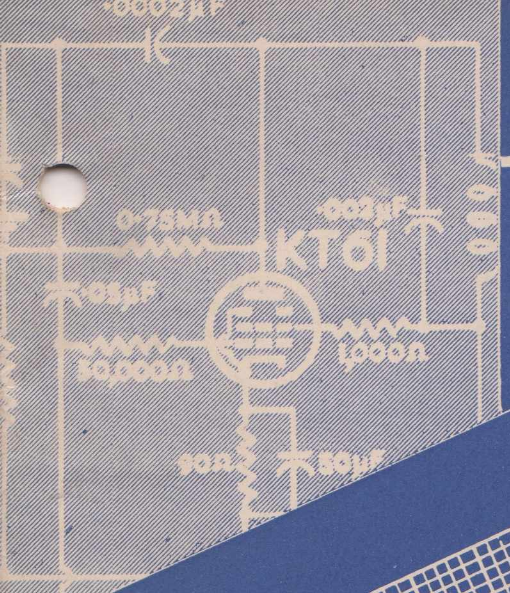
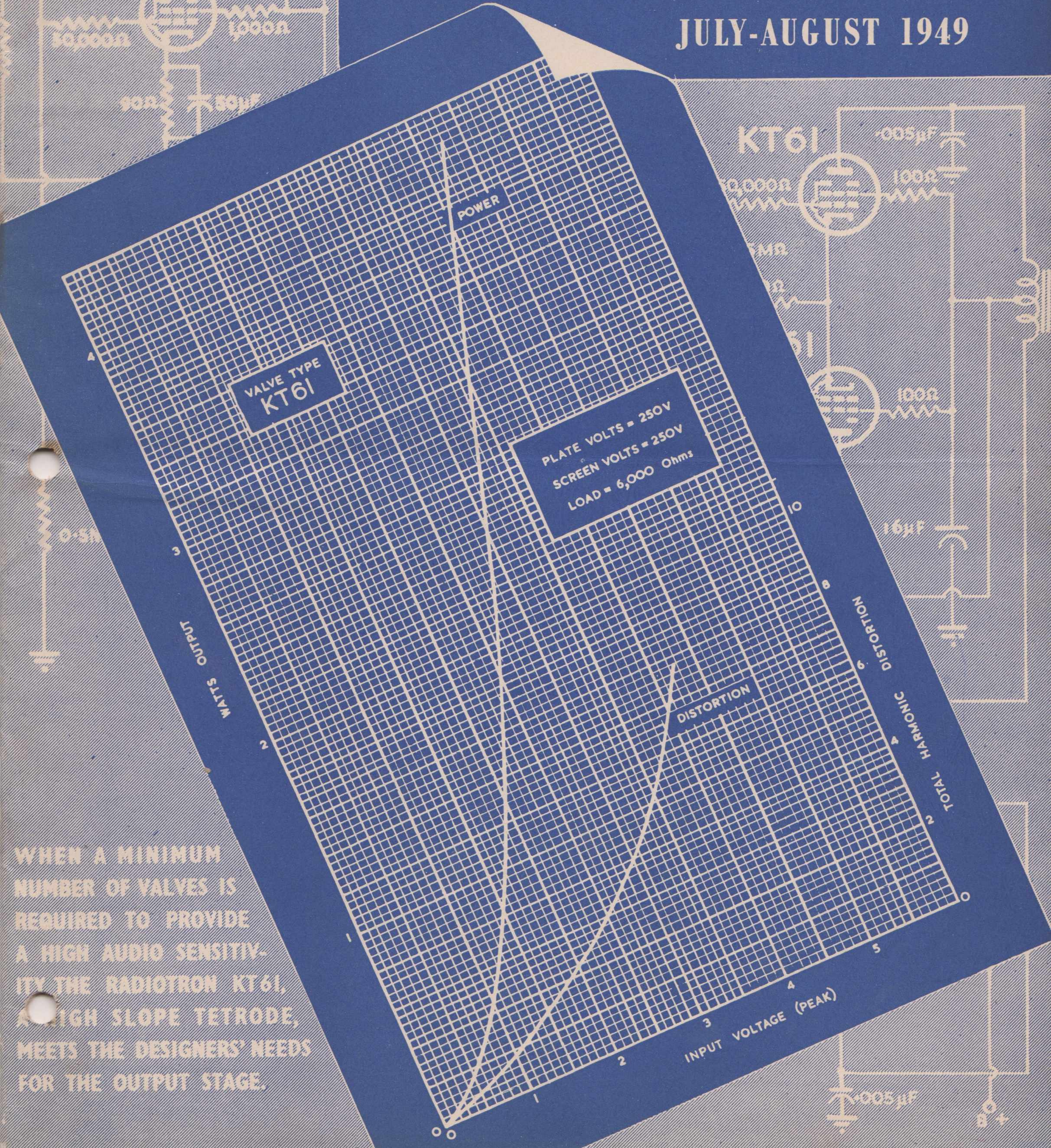
Radiotronics

NUMBER 138
JULY-AUGUST 1949





WHEN A MINIMUM NUMBER OF VALVES IS REQUIRED TO PROVIDE A HIGH AUDIO SENSITIVITY THE RADIOTRON KT61, A HIGH SLOPE TETRODE, MEETS THE DESIGNERS' NEEDS FOR THE OUTPUT STAGE.

FEATURES OF FLUORESCENT SCREENS

The phosphor number of any cathode ray tube is indicated by the final two symbols of the type number. Thus type 5BP1 has a P1 phosphor number.

Fluorescent screens of cathode-ray tubes are identified according to phosphor number, e.g., P-1, P-4, P-5, P-7, P-11 and P-15.

Phosphor P-1 produces a brilliant spot having green fluorescence and medium persistence. Types having this phosphor are particularly useful for general oscillographic applications in which recurrent wave phenomena are to be observed visually.

Phosphor P-4 is a highly efficient screen having white fluorescence and medium persistence. Types having this phosphor are of particular interest for television picture tubes.

Phosphor P-5 produces a highly actinic spot having bluish fluorescence and very short persistence. Types having this phosphor are especially useful in photographic applications involving film moving at very high speeds.

Phosphor P-7 is a long-persistence, cascade (two-layer) screen. During excitation by the electron beam, this phosphor produces a bluish fluorescence of short persistence. After excitation, the screen exhibits a greenish-yellow phosphorescence which persists for several minutes. Types having this phosphor are particularly useful where either extremely low-speed recurrent phenomena or medium-speed non-recurrent phenomena are to be observed.

Phosphor P-11 produces a brilliant actinic spot of bluish fluorescence and has sufficiently short persistence to permit its use in all moving film photographic applications without blurring except in those where film moves at a high speed. P-11 screens, because of their unusually high brightness characteristic, may also be used for visual observation of phenomena.

Phosphor P-15 produces a spot of very short persistence and having both blue-green and near-ultraviolet fluorescence. The persistence of the latter is even shorter than that of the blue-green fluorescence, a feature which makes this phosphor particularly suitable for the high-speed scanning requirements of a flying-spot signal generator.

BACK NUMBERS.

The following issues of Radiotronics are no longer available — 117, 118, 124, 125, 126, 127, 128 and 129.

Radiotronics

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Radiotron Type KT61
Power Output Tetrode

General

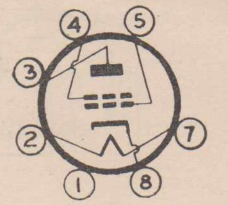
The KT61 valve is a high slope power amplifier tetrode fitted with a six watt indirectly heated cathode, for use in the output stage of an audio amplifier.

It has a high power sensitivity and should not normally be used in amplifiers which already have a high order of audio gain (in excess of 80 db), if microphony is to be avoided.

Maximum ratings and typical operating conditions are as follows:—

Heater:	
Voltage	6.3 a.c. or d.c. volts
Current	0.95 approx. amp.
Direct Interelectrode Capacitances:	
Plate to Grid	1.6 μμF
Input	17.3 μμF
Output	10.2 μμF
Maximum Overall Length	$4\frac{11}{16}$″
Maximum Diameter	$1\frac{3}{4}$″
Base	Octal 7-pin

Pin 1. Not Connected.
Pin 2. Heater.
Pin 3. Plate.
Pin 4. Screen Grid.
Pin 5. Control Grid.
Pin 6. Pin omitted.
Pin 7. Heater.
Pin 8. Cathode.



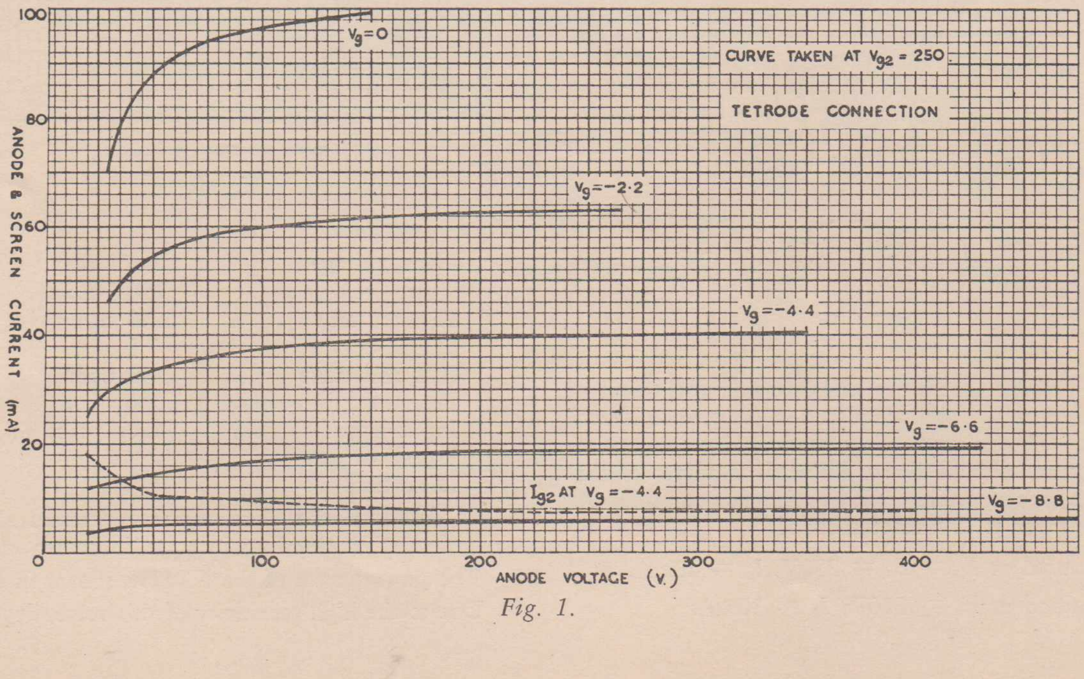


Fig. 1.

Characteristics

	Tetrode	Triode
Plate Voltage	275 V max.	350 V max.
Plate Current	40 mA max.	40 mA max.
Plate Dissipation	10 W max.	10 W max.
Screen Voltage	275 V max.	
Screen Current	7.5 mA max.	
Screen Dissipation	1.9 W	
Self Bias Resistance	90 ohms	
Mutual Conductance	10,500μmhos*	13,000μmhos†

Single valve class "A" amplifier: tetrode connection

For optimum results the KT61 valve should be operated at a plate and screen voltage of 250V, the conditions being set forth in the table below.

The plate load impedance should be kept nearly constant over the working frequency range if a level response is desired.

One suitable circuit is shown in Fig. 2: the valve is preceded by a triode or diode-triode such as the 6AV6. The overall gain given by this combination is high and full output will be obtained with an input signal of about 0.1V peak; should this sensitivity be considered excessive a simple degenerative circuit may be used as Fig. 3.

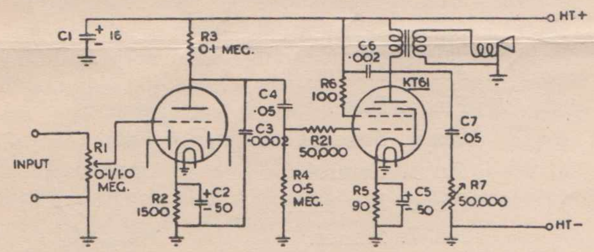


Fig. 2.

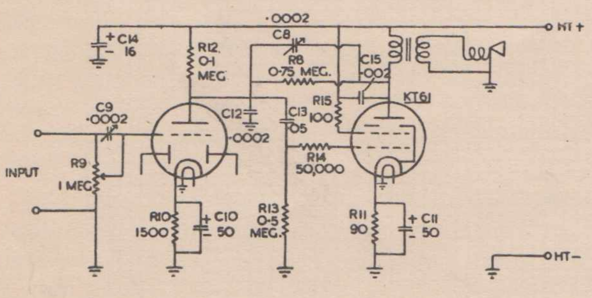


Fig. 3.

To prevent instability and parasitic oscillation a resistance of 100 ohms is placed in the tetrode screen circuit. This is more effective than the usual plate stopper and should always be used on valves of the tetrode type, especially with push-pull operation. A grid stopper is also recommended.

* Measured at $E_a = E_s = 250V$, $I_a = 40mA$.

