RADIOTRONICS

AMALGAMATED WIRELESS VALVE COMPANY LIMITED

Technical Bulletin No. 60

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RADIOTRON ALL-METAL VALVES

Two additional types have recently been released (6R7 and 6X5) while additional technical information is now made available on types 5Z4, 6A8 and 6L7.

RADIOTRON 5Z4 (New Construction)

Full Wave High Vacuum Rectifier

The 5Z4 is an indirectly-heated rectifier having ratings somewhat similar to type 80, except that the internal impedance is extremely low. It should not be confused with type 5Z3 which is a heavy duty rectifier of the filament type. It is interchangeable with type 5Y3, but having a much lower internal impedance the D.C. output voltage will be greater and care should be taken to avoid any excessive voltages. Due to its lower internal impedance the 5Z4 offers less obstruction to surges (unless a choke input filter is used), and this factor should be considered very carefully in the design of receivers.

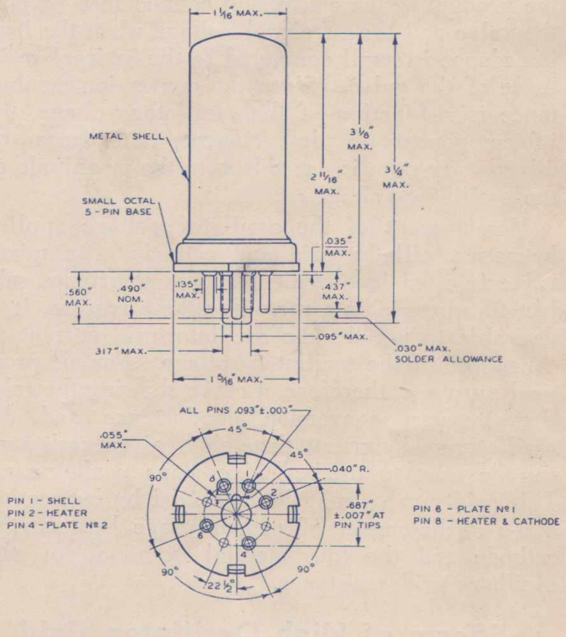
Radiotron 5Z4 valves have been very completely tested in the Laboratory of Amalgamated Wireless Valve Coy. Ltd., both on surges and steady running, and have given very satisfactory performance up to 500 hours' operation. There is every evidence that Radiotron 5Z4 will give long life and reliable performance. At the same time it is only reasonable to point out that due to their low internal impedance they will not stand abuse such as a short-circuited output (e.g., a filter condenser) or heavy surges on full load. The 5Z4, however, has two distinct advantages over types 80 or 5Y3:—

1. The indirectly-heated cathode prevents excessive plate voltage on the other valves and components in the receiver during the warming-up period.
2. A lower transformer secondary voltage is required for the same D.C. output voltage.

As anticipated in Radiotronics Technical Bulletin No. 58, the 5Z4 is now available with the improved construction. The electrical characteristics remain unchanged but for convenient reference, are repeated.

RADIOTRON 5Z4

OUTLINE DRAWING



BOTTOM VIEW OF BASE

Tentative Data

Heater Voltage	5.0 volts.
Heater Current	2.0 amperes.
A.C. Plate Voltage per plate	400 max. volts R.M.S
Peak Inverse Voltage	1100 max. volts.
D.C. Output Current	125 max. milliamperes.
Maximum Overall Length	3¼"
Maximum Diameter	1.5/16"
Base	Small Octal 5-pin.

THE OPERATION OF RADIOTRON 6A8

Optimum performance of a superheterodyne receiver cannot be realized unless the mixer-oscillator section satisfies certain requirements. Unfortunately, however, these requirements usually conflict with other conditions for optimum performance. In practice, therefore, it is necessary to effect a suitable compromise. For example, the oscillator voltage of the 6A8 must be greater than a certain minimum value for reasonable mixer-stage gain. It has been found that this requirement immediately limits the frequency range which can be covered in a single band. Hence, a compromise between frequency coverage and mixer-stage gain must be reached. It is the purpose of this note to discuss some of the problems associated with the design of pentagrid-converter circuits and to present data on the operation of the 6A8, the all-metal pentagrid-converter valve.

A pentagrid converter produces an i-f component of plate current because of modulation in the electron stream of an r-f signal by an oscillator voltage applied to the No. 1 grid. The magnitude of the i-f component of plate current is equal to the product of the conversion conductance (g_c) of the valve and the r-f signal voltage when the load impedance is small compared to the internal resistance of the valve. Since the conversion conductance is a function of the oscillator voltage, the i-f component of plate current, and hence the mixer-stage gain, is dependent on the magnitude of the oscillator voltage.

