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RCA

RECEIVING TUBE MANUAL

RADIO CORPORATION of AMERICA

TUBE DEPARTMENT — HARRISON, N. J.

TECHNICAL SERIES RC 16

CONTENTS

Key to Socket Connection Diagrams

Bottom Views

BC = Base Sleeve
BS = Base Shell
C = External Conductive Coating
DJ = Deflecting Electrode
ES = External Shield
F = Filament
F_M = Filament Mid-Tap

G = Grid
H = Heater
H_L = Heater Tap for Panel Lamp
H_M = Heater Mid-Tap
IC = Internal Connection—Do Not Use
IS = Internal Shield

K = Cathode
NC = No Connection
P = Plate (Anode)
RC = Ray-Control Electrode
S = Shell
TA = Target
U = Unit
• = Gas-Type Tube

Alphabetical Subscripts B,D,HP,HX,P, and T indicate, respectively, beam unit, diode unit, heptode unit, hexode unit, pentode unit, and triode unit in multi-unit types.

7-53

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RCA Receiving Tube MANUAL

THIS MANUAL like its preceding editions has been prepared to assist those who work or experiment with electron tubes and circuits. It will be found valuable by engineers, radio servicemen, technicians, experimenters, students, radio amateurs, and all others technically interested in electron tubes.

The material in this edition has been augmented and revised to keep abreast of the technological advances in electronic fields. Many tube types widely used in the design of new electronic equipment prior to the war are now chiefly of renewal interest; in their place, new advanced types including the miniatures are being used. Consequently, in the Tube Types Section, the presentation on the older types has been limited to essential basic data while detailed information has been given on the newer more important types.

In addition to the tube types covered in this Manual, the TUBE DEPARTMENT of RADIO CORPORATION OF AMERICA offers a complete line of electron tubes including:

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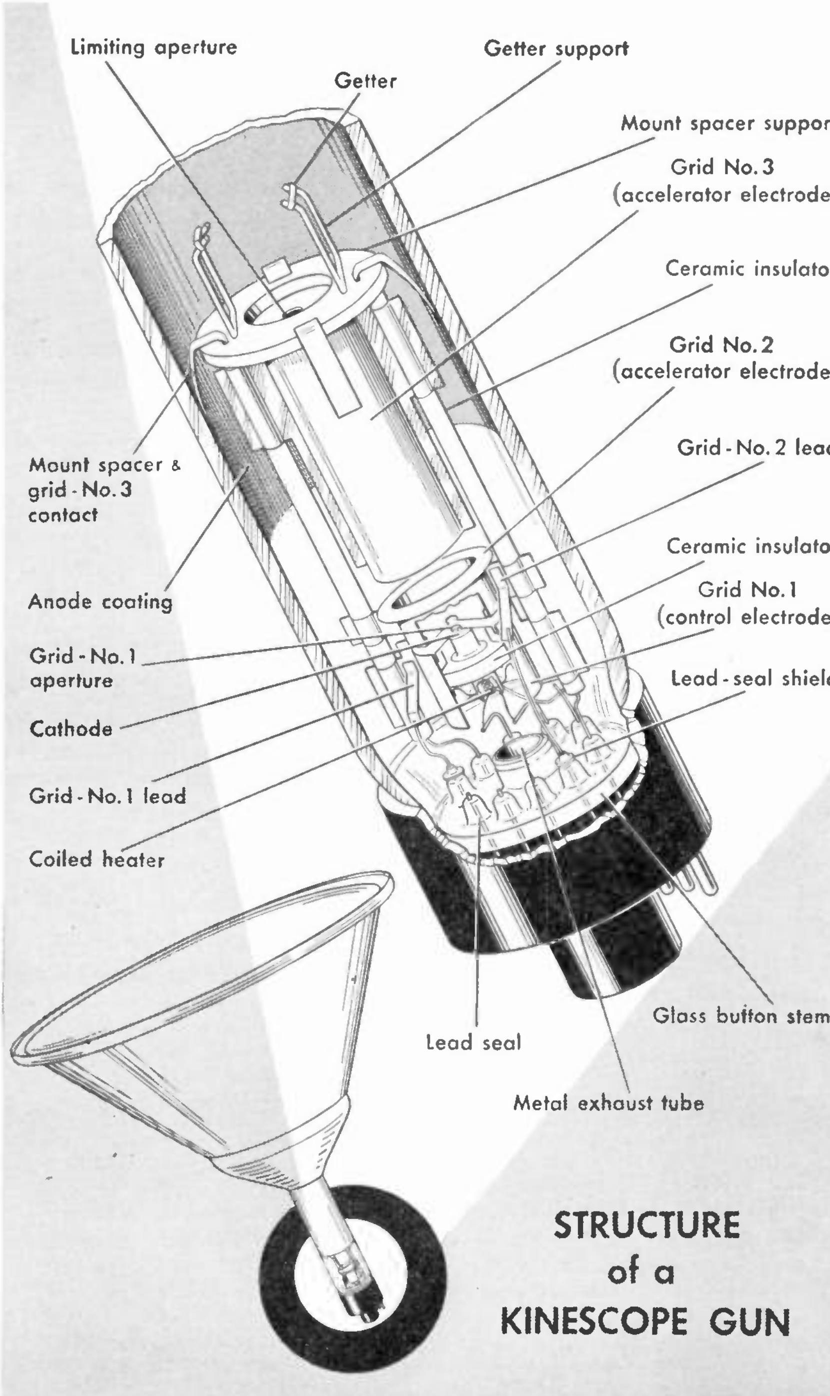


STRUCTURE of a KINESCOPE GUN

RCA Receiving Tube
MANUAL

Electrons, Electrodes, and Electron Tubes

The electron tube is a marvelous device. It makes possible the performing of operations, amazing in conception, with a precision and a certainty that are astounding. It is an exceedingly sensitive and accurate instrument—the product of coordinated efforts of engineers and craftsmen. Its construction requires materials from every corner of the earth. Its use is world-wide. Its future possibilities, even in the light of present-day accomplishments, are but dimly foreseen; for each development opens new fields of design and application.

The importance of the electron tube lies in its ability to control almost instantly the flight of the millions of electrons supplied by the cathode. It accomplishes this with a minimum of control energy. Because it is almost instantaneous in its action, the electron tube can operate efficiently and accurately at electrical requencies much higher th an those attainable with rotating machines.

ELECTRONS

All matter exists in the solid, liquid, or gaseous state. These three forms consist entirely of minute divisions known as molecules. Molecules are assumed to be composed of atoms. According to a present accepted theory, atoms have a nucleus which is a positive charge of electricity. Around this nucleus revolve tiny charges of negative electricity known as **electrons.** Scientists have estimated that these invisible bits of electricity weigh only 1/30-billion, billion, billion, billionths of an ounce, and that they may travel at speeds of thousands of miles per second.

Electron movement may be accelerated by the addition of energy. Heat is one form of energy which can be conveniently used to speed up the electron. For example, if the temperature of a metal is gradually raised, the electrons in the metal gain velocity. When the metal becomes hot enough to glow, some electrons may acquire sufficient speed to break away from the surface of the metal. This action, which is accelerated when the metal is heated in a vacuum, is utilized in most electron tubes to produce the necessary electron supply.

An electron tube consists of a cathode, which supplies electrons, and one or more additional electrodes, which control and collect these electrons, mounted in an evacuated envelope. The envelope may be a glass bulb or a metal shell.

CATHODES

A cathode is an essential part of an electron tube because it supplies the electrons necessary for tube operation. When energy in some form is applied to the cathode, electrons are released. Heat is the form of energy generally used. The method of heating the cathode may be used to distinguish between the different forms of cathodes. For example, a directly heated cathode, or filament-cathode, is a wire heated by the passage of an electric current. An indirectly heated cathode, or heater-cathode, consists of a filament, or heater, enclosed in a metal sleeve. The sleeve carries the electron-emitting material on its outside surface and is heated by radiation and conduction from the heater.

A **filament, or directly heated cathode**, may be further classified by identifying the filament or electron-emitting material. The materials in regular use are tungsten, thoriated tungsten, and metals which have been coated with alkaline-earth oxides. Tungsten filaments are made from the pure metal. Since they must operate at high temperatures (a dazzling white) to emit sufficient electrons, a relatively large amount of filament power is required. Thoriated-tungsten filaments are made from tungsten impregnated with thoria. Due to the presence of thorium, these filaments liberate electrons at a more moderate temperature of about 1700°C (a bright yellow) and are, therefore, much more economical of filament power than are pure tungsten filaments. Alkaline earths are usually applied as a coating on a nickel-alloy wire or ribbon. This coating, which is dried in a relatively thick layer on the filament, requires only a very low temperature of about 700-750°C (a dull red) to produce a copious supply of electrons. Coated filaments operate very efficiently and require relatively little filament power. However, each of these cathode materials has special advantages which determine the choice for a particular application.

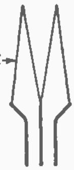


Fig. 1

Directly heated filament-cathodes require comparatively little heating power. They are used in almost all of the tube types designed for battery operation because it is, of course, desirable to impose as small a drain as possible on the batteries. Examples of battery-operated filament types are the 1A7-GT, 1R5, 1U4, 3V4, and 31. AC-operated types having directly heated filament-cathodes include the 2A3 and 5Y3-GT.

An **indirectly heated cathode, or heater-cathode**, consists of a thin metal sleeve coated with electron-emitting material. Within the sleeve is a heater which is insulated from the sleeve. The heater is made of tungsten or tungsten-alloy wire and is used only for the purpose of heating the cathode sleeve and sleeve coating to an electron-emitting temperature. Useful emission does not take place from the heater wire.

Fig. 2

The heater-cathode construction is well adapted for use in electron tubes intended for operation from ac power lines and from storage batteries. The use of separate parts for emitter and heater functions, the electrical insulation of the heater from the emitter, and the shielding effect of the sleeve may all be utilized in the design of the tube to minimize the introduction of hum from the ac heater supply and to minimize electrical interference which might enter the tube circuit through the heater-supply line. From the viewpoint of circuit design, the heater-cathode construction offers advantages in connection flexibility due to the electrical separation of the heater from the cathode. Another advantage of the heater-cathode construction is that it makes practical the design of a rectifier tube with close spacing between its cathode and plate, and of an amplifier tube with close spacing between its cathode and grid. In a close-spaced rectifier tube the voltage drop in the tube is low and the regulation is, therefore, improved. In an amplifier tube, the close spacing increases the gain obtainable from the tube. Because of the advantages of the heater-cathode construction, almost all present-day receiving tubes designed for ac operation have heater-cathodes.

GENERIC TUBE TYPES

Electrons are of no value in an electron tube unless they can be put to work. A tube is, therefore, designed with the parts necessary to utilize electrons as well as to produce them. These parts consist of a cathode and one or more supplementary electrodes. The electrodes are enclosed in an evacuated envelope with the necessary connections brought out through air-tight seals. The air is removed from the envelope to allow free movement of the electrons and to prevent injury to the emitting surface of the cathode. When the cathode is heated, electrons leave the cathode surface and form an invisible cloud in the space around it. Any positive electric potential within the evacuated envelope will offer a strong attraction to the electrons (unlike electric charges attract; like charges repel).

DIODES

The simplest form of electron tube contains two electrodes, a cathode and an anode (plate) and is often called a diode, the family name for a two-electrode tube. In a diode, the positive potential is supplied by a suitable electrical source connected between the plate terminal and a cathode terminal. Under the influence of the positive plate potential, electrons flow from the cathode to the plate and return through the external plate-battery circuit to the cathode, thus completing the circuit. This flow of electrons is known as the plate current, and may be measured by a sensitive current meter.

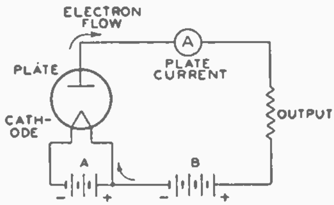


Fig. 3

If a negative potential is applied to the plate, the free electrons in the space surrounding the cathode will be forced back to the cathode and no plate current will flow. Thus, electrons can flow from the cathode to the plate but not from the plate to the cathode. If an alternating voltage is applied to the plate, the plate is alternately made positive and negative. Plate current flows only during the time when the plate is positive. Hence the current through the tube flows in one direction and is said to be rectified. See Fig. 4. Diode rectifiers are used in ac receivers to convert ac to dc voltage for the electrodes of the other tubes in the receiver. Rectifier tubes may have one plate and one cathode. The 1-v and 35W4 are of this form and are called **half-wave rectifiers**, since current can flow only during one-half of the alternating-current cycle. When two plates and one or more cathodes are used in the same tube, current may be obtained on both halves of the ac cycle. The 6X4, 5Y3-GT, and 5U4-G are examples of this type and are called **full-wave rectifiers**.

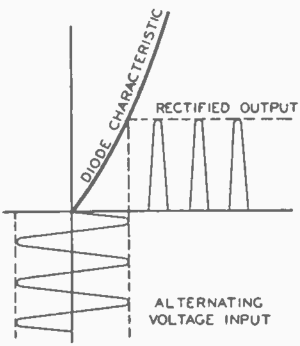


Fig. 4

Not all of the electrons emitted by the cathode reach the plate. Some return to the cathode while others remain in the space between the cathode and plate for a brief period to produce an effect known as **space-charge**. This charge has a repelling action on other electrons which leave the cathode surface and impedes their passage to the plate. The extent of this action and the amount of space-charge depend on the cathode temperature and the plate potential. The higher the plate potential, the less is the tendency for electrons to remain in the space-charge region and repel others. This effect may be noted by applying increasingly higher plate voltages to a tube operating at a fixed heater or filament voltage. Under these conditions, the maximum number of available electrons is fixed, but increasingly higher plate voltages will succeed in attracting a greater proportion of the free electrons.

Beyond a certain plate voltage, however, additional plate voltage has little effect in increasing the plate current. The reason is that all of the electrons emitted by the cathode are already being drawn to the plate. This maximum current is called **saturation current** (see Fig. 5) and because it is an indication of the total number of electrons emitted, it is also known as the **emission current**, or, simply,

emission. Tubes are sometimes tested by the measurement of their emission current but it is generally not advisable to measure the full value of emission because this value would be sufficiently large to cause change in the tube's characteristics or even to damage the tube. Consequently, while the test value of emission current is somewhat larger than the maximum current which will be required from the cathode in the use of the tube, it is ordinarily less than the full emission current. The emission test, therefore, is used to indicate whether the cathode can supply a sufficient number of electrons for satisfactory operation of the tube.

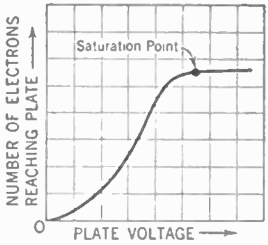


Fig. 5

If space charge were not present to repel electrons coming from the cathode, it follows that the same plate current could be produced at a lower plate voltage. One way to make the effect of space charge small is to make the distance between plate and cathode small. This method is used in rectifier types, such as the 5V4-G and the 25Z6-GT, having heater-cathodes. In these types the radial distance between cathode and plate is only about two hundredths of an inch. Another method of reducing space-charge effect is utilized in the **mercury-vapor rectifier tubes,** such as the 83. This tube contains a small amount of mercury, which is partially vaporized when the tube is operated. The mercury vapor consists of mercury atoms permeating the space inside the bulb. These atoms are bombarded by the electrons on their way to the plate. If the electrons are moving at a sufficiently high speed, the collisions will tear off electrons from the mercury atoms. When this happens, the mercury atom is said to be "**ionized,**" that is, it has lost one or more electrons and, therefore, is charged positive. Ionization, in the case of mercury vapor, is made evident by a bluish-green glow between the cathode and plate. When ionization due to bombardment of mercury atoms by electrons leaving the cathode occurs, the space-charge is neutralized by the positive mercury ions so that increased numbers of electrons are made available. A mercury-vapor rectifier has a small voltage drop between cathode and plate (about 15 volts). This drop is practically independent of current requirements up to the limit of emission of electrons from the cathode, but is dependent to some degree on bulb temperature.

An **ionic-heated-cathode rectifier tube** is another type which depends for its operation on gas ionization. The 0Z4 and 0Z4-G are tubes in this classification. They are of the full-wave design and contain two anodes and a coated cathode sealed in a bulb under a reduced pressure of inert gas. The cathode in each of these types becomes hot during tube operation but the heating effect is caused by bombardment of the cathode by the ions from within the tube rather than by heater or filament current from an external source. The internal structure of the tube is designed so that when sufficient voltage is applied to the tube, ionization of the gas occurs between the anode which is instantaneously positive and the cathode. Under normal operating voltages, ionization does not take place between the anode that is negative and the cathode. This, of course, satisfies the requirements for rectification. The initial small flow of current through the tube is sufficient to raise the cathode temperature quickly to incandescence whereupon the cathode emits electrons. The voltage drop in such tubes is slightly higher than that of the usual hot-cathode gas rectifiers because energy is taken from the ionization discharge to keep the cathode at operating temperature. Proper operation of these rectifiers requires a minimum flow of load current at all times in order to maintain the cathode at the temperature required to supply sufficient emission.

TRIODES

When a third electrode, called the **grid,** is placed between the cathode and plate, the tube is known as a triode, the family name for a three-electrode tube.

The grid usually is a winding of wire extending the length of the cathode. The spaces between turns are comparatively large so that the passage of electrons from cathode to plate is practically unobstructed by the turns of the grid. The purpose of the grid is to control the flow of plate current. When a tube is used as an amplifier, a negative dc voltage is usually applied to the grid. Under this condition the grid does not draw appreciable current.

The number of electrons attracted to the plate depends on the combined effect of the grid and plate polarities. When the plate is positive, as is normal, and the dc grid voltage is made more and more negative, the plate is less able to attract electrons to it and plate current decreases. When the grid is made less and less negative (more and more positive), the plate more readily attracts electrons to it and plate current increases. Hence, when the voltage on the grid is varied in accordance with a signal, the plate current varies with the signal. Because a small voltage applied to the grid can control a comparatively large amount of plate current, the signal is amplified by the tube. Typical three-electrode tube types are the 6C4, 6J5, and 2A3.

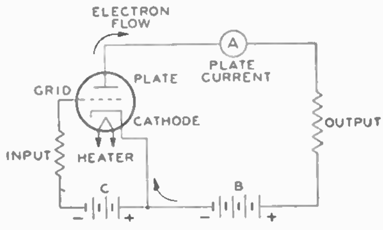


Fig. 6

The grid, plate, and cathode of a triode form an electrostatic system, each electrode acting as one plate of a small capacitor. The capacitances are those existing between grid and plate, plate and cathode, and grid and cathode. These capacitances are known as **interelectrode capacitances**. Generally, the capacitance between grid and plate is of the most importance. In high-gain radio-frequency amplifier circuits, this capacitance may act to produce undesired coupling between the **input circuit**, the circuit between grid and cathode, and the **output circuit**, the circuit between plate and cathode. This coupling is undesirable in an amplifier because it may cause instability and unsatisfactory performance.

TETRODES

The capacitance between grid and plate can be made small by mounting an additional electrode, called the screen (grid No. 2), in the tube. With the addition of the screen, the tube has four electrodes and is, accordingly, called a tetrode. The screen is mounted between the grid and the plate and acts as an electrostatic shield between them, thus reducing the grid-to-plate capacitance. The effectiveness of this shielding action is increased by connecting a bypass capacitor between screen and cathode. By means of the screen and this bypass capacitor, the grid-plate capacitance of a tetrode is made very small. In practice, the grid-plate capacitance is reduced from several micromicrofarads ($\mu\mu f$) for a triode to 0.01 $\mu\mu f$ or less for a screen-grid tube.

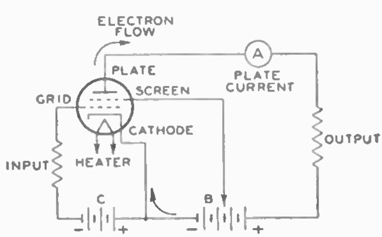


Fig. 7

The screen has another desirable effect in that it makes plate current practically independent of plate voltage over a certain range. The screen is operated at a positive voltage and, therefore, attracts electrons from the cathode. But because of the comparatively large space between wires of the screen, most of the electrons drawn to the screen pass through it to the plate. Hence the screen supplies an electrostatic force pulling electrons from the cathode to the plate. At the same time the screen shields the electrons between cathode and screen from the plate so that the plate exerts very little electrostatic force on electrons near the cathode. So long as the plate voltage is higher than the screen voltage, plate current in a screen-grid tube depends to a great degree on the screen voltage and very little on the plate voltage. The fact that plate current in a screen-grid tube is largely independent of plate voltage makes it possible to obtain much higher amplification with a tetrode than with a triode. The low grid-plate capacitance makes it possible to obtain this high amplification without plate-to-grid feedback and resultant instability. Representative screen-grid types are the 32 and 24-A.

PENTODES

In all electron tubes, electrons striking the plate may, if moving at sufficient speed, dislodge other electrons. In two- and three-electrode types, these dislodged electrons usually do not cause trouble because no positive electrode other than the plate itself is present to attract them. These electrons, therefore, are drawn back to the plate. Emission caused by bombardment of an electrode by electrons from the cathode is called **secondary emission** because the effect is secondary to the original cathode emission. In the case of screen-grid tubes, the proximity of the positive screen to the plate offers a strong attraction to these secondary electrons and particularly so if the plate voltage swings lower than the screen voltage. This effect lowers the plate current and limits the permissible plate-voltage swing for tetrodes.

The plate-current limitation is removed when a fifth electrode is placed within the tube between the screen and plate. This fifth electrode is known as the **suppressor** (grid No. 3) and is usually connected to the cathode. Because of its nega-

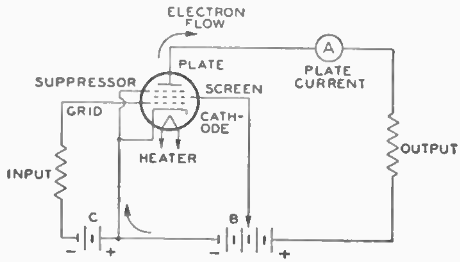
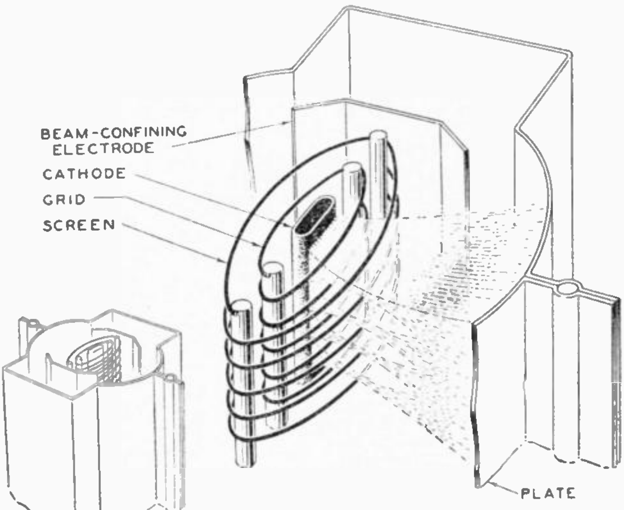


Fig. 8

tive potential with respect to the plate, the suppressor retards the flight of secondary electrons and diverts them back to the plate where they cannot cause trouble. The family name for a five-electrode tube is "pentode". In power-output pentodes, the suppressor makes possible higher power output with lower grid-driving voltage; in radio-frequency amplifier pentodes the suppressor makes possible high voltage amplification at moderate values of plate voltage. These desirable features are due to the fact that the plate-voltage swing can be made very large. In fact, the plate voltage may be as low as, or lower than, the screen voltage without serious loss in signal-gain capability. Representative pentodes used for power amplification are the 3V4 and 6K6-GT; representative pentodes used for voltage amplification are the 1U4, 6SJ7, 12SK7, and 6BA6.