† Measured at $E_a = 250V$, $I_a = 30mA$.

The output transformer should be designed to handle the plate current of this valve, while still maintaining a high inductance and low leakage inductance: its approximate ratio may be obtained by:

$$\frac{\text{Primary turns}}{\text{Secondary turns}} = \sqrt{\frac{\text{Opt. load impedance}}{\text{Voice coil impedance}}}$$

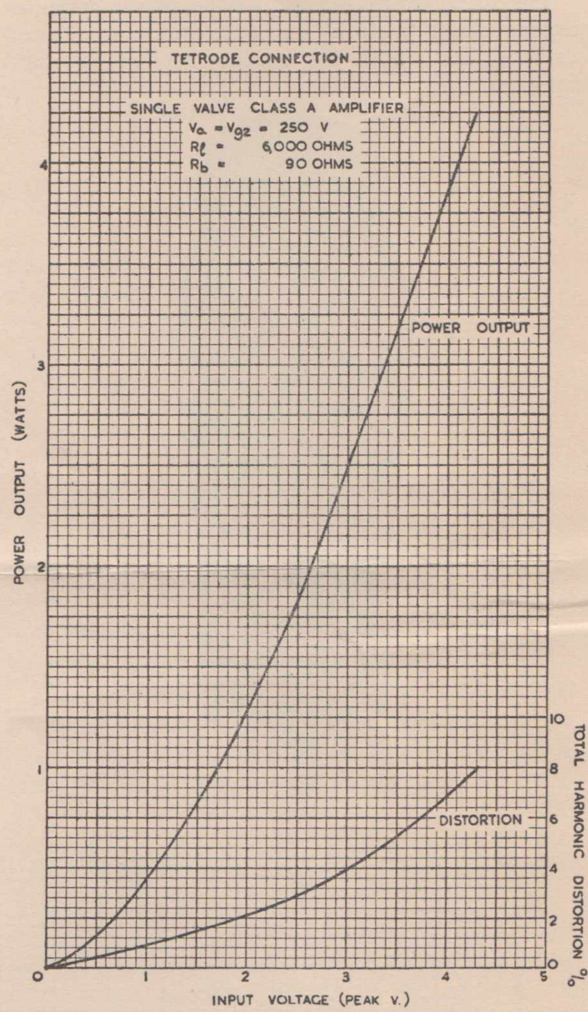


Fig. 4.

Operating data

Plate voltage	250V max.
Screen voltage	250V max.
Plate current	40 mA
Screen current	7.5 mA
Bias resistance	90 ohms.
Plate load impedance	6000 ohms.
Input signal to grid	4.3V peak, 3V r.m.s.
Power output	4.3W
Distortion	8%

At full load the plate current decreases slightly with a corresponding increase in screen current. The performance of the KT61 is shown in Fig. 4. Due to the high sensitivity of this valve, degenera-

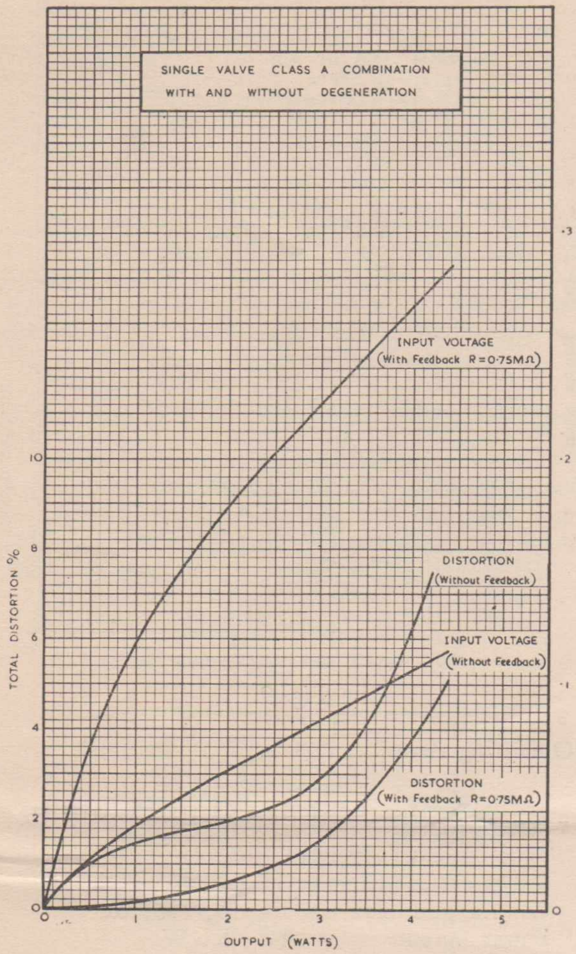


Fig. 5.

tion can be incorporated — Fig. 3 gives a recommended circuit — the overall sensitivity is reduced, but is still high enough for normal use. Degeneration is introduced into the plate circuit of the triode by means of the resistance *R8*: the curves in Fig. 5 show the reduction in distortion and sensitivity to be expected. An even more important advantage is the levelling of the frequency response when an inductive load is used — the curves in Fig. 6, demonstrate the improvement on a typical loudspeaker — it will be seen that the bass resonance is largely removed and that the tendency for the output to increase with frequency is prevented. In simple superheterodyne receivers the attenuation of the higher audio frequencies by the i-f amplifier is partly compensated by the rising frequency response of the output stage — degeneration prevents this, making it desirable to boost the treble in another part of the circuit — a small condenser *C9*, preferably variable, connected across the volume control *R9* will perform this function.

The effect of a small condenser in parallel with the resistance *R8* is also shown: a considerable range of tone control is possible, and this should be used instead of the usual series resistance-condenser method, which is inoperative with degeneration.

Two valve class AB push pull amplifier: tetrode connection

The KT61 valve is suitable for use in push-pull amplifiers when a higher output is required. A suitable circuit is shown in Fig. 7; the driver transformer can be of low ratio and degeneration can be added if desired. The curves in Fig. 8 show the performance, under 250 volt conditions.

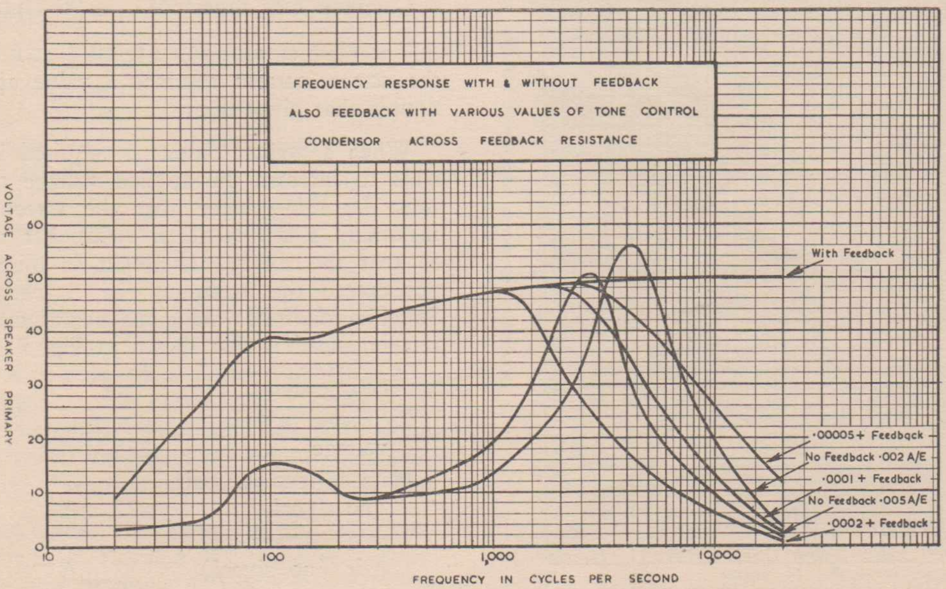


Fig. 6.

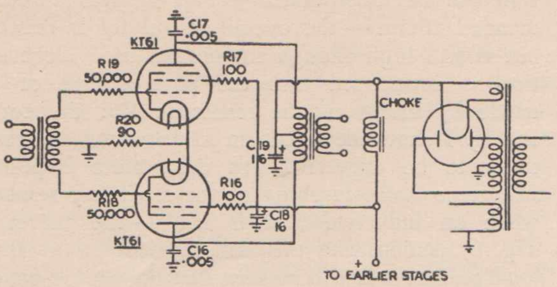


Fig. 7.

The plate and screen currents rise slightly at full load but a power unit having a regulation equal to 500-750 ohms internal resistance is suitable. If desired the plate supply may be taken direct from the first smoothing condenser, due to the small amount of filtration necessary; the screen supply and the plate supply to the earlier valves must be smoothed in the normal manner.

Stopper resistances are desirable in the screen and control grid circuits to prevent parasitic oscillation.

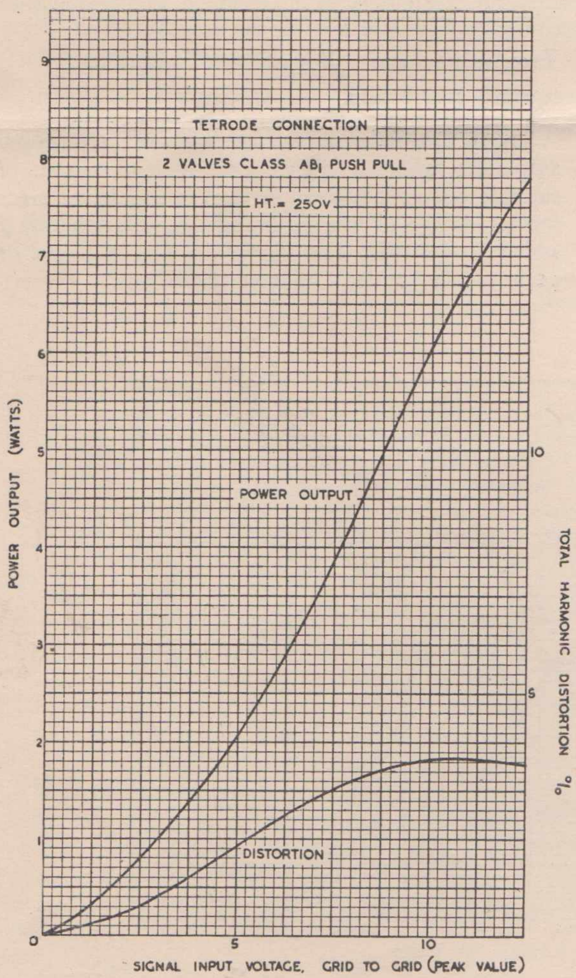


Fig. 8.

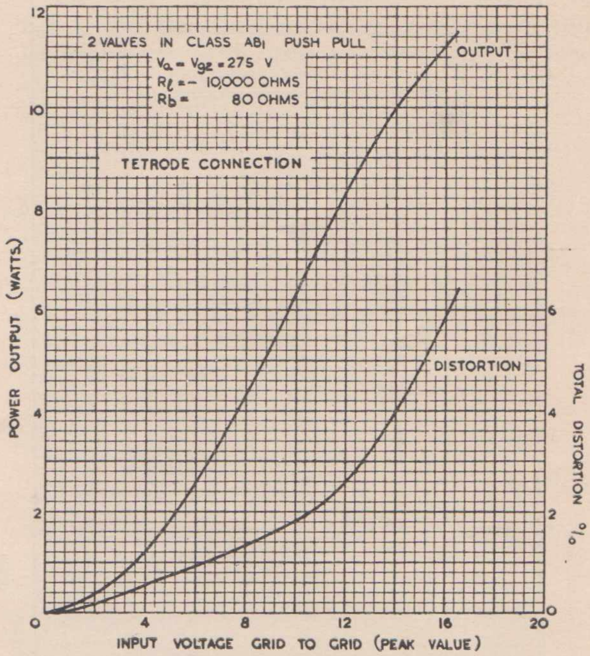


Fig. 9.

Operating data

Plate voltage	250 V max.
Screen voltage	250 V max.
Plate current (2 valves)	56 mA
Screen current (2 valves)	12 mA
Control grid bias	–6 V approx.
Power output	8.6 W
Distortion	4%
Input signal (grid to grid)	14V peak, 10V r.m.s.
Plate load impedance	10,000 ohms
Common bias resistance	90 ohms.

The plate current will rise 10% at full load while the screen current assumes a value approximately double that given above.

When a greater output is required it is permissible to increase the applied voltage to 275V. It must be remembered that the screen current at maximum signal is nearly twice that at no signal, so that the screen dissipation at this point must not exceed the maximum, i.e. 3 watts per valve. Suitable conditions are given below and the circuit recommended is that shown in Fig. 7.

Operating data

Plate and screen voltage	275 V
Plate current per pair (no signal)	72 mA
Screen current per pair (no signal)	12 mA
Screen dissipation at maximum signal	3 W

Plate to plate load	10,000 ohms
Common self-bias resistance	80 ohms
Input signal (grid to grid)	17.5V peak, 12.3V r.m.s.
Power output	11.5 W
Distortion	6.5%

At maximum signal the total plate current increases to 76 mA, and the screen current is almost doubled. It will be noticed that the self-bias resistance has been lowered in value; this is also satisfactory at $E_a = 250$ volts. The curves in Fig. 9 give the performance in detail.

