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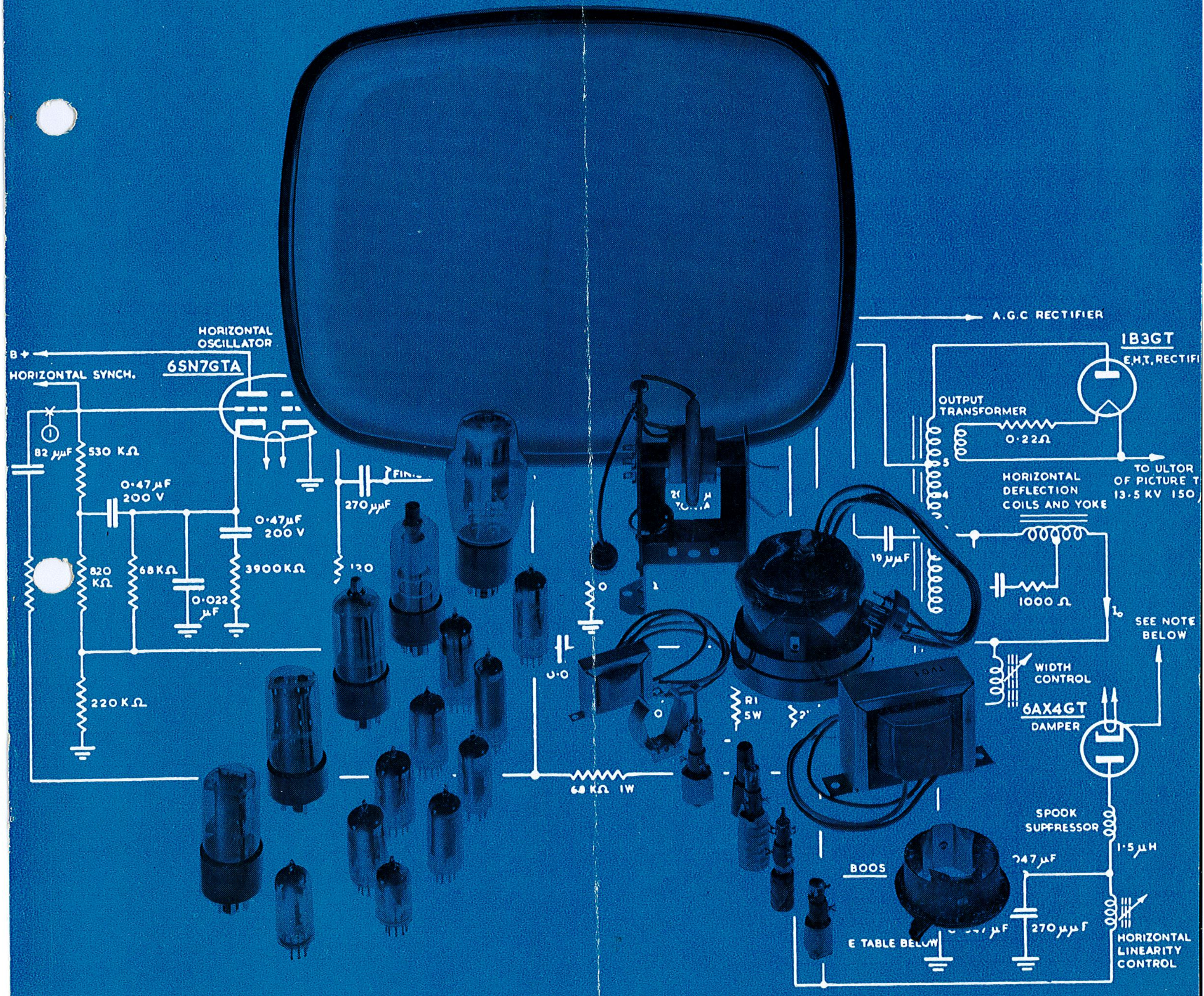

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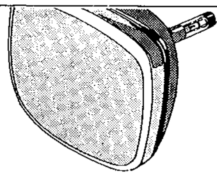

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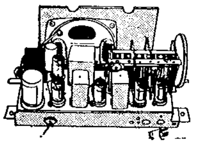

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This article is essentially practical in that it discusses voltage supplies, protective devices, circuit layout, wiring considerations, sockets and ventilation of power valves.

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A SYNC CLIPPER-AMPLIFIER

using the RADIOTRON 12AU7

by P. G. Gonda, A.S.T.C., M.I.R.E. (Aust.) *

Summary.

Circuit description and performance details of a simple sync clipper-amplifier, functioning with positive going video inputs from 8V p-p upwards, are given

INTRODUCTION.

In all modern TV systems the picture intelligence is transmitted by specifying (a) the brightness, and (b) the position of a number of picture elements of the image. **Brightness** is conveyed by amplitude modulation of the transmitted carrier wave; in the Australian system increased carrier amplitude corresponds to a darker picture element. The **position** of the picture element is conveyed basically by sync pulses which ensure that the scanning process at the received picture tube end is in synchronism with that at the camera end.

In other words, the vertical sync pulses transmitted just before the camera "looks" at the top left-hand picture element, and the horizontal sync pulses transmitted just before the camera commences to scan a new line — in conjunction with suitable circuitry in the receiver — ensure that the brightness information transmitted will be assigned to spots on the picture tube screen in a relative position, which will always correspond to that in the original image.