Measurement of the oscillator voltage applied between oscillator grid and cathode of a mixer valve is often inconvenient and is sometimes subject to appreciable error. For these reasons, it is desirable to use the d-c oscillator-grid current as a measure of the oscillator voltage. For all practical purposes, therefore, a curve showing the relation between conversion conductance and d-c oscillator-grid current through a given resistance can be used to predict mixer-stage performance. This grid current may be measured by connecting a d-c milliammeter of proper range between the cathode and the low-potential terminal of the oscillator-grid resistance.

Effects of High Oscillator Grid Currents

In the usual type of oscillator circuit, the oscillator voltage nearly always increases with frequency throughout any wave range of an all-wave receiver; this increase is due to the increasing impedance of the tuned circuit and to the increasing plate-grid feedback as the receiver is tuned to the high-frequency end of the band. Thus, if the oscillator-grid current is made high at the low-frequency end of a range, good mixer-stage gain throughout that band might be expected. However, experience has shown that the frequency range of the band may be seriously limited if the size of the tickler is increased in order to obtain high oscillator-grid current at the low-frequency end.

It has been found that the upper frequency limit of the range can be determined by the resonance frequency of the tickler coil and its associated shunt capacitance; this resonance frequency may lie within the theoretical tuning range of the band. When such a condition exists, the tickler determines the frequency of oscillation; this frequency remains fixed for any higher-frequency setting of the tuning condenser. Experience has shown that it is possible to obtain a tuning ratio of slightly more than 3 to 1 when the highest-frequency band tunes to approximately 18 megacycles and when the grid current throughout this frequency range is sufficient to insure good mixer-stage gain. In general, for frequencies higher than 18 megacycles this tuning ratio decreases, because the inductance of the tickler and the magnitude of the shunt capacitance do not change rapidly. A maximum oscillator-grid current for each operating condition is recommended. Currents in excess of these recommended values may seriously curtail the effective tuning ratio.

Another reason for limiting the size of the tickler is to prevent the oscillator from relaxing periodically. It has been found that, for the given values of oscillator-grid resistance and capacitance, relaxation effects may occur when the oscillator-grid current exceeds the maximum value recommended.

Oscillator-Grid Current Requirements

Curves of conversion conductance and cathode current (I_k) vs. oscillator-grid current through 50,000 ohm (I_{c1}) for the 6A8 are shown in Figs. 1 to 4; these curves correspond to the four operating conditions normally encountered in practice. Consider Fig. 1, which pertains to 250-volt, fixed-bias operation. As the oscillator-grid current decreases, the cathode current rises; I_k eventually exceeds the rated maximum current of 14 ma. The high cathode current at small oscillator-grid currents is a result of the small negative bias on the oscillator-grid at low oscillator voltages.

The conversion conductance of the 6A8 varies with I_{c1}. The curve approaches flatness over a large range of oscillator-grid currents, but drops quite rapidly for small values of I_{c1}. Thus, when $I_{o1} = 120$ microamperes (0.12 milliampere), the cathode current is 14 milliamperes, the maximum rated value, and the conversion conductance is 350 micromhos.

It is evident from Fig. 1 that I_{c1} should not be less than 120 microamperes for the operating con-

SUMMARY TABLE

TYPICAL OPERATION OF THE 6A8.

	100-VOLT CONDITIONS FOR			250-VOLT CONDITIONS FOR			
	Recommended MAXIMUM Osc.-Grid Cur.	Recommended MINIMUM Osc.-Grid Cur.		Recommended MAXIMUM Osc.-Grid Cur.	Recommended MINIMUM Osc.-Grid Cur.		
	Fixed- or Self-Bias *(Figs. 3 & 4)*	Fixed-Bias *(Fig. 3)*	Self-Bias *(Fig. 4)*	Fixed- or Self-Bias *(Figs. 1 & 2)*	Fixed-Bias *(Fig. 1)*	Self-Bias *(Fig. 2)*	
Plate Voltage	100	100	100	250	250	250	Volts
Screen Voltage	50	50	50	100 max.	100 max.	100 max.	Volts
Anode-Grid Voltage	100	100	100	250 ‡	250 ‡	250 ‡	Volts
Control-Grid Voltage *	-1.5 min	-1.5 min.	-1.5 min.	-3 min.	-3 min.	-3 min.	Volts
Oscillator-Grid Resistor	50000	50000	50000	50000	50000	50000	Ohms
Oscillator-Grid Condenser	50	50	50	50	50	50	μμf
Oscillator-Grid Current	0.25 max.	0.05 min.	0.05 min.	0.5 max.	0.12 min.	0.09 min.	Milliamperes
Plate Current	1.2	2.1	1.7	3.3	5.3	4.2	Milliamperes
Screen Current	1.5	2.1	2.0	3.2	4.3	4.7	Milliamperes
Anode-Grid Current	1.6	2.1	2.2	4.0	4.4	5.1	Milliamperes
Conversion Conductance	350	250	250	500	350	300	Micromhos
Grid Voltage (Approx.) for Conv. Cond. of 2 μmhos	-20	-20	-20	-45	-45	-45	Volts

* When self-bias is used, the self-bias resistor should have a value of 350 ohms for the 100-volt conditions, and 300 ohms for the 250-volt conditions.