Two valves push-pull class AB1: triode connected

The KT61 valve may be used triode connected in a push-pull circuit when a reasonable power output is required, coupled with very low distortion: suitable conditions are given below, using the circuit shown in Fig. 10.

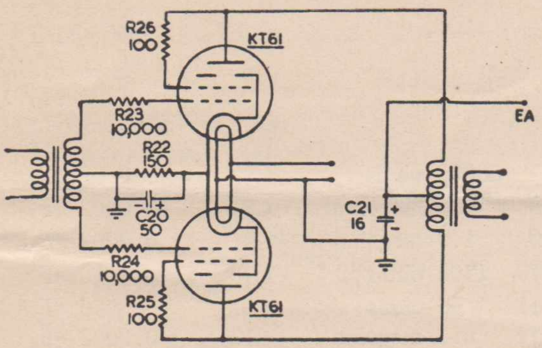


Fig. 10.

Operating data

Plate and screen voltage	350 V
Plate and screen current per pair	63 mA
Plate to plate load	6,000 ohms
Common self-bias resistance	150 ohms
Power output	6 W
Distortion	2%
Signal input (grid to grid)	23V peak, 16.3V r.m.s.

There is a rise in plate current of 10 mA at maximum signal. The curves, Fig. 11, show the performance in detail. The condenser *C20*, shunting the bias resistance should not be omitted: a big increase in the distortion will occur if this is done.

The screen grids are joined to the plates via small resistances *R25* and *R26*: These in conjunction with the grid stoppers *R23* and *R24*, suppress parasitic oscillations.

Curves connecting power output with applied voltage for a single valve, and for two valves in push-pull, are given in Fig. 12. Triode characteristics are shown in Fig. 13.

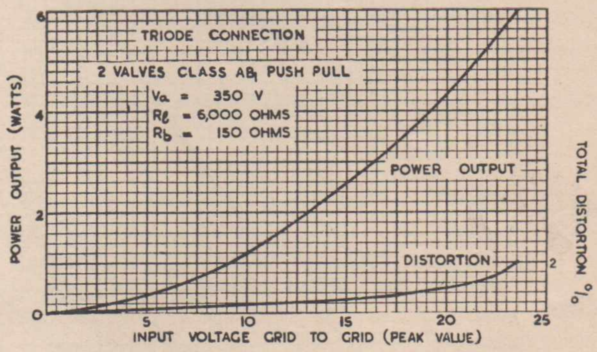


Fig. 11.

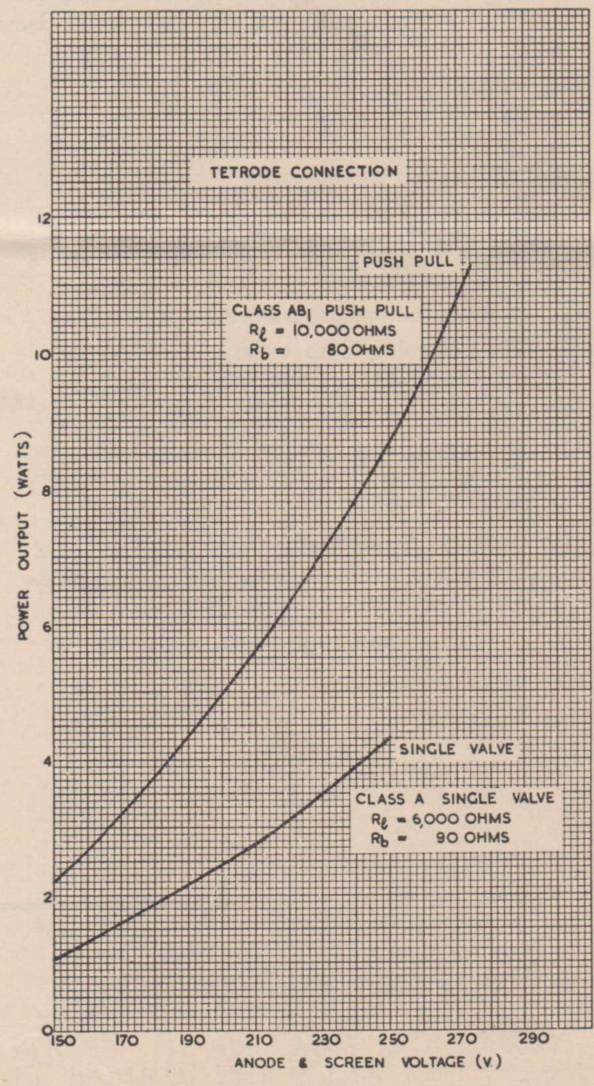


Fig. 12.

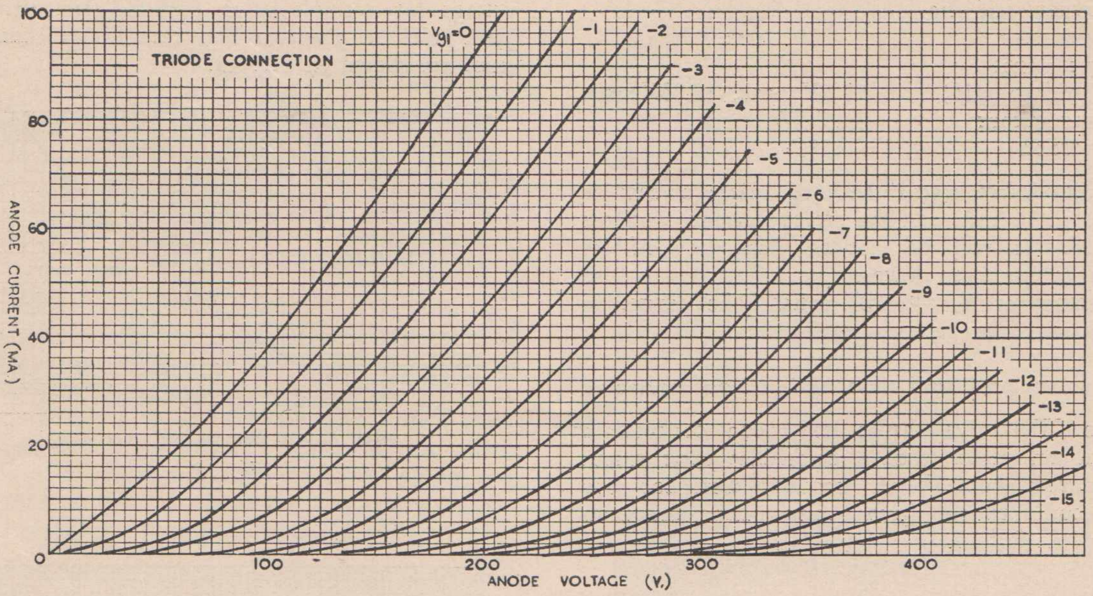


Fig. 13.

Precautions

The following precautions should be observed:

(1) Self bias must always be used due to the high mutual conductance.

(2) A screen stopper resistance should be used.

(3) The control grid to cathode resistance should not exceed 0.5 megohm.

(4) The plate and grid circuits must be isolated.

(5) The valve must not be operated with screen voltage applied if the plate is disconnected from the H.T. supply.

(6) Adequate ventilation must be provided.

(7) The voltage between heater and cathode should not be excessive.

Component values

R1	0.1 – 1.0 megohm	C1	16 μF
R2	.1500 ohms	C2	50 μF
R3	0.1 megohm	C3	0.0002 μF
R4	0.5 megohm	C4	0.05 μF
R5	90 ohms	C5	50 μF
R6	100 ohms	C6	0.002 μF
R7	50000 ohms	C7	0.05 μF
R8	0.75 megohm	C8	0.0002 μF
R9	1.0 megohm	C9	0.0002 μF
R10	1500 ohms	C10	50 μF
R11	90 ohms	C11	50 μF
R12	0.1 megohm	C12	0.0002 μF
R13	0.5 megohm	C13	0.05 μF
R14	50000 ohms	C14	16 μF
R15	100 ohms	C15	0.002 μF
R16	100 ohms	C16	0.005 μF
R17	100 ohms	C17	0.005 μF
R18	50000 ohms	C18	16 μF
R19	50000 ohms	C19	16 μF
R20	90 ohms	C20	50 μF
R21	50000 ohms	C21	16 μF
R22	150 ohms		
R23	10000 ohms		
R24	10000 ohms		
R25	100 ohms		
R26	100 ohms		

CORRECTION RADIOTRONICS 136

Oscillator Coil Details, page 19, the high frequency tuned winding should be 8 turns and the feedback winding should be 5.7 turns.

CORRECTION RADIOTRONICS 137

The equation at the top of column 2, page 32, should read:

$$E = 23 \frac{\sqrt{P}}{d} \text{ volts per metre.}$$

Radiotron Type 6AR7-GT

(TENTATIVE DATA)

A new addition to the range of Australian made Radiotrons is the 6AR7-GT which is a self-shielded, multi-unit valve containing two diodes and a remote cut-off pentode in one envelope. In conjunction with the X61M and the KT61, it will form the basis of a high performance "straight" 3/4 valve set.

This diode pentode provides high stage gain as an r-f, i-f or a-f amplifier and can also be used satisfactorily as a reflex amplifier with low distortion. It is intended that this new valve will be used in all future radio set production superseding the popular 6G8-G.

GENERAL DATA

Electrical

Heater, for unipotential cathode

Voltage (a.c. or d.c.)	6.3 volts
Current	0.3 ampere

Direct Interelectrode Capacitances*

Pentode Unit

Grid No. 1 to plate (C_{g1p})	.003 μμF max.
Input C_{g1} (K+h+g2+g3+ internal shield)	5.5 μμF
Output C_p (K+h+g2+g3+ internal shield)	7.5 μμF

Diode Units

Diode No. 1 — Diode No. 2	0.3 μμF max.

Mechanical

Mounting position	any
Maximum overall length	$3\frac{3}{8}$"
Maximum seated length	$3\frac{1}{16}$"
Maximum diameter	$1\frac{5}{16}$"
Bulb	T9
Cap	Skirted miniature — Style C
Base	Small Wafer Octal 8 pin, sleeve

Basing Designation

Pin 1 Heater
Pin 2 Base shield and metal shell
Pin 3 Pentode plate
Pin 4 Grid No. 2 (Screen grid)
Pin 5 Diode No. 2
Pin 6 Diode No. 1
Pin 7 Cathode, Grid No. 3 and internal shields
Pin 8 Heater
Cap Grid No. 1

* With no additional external shield.

PENTODE UNIT

Maximum Ratings, Design-Centre Values

Plate voltage	300 max.
Grid No. 2 (Screen) voltage	125 max.
Grid No. 2 Supply voltage	300 max.
Plate dissipation	2.25 max. watts
Screen dissipation	0.35 max. watts
Grid No. 1 (Control grid) voltage	
Negative bias value	0 min. volts
Peak Heater-Cathode voltage:	
Heater negative with respect to cathode	90 max. volts
Heater positive with respect to cathode	90 max. volts

Typical Operation and Characteristics—

Class A1 Amplifier

Plate voltage	250 volts
Grid No. 2 voltage	100 volts
Grid No. 1 voltage	–2.0 volts
Transconductance	2500 micromhos
Grid No. 1 voltage (approx.) for a transconductance of 20 micromhos	–25 volts
Plate current	7.0 mA
Grid No. 2 current	1.8 mA
Plate resistance	1.2 megohm

DIODE UNITS

The two diode plates are placed around a cathode, the sleeve of which is common to the pentode unit. Each diode plate has its own base pin. The minimum diode current per plate with an applied d.c. voltage of 10 volts is 0.8 milliampere.

New RCA Release

Radiotron type 5825

The 5825 is a new, half-wave, rectifier valve designed for use in r-f operated, high-voltage, low-current power supplies. It is suitable for industrial and other applications requiring a rectifier having higher voltage-handling capability than the Radiotron 1B3-GT. Operation at full ratings is permissible up to 250 kilocycles.

The 5825 is rated to withstand a maximum peak inverse plate voltage of 60000 volts, and to pass a maximum d.c. output current of 2 milliamperes.

Among the design features of the 5825 which make it particularly suitable for use as a rectifier in compact, high-voltage equipment, is its thoriated-tungsten filament requiring only 2 watts. The filament can conveniently be isolated from ground by operating it either from a separate winding on an r-f transformer or from a resonant transformer excited by the capacitance current through the valve.

A single 5825 in a half-wave circuit is capable of supplying a maximum d.c. output voltage of about 27000 volts at the rated output current of 2 milliamperes. In a voltage-doubler circuit, two 5825's will give about 54000 volts; and in a voltage-tripler circuit, three 5825's will deliver about 81000 volts.

Radio-Frequency Performance of Some Receiving Valves in Television Circuits*†

By ROBERT M. COHEN

Reprinted from RCA Review, March, 1948, Vol. IX, No. 1, by courtesy of the Radio Corporation of America.