The suitable circuitry referred to is basically the sync clipper — amplifier, which separates the video (or brightness information) from the sync information, the wave shaping circuits, which separate the horizontal and vertical sync pulses, and the deflection oscillators, which — in synchronism with these pulses — produce the sawtooth currents required for magnetic deflection of the electron beam in the picture tube.

Whilst a description of the exact nature of these sync pulses is outside the scope of this article, it should be noted that they are superimposed on "blanking pulses"; i.e., for the duration of sync pulses the picture information transmitted is always "black". This permits separation of the sync pulses from the picture information (video) by clippers with a clipping threshold at (or above) black level. This method is universally used in receiver circuitry and also in the circuit described below.

Regarding the position of the sync clipper in the TV receiver, it is obvious from the above that it will be followed by the horizontal-to-vertical separating circuits, the outputs of which synchronise their respective deflection oscillators.

The input to the sync clipper could be derived from basically 2 points: the video detector or the video amplifier output. The "composite video" (i.e., video, blanking and sync pulses) is present at both points. As the level at the video detector is only 3 to 5 V p-p, it is decidely advantageous to derive the input from the video amplifier output. The level there will be — for a normal picture — 30 to 80 V p-p, depending on the viewing conditions and picture tube characteristics. Under adverse receiving conditions, however, the video amplitude may be as low as 15 V p-p.

GENERAL REQUIREMENTS.

The technical requirements of a sync clipper-amplifier may be summarised as follows:—

a. Its output should consist of sync pulses only — video, blanking pulses and noise should be effectively suppressed to avoid spurious triggering of the deflection oscillators.

b. The output should be sufficient to synchronise positively the deflection oscillators, taking into account the attenuation occurring in the wave shaping networks.

c. The output should be independent of the input provided the latter exceeds 15 V p-p.

d. Whilst the amount of tolerable waveform distortion will depend on the nature of the deflection oscillator, a fast rise time — to ensure accurate synchronisation — is generally important.

* Applications Laboratory, A.W.V. Co.

The circuit described below will effectively separate the sync content from the input video signal and will yield an output of 45 V p-p independent — regarding both amplitude and waveform of the amplitude of the video input, provided this exceeds 8 V p-p. This feature permits taking the input from the video amplifier plate, even when contrast control is effected by varying the gain of same. Tests indicate that the circuit provides a degree of discrimination against ignition type interference adequate for good quality commercial television receivers.

The other function normally associated with synchronizing circuits, namely that of separating and shaping vertical and horizontal sync pulses, will be dealt with only briefly as the nature of these pulses (amplitude, waveform and source impedance) is determined by the succeeding deflection oscillators which are to be synchronised. The 45 V p-p output of the circuit, at a source impedance less than 10,000 ohms, will cater for all currently used deflection oscillators and the wave shaping networks required thereby.

CIRCUIT DESCRIPTION.

Figure 1 shows the circuit of a sync clipper-amplifier using the Radiotron 12AU7 twin triode.

The positive going video signal is applied to the grid of the first triode via a network consisting of R_1, R_2, R_3, C_1 and C_2. R_1 isolates the stray capacities of the circuit from the plate of the video amplifier; R_3 and C_1 — in conjunction with grid current — clamp the positive peaks of the video signal ("sync tips") at earth potential; while R_2 and C_2 form a short time-constant noise filter network.

From Thevenin's theorem the voltage divider type plate load formed by R_4 and R_5 is equivalent to a plate supply voltage of 25 V in series with a resistance of approximately 30,000 ohms (plate load). Under these conditions the cut-off control grid voltage is only —2 V. Therefore, in case of a composite video input of 8 V p-p, the video content will not appear at the plate. The plate voltage swing will be approximately 20 V p-p, from +25 V to +5 V. (See W_1 and W_2, Fig. 2.)

The second stage is cathode biased to 15 V when driven. Thus clipping due to grid current will occur whenever the plate voltage of the first stage exceeds +15 V. This cliipping is effective in removing most of the video content appearing at the plate of the first stage due to grid-plate capacity. (See W_3, Fig. 2.)

The plate supply dividing network of the second stage is equivalent to a plate supply voltage of approximately 90 V in series with a 10,000 ohm plate load resistance. Under these conditions the plate current will be cut off at approximately —7 V control grid-to-cathode voltage. As the cathode potential is held at +15 V, further clipping will take place. The plate voltage swing of the second stage is 45 V p-p. (See W_9, Fig. 2.)

Figure 3 shows an 8 V p-p horizontal blanking and sync pulse and the three levels of clipping effected by the circuit. For simplicity's sake, the pulse has been shown as having equal amplitude whilst passing through the various stages. The actual amplitudes, of course, are those shown in Fig. 2.