BEAM POWER TUBES

A **beam power tube** is a tetrode or pentode in which directed electron beams are used to increase substantially the power-handling capability of the tube. Such a tube contains a cathode, a control-grid, a screen, a plate, and, optionally, a suppressor grid. When a beam power tube is designed without an actual suppressor, the electrodes are so spaced that secondary emission from the plate is suppressed by space-charge effects between screen and plate. The space charge is produced by the slowing up of electrons traveling from a high-potential screen to a lower-potential plate. In this low-velocity region, the space charge produced is sufficient to repel secondary electrons emitted from the plate and to cause them to return to the plate. Beam power tubes of this design employ beam-confining electrodes at cathode potential to assist in producing the desired beam effects and to prevent stray electrons from the plate from returning to the screen outside of the beam. A feature of a beam power tube is its low screen current. The screen and the grid are spiral wires wound so that each turn of the screen is shaded from the cathode by a grid turn. This alignment of the screen and grid causes the electrons to travel in sheets between the turns of the screen so that very few of them strike the screen. Because of the effective suppressor action provided by space charge and because of the low current drawn by the screen, the beam power tube has the advantages of high power output, high power sensitivity, and high efficiency.



INTERNAL STRUCTURE OF TYPE 6L6 BEAM POWER TUBE

Fig. 9

Fig. 9 shows the structure of a beam power tube employing space-charge suppression and illustrates how the electrons are confined to beams. The beam condition illustrated is that for a plate potential less than the screen potential. The high-density space-charge region is indicated by the heavily dashed lines in the beam. Note that the edges of the beam-confining electrodes coincide with the dashed portion of the beam. In this way the space-charge potential region is extended beyond the beam boundaries and stray secondary electrons are prevented from returning to the screen outside of the beam. The space-charge effect may also be obtained by use of an actual suppressor grid. Examples of beam power tubes are 6L6, 6V6-GT, and 50C5.

MULTI-ELECTRODE and MULTI-UNIT TUBES

Early in the history of tube development and application, tubes were designed for general service; that is, a single tube type—a triode—was used as a radio-frequency amplifier, an intermediate-frequency amplifier, an audio-frequency amplifier, an oscillator, or a detector. Obviously, with this diversity of application, one tube did not meet all requirements to the best advantage.

Later and present trends of tube design are the development of "specialty" types. These types are intended either to give optimum performance in a particular application or to combine in one bulb functions which formerly required two or more tubes. The first class of tubes includes such examples of specialty types as the 6F6, 12SK7, 6L7, and 6K8. Types of this class generally require more than three electrodes to obtain the desired special characteristics and may be broadly classed as multi-electrode types. The 6L7 is an especially interesting type in this class. This tube has an unusually large number of electrodes, namely seven, exclusive of the heater. Plate current in the tube is varied at two different frequencies at the same time. The tube is designed primarily for use as a mixer in superheterodyne receivers. In tnis use, the tube mixes the signal frequency with the oscillator frequency to give an intermediate-frequency output.

Tubes of the multi-electrode class often present interesting possibilities of application besides the one for which they are primarily designed. The 6L7, for instance, can also be used as a variable-gain audio amplifier in volume-expander and compressor application. The 6F6, besides its use as a power-output pentode, can also be connected as a triode and used as a driver for a pair of 6L6's.

The second class includes multi-unit tubes such as the twin-diode triodes 6BF6 and 6SQ7, as well as the twin-diode pentodes 1F7-G and 12C8 and the twin class A and class B types 12AU7 and 6N7, respectively. In this class also is included the multi-unit type 117N7-GT. This tube combines in one bulb a diode for use as a power rectifier and a power-output pentode. Related to multi-unit tubes are the electron-ray types 6U5, 6E5, and 6AB5/6N5. These combine a triode amplifier with a fluorescent target. Full-wave rectifiers are also multi-unit types.

A third class of tubes combines features of each of the other two classes. Typical of this third class are the pentagrid-converter types 1R5, 6BE6, and 6SA7. These tubes are similar to the multi-electrode types in that they have seven electrodes, all of which affect the electron stream; and they are similar to the multi-unit tubes in that they perform simultaneously the double function of oscillator and mixer in superheterodyne receivers.

KINESCOPES

The kinescope is a multi-electrode tube used principally in television receivers for picture display. It consists essentially of an electron gun, a glass or metal-and-glass envelope and face-plate combination, and a fluorescent screen.

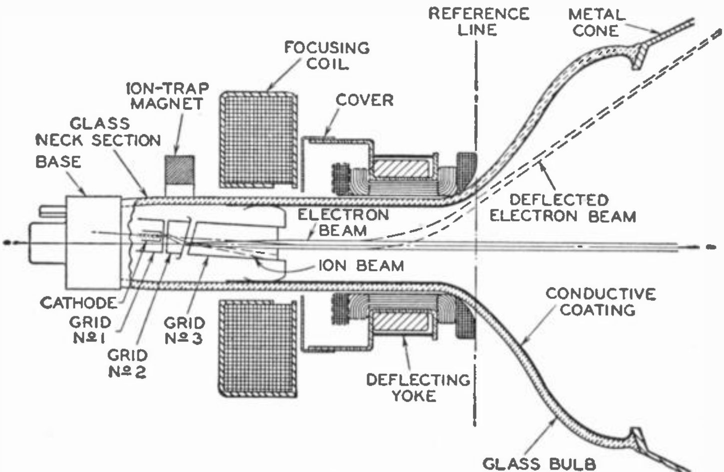


Fig. 10

The electron gun includes a cathode for the production of free electrons, an electron "lens" system for accelerating the electrons and forming or focusing them into a very narrow beam, and, optionally, a device for "trapping" unwanted ions out of the electron beam.

Deflection of the beam is accomplished either electrostatically by means of deflecting electrodes within the envelope of the tube, or electromagnetically by means of a deflecting yoke placed on the neck of the tube. Fig. 10 shows the structure of the gun section of a kinescope and illustrates how the electron beam is formed, how the ions are separated from the electron beam by means of the tilted-gun and ion-trap-magnet arrangement, and how the beam is deflected by means of an electromagnetic deflecting yoke.

The screen is a white-fluorescing phosphor (No. 4) of either the silicate or the sulfide type. The spectral distribution of the energy emitted by the silicate type is shown by the curve in the TUBE TYPES SECTION under type 5TP4, and that for the sulfide type in the same section under type 12LP4-A. The persistence of the phosphorescence exhibited by either type of the phosphor No. 4 is such that its brightness does not exceed 7 per cent of the peak value in 33 milliseconds after excitation is removed.

Complete classification of tubes by services and filament or heater voltages is given on the chart at the beginning of the TUBE TYPES SECTION.

Electron Tube Characteristics

The term "characteristics" is used to identify the distinguishing electrical features and values of an electron tube. These values may be shown in curve form or they may be tabulated. When given in curve form, they are called characteristic curves and may be used for the determination of tube performance and the calculation of additional tube factors.

Tube characteristics are obtained from electrical measurements of a tube in various circuits under certain definite conditions of voltages. Characteristics may be further described by denoting the conditions of measurements. For example Static Characteristics are the values obtained with different dc potentials applied, to the tube electrodes, while Dynamic Characteristics are the values obtained with an ac voltage on the control grid under various conditions of dc potentials on the electrodes. The dynamic characteristics, therefore, are indicative of the performance capabilities of a tube under actual working conditions.

Static characteristics may be shown by plate characteristics curves and transfer (mutual) characteristics curves. These curves present the same information, but in two different forms to increase its usefulness. The plate characteristic curve

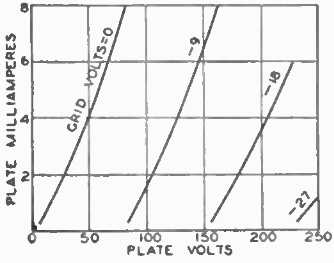


Fig. 11

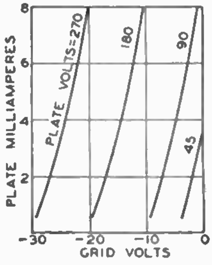


Fig. 12

is obtained by varying plate voltage and measuring plate current for different control-grid bias voltages, while the transfer-characteristic curve is obtained by varying control-grid bias voltage and measuring plate current for different plate voltages. A plate-characteristic family of curves is illustrated by Fig. 11. Fig. 12 gives the transfer characteristic family of curves for the same tube.

Dynamic characteristics include amplification factor, plate resistance, control-grid—plate transconductance and certain detector characteristics, and may be shown in curve form for variations in tube operating conditions.

The **amplification factor,** or μ, is the ratio of the change in plate voltage to a change in control-electrode voltage in the opposite direction, under the condition that the plate current remains unchanged, and that all other electrode voltages are maintained constant. For example, if, when the plate voltage is made 1 volt more positive, the grid voltage must be made 0.1 volt more negative to hold plate current unchanged, the amplification factor is 1 divided by 0.1, or 10. In other words, a small voltage variation in the grid circuit of a tube has the same effect on the plate current as a large plate-voltage change—the latter equal to the product of the grid-voltage change and amplification factor. The μ of a tube is useful for calculating stage gain. This use is discussed in the ELECTRON TUBE APPLICATIONS SECTION.

Plate resistance (r_p) of a radio tube is the resistance of the path between cathode and plate to the flow of alternating current. It is the quotient of a small change in plate voltage divided by the corresponding change in plate current and is expressed in ohms, the unit of resistance. Thus, if a change of 0.1 milliampere (0.0001 ampere) is produced by a plate voltage variation of 1 volt, the plate resistance is 1 divided by 0.0001, or 10000 ohms.

Control-grid—plate transconductance, or simply **transconductance** (g_m), is a factor which combines in one term the amplification factor and the plate resistance, and is the quotient of the first divided by the second. This term is also known as mutual conductance. Transconductance may be more strictly defined as the quotient of a small change in plate current (amperes) divided by the small change in the control-grid voltage producing it, under the condition that all other voltages remain unchanged. Thus, if a grid-voltage change of 0.5 volt causes a plate-current change of 1 milliampere (0.001 ampere), with all other voltages constant, the transconductance is 0.001 divided by 0.5, or 0.002 mho. A "mho" is the unit of conductance and was named by spelling ohm backwards. For convenience, a millionth of a mho, or a micromho (μmho), is used to express transconductance. Thus, in the example, 0.002 mho is 2000 micromhos.

Conversion transconductance (g_c) is a characteristic associated with the mixer (first detector) function of tubes and may be defined as the quotient of the intermediate-frequency (if) current in the primary of the if transformer divided by the applied radio-frequency (rf) voltage producing it; or more precisely, it is the limiting value of this quotient as the rf voltage and if current approach zero. When the performance of a frequency converter is determined, conversion transconductance is used in the same way as control-grid—plate transconductance is used in single-frequency amplifier computations.

The **plate efficiency** of a power amplifier tube is the ratio of the ac power output to the product of the average dc plate voltage and dc plate current at full signal, or

$$\text{Plate efficiency (\%)} = \frac{\text{power output watts}}{\text{average dc plate volts} \times \text{average dc plate amperes}} \times 100$$

The **power sensitivity** of a tube is the ratio of the power output to the square of the input signal voltage (rms) and is expressed in mhos as follows:

$$\text{Power sensitivity (mhos)} = \frac{\text{power output watts}}{(\text{input signal volts, rms})^2}$$

The **input capacitance** of an electron tube is the capacitance between the input electrode and all other electrodes, except the output electrode, connected together. When input capacitance measurements are made, it is usual practice to ground the output electrode and to connect such elements as the heater and shields together with the other electrodes.

The **output capacitance** of an electron tube is the capacitance between the output electrode and all other electrodes, except the input electrode, connected together. When output capacitance measurements are made, it is usual practice to ground the input electrode and to connect such elements as the heater and shields together with the other electrodes.

Electron Tube Applications

The diversified applications of an electron receiving tube have, within the scope of this section, been treated under eight headings. These are: Amplification, Rectification, Detection, Automatic Volume Control, Tuning Indication with Electron-Ray Tubes, Oscillation, Frequency Conversion, and Automatic Frequency Control. Although these operations may take place at either radio or audio frequencies and may involve the use of different circuits and different supplemental parts, the general considerations of each kind of operation are basic.

AMPLIFICATION

The amplifying action of an electron tube was mentioned under **Triodes** in the section on ELECTRONS, ELECTRODES, and ELECTRON TUBES.

This action can be utilized in electronic circuits in a number of ways, depending upon the results desired. Four classes of amplifier service recognized by engineers are covered by definitions standardized by the Institute of Radio Engineers. This classification depends primarily on the fraction of input cycle during which plate current is expected to flow under rated full-load conditions. The classes are class A, class AB, class B, and class C. The term, cutoff bias, used in these definitions is the value of grid bias at which plate current is some very small value.

Class A Amplifier. A class A amplifier is an amplifier in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows at all times.

Class AB Amplifier. A class AB amplifier is an amplifier in which the grid bias and alternating grid voltages are such that plate current in a specific tube flows for appreciably more than half but less than the entire electrical cycle.

Class B Amplifier. A class B amplifier is an amplifier in which the grid bias is approximately equal to the cutoff value so that the plate current is approximately zero when no exciting grid voltage is applied, and so that plate current in a specific tube flows for approximately one-half of each cycle when an alternating grid voltage is applied.

Class C Amplifier. A class C amplifier is an amplifier in which the grid bias is appreciably greater than the cutoff value so that the plate current in each tube is zero when no alternating grid voltage is applied, and so that plate current flows in a specific tube for appreciably less than one-half of each cycle when an alternating grid voltage is applied.

NOTE:—To denote that grid current does not flow during any part of the input cycle, the suffix 1 may be added to the letter or letters of the class identification. The suffix 2 may be used to denote that grid current flows during some part of the cycle.

For radio-frequency amplifiers which operate into a selective tuned circuit, as in radio transmitter applications, or under requirements where distortion is not an important factor, any of the above classes of amplifiers may be used, either with a single tube or a push-pull stage. For audio-frequency amplifiers in which distortion is an important factor, only class A amplifiers permit single-tube operation. In this case, operating conditions are usually chosen so that distortion is kept below the conventional 5% for triodes and the conventional 7 to 10% for tetrodes or pentodes. Distortion can be reduced below these figures by means of special circuit arrangements such as that discussed under **inverse feedback**. With class A amplifiers, reduced distortion with improved power performance can be obtained by using a push-pull stage for audio service. With class AB and class B amplifiers, a balanced amplifier stage using two tubes is required for audio service.

As a **class A voltage amplifier**, an electron tube is used to reproduce grid voltage variations across an impedance or a resistance in the plate circuit. These variations are essentially of the same form as the input signal voltage impressed on the grid, but of increased amplitude. This is accomplished by operating the tube at a suitable grid bias so that the applied grid-input voltage produces plate-current variations proportional to the signal swings. Since the voltage variation obtained in the plate circuit is much larger than that required to swing the grid, amplification of the signal is obtained. Fig. 13 gives a graphical illustration of this method of amplification and shows, by means of the grid-voltage vs. plate-current characteristics curve, the effect of an input signal (S) applied to the grid of a tube. O is the resulting amplified plate-current variation.

The plate current flowing through the load resistance (R) of Fig. 14 causes a voltage drop which varies directly with the plate current. The ratio of this voltage variation produced in the load resistance to the input signal voltage is the voltage

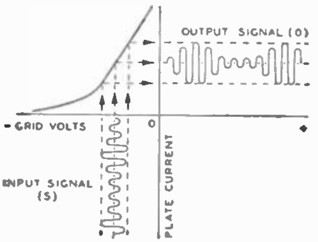


Fig. 13

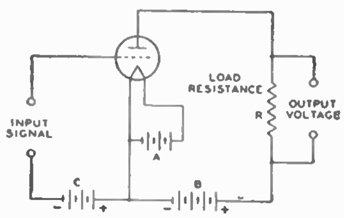


Fig. 14

amplification, or **gain**, provided by the tube. The voltage amplification due to the tube is expressed by the following convenient formulas:

$$\text{Voltage amplification} = \frac{\text{amplification factor} \times \text{load resistance}}{\text{load resistance} + \text{plate resistance}}, \text{ or}$$

$$\frac{\text{transconductance in micromhos} \times \text{plate resistance} \times \text{load resistance}}{1000000 \times (\text{plate resistance} + \text{load resistance})}$$

From the first formula, it can be seen that the gain actually obtainable from the tube is less than the tube's amplification factor but that the gain approaches the amplification factor when the load resistance is large compared to the tube's plate resistance. Fig. 15 shows graphically how the gain approaches the mu of the tube as load resistance is increased. From the curve it can be seen that to obtain high gain in a voltage amplifier, a high value of load resistance should be used.

In a **resistance-coupled amplifier**, the load resistance of the tube is approximately equal to the resistance of the plate resistor in parallel with the grid resistor of the following stage. Hence, to obtain a large value of load resistance, it is necessary to use a plate resistor and a grid resistor of large resistance. However, the plate resistor should not be too large because the flow of plate current through the plate resistor produces a voltage drop which reduces the plate voltage applied to the tube. If the plate resistor is too large, this drop will be too large, the plate voltage on the tube will be too small, and the voltage output of the tube will be too small. Also, the grid resistor of the following stage should not be too large, the actual maximum value being dependent on the particular tube type. This precaution is necessary because all tubes contain minute amounts of residual gas which cause a minute flow of current through the grid resistor. If the grid resistor is too large, the positive bias developed by the flow of this current through the resistor decreases the normal negative bias and produces an increase in the plate current. This increased current may over-heat the tube and cause liberation of more gas which, in turn, will cause further decrease in bias. The action is cumulative and results in a runaway condition which can destroy the tube. A higher value of grid resistance is permissible when cathode bias is used than when fixed bias is used. When cathode bias is used, a loss in bias due to grid-emission effects is nearly completely offset by an increase in bias due to the voltage drop across the cathode resistor. The recommended values of plate resistor and grid resistor for the tube types used in resistance-coupled circuits, and the values of gain obtainable, are shown in the RESISTANCE-COUPLED AMPLIFIER SECTION.

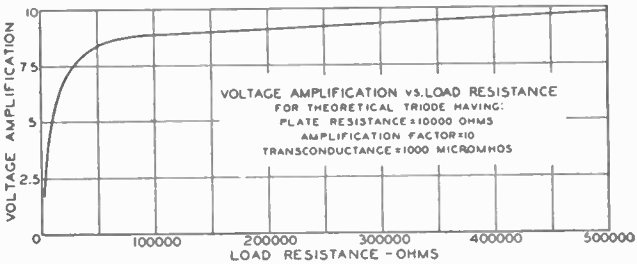


Fig. 15

The **input impedance** of an electron tube, that is, the impedance between grid and cathode is made up of (1) a reactive component due to the capacitance between grid and cathode, (2) a resistive component resulting from the time of transit of electrons between cathode and grid, and (3) a resistive component developed by the part of the cathode lead inductance which is common to both the input and output circuits. Components (2) and (3) are dependent on the frequency of the incoming signal. The input impedance is very high at audio frequencies when a tube is operated with its grid biased negative. Hence, in a class A_1 or class AB_1 transformer-coupled audio amplifier, the loading imposed by the grid on the input transformer is negligible. The secondary impedance of a class A_1 or class AB_1 input transformer can, therefore, be made very high since the choice is not limited by the input impedance of the tube; however, transformer design considerations may limit the choice. At the higher radio frequencies, the input impedance may become very low even when the grid is negative, due to the finite time of passage of electrons between cathode and grid and to the appreciable lead reactance. This impedance drops very rapidly as the frequency is raised and increases input-circuit loading. In fact, the input impedance may become low enough at very high radio frequencies to affect appreciably the gain and selectivity of a preceding stage. Tubes such as the "acorn" types and the high-frequency miniatures have been developed to have low input capacitances, low electron transit time, and low lead inductance so that their input impedance is high even at the ultra-high radio frequencies. **Input admittance** is the reciprocal of input impedance.

A **remote-cutoff amplifier** tube is a modified construction of a pentode or a tetrode type and is designed to reduce modulation-distortion and cross-modulation in radio-frequency stages. **Cross-modulation** is the effect produced in a radio receiver by an interfering station "riding through" on the carrier of the station to which the receiver is tuned. **Modulation-distortion** is a distortion of the modulated carrier and appears as audio-frequency distortion in the output. This effect is produced by a radio-frequency amplifier stage operating on an excessively curved characteristic when the grid bias has been increased to reduce volume. The offending stage for cross-modulation is usually the first radio-frequency amplifier, while

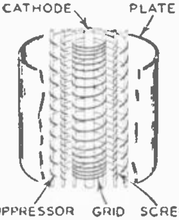


Fig. 16

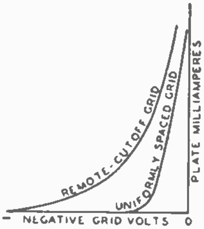


Fig. 17

for modulation-distortion, the cause is usually the last intermediate-frequency stage. The characteristics of remote-cutoff types are such as to enable them to handle both large and small input signals with minimum distortion over a wide range.

Fig. 16 illustrates the construction of the control grid in such a tube. The remote-cutoff action is due to the structure of the grid which provides a variation in amplification factor with change in grid bias. The grid is wound with open spacing at the middle and with close spacing at the ends. When weak signals and low grid bias are applied to the tube, the effect of the non-uniform turn spacing of the grid on cathode emission and tube characteristics is essentially the same as for uniform spacing. As the grid bias is made more negative to handle larger input signals, the electron flow from the sections of the cathode enclosed by the ends of the grid is cut off. The plate current and other tube characteristics are then dependent on the electron flow through the open section of the grid. This action changes the gain of the tube so that large signals may be handled with minimum distortion due to cross-modulation and modulation-distortion. Fig. 17 shows a typical plate-current vs. grid-voltage curve for a remote-cutoff type compared with the curve for a type having a uniformly spaced grid. It will be noted that while the curves are similar at small grid-bias voltages, the plate current of the remote-cutoff tube drops quite slowly with large values of bias voltage. This slow change makes it possible for the tube to handle large signals satisfactorily. Since remote-cutoff types can accommodate large and small signals, they are particularly suitable for use in sets having automatic volume control. Remote-cutoff tubes also are known as variable-mu types. The 6SK7 is a representative remote-cutoff type.

As a **class A power amplifier**, an electron tube is used in the output stage of a radio receiver to supply a relatively large amount of power to the loudspeaker. For this application, large power output is of more importance than high voltage amplification; therefore, gain possibilities are sacrificed in the design of power tubes to obtain power-handling capability. Triodes, pentodes, and beam power tubes designed for power amplifier service have certain inherent features for each structure. Power tubes of the triode type for class A service are characterized by low power sensitivity, low plate-power efficiency, and low distortion. Power tubes of the pentode type are characterized by high power sensitivity, high plate-power efficiency and, usually, somewhat higher distortion than class A triodes. Beam power tubes such as the 6L6 have still higher power sensitivity and efficiency and have higher power-output capability than triode or conventional pentode types.

A class A power amplifier is used also as a driver to supply power to a class AB_2 or a class B stage. It is usually advisable to use a triode, rather than a pentode, in a driver stage because of the lower plate impedance of the triode.