‡ This is an Anode-Grid Supply voltage applied through a 20,000-ohm voltage-dropping resistor.

NOTE: Total Cathode Current = 14 milliamperes maximum. Anode-Grid Voltage = 200 volts maximum.

RADIOTRON 6A8

OPERATION CHARACTERISTICS
WITH 50000-OHM OSCILLATOR-GRID LEAK

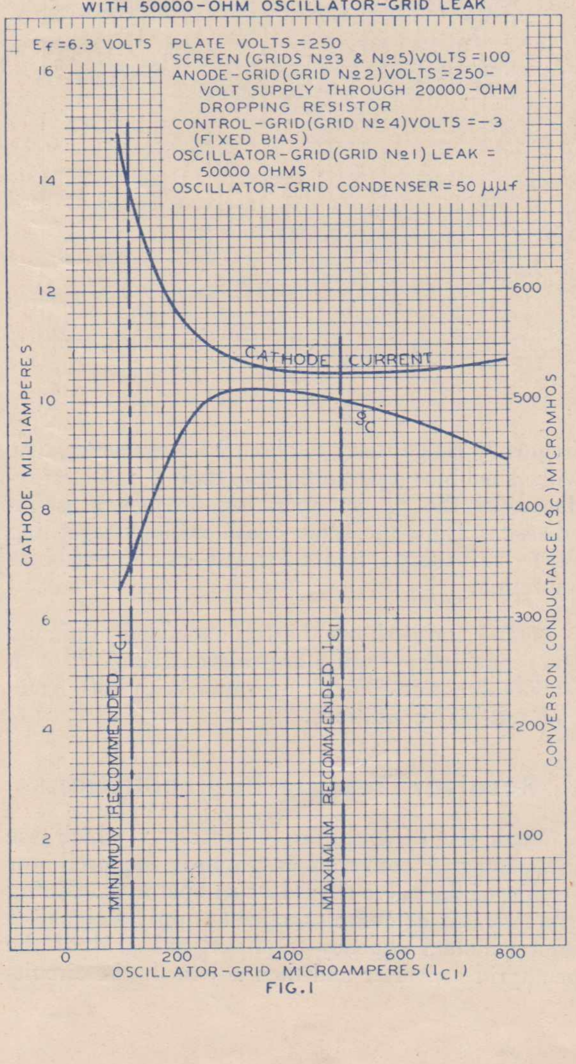


FIG. 1

RADIOTRON 6A8

OPERATION CHARACTERISTICS
WITH 50000-OHM OSCILLATOR-GRID LEAK

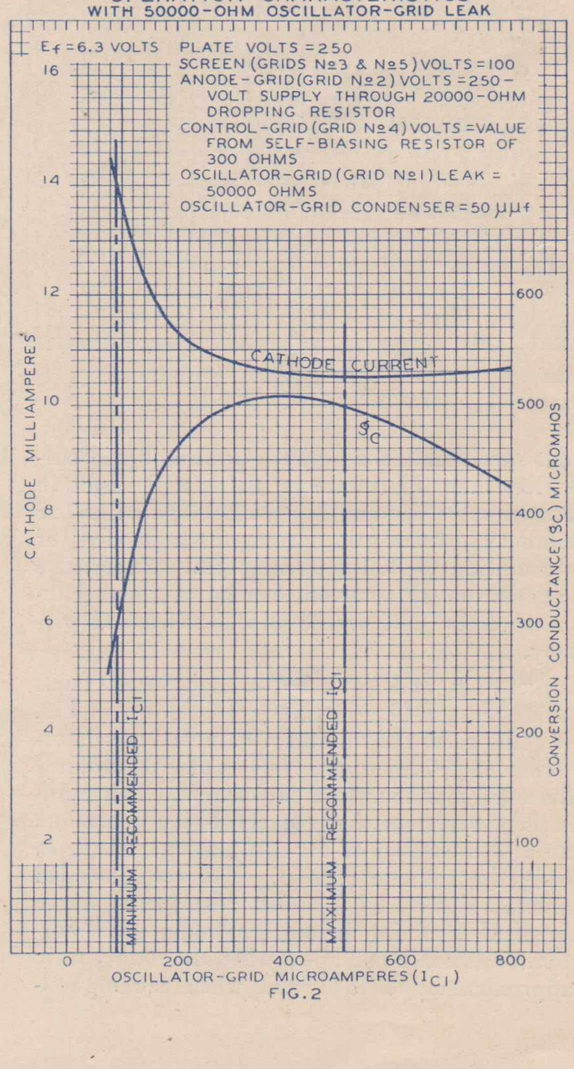


FIG. 2

RADIOTRON 6A8