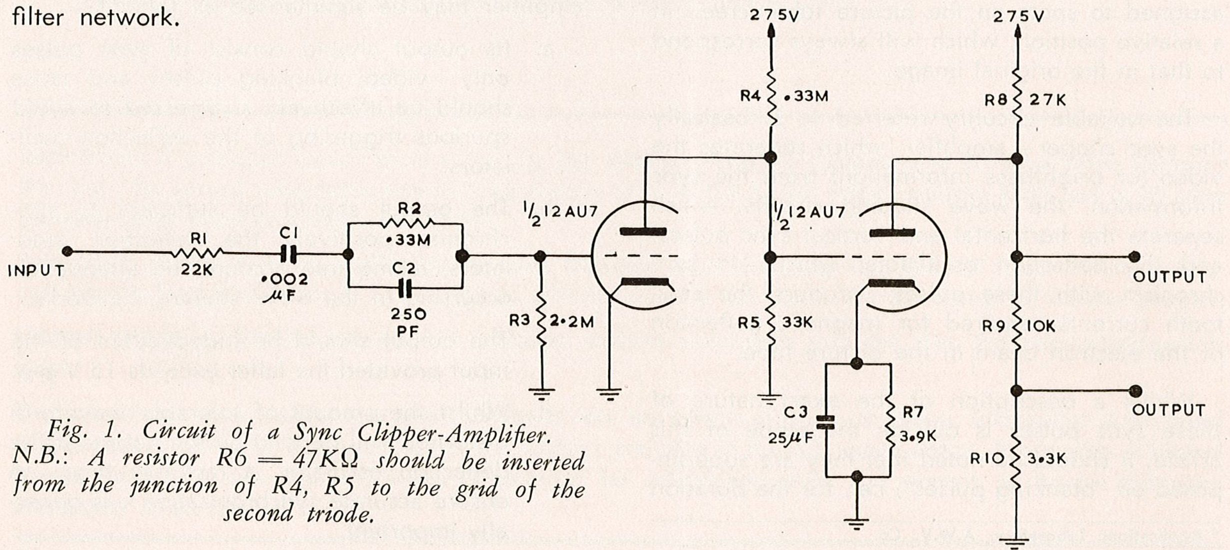


Fig. 1. Circuit of a Sync Clipper-Amplifier. N.B.: A resistor R6 = 47KΩ should be inserted from the junction of R4, R5 to the grid of the second triode.

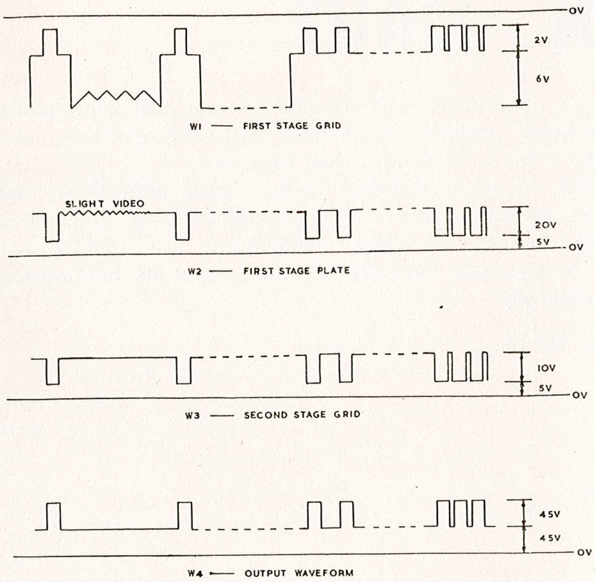


FIG. 2 .. .. .. Waveforms.

PERFORMANCE SPECIFICATION.

Input: 8 V p-p positive going (minimum).

Output: 45 V p-p, positive going, sync tips clipped at +90 V.

Video Content of Output (measured with Marconi Test Pattern Signal).

Input	Video in output relative to 45 V p-p
10 V p-p	0.6%
100 V p-p	6%

Rise Time:**

Input	Rise time
10 V p-p	0.8 micro seconds.
100 V p-p	0.7 micro seconds.

** Time required by the leading edge of the output pulses to rise from 10% to 90% of their final amplitude.

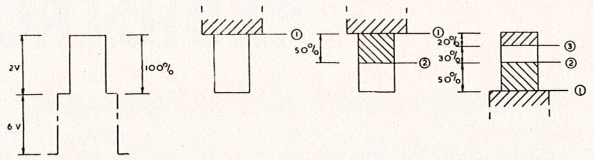


FIG. 3 .. .. ..

Relative Clipping Levels at 8 V p-p (min.) input.

(a) due to cut-off in first stage.

(b) due to grid current in second stage.

(c) due to cut-off in second stage.

PULSE SHAPING CIRCUITS.

As mentioned in the introductory section, the amplitude, waveform, and source impedance of the actual synchronising pulses are largely determined by the deflection oscillators controlled by them.

Figure 4 shows a network which will yield satisfactory performance when used in conjunction with the A.W.V. 70° or 90° deflection circuits using either of the Radiotrons 12BH7 or 6CM7 twin triodes as vertical blocking oscillator and output amplifier, and the Radiotron 6SN7GTA twin triode as horizontal frequency control and oscillator in a "synchroguide" circuit.

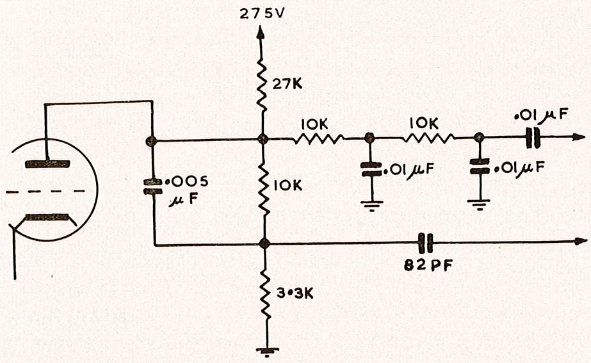
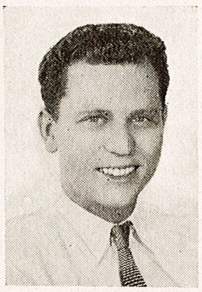


Fig. 4. Wave shaping network suitable for A.W.V. 70° and 90° deflection circuits.

(a) from 0.01 μF — to vertical oscillator valve.

(b) from 82 pF — to horizontal oscillator valve.