Power tubes connected in either **parallel** or **push-pull** may be employed as class A amplifiers to obtain increased output. The parallel connection (Fig. 18) provides twice the output of a single tube with the same value of grid-signal voltage. With this connection, the effective transconductance of the stage is doubled, and the effective plate resistance and the load resistance required are halved as compared with single-tube values. The push-pull connection (Fig. 19), although it requires twice the grid-signal voltage, has, in addition to providing increased power, other important advantages over single-tube operation. Distortion caused by even-order harmonics and hum caused by plate-voltage-supply fluctuations are either eliminated or decidedly reduced through cancellation. Since distortion for push-pull operation is less than for single-tube operation, appreciably more than twice single-tube output can be obtained by decreasing the load resistance for the stage to a value approaching the load resistance for a single tube. For either parallel or push-pull class A operation of two tubes, all electrode currents are doubled while all dc electrode voltages remain the same as for single-tube operation. If a cathode resistor is used, its value should be about one-half that for a single tube. Should oscillations occur with either type of connection, they can often be eliminated by connecting a non-inductive resistor of approximately 100 ohms in series with each grid at the socket terminal.

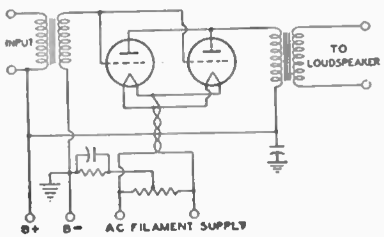


Fig. 18

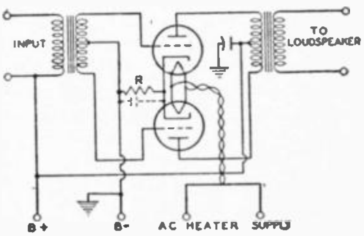


Fig. 19

Operation of power tubes so that the grids run positive is inadvisable except under conditions such as those discussed in this section for class AB and class B amplifiers.

Calculation of the **power output of a triode** used as a class A amplifier with either an output transformer or a choke having low dc resistance can be made without serious error from the plate family of curves by assuming a resistance load. The proper plate current, grid bias, optimum load resistance, and the per cent second-harmonic distortion can also be determined. The calculations are made graphically and are illustrated in Fig. 20 for given conditions. The procedure is as follows: (1) Locate the zero-signal bias point P by determining the zero-signal bias Ec_o from the formula:

$$\text{Zero-signal bias } (Eco) = -(0.68 \times Eb)/\mu$$

where E_b is the chosen value in volts of dc plate voltage at which the tube is to be operated, and μ is the amplification factor of the tube. This quantity is shown as negative to indicate that a negative bias is used. (2) Locate on the plate family the value of zero-signal plate current, I_o, corresponding to point P. (3) Locate $2I_o$, which is twice the value of I_o and corresponds to the value of the maximum-signal plate current I_{max}. (4) Locate the point X on the dc bias curve at zero volts, $E_c = 0$, corresponding to the value of I_{max}. (5) Draw a straight line XY through X and P.

Line XY is known as the load resistance line. Its slope corresponds to the value of the load resistance. The load resistance in ohms is equal to $(E_{max} - E_{min})$ divided by $(I_{max} - I_{min})$, where E is in volts and I is in amperes.

It should be noted that in the case of filament types of tubes, the calculations are given on the basis of a dc-operated filament. When, however, the filament is ac-operated, the calculated value of dc bias should be increased by approximately one-half the filament voltage rating of the tube.

The value of zero-signal plate current I_o should be used to determine the plate dissipation, an important factor influencing tube life. In a class A amplifier under no-signal conditions, the plate dissipation is equal to the power input, i.e., the product of the dc plate voltage E_o and the zero-signal dc plate current I_o. If it is found that the plate-dissipation rating of the tube is exceeded with the zero-signal bias Ec_o calculated above, it will be necessary to increase the bias by a sufficient amount so that the actual plate dissipation does not exceed the rating before proceeding further with the remaining calculations.

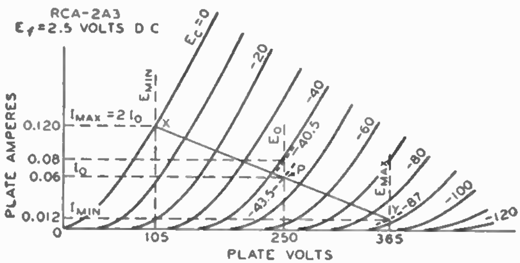


Fig. 20

For power output calculations, it is assumed that the peak alternating grid voltage is sufficient (1) to swing the grid from the zero-signal bias value Ec_o to zero bias ($E_c = 0$) on the positive swing and (2) to swing the grid to a value twice the zero-signal bias value on the negative swing. During the negative swing, the plate voltage and plate current reach values of E_{max} and I_{min}; during the positive swing, they reach values of E_{min} and I_{max}. Since power is the product of voltage and current, the power output as shown by a wattmeter is given by

$$\text{Power output} = \frac{(I_{max} - I_{min}) \quad (E_{max} - E_{min})}{8}$$

where E is in volts, I is in amperes, and power output is in watts.

In the output of power amplifier triodes, some distortion is present. This distortion is due predominantly to second harmonics in single-tube amplifiers. The percentage of second-harmonic distortion may be calculated by the following formula:

$$\%\ \text{2nd-harmonic distortion} = \frac{\frac{I_{max} + I_{min}}{2} - I_o}{I_{max} - I_{min}} \times 100$$

where I_o is the zero-signal plate current in amperes. In case the distortion is excessive, the load resistance should be increased or decreased slightly and the calculations repeated.

Example: Determine the load resistance, power output, and distortion of a triode having an amplification factor of 4.2, a plate-dissipation rating of 15 watts, and plate characteristics curves as shown in Fig. 20. The tube is to be operated at 250 volts on the plate.

Procedure: For a first approximation, determine the operating point P from the zero-signal bias formula, $Ec_o = -(0.68 \times 250)\ /4.2 = -40.5$ volts. From the curve for this voltage, it is found that the zero-signal plate current I_o at a plate voltage of 250 volts is 0.08 ampere and, therefore, the plate-dissipation rating is exceeded

(0.08 × 250 = 20 watts). Consequently, it is necessary to reduce the zero-signal plate current to 0.06 ampere at 250 volts. The grid bias is now seen to be −43.5 volts. Note that the curve was taken with a dc filament supply; if the filament is to be operated on an ac supply, the bias must be increased by about one-half the filament voltage, or to −45 volts, and the circuit returns made to the mid-point of the filament circuit.

Point X can now be determined. Point X is at the intersection of the dc bias curve at zero volts with I_{max}, where $I_{max} = 2I_o = 2 \times 0.06 = 0.12$ ampere. Line XY is drawn through points P and X. E_{max}, E_{min}, and I_{min} are then found from the curves. Substituting these values in the power output formula, we obtain

$$\text{Power output} = \frac{(0.12 - 0.012) \quad (365 - 105)}{8} = 3.52 \text{ watts}$$

The resistance represented by load line XY is

$$\frac{(365 - 105)}{(0.12 - 0.012)} = 2410 \text{ ohms}$$

If now the values from the curves are substituted in the distortion formula, we obtain

$$\%\ \text{2nd-harmonic distortion} = \frac{\dfrac{0.12 + 0.012}{2} - 0.06}{0.12 - 0.012} \times 100 = 5.5\%$$

It is customary to select the load resistance so that the distortion does not exceed five per cent. When the method shown is used to determine the slope of the load resistance line, the second-harmonic distortion generally does not exceed five per cent. In the example, however, the distortion is excessive and it is desirable, therefore, to use a slightly higher load resistance. A load resistance of 2500 ohms will give a distortion of about 4.9 per cent. The power output is reduced only slightly to 3.5 watts.

Operating conditions for **triodes in push-pull** depend on the type of operation desired. Under class A conditions, distortion, power output, and efficiency are all relatively low. The operating bias can be anywhere between that specified for single-tube operation and that equal to one-half the grid-bias voltage required to produce plate-current cutoff at a plate voltage of $1.4E_o$ where E_o is the operating plate voltage. Higher bias than this value requires higher grid-signal voltage and results in class AB_1 operation which is discussed later.

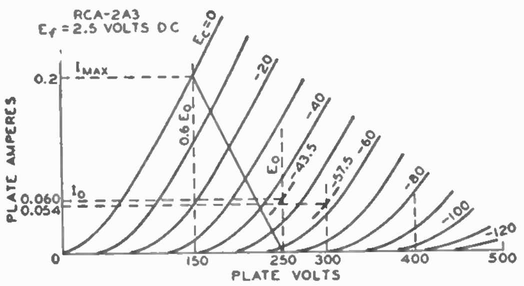


Fig. 21

The method for calculating power output for **triodes in push-pull class A operation** is as follows: Erect a vertical line at $0.6E_o$ (see Fig. 21), intersecting the $E_c = 0$ curve at the point I_{max}. Then, I_{max} is determined from the curve for use in the formula

$$\text{Power output} = (I_{max} \times E_o)/5$$

If I_{max} is expressed in amperes and E_o in volts, power output is in watts.

The method for determining the proper load resistance for triodes in push-pull is as follows: Draw a load line through I_{max} on the zero-bias curve and through the E_o point on the zero-current axis. Four times the resistance represented by this load line is the plate-to-plate load for two triodes in a class A push-pull amplifier. Expressed as a formula,

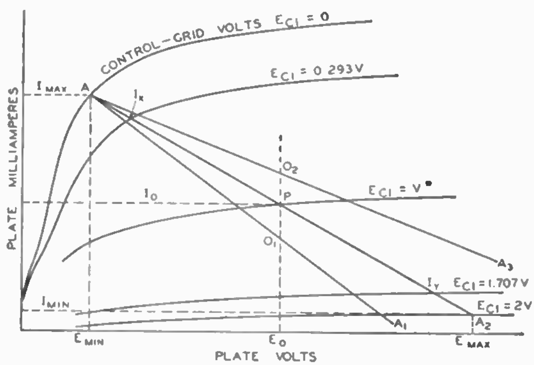
$$\text{Plate-to-plate load } (R_{pp}) = 4 \times (E_o - 0.6E_o)/I_{max}$$

E_o is expressed in volts, I_{max} in amperes, and R_{pp} in ohms.

Example: Assume that the plate voltage (E_o) is to be 300 volts, and the plate dissipation rating of the tube is 15 watts. Then, for class A operation, the operating bias can be equal to, but not more than, one-half the grid bias for cutoff with a plate voltage of $1.4 \times 300 = 420$ volts. (Since cutoff bias is approximately -115 volts at a plate voltage of 420 volts, one-half of this value is -57.5 volts bias.) At this bias, the plate current is found from the plate family to be 0.054 ampere and, therefore, the plate dissipation is 0.054×300 or 16.2 watts. Since -57.5 volts is the limit of bias for class A operation of these tubes at a plate voltage of 300 volts, the dissipation cannot be reduced by increasing the bias and it, therefore, becomes necessary to reduce the plate voltage.

If the plate voltage is reduced to 250 volts, the bias will be found to be -43.5 volts. For this value, the plate current is 0.06 ampere, and the plate dissipation is 15 watts. Then, following the method for calculating power output, erect a vertical line at $0.6E_o = 150$ volts. The intersection of the line with the curve $E_c = 0$ is I_{max} or 0.2 ampere. When this value is substituted in the power formula, the power output is $(0.2 \times 250)/5 = 10$ watts. The load resistance is determined from the load formula: Plate-to-plate load $(R_{pp}) = 4(250 - 150)/0.2 = 2000$ ohms.

Power output for a pentode or a beam power tube as a class A amplifier can be calculated in much the same way as for triodes. The calculations can be made graphically from a special plate family of curves, as illustrated in Fig. 22.



*V is the Negative Control-Grid Bias Voltage at the Operating Point

Fig. 22

From a point A just above the knee of the zero-bias curve, draw arbitrarily selected load lines to intersect the zero-plate-current axis. These lines should be on both sides of the operating point P whose position is determined by the desired operating plate voltage E_o, and one-half the maximum-signal plate current. Along any load line, say AA_1, measure the distance AO_1. On the same line, lay off an equal distance O_1A_1. For optimum operation, the change in bias from A to O_1 should be nearly equal to the change in bias from O_1 to A_1. If this condition can not be met with one line, as is the case for the line first chosen, then, another should be chosen. When the most satisfactory line has been selected, its resistance may be determined by the following formula:

$$\text{Load resistance } (R_p) = \frac{E_{max} - E_{min}}{I_{max} - I_{min}}$$

The value of R_p may then be substituted in the following formula for calculating power output.

$$\text{Power output} = \frac{[I_{max} - I_{min} + 1.41\ (I_x - I_y)]^2 R_p}{32}$$

In both of these formulas, I is in amperes, E is in volts, R_p is in ohms, and power output is in watts. I_x and I_y are the current values on the load line at bias voltages of $Ec_1 = V - 0.707V = 0.293V$ and $Ec_1 = V + 0.707V = 1.707V$, respectively.

Calculations for distortion may be made by means of the following formulas. The terms used have already been defined.

$$\%\ \text{2nd-harmonic distortion} = \frac{I_{max} + I_{min} - 2\ I_o}{I_{max} - I_{min} + 1.41\ (I_x - I_y)} \times 100$$

$$\%\ \text{3rd-harmonic distortion} = \frac{I_{max} - I_{min} - 1.41\ (I_x - I_y)}{I_{max} - I_{min} + 1.41\ (I_x - I_y)} \times 100$$

$$\%\ \text{total (2nd and 3rd) harmonic distortion} = \sqrt{(\%\text{2nd})^2 + (\%\text{3rd})^2}$$

The **conversion curves** given in Fig. 23 apply to electron tubes in general but are particularly useful for power tubes. These curves can be used for calculating approximate operating conditions for a plate voltage which is not included in the published data on operating conditions. For instance, suppose it is desired to operate two 6L6's in class A_1 push-pull, fixed bias, with a plate voltage of 200 volts. The nearest published operating conditions for this class of service are for a plate voltage of 250 volts. The operating conditions for the new plate voltage can be determined as follows: First compute the ratio of the new plate voltage to the plate voltage of the published data. In the example, this ratio is 200/250 = 0.8. This figure is the Voltage Conversion Factor, F_e. Multiply by this factor the published values for 250-volt operation in order to obtain the new values of grid bias and screen voltage. This gives a grid bias of $-16 \times 0.8 = -12.8$ volts, and a screen voltage of $250 \times 0.8 = 200$ volts for the new conditions.

To obtain the rest of the new conditions, multiply the published values by factors shown on the chart as corresponding to the voltage conversion factor of 0.8. In this chart,

- F_i applies to plate current and to screen current,
- F_p applies to power output
- F_r applies to load resistance and plate resistance,
- F_{gm} applies to transconductance.

Thus, to find the power output for the new conditions, determine the value of F_p for a

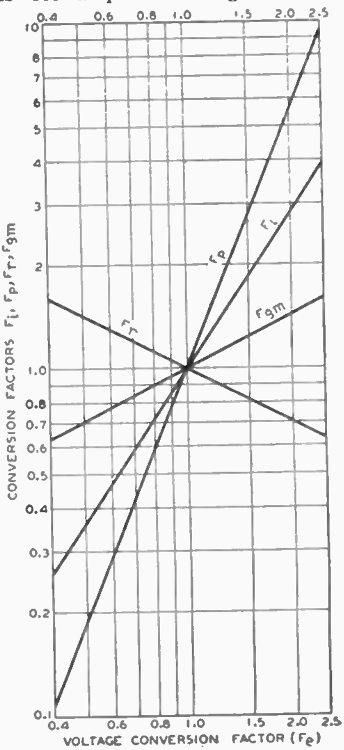


Fig. 23

voltage conversion factor of 0.8. The chart shows that this value of F_p is 0.6. Multiplying the published value of power output by 0.6, the power output for the new conditions is $14.5 \times 0.6 = 8.7$ watts.

A class AB power amplifier employs two tubes connected in push-pull with a higher negative grid bias than is used in a class A stage. With this higher negative bias, the plate and screen voltages can usually be made higher than for class A because the increased negative bias holds plate current within the limit of the tube's plate-dissipation rating. As a result of these higher voltages, more power output can be obtained from class AB operation.

Class AB amplifiers are subdivided into class AB_1 and class AB_2. In class AB_1 there is no flow of grid current. That is, the peak signal voltage applied to each grid is not greater than the negative grid-bias voltage. The grids therefore are not driven to a positive potential and do not draw grid current. In class AB_2, the peak signal voltage is greater than the bias so that the grids are driven positive and draw grid current.

Because of the flow of grid current in a class AB_2 stage there is a loss of power in the grid circuit. The sum of this loss and the loss in the input transformer is the total driving power required by the grid circuit. The driver stage should be capable of a power output considerably larger than this required power in order that distortion introduced in the grid circuit be kept low. The input transformer used in a class AB_2 amplifier usually has a step-down turns ratio.

Because of the large fluctuations of plate current in a class AB_2 stage, it is important that the plate power supply should have good regulation. Otherwise the fluctuations in plate current cause fluctuations in the voltage output of the power supply, with the result that power output is decreased and distortion is increased. To obtain satisfactory regulation it is usually advisable to use a low-drop rectifier, such as the 5V4-G, with a choke-input filter. In all cases, the resistance of the filter choke and power transformers should be as low as possible.

In **class AB_1 push-pull amplifier service using triodes**, the operating conditions may be determined graphically by means of the plate family if E_o, the desired operating plate voltage, is given. In this service, the dynamic load line does not pass through the operating point P as in the case of the single-tube amplifier, but through the point D in Fig. 24. Its position is not affected by the operating grid bias provided the plate-to-plate load resistance remains constant. Under these conditions, grid bias has only a small effect on the power output. Grid bias cannot be neglected, however, since it is used to find the zero-signal plate current and, from it, the zero-signal plate dissipation. Since the grid bias is higher in class AB_1 than in class A service for the same plate voltage, this "overbiased" condition permits the use of a higher signal voltage without grid current being drawn and, therefore, higher power output is obtained than in class A service.

In general, for any load line through point D, Fig. 24, the plate-to-plate load resistance in ohms of a push-pull amplifier is $R_{pp} = 4E_o/I'$, where I' is the plate current value in amperes at which the load line as projected intersects the plate current axis and E_o is in volts. This is another form of the formula, given under push-pull class A amplifiers, $R_{pp} = 4(E_o - 0.6E_o)/I_{max}$, but is more general. Power output $= (I_{max}/\sqrt{2})^2 \times R_{pp}/4$, where I_{max} is the peak plate current at zero grid volts for the load chosen. This formula simplified is $(I_{max})^2 \times R_{pp}/8$. The maximum-signal average plate current is $2I_{max}/\pi$ or $0.636\ I_{max}$; the maximum-signal average power input is $0.636\ I_{max}\ E_o$.

It is desirable to simplify these formulas for a first approximation. This simplification can be made if it is assumed that the peak plate current, I_{max}, occurs at the point of the zero-bias curve corresponding approximately to $0.6E_o$. The simplified formulas are:

Power output (for two tubes) = $(I_{max} \times E_o)/5$

Plate-to-plate load resistance $(R_{pp}) = 1.6E_o/I_{max}$

where E_o is in volts, I_{max} is in amperes, R_{pp} is in ohms, and power output is in watts.

It may be found during subsequent calculations that the distortion or the plate dissipation is excessive for this approximation; in that case, a different load resistance must be selected using the first approximation as a guide and the process repeated to obtain satisfactory operating conditions.

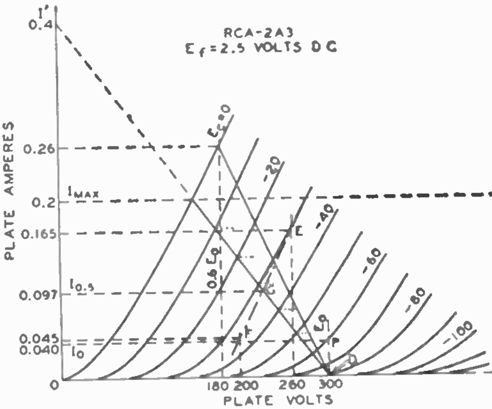


Fig. 24

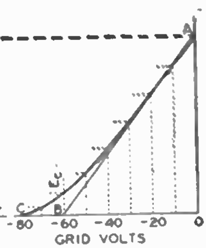


Fig. 25

Example: Fig. 24 illustrates the application of the method to a pair of 2A3's operated at E_o = 300 volts. The tubes have a plate-dissipation rating each of 15 watts. The method is to erect a vertical line at $0.6E_o$, or at 180 volts, which intersects the E_c = 0 curve at the point I_{max} = 0.26 ampere. Using the simplified formulas, we obtain

Plate-to-plate load resistance $(R_{pp}) = (1.6 \times 300)/0.26 = 1845$ ohms

Power output = $(0.26 \times 300)/5 = 15.6$ watts

At this point, it is well to determine the plate dissipation and to compare it with the maximum rated value. From the average plate current formula ($0.636\ I_{max}$) mentioned previously, the maximum-signal average plate current is 0.166 ampere. The product of this current and the operating plate voltage is 49.8 watts, the average input to the two tubes. From this value, subtract the power output of 15.6 watts to obtain the total dissipation for both tubes which is 34.2 watts. Half of this value, 17 watts, is in excess of the 15-watt rating of the tube and it is necessary, therefore, to assume another and higher load resistance so that the plate-dissipation rating will not be exceeded.

It will be found that at an operating plate voltage of 300 volts, the 2A3's require a plate-to-plate load resistance of 3000 ohms. From the formula for R_{pp}, the value of I′ is found to be 0.4 ampere. The load line for the 3000-ohm load resistance is then represented by a straight line from the point I′ = 0.4 ampere on the plate-current ordinate to the point E_o = 300 volts on the plate-voltage abscissa. At the intersection of the load line with the zero-bias curve, the peak plate current, I_{max}, can be read at 0.2 ampere. Then

Power output = $(I_{max}/\sqrt{2})^2\ R_{pp}/4 = (0.2/1.41)^2\ 3000/4 = 15$ watts

Proceeding as in the first approximation, we find that the maximum-signal average plate current, $0.636I_{max}$, is 0.127 ampere, and the maximum-signal average power input is 38.1 watts. This input minus the power output is 38.1 − 15 = 23.1 watts.

This is the dissipation for two tubes; the value per tube is 11.6 watts, a value well within the rating of this tube type.

The operating bias and the zero-signal plate current may now be found by use of a curve which is derived from the plate family and the load line. Fig. 25 is a curve of instantaneous values of plate current and dc grid-bias voltages taken from Fig. 24. Values of grid bias are read from each of the grid-bias curves of Fig. 24 along the load line and are transferred to Fig. 25 to produce the curved line from A to C. A tangent to this curve, starting at A, is drawn to intersect the grid-voltage abscissa. The point of intersection, B, is the operating grid bias for fixed-bias operation. In the example, the bias is –60 volts. Refer back to the plate family at the operating conditions of plate volts = 300 and grid bias = –60 volts; the zero-signal plate current per tube is seen to be 0.04 ampere. This procedure locates the operating point for each tube at P. The plate current must be doubled, of course, to obtain the zero-signal plate current for both tubes. Under maximum-signal conditions, the signal voltage swings from zero-signal bias voltage to zero bias for each tube on alternate half cycles. Hence, in the example, the peak af signal voltage per tube is 60 volts, or the grid-to-grid value is 120 volts.

