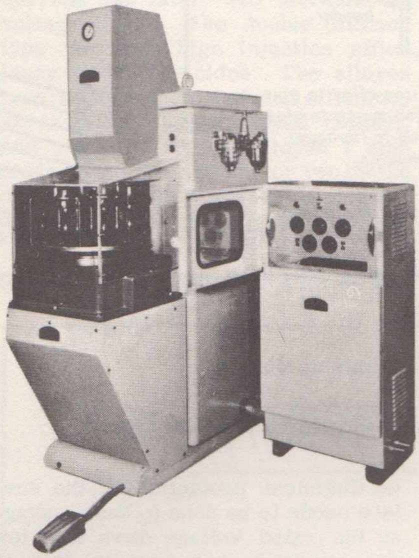
SLEE Laminar Flow Bench

AWV were recently appointed Australian agents for the South London Electrical Equipment Co. Ltd. (SLEE). SLEE manufacture a broad range of equipment, a brief description of which is given below.

(i) Clean Apparatus and Rooms, including Clean Rooms, Air Filtration and Conditioning Equipment, Laminar Flow Benches, Plenum and Dry Glove Boxes.

(ii) Temperature Control Equipment. This range of equipment includes Climatic Simulators, Refrigerators (designed to operate at temperatures in excess of -70°C), High Vacuum Ovens and Gas Recriculating Ovens.

(iii) Welding Machines and Controls. Two basic type of welders are available with several variations. (a) Miniature Welders - this range of machine will weld wires of 0.0007" to 3/16" rod. (b) Precision Projection Welders - lead alignment may be maintained to better than 0.00075". A series of Synchronous and Capacitition Discharge Welding Controls are available to suit the above welders.



SLEE Rotary Table Projection Welding Machine.

(iv) Micro-electronic Equipment - Amongst the range of equipment made by SLEE for use in the production of micro-circuits are - Wedge and Ball Bonders, Disc Mounting Machines, Mask Alignment Machines, Diamond Scribing Equipment, Single and Twin Spot Microwelders, Spinners and Thick Film Soldering Equipment.

(v) In addition to the above items SLEE manufacture various other equipments used in electronic devices production and in the medical and dental field.

RADAR PROTECTOR CELL

A new X-band TR cell (BS850) has been added to the range of duplexer devices manufactured by English Electric Valve Co. Ltd.

A broad-band single primer cell for marine radar applications, this device uses quartz wool behind the input window which eliminates the requirement for water vapour as a recovery agent, and so provides a recovery characteristic which leads to an improved radar AGC performance. An added benefit of this cell is an improved primer life.

Frequency range of the BS850 is from 9300MHz to 9500MHz and maximum peak operating power is 50kW.

Its dimensions are, height 2.438 ins. (61.92 mm), width across the waveguide flange 1.625 ins. (41.28 mm) and depth 1 in. (25.4 mm).

EEV PULSE MAGNETRON

Marine Radar Magnetron Type M5039

English Electric Valve Co. Ltd. has announced a new fixed frequency pulse magnetron developed primarily for marine radar applications.

Designed to have a considerably improved life and better resistance to corrosion compared with previous 20 kW to 25 kW marine radar magnetrons, this type M5039 is one of a range of EEV magnetrons with a more rugged ceramic construction replacing the former glass components. Resistance to the corrosive effects of salt spray and humidity is further improved by the use of nickel cladded magnet pole pieces.

The M5039 has a frequency range from 9345MHz to 9405MHz, typical peak output power of 25kW and a maximum peak anode current rating of 10A. It will operate at a high rate of rise of voltage pulse (up to 200kV/μs) and over a wide range of pulse lengths (0.05μs - 2μs). Natural or forced-air cooling can be employed.

Maximum physical dimensions are height 3.312 ins. (84.13 mm), width 5.249 ins. (133.33 mm) and depth 4.468 ins. (113.49 mm).

FORCED-AIR COOLED POWER TRIODE

Type BR1183 Power Triode for RF Heating

A new forced-air triode (type BR1183) has been added to the range of power valves manufactured by English Electric Valve Co. Ltd. for both induction and dielectric industrial radio frequency heating.

This new valve uses the latest construction techniques: the filament/grid terminal structure is coaxial; the air-cooled radiator is integral with the anode; ceramics replace glass.