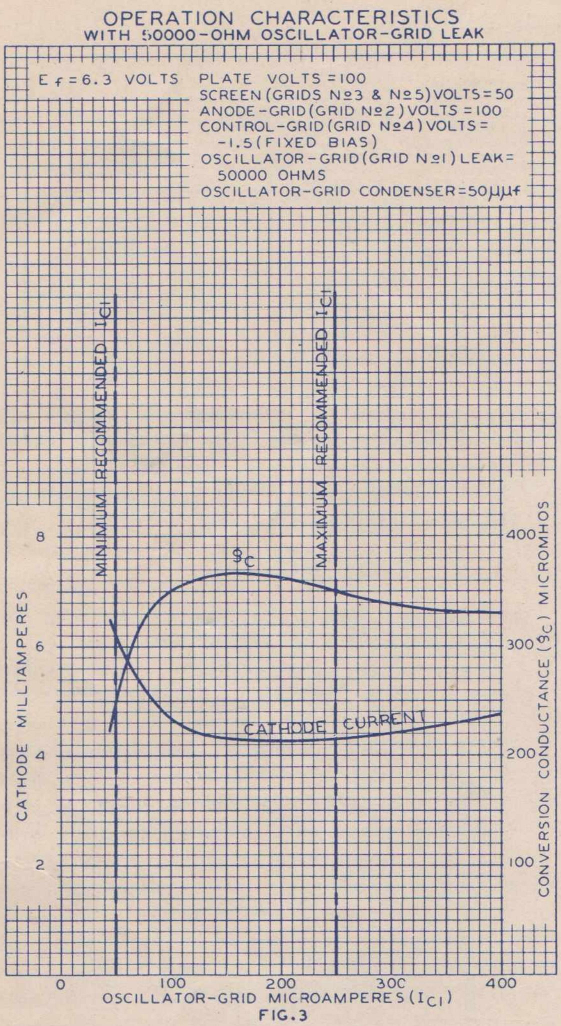


FIG. 3

RADIOTRON 6A8

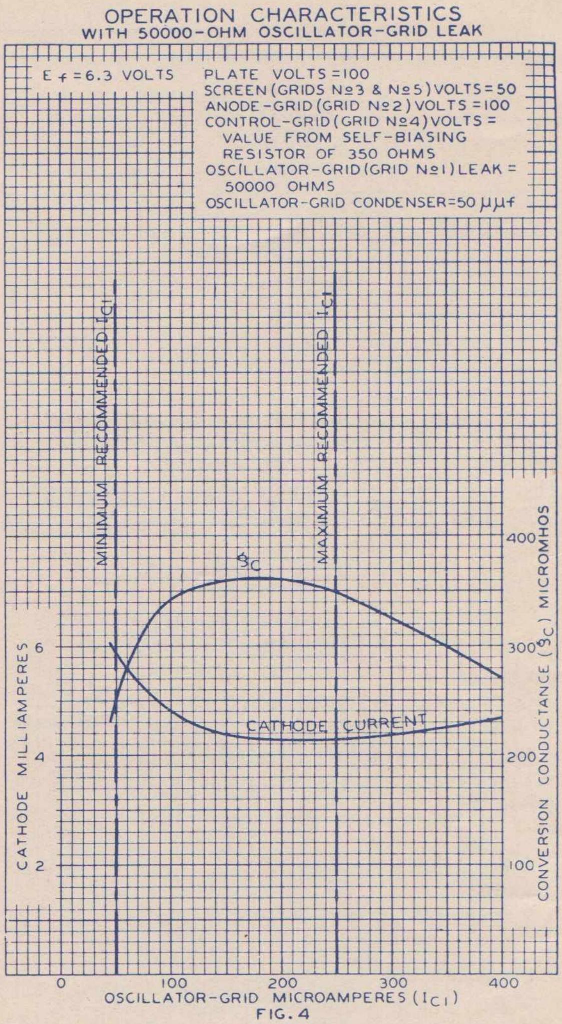


FIG. 4

ditions specified in the figure. Oscillator-grid currents less than this minimum value will result in decreased valve life and low mixer-stage gain. The maximum oscillator-grid current recommended for this condition is 500 microamperes. Experience has shown that this current can be obtained without any of the undesirable effects mentioned previously.