SUMMARY—*Several types of receiving valves may be used to advantage in television receivers designed to tune all thirteen channels. This paper discusses the performance of these valve types in radio-frequency amplifier, mixer, and local oscillator applications. Both push-pull "balanced" circuits and single-ended "unbalanced" circuits are discussed. Data are presented for over-all gain, noise, image rejection, and, to a lesser extent, on oscillator frequency stability. These data are taken at two representative channels in the television band: Channel No. 4 (66 to 72 megacycles) and Channel No. 11 (198 to 204 megacycles).*

Introduction

The design of television tuners involves consideration of a number of factors which as yet are not fully evaluated due to lack of sufficient field experience. These factors are briefly described before discussing the performance of valves in specific tuner designs.

An essential requirement of a tuning unit is that the local oscillator produce low radiation. A figure of 0.01 microwatts has been suggested[1] as the maximum tolerable amount of local oscillator radiation that will cause no appreciable radiation interference with receivers fifty feet apart operating in the field-strength region of about 500 microvolts per metre. This requirement is difficult to achieve in practice and necessitates the use of a radio-frequency stage to reduce the transfer of oscillator voltage from the mixer circuit to the antenna. In addition, enclosure of the entire tuning unit in a shield is advisable to prevent direct radiation by the oscillator tank circuit.

The significance of good signal-to-noise ratio is another important consideration in tuner design and performance. There is some evidence that a signal input voltage between ten to twenty times the root-mean-square value of equivalent noise is needed to produce a picture having barely satisfactory entertainment value when the receiver is in a noise-free location. The better the signal-to-noise ratio of a receiver, the more capable it is of satisfactory performance in suburban areas and the less critical the antenna design. In most television tuners, the main portion of the random noise is attributed to the first amplifier valve.[2, 3] Valves which are space-charge limited produce an equivalent noise voltage, referred to the signal grid, which is a function of transconductance. High-transconductance triodes have low noise factors and are valuable as radio-frequency amplifiers at high frequencies.

A third important factor is accurate termination of the antenna system in order to prevent standing waves on the transmission line. It is complicated by the wide frequency range required of a thirteen-channel system. Proper termination of the antenna must be accomplished at the receiver terminals of the transmission line because so-called "wide-range" television antennas present a widely varying impedance at the antenna terminals of the transmission cable. If the antenna is mismatched and the receiver mismatch is of the order of 10 per cent. at the receiver terminals, noticeable loss of high-frequency response in high-fidelity receivers may result. If the mismatch is large and the transmission line is long, double images or ghosts may result. Many designers believe that the elimination of the adjustably-tuned antenna circuit is economically justified and terminate the 300-ohm antenna cable at the input terminals of the first amplifier valve with resistance loading to provide the proper impedance and a fixed inductance to provide a broadly tuned resonant circuit. This loading, of course, adversely affects the noise performance of the receiver, limiting its effective sensitivity. It may also adversely affect the receiver in other ways which are discussed in a later paragraph.

* Decimal Classification: R262 × R593.6.

† This paper was presented in abbreviated form at the Winter Technical Meeting of the I.R.E. in New York City in March 1947, and at the I.R.E. Chicago Engineering Conference in April 1947.

[1] E. W. Herold, "Local Oscillator Radiation and Its Effect on Television Picture Contrast", *RCA REVIEW*, Vol. VII, No. 1, pp. 32-53, March, 1946.

[2] B. J. Thompson, D. O. North, and W. A. Harris, "Fluctuations in Space-Charge-Limited Currents at Moderately High Frequency", *RCA REVIEW*, Vol. IV, No. 3, pp. 269-285, January, 1940.

[3] W. R. Ferris and D. O. North, "Fluctuations Induced in Vacuum Tube Grids at High Frequencies", *Proc. I.R.E.*, Vol. 29, No. 2, pp. 49-50, February, 1941.

Test methods

On the basis of the foregoing considerations, several tuning units were constructed representative of current engineering practice. The minimum bandwidth of the radio-frequency circuits was six megacycles in any channel. Measurements of each unit were made on Channel No. 4 and Channel No. 11 (See Table 2). These are, respectively, the middle channels of the low-frequency and high-frequency television bands. A block diagram of the equipment employed in making these measurements is shown in Figure 1.

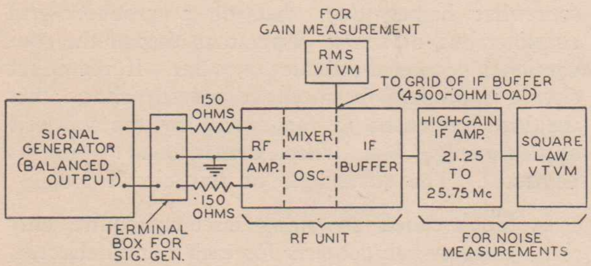


Fig. 1.—Block diagram of test set-up.

Noise measurements were made using a high-gain intermediate-frequency amplifier which had a bandwidth of 4.5 megacycles and was terminated with a square-law vacuum-tube voltmeter. The signal generator employed has a balanced output terminated with a 150-ohm resistor in each conductor. In order to measure the equivalent noise voltage referred to the antenna terminals of the receiver, it is necessary to reduce the output of the signal generator to zero. The value indicated on the meter is proportional to the square of the amplified noise voltage. An unmodulated carrier signal is then applied from the signal generator and its value is adjusted to provide an output indication that is twice that of the noise. The equivalent noise voltage is then equal to the value indicated on the signal generator. The ratio of this equivalent noise voltage to that produced by the thermal agitation noise in the 300-ohm antenna circuit (5.0 microvolts when the bandwidth is 4.5 megacycles) is expressed in decibels as the noise figure. Gain figures are obtained by dividing the output voltage, measured using a 4500-ohm load impedance at the grid of the first intermediate-frequency amplifier, by the value of signal input voltage as indicated on the signal generator.

The possibility of including channel switches in these experimental tuning units was given consideration. However, channel switches and their connecting leads or continuously variable inductors introduce additional circuit reactances which would vary with each design.

Balanced push-pull circuits

The circuit shown in Figure 2 is of the balanced type consisting of a neutralized push-pull 6J6 radio-frequency amplifier followed by a 6J6 mixer with push-pull grids and parallel plates. The local oscillator is also a 6J6 connected in push-pull in a conventional Hartley circuit.

The advantages of this arrangement can be summarized as follows:

1. Common cathode connection for push-pull operation cancels the inductive reactance of the cathode lead thereby reducing degeneration.
2. Push-pull mixing allows rejection of certain spurious responses.
3. The fixed-tuned extremely broad input circuit affords good antenna match and reduces cost of channel switch by eliminating two tuned circuits.
4. Push-pull circuits do not require switching at high-current points of circuit.
5. Uniform performance from 44 to 216 megacycles is obtained.
6. The absence of radio-frequency current in ground return leads permits greater flexibility of mechanical design.

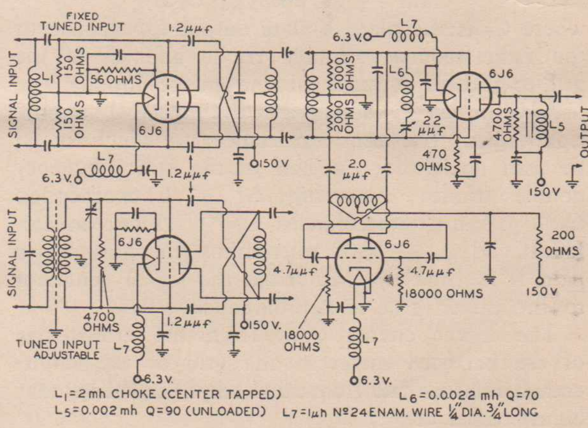


Fig. 2.—Push-pull radio-frequency amplifier, oscillator, and balanced-input mixer.

The disadvantages of this circuit arrangement are:

1. The circuit requires an intermediate-frequency trap in mixer grid circuit.
2. The circuit may require a narrow-band mixer plate circuit so that the trap in the mixer grid will be effective.
3. Minimum of six switch-contact points per channel is needed.
4. There is a large amount of local oscillator radiation when the radio-frequency amplifier is unbalanced.
5. An unbalanced (push-push) component of local oscillator voltage at the mixer grids is readily passed through the capacitance of the radio-frequency stage to the antenna lead causing additional radiation.

The alternate adjustably-tuned input arrangement given in Figure 2 (see also Table 3) offers improved signal-to-noise ratios but at the expense of requiring additional tuned circuits. These circuits add to the complexity of the selector switches and also increase the possibility of antenna mismatch and the attendant reflections. In addition, neutralization of the radio-frequency amplifier is more critical.

The over-all measured gain (i.e., ratio of intermediate-frequency grid voltage to signal generator voltage) of the tuning unit shown in Figure 2 is 60. The distribution of the over-all gain is approximately: radio-frequency amplifier, seven to ten; mixer, six to eight. The equivalent noise is approximately 13 decibels above the theoretical minimum value attributed to the thermal effect of a 300-ohm resistor. The image-rejection figure for this system is 35 decibels.

When the tuned-input circuit is used, the gain is increased to approximately 120. The equivalent noise is reduced to 6 decibels and the image rejection is improved to 45 decibels.

A computation of gain from the grid of the untuned radio-frequency amplifier stage to the grid of the mixer is given approximately by

$$\text{Gain} = g_m / 2\pi\Delta f \sqrt{C_1 C_o}$$

where C_o is the plate-to-plate output capacitance of the radio-frequency double triode and C_1 is the grid-to-grid capacitance of the mixer input. The bandwidth, Δf, is measured at the 3-decibel attenuation points. The transconductance, g_m, which should be used is that for one-half of the radio-frequency double triode. Assuming $\Delta f = 6$ megacycles, $C_o = 6.5$ micromicrofarads, $C_1 = 7.5$ micromicrofarads and $g_m = 5300$ micromhos, the grid-to-grid gain is 20, and the gain from the signal generator to the mixer grid is approximately 10.

The mixer circuit gain, from the grid-to-grid of the balanced mixer to the grid of the single-ended intermediate-frequency amplifier valve may be expressed as

$$\text{Gain} = g_c R_L$$

where R_L is the impedance of the mixer plate circuit (4500 ohms) and g_c is the conversion transconductance of each half of the 6J6. Assuming the latter to be one-quarter of the transconductance, or 1325 micromhos, the gain is 6.

The over-all gain is the product of the individual stage gains and is thus equal to 60, which is in exact agreement with the measured values.

The equivalent thermal-agitation noise voltage for the 300-ohm dummy antenna is 5.0 microvolts for a bandwidth of 4.5 megacycles. The measured value of equivalent noise voltage is 21 microvolts. Thus, the noise figure is

$$20 \text{ Log}_{10} \frac{E \text{ measured}}{E\ 300\Omega} = 20 \text{ Log}_{10} \frac{21}{5} = 13 \text{ decibels}$$

It was found that the particular tuned input circuit used, increased the signal voltage and the antenna noise voltage equally, and by a factor of 2. Since the noise attributable to the valve does not materially increase, one would expect the signal-to-noise ratio to be improved by a factor of nearly two, making the noise figure for the tuned input circuit approximately 7 decibels above the thermal noise of the 300-ohm antenna. The 6-decibel value actually measured is in good agreement with the predicted value.

Unbalanced circuit

A radio-frequency unit* utilizing a single-ended 6AG5 mixer driven by a pentode radio-frequency amplifier having an unusual type of balanced input circuit is given in Figure 3 (see also Table 4). The input impedance of the radio-frequency amplifier is somewhat higher than that of a grounded-grid amplifier but, of course, lower than that of the conventional grounded-cathode amplifier. If the input circuit is properly balanced, it is easily shown that the load presented to the circuit by the valve is approximately $2/g_k$ when transit-time loading is neglected. The advantages of this circuit are:

1. Single-ended switching circuits require only three switch contacts for each station selected.
2. Local oscillator radiation is lower than that provided by the circuit shown in Figure 2 and is not critical as to balance.
3. The broad, fixed-tuned input circuit (substantially non-reactive termination) aids in preventing reflections.

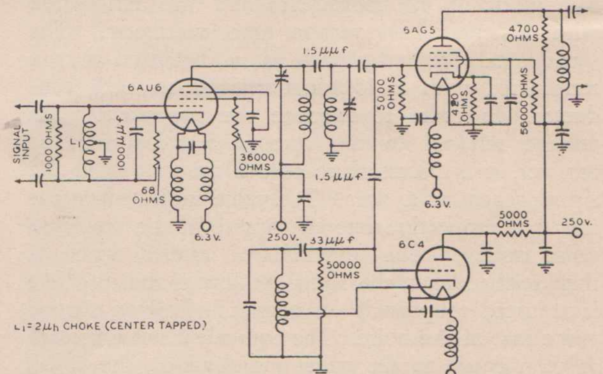


Fig. 3.—Radio-frequency unit, unbalanced circuit.

The disadvantages are:

1. Pentode valves produce more noise than triodes.
2. Lower gain is obtained than with push-pull twin triodes.
3. The transconductance available per valve may be less than that obtainable with twin triodes when the triodes are used in parallel.
4. The unbalanced mixer-grid circuits permit reception of more spurious responses than do push-pull mixers.