As a result the BR1183 can operate at full ratings up to 50MHz, giving an output of 70kW under class C unmodulated conditions. Although the maximum continuous anode dissipation is 20kW, the valve can cope more easily with overloads, and is more robust, so giving longer life in industrial service.

The BR1183 has an overall nominal length of 15.98 ins. (406 mm), a nominal overall diameter of 10 ins. (254 mm) and a net weight of approximately 40 lbs. (18 kg).

This valve is the second of a new series of industrial ceramic triodes being developed at EEV. The BR/BW1181 was announced earlier this year; others will follow shortly.

C710132B PHOTOMULTIPLIER TUBE

Recently announced by RCA the C710132B is a Developmental Ruggedized 1.1/2" diameter, 10-stage, head-on type of photomultiplier tube having a hemispherical faceplate, S-11 spectral response and high-stability, copper-beryllium dynodes. The hemispherical faceplate enhances collection of incident radiation over a solid angle of greater than 2π steradians.

The C710132B has an extremely rugged construction and utilizes a special photocathode connection which assures continuous contact with the cathode when the tube is subjected to rough usage. The structure of the tube has been designed to meet the MIL-E-5272C specification and the tubes are 100% tested to it.

The C710132B is designed especially for use in rocket, satellite, and similar aerospace systems. The typical anode dark current is 8×10^{-10}A at 1250V and 22°C whilst the quantum efficiency is typically 20% at 4200Aν. This tube is supplied with a small-shell duodecal base attached to semiflexible leads to facilitate testing prior to installation. After testing, the attached base should be removed.

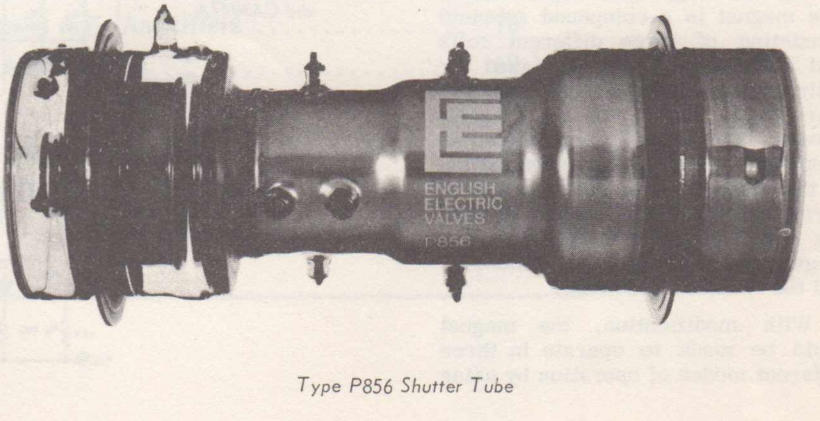
EEV SHUTTER TUBE

The English Electric Valve Co. Ltd. have recently released a High-Speed Photography Shutter Tube type P856.

When installed in a suitable camera, the P856 tube can present on its fluorescent screen a sequence of frames showing the development of a high-speed event. Shuttering speeds in excess of 20,000,000 per second can be obtained and the number of frames to be recorded can be selected to be from 8 to 32. Exposure times better than 10 nanoseconds can be achieved.

The shutter action is achieved by deflecting the electron beam over a slit in an aperture plate in the tube.

Electrostatically focused, the P856 has an S11 photocathode with a 15 μA/L minimum sensitivity (to 2854°K tungsten light).



Type P856 Shutter Tube

R.C.A. SUPERCONDUCTING MAGNET

R.C.A. recently announced that they had designed and manufactured the first commercially available superconductive magnet in the world to have obtained a field of 150 Kilogauss in a $1\frac{1}{2}$ inch clear bore.

In order to manufacture the magnet R.C.A. perfected a technique for cladding selected thicknesses of high purity, high-resistivity-ratio copper to both sides of vapour-deposited niobiumtin ribbons. R.C.A. 'VAPO-DEP' ribbon, clad with an appropriate thickness of copper for a particular coil design, has greatly increased stability. That is, the copper surrounding the superconductor substantially reduces the current-degrading effects of flux jumps, those local discontinuities in superconductors that can accumulate to trigger a quenching of the entire solenoid.

To evaluate the high performance of these developmental materials in actual devices, several different types of coils were designed and built. In every case, performance of the copper-clad ribbons exceeded design expectations.