Curves of g_c and I_k vs. I_{c1} through 50,000 ohms for 250-volt, self-bias operation are shown in Fig. 2. In this case, the minimum value of oscillator-grid current (90 microamperes) is also determined by the rated maximum cathode current. This minimum is lower than that for fixed-bias operation, because of the effect of the self-biasing resistor in limiting the cathode current. The recommended minimum value of I_{c1} is 500 microamperes. These recommended minimum and maximum oscillator-grid currents can be obtained when the tuning ratio is approximately 3 to 1 and when the highest-frequency range tunes to about 18 megacycles. As with fixed-bias operation, the tuning ratio is reduced as the upper operating frequency is increased. Thus, the same considerations regarding tickler-coil design obtain for self- as for fixed-bias operation.

Figs. 3 and 4 shows the recommended minimum and maximum oscillator-grid currents through 50,000 ohms for 100-volt operation with both fixed- and self-bias conditions.

Receiver Testing in Production

When the i-f amplifier of receivers which use the pentagrid converter is aligned, the oscillator section of the valve should be in operation. During this test, it is common practice to apply a signal of intermediate frequency to the signal grid of the pentagrid converter and then adjust the i-f circuits for maximum gain. If the oscillator is not operating, the bias of the oscillator-grid is zero; consequently, the gain of the mixer stage as an amplifier is higher than that which can be obtained when the oscillator is operating. The i-f gains obtained with and without the oscillator in operation may lead to erroneous conclusions.

As pointed out previously, the gain of the mixer stage is a function of the oscillator-grid current. Therefore, when aligning the i-f circuits with the oscillator in operation, it is important that the settings of the gang condenser and the oscillator padding condensers should be approximately the same in all receivers. By observing this precaution, the tester is able to compare the i-f gain of any receiver with some standard under similar operating conditions.

It should be emphasized that there may be no definite relation between the gain of the 6A8 when it is operated as an amplifier and when it is operated as a converter. The gain of the 6A8 when it is used as a converter should be compared to a standard which is also used as a converter.

Blocking of the Receiver when Tuned to a Strong High Frequency Signal

Some receivers seem to block, or motor-boat, when tuned to a strong high-frequency signal. In a number of cases, this has been traced to poor regulation of the oscillator-anode and screen voltage sources. The voltages for these electrodes are usually obtained from the low-voltage side of a filter choke, which may have a resistance of 1000 ohms or more. Variations in current through this choke, caused by tuning the receiver to a strong signal, change the voltage applied to the oscillator-anode and screen. This change in voltage shifts the frequency of the oscillator voltage; this shift becomes important at high radio frequencies. Hence, the oscillator detunes periodically at an audio-frequency rate and consequently produces modulation of the carrier amplitude.

Fig. 5 is a circuit which minimizes this effect. The oscillator-anode and screen voltages are applied through the resistance-capacity filter (R C); C_1 is a mica high-frequency by-pass condenser and R_1 is a screen voltage-dropping resistor. The values of R and R_1 depend on the voltage input to the filter. Since the filtering action is dependent on the time constant of R and C, not more than one valve (the pentagrid converter) should be supplied by this filter, as the value of R is inversely proportional to the current through it. In general, this circuit is not necessary on 100-volt operation, because the filter choke usually has a sufficiently low resistance to provide good regulation.

SCHEMATIC CIRCUIT FOR TYPE 6A8
WITH POWER-SUPPLY FILTER

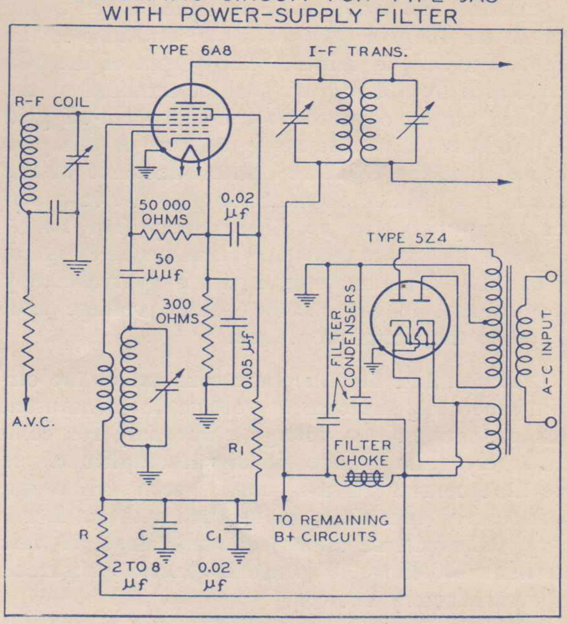


Fig. 5.