Mr. P. Gonda was born in Budapest, Hungary, in 1926. He received the Radio Engineering Diploma (Credit) in 1950. In 1956 he joined Amalgamated Wireless Valve Company. He is at present engaged in developing television circuitry around the Radiotron range of TV receiving valves. Mr. Gonda is a Member of the Institute of Radio Engineers (Australia).

RADIOTRON 12AU7

Radiotron type 12AU7 is a heater-cathode type of medium-mu, twin-triode amplifier featuring a small glass envelope with integral button 9-pin base, separate terminals for each cathode, and a mid-tapped heater to permit operation from either a 6.3 — or 12.6 — volt supply.

Having characteristics which are very similar to those of the larger type 6SN7GTA, the 12AU7 is useful in many diversified applications including multivibrators, synchronising amplifiers, oscillators, mixers and numerous industrial control devices. In such equipment, the 12AU7 can be used to advantage because of its compact size, its separate cathode terminals and its economical consumption of heater power at either of the two voltages.

GENERAL DATA

	Series	Parallel	
Heater arrangement	Series	Parallel	
Heater Voltage	12.6	6.3	volts
Heater Current	0.15	0.3	amp

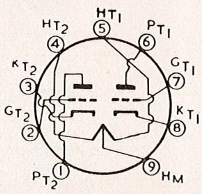
Mounting Position	Any
Maximum Overall Length	2$\frac{3}{16}$"
Maximum Seated Length	1$\frac{15}{16}$"
Length, Base Seat to Bulb Top (Excluding tip)	1$\frac{9}{16}$" + $\frac{3}{32}$"
Maximum Diameter	$\frac{7}{8}$"
Bulb	T6½"
Base	Small button Noval 9-Pin (JETEC No. E9-1)

Direct Interelectrode Capacitances (Approx.):

	Unit No. 1	Unit No. 2	
Without external shield:			
Grid to plate	1.5	1.5	μμF
Grid to Cathode and heater	1.6	1.6	μμF
Plate to cathode and heater	0.4	0.32	μμF
With external shield connected to cathode:			
Grid to plate	1.5	1.5	μμF
Grid to cathode and heater	1.8	1.8	μμF
Plate to cathode and heater	2	2	μμF

Socket Connections

Pin 1 — Plate of Unit No. 2.
Pin 2 — Grid of Unit No. 2.
Pin 3 — Cathode of Unit No. 2.
Pins 4 & 9 — Heater of Unit No. 2.
Pins 5 & 9 — Heater of Unit No. 1.



(bottom view)

Pin 6 — Plate of Unit No. 1.
Pin 7 — Grid of Unit No. 1.
Pin 8 — Cathode of Unit No. 1.
Pin 9 — Heater Mid-Tap.

AMPLIFIER — Class A_1

Values are for Each Unit.

Maximum Ratings. Design-Centre Values:

Plate voltage	300	max.	volts
Cathode current	20	max.	mA
Plate Dissipation	2.75	max.	watts
Peak Heater-Cathode Voltage:			
Heater negative with respect to cathode	200	max.	volts
Heater positive with respect to cathode	200*	max.	volts
Maximum Circuit Values:			
Grid-Circuit Resistance:			
For fixed-bias operation	0.25	max.	megohm
For cathode-bias operation	1.0	max.	megohm

Characteristics,

Plate Voltage	100	250	volts
Grid Voltage	0	−8.5	volts
Amplification Factor	20	17	
Plate Resistance (Approx.)	6500	7700	ohms
Transconductance	3100	2200	μmhos
Plate Current	11.8	10.5	mA
Grid Voltage (Approx.) for plate current of 10 μamp	—	−24	volts

* *The d.c. component must not exceed 100 volts.*

HORIZONTAL DEFLECTION OSCILLATOR

Values are for Each Unit.

Maximum Ratings. Design-Centre Values:

For operation in a 625-line, 25-frame system.

D.C. Plate voltage	300	max.	volts
Peak Negative-Pulse Grid Voltage§	600	max.	volts
Cathode Current:			
Peak	300	max.	mA
Average	20	max.	mA
Plate Dissipation	2.75	max.	watts
Peak Heater-Cathode Voltage:			
Heater negative with respect to cathode	200	max.	volts
Heater positive with respect to cathode	200	max.	volts
Maximum Circuit Values:			
Grid-Circuit Resistance:			
For fixed-bias, grid-resistor bias, or cathode-bias operation	2.2	max.	megohms

§ *This rating is applicable where the duration of the voltage pulse does not exceed 15 per cent of one horizontal scanning cycle. In a 625-line, 25-frame, 15 per cent of one horizontal scanning cycle is 10 microseconds.*

VERTICAL DEFLECTION OSCILLATOR

Values are for Each Unit.

Maximum Ratings. Design-Centre Values:

For operation in a 625-line, 25-frame system.

D.C. Plate Voltage	300	max.	volts
Peak Negative-Pulse Grid Voltage	400	max.	volts
Cathode Current:			
Peak	60	max.	mA
Average	20	max.	mA
Plate Dissipation	2.75	max.	watts
Peak Heater-Cathode Voltage:			
Heater negative with respect to cathode	200	max.	volts
Heater positive with respect to cathode	200*	max.	volts
Maximum Circuit Values:			
Grid-Circuit Resistance:			
For fixed-bias, grid-resistor bias, or cathode-bias operation	2.2	max.	megohms

VERTICAL DEFLECTION AMPLIFIER

Values are for Each Unit.