As in the case of the push-pull class A amplifier, the second-harmonic distortion in a class AB_1 amplifier using triodes is very small and is largely cancelled by virtue of the push-pull connection. Third-harmonic distortion, however, which may be larger than permissible, can be found by means of composite characteristic curves. A complete family of curves can be plotted, but for the present purpose only the one corresponding to a grid bias of one-half the peak grid-voltage swing is needed. In the example, the peak grid voltage per tube is 60 volts, and the half value is 30 volts. The composite curve, since it is nearly a straight line, can be constructed with only two points (see Fig. 24). These two points are obtained from deviations above and below the operating grid and plate voltages. In order to find the curve for a bias of –30 volts, we have assumed a deviation of 30 volts from the operating grid voltage of –60 volts. Next assume a deviation from the operating plate voltage of, say, 40 volts. Then at 300 – 40 = 260 volts, erect a vertical line to intersect the (–60) – (–30) = –30-volt bias curve and read the plate current at this intersection which is 0.167 ampere; likewise, at the intersection of a vertical line at 300 + 40 = 340 volts and the (–60) + (–30) = –90-volt bias curve, read the plate current. In this example, the plate current is estimated to be 0.002 ampere. The difference of 0.165 ampere between these two currents determines the point E on the 300 – 40 = 260-volt vertical. Similarly, another point F on the same composite curve is found by assuming the same grid-bias deviation but a larger plate-voltage deviation, say, 100 volts. We now have points at 260 volts and 0.165 ampere (E), and at 200 volts and 0.045 ampere (F). A straight line through these points is the composite curve for a bias of –30 volts, shown as a long-short dash line in Fig. 24. At the intersection of the composite curve and the load line, G, the instantaneous composite plate current at the point of one-half the peak signal swing is determined. This current value, designated $I_{0.5}$ and the peak plate current, I_{max}, are used in the following formula to find peak value of the third-harmonic component of the plate current.

$$I_{h3} = (2I_{0.5} - I_{max})/3$$

In the example, where $I_{0.5}$ is 0.097 ampere and I_{max} is 0.2 ampere, $I_{h3} = (2 \times 0.097 - 0.2)/3 = (0.194 - 0.2)/3 = -0.006/3 = -0.002$ ampere. (The fact that I_{h3} is negative indicates that the phase relation of the fundamental (first-harmonic) and third-harmonic components of the plate current is such as to result in a slightly peaked wave form. I_{h3} is positive in some cases, indicating a flattening of the wave form.)

The peak value of the fundamental or first-harmonic component of the plate current

$$I_{h1} = 2/3\ (I_{max} + I_{0.5})$$

In the example: $I_{h1} = 2/3\ (0.2 + 0.097) = 0.198$ ampere. Then, the percentage of third-harmonic distortion is $(I_{h3}/I_{h1})\ 100 = (0.002/0.198)100 = 1\%$ approx.

A class AB_2 amplifier employs two tubes connected in push-pull as in the case of class AB_1 amplifiers. It differs in that it is biased so that plate current flows somewhat more than half the electrical cycle but less than the full cycle, the peak signal voltage is greater than the dc bias voltage, grid current is drawn, and consequently, power is consumed in the grid circuit. These conditions permit obtaining high power output without excessive plate dissipation.

The sum of the power used in the grid circuit and the losses in the input transformer is the total driving power required by the grid circuit. The driver stage should be capable of a power output considerably larger than this required power in order that distortion introduced in the grid circuit be kept low. In addition, the internal impedance of the driver stage as reflected into or as effective in the grid circuit of the power stage should always be as low as possible in order that distortion may be kept low. The input transformer used in a class AB_2 stage usually has a step-down ratio adjusted for this condition.

Load resistance, plate dissipation, power output, and distortion determinations are similar to those for class AB_1. These quantities are interdependent with peak grid-voltage swing and driving power; a satisfactory set of operating conditions involves a series of approximations. The load resistance and signal swing are limited by the permissible grid current and power, and the distortion. With either a high load resistance or excessive signal swing, the plate-dissipation rating will be exceeded, distortion will be high, and the driving power will be unnecessarily high.

A class B amplifier employs two tubes connected in push-pull, so biased that plate current is almost zero when no signal voltage is applied to the grids. Because of this new value of no-signal plate current, class B amplification has the same advantage as class AB_2, i.e., large power output can be obtained without excessive plate dissipation. The difference between class B and class AB_2 is that, in class B, plate current is cut off for a larger portion of the negative grid swing, and the signal swing is even larger than in class AB_2 operation.

Because a class B amplifier is usually operated at zero or low bias, each grid is at a positive potential during all or most of the positive half-cycle of its signal swing and consequently draws considerable grid current. There is, therefore, a loss of power in the grid circuit. This condition imposes the same requirement in the driver stage as in a class AB_2 stage, that is, the driver should be capable of delivering considerably more power output than the power required for the class B grid circuit in order that distortion be low. Likewise, the interstage transformer between the driver and class B stage usually has a step-down turns ratio.

Determination of load resistance, plate dissipation, power output, and distortion is similar to that for a class AB_2 stage.

Power amplifier tubes designed for class A operation can be used in class AB_2 and class B service under suitable operating conditions. There are several tube types designed especially for class B service. The characteristic common to all of these types is a high amplification factor. With a high amplification factor, plate current is small even when the grid bias is zero. These tubes, therefore, can be operated in class B service at a bias of zero volts so that no bias supply is required. A number of class B amplifier tubes consist of two triode units mounted in one tube. The two units can be connected in push-pull so that only one tube is required for a class B stage. Examples of twin triodes used in class B service are the 6N7, 6A6, and 1G6-GT.

An **inverse-feedback** circuit, sometimes called a **degenerative** circuit, is one in which a portion of the output voltage of a tube is applied to the input of the same or a preceding tube in opposite phase to the signal applied to the tube. Two important advantages of feedback are: (1) reduced distortion from each stage included in the feedback circuit and (2) reduction in the variations in gain due to changes in line voltage, possible differences between tubes of the same type, or variations in the values of circuit constants included in the feedback circuit.

Inverse feedback is used in audio amplifiers to reduce distortion in the output stage where the load impedance on the tube is a loudspeaker. Because the impedance of a loudspeaker is not constant for all audio frequencies, the load impedance on the output tube varies with frequency. When the output tube is a pentode or beam power tube having high plate resistance, this variation in plate load impedance can, if not corrected, produce considerable frequency distortion. Such frequency distortion can be reduced by means of inverse feedback. Inverse feedback circuits are of the **constant-voltage** type and the **constant-current** type.

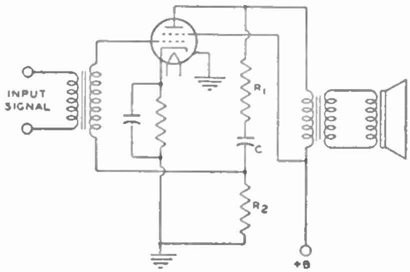


Fig. 26

The application of the **constant-voltage** type of inverse feedback to a power output stage using a single beam power tube is illustrated by Fig. 26. In this circuit, R_1, R_2, and C are connected across the output of the 6L6 as a voltage divider. The secondary of the grid-input transformer is returned to a point on this voltage divider. Capacitor C blocks the dc plate voltage from the grid. However, a portion of the tube's af output voltage, approximately equal to the output voltage multiplied by the fraction $R_2/(R_1 + R_2)$, is applied to the grid. A decrease in distortion results which is explained in the curves of Fig. 27.

Consider first the amplifier without the use of inverse feedback. Suppose that when a signal voltage e_s is applied to the grid the af plate current i'_p has an irregularity in its positive half-cycle. This irregularity represents a departure from the waveform of the input signal and is, therefore, distortion. For this plate-current waveform, the af plate voltage has a waveform shown by e'_p. The plate-voltage waveform is inverted compared to the plate-current waveform because a plate-current increase produces an increase in the drop across the plate load. The voltage at the plate is the difference between the drop across the load and the supply voltage; thus, when plate current goes up, plate voltage goes down; when plate current goes down, plate voltage goes up.

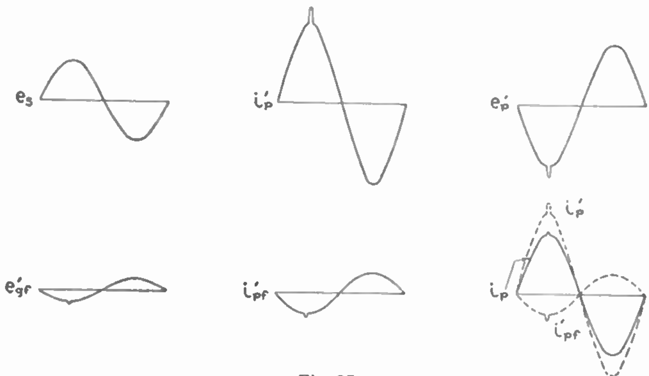


Fig. 27

Now suppose that inverse feedback is applied to the amplifier. The voltage fed back to the grid has the same waveform and phase as the plate voltage, but is smaller in magnitude. Hence, with a plate voltage of waveform shown by e'_p, the feedback voltage appearing on the grid is as shown by e'_{gf}. This voltage applied to the grid produces a component of plate current i'_{pf}. It is evident that the irregularity in the waveform of this component of plate current would act to cancel the original irregularity and thus reduce distortion.

After the correction of distortion has been applied by inverse feedback, the relations are as shown in the curve for i_p. The dotted curve shown by i'_{pf} is the component of plate current due to the feedback voltage on the grid. The dotted curve shown by i'_p is the component of plate current due to the signal voltage on the grid. The algebraic sum of these two components gives the resultant plate current shown by the solid curve of i_p. Since i'_p is the plate current that would flow without inverse feedback, it can be seen that the application of inverse feedback has reduced the irregularity in the output current. In this manner inverse feedback acts to correct any component of plate current that does not correspond to the input signal voltage, and thus reduces distortion.

From the curve for i_p, it can be seen that, besides reducing distortion, inverse feedback also reduces the amplitude of the output current. Consequently, when inverse feedback is applied to an amplifier there is a decrease in power output as well as a decrease in distortion. However, by increasing the signal voltage, it is practical to bring the power output back to its full value. Hence, the application of inverse feedback to an amplifier requires that more driving voltage be applied to obtain full power output but this output is obtained with less distortion.

Inverse feedback may also be applied to resistance-coupled stages as shown in Fig. 28. The circuit is conventional except that a feedback resistor, R_3, is connected between the plate of tubes T_1 and T_2. The output signal voltage of T_1 and a portion of the output signal voltage of T_2 appears across R_2. Because the distortion generated in the plate circuit of T_2 is applied to its grid out of phase with the input signal, the distortion in the output of T_2 is comparatively low. With sufficient inverse feedback of the constant-voltage type in a power-output stage, it is not necessary to employ a network of resistance and capacitance in the output circuit to reduce response at high audio frequencies. Inverse-feedback circuits can also be applied to push-pull class A and class AB_1 amplifiers. When the circuit in Fig. 26 is used in push-pull, the input transformer must have a separate secondary for each grid. Inverse feedback is not recommended for use in amplifiers drawing grid power because of the resistance introduced in the grid circuit.

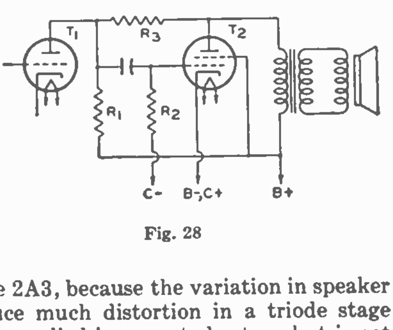


Fig. 28

Constant-current inverse feedback is usually obtained by omitting the bypass capacitor across a cathode resistor. This method decreases the gain and the distortion but increases the plate resistance of the tube. When the plate resistance of an output tube is increased, the output voltage rises at the resonant frequency of the loudspeaker and accentuates hangover effects.

Inverse feedback is not generally applied to a triode power amplifier, such as the 2A3, because the variation in speaker impedance with frequency does not produce much distortion in a triode stage having low plate resistance. It is sometimes applied in a pentode stage but is not always convenient. As has been shown, when inverse feedback is used in an amplifier, the driving voltage must be increased in order to give full power output.

When inverse feedback is used with a pentode, the total driving voltage required for full power output may be inconveniently large. Because a beam power tube gives full power output on a comparatively small driving voltage, inverse feedback is especially applicable to beam power tubes. By means of inverse feedback, the high efficiency and high power output of beam power tubes can be combined with freedom from the effects of varying speaker impedance.

Another important application of inverse feedback is in the **cathode follower** circuit, an example of which is given in Fig. 29. In this application, there is no load resistance in the plate circuit; the output is taken from the load resistance in the cathode circuit. The voltage amplification of a cathode follower may be expressed by the following convenient formulas.

For a triode:

$$\text{Voltage amplification} = \frac{\text{amplification factor} \times \text{load resistance}}{\text{plate resistance} + \text{load resistance} \times (\text{amplification factor} + 1)}$$

For a pentode:

$$\text{Voltage amplification} = \frac{\text{transconductance} \times \text{load resistance}}{1 + (\text{transconductance} \times \text{load resistance})}$$

Resistance values are in ohms; transconductance values are in mhos. From these formulas it can be seen that the voltage amplification is always less than unity.

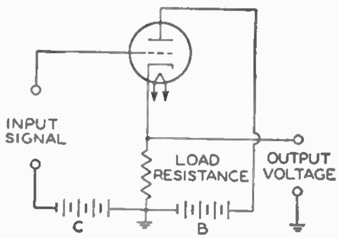


Fig. 29

In addition to having a wide frequency response, the cathode follower has the features of high input impedance and low output impedance. These features permit the cathode follower to be used to match a high-impedance source to a low-impedance load. Typical applications would be the connection of a high-impedance crystal phonograph pickup to a low-impedance transmission line, or the connection of a wide-band, high-impedance, video signal source to a low-impedance transmission line. In audio applications, however, the use of an unbypassed cathode resistor, as required by a cathode-follower stage, is not recommended unless the signal level of the stage is fairly high and the gain of the succeeding stages is moderate.

Selection of a suitable tube and its operating conditions for use in a cathode-follower circuit having a specified output impedance can be made, in most practical cases, by the use of the following formula to determine the required tube transconductance.

$$\text{Required transconductance (micromhos)} = \frac{1{,}000{,}000}{\text{output impedance (ohms)}}$$

Once the required transconductance is obtained, a suitable tube and its operating conditions may be determined from the TECHNICAL DATA SECTION. The conversion curves given in Fig. 23 may be used for calculating operating conditions for values of transconductance not included in the tabulated data. After the operating conditions have been determined, the value of the required cathode load resistance may be calculated from the following formula.

For triode:

$$\text{Cathode load resistance} = \frac{\text{output impedance} \times \text{plate resistance}}{\text{plate resistance} - \text{output impedance } (1 + \text{amplification factor})}$$

For pentode:

$$\text{Cathode load resistance} = \frac{\text{output impedance}}{1 - (\text{transconductance} \times \text{output impedance})}$$

Resistance and impedance values are in ohms; transconductance values are in mhos.

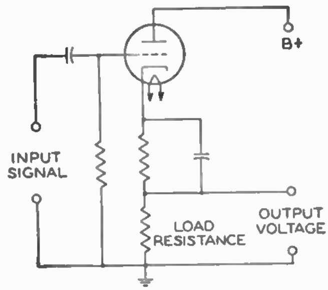


Fig. 30

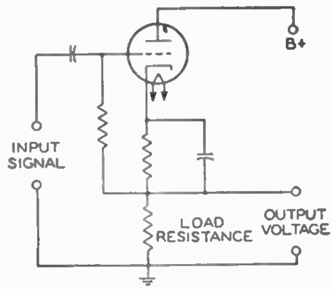


Fig. 31

If the value of the cathode load resistance calculated to give the required output impedance does not give the required operating bias, the basic cathode-follower circuit can be modified in a number of ways. Two of the more common modifications are given in Figs. 30 and 31. In Fig. 30 the bias is increased by adding a bypassed resistance between the cathode and the unbypassed load resistance and returning the grid to the low end of the load resistance. In Fig. 31 the bias is reduced by adding a bypassed resistance between the cathode and the unbypassed load resistance but, in this case, the grid is returned to the junction of the two cathode resistors so that the bias voltage is only the dc voltage drop across the added resistance. The size of the bypass capacitor should be large enough so that it presents negligible reactance at the lowest frequency to be handled. In both cases the B-supply should be increased to make up for the voltage taken for biasing. Example: Select a suitable tube and determine the operating conditions and circuit components for a cathode-follower circuit having an output impedance that will match a 500-ohm transmission line. Procedure: First, determine the approximate transconductance required.

$$\text{Required transconductance} = \frac{1{,}000{,}000}{500} = 2000 \text{ micromhos}$$

A survey of the tubes that have a transconductance in this order of magnitude shows that type 12AX7 is among the tubes to be considered. Referring to the characteristics given in the technical data section for one triode unit of high-mu twin triode 12AX7, we find that for a plate voltage of 250 volts and a bias of –2 volts, the transconductance is 1600 micromhos, the plate resistance is 62500 ohms, the amplification factor is 100, and the plate current is 0.0012 ampere. When these values are used in the expression for determining the cathode load resistance, we obtain

$$\text{Cathode load resistance} = \frac{500 \times 62500}{62500 - 500\,(100 + 1)} = 2600 \text{ ohms}$$

The voltage across this resistor when the plate current of 0.0012 ampere flows is 2600 × 0.0012 = 3.12 volts. Since the required bias voltage is only –2 volts, the circuit arrangement given in Fig. 31 is employed. The bias is furnished by a resistance that will have a voltage drop of 2 volts when it carries a current of 0.0012 ampere. The required bias resistance, therefore, is 2/0.0012 = 1670 ohms. If 60 cycles per second is the lowest frequency to be passed, 20 microfarads is a suitable value for the bypass capacitor. The B-supply, of course, is increased by the voltage drop across the cathode resistance which, in this example, is approximately 5 volts. The B–supply, therefore, is $250 + 5 = 255$ volts.

Since it is desirable to eliminate, if possible, the bias resistor and bypass capacitor, it is worthwhile to try other tubes and other operating conditions to obtain a value of cathode load resistance which will also provide the required bias. If the triode section of twin diode—high-mu triode 6AT6 is operated under the conditions given in the technical data section with a plate voltage of 100 volts and a bias of −1 volt, it will have an amplification factor of 70, a plate resistance of 54000 ohms, a transconductance of 1300 micromhos, and a plate current of 0.0008 ampere.

Then,

$$\text{Cathode load resistance} = \frac{500 \times 54000}{54000 - 500\,(70 + 1)} = 1460 \text{ ohms}$$

The bias voltage obtained across this resistance is $1460 \times 0.0008 = 1.17$ volts. Since this value is for all practical purposes close enough to the required bias, no additional bias resistance will be required and the grid may be returned directly to ground. There is no need to adjust the B–supply voltage to make up for the drop in the cathode resistor. The voltage amplification for the cathode-follower circuit utilizing the triode section of type 6AT6 is

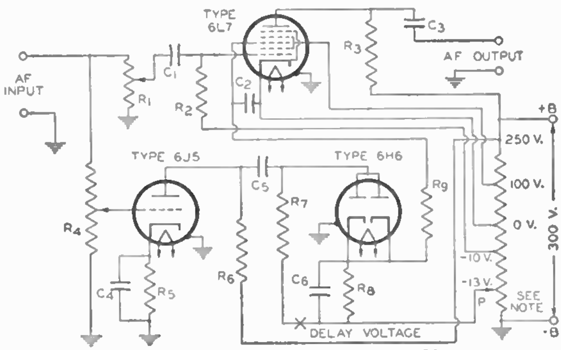
$$\text{Voltage amplification} = \frac{70 \times 1460}{54000 - 1460\,(70 + 1)} = 0.65$$

For applications in which the cathode follower is used to isolate two circuits—for example, when it is used between a circuit being tested and the input stage of an oscilloscope or a vacuum-tube voltmeter—voltage output and not impedance matching is the primary consideration. In such applications it is desirable to use a relatively high value of cathode load resistance, such as 50,000 ohms, in order to get the maximum voltage output. In order to obtain proper bias, a circuit such as that of Fig. 31 should be used. With a high value of cathode resistance, the voltage amplification will approximate unity.

A **corrective filter** can be used to improve the frequency characteristic of an output stage using a beam power tube or a pentode when inverse feedback is not applicable. The filter consists of a resistor and a capacitor connected in series across the primary of the output transformer. Connected in this way, the filter is in parallel with the plate load impedance reflected from the voice-coil by the output transformer. The magnitude of this reflected impedance increases with increasing frequency in the middle and upper audio range. The impedance of the filter, however, decreases with increasing frequency. It follows that by use of the proper values for the resistance and the capacitance in the filter, the effective load impedance on the output tubes can be made practically constant for all frequencies in the middle and upper audio range. The result is an improvement in the frequency characteristic of the output stage.

The resistance to be used in the filter for a push-pull stage is 1.3 times the recommended plate-to-plate load resistance; or, for a single-tube stage, is 1.3 times the recommended plate load resistance. The capacitance in the filter should have a value such that the voltage gain of the output stage at a frequency of 1000 cycles or higher is equal to the voltage gain at 400 cycles. A method of determining the proper value of capacitance for the filter is to make two measurements of the output voltage across the primary of the output transformer: first, when a 400-cycle signal is applied to the input, and second, when a 1000-cycle signal of the same voltage as the 400-cycle signal is applied to the input. The correct value of capacitance is the one which gives equal output voltages for the two signal inputs. In practice, this value is usually found to be in the order of 0.05 μf.

A volume expander can be used in a phonograph amplifier to make more natural the reproduction of music which has a very large volume range. For instance, in the music of a symphony orchestra, the sound intensity of the loud passages is very much higher than that of the soft passages. When this music is recorded, it is not feasible to make the ratio of maximum amplitude to minimum amplitude as large on the record as it is in the original music. The recording process is therefore monitored so that the volume range of the original is compressed on the record. To compensate for this compression, a volume-expander amplifier has a variable gain which is greater for a high-amplitude signal than for a low-amplitude signal. The volume expander, therefore, amplifies loud passages more than soft passages and thus can restore to the music reproduced from the record the volume range of the original.



C_1, C_3, C_5 = 0.1 μf
C_2, C_4, C_6 = 0.5 μf
R_1 = 1-Megohm Potentiometer (Volume Control)
R_2 = 1 Megohm
R_3, R_6 = 100,000 ohms, 1 watt
R_4 = 1-Megohm Potentiometer (Expansion Control)
R_5 = 10,000 ohms, 0.1 watt
R_7 = 100,000 ohms, 0.1 watt
R_8 = 250,000 ohms, 0.1 watt
R_9 = 500,000 ohms, 0.1 watt

Fig. 32

A volume expander circuit is shown in Fig. 32. In this circuit, the gain of the 6L7 as an audio amplifier can be varied by changing the bias on grid No. 3. When the bias on grid No. 3 is made less negative, the gain of the 6L7 increases. The signal to be amplified is applied to grid No. 1 of the 6L7 and is amplified by the 6L7. The signal is also applied to the grid of the 6J5, is amplified by the 6J5, and is rectified by the 6H6. The rectified voltage developed across R_8, the load resistor of the 6H6, is applied as a positive bias voltage to grid No. 3 of the 6L7. Then, when the amplitude of the signal input increases, the voltage across R_8 increases, and the bias on grid No. 3 of the 6L7 is made less negative. Because this reduction in bias increases the gain of the 6L7, the gain of the amplifier increases with increase in signal amplitude and thus produces volume expansion of the signal. The voltage gain of the expander varies from 5 to 20.