* The input circuit is a development of R. Romero, Industry Service Laboratory, RCA Laboratories Division, New York, N. Y.

5. Non-uniform performance from 44 to 216 megacycles is obtained with available pentodes.

The over-all measured gain of this system, when a 6AU6 is used as the radio-frequency amplifier, a 6AG5 as the mixer, and a 6C4 as the local oscillator, is 30 at Channel No. 4 and 25 at Channel No. 11. The noise figure is approximately 20 decibels at both frequencies. The image-rejection values for this circuit are 35 decibels at Channel No. 4 and 30 decibels at Channel No. 11. The 6BA6 may also be used in this circuit as a radio-frequency amplifier but, due to its lower transconductance will give slightly lower gain.

The gain of the 6AU6 radio-frequency amplifier (i.e., ratio of grid-to-ground voltage on the mixer to grid-to-cathode voltage of the radio-frequency amplifier) is calculated below. Even though there is signal impedance between cathode and ground, the full value of g_m is used because the input signal is applied between grid and cathode, and not between grid and ground.

Gain (for the 6AU6) $= g_m/2\pi\Delta f\ \sqrt{C_o C_i} = 10$

where g_m, the 6AU6 mutual conductance, is equal to 5200 micromhos, C_o is the plate-to-ground output capacitance of 14 micromicrofarads, C_i is the grid-to-ground mixer input capacitance of 14 micromicrofarads, and Δf is the bandwidth, 6 megacycles, to the 3-decibel attenuation points.

Because there is an antenna-termination loss of 6 decibels with the matched-impedance input, the gain from the signal generator to the plate circuit of the radio-frequency amplifier is 5.

The gain from the grid of the 6AG5 mixer to the grid of the intermediate-frequency amplifier is given approximately by

Gain $= g_c\ R_L = 1250 \times 10^{-6} \times 4500 = 5.6$

where R_L is the impedance of the mixer plate circuit (4500 ohms) and g_c is the conversion transconductance of the 6AG5, assuming the latter to be one-quarter of the transconductance or 1250 micromhos.

The over-all gain is $5 \times 5.6 = 28$ which checks reasonably well with the measured values given above.

The measured value of equivalent noise voltage is approximately 45 microvolts or 20 decibels above the thermal noise of a 300-ohm antenna.

Grounded-grid radio-frequency amplifier and cathode-coupled mixer

A circuit using a twin triode as a grounded-grid radio-frequency amplifier working into a second twin triode used as a cathode-coupled mixer[4] is given in Figure 4 (see also Table 5). The antenna matching transformer used in this investigation required three changes in tap positions in the low-frequency bands and two in the high-frequency ones. The advantages of this circuit are:

1. It requires fewer switch contacts than double-ended circuits.
2. This circuit has less oscillator radiation than any of the others.
3. Oscillator injection is accomplished by means of a separate grid thereby requiring less critical excitation adjustment.
4. The fixed-tuned input circuit affords non-critical antenna match.
5. Low noise from triode valves results in higher signal-to-noise ratio.
6. Uniform performance from 44 to 216 megacycles is obtained.

The disadvantages are:

1. Lower gain for each stage than that obtained from push-pull twin triodes.
2. Input circuit requires more additional switch contacts than circuit shown in Figure 3.

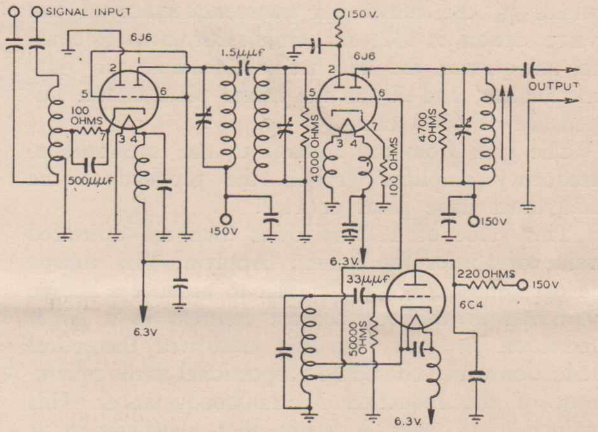


Fig. 4.—Radio-frequency unit with grounded-grid triode radio-frequency amplifier, twin-triode cathode-coupled mixer, and triode oscillator.

The gain of this circuit is uniform over the frequency range of the television band and is approximately 15. The noise figure is 8 decibels at Channel No. 4 and 9 decibels at Channel No. 11. Image rejection is approximately 40 decibels at both channels.

The use of both halves of the 6J6 in parallel as a grounded-grid radio-frequency amplifier is not desirable because the valve does not have sufficient plate-to-cathode shielding for this application. The 6J4 is recommended for use in this circuit in television receivers in which higher valve cost is justified. When the 6J4 is substituted for the 6J6 radio-frequency amplifier, the gain is increased to 30 and the noise figure is improved to 6 decibels in both channels. The image rejection is not measurably changed.

The calculated gain of the grounded-grid radio frequency amplifier measured from the antenna to the grid of the mixer is calculated as shown below.[5]

[4] G. C. Sziklai and A. C. Schroeder, "Cathode-Coupled Wide Band Amplifiers", *Proc. I.R.E.*, Vol. 33, No. 10, pp. 701-709, October, 1945.

[5] M. C. Jones, "Grounded Grid Radio-Frequency Voltage Amplifiers", *Proc. I.R.E.*, Vol. 32, No. 7, pp. 423-429, July, 1944.

$$\text{Gain} = \frac{1}{4\pi\Delta f \sqrt{C_o C_i}} \sqrt{\frac{g_m}{R_{ant}}} = 3.7.$$

In this equation Δf, the bandwidth measured at the 3-decibel attenuation points, is 6 megacycles, C_o is the radio-frequency amplifier plate-to-ground output capacitance of 14 micromicrofarads, C_i is the mixer grid-to-ground input capacitance of 16 micromicrofarads, R_{ant} is the antenna transmission line impedance of 300 ohms, and g_m, the transconductance of one section of the 6J6, is 5300 micromhos. It was not possible to use both halves of the 6J6 in a grounded-grid circuit because of excessive regeneration.

The calculated gain of the cathode-coupled twin-triode mixer from the mixer grid to the intermediate-frequency amplifier grid is approximately[4]

$$\text{Gain} = g_c R_L/2 = 3.0$$

where g_c, the conversion transconductance of one valve section, is 1325 micromhos, assuming g_c equal to one-quarter the 6J6 transconductance of 5300 micromhos; and R_L is the mixer plate circuit impedance of 4500 ohms.

The gain from the antenna to the intermediate-frequency amplifier grid is the product of the individual stage gains or 11.2.

This value of 11.2 is lower than the measured value of 15 for the system. Applying bias voltage to the radio-frequency amplifier to produce a known variation in transconductance resulted in a larger reduction in gain than the calculated theoretical reduction which should be proportional to the square-root of the reduction in transconductance. This reduction in gain indicates that regeneration is present in the radio-frequency amplifier, although not to such an extent as to produce instability.

Oscillator design

The problems of local oscillator design are similar in all of the circuits described. Type 6J6 works well as a push-pull oscillator in circuits using push-pull mixers or in applications where high power output is necessary in order to excite the mixer valve sufficiently. Type 6C4 is suitable for use in single-ended circuits having efficient oscillator injection. In circuits where the cathode is tapped on the oscillator grid coil, radio-frequency chokes should be placed in series with the oscillator heater leads and the heater should be by-passed to the cathode to reduce microphonics. Ceramic sockets or mica-filled rubber-wafer sockets are recommended for use with the oscillator valve to reduce frequency drift during warm-up. When the valves are used in oscillator circuits similar to those described in this paper, the warm-up drift expressed as a change of capacitance across the oscillator tank circuit is approximately 0.025 micromicrofarads for type 6J6 and 0.009 micromicrofarads for type 6C4.

Interference effects with fixed-tuned-input circuits

Several of the circuits described in this paper employ a very broad fixed-tuned antenna-input circuit. Although the use of such circuits reduces antenna matching problems and reduces the cost of the receiver, interference effects may be severe. The use of the input circuit of Figure 3 is beneficial in reducing the interference effect. Strong signals on the grids of the radio-frequency amplifier will cause the valve to generate undesired harmonics. If the plate circuit of the radio-frequency amplifier resonates at a frequency which is a multiple of the interfering signal, strong interference will result. For example, a receiver tuned to the upper-frequency channels would be subject to second-harmonic interference generated by strong frequency-modulated signals operating in the 88 to 108 megacycle band. The push-pull radio-frequency amplifier circuit will not generate strong even-order harmonics, but will be susceptible to strong signals whose frequency is one-third that of the desired signal. One of the important advantages of the grounded-grid radio-frequency amplifier is that it is less susceptible to harmonic generation because of the degeneration introduced by the impedance in the cathode circuit.

Table 1—Summary of Test Results

Circuit	Measured Gain* Channel No. 4	Measured Gain* Channel No. 11	Image Rejection (decibels) Channel No. 4	Image Rejection (decibels) Channel No. 11	Noise Figure (decibels) Channel No. 4	Noise Figure (decibels) Channel No. 11
Figure No. 2						
6J6 Fixed-tuned Input	60	60	35	35	13	13
6J6 Adjustably Tuned Input	120	120	45	45	6	6
Figure No. 3						
6AU6 Grid-Cathode Input	30	25	35	30	20	20
Figure No. 4						
Grounded Grid Radio-Frequency Amplifier and Cathode-Coupled Mixer 1/2 6J6 Radio-Frequency Amplifier	15	15	40	40	8	9
Figure No. 4						
With 6J4 Radio-Frequency Amplifier	30	30	40	40	6	6

* Measured gain figures are obtained by dividing the mixer intermediate-frequency output voltage developed across a 4500-ohm load, by the value of signal input voltage as indicated on the signal generator using a 300-ohm dummy antenna. (See Figure 1).

Table 2—Television Channel Assignments

Channel No.	Channel Frequency (Megacycles)	Oscillator Frequency (Megacycles)
1*	44-50	71
2	54-60	81
3	60-66	87
4	66-72	93
5	76-82	103
6	82-88	109
7	174-180	201
8	180-186	207
9	186-192	213
10	192-198	219
11	198-204	225
12	204-210	231
13	210-216	237

Picture carrier is placed 1.25 megacycles above low-frequency edge of band. Sound carrier is placed 5.75 megacycles above low-frequency edge of band. Thus, in Channel No. 1, picture carrier is 45.25 megacycles and sound carrier is 49.75 megacycles.

(* Will probably be assigned by Federal Communications Commission (U.S.A.) to services other than television.)

Table 3—Operating Conditions for Circuit of Figure 2

	Radio-Frequency Amplifier 6J6	Mixer 6J6	Oscillator 6J6	
Plate Supply Voltage	150	150	150	volts
Plate Current	10*	9†	12*	milliamperes
Grid Voltage	−1.2	−4.5	−19*	volts
Grid Current	—	0.1**	1.1	milliamperes

* Per triode unit.
** Per triode unit with oscillator on.
† Plates in parallel.

Table 4—Operating Conditions for Circuit of Figure 3

	Radio-Frequency Amplifier 6AU6	Mixer 6AG5	Oscillator 6C4	
Plate and Grid — No. 2 Supply Voltage	250	250	250	volts
Plate Current	11	6	11	milliamperes
Grid-No. 2 Voltage	95	150	—	volts
Grid-No. 2 Current	4.3	1.8	—	milliamperes
Grid-No. 1 Voltage	—	−4.25	−25	volts
Grid-No. 1 Current	—	20	500	microamperes

Table 5—Operating Conditions for Circuit of Figure 4

	Radio-Frequency Amplifier 6J6	Mixer 6J6	Oscillator 6C4	
Plate Supply Voltage	150	150	150	volts
Plate Current	9.5†	10.2* 10.5**	11	milliamperes
Grid Voltage	−1	−2	−10	volts
Grid Current	0	‡	0.2	milliamperes

* Input triode unit.
** Output triode unit.
† Per triode unit.
‡ Not measured.

New Modulator Circuit Utilizes 807's in Class B With Zero Bias*

By A. M. SEYBOLD

Devices and arrangements shown or described herein may use patents of RCA and others. Information contained herein is furnished without responsibility by RCA for its use and without prejudice to RCA's patent rights.

During the intervening years since its development by RCA back in 1936, the 807 has become the Amateurs' favorite r-f transmitting valve. However, comparatively little use has been made of its excellent class AB_2 characteristics in a-f modulator service, perhaps because of the difficulties encountered in providing the required regulation of control-grid bias and screen-grid voltages.

In order to avoid these difficulties, the possibility of using this valve as a zero-bias triode in class B audio service was intriguing. Its low price, its small size, and its ability to deliver a great deal of power at low plate voltage provided the impetus for a series of experiments. The first idea was to tie the control grid and the screen grid together in a manner similar to the way the old type 46 was operated in zero-bias class B service. This produced a low-perveance triode with a plate family of curves that indicated high distortion and low efficiency.