Maximum Ratings, Design-Centre Values Except as Noted:

For operation in a 625-line, 25-frame system

D.C. Plate Voltage	300	max.	volts
Peak Positive-Pulse Plate Voltage‡			
(Absolute maximum)	1200†	max.	volts
Peak Negative-Pulse Grid Voltage	250	max.	volts
Cathode Current:			
Peak	60	max.	mA
Average	20	max.	mA
Plate Dissipation	2.75	max.	watts
Peak Heater-Cathode Voltage:			
Heater negative with respect to cathode	200	max.	volts
Heater positive with respect to cathode	200*	max.	volts
Maximum Circuit Values:			
Grid-Circuit Resistance:			
For cathode-bias operation	2.2	max.	megohms

* *The d.c. component must not exceed 100 volts.*

‡ *This rating is applicable where the duration of the voltage pulse does not exceed 15 per cent of one vertical scanning cycle. In a 625-line, 25-frame system, 15 per cent of one vertical scanning cycle is 3 milliseconds.*

† *Under no circumstances should this absolute value be exceeded.*

POWER-VALVE INSTALLATION

Because power valves usually operate at high voltages and temperatures, draw heavy currents, and are used in high-efficiency circuits, terminal connections for such valves should have large-area, low-resistance contacts capable of accommodating relatively large wire sizes and utilize high-quality insulation.

Sockets or **mountings** for power valves having filamentary cathodes should be installed, as a general rule, so that the valves are operated in a vertical position with the base or filament end down. Vertical operation minimises the danger of internal short circuits which may be caused by thermal expansion or sagging of the filament. Certain filamentary-cathode vacuum types may be operated in other than vertical positions, provided precautions specified in the valve data are observed. Valves having indirectly heated cathodes may generally be operated in any position.

If equipment is to be subjected to mechanical shock or vibration, the equipment housing, the valve mountings, or both should include some form of shock-absorbing suspension, and suitable means should be employed to lock the valves in their sockets or mountings.

VENTILATION.

Power-valve equipment design should always permit the unimpeded circulation of air around all valves and include provision for adequate ventilation of valve and equipment enclosures so that envelope temperatures will not become high enough to damage the valves or their associated circuit components.

Most valves are designed for operation at maximum ratings with natural convection cooling. Certain types, however, such as the 6161, require forced-air cooling. Other types, such as the 826, 829-B, and 833-A, can be operated with natural convection cooling, but carry substantially higher ratings when forced-air is employed. Maximum permissible bulb temperatures and forced-air flow and pressure requirements are given in the valve data for most types.

The glass portions of a valve envelope should not be exposed to the spray of any liquid or be permitted to come in contact with metal objects such as circuit wiring or grounded metal shields because excessive temperature differences may cause envelope fractures. Shields should not fit so closely as to impede the free circulation of air around the valves. In many cases, they may be designed to produce a "chimney" effect which will increase the draft and improve valve ventilation.

This article is reprinted with acknowledgment to R.C.A. from "R.C.A. Transmitting Tubes".

The maximum permissible bulb temperature of a vacuum valve or inert-gas valve is determined principally by the softening point of the glass employed, or by the point at which gas may be released by the envelope in the case of mercury-vapor valves, both minimum and maximum bulb-temperature limits are specified to assure satisfactory vaporization of the mercury.

WIRING CONSIDERATIONS.

Energy losses in power-valve circuit wiring limit operating efficiencies and may produce undesirable heat. These losses may be caused by conductor resistance (I^2R losses), leakage (E^2/R losses), radiation, or stray coupling.

Excessive I^2R losses in power-valve circuit wiring can be avoided by the use of conductors having adequate current-carrying capacity and the lowest possible resistance, and layouts which permit short, direct, connecting leads. Filament- and heater-circuit conductors are particularly susceptible to large I^2R losses because they carry currents of high average (d.c.) or r.m.s. (a.c.) value, and because their resistance is increased by heat received by direct thermal conduction from the valve filaments or heaters. When an installation requires the use of long filament-supply leads or operation of several high-current valves from a common filament-supply line, these losses may cause filament voltages to decrease below the minimum values specified in the valve data and the valves may be damaged. In such cases, conductors of adequate size should be used to avoid excessive losses or sufficient excess voltage should be provided at the supply to compensate for the resulting losses. In the latter case, means of adjusting the supply voltage and suitable metering facilities should be provided to assure that correct filament or heater voltage is received at all terminals.

Excessive I^2R losses in signal conductors may also cause improper operation and valve damage, particularly in driving circuits where the signal provides the required operating bias as well as protection of the tube. In the selection of signal conductors, consideration must be given to "skin effect", which causes current to concentrate nearer the surface of a conductor as the frequency increases, as well as to the type of circuit and the waveform of the signal current.

A signal conductor should have low resistance at the highest frequency involved, and be capable of carrying the highest peak currents flowing in the circuit with negligible heating. Solid or stranded conductors are suitable for a-f applications, and a special type of multiple-strand conductor called "Litzendraht" for low- and medium-power r-f applications at frequencies up to approximately 3 megacycles per second. At higher frequencies it is advisable to use tubular conductors, which should be silver-plated, if possible, to obtain maximum surface conductivity and to minimise the effects of oxidation.

Leakage (E^2/R) losses are caused primarily by inadequate or improper insulating materials, or by insufficient separation between air-insulated conductors. In the selection of insulating materials for power-valve installations, consideration should be given to the fact that very high peak-signal voltages may be developed in circuits operating at relatively low d.c. potentials. In addition, the type of insulating material used at any point must be suitable for the temperature and frequency involved.