Grid No. 1 of the 6L7 is a variable-mu grid and, therefore, will produce distortion if the input signal voltage is too large. For that reason, the signal input to the 6L7 should not exceed a peak value of 1 volt. This value is of the same order as the voltage obtainable from a magnetic phonograph pick-up. The no-signal bias voltage on grid No. 3 is controlled by adjustment of contact P. This contact should be adjusted initially to give a no-signal plate current of 0.15 milliampere in the 6L7. No further adjustment of contact P is required if the same 6L7 is always used. If it is desired to delay volume expansion until the signal input reaches a certain amplitude, the delay voltage can be inserted as a negative bias on the 6H6 plates at the point marked X in the diagram. All terminal points on the power-supply voltage divider should be adequately bypassed.

A phase inverter is a circuit used to provide resistance coupling between the output of a single-tube stage and the input of a push-pull stage. The necessity for a phase inverter arises because the signal-voltage inputs to the grids of a push-pull stage must be 180 degrees out of phase and approximately equal in amplitude with respect to each other. Thus, when the signal voltage input to a push-pull stage swings the control grid of one tube in a positive direction, it should swing the other grid in a negative direction by a similar amount. With transformer coupling between stages, the out-of-phase input voltage to the push-pull stage is supplied by means of the center-tapped secondary. With resistance coupling, the out-of-phase input voltage is obtained by means of the inverter action of a tube.

Fig. 33 shows a push-pull power amplifier, resistance-coupled by means of a phase-inverter circuit to a single-stage triode T_1. Phase inversion in this circuit is provided by triode T_2. The output voltage of T_1 is applied to the grid of T_3. A portion of the output voltage of T_1 is also applied through the resistors R_3 and R_5 to the grid of T_2. The output voltage of T_2 is applied to the grid of T_4. When the output voltage of T_1 swings in the positive direction, the plate current of T_2 increases. This action increases the voltage drop across the plate resistor R_2 and swings the plate of T_2 in the negative direction. Thus, when the output voltage of T_1 swings positive, the output voltage of T_2 swings negative and is, therefore, 180° out of phase with the output voltage of T_1. In order to obtain equal voltages at E_a and E_b, $(R_3+R_5)/R_5$ should equal the voltage gain of T_2. Under the conditions where a twin-type tube or two tubes having the same characteristics are used at T_1 and T_2, R_4 should be equal to the sum of R_3 and R_5. The ratio of R_3+R_5 to R_5 should be the same as the voltage gain ratio of T_2 in order to apply the correct value of signal voltage to T_2. The value of R_5 is, therefore, equal to R_4 divided by the voltage gain of T_2; R_3 is equal to R_4 minus R_5. Values of R_1, R_2, R_3 plus R_5, and R_4 may be taken from the chart in the RESISTANCE-COUPLED AMPLIFIER SECTION. In the practical application of this circuit, it is convenient to use a twin-triode tube combining T_1 and T_2. A phase-inverter circuit using a 12SC7 is shown in the CIRCUIT SECTION.

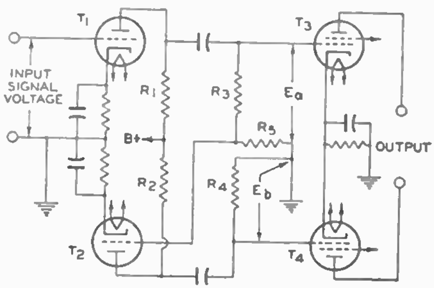


Fig. 33

An amplifier may also be used as a **limiter.** One use of a limiter is in receivers designed for the reception of frequency-modulated signals. The limiter in FM receivers has the function of eliminating amplitude variations from the input to the detector. Because in an FM system, amplitude variations are primarily the result of noise disturbances, the use of a limiter prevents such disturbances from being reproduced in the audio output. The limiter usually follows the last if stage where it can minimize the effects of disturbances coming in on the rf carrier and those produced locally.

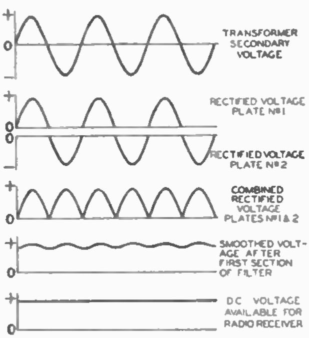
The limiter is essentially an if voltage amplifier designed for saturated operation. Saturated operation means that an increase in signal voltage above a certain value produces very little increase in plate current. A signal voltage which is never less than sufficient to cause saturation of the limiter, even on weak signals, is supplied to the limiter input by the preceding stages. Any change in amplitude, therefore, such as might be produced by noise voltage fluctuation, is not reproduced in the limiter output. The limiting action, of course, does not interfere with the reproduction of frequency variations. Plate-current saturation of the limiter may be obtained by the use of grid-resistor-and-capacitor bias with plate and screen voltages which are low compared with customary if-amplifier operating conditions. As a result of these design features, the limiter is able to maintain its output voltage at a constant amplitude over a wide range of input-signal voltage variations. The output of the limiter is frequency-modulated if voltage, the mean frequency of which is that of the if amplifier. This voltage is impressed on the input of the detector.

The reception of FM signals without serious distortion requires that the response of the receiver be such that satisfactory amplification of the signal is provided over the entire range of frequency deviation from the mean frequency. Since the frequency at any instant depends on the modulation at that instant, it follows that excessive attenuation toward the edges of the band, in the rf or if stages, will cause distortion. This means that, in a high-fidelity receiver, the amplifiers must be capable of amplifying, for the maximum permissible frequency deviation of 75 kilocycles, a band 150 kilocycles wide. Suitable tubes for this purpose are the 6BA6 and 6BJ6.

RECTIFICATION

The rectifying action of a diode finds an important application in supplying a receiver with dc power from an ac line. A typical arrangement for this application includes a rectifier tube, a filter, and a voltage divider. The rectifying action of the tube is explained briefly under **Diodes**, in the ELECTRONS, ELECTRODES, AND ELECTRON TUBE SECTION. The function of a filter is to smooth out the ripple of the tube output, as indicated in Fig. 34. The action of the filter is explained in ELECTRON TUBE INSTALLATION SECTION under **Filters.** The voltage divider is used to cut down the output voltage to the values required by the plates, screens, and grids of the tubes in the receiver.

A half-wave rectifier and **a full-wave rectifier** circuit are shown in Fig. 35. In the half-wave circuit, current flows through the rectifier tube to the filter on every other half-cycle of the ac input voltage when the plate is positive with respect to the cathode. In the full-wave circuit, current flows to the filter on every half-cycle, through plate No. 1 on one half-cycle when plate No. 1 is positive with respect to the cathode, and through plate No. 2 on the next half-cycle when plate No. 2 is positive with respect to the cathode. Because the current flow to the filter is more uniform in the full-wave circuit than in the half-wave circuit, the output of the full-wave circuit requires less filtering. Rectifier operating information and circuits are given under each rectifier tube type and in the CIRCUIT SECTION, respectively.



FULL-WAVE RECTIFICATION

Fig. 34

Parallel operation of rectifier tubes furnishes an output current greater than that obtainable with the use of one tube. For example, when two full-wave rectifier tubes are connected in parallel, the plates of each tube are connected together and each tube acts as a half-wave rectifier. The allowable voltage and load conditions per tube are the same as for full-wave service but the total load-handling capability of the complete rectifier

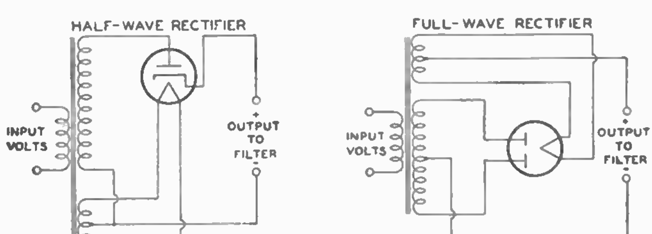


Fig. 35

is approximately doubled. When mercury-vapor rectifier tubes are connected in parallel, a stabilizing resistor of 50 to 100 ohms should be connected in series with each plate lead in order that each tube will carry an equal share of the load. The value of the resistor to be used will depend on the amount of plate current that passes through the rectifier. Low plate current requires a high value; high plate current, a low value. When the plates of mercury-vapor rectifier tubes are connected in parallel, the corresponding filament leads should be similarly connected. Otherwise, the tube drops will be considerably unbalanced and larger stabilizing resistors will be required. Two or more vacuum rectifier tubes can also be connected in parallel to give correspondingly higher output current and, as a result of paralleling their internal resistances, give somewhat increased voltage output. With vacuum types, stabilizing resistors may or may not be necessary depending on the tube type and the circuit.

A **voltage-doubler** circuit of simple form is shown in Fig. 36. The circuit derives its name from the fact that its dc voltage output can be as high as twice the peak value of ac input. Basically, a voltage doubler is a rectifier circuit arranged so that the output voltages of two half-wave rectifiers are in series. The action of a voltage doubler is briefly as follows. On the positive half-cycle of the ac input, that is, when the upper side of the ac input line is positive with respect to the lower side, the upper diode passes current and feeds a positive charge into the upper capacitor. As positive charge accumulates on the upper plate of the capacitor, a positive voltage builds up across the capacitor. On the next half-cycle of the ac input, when the upper side of the line is negative with respect to the lower side, the lower diode passes current so that a negative voltage builds up across the lower capacitor. As long as no current is drawn at the output terminals from the capacitor, each capacitor can charge up to a voltage of magnitude E, the peak value of the ac input. It can be seen from the diagram that with a voltage of +E on one capacitor and -E on the other, the total voltage across the capacitors is 2E. Thus the voltage doubler supplies a no-load dc output voltage twice as large as the peak ac input voltage. When current is drawn at the output terminals by the load, the output voltage drops below 2E by an amount that depends on the magnitude of the load current and the capacitance of the capacitors. The arrangement shown in Fig. 36 is called a full-wave voltage doubler because each rectifier passes current to the load on each half of the ac input cycle.

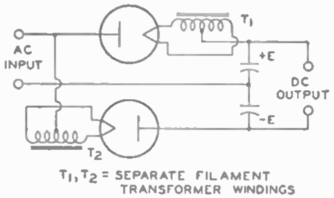
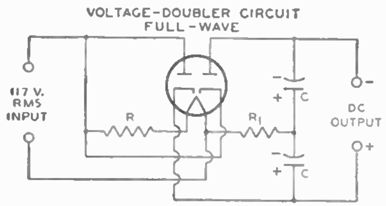
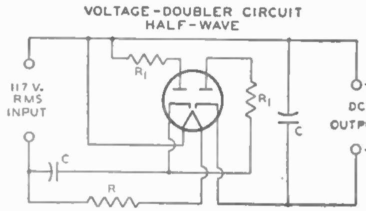


Fig. 36

Two rectifier types especially designed for use as voltage doublers are the 25Z6-GT and 117Z6-GT. These tubes combine two separate diodes in one tube. As voltage doublers, the tubes are used in "transformerless" receivers. In these receivers, the heaters of all tubes in the set are connected in series with a voltage-dropping resistor across the line. The connections for the heater supply and the voltage-doubling circuit are shown in Figs. 37 and 38.

With the full-wave voltage-doubler circuit in Fig. 37, it will be noted that the dc load circuit can not be connected to ground or to one side of the ac supply line. This presents certain disadvantages when the heaters of all the tubes in the set are connected in series with a resistance across the ac line. Such a circuit arrangement may cause hum because of the high ac potential between the heaters and cathodes of the tubes. The circuit in Fig. 38 overcomes this difficulty by making one side of the ac line common with the negative side of the dc load circuit. In this circuit, one half of the tube is used to charge a capacitor which, on the following half cycle, discharges in series with the line voltage through the other half of the tube. This circuit is called a half-wave voltage doubler because rectified current flows to the load only on alternate halves of the ac input cycle. The voltage regulation of this arrangement is somewhat poorer than that of the full-wave voltage doubler.





R = HEATERS OF OTHER TUBES IN SERIES WITH VOLTAGE-DROPPING RESISTOR
R_1 = PROTECTIVE RESISTOR

Fig. 37

Fig. 38

DETECTION

When speech or music is transmitted from a radio station, the station radiates a radio-frequency (rf) wave which is of either of two general types. In one type, the wave is said to be amplitude modulated when its frequency remains constant and the amplitude is varied. In the other type, the wave is said to be frequency modulated when its amplitude remains essentially constant but its frequency is varied. In either case, the varying component is modulated in accordance with the audio frequencies (af) of the speech or music being transmitted.

The function of the receiver is to reproduce the original af modulating wave from the modulated rf wave. The receiver stage in which this function is performed is called the demodulator or detector stage.

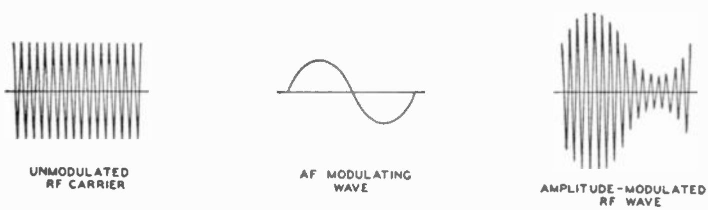


Fig. 39

The effect of **amplitude modulation** on the waveform of the rf wave is shown in Fig. 39. There are three different basic circuits used for the detection of amplitude-modulated waves: the diode detector, the grid-bias detector, and the grid-resistor detector. These circuits are alike in that they eliminate, either partially or completely, alternate half-cycles of the rf wave. With alternate half-cycles removed, the audio variations of the other half-cycles can be amplified to drive headphones or a loudspeaker.

A **diode-detector** circuit is shown in Fig. 40. The action of this circuit when a modulated rf wave is applied is illustrated by Fig. 41. The rf voltage applied to the circuit is shown in light line; the output voltage across capacitor C is shown in heavy line. Between points (a) and (b) on the first positive half-cycle of the applied rf voltage, capacitor C charges up to the peak value of the rf voltage. Then as the applied rf voltage falls away from its peak value, the capacitor holds the cathode at a potential more positive than the voltage applied to the anode. The capacitor thus temporarily cuts off current through the diode. While the diode current is cut off, the capacitor discharges from (b) to (c) through the diode load resistor R. When the rf voltage on the anode rises high enough to exceed the potential at which the capacitor holds the cathode, current flows again and

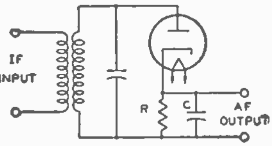


Fig. 40

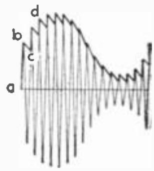


Fig. 41

the capacitor charges up to the peak value of the second positive half-cycle at (d). In this way, the voltage across the capacitor follows the peak value of the applied rf voltage and reproduces the af modulation. The curve for voltage across the capacitor, as drawn in Fig. 41, is somewhat jagged. However, this jaggedness, which represents an rf component in the voltage across the capacitor, is exaggerated in the drawing. In an actual circuit the rf component of the voltage across the capacitor is negligible. Hence, when the voltage across the capacitor is amplified, the output of the amplifier reproduces the speech or music originating at the transmitting station.

Another way to describe the action of a diode detector is to consider the circuit as a half-wave rectifier. When the rf signal on the plate swings positive, the tube conducts and the rectified current flows through the load resistance R. Because the dc output voltage of a rectifier depends on the voltage of the ac input, the dc voltage across C varies in accordance with the amplitude of the rf carrier and thus reproduces the af signal. Capacitor C should be large enough to smooth out rf or if variations but should not be so large as to affect the audio variations. Two diodes can be connected in a circuit similar to a full-wave rectifier to give full-wave detection. However, in practice, the advantages of this connection generally do not justify the extra circuit complication.

The diode method of detection has the advantage over other methods in that it produces less distortion. The reason is that the dynamic characteristics of a diode can be made more linear than that of other detectors. A diode has the disadvantages that it does not amplify the signal, and that it draws current from the input circuit and therefore reduces the selectivity of the input circuit. However, because the diode method of detection produces less distortion and because it permits the use of simple avc circuits without the necessity for an additional voltage supply, the diode method of detection is most widely used in broadcast receivers.

A typical diode-detector circuit using a twin-diode triode tube is shown in Fig. 42. Both diodes are connected together. R_1 is the diode load resistor. A portion of the af voltage developed across this resistor is applied to the triode grid through the volume control R_3. In a typical circuit, resistor R_1 may be tapped so that five-sixths of the total af voltage across R_1 is applied to the volume control. This tapped connection reduces the af voltage output of the detector circuit slightly but it reduces audio distortion and improves the rf filtering. DC bias for the triode section is provided by the cathode-bias resistor R_2 and the audio bypass capacitor C_3. The function of capacitor C_2 is to block the dc bias of the cathode from the grid. The function of capacitor C_4 is to bypass any rf voltage on the grid to cathode. A twin-diode pentode may also be used in this circuit. With a pentode, the af output should be resistance-coupled rather than transformer-coupled.

Another diode-detector circuit, called a diode-biased circuit, is shown in Fig. 43. In this circuit, the triode grid is connected directly to a tap on the diode load resistor. When an rf signal voltage is applied to the diode, the dc voltage at the tap supplies bias to the triode grid. When the rf signal is modulated, the

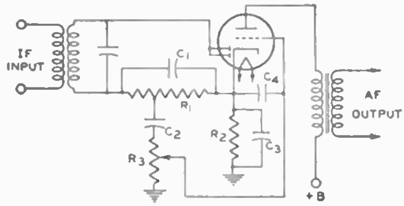


Fig. 42

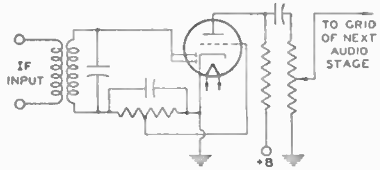


Fig. 43

af voltage at the tap is applied to the grid and is amplified by the triode. The advantage of this circuit over the self-biased arrangement shown in Fig. 42 is that the diode-biased circuit does not employ a capacitor between the grid and the diode load resistor, and consequently does not produce as much distortion of a signal having a high percentage of modulation.

However, there are restrictions on the use of the diode-biased circuit. Because the bias voltage on the triode depends on the average amplitude of the rf voltage applied to the diode, the average amplitude of the voltage applied to the diode should be constant for all values of signal strength at the antenna. Otherwise there will be different values of bias on the triode grid for different signal strengths and the triode will produce distortion. Since there is no bias applied to the diode-biased triode when no rf voltage is applied to the diode, sufficient resistance should be included in the plate circuit of the triode to limit its zero-bias plate current to a safe value. These restrictions mean, in practice, that the receiver should have a separate-channel avc system. With such an avc system, the average amplitude of the signal voltage applied to the diode can be held within very close limits for all values of signal strength at the antenna. The tube used in a diode-biased circuit should be one which operates at a fairly large value of bias voltage. The variations in bias voltage are then a small percentage of the total bias and hence produce small distortion. Tubes taking a fairly large bias voltage are types such as the 6BF6 or 6ST7 having a medium-mu triode. Tube types having a high-mu triode or a pentode should not be used in a diode-biased circuit.

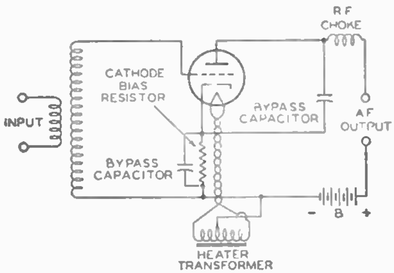


Fig. 44

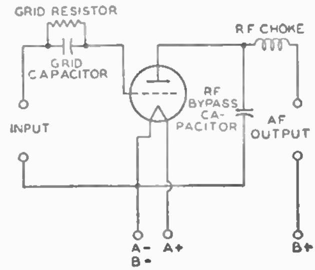


Fig. 45

A **grid-bias detector** circuit is shown in Fig. 44. In this circuit, the grid is biased almost to cutoff, i.e., operated so that the plate current with zero signal is practically zero. The bias voltage can be obtained from a cathode-bias resistor, a C-battery, or a bleeder tap. Because of the high negative bias, only the positive half-cycles of the rf signal are amplified by the tube. The signal is, therefore, detected in the plate circuit. The advantages of this method of detection are that it amplifies the signal, besides detecting it, and that it does not draw current from the input circuit and therefore does not lower the selectivity of the input circuit.

The **grid-resistor-and-capacitor method**, illustrated by Fig. 45, is somewhat more sensitive than the grid-bias method and gives its best results on weak signals. In this circuit, there is no negative dc bias voltage applied to the grid. Hence, on the positive half-cycles of the rf signal, current flows from grid to cathode. The grid and cathode thus act as a diode detector, with the grid resistor as the diode load resistor and the grid capacitor as the rf bypass capacitor. The voltage across the capacitor then reproduces the af modulation in the same manner as has been explained for the diode detector. This voltage appears between the grid and cathode and is therefore amplified in the plate circuit. The output voltage thus reproduces the original af signal.

In this detector circuit, the use of a high-resistance grid resistor increases selectivity and sensitivity. However, improved af response and stability are obtained with lower values of grid-resistor resistance. This detector circuit has the advantage that it amplifies the signal but has the disadvantage that it draws current from the input circuit and therefore lowers the selectivity of the input circuit.

The effect of **frequency modulation** on the waveform of the rf wave is shown in Fig. 46. In this type of transmission, the frequency of the rf wave deviates from a mean value, at an af rate depending on the modulation, by an amount that is determined in the transmitter and is proportional to the amplitude of the af modulation signal. For this type of modulation, a detector is required to discriminate between deviations above and below the mean frequency and to translate those deviations into a voltage whose amplitude varies at audio frequencies. Since the deviations occur at an audio frequency, the process is one of demodulation, and the degree of frequency deviation determines the amplitude of the demodulated (af) voltage.

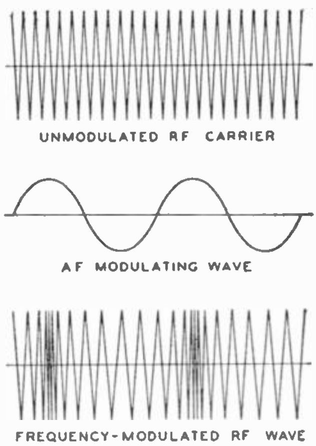


Fig. 46

A simple circuit for converting frequency variations to amplitude variations is a circuit which is tuned so that the mean radio frequency is on one slope of its resonance characteristic, as at A of Fig. 47. With modulation, the frequency swings between B and C, and the voltage developed across the circuit varies at the modulating rate. In order that no distortion will be introduced in this circuit, the frequency swing must be restricted to the portion of the slope which is effectively straight. Since this portion is very short, the voltage developed is low. Because of these limitations, this circuit is not commonly used but it serves to illustrate the principle.