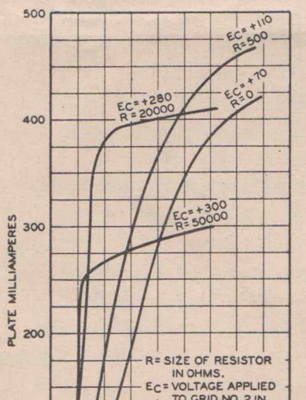


Fig. 1—Effect of the resistor in the No. 1 grid circuit upon EB vs. IB characteristics.

Another idea was to ground the control grids and put the driving signal on the screen grids at zero-bias. This arrangement produced a good plate family, but required excessive driving voltage for satisfactory power output. Several other schemes were tested with varying results and finally there was achieved one-hundred and twenty watts of audio — with less than six watts of driving power — at only 750 plate volts. It is very simple. Just connect

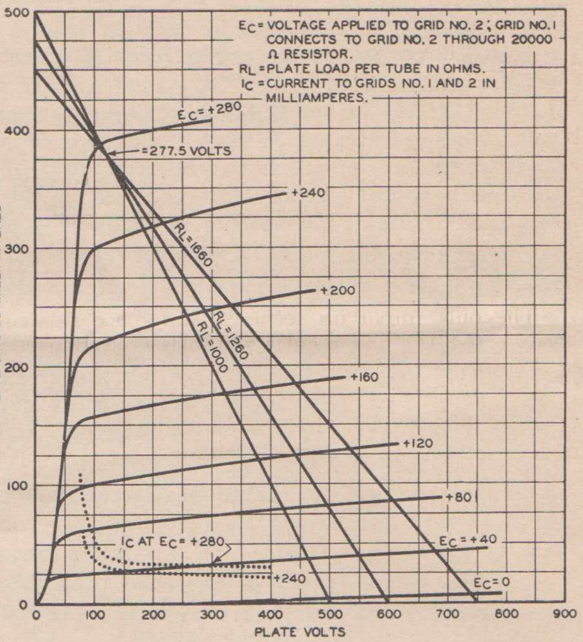


Fig. 2—The 807 plate family with a 20,000 ohm resistor in the No. 1 grid circuit.

the cathodes to the ground, put the driver transformer between the screen grids, and ground the centre tap. Then, connect the control grid of each valve to its screen grid through a 20,000-ohm resistor. During the development of this circuit, plate families were taken with various values of resistance between the No. 2 grid and the No. 1 grid. The series of curves shown in Fig. 1 illustrate the effect of the resistance in the No. 1 grid circuit upon the shape of the diode line. The driving voltage designated *Ec* is that which is applied directly to the No. 2 grid. Low values of resistance give poor knees, but as the resistance is increased, the knees improve, until the optimum condition is reached at about 20,000 ohms.

* In response to numerous requests for information on 807's triode connected in class B, this article is reprinted from Ham Tips by courtesy of the Radio Corporation of America.

With this value, it can be seen from Fig. 2 that a satisfactory plate family is produced. Grid-current curves for the new zero bias connection are shown as dotted lines, and plate load lines are shown for three operating voltages. With a 750-volt supply, a plate-to-plate load of 6600 ohms, and a driving source giving 555 peak volts grid-to-grid, 120 watts of audio are available. The power to drive the grids is greater than that needed for class AB_2, but this is no hardship because a push-pull triode driver will easily furnish the 5.3 watts needed. Figure 3 shows the circuit for driver and output stages used in the tests.

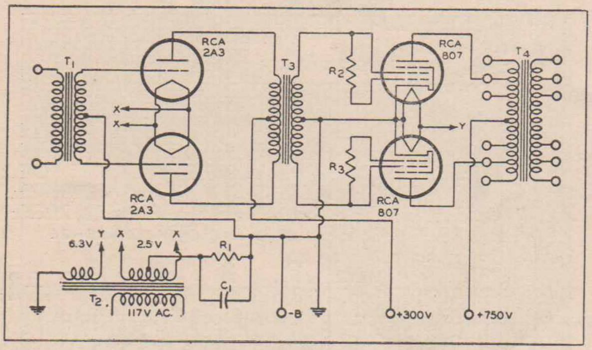


Fig. 3—Schematic for driver and output stages used in the tests.

The only important technical difference between zero bias 807's and regular zero-bias class B triodes is in the values of positive grid impedance. Whereas most of the high-mu zero-bias triodes require low-voltage high-current driving signals, the 807's take excitation at high voltage but with low current.

Computations for driver valves and transformer ratios for the new method of operation are not difficult to make. The 807's present to the driver a fairly constant load applied continuously, so the computations are just a matter of matching impedances. First, it is necessary to select the driver valves and establish a set of conditions for them that will provide at least 20% more output than that required to drive the modulator valves. For example, use a pair of 2A3's, which will give ten watts with a plate-to-plate load of 5000 ohms. The equivalent grid resistance of an 807 operated class B is 7100 ohms, so the driver transformer impedance ratio will be about 1 to 1.4 step-up between total primary and one half secondary (impedance ratio = 7100/5000). This is equivalent to a turns ratio of 1 to approximately 1.2, because the turns ratio is equal to the square root of the impedance ratio (1.18 = $\sqrt{1.4}$).

If your driver transformer doesn't have the required turns ratio in the forward direction, it may be correct when reversed, i.e., with the primary used as the secondary. If this expedient does not work, it will be necessary to get a new driver transformer or a matching transformer to work in conjunction with the one you have. If a public address amplifier is used for a driver, one solution is to use a low-cost universal output transformer rated at 6 watts or more as a matching transformer. With its primary connected to the grids of the push-pull 807's its secondary (use as a primary) will match a wide range of output impedances such as are common to most PA amplifiers.

Radiotron 807's, used as zero-bias class B modulators, will furnish enough high-quality audio to fully modulate a quarter-kilowatt transmitter.

Parts list

T1	Input audio transformer
T2	Filament transformer
T3	Driver transformer
T4	Modulation transformer
R1	780 ohms, 10 watts, wire wound
R2, R3	20,000 ohms, 1 watt, carbon
C1	16 or 20 μF, 100 volt, electrolytic.

REDUCTION IN PEAK-INVERSE VOLTAGE RATING OF TYPE 1B3-GT

R.C.A. application note AN-137; reprinted by courtesy of the Radio Corporation of America.

The maximum peak-inverse voltage for type 1B3-GT should not be permitted to exceed 30,000 volts, on a design-centre basis. Although the original tentative data for this type listed a maximum peak-inverse voltage of 40,000 volts, further experience has indicated that this value should be reduced to 30,000 volts. After prolonged operation with a peak-inverse voltage of 40,000 volts, some valves have developed air leaks caused by deterioration of the glass bulb. The effect observed has been attributed to a combination of electrolysis and bombardment by high-velocity electrons.

This change in rating does not affect existing equipment because current practice in the design of high-voltage supplies has been to use peak-inverse voltages well below 40,000 volts. The new rating of 30,000 volts permits the development of as much as 15,000 volts d.c. at no load from a sine-wave-operated system such as an r-f power supply or almost 30,000 volts from a pulse-operated supply using a single rectifier valve. Considerations of coil design, however, have led most equipment designers to prefer voltage doubler or tripler circuits for d.c. voltages in excess of 10,000 volts.

New Triode Operating Conditions for Radiotron Type 807

A-F POWER AMPLIFIER & MODULATOR— Class AB_1*

Triode Connected—Grid No. 2 Connected to Plate

Maximum Ratings,

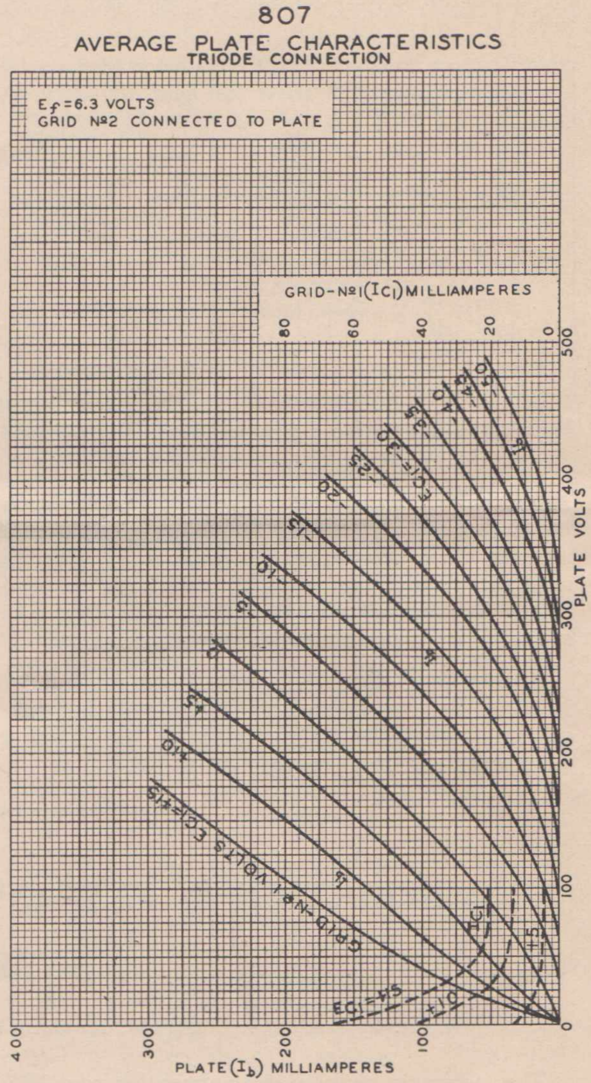
Absolute Values:

	CCS†‡	ICAS§‡	
D.C. Plate Voltage	400 max.	400 max.	volts
Max.-Sig. D.C. Plate Current●	125 max.	125 max.	mA
Plate Dissipation●	25 max.	30 max.	watts
Peak Heater-Cathode Voltage:			
Heater negative with respect to cathode .	135 max.	135 max.	volts
Heater positive with respect to cathode .	135 max.	135 max.	volts

Typical Operation:

Values are for 2 valves.

D.C. Plate Voltage	400	400	volts
D.C. Grid-No. 1 (Control-Grid) Voltage	–45	–45	volts
Peak A-F Grid-No. 1-to-Grid-No. 1 Voltage**	90	90	volts
Zero-Signal D.C. Plate Current	60	60	mA
Max.-Signal D.C. Plate Current	140	140	mA
Effective Load Resistance (Plate-to-plate)	3000	3000	ohms
Max.-Signal Driving Power (Approx.)*	0	0	watts
Total Harmonic Distortion	3	3	%
Max.-Signal Power Output (Approx.)	30	30	watts



‡ In class AB_1 service, the normal design limitation is the requirement that grid-No. 1 current should not flow. For this reason, the typical operating values shown for both CCS and ICAS ratings are the same.

** The driver stage should be capable of supplying the No. 1 grids of the class AB_1 stage with the specified driving voltage at low distortion.

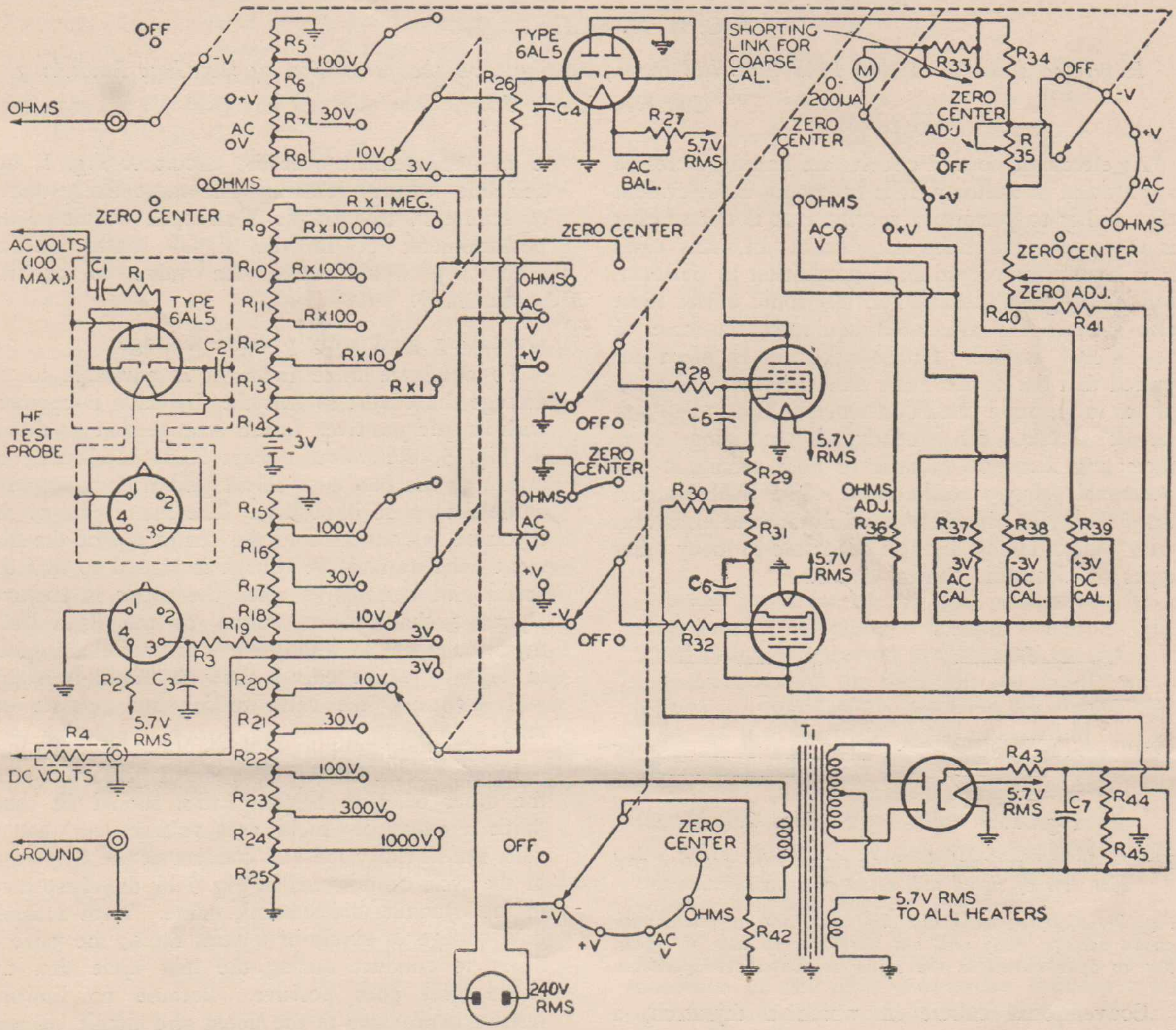
† Continuous commercial service.