As a general rule, conductors having enamel, plastic, or fabric coverings should be used only in supply circuits and low-frequency signal circuits operating at low voltages. Supply-circuit conductors should be installed in comparatively cool locations as far from signal conductors and unshielded signal components as possible. Such conductors, when completely insulated, may usually be grouped or cabled together on the chassis or framework of the equipment. When high voltages or very high temperatures are involved, it is generally preferable to use bare conductors which are adequately spaced and supported by insulators of suitable mechanical design.

R-F signal conductors, particularly those carrying v.h.f. or u.h.f. currents, should not be insulated, except at points where mechanical support is necessary, because practically all types of surface insulation absorb appreciable energy in the presence of r-f fields. These conductors should be isolated from each other, from circuit components, and from the equipment structure.

Losses of signal energy by **radiation** from circuit conductors increase with current and with the length of the conductors, but usually do not become appreciable until conductor length approaches a substantial fraction of a half-wavelength at the operating frequency. Lead length requires careful consideration in v.h.f. and u.h.f. equipment, however, because of the close relationship between practical conductor dimensions and signal wavelengths.

Stray coupling in circuit wiring may produce out-of-phase signal currents in a conductor. These currents cause degeneration losses. Such losses may be minimised by the use of short, direct, circuit connections. These considerations are discussed below under "Circuit Returns".

Cap or wire bulb terminals such as those used on the 807 and 6524 should never be used to support coils, capacitors, or other circuit components because the resulting mechanical stresses may fracture the bulb seals. Connections to bulb terminals should always be made with soft metallic braid or ribbon, or with other types of conductors having good mechanical flexibility and low electrical resistance. Under no circumstances should connections be soldered to cap or wire bulb terminals because the high temperatures developed may soften or crack the bulb seals. The long, flexible wire terminal leads used on subminiature types such as the 5718, however, may be soldered directly to circuit components, provided speed and care are used to minimise the transmission of heat to the bulb seals.

CIRCUIT RETURNS.

All currents in a power valve (except heater current) originate in and return to the cathode, which is, therefore, a common terminal of all supply and signal circuits associated with the valve. The direct currents drawn by the valve electrodes return to the cathode through the power-supply and bias circuits. Although these circuits also provide return paths to the cathode for signal currents, they usually contain resistive and reactive components which offer considerable impedance to a.c. signals and thus cause substantial loss of signal energy. When a single power supply is used for more than one stage, its internal impedance may also act as a coupling device between stages and thus introduce undesired degeneration or regeneration. These effects may generally be avoided by the use of separate a.c. and d.c. return paths to cathode from each electrode or signal circuit of a valve.

D.C. circuit returns for a power valve employing fixed bias, grid-resistor bias, or a combination of the two, are made to the cathode terminal of the valve. When cathode-resistor bias is used, either alone or in combination with another type of bias, the d.c. circuit returns are usually connected to the more negative terminal of the cathode resistor. If the d.c. voltage drop across the cathode resistor is greater than the bias required, however, the grid circuit d.c. return for the valve may be connected to a tap on the cathode resistor which provides the desired bias voltage. When an r-f choke coil or a resonant network is connected in series with the cathode of a power valve employing fixed or grid-resistor bias, d.c. circuit returns are made in the same manner as when cathode-resistor bias is used. In a filamentary-cathode power valve, the heating current creates a voltage drop in the cathode which is equivalent to a bias voltage equal to about one-half the filament voltage. The polarity and value of this drop must be considered in determining the point to be used for d.c. circuit returns.

When d.c. filament voltage is applied to a filamentary-cathode valve, all d.c. circuit returns should be connected to the negative filament terminal of the valve. The use of this point for d.c. returns provides a small amount of protective bias for the valve because the grid is maintained at a negative potential with respect to the cathode in the event that external bias fails or is accidentally removed.

When a.c. voltage is applied to a filamentary cathode, d.c. circuit returns should be made to the mid-point of the filament or filament-supply circuit to minimise hum. A convenient point for these returns is a centre tap on the supply winding of the filament transformer, or the junction of two equal resistors connected in series across the filament circuit.

Most heater-cathode valves have a single cathode terminal which is used for all circuit returns or for connection of a cathode resistor. In some heater-cathode valves, however, two or more cathode terminals are provided to permit the use of separate a.c. return leads from the input and output circuits of the valve and thus minimise cathode-lead degeneration. Because these terminals are connected in parallel internally, any one of them may be used as the d.c. return point of the valve or for connection of a cathode resistor.

When a heater-cathode valve is operated with fixed bias or grid-resistor bias, or with cathode-resistor bias within the maximum heater-cathode voltage rating of the valve. the heater should be connected to the d.c. return point of the valve. In other cases, the heater should be connected to the valve cathode or to a point having the same d.c. potential as the cathode. Although either of the heater terminals may generally be used for this connection, it may sometimes be necessary to use a centre tap on the heater winding of the supply transformer or a centre-tapped resistor across the heater circuit to minimise hum.

The use of separate a.c. and d.c. returns in power-valve installations minimises signal-energy losses in power-supply and bias circuits. It also minimises degenerative or regenerative effects which may result if common signal-return paths are used for the input and output circuits of a valve or for the circuits of more than one valve. **A.C. returns** are generally made through capacitors directly to the cathode, or to points having the same a.c. potential as the cathode, regardless of the location of the d.c. return point.

In a-f applications, the grid, plate, and screen-grid circuit returns of the valve may be bypassed individually to the chassis or to a common ground bus (and thus to the cathode), as shown in Fig. 1, by capacitors which have very low impedance at audio frequencies. In this case, the length of the portions of chassis or ground bus used as common a.c. return paths is not critical because the impedance of such paths at audio frequencies is generally negligible.