The faults of the simple circuit are overcome in a push-pull arrangement, sometimes called a **discriminator circuit**, such as that shown in Fig. 48. Because of the phase relationships between the primary and each half of the secondary of the input transformer (each half of the secondary is connected in series with the

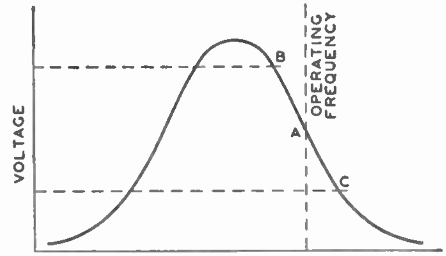


Fig. 47

primary through capacitor C_2), the rf voltages applied to the diodes become unequal as the rf signal swings from the resonant frequency in each direction. Since the swing occurs at audio frequencies (determined by the af modulation), the voltage developed across the diode load resistors, R_1 and R_2 connected in series, varies at

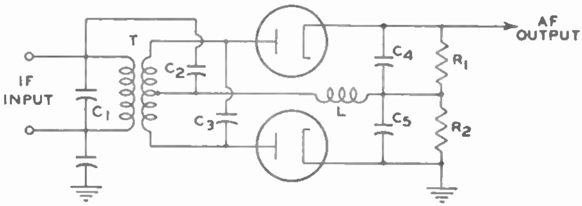


Fig. 48

audio frequencies. The output voltage depends on the difference in amplitude of the voltages developed across R_1 and R_2. These voltages are equal and of opposite sign when the rf carrier is not modulated and the output is, therefore, zero. When modulation is applied, the output voltage varies as indicated in Fig. 49.

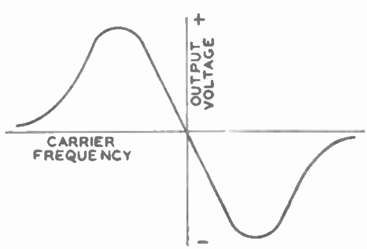


Fig. 49

Because this type of FM detector is sensitive to amplitude variations in the rf carrier, a limiter stage is frequently used to remove most of the amplitude modulation from the carrier. (See Limiters under **Amplification**.)

Another form of detector for frequency-modulated waves is called a **ratio detector.** This FM detector, unlike the previous one which responds to a difference in voltage, responds only to changes in the ratio of the voltage across the two diodes (Fig. 50) and is, therefore, insensitive to changes in the differences in the voltages due to amplitude modulation of the rf carrier.

The basic ratio detector is given in Fig. 50. The plate load for the final intermediate-frequency-amplifier stage is the parallel resonant circuit consisting of C_1 and the primary transformer T. The tuning and coupling of the transformer is practically the same as in the previous circuit and, therefore, the rf voltages applied to the diodes depend upon how much the rf signal swings from the resonant frequency in each direction. At this point the similarity ends.

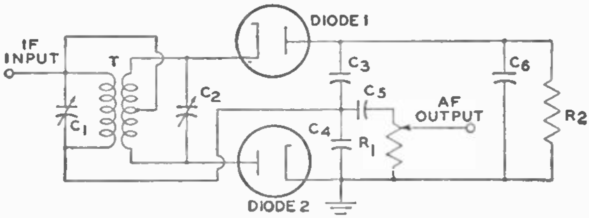


Fig. 50

Diode 1, R_2, and diode 2 complete a series circuit fed by the secondary of the transformer T. The two diodes are connected in series so that they conduct on the same rf half-cycle. The rectified current through R_2 causes a negative voltage to appear at the plate of diode 1. Because C_6 is large, this negative voltage at the plate of diode 1 remains constant even at the lowest audio frequencies to be reproduced. The rectified voltage across C_3 is proportional to the voltage across diode 1, and the rectified voltage across C_4 is proportional to the voltage across diode 2. Since the voltages across the two diodes differ according to the instantaneous frequency of the carrier, the voltages across C_3 and C_4 differ proportionately, the voltage across C_3 being the larger of the two voltages at carrier frequencies below the intermediate frequency and the smaller at frequencies above the intermediate frequency. These voltages across C_3 and C_4 are additive and their sum is fixed by the constant voltage across C_6. Therefore, while the ratio of these voltages varies at an audio rate, their sum is always constant. The voltage across C_4 varies at an audio rate when a frequency-modulated rf carrier is applied to the ratio detector; this audio voltage is extracted and fed to the audio amplifier. For a complete circuit utilizing this type of detector, refer to the CIRCUIT SECTION.

AUTOMATIC VOLUME CONTROL

The chief purposes of automatic volume control in a receiver are to prevent fluctuations in loudspeaker volume when the signal at the antenna is fading in and out, and to prevent an unpleasant blast of loud volume when the set is tuned from a weak signal, for which the volume control has been turned up high, to a strong signal. To accomplish these purposes, an automatic volume control circuit regulates the receiver's rf and if gain so that this gain is less for a strong signal than for a weak signal. In this way, when the signal strength at the antenna changes, the avc circuit reduces the resultant change in the voltage output of the last if stage and consequently reduces the change in the speaker's output volume.

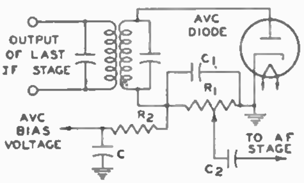


Fig. 51

The avc circuit reduces the rf and if gain for a strong signal usually by increasing the negative bias of the rf, if, and frequency-mixer stages when the signal increases. A simple avc circuit is shown in Fig. 51. On each positive half-cycle of the signal voltage, when the diode plate is positive with respect to the cathode, the diode passes current. Because of the flow of diode current through R_1, there is a voltage drop across R_1 which makes the left end of R_1 negative with respect to ground. This voltage drop across R_1 is applied, through the filter R_2 and C, as negative bias on the grids of the preceding stages. Then, when the signal strength at the antenna increases, the signal applied to the avc diode increases, the voltage drop across R_1 increases, the negative bias voltage applied to the rf and if stages increases, and the gain of the rf and if stages is decreased. Thus the increase in signal strength at the antenna does not produce as much increase in the output of the last if stage as it would produce without avc. When the signal strength at the antenna decreases from a previous steady value, the avc circuit acts, of course, in the reverse direction, applying less negative bias, permitting the rf and if gain to increase, and thus reducing the decrease in the signal output of the last if stage. In this way, when the signal strength at the antenna changes, the avc circuit acts to prevent change in the output of the last if stage, and thus acts to prevent change in loudspeaker volume.

The filter, C and R_2, prevents the avc voltage from varying at audio frequency. The filter is necessary because the voltage drop across R_1 varies with the modulation of the carrier being received. If avc voltage were taken directly from R_1 without filtering, the audio variations in avc voltage would vary the receiver's gain so as to smooth out the modulation of the carrier. To avoid this effect, the avc voltage is taken from the capacitor C. Because of the resistance R_2 in series with C, the capacitor C can charge and discharge at only a comparatively slow rate. The avc voltage therefore cannot vary at frequencies as high as the audio range but can vary at frequencies high enough to compensate for most fading. Thus the filter permits the avc circuit to smooth out variations in signal due to fading, but prevents the circuit from smoothing out audio modulation.

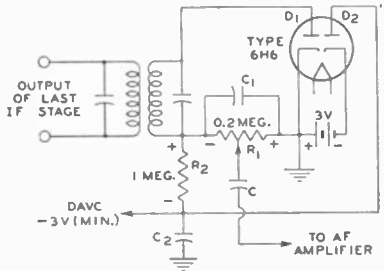


Fig. 52

It will be seen that an avc circuit and a diode-detector circuit are much alike. It is therefore convenient in a receiver to combine the detector and the avc diode in a single stage. Examples of how these functions are combined in receivers are shown in CIRCUIT SECTION.

In the circuit shown in Fig. 51, a certain amount of avc negative bias is applied to the preceding stages on a weak signal. Since it may be desirable to maintain the receiver's rf and if gain at the maximum possible value for a weak signal, avc circuits are designed in some cases to apply no avc bias until the signal strength exceeds a certain value. These avc circuits are known as delayed avc, or, davc circuits. A davc circuit is shown in Fig. 52. In this circuit, the diode section D_1 of the 6H6 acts as detector and avc diode. R_1 is the diode load resistor and R_2 and C_2 are the avc filter. Because the cathode of diode D_2 is returned through a fixed supply of −3 volts to the cathode of D_1, a dc current flows through R_1 and R_2 in series with D_2. The voltage drop caused by this current places the avc lead at approximately −3 volts (less the negligible drop through D_2). When the average amplitude of the rectified signal developed across R_1 does not exceed 3 volts, the avc lead remains at −3 volts. Hence, for signals not strong enough to develop 3 volts across R_1, the bias applied to the controlled tubes stays constant at a value giving high sensitivity. However, when the average amplitude of rectified signal voltage across R_1 exceeds 3 volts, the plate of diode D_2 becomes more negative than the cathode of D_2 and current flow in diode D_2 ceases. The potential of the avc lead is then controlled by the voltage developed across R_1. Therefore, with further increase in signal strength, the avc circuit applies an increasing avc bias voltage to the controlled stages. In this way, the circuit regulates the receiver's gain for strong signals, but permits the gain to stay constant at a maximum value for weak signals.

It can be seen in Fig. 52 that a portion of the –3 volts delay voltage is applied to the plate of the detector diode D_1, this portion being approximately equal to $R_1/(R_1 + R_2)$ times –3 volts. Hence, with the circuit constants as shown, the detector plate is made negative with respect to its cathode by approximately one-half volt. However, this voltage does not interfere with detection because it is not large enough to prevent current flow in the tube.

TUNING INDICATION WITH ELECTRON-RAY TUBES

Electron-ray tubes are designed to indicate visually by means of a fluorescent target the effects of a change in controlling voltage. One application of them is as tuning indicators in radio receivers. Types such as the 6U5, 6E5, and the 6AB5/6N5 contain two main parts: (1) a triode which operates as a dc amplifier and (2) an electron-ray indicator which is located in the bulb as shown in Fig. 53. The target is operated at a positive voltage and therefore attracts electrons from the cathode. When the electrons strike the target they produce a glow on the fluorescent coating of the target. Under these conditions, the target appears as a ring of light.

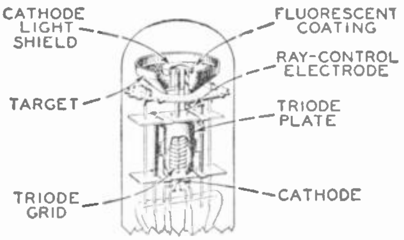


Fig. 53

A ray-control electrode is mounted between the cathode and target. When the potential of this electrode is less positive than the target, electrons flowing to the target are repelled by the electrostatic field of the electrode, and do not reach that portion of the target behind the electrode. Because the target does not glow where it is shielded from electrons, the control electrode casts a shadow on the glowing target. The extent of this shadow varies from approximately 100° of the target when the control electrode is much more negative than the target to 0° when the control electrode is at approximately the same potential as the target.

In the application of the electron-ray tube, the potential of the control electrode is determined by the voltage on the grid of the triode section, as can be seen in Fig. 54. The flow of the triode plate current through resistor R produces a voltage drop which determines the potential of the control electrode. When the voltage of the triode grid changes in the positive direction, plate current increases, the potential of the control electrode goes down because of the increased drop across R, and the shadow angle widens. When the potential of the triode grid changes in the negative direction, the shadow angle narrows.

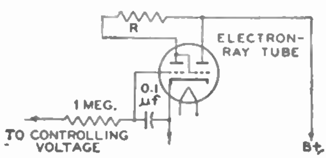


Fig. 54

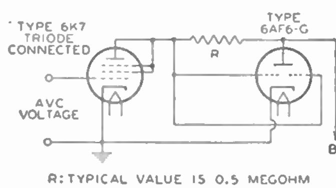


Fig. 55

Another type of indicator tube is the 6AF6-G. This tube contains only an indicator unit but employs two ray-control electrodes mounted on opposite sides of the cathode and connected to individual base pins. It employs an external dc amplifier. See Fig. 55. Thus, two symmetrically opposite shadow angles may be obtained by connecting the two ray-control electrodes together; or, two unlike patterns may be obtained by individual connection of each ray-control electrode to its respective amplifier.

In radio receivers, avc voltage is applied to the grid of the dc amplifier. Since avc voltage is at maximum when the set is tuned to give maximum response to a station, the shadow angle is at minimum when the receiver is tuned to resonance with the desired station.

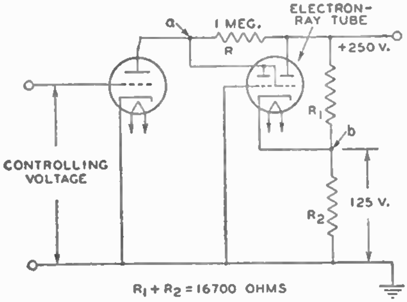


Fig. 56

The choice between electron-ray tubes depends on the avc characteristic of the receiver. The 6E5 contains a sharp-cutoff triode which closes the shadow angle on a comparatively low value of avc voltage. The 6AB5/6N5 and 6U5 each have a remote-cutoff triode which closes the shadow on a larger value of avc voltage than the 6E5. The 6AF6-G may be used in conjunction with dc amplifier tubes having either remote- or sharp-cutoff characteristics.

The sensitivity indication of electron-ray tubes can be increased by using a separate dc amplifier to control the action of the ray-control electrode in the tuning indicator tube. This arrangement increases the maximum shadow angle from the usual 100° to approximately 180°. A circuit for obtaining wide-angle tuning is shown in Fig. 56.

OSCILLATION

As an oscillator, an electron tube can be employed to generate a continuously alternating voltage. In present-day radio broadcast receivers, this application is limited practically to superheterodyne receivers for supplying the heterodyning frequency. Several circuits (represented in Figs. 57 and 58) may be utilized, but they all depend on feeding more energy from the plate circuit to the grid circuit than is required to equal the power loss in the grid circuit. Feedback may be

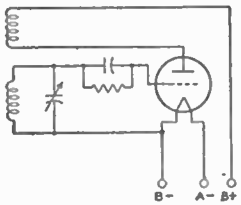


Fig. 57

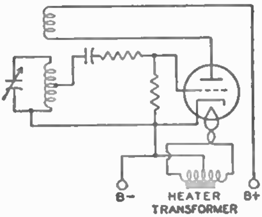


Fig. 58

produced by electrostatic or electromagnetic coupling between the grid and plate circuits. When sufficient energy is fed back to more than compensate for the loss in the grid circuit, the tube will oscillate. The action consists of regular surges of power between the plate and the grid circuit at a frequency dependent on the circuit constants of inductance and capacitance. By proper choice of these values, the frequency may be adjusted over a very wide range.

The **relaxation oscillator** is an oscillator with a non-sinusoidal output. It differs from the preceding type in that the oscillations are obtained by abruptly releasing energy previously stored in the electric field of a capacitor. A **multivibrator** is a special type of relaxation oscillator used in television receivers and other electronic applications. A multivibrator may be considered as a two-stage resistance-coupled amplifier in which the output of each tube is coupled into the input of the other tube in order to sustain oscillations.

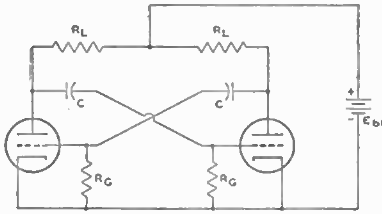


Fig. 59

Fig. 59 is a basic multivibrator circuit of the free-running type. In this circuit, oscillations are maintained by the alternate shifting of conduction from one tube to the other. The cycle starts with one tube usually at zero bias and the other at cutoff or beyond. Each tube introduces a 180° phase shift so that the energy fed back has the phase relation necessary to sustain oscillation. The frequency of oscillation is determined primarily by the constants of the resistance-capacitance coupling circuits.

FREQUENCY CONVERSION

Frequency conversion is used in superheterodyne receivers to change the frequency of the rf signal to an intermediate frequency. To perform this change in frequency, a frequency-converting device consisting of an oscillator and a frequency mixer is employed. In such a device, shown diagrammatically in Fig. 60, two voltages of different frequency, the rf signal voltage and the voltage generated by the oscillator, are applied to the input of the frequency mixer. These voltages beat, or heterodyne, within the mixer tube to produce a plate current having, in addition to the frequencies of the input voltages, numerous sum and difference frequencies. The output circuit of the mixer stage is provided with a tuned circuit which is adjusted to select only one beat frequency, i.e., the frequency equal to the difference between the signal frequency and the oscillator frequency. The selected output frequency is known as the intermediate frequency, or if. The output frequency of the mixer tube is kept constant for all values of signal frequency by tuning the oscillator to the proper frequency.

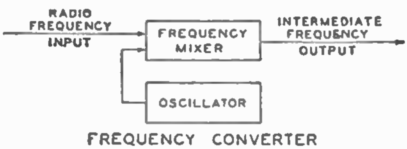


Fig. 60

Important advantages gained in a receiver by the conversion of signal frequency to a fixed intermediate frequency are high selectivity with few tuning stages and a high, as well as stable, overall gain for the receiver.

Several methods of frequency conversion for superheterodyne receivers are of interest. These methods are alike in that they employ a frequency-mixer tube in which plate current is varied at a combination frequency of the signal frequency and the oscillator frequency. These variations in plate current produce across the tuned plate load a voltage of the desired intermediate frequency. The methods differ in the types of tubes employed and in the means of supplying input voltages to the mixer tube.

A method widely used before the availability of tubes especially designed for frequency-conversion service and currently used in many FM, television, and standard broadcast receivers, employs as mixer tube either a triode, a tetrode, or a pentode, in which oscillator voltage and signal voltage are applied to the same grid. In this method, coupling between the oscillator and mixer circuits is obtained by means of inductance or capacitance.

A second method employs a tube having an oscillator and frequency mixer combined in the same envelope. In one form of such a tube, coupling between the two units is obtained by means of the electron stream within the tube. One arrangement of the electrodes for this type is shown in Fig. 61. Since five grids are used, the tube is called a pentagrid converter. Grids No. 1, No. 2, and the cathode are connected to an external circuit to act as a triode oscillator. Grid No. 1 is the grid of the oscillator and grid No. 2 is the anode. These and the cathode can be considered as a composite cathode which supplies to the rest of the tube an electron stream that varies at the oscillator frequency. This varying electron stream is further controlled by the rf signal voltage on grid No. 4. Thus, the variations in plate current are due to the combination of the oscillator and the signal frequencies. The purpose of grids No. 3 and No. 5, which are connected together within the tube, is to accelerate the electron stream and to shield grid No. 4 electrostatically from the other electrodes. The 6A8 is an example of a pentagrid-converter type.

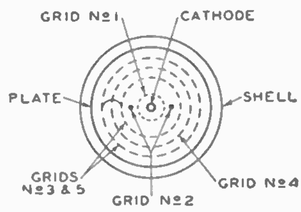


Fig. 61

Pentagrid-converter tubes of this design are good frequency-converting devices at medium frequencies but their performance is better at the lower frequencies than at the high ones. This is because the output of the oscillator drops off as the frequency is raised and because certain undesirable effects produced by interaction between oscillator and signal sections of the tube increase with frequency. To minimize these effects, several of the pentagrid-converter tubes are designed so that no electrode functions alone as the oscillator anode. In these tubes, grid No. 1 functions as the oscillator grid, and grid No. 2 is connected within the tube to the screen (grid No. 4). The combined two grids Nos. 2 and 4 shield the signal grid (grid No. 3) and act as the composite anode of the oscillator triode. Grid No. 5 acts as the suppressor. Converter tubes of this type are designed so that the space charge around the cathode is unaffected by electrons from the signal grid. Further-

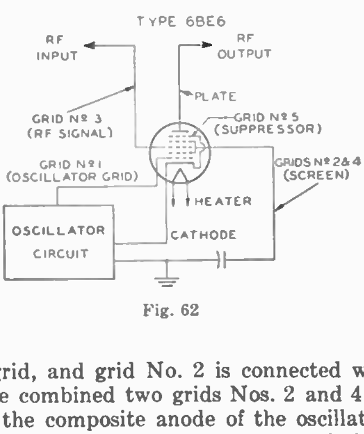


Fig. 62

more, the electrostatic field of the signal grid also has little effect on the space charge. The result is that rf voltage on the signal grid produces little effect on the cathode current. There is, therefore, little detuning of the oscillator by avc bias because changes in avc bias produce little change in oscillator transconductance or in the input capacitance of grid No. 1. Examples of the pentagrid converters discussed in this paragraph are the single-ended types 1R5 and 6BE6. A schematic diagram illustrating the use of the 6BE6 with self-excitation is given in Fig. 62; the 6BE6 may also be used with separate excitation. A complete circuit is shown in the CIRCUIT SECTION.

Another method of frequency conversion utilizes a separate oscillator having its grid connected to the No. 1 grid of a mixer hexode. A tube utilizing this construction is the 6K8 and a top view of its electrode arrangement is shown in Fig. 63. The cathode, triode grid No. 1, and triode plate form the oscillator unit of the tube. The cathode, hexode mixer grid (grid No. 1), hexode double-screen (grids Nos. 2 and 4), hexode mixer grid (grid No. 3), and hexode plate constitute the mixer unit. The internal shields are connected to the shell of the tube and act as a suppressor for the hexode unit. The action of the 6K8 in converting a radio-frequency signal to an intermediate frequency depends on (1) the generation of a local frequency by the triode unit, (2) the transferring of this frequency to the hexode grid No. 1, and (3) the mixing in the hexode unit of this frequency with that of the rf signal applied to the hexode grid No. 3. The 6K8 is not critical to changes in oscillator-plate voltage or signal-grid bias and, therefore, finds important use in all-wave receivers to minimize frequency-shift effects at the higher frequencies.

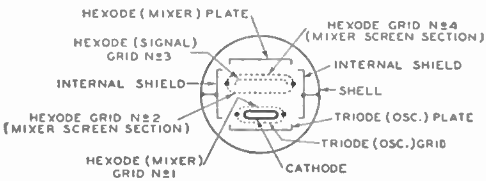


Fig. 63

A further method of frequency conversion employs a tube called a pentagrid mixer. This type has two independent control grids and is used with a separate oscillator tube. RF signal voltage is applied to one of the control grids and oscillator voltage is applied to the other. It follows, therefore, that the variations in plate current are due to the combination of the oscillator and signal frequencies. The arrangement of electrodes in a pentagrid-mixer tube is shown in Fig. 64. The tube contains a heater cathode, five grids, and a plate. Grids Nos. 1 and 3 are control grids. The rf signal voltage is applied to grid No. 1. This grid has a remote-cutoff characteristic and is suited for control by avc bias voltage. The oscillator voltage is applied to grid No. 3. This grid has a sharp-cutoff characteristic and produces a comparatively large effect on plate current for a small amount of oscillator voltage. Grids Nos. 2 and 4 are connected together within the tube. They accelerate the electron stream and shield grid No. 3 electrostatically from the other electrodes. Grid No. 5, connected within the tube to the cathode, functions similarly to the suppressor in a pentode. The 6L7 and 6L7-G are pentagrid-mixer tubes.

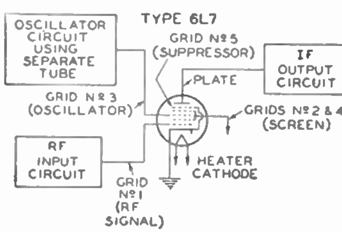


Fig. 64

AUTOMATIC FREQUENCY CONTROL

An automatic frequency control (afc) circuit provides a means of correcting automatically the intermediate frequency of a superheterodyne receiver if, for any reason, it drifts from the frequency to which the if stages are tuned. This correction is made by adjusting the frequency of the oscillator. Such a circuit will automatically compensate for slight changes in rf carrier or oscillator frequency as well as for inaccurate manual or push-button tuning.