RADIOTRON 6L7 AS A VOLUME EXPANDER

The ratio of maximum to minimum amplitudes that is feasible to record phonographically is not sufficient to take care of very large volume changes, such as may be produced by a symphony orchestra. For this reason, very large ranges in sound intensity are reduced in some way before the record is made. Such reduction, known as "compression," is usually accomplished manually by careful monitoring.

Most home phonographs have no provision for expanding the signal in order to compensate for the compression introduced at the time of recording. Hence, passages are distorted in the sense that they are not reproduced with full volume range. If full compensation for compression is desired, it is necessary to provide the phonograph with some means for increasing the amplification of loud passages in the same proportion that they were compressed at the recorder. However, if the volume control on the phonograph is set for reasonably loud volume on expanded passages, the residual noise level in the room may impair reception of soft passages when full expansion is used. Therefore, full compensation may not be desirable.

The characteristics of the type 6L7 valve permit its use in a comparatively simple volume-expander circuit. This valve has a heater, a cathode, five grids, and a plate. Two of the five grids are control grids; the first (G_1) has a remote cut-off characteristic and the second (G_3) has a sharp cut-off characteristic. Of the three remaining grids, two are screens and one is a suppressor.

The schematic diagram of a volume expander is appended. The signal to be expanded is fed to the remote cut-off grid (G_1) of a 6L7 and also to the input of a 6C5, as shown. The output of the 6C5 is rectified by a 6H6; the positive terminal of the rectified output connects to the sharp cut-off grid (G_3) of the 6L7. The no-signal bias of this grid is such that the G_1-Plate transconductance of the 6L7 is low (under 50 micromhos). When a signal is applied, the rectified voltage fed to G_3 increases the transconductance, and hence the gain, of the 6L7. This increase in gain is approximately proportional to the rectified diode voltage and, hence, to the signal amplitude.

It is essential that the time constant of the circuit generating the control voltage be so adjusted that changes in this voltage occur only for comparatively slow changes in signal amplitude. If the time constant is too short, speech will sound particularly unnatural; if the time constant is too long, there will be an objectionable lag. A time constant of 0.25 to 0.5 second is generally regarded as a satisfactory choice.

Distortion of the signal due to the characteristic of the remote cut-off grid (G_1) is appreciable for large signals. Therefore, the maximum signal input to G_1 should be 1 volt peak, which is of the same order as that obtainable from the usual magnetic phonograph pick-up.

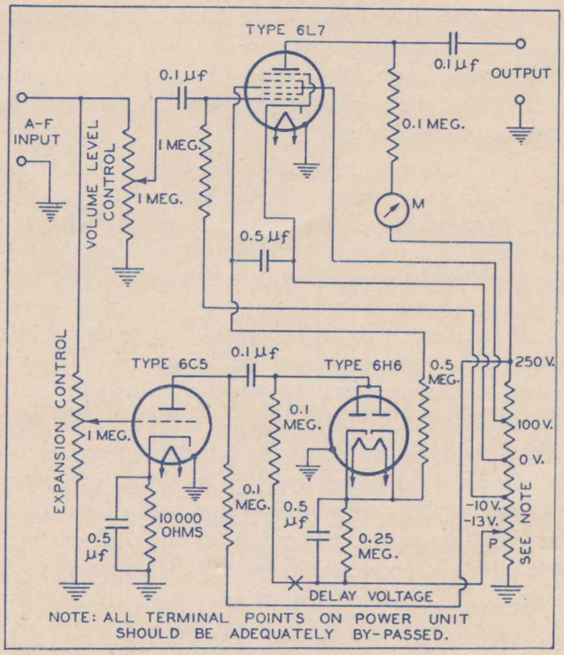
The plate-current value of the 6L7 serves as a good measure of the degree of expansion. It is suggested, therefore, that the initial bias on G_3 be adjusted for a no-signal plate current of approximately 0.15 milliampere by means of potentiometer P. This potentiometer requires no further adjustment if the same 6L7 is always used. The plate of the 6H6 may be biased negatively in order to delay expansion until a predetermined signal amplitude is reached. This delay voltage may be inserted at point X.

Although this system can operate from a radio receiver to provide expansion, it is suggested that, at the present time, volume expansion be used for phonograph reproduction only. Since large unanticipated changes in sound level during a broadcast may not be adequately monitored, the expander will act to exaggerate these changes. It is not probable that such accidental changes will be present in a phonograph record.

RADIOTRON 6R7
Duo-Diode-Triode

The 6R7 is a recent addition to the All-Metal valve series and has no exact equivalent in the glass series. The nearest equivalent is type 85, but the 6R7 has considerably greater amplification factor and mutual conductance. The plate

VOLUME EXPANDER CIRCUIT USING RADIOTRON 6L7



resistance of the 6R7 is very little greater than the 85 and is very suitable for transformer coupling. The 6R7 may also be used as a driver valve in cases where only a medium driver power is required.