At radio frequencies, however, a distance of even a fraction of an inch between points on a chassis or ground bus may represent a substantial impedance and produce undesirable coupling effects. The a.c. circuit returns of an r-f stage should, therefore, be connected directly to the appropriate cathode terminals of the valve socket or to a single point on the chassis which is at the same a.c. potential as the cathode.

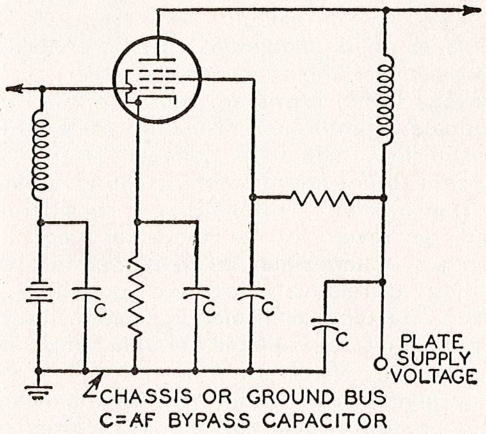


Fig. 1.

Fig. 2 is a semi-pictorial diagram showing the a.c. circuit returns required in a high-frequency amplifier stage using a beam power valve. Bypass capacitors are used across each side of the filament centre-tap resistor to minimise the r-f impedance of the filament circuit. Capacitors used in r-f bypass applications should be specifically designed for use at the required operating frequencies.

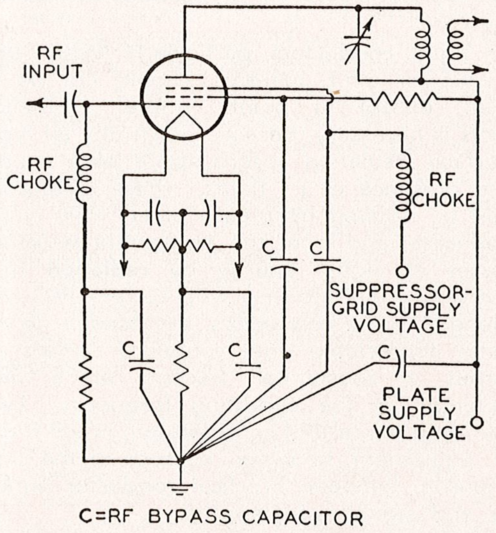


Fig. 2.

FILAMENT OR HEATER SUPPLY.

A.C. voltage is generally used to heat the cathodes of power valves because of the convenience and economy with which the relatively low voltages required may be obtained from transformers. The operating voltages applied to thoriated-tungsten or oxide-coated filamentary cathodes should not be permitted to vary more than plus or minus five per cent. from the values specified in the valve data. Heater voltages for unipotential cathodes should be maintained within plus or minus ten per cent. of rated values unless smaller tolerances are specified in the data for individual valve types. Voltage variations greater than those specified may damage the emitting surface of the cathode, or in other ways cause unsatisfactory valve operation or short life.

When filamentary-cathode power valves are heated with direct current, any current- or voltage-control devices employed should be placed in the branches of the supply circuit feeding the individual valves. When alternating current is used, such control devices should be placed in the primary circuits of the filament-supply transformers. When a filamentary cathode is heated by low-frequency alternating current, hum may be introduced into the valve circuit by (1) a periodic variation in the electron emission as the heating current increases and decreases in value; (2) interaction between the magnetic field of the space-charge and that of the filament; and (3) the electrostatic field of the filament. The principal source is usually the electrostatic field of the filament, which induces hum voltages in the signal electrodes of the valve in proportion to the filament voltage and the capacitance between the filament and other electrodes.

PLATE SUPPLY.

Power-rectifier valves normally obtain their plate-supply voltage from the secondary windings of high-voltage transformers connected to commercial power lines or to local sources of low-frequency a.c. voltage. Power-amplifier valves usually obtain plate voltage from rectifiers provided with suitable filter circuits, although batteries or local d.c. generators are sometimes used, especially in portable and mobile equipment.

SUPPRESSOR-GRID SUPPLY.

Voltage for the grid No. 3 suppressor grid of a power pentode may be obtained from any d.c. source which is substantially free from ripple or other undesirable fluctuations in potential. When an application requires that a suppressor grid draw a varying current the d.c. supply should be a battery or other source having good voltage regulation. This requirement is particularly important when a suppressor grid is used as a modulating electrode because the average suppressor-grid current may then vary with the amplitude of the modulating signal.

SCREEN-GRID SUPPLY.

Grid-No. 2 or screen-grid voltage for a beam power valve, pentode, or tetrode may be obtained from a separate d.c. power supply or from the plate supply for the tube. In the latter case, the required voltage may be obtained either from a suitable tap on a voltage divider or through a dropping resistor from the plate-voltage supply point, depending on the type of multigrid valve used and on the application.

A multigrid valve may fail prematurely if its screen-grid current input exceeds the maximum value shown in the valve data. Excessive screen-grid current may be drawn if the valve is operated without adequate bias or plate voltage. Because the latter condition is most likely to occur when screen-grid and plate voltages are obtained from separate supplies, such supplies should be designed so that plate voltage is always applied before or simultaneously with screen-grid voltage and removed simultaneously with or after the removal of screen-grid voltage. In addition, any means employed for the reduction of plate voltage should automatically produce a proportional reduction in screen-grid voltage.