An afc system requires two sections: a frequency detector and a variable reactance. The detector section may be essentially the same as the FM detector illustrated in Fig. 48 and discussed under **Detection**. In the afc system, however, the output is a dc control voltage, the magnitude of which is proportional to the amount of frequency shift. This dc control voltage is used to control the grid bias of an electron tube which comprises the variable reactance section (Fig. 65). The

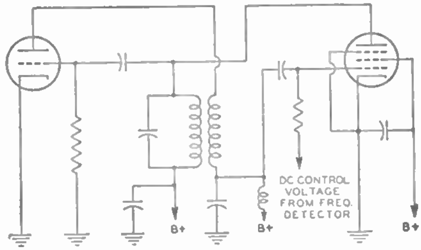


Fig. 65

plate current of the reactance tube is shunted across the oscillator tank circuit. Because the plate current and plate voltage of the reactance tube are almost 90° out of phase, the control tube affects the tank circuit in the same manner as a reactance. The grid bias of the tube determines the magnitude of the effective reactance and, consequently, a control of this grid bias can be used to control the oscillator frequency.

Electron Tube Installation

The installation of electron tubes requires care if high-quality performance is to be obtained from the associated circuits. Installation suggestions and precautions which are generally common to all types of tubes are covered in this section. Careful observance of these suggestions will do much to help the experimenter and electronic technician obtain the full performance capabilities of radio tubes and circuits. Additional pertinent information is given under each tube type and in the CIRCUIT SECTION.

FILAMENT AND HEATER POWER SUPPLY

The design of electron tubes allows for some variation in the voltage and current supplied to the filament or heater, but most satisfactory results are obtained from operation at the rated values. When the voltage is low, the temperature of the cathode is below normal, with the result that electron emission is limited. This may cause unsatisfactory operation and reduced tube life. On the other hand, high cathode voltage causes rapid evaporation of cathode material and shortens tube life. To insure proper tube operation, the filament or heater voltage should be checked at the socket terminals by means of an accurate voltmeter while the receiver is in operation. In the case of series operation of heaters or filaments, correct adjustment can be checked by means of an ammeter in the heater or filament circuit.

The filament or heater voltage supply may be a direct-current source (a battery or a dc power line) or an alternating-current power line, depending on the type of service and type of tube. Frequently, a resistor (either variable or fixed) is used with a dc supply to permit compensation for battery voltage variations or to adjust the tube voltage at the socket terminals to the correct value. Ordinarily, a step-down transformer is used with an ac supply to provide the proper filament or heater voltage. Receivers intended for operation on both dc and ac power lines have the heaters connected in series with a suitable resistor and supplied directly from the power line.

DC filament or heater operation should be considered on the basis of the source of power. In the case of the battery supply for the 1.4-volt filament tubes, it is unnecessary to use a voltage-dropping resistor in series with the filament and a single dry-cell; the filaments of these tubes are designed to operate satisfactorily over the range of voltage variations that normally occur during the life of a dry-cell. Likewise, no series resistor is required when the 1.25-volt filament subminiatures are operated from a single 1.5-volt flashlight-type dry-cell, when the 2-volt filament type tubes are operated from a single storage cell, or when the 6.3-volt series are operated from a 6-volt storage battery. In the case of dry-battery supply for 2-volt filament tubes, a variable resistor in series with the filament and the battery is required to compensate for battery variations. Turning the set on and off by means of the rheostat is advised to prevent over-voltage conditions after an off-period, for the voltage of dry-cells rises during off-periods. In the case of storage-battery supply, air-cell-battery supply, or dc power supply, a non-adjustable resistor of suitable value may be used. It is well to check initial operating conditions, and thus the resistor value, by means of a voltmeter or ammeter.

The **filament or heater resistor** required when filaments and/or heaters are operated in parallel can be determined easily by a simple formula derived from Ohm's law.

$$\text{Required resistance (ohms)} = \frac{\text{supply volts} - \text{rated volts of tube type}}{\text{total rated filament current (amperes)}}$$

Thus, if a receiver using three 32's, two 30's, and two 31's is to be operated from dry batteries, the series resistor is equal to 3 volts (the voltage from two dry-cells in series) minus 2 volts (voltage rating for these tubes) divided by 0.56 ampere (the sum of 5×0.060 ampere $+ 2 \times 0.130$ ampere), i.e., approximately 1.8 ohms. Since this resistor should be variable to allow adjustment for battery depreciation, it is advisable to obtain the next larger commercial size, although any value between 2 and 3 ohms will be quite satisfactory. Where much power is dissipated in the resistor, the wattage rating should be sufficiently large to prevent overheating. The power dissipation in watts is equal to the voltage drop in the resistor multiplied by the total filament current in amperes. Thus, for the example above $1 \times 0.56 = 0.56$ watt. In this case, the value is so small that any commercial rheostat with suitable resistance will be adequate.

For the case where the heaters and/or filaments of several tubes are operated in series, the resistor value is calculated by the following formula, also derived from Ohm's law.

$$\text{Required resistance (ohms)} = \frac{\text{supply volts} - \text{total rated volts of tubes}}{\text{rated amperes of tubes}}$$

Thus, if a receiver having one 6SA7, one 6SK7, one 6SF7, one 25L6-GT, and one 25Z6-GT is to be operated from a 117-volt power line, the series resistor is equal to 117 volts (the supply voltage) minus 68.9 volts (the sum of 3×6.3 volts $+ 2 \times 25$ volts) divided by 0.3 ampere (current rating of these tubes), i.e., approximately 160 ohms. The wattage dissipation in the resistor will be 117 volts minus 68.9 volts times 0.3 ampere, or approximately 14.4 watts. A resistor having a wattage rating in excess of this value should be chosen.

It will be noted in the example for series operation that all tubes have the same current rating. If it is desired to connect in series tubes having different heater- or filament-current ratings, each tube of the lower rating should have a shunt resistor placed across its heater or filament terminals to pass the excess current. The value of this shunt resistor can be calculated from the following formula, where tube A is the tube in the series connection having the highest heater-current rating and tube B is any tube having a heater-current rating lower than tube A.

$$\text{Heater shunt resistance (ohms), tube B} = \frac{\text{heater volts, tube B}}{\text{rated heater amperes, tube A} - \text{rated heater amperes, tube B}}$$

For example, if a 6N7 having a 6.3-volt, 0.8-ampere heater is to be operated in a series-heater circuit employing several 6.3-volt tubes having heater ratings of 0.3 ampere, the required shunt resistance for each of the latter types would be

$$\text{Heater shunt resistance} = \frac{6.3}{0.8 - 0.3}\text{, or 12.6 ohms}$$

The value of a series voltage-dropping resistor for a sequence of tubes having one or more shunt resistors should be calculated on the basis of the tube having the highest heater-current rating.

When the series-heater connection is used in ac/dc receivers, it is usually advisable to arrange the heaters in the circuit so that the tubes most sensitive to hum disturbances are at or near the ground potential of the circuit. This arrangement reduces the amount of ac voltage between the heaters and cathodes of these tubes and minimizes the hum output of the receiver. The order of heater connection, by tube function, from chassis to the rectifier-cathode side of the ac line is shown in Fig. 66.

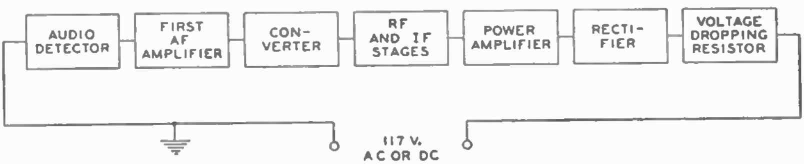


Fig. 66

AC filament or heater operation should be considered on the basis of either a parallel or a series arrangement of filaments and/or heaters. In the case of the parallel arrangement, a step-down transformer is employed. Precautions should be taken to see that the line voltage is the same as that for which the primary of the transformer is designed. The line voltage may be determined by measurement with an ac voltmeter (0-150 volts).

If the line voltage measures in excess of that for which the transformer is designed, a resistor should be placed in series with the primary to reduce the line voltage to the rated value of the transformer primary. Unless this is done, the excess input voltage will cause proportionally excessive voltage to be applied to the tubes. Any electron tube may be damaged or made inoperative by excessive operating voltages.

If the line voltage is consistently below that for which the primary of the transformer is designed, it may be necessary to install a booster transformer between the ac outlet and the transformer primary. Before such a transformer is installed, the ac line fluctuations should be very carefully noted. Some radio sets are equipped with a line-voltage switch which permits adjustment of the power transformer primary to the line voltage. When this switch is properly adjusted, the series-resistor or booster-transformer method of controlling line voltage is seldom required.

In the case of the series arrangements of filaments and/or heaters, a voltage-dropping resistance in series with the heaters and the supply line is usually required. This resistance should be of such value that, for normal line voltage, tubes will operate at their rated heater or filament current. The method for calculating the resistor value is given above.

When the filaments of battery-type tubes are connected in series, the total filament current is the sum of the current due to the filament supply and the plate and screen (cathode) currents returning to B (–) through the tube filaments. Consequently, in a series filament string it is necessary to add shunt resistors across each filament section to bypass this cathode current in order to maintain the filament voltage at its rated value.

HEATER-TO-CATHODE CONNECTION

The cathodes of heater-type tubes, when operated from ac, should be connected to the mid-tap on the heater supply winding, to the mid-tap of a 50-ohm (approximate) resistor shunted across the winding, or to one end of the heater supply winding depending on circuit requirements. If none of these methods is used, it is important to keep the heater-cathode voltage within the ratings given in the TUBE TYPES SECTION.

Hum from ac-operated heater tubes used in high-gain audio amplifiers may frequently be reduced to a negligible value by employing a 15- to 40-volt bias between the heater and cathode elements of the tubes. The bias should be connected so that the tube cathode is negative with respect to its heater. Such bias can be obtained from either B batteries or a well-filtered rectifier. If the regular plate-supply rectifier of the amplifier is employed as the bias voltage source, it is good practice to add an additional filter stage in the bias voltage circuit to insure a hum-free bias source.

If a large resistor is used between heater and cathode, it should be bypassed by a suitable filter network or objectionable hum may develop. The hum is due to the fact that even a minute pulsating leakage current flowing between the heater and cathode will develop a small voltage across any resistance in the circuit. This hum voltage is amplified by succeeding stages. When a series-heater arrangement is used, the cathode circuits should be connected either directly or through biasing resistors to the negative side of the dc plate supply, which is furnished either by the dc power line or by the ac power line through a rectifier.

PLATE VOLTAGE SUPPLY

The plate voltage for electron tubes is obtained from batteries, rectifiers, direct-current power lines, and small local generators. Auto radios have brought about the commercial development of a number of devices for obtaining a high-voltage dc supply either from the car storage-battery or from a generator driven by the car engine.

The maximum plate-voltage value for any tube type should not be exceeded if most satisfactory performance is to be obtained. Plate voltage should not be applied to a tube unless the corresponding recommended voltage is also supplied to the grid.

It is recommended that the primary circuit of the power transformer be fused to protect the rectifier tube(s), the power transformer, filter capacitor, and chokes in case a rectifier tube fails.

GRID VOLTAGE SUPPLY

The recommended grid voltages for different operating conditions have been carefully determined to give the most satisfactory performance. Grid voltage may be obtained from a fixed source such as a separate C-battery or a tap on the voltage divider of the high-voltage dc supply, from the voltage drop across a resistor in the cathode circuit, or from the voltage drop across a resistor in the grid circuit. The first method is called "fixed bias;" the second is called "cathode bias" or "self bias;" the third is called "grid-resistor bias" and is sometimes incorrectly referred to in receiving-tube practice as "zero-bias operation." In any case, the object is to make the grid negative with respect to the cathode by the specified voltage. When a C-battery is used, the negative terminal is connected to the grid return and the positive terminal is connected to the negative filament socket terminal, or to the cathode terminal if the tube is of the heater-cathode type. If the filament is supplied with alternating current, this connection is usually made to the center-tap of a low resistance (20-50 ohms) shunted across the filament terminals. This method reduces hum disturbances caused by the ac supply. If bias voltages are obtained from the voltage divider of a high-voltage dc supply, the grid return is connected to a more negative tap than the cathode.

The **cathode-biasing** method utilizes the voltage drop produced by the cathode current flowing through a resistor connected between the cathode and the negative terminal of the B-supply. See Fig. 67. The cathode current is, of course, equal to

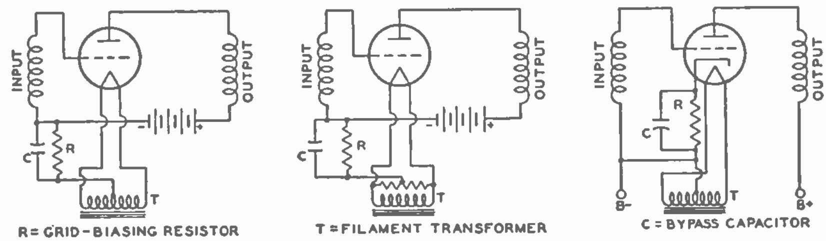


Fig. 67

the plate current in the case of a triode, or to the sum of the plate and screen currents in the case of a tetrode, pentode, or beam power tube. Since the voltage drop along the resistance is increasingly negative with respect to the cathode, the required negative grid-bias voltage can be obtained by connecting the grid return to the negative end of the resistance.

The value of the resistance for cathode-biasing a single tube can be determined from the following formula:

$$\text{Resistance (ohms)} = \frac{\text{desired grid-bias voltage} \times 1000}{\text{rated cathode current in milliamperes}}$$

Thus, the resistance required to produce 9 volts bias for a triode which operates at 3 milliamperes plate current is $9 \times 1000/3 = 3000$ ohms. If the cathode current of more than one tube passes through the resistor, or if the tube or tubes employ more than three electrodes, the total current determines the size of the resistor.

Bypassing of the cathode-bias resistor depends on circuit-design requirements. In rf circuits the cathode resistor should be bypassed. In af circuits the use of an unbypassed resistor will reduce distortion by introducing degeneration into the circuit. However, the use of an unbypassed resistor decreases power sensitivity. When bypassing is used, it is important that the bypass capacitor be sufficiently large to have negligible reactance at the lowest frequency to be amplified. In the case of power-output tubes of high transconductance such as the beam power tubes, it may be necessary to shunt the bias resistor with a small mica capacitor (approximately 0.001 μf) in order to prevent oscillations. The usual af bypass may or may not be used, depending on whether or not degeneration is desired. In tubes having high values of transconductance, such as the 6BA6, 12AW6, and 6AC7, input capacitance and input conductance change appreciably with plate current. When such a tube having a separate suppressor connection is used as an rf amplifier, these changes may be minimized by leaving a portion of the cathode-bias resistor unbypassed. In order to minimize feedback when this method is used, the external grid-plate (wiring) capacitances should be kept to a minimum, the screen should be bypassed to ac ground, and the suppressor should be connected to ac ground. The use of a cathode resistor to obtain bias voltage is not recommended for audio amplifiers in which there is appreciable shift of electrode currents with the application of a signal. In such amplifiers, a separate fixed supply is recommended.

The **grid-resistor biasing** method is also a self-bias method because it utilizes the voltage drop across the grid resistor produced by small amounts of grid current flowing in the grid-cathode circuit. This current is due to (1) an electromotive potential difference between the materials comprising the grid and cathode and (2) grid rectification when the grid is driven positive. A large value of grid resistor is required in order to limit this current to a very small value and to avoid undesirable loading effects on the preceding stage. Examples of this method of bias are given in circuits 16-1 and 16-4 in the CIRCUIT SECTION. In both of these circuits, the audio amplifier type 1U5 or 12AV6 has a 10-megohm resistor between the grid and the negative filament or cathode to furnish the required bias which is usually less than 1 volt. This method of biasing is used principally in the early voltage amplifier stages (usually employing high-mu triodes) of audio amplifier circuits, where the tube dissipation will not be excessive under zero-signal conditions.

A grid resistor is also used in many oscillator circuits for obtaining the required bias. In these circuits, the grid voltage is relatively constant and its magnitude is usually in the order of 5 volts or more. Consequently, the bias voltage is obtained only through grid rectification. A relatively low value of resistor, 0.1 megohm or less, is used. Oscillator circuits employing this method of bias are given in circuits 16-1 and 16-4 in the CIRCUIT SECTION.

Grid-bias variation for the rf and if amplifier stages is a convenient and frequently used method for controlling receiver volume. The variable voltage supplied to the grid may be obtained: (1) from a variable cathode resistor as shown in Figs. 68 and 69; (2) from a bleeder circuit by means of a potentiometer as shown in Fig. 70; or (3) from a bleeder circuit in which the bleeder current is varied by a tube used for automatic volume control. The latter circuit is shown in Fig. 51.

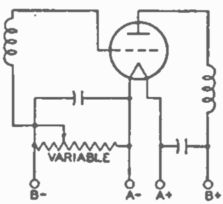


Fig. 68

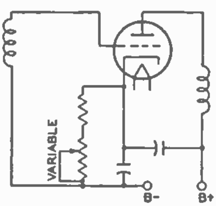


Fig. 69

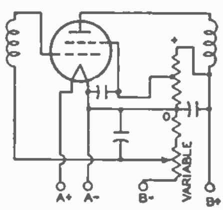


Fig. 70

In all cases it is important that the control be arranged so that at no time will the bias be less than the recommended minimum grid-bias voltage for the particular tubes used. This requirement can be met by providing a fixed stop on the potentiometer, by connecting a fixed resistance in series with the variable resistance, or by connecting a fixed cathode resistance in series with the variable resistance used for regulation. Where receiver gain is controlled by grid-bias variation, it is advisable to have the control voltages extend over a wide range in order to minimize cross-modulation and modulation-distortion. A remote-cutoff type of tube should, therefore, be used in the controlled stages.

SCREEN VOLTAGE SUPPLY

The positive voltage for the screen (grid No. 2) of screen-grid tubes may be obtained from a tap on a voltage divider, from a potentiometer, or from a series resistor connected to a high-voltage source, depending on the structure of the particular tube type and its application. The screen voltage for tetrodes should be obtained from a voltage divider or a potentiometer rather than through a series resistor from a high-voltage source because of the characteristic screen-current variations of tetrodes. Fig. 71 shows a tetrode with its screen voltage obtained from a potentiometer. When pentodes or beam power tubes are operated under conditions where a large shift of plate and screen currents does not take place with the application of the signal, the screen voltage may be obtained through a series resistor from a high-voltage source. This method of supply is possible because of the high uniformity of the screen-current characteristic in pentodes and beam power tubes. Because the screen voltage rises with increase in bias and resulting decrease in screen current, the cutoff characteristic of a pentode is extended by this method of supply. The method is sometimes used to increase the range of signals

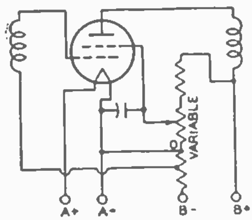


Fig. 71

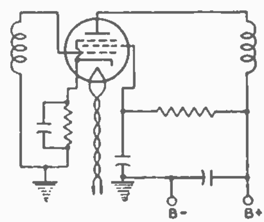


Fig. 72

which can be handled by a pentode. When used in resistance-coupled amplifier circuits employing pentodes in combination with the cathode-biasing method, it minimizes the need for circuit adjustments. Fig. 72 shows a pentode with its screen voltage supplied through a series resistor.

When power pentodes and beam power tubes are operated under conditions such that there is a large change in plate and screen currents with the application of signal, the series-resistor method of obtaining screen voltage should not be used. A change in screen current appears as a change in the voltage drop across the series resistor in the screen circuit; the result is a change in the power output and an increase in distortion. The screen voltage should be obtained from a point in the plate-voltage-supply filter system having the correct voltage, or from a separate source.

It is important to note that the plate voltage of tetrodes, pentodes, and beam power tubes should be applied before or simultaneously with the screen voltage. Otherwise, with voltage on the screen only, the screen current may rise high enough to cause excessive screen dissipation.

Screen-voltage variation for the rf amplifier stages has sometimes been used for volume control in older-type receivers. Reduced screen voltage lowers the transconductance of the tube and results in reduced gain per stage. The voltage variation is obtained by means of a potentiometer shunted across the screen voltage supply. See Fig. 71. When the screen voltage is varied, it is essential that the screen voltage never exceed the rating of the tube. This requirement can be met by providing a fixed stop on the potentiometer.

SHIELDING

In high-frequency stages having high gain, the output circuit of each stage must be shielded from the input circuit of that stage. Each high-frequency stage also must be shielded from the other high-frequency stages. Unless shielding is employed, undesired feedback may occur and may produce many harmful effects on receiver performance. To prevent this feedback, it is a desirable practice to shield separately each unit of the high-frequency stages. For instance, in a superheterodyne receiver, each if and rf coil may be mounted in a separate shield can. Baffle plates may be mounted on the ganged tuning capacitor to shield each section of the capacitor from the other sections. The oscillator coil may be especially well shielded by being mounted under the chassis. The shielding precautions required in a receiver depend on the design of the receiver and the layout of the parts. In all receivers having high-gain high-frequency stages, it is necessary to shield separately each tube in high-frequency stages. When metal tubes, and in particular the single-ended types, are used, complete shielding of each tube is provided by the metal shell which is grounded through its grounding pin at the socket terminal. The grounding connection should be short and heavy. Many modern tubes of glass construction have internal shields connected usually to the cathode and where present are indicated in the socket diagram.

DRESS OF CIRCUIT LEADS

At high frequencies such as are encountered in FM and television receivers, lead dress, that is, the location and arrangement of the leads used for connections in the receiver, is very important. Because even a short lead provides a large impedance at high frequencies, it is necessary to keep all high-frequency leads as short as possible. This precaution is especially important for ground connections and for all connections to bypass capacitors and hf filter capacitors. The ground connections of plate and screen bypass capacitors of each tube should be kept short and made directly to cathode ground.

Particular care should be taken with the lead dress of the input and output circuits of an hf stage so that the possibility of stray coupling is minimized. Unshielded leads connected to shielded components should be dressed close to the chassis. As the frequency increases, the need for paying careful attention to lead dress becomes increasingly important.

In high-gain audio amplifiers, these same precautions should be taken to minimize the possibility of self-oscillation.

FILTERS

Feedback effects also are caused in radio receivers by coupling between stages through common voltage-supply circuits. Filters find an important use in minimizing such effects. They should be placed in voltage-supply leads to each tube in

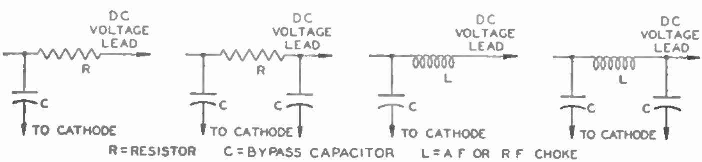


Fig. 73

order to return the signal current through a low-impedance path direct to the tube cathode rather than by way of the voltage-supply circuit. Fig. 73 illustrates several forms of filter circuits. Capacitor C forms the low-impedance path, while the choke or resistor assists in diverting the signal through the capacitor by offering a high-impedance to the power-supply circuit.

The choice between a resistor and a choke depends chiefly upon the permissible dc voltage drop through the filter. In circuits where the current is small (a few milliamperes), resistors are practical; where the current is large or regulation important, chokes are more suitable.

The minimum practical size of the capacitors may be estimated in most cases by the following rule: The impedance of the capacitor at the lowest frequency amplified should not be more than one-fifth of the impedance of the filter choke or resistor at that frequency. Better results will be obtained in special cases if the ratio is not more than one-tenth. Radio-frequency circuits, particularly at high frequencies, require high-quality capacitors. Mica capacitors are preferable. Where stage shields are employed, filters should be placed within the shield.