With resistance coupling the 6Q7 will generally be preferred, owing to its greater stage gain, but the 6R7 may be used with resistance coupling if desired.

RADIOTRON 6R7 DUO-DIODE-TRIODE
(Tentative Data)

Heater Voltage (A.C. or D.C.)	6.3 Volts.
Heater Current	0.3 Ampere.
Maximum Overall Length	3-1/8"
Maximum Diameter	1.5/16"
Cap	Miniature.
Base	Small Octal 7-pin.

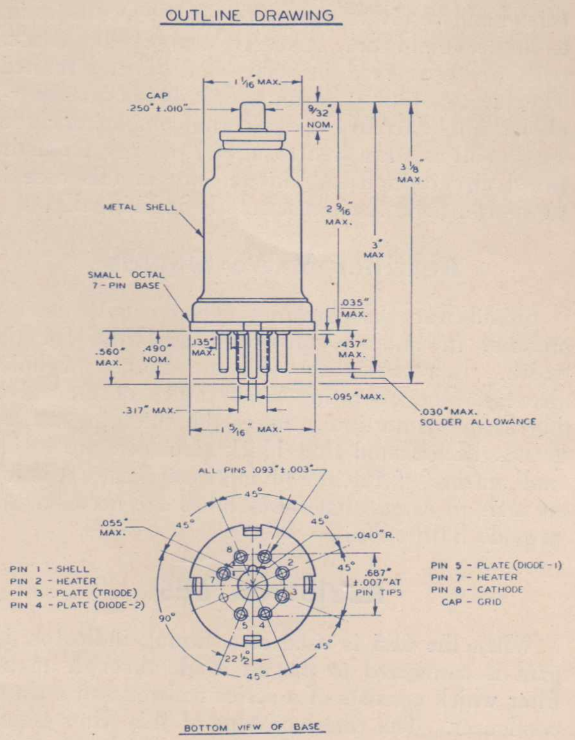
Triode Unit—as Class A Amplifier

Plate Voltage	250 max.	Volts.
Grid Voltage	–9	Volts.
Amplification Factor	16	
Plate Resistance	8500	Ohms.
Mutual Conductance	1900	Micromhos.
Plate Current	9.5	Milliamperes.

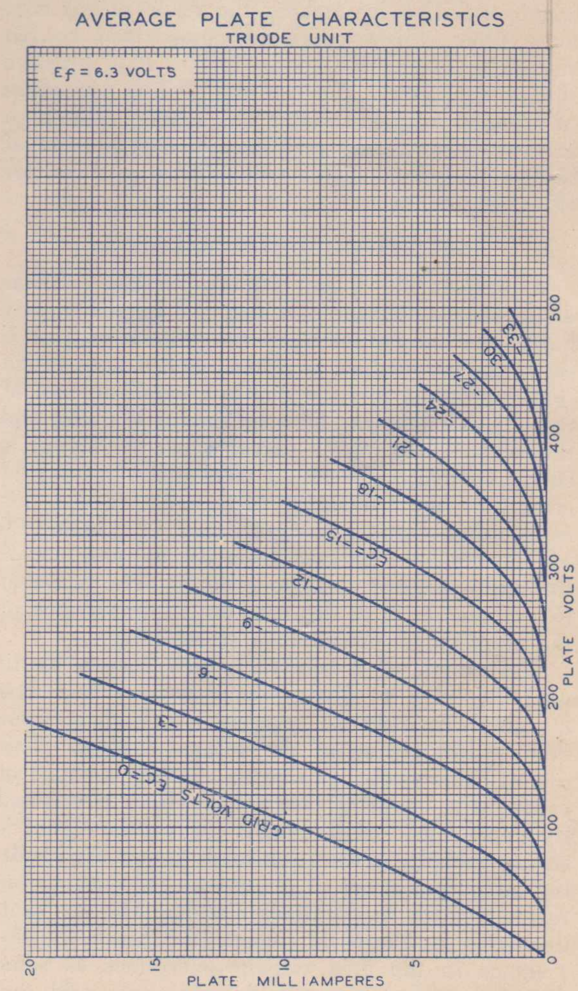
Diode Units

The two diode units are placed around a cathode, the sleeve of which is common to the triode unit. Each diode plate has its own base pin.

RADIOTRON 6R7



RADIOTRON 6R7



RADIOTRON 6X5

The latest addition to the Radiotron All-Metal Valve series is the 6X5, a full wave indirectly-heated rectifier somewhat similar to type 84. Its principal application will be to automobile or other 6-volt battery receivers which obtain their B supply from the A battery, but it may also be used in A.C. receivers if so desired.