§ Intermittent commercial and amateur service.

* Subscript 1 indicates that grid-No. 1 current does not flow during any part of the input cycle.

● Averaged over any audio-frequency cycle of sine-wave form.

AN ELECTRONIC VACUUM-TUBE VOLTMETER



C_1 C_3 = 0.05 μf, oil-filled, 600 v.
C_2 = 47 μμf, ceramic
C_4 C_5 C_6 = 3300 μμf, mica
C_7 = 0.25 μf, tubular, 400 v.
R_1 = 82 ohms, 0.5 watt
R_2 = 2.4 ohms, 1 watt
R_3 R_{19} = 3.9 megohms, 0.5 watt
R_4 = 1 megohm, 0.5 watt
R_5 = 0.12 megohm, 0.5 watt
R_6 = 0.27 megohm, 0.5 watt
R_7 = 0.91 megohm, 0.5 watt
R_8 = 3.3 megohms, 0.5 watt
R_9 = 9.9 megohms ± 1%, 0.5 watt
R_{10} = 90000 ohms ± 1%, 0.5 watt
R_{11} = 9000 ohms ± 1%, 0.5 watt
R_{12} = 900 ohms ± 1%, 0.5 watt
R_{13} = 90 ohms ± 1%, 0.5 watt
R_{14} = 9.5 ohms ± 1%, 0.5 watt
R_{15} = 0.121 megohm ± 1%, 0.5 watt
R_{16} = 0.290 megohm ± 1%, 0.5 watt
R_{17} = 0.830 megohm ± 1%, 0.5 watt
R_{18} = 3.12 megohms ± 1%, 0.5 watt
R_{20} = 7 megohms (two 3.5-megohm ± 1%, 2-watt resistors in series)
R_{21} = 2 megohms ± 1%, 1 watt
R_{22} = 0.70 megohm ± 1%, 0.5 watt
R_{23} = 0.20 megohm ± 1%, 0.5 watt
R_{24} = 70000 ohms ± 1%, 0.5 watt
R_{25} = 30000 ohms ± 1%, 0.5 watt
R_{26} = 8.2 megohms, 0.5 watt
R_{27} = Potentiometer, 20 ohms, 5 watts
R_{28} R_{32} = 3.3 megohms, 0.5 watt
R_{29} R_{31} = 3000 ohms, 0.5 watt
R_{30} = 39000 ohms, 0.5 watt
R_{33} = 3300 ohms, 0.5 watt
R_{34} R_{41} = 18000 ohms, 0.5 watt
R_{35} = Potentiometer, 30000 ohms, 2 watts
R_{36} R_{40} = Potentiometers, 7000 ohms, 2 watts
R_{37} R_{38} R_{39} = Potentiometers, 8000 ohms, 2 watts
R_{42} = 5.6 megohms, 1 watt
R_{43} = 6200 ohms, 0.5 watt
R_{44} = 15000 ohms, 0.5 watt
R_{45} = 20000 ohms, 0.5 watt
T_1 = Power transformer, 100-0-100 volts RMS, dc load current less than 5 ma.

A number of requests have been received for circuit details of a vacuum-tube voltmeter useful for d.c., a.c. and r-f measurements. We reprint herewith with acknowledgments to RCA a suitable schematic diagram. No other details are available and the construction of this specialised instrument should not be attempted except by those with experience in this field. Should the amplifier valves — type 6K6-GT be unobtainable, type 6F6-G can be substituted, with a slight reduction in heater voltage if grid emission is troublesome. Type 6X5-GT is recommended as the rectifier.

Fail-Safe Operation of Electronic Control Circuits

G. D. HANCHETT, JR.*

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As electronic control circuits are finding increased application in industry, it is becoming more evident that ability to perform a specific task is not all that is required of an electronic device. In many cases it is highly important that, in addition to performing its assigned function, an electronic device must also protect the associated equipment in case of operational failure. Furthermore, it is often required that the device make some positive indication of its inoperative condition when it fails. Fail-safe circuit design, consequently, is receiving ever-increasing attention because of both economic and personnel safety considerations. The methods outlined here for the design of a fail-safe thyratron relay-control circuit are also adaptable to many other types of electronic control circuits.

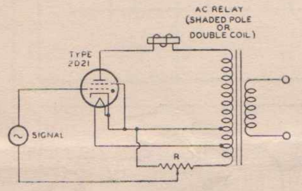


Fig. 1.

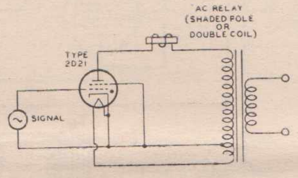


Fig. 2.

Fig. 1—In conventional thyratron circuit with negative grid bias, loss of signal will result in relay operation.

Fig. 2—Applying grid bias 180 deg. out of phase with anode voltage, relay will not operate with loss of signal, but an open circuit in the signal source causes operation.

Conventional circuit in which a thyratron, a RCA-2D21 in this case, is connected as a switching valve to control a relay or contactor is shown in Fig. 1. In this circuit anode voltage is supplied by the high voltage winding of a power transformer. The relay or contactor is usually of the shaded pole or double coil type and is connected in series with the thyratron anode. The valve is kept from conducting by applying to the control grid either a negative d.c. signal or an a.c. signal that is 180 deg. out of phase with the anode voltage. Although this simple circuit works satisfactorily, it is far from fail-safe. Its outstanding fault, of course, is that loss of signal will result in relay operation.

Another arrangement of this circuit which does provide protection for loss of signal is shown in Fig. 2. In this circuit, a grid bias 180 deg. out of phase with the anode voltage is used and the signal is then required to overcome the bias in order to cause relay operation. Although this circuit is an improvement over the circuit of Fig. 1, undesirable features remain. The most likely source of failure in this circuit is an open circuit in the potentiometer or in the signal source. Either eventuality would cause the valve to conduct continuously.

Operating grid with positive voltage

To eliminate these faults, it is advisable to rearrange the circuit so that the thyratron is operated with its grid positive. In this arrangement, as shown in Fig. 3, the valve is kept from conducting by operating the No. 2 or shield grid slightly negative while the anode is positive. The shield grid of the thyratron is connected to the centre tap of the filament winding and the voltage is phased so that the shield grid is negative when the anode is positive. Dynamic characteristic curves of the RCA-2D21 thyratron used as a positive grid valve are given in Fig. 4. These curves show that loss of signal will *not* cause the valve to fire and operate the relay.

In the circuit of Fig. 3, a shield grid voltage in the order of 3 to 6 volts r.m.s. should be used. With a value of shield grid voltage less than 3 volts r.m.s., the valve will conduct at the beginning of the cycle as indicated in Fig. 5 by the sharp drop in the dynamic characteristic curve. With a shield grid voltage in excess of 6 volts r.m.s., the valve is likely to conduct during the half cycle that the shield grid goes positive. Because no limiting resistor is provided in the shield grid circuit, damage to the thyratron would result.

If signal voltages of large magnitude were available, in-phase control grid bias would not be required. In most cases, however, it is desirable to obtain maximum sensitivity. In order to operate the thyratron at maximum sensitivity, an in-phase bias control resistor *R* is utilized. This resistor provides sufficient bias voltage so that a signal of a volt or two will be ample for the thyratron throughout its life. The potentiometer for controlling the in-phase bias on the control grid also provides bias adjustment when a new valve is placed in service.

As a thyratron ages, the critical grid voltage advances in the positive direction. Therefore, with a positive-grid circuit the advance causes the valve to require more signal for conduction and, of course, eventually when the signal used is not sufficient to fire the valve, the circuit will fail-safe.

In the circuit of Fig. 3, the relay or contactor in the anode circuit has no shaded pole and is shunted

* Tube Department, Radio Corporation of America.

with an *RC* filter. This filter is another fail-safe feature. If the inverse impedance of the thyratron becomes low because of inverse breakdown or a short circuit, an a.c. component of voltage would appear across the relay but the current would be shunted through the *RC* filter and the relay would, therefore, remain de-energized.

Even though the circuit of Fig. 3 provides protection against failure of signal voltage, it has other features that are not desirable for fail-safe operation. For instance, if a short occurs in the shield grid circuit, the shield grid bias is lost and the relay closes whether or not the signal is present. A circuit which is protected against this type of fault is shown in Fig. 5. In this circuit, the anode return is made through the shield grid of the thyratron. This arrangement is possible because the RCA-2D21 has two shield grid leads. With this arrangement, a short-circuit between shield grid pin 5 or 7 and cathode pin 2 would result in a safe condition because the connection between the cathode and base pin inside the thyratron is a thin nickel strip which would burn out when connected directly across the 3.15-volt section of the filament winding. If the transformer is designed so that under short-circuit conditions at least 10 amp will flow, enough current is available to burn out the thin nickel between base pin and cathode and thereby open the cathode circuit. In addition, a heater-cathode short between pins 2 and 4 would also result in fail-safe operation, although in this case the heater would probably burn

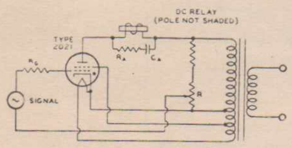


Fig. 3.

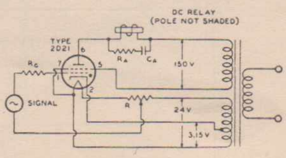


Fig. 4.

Fig. 3—Operating the valve with positive grid prevents operation in event of loss of signal. Bias voltage is critical, however, and must be adjustable.

Fig. 4—Dynamic characteristics of the RCA-2D21 thyratron used in a positive grid circuit. Loss of a positive signal will not cause the valve to fire.

open. Heater-cathode leakage, on the other hand, will have little or no effect upon the operation of the circuit until the condition is so severe that the heater actually burns out. Any open element in the thyratron circuit will cause the circuit to fail-safe because each valve element must carry current for proper operation.

If either end of the potentiometer *R* were to open, the circuit would fail-safe because an open heater circuit would result and the thyratron would lose its emission. In order to make sure that the in-phase a.c. control grid bias is present, the heater current is passed through the potentiometer control. Opening of the potentiometer arm would, therefore, remove the a.c. in-phase bias voltage from the control grid. Because this grid voltage must be positive in order to obtain valve conduction, its removal results in fail-safe operation.

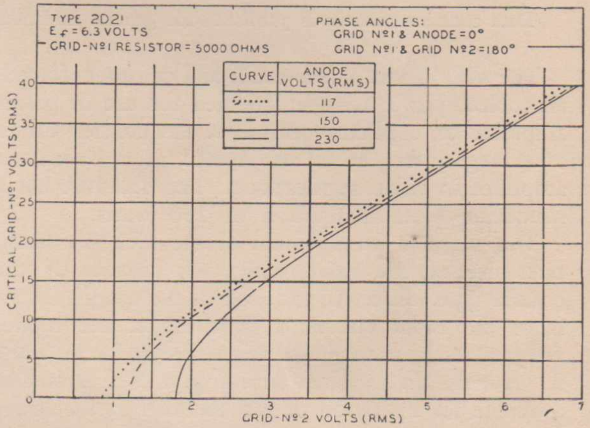


Fig. 5—When the anode return is made through the shield grid, a short occurring in the shield grid circuit will burn through the cathode lead and cause the circuit to fail-safe.

When the value of the grid resistor can be less than about 5000 ohms, a fail-safe condition results when the grid is shorted to the anode because a low impedance shunts the thyratron and insufficient d.c. current is available to operate the relay. The occurrence of this particular fault, however, is not very likely since the anode lead of the RCA-2D21 valve is shielded with a small ceramic sleeve which insulates the anode from other elements outside of the valve structure. Within the valve structure, it is impossible for the control grid to touch the anode without first touching the shield grid.