Another important application of filters is to smooth the output of a rectifier tube. See **Rectification**. A smoothing filter usually consists of capacitors and iron-core chokes. In any filter-design problem, the load impedance must be considered as an integral part of the filter because the load is an important factor in filter performance. Smoothing effect is obtained from the chokes because they are in series with the load and offer a high impedance to the ripple voltage. Smoothing effect is obtained from the capacitors because they are in parallel with the load and store energy on the voltage peaks; this energy is released on the voltage dips and serves to maintain the voltage at the load substantially constant. Smoothing filters are classified as choke-input or capacitor-input according to whether a choke or capacitor is placed next to the rectifier tube. See Fig. 74.

The CIRCUIT SECTION gives a number of examples of rectifier circuits with recommended filter constants.

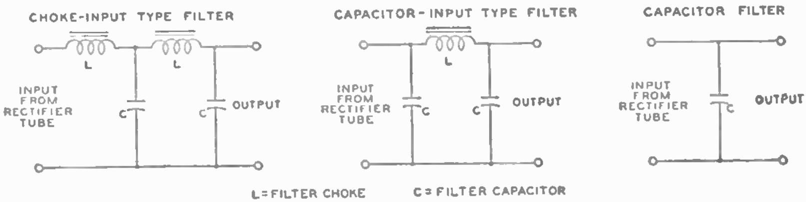


Fig. 74

If an input capacitor is used, consideration must be given to the instantaneous peak value of the ac input voltage. This peak value is about 1.4 times the rms value as measured by an ac voltmeter. Filter capacitors, therefore, especially the input capacitor, should have a rating high enough to withstand the instantaneous peak value if breakdown is to be avoided. When the input-choke method is used, the available dc output voltage will be somewhat lower than with the input-capacitor method for a given ac plate voltage. However, improved regulation together with lower peak current will be obtained.

Mercury-vapor and gas-filled rectifier tubes occasionally produce a form of local interference in radio receivers through direct radiation or through the power line. This interference is generally identified in the receiver as a broadly tunable 120-cycle buzz (100 cycles for 50-cycle supply line, etc.). It is usually caused by the formation of a steep wave front when plate current within the tube begins to flow on the positive half of each cycle of the ac supply voltage. There are several ways of eliminating this type of interference. One is to shield the tube. Another is to insert an rf choke having an inductance of one millihenry or more between each plate and transformer winding and to connect high-voltage, rf bypass capacitors between the outside ends of the transformer winding and the center tap. See Fig. 75. The rf chokes should be placed within the shielding of the tube. The rf bypass capacitors should have a voltage rating high enough to withstand the peak voltage of each half of the secondary, which is approximately 1.4 times the

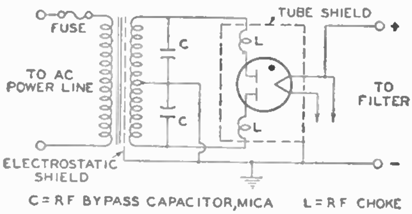


Fig. 75

rms value. Transformers having electrostatic shielding between primary and secondary are not likely to transmit rf disturbances to the line. Often the interference may be eliminated simply by making the plate leads of the rectifier extremely short. In general, the particular method of interference elimination must be selected by experiment for each installation.

OUTPUT-COUPLING DEVICES

An output-coupling device is used in the plate circuit of a power output tube to keep the comparatively high dc plate current from the winding of an electromagnetic speaker and, also, to transfer power efficiently from the output stage to a loudspeaker of either the electromagnetic or dynamic type.

Fig. 76

Output-coupling devices are of two types, (1) choke-capacitor and (2) transformer. The choke-capacitor type includes an iron-core choke with an inductance of not less than 10 henrys which is placed in series with the plate and B-supply. The choke offers a very low resistance to the dc plate current component of the signal voltage but opposes the flow of the fluctuating component. A bypass capacitor of 2 to 6 μf supplies a path to the speaker winding for the signal voltage. The transformer type is constructed with two separate windings, a primary and a secondary wound on an iron core. This construction permits designing each winding to meet the requirements of its position in the circuit. Typical arrangements of each type of coupling device are shown in Fig. 76. Examples of transformers for push-pull stages are shown in several of the circuits given in the CIRCUIT SECTION.

HIGH-VOLTAGE CONSIDERATIONS FOR KINESCOPES

Like other high-voltage devices, kinescopes require that certain precautions be observed to minimize the possibility of failure caused by humidity, dust, and corona.

Humidity Considerations. When humidity is high, a continuous film of moisture may form on the glass bulb immediately surrounding the anode cavity cap of all-glass kinescopes or on the glass part of the cone of metal kinescopes. This film may permit sparking to take place over the glass surface to the external conductive coating or to the metal cone. Such sparking may introduce noise into the receiver. To prevent such a possibility, the uncoated bulb surface around the cap and the glass part of the cone of metal kinescopes should be kept clean and dry.

Dust Considerations. The accumulation of dust on the uncoated area of the bulb around the anode cap of all-glass kinescopes or on the glass part of the cone or insulating supports for metal kinescopes will decrease the insulating qualities of these parts. The dust usually consists of fibrous materials and may contain soluble salts. The fibers absorb and retain moisture; the soluble salts provide electrical leakage paths that increase in conductivity as the humidity increases. The resulting high leakage currents may overload the high-voltage power supply. It is recommended, therefore, that the uncoated bulb surface of all-glass kinescopes and the coated glass surface and insulating supports for metal kinescopes be kept clean and free from dust or other contamination such as finger-prints. The coated glass surface of the metal kinescopes may be cleaned with a soapless detergent, such as Dreft, then rinsed with clean water, and immediately dried.

Corona Considerations. A high-voltage system may be subject to corona, especially when the humidity is high, unless suitable precautions are taken. Corona, which is an electrical discharge appearing on the surface of a conductor when the voltage gradient exceeds the breakdown value of air, causes deterioration of organic insulating materials through formation of ozone, and induces arc-over at points and sharp edges. Sharp points or other irregularities on any part of the high-voltage system may increase the possibility of corona and should be avoided. In the metal-cone kinescopes, the metal lip at the maximum diameter has rounded edges to prevent corona. Adequate spacing between the lip and any grounded element in the receiver, or between the small end of the metal cone and any grounded element, should be provided to preclude the possibility of corona. Such spacing should not be less than 1 inch of air. Similarly, an air space of 1 inch, or equivalent, should be provided around the body of the metal cone. As a further precaution to prevent corona, the deflecting-yoke surface on the end adjacent to the cone should present a smooth electrical surface with respect to the small end of the metal cone or the anode terminal of all-glass tubes. For metal kinescopes, the end of the yoke should not touch the glass part of the cone above the Reference Line (see Kinescope Outline Drawings in OUTLINES SECTION), but can follow the glass contour, departing gradually from it. For all-glass kinescopes, the yoke should touch the bulb cone near the Reference Line, and should follow the cone contour, departing gradually from it.

KINESCOPE SAFETY CONSIDERATIONS

Tube Handling. Breakage of kinescopes, which contain a high vacuum, may result in injury from flying glass. Do not strike or scratch the tube or subject it to more than moderate pressure when installing it in or removing it from electronic equipment.

High-Voltage Precautions. In the use of kinescopes, it should always be remembered that high voltages may appear at normally low-potential points in the circuit because of capacitor breakdown or incorrect circuit connections. Therefore, before any part of the circuit is touched the power-supply switch should be turned off, the power plug disconnected, and both terminals of any capacitors grounded.

X-Ray Radiation Precautions. All types of picture tubes may be operated at voltages (if ratings permit) up to 16 kilovolts without producing harmful x-ray radiation and without danger of personal injury on prolonged exposure at close range. Above 16 kilovolts, special x-ray shielding precautions may be necessary.

Interpretation of Tube Data

The tube data given in the following TUBE TYPES SECTION include ratings, typical operation values, characteristics, and characteristic curves.

The values for grid-bias voltages, electrode voltages, and electrode supply voltages are given with reference to a specified **datum point** as follows: For types having filaments heated with dc, the negative filament terminal is taken as the datum point to which other electrode voltages are referred. For types having filaments heated with ac, the mid-point (i.e., the center tap on the filament-transformer secondary, or the mid-point on a resistor shunting the filament) is taken as the datum point. For types having unipotential cathodes indirectly heated, the cathode is taken as the datum point.

Electrode voltage and current **ratings** are in general self-explanatory, but a brief explanation of other ratings will aid in the understanding and interpretation of tube data.

Plate dissipation is the power dissipated in the form of heat by the plate as a result of electron bombardment. It is the difference between the power supplied to the plate of the tube and the power delivered by the tube to the load.

Grid-No. 2 (Screen) Input is the power applied to the grid-No. 2 electrode and consists essentially of the power dissipated in the form of heat by grid No. 2 as a result of electron bombardment. With tetrodes and pentodes, the power dissipated in the screen circuit is added to the power in the plate circuit to obtain the total B-supply input power.

Peak heater-cathode voltage is the highest instantaneous value of voltage that a tube can safely stand between its heater and cathode. This rating is applied to tubes having a separate cathode terminal and used in applications where excessive voltage may be introduced between heater and cathode.

Maximum peak inverse plate voltage is the highest instantaneous plate voltage which the tube can withstand recurrently in the direction opposite to that in which it is designed to pass current. For mercury-vapor tubes and gas-filled tubes, it is the safe top value to prevent arc-back in the tube operating within the specified temperature range. Referring to Fig. 77, when plate A of a full-wave rectifier tube is positive, current flows from A to C, but not from B to C, because B is negative. At the instant plate A is positive, the filament is positive (at high voltage) with respect to plate B. The voltage between the positive filament and the negative plate B is in inverse relation to that causing current flow. The peak value of this voltage is limited by the resistance and nature of the path between plate B and filament. The maximum value of this voltage at which there is no danger of breakdown of the tube is known as maximum peak inverse voltage. The relations between peak inverse voltage, rms value of ac input voltage, and dc output voltage depend largely on the individual characteristics of the rectifier circuit and the power supply. The presence of line surges or any other transient, or wave-form distortion may raise the actual peak voltage to a value higher than that calculated for sine-wave voltages. Therefore, the actual inverse voltage, and not the calculated value, should be such as not to exceed the rated maximum peak inverse voltage for the rectifier tube. A calibrated cathode-ray

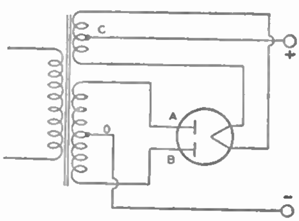


Fig. 77

oscillograph or a peak-indicating electronic voltmeter is useful in determining the actual peak inverse voltage. In single-phase, full-wave circuits with sine-wave input and with no capacitor across the output, the peak inverse voltage on a rectifier tube is approximately 1.4 times the rms value of the plate voltage applied to the tube. In single-phase, half-wave circuits with sine-wave input and with capacitor input to the filter, the peak inverse voltage may be as high as 2.8 times the rms value of the applied plate voltage. In polyphase circuits, mathematical determination of peak inverse voltage requires the use of vectors.

Maximum peak plate current is the highest instantaneous plate current that a tube can safely carry recurrently in the direction of normal current flow. The safe value of this peak current in hot-cathode types of rectifier tubes is a function of the electron emission available and the duration of the pulsating current flow from the rectifier tube in each half-cycle.

The value of peak plate current in a given rectifier circuit is largely determined by filter constants. If a large choke is used at the filter input, the peak plate current is not much greater than the load current; but if a large capacitor is used at the filter input, the peak current may be many times the load current. In order to determine accurately the peak plate current in any rectifier circuit, measure it with a peak-indicating meter or use an oscillograph.

Maximum dc output current is the highest average plate current which can be handled continuously by a rectifier tube. Its value for any rectifier tube type is based on the permissible plate dissipation of that type. Under operating conditions involving a rapidly repeating duty cycle (steady load), the average plate current may be measured with a dc meter.

Typical Operation Values. Values for typical operation are given for many types in the TUBE TYPES SECTION. These values should not be confused with ratings, because a tube can be used under any suitable conditions within its maximum ratings, according to the application.

The power output value for any operating condition is an approximate tube output—that is, plate input minus plate loss. Circuit losses must be subtracted from tube output in order to determine the useful output.

Characteristics are covered in the ELECTRON TUBE CHARACTERISTICS SECTION and such data should be interpreted in accordance with the definitions given in that section. **Characteristic curves** represent the characteristics of an average tube. Individual tubes, like any manufactured product, may have characteristics that range above or below the values given in the characteristic curves.

Although some curves are extended well beyond the maximum ratings of the tube, this extension has been made only for convenience in calculations. Do NOT operate a tube outside of its maximum ratings.

All tubes in this Manual are rated according to the "**design-center system**" as given in RMA Standard M8-210. This standard takes into account the normal voltage variations of the various power-supply sources used for modern radio receivers. The Standard M8-210, used with permission of the Engineering Department of the Radio Manufacturers Association, follows:

It shall be standard to interpret the ratings on receiving types of tubes according to the following conditions:

1. CATHODE—The heater or filament voltage is given as a normal value unless otherwise stated. This means that transformers or resistances in the heater or filament circuit should be designed to operate the heater or filament at rated value for full-load operating conditions under average supply-voltage conditions. A reasonable amount of leeway is incorporated in the cathode design so that moderate fluctuations of heater or filament voltage downward will not cause marked falling off in response; also moderate voltage fluctuations upward will not reduce the life of the cathode to an unsatisfactory degree.

A. 1.4-Volt Battery Tube Types—The filament power supply may be obtained from dry-cell batteries, from storage batteries, or from a power line. With dry-cell battery supply, the filament may be connected either directly across a battery rated at a terminal potential of 1.5 volts, or in series with the filaments of similar tubes across a power supply consisting of dry cells in series. In either case, the voltage across each 1.4-volt section of filament should not exceed 1.6 volts. With power-line or storage-battery supply, the filament may be operated in series with the filaments of similar tubes. For such operation, design adjustments should be made so that, with tubes of rated characteristics, operating with all electrode voltages applied and on a normal line voltage of 117 volts or on a normal storage-battery voltage of 2.0 volts per cell (without a charger) or 2.2 volts per cell (with a charger), the voltage drop across each 1.4-volt section of filament will be maintained within a range of 1.25 to 1.4 volts with a nominal center of 1.3 volts. In order to meet the recommended conditions for operating filaments in series from dry-battery, storage-battery, or power-line sources it may be necessary to use shunting resistors across the individual 1.4-volt sections of filament.

B. 2.0-Volt Battery Tube Types—The 2.0-volt line of tubes is designed to be operated with 2.0 volts across the filament. In all cases the operating voltage range should be maintained within the limits of 1.8 volts to 2.2 volts.

2. **POSITIVE POTENTIAL ELECTRODES**—The power sources for the operation of radio equipment are subject to variations in their terminal potential. Consequently, the maximum ratings shown on the tube-type data sheets have been established for certain Design Center Voltages which experience has shown to be representative. The Design Center Voltages to be used for the various power supplies together with other rating considerations are as given below:

A. AC or DC Power Line Service in U.S.A. The design center voltage for this type of power supply is 117 volts. The maximum ratings of plate voltages, screen-supply voltages, dissipations, and rectifier output currents are design maximums and should not be exceeded in equipment operated at a line voltage of 117 volts.

B. Storage-Battery Service—When storage-battery equipment is operated without a charger, it should be designed so that the published maximum values of plate voltages, screen-supply voltages, dissipations, and rectifier output currents are never exceeded for a terminal potential at the battery source of 2.0 volts per cell. When storage-battery equipment is operated with a charger, it should be designed so that 90% of the same maximum values is never exceeded for a terminal potential at the battery source of 2.2 volts.

C. "B"-Battery Service—The design center voltage for "B" batteries is the normal voltage rating of the battery block, such as 45 volts, 90 volts, etc. Equipment should be designed so that under no condition of battery voltage will the plate voltages, the screen-supply voltages, or dissipations ever exceed the recommended respective maximum values shown in the data for each tube type by more than 10%.

D. Other Considerations—

a. Class A_1 Amplifiers—The maximum plate dissipation occurs at the "Zero-Signal" condition. The maximum screen dissipation usually occurs at the condition where the peak-input signal voltage is equal to the bias voltage.

b. Class B Amplifiers—The maximum plate dissipation theoretically occurs at approximately 63% of the "Maximum-Signal" condition, but practically may occur at any signal voltage value.

c. Converters—The maximum plate dissipation occurs at the "Zero-Signal" condition and the frequency at which the oscillator-developed bias is a minimum. The screen dissipation for any reasonable variation in signal voltage must never exceed the rated value by more than 10%.

d. Screen Ratings—When the screen voltage is supplied through a series voltage-dropping resistor, the maximum screen voltage rating may be exceeded, provided the maximum screen dissipation rating is not exceeded at any signal condition, and the maximum screen voltage rating is not exceeded at the maximum-signal condition. Provided these conditions are fulfilled, the screen-supply voltage may be as high as, but not above, the maximum plate voltage rating.

3. TYPICAL OPERATION—For many receiving tubes, the data show typical operating conditions in particular services. These typical operating values are given to show concisely some guiding information for the use of each type. They are not to be considered as ratings, because the tube can be used under any suitable conditions within its rating limitations.

RCA Receiving Tube Classification Chart

RCA receiving tubes are classified in the following chart according to function and filament or heater voltage. Types having similar electrical characteristics

A—Kinescopes

KINESCOPES					
	Approx. Envelope Diameter (Inches)		3-14	16-17	19-27
	Focusing Method	Deflection Method			
Directly Viewed	electrostatic	electrostatic	3KP4 7JP4		
Directly Viewed	electrostatic	magnetic	7DP4 9AP4 12AP4	17GP4 17HP4 17LP4 17TP4	20MP4 21MP4
Directly Viewed	magnetic	magnetic	10BP4-A 10FP4-A 12KP4-A 12LP4-A 14CP4 14EP4	16AP4-A 16DP4-A 16GP4 16GP4-B 16KP4 16LP4-A 16RP4 16TP4 16WP4-A 17BP4-A 17CP4 17JP4 17QP4	19AP4-A 19AP4-B 20CP4 21AP4 21FP4 21FP4-A 21LP4-A 27MP4
Projection	electrostatic	magnetic	5TP4		

B—Rectifiers, Detectors, Power and Voltage Amplifiers, Converters and Mixers, Electron-Ray Tubes

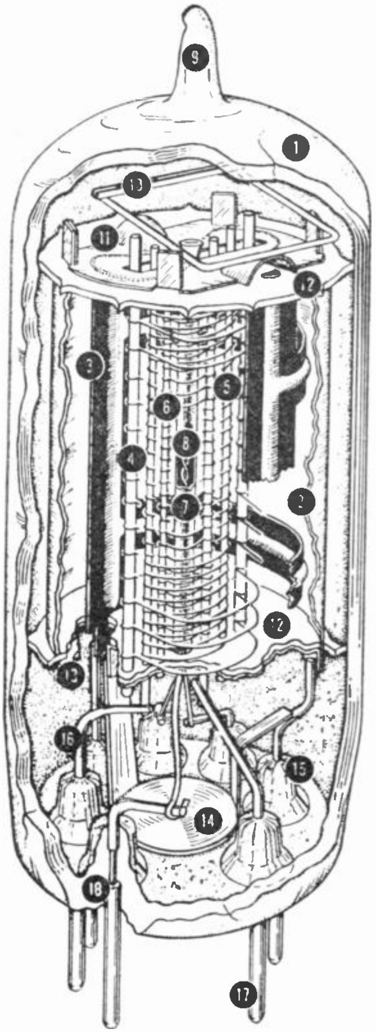
Types having similar characteristics and the same filament or heater voltage are bracketed.

Filament or Heater Volts			1.25—1.4 Sub-miniature	1.25—1.4 Miniature	1.25—1.4 Other	2.0—5.0 Octal	2.0—5.0 Other	6.3—117.0 Miniature	6.3—117.0 Octal	Other
RECTIFIERS *(For rectifiers with amplifier units, see POWER AMPLIFIERS).*										
Half-Wave	vacuum	Peak Inverse Volts: Below 1500						35W4 45Z3 117Z3	6W4-GT 25W4-GT 6AX4-GT 12AX4-GT (35Z4-GT 35Z5-GT) 45Z5-GT 117Z4-GT	1-v 12Z3 35Y4 35Z3
Half-Wave	vacuum	Above 1500	1V2 1X2-A		1B3-GT					81
Full-Wave	vacuum	Peak Inverse Volts: Below 1500				(5Y3-G, 5AZ4 5Y3-GT, 5Y4-G) (5V4-G 5W4-GT)	(5Z4 80) 83-v)	(6X4 12X4	6X5, 6X5-GT) 6AX5-GT 6ZY5-G 84/6Z4	7Y4 7Z4
Full-Wave	vacuum	Above 1500				(5T4, 5U4-G 5X4-G	5Z3)			
Full-Wave	mercury-vapor	Above 1500					82 83			
Full-Wave	gas	Below 1500				Cold-Cathode Types 0Y4, 0Z4, 0Z4-G				
Doubler	vacuum	Peak Inverse Volts: Below 1500							(25Z6, 25Z6-GT (50Y6-GT) (50Y7-GT) 117Z6-GT	25Z5) 50X6
DIODE DETECTORS *(For diode detectors with amplifier units, see VOLTAGE AMPLIFIERS and also POWER AMPLIFIERS).*										
One Diode				1A3						
Two Diodes								6AL5 12AL5	(6H6, 6H6-GT) 12H6	7A6
POWER AMPLIFIERS with and without Rectifiers, Diode Detectors, and Voltage Amplifiers.										
Triodes	low-mu	single unit					2A3 31 49 45 46 71-A		6B4-G	6A3 50
Triodes	low-mu	twin unit							6AS7-G	
Triodes	high-mu	single unit							6AC5-GT	
Triodes	high-mu	twin unit			1G6-GT	(1J6-GT	19) 53		(6N7, 6N7-GT 6AQ7-GT 6Z7-G	6A6) 79
Triodes	direct-coupled arrangement								6N6-G	6B5
Beam Tubes	single unit				(1Q5-GT) (3Q5-GT*) 1T5-GT 3LF4			6AS5 6BF5 6AQ5 12AQ5 (35B5, 35C5) (50B5, 50C5)	6AU5-GT 6BG6-G 6BQ6-GT 6CD6-G (6V6 6V6-GT) 6AV5-GT 12V6-GT 6W6-GT 25BQ6-GT 6Y6-G 19BG6-G 50C6-G (6L6 (6L6-G) 25L6 (25L6-GT) 35L6-GT 50L6-GT	7A5 14A5 7C5 14C5 35A5 50A5
Beam Tubes	with rectifier								32L7-GT 70L7-GT (117L7/M7-GT) (117P7-GT) 117N7-GT	
Pentodes	single unit		1AC5	(1S4 3S4*) (3Q4* 3V4*)	1A5-GT 1C5-GT 1LA4 1LB4	(1F4 1G5-G	1F5-G) 2A5 33 47 59	6CL6 (6AK6 6AR5	6AG7 6C6-G) (6F6, 6F6-G, 6F6-GT (6K6-GT (25A6	7B5 7AD7 42) 38 41) 89 43)
Pentodes	with medium-mu triode								6AD7-G	
Pentodes	with diode and triode				1D8-GT					
Pentodes	with rectifier									12A7
Pentodes	twin unit					1E7-GT				

are grouped in brackets. For more complete data on these types, refer to the TUBE TYPES SECTION. When choosing a tube type, refer to information on *Preferred Types* and the listing of *Types Not Recommended for New Equipment Design* on the