The characteristics (subject to confirmation) will be as follows:—

Cathode	Indirectly heated.
Heater Voltage	6.3 Volts A.C. or D.C.
Heater Current	0.6 amp.

Maximum Operating Conditions

A.C. Voltage per Plate (R.M.S.)	375 max. Volts.
Peak Inverse Voltage	1250 max. Volts.
D.C. Output Current	75 max. M.A.
Peak Plate Current	375 max. M.A.

HELPFUL HINTS

The A.V.C. Circuit

When separate diodes are used in a-v-c and second-detector circuits, it may be desirable to feed the a-v-c diode from the primary, rather than from the secondary, of the last i-f transformer. With this connection, advantage is taken of the difference in selectivity between the input and output terminals of this transformer. The primary connection facilitates tuning and provides better quality when the receiver is detuned slightly. The voltage-frequency curve taken across the primary of the usual i-f transformer is broader than that taken across the secondary. Thus, when the a-v-c diode is fed from the primary, the a-v-c voltage does not fall rapidly as the receiver is detuned slightly. Because of this characteristic, the high audio frequencies are not over-emphasized for slight detuning.

In many radio receivers the distortion present in the output at low signal levels increases rapidly with the degree of modulation of a signal. The results of a number of tests show that most of this distortion originates in the second-detector circuit and that it can be minimised by changing some of the circuit constants. In order that a diode will rectify a high-percentage modulated signal with little distortion, the a-c and d-c diode load impedances should be nearly equal. Practically, this condition can be fulfilled by making the value of the first a-v-c filter resistor high in comparison to the resistance of the d-c diode load. This practice should supplement the now-established procedure of using an a-f grid resistor which has a value high in comparison to the resistance of that portion of the d-c diode load across which the a-f grid resistor effectively connects.

Multi-purpose Valves

A receiver which uses a multi-purpose valve as diode second-detector and first a-f amplifier may have some a-f output when the volume control is set in the zero-output position. It has been found that this output is often due to a small amount of capacitative coupling between the diode plates and the output-plate of the valve; when the signal is strong enough, rectification takes place in the grid circuit of the following valve. To reduce this zero-setting output, a capacitance of about 200 $\mu\mu$f should be connected from the output-plate of the multi-purpose valve to ground. The effect of this condenser is to decrease the r-f impedance of the output-plate circuit to a small value.

The output of a receiver which uses a multi-purpose valve as diode second-detector and first a-f amplifier may be severely distorted at some definite low setting of the volume control. This distortion is probably due to a small amount of capacitative coupling between the diode plates and the control grid of the valve. When the signal is strong enough, rectification takes place; the resulting a-f output is out of phase with the output, due to rectification in the diode circuit. The per cent. distortion is, therefore, increased. Since the impedance in the grid circuit determines to some extent the r-f voltage developed across grid and cathode, and since the output is most distorted when the two a-f voltages are equal in magnitude, the distortion is maximum at a certain low setting of the volume control. The remedy is to reduce the impedance of the grid circuit to radio-frequency voltages by connecting a capacitance of about 200$\mu\mu$f from grid to ground.

R-F Circuit

The cause of dead spots in the tuning range of many receivers has been traced to absorption of energy from the active tuned circuit by an adjacent unused circuit. This condition is prevalent in three-band receivers that have three r-f coils inside a single shield-can. Usually, two of the unused coils are connected in series and short circuited. The larger of the two unused coils acts as an r-f choke in PARALLEL with the small coil; the small coil is then free to absorb energy from the tuned circuit in use. The remedy in this case is to short-circuit the unused coils individually.

Rectifier Valve Shields

Shields for glass rectifier valves usually have a number of holes to provide ventilation for the valve. Increase in the size or number of holes decreases the operating temperature of the valve, but at the same time reduces the shielding action. It has been found that black paint on the inside and outside of the shield increases heat radiation to such an extent that fewer holes are necessary to provide bulb cooling.

Radiotron 6E5

When the 6E5 is used as a tuning indicator, its grid is connected to the a-f diode through an a-f filter which consists of a series resistor and a shunt condenser. The time constant of this filter is important in determining the rate at which the target shadow increases or decreases. If the time constant is small and the dial is turned rapidly through resonance, the fluorescent area overshoots the value corresponding to slow tuning; if the time constant is too large and the dial is turned rapidly through resonance, the change in area will be less than that corresponding to slow tuning. In either case, it may be difficult to tune to resonance. In general, the time constant of this circuit should be about the same as that of the a-v-c system, so that the voltage applied to the grid of the 6E5 follows the a-v-c voltage.

Radiotron 84

The maximum current rating of the type 84 rectifier valve has been increased from 50 to 60 milliamperes for full-wave operation. The current rating for half-wave operation with both diodes in parallel remains at 75 milliamperes, maximum.