If it is desirable to have a higher impedance in the control grid circuit and still retain a fail-safe condition in case of a short-circuit between control grid and anode, a cathode-follower type of circuit should be utilized between the input source and the thyratron. When any extra components are added to a simple circuit such as that of Fig. 5, it is necessary, of course, to be sure that the added items do not alter the circuit in such a way that its fail-safe features are cancelled.

Although it is possible to protect circuits for single faults, a double combination of faults will in some cases prevent fail-safe operation. However, if good design principles are utilized and high quality components used, two or more faults occurring at precisely the same instant are very unlikely. Because complete fail-safe conditions may not be required for many applications, the designer should first determine what degree of fail-safe operation is necessary. There are many simple arrangements which cause no additional expense that can be used to protect a circuit. These, of course, should be given first consideration. They include, first, the use of positive grid operation and, second, the technique of returning the anode circuit through the shield grid.

Radiotron Type 4X150A U-H-F Power Tetrode

Reprinted by courtesy of the Radio Corporation of America.

Data contained herein is published for general information. No stocks of this valve are at present held in Australia.

The 4X150A is a very small and compact, forced-air-cooled, power tetrode intended for use in power amplifier or oscillator service at frequencies up to 500 megacycles. It is also useful as a wide-band amplifier in video applications. The 4X150A has a maximum plate dissipation of 150 watts.

The terminal arrangement of the 4X150A facilitates use of the valve with tank circuits of the coaxial type. Effective isolation of the output circuit from the input circuit is provided at the higher frequencies by the contact-ring terminal for grid No. 2. A base-pin termination for grid No. 2 is also available for operation of the 4X150A at the lower frequencies.

GENERAL DATA

Electrical:

Heater, for Unipotential Cathode:

Voltage (a.c. or d.c.)	6.0	volts
Current	2.6	amperes
Minimum Heating Time	30	seconds
Transconductance, for plate volts = 500, grid-No. 2 volts = 250, and plate mA = 250	12000	micromhos
Mu-Factor, Grid No. 2 to Grid No. 1	5	

Direct Interelectrode Capacitances:•

Grid No. 1 to Plate	0.02	μμF
Input	16.1	μμF
Output	4.7	μμF

Mechanical:

Mounting Position	Any
Maximum Overall Length	2.468"
Maximum Seated Length	1.912"
Maximum Diameter	1.645"
Base	Lock-in 8-Pin
Radiator	Integral part of valve

Air Flow:

Through Radiator (For max. plate dissipation) .... 5.6 min. cfm

The specified air flow at a pressure of 0.26 inch of water should be delivered by a blower through the radiator before and during the application of any voltages.

To Base:

Forced-air cooling of the base end of the valve must be provided to limit the temperature of the base seals to the specified value.

Base-Seals Temperature .... 150 max. °C

PLATE-MODULATED R-F POWER AMPLIFIER— Class C Telephony

Carrier conditions per valve for use with a max. modulation factor of 1.0

Maximum CCS° Ratings, *Absolute Values:*

For operating frequencies up to 500 Mc/s

D.C. Plate Voltage	1000 max.	volts
D.C. Grid-No. 2 (Screen) Voltage	300 max.	volts
D.C. Grid-No. 1 (Control-Grid) Voltage	–250 max.	volts
D.C. Plate Current	200 max.	mA
Plate Dissipation	100 max.	watts
Grid-No. 2 Dissipation	15 max.	watts
Grid-No. 1 Dissipation	2 max.	watts

Maximum Circuit Value:

Grid-No. 1-Circuit Resistance ...... 25000 max. ohms

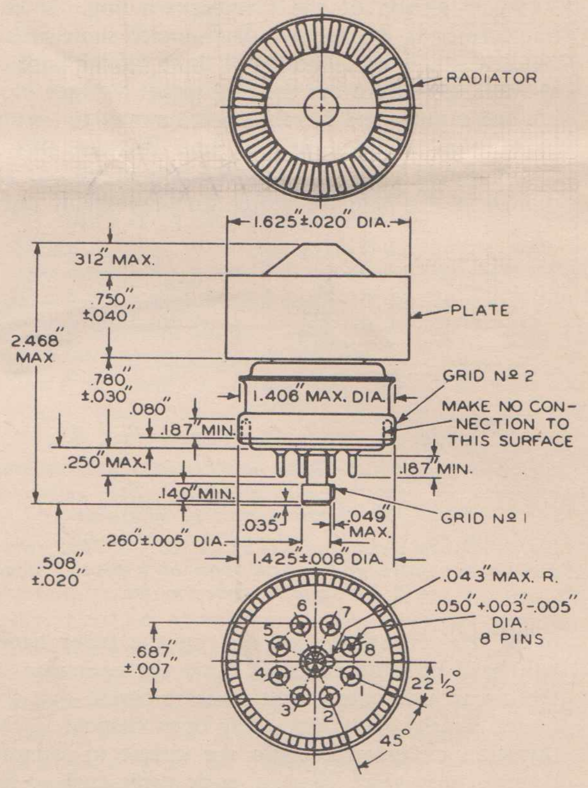
R-F POWER AMPLIFIER & OSC.— Class C Telegraphy‡ and R-F POWER AMPLIFIER—

Maximum CCS° Ratings, *Absolute Values:*

For operating frequencies up to 500 Mc/s.

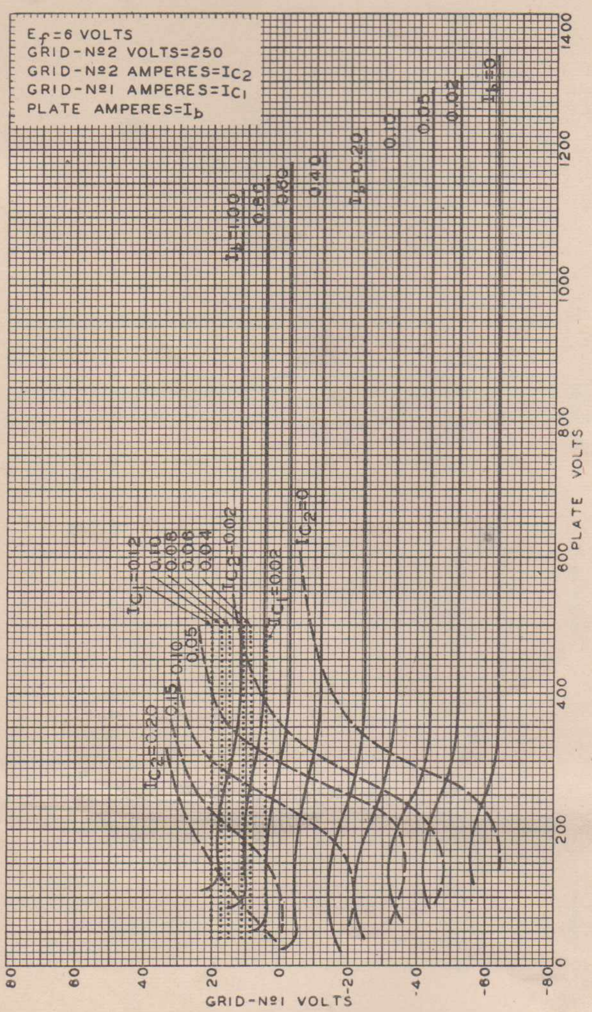
D.C. Plate Voltage	1250 max.	volts
D.C. Grid-No. 2 (Screen) Voltage	300 max.	volts
D.C. Grid-No. 1 (Control-Grid) Voltage	–250 max.	volts
D.C. Plate Current	250 max.	mA
Plate Dissipation	150 max.	watts
Grid-No. 2 Dissipation	15 max.	watts
Grid-No. 1 Dissipation	2 max.	watts

DIMENSIONAL OUTLINE



Typical Operation at Frequencies up to 165 Mc/s.

Heater Voltage	6	6	6	6	volts
D.C. Plate Voltage	600	750	1000	1250	volts
D.C. Grid-No. 2 Voltage	250	250	250	250	volts
D.C. Grid-No. 1 Voltage	–75	–80	–80	–90	volts
Peak R-F Grid-No. 1 Voltage (Approx.)	91	96	95	106	volts
D.C. Plate Current	200	200	200	200	mA
D.C. Grid-No. 2 Current	37	37	31	20	mA
D.C. Grid-No. 1 Current (Approx.)*	11	11	10	11	mA



Average constant-current characteristics of type 4X150A.

Driving Power (Approx.)*	......	1.0	1.1	1.0	1.2 watts
Power Output (Approx.)*	....	85	110	150	195 watts

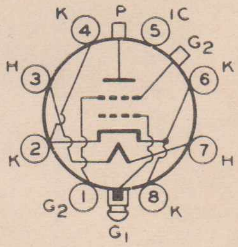
Typical Operation at 500 Mc/s with Coaxial Cavity:

Heater Voltage**	5.2	5.2	5.2	5.2	volts
D.C. Plate Voltage	600	800	1000	1250	volts
D.C. Grid-No. 2 Voltage	250	250	250	280	volts
D.C. Grid-No. 1 Voltage	−110	−110	−110	−115	volts
D.C. Plate Current	170	200	200	200	mA
D.C. Grid-No. 2 Current	6	7	7	5	mA
D.C. Grid-No. 1 Current (Approx.)*	6	10	11	10	mA
Driver Output Power (Approx.)	15	20	25	30	watts
Power Output (Approx.)	50	96	122	140	watts

Maximum Circuit Value:

Grid-No. 1-Circuit Resistance .... 25000 max. ohms

SOCKET CONNECTIONS
Bottom View



PIN 1: GRID No.2 (For use at the lower frequencies)
PIN 2: CATHODE
PIN 3: HEATER
PIN 4: CATHODE
PIN 5: INTERNAL CONNECTION—Do not use
PIN 6: CATHODE
PIN 7: HEATER
PIN 8: CATHODE
RADIATOR: PLATE
CONTACT-RING: GRID No.2 (For use at the higher frequencies)

● With no external shield.

° Continuous Commercial Service.

Key-down conditions per valve without amplitude modulation. Amplitude modulation essentially negative may be used if the positive peak of the audio-frequency envelope does not exceed 115% of the carrier conditions.

* The grid-No. 1 current and driving power required to obtain the desired power output will vary with the plate loading. If the plate circuit presents a relatively low resistance to the valve, the desired output can be obtained with relatively low grid-No. 1 current and driving power, but plate-circuit efficiency is sacrificed. Conversely, if the valve operates into a relatively high load resistance, relatively high grid-No. 1 current and driving power are required to obtain the desired output and the plate-circuit efficiency will be high. In practice, a compromise must be made between these extremes.

In order to permit considerable range of adjustment, and also to provide for losses in the grid-No. 1 circuit and the coupling circuits, the driver stage should have considerably more output capability than the typical driving power shown in the tabulated data. This recommendation is particularly important near the maximum rated frequency where there are other losses of driving power, such as those caused by radiation and transit-time effects.

** The cathode of the 4X150A in u-h-f service is subjected to considerable back bombardment resulting from transit-time effects. This back bombardment raises the temperature of the cathode. The magnitude of the heating due to back bombardment is a function of the operating conditions and frequency, and must be compensated by reduction of the heater input in order to prevent overheating of the cathode and resultant short life. When long life in continuous service is desired, the 4X150A should always be put in operation with full rated heater voltage (6 volts) which should then be reduced to a value depending on the operating conditions and frequency. At 500 Mc/s and with typical operating conditions, the value of heater voltage should be approximately 5.2 volts. At lower frequencies, less reduction in heater voltage is required. After the heater voltage is reduced, circuit readjustment may be necessary.

RADIOTRON RECOMMENDED EQUIPMENT TYPES FOR 1949-1950

	PENTODES Remote Cutoff	PENTODES Sharp Cutoff	CONVERTERS	DIODE TRIODES	DIODE PENTODES	POWER OUTPUT	RECTIFIERS	MISCELLANEOUS
1.4 Volt Batt. Miniatures	**1T4**	—	**1R5**	—	**1S5**	**3S4** **3V4**	—	—
2 Volt Batt. Octal	1M5-G	1K5-G	1C7-G	—	1K7-G	1L5-G 1J6-G	—	1H4-G Triode
6.3 Volt A.C. Miniatures	**6BA6**	**6AU6**	**6BE6**	**6AV6**	—	**6AQ5**	**6X4**	6J6 Twin Triode 6AL5 Twin Diode
6.3 Volt A.C. Types	6U7-G 6SK7-GT	6J7-G 6SJ7-GT	**6A8-G** **X61M**	**6SQ7-GT** —	**6AR7-GT** 6G8-G	**6V6-GT** **KT61** **807**	**6X5-GT** **5Y3-GT** U52/5U4-G	6SN7-GT Twin Triode 6J7-G/1620 Y61 Tuning Indicator
A.C./D.C. Types	W76	—	X76M	DH76	—	KT71	U76	161 Barretter

N.B.—Types underlined are recommended in preference to those not underlined.