The danger of excessive screen-grid voltage is present principally when screen-grid voltage is obtained from the plate supply through a series dropping resistor. In this type of supply circuit, sufficient resistance is connected between the screen grid and the plate supply to assure that the screen-grid voltage and dissipation at the values of screen-grid current, bias, and driving voltage required for full output are within the maximum ratings for the valve. Any condition which reduces the current through the screen-grid dropping resistor to a very low value, therefore, may cause the screen-grid voltage to rise to an excessive value.

Such conditions are most likely to occur in telegraphy transmitters employing "blocked-grid" keying or other methods of keying which cut off or substantially reduce plate and screen-grid currents of multigrid valves when the key is up. Although Class C Telegraphy ratings for most multigrid valves permit a rise in screen-grid voltage under key-up conditions, the maximum permissible screen-grid voltage under these conditions is generally substantially less than the plate-supply voltage. Screen-grid voltage for a keyed multigrid amplifier should, therefore, be obtained from a separate supply or a voltage-divider arrangement, rather than by the series-resistor method. In cases where a series-resistor screen-grid supply voltage is used, precautions should be taken to keep the screen-grid voltage within the maximum value specified in the valve data for key-up conditions.

CONTROL-GRID (BIAS) SUPPLY.

Control-grid voltage or bias for a power valve may be obtained from a separate power supply or a resistor in the grid or cathode circuit. Fixed bias is obtained from an independent battery, resistor bias is obtained by rectification of a portion of the input signal or driving voltage applied to the valve. Although this type of bias is the most economical, and can provide relatively large bias voltages or voltages which vary with the input signal, it does not provide protection against excessive plate and screen-grid current in the event the driving voltage fails or is removed. Grid-resistor bias, therefore, is usually used in combination with other means to protect the valves against excessive plate and screen dissipation.

Cathode-resistor bias is obtained from the voltage drop developed across a cathode resistor by the combined d.c. currents of the valve electrodes. This type of bias provides automatic protection against excessive plate, screen-grid, and control-grid current because any increase in total cathode current produces a corresponding increase in bias voltage. Cathode-resistor bias cannot be used alone if bias voltage equal to or greater than the cutoff voltage is required. Because the effective plate and screen-grid voltages of the valve are reduced by the extent of the voltage drop in the cathode resistor, this type of bias is used principally when relatively small bias voltages are required or as a means of providing a minimum protective bias when the principal operating bias is obtained by the grid-resistor method.

SUPPLY-VOLTAGE VARIATIONS.

Because a valve may be seriously damaged if its absolute maximum voltage ratings are exceeded, consideration must be given to the variations in electrode voltages which result from line-voltage fluctuations, load variations, and normal manufacturing tolerances in circuit-component values. The operating voltage for each valve electrode should be low enough so that the absolute maximum rated voltages of the valve will not be exceeded under any combination of these variations, or the voltage supplies should have sufficient regulation to permit the use of maximum rated voltages without danger of exceeding the valve ratings.

PROTECTIVE DEVICES.

Power-valve installations should always be adequately equipped with protective devices to prevent damage to the equipment and/or personal injury. Devices which provide valve and circuit protection include:

(1) fuses or relays which automatically remove power from the equipment, or from a particular circuit, in the event of improper operation;

(2) meters, or facilities for external metering, to permit checking of important circuit operating conditions.

The most common cause of damage to valves and equipment in power-valve installations is excessive plate or screen-grid current. For adequate protection, therefore, each stage of a power-valve installation should be equipped with fuses or relays which will remove all positive electrode voltages if the plate or screen-grid current reaches a value about 50 per cent. above normal. Separate protective devices should be provided for plate and screen-grid circuits of multigrid valves.

Facilities should be provided for the measurement of plate, screen-grid, and filament (or heater) voltages, and plate, screen-grid and control-grid currents. Control-grid-current measurements are particularly valuable in r-f amplifier and frequency-multiplier stages because they facilitate tuning and neutralizing adjustments in addition to providing indications of drive conditions. Because correct filament and heater voltages are essential for maximum valve life, these voltages should always be measured directly at the valve sockets with meters having high accuracy and low power requirements.

For reasons of economy, a single d.c. milliameter is sometimes placed in the cathode-return lead or the negative high-voltage supply lead of a valve for the measurement of total cathode current. In such cases, the meter should be shunted with a resistor to protect the valve cathode and the meter from high d.c. potentials with respect to ground in the event of an open circuit in the meter. A shunting resistor having a value of about 100 times the resistance of the meter is generally satisfactory, and introduces an error in meter reading of only about one per cent.

SAFETY CONSIDERATIONS.

Because the rated plate and screen-grid voltages of most power valves are high enough to be extremely dangerous to the user, care should be taken during maintenance of power-valve equipment to insure that all primary power is disconnected and all exposed circuit parts are effectively grounded. When circuit adjustments are made on "live" equipment, very great care should be taken to avoid contact with any circuit parts which are not at ground potential. Such adjustments should never be made unless another person capable of applying treatment for electric shock is present.

In the design of equipment, personal-safety considerations require the grounding of all operating controls and exposed surfaces, enclosure of all live circuit elements, and the incorporation of "interlock" switches at all points of access to the interior of the equipment. These switches should automatically open the primary circuits of all high-voltage power supplies when access is required.

ERRATA

In the February issue of Radiotronics, there are two points which should be corrected.

1. THB1 (Horizontal Blocking Oscillator Transformer)
   Self-resonant frequency > 285 Kc/s
2. TVO1 (Vertical Output Transformer)
   Primary Inductance > 38H.