Success of the very high field magnet announced today can be considered as making the completion of a series of in-coil performance tests of these materials. Based on an evaluation of results, further refinements and optimisations are now in process which are aimed at establishing a family of compatible ribbon types. A new family of high performance materials will be announced in the very near future along with an extended line of superconductive magnets with field strengths ranging to 150 kilogauss.

The new high-field superconductive magnet is a compound solenoid consisting of three different coils that were specifically designed for optimized performance in a particular field region of the magnet. Several new terms were coined to properly describe the construction of the magnet - the inner section is normally called the "insert" and led the engineers to call the other two larger magnet sections the "midsert" and the "outsert" sections.

With modification, the magnet could be made to operate in three different modes of operation by using various combinations of the "insert", "midsert" and "outsert" sections. The "outsert" section alone should produce a field of approximately 40 kilogauss with a 9.3/16-inch clear working bore. If the "midsert" and "insert" sections were used together the combination should produce a field of 100 kilogauss with a clear working bore of $1\frac{1}{2}$-inches. With all three sections working in combination the field would be a maximum of 150 kilogauss with a $1\frac{1}{2}$-inch clear working bore.

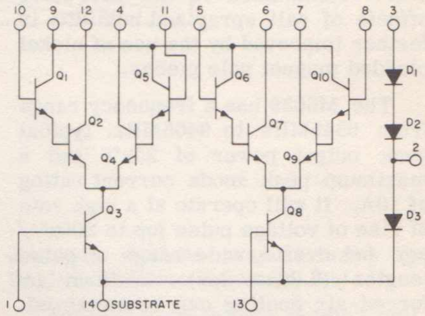
Homogeneity of the magnets is rated at 0.02% in a inch diameter spherical volume.

NEW INTEGRATED CIRCUITS CA3047, CA3047A, CA3050, CA3051

A further four devices have been added to the rapidly expanding range of RCA linear integrated circuits available from AWV.

The CA3047 and CA3047A are electrically identical to the CA3033 and CA3033A respectively, but are packaged in the popular "dual-in-line" plastic package and designed to operate over the temperature range of 0°C to +70°C. The circuit is a high performance operational amplifier consisting of two differential amplifiers in cascade and a single-ended class-B power output stage on a single monolithic silicon chip. This device features high input impedance, high gain, high power output, and low input-offset voltage and current.

The CA3047 and CA3047A are suitable for use in many applications amongst these are: Comparator, Integrator, Differentiator, Audio Amplifier, Servo Driver, DC Amplifier, Multivibrator, Narrow Band and Band Pass Amplifiers.



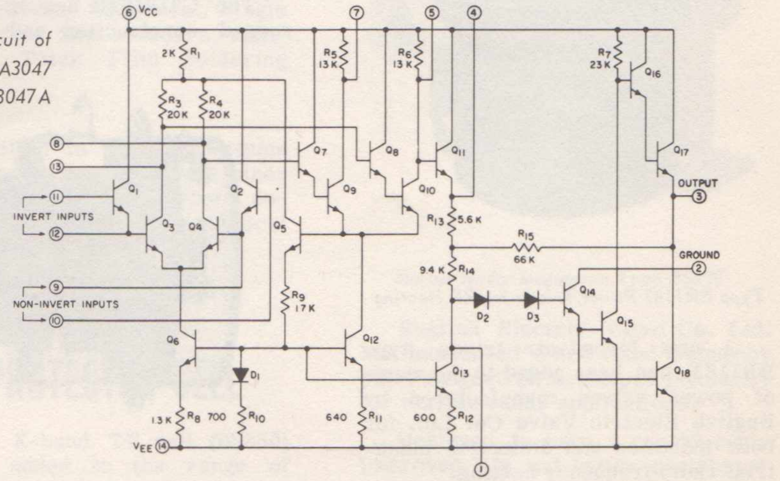
Circuit of CA3050 and CA3051

The CA3050 and CA3051 each consists of two differential amplifiers with associated constant constant current transistors on a common substrate. Each amplifier is driven by Darlington-connected emitter follower inputs to provide high input impedance, low bias current, and low offset current. A string of diodes is included to provide temperature-compensated bias to the constant current transistors and a low impedance bias point for the inputs to the differential amplifiers when a single power supply is used.

The CA3050 is supplied in an Hermetic 14-lead Dual-In-Line ceramic package rated for operation over the full military temperature range of -55° C to +125 °C.

The CA3051 is supplied in a Dual-In-Line plastic package for applications requiring only a limited temperature range -25° C to +85° C.

Circuit of CA3047 and CA3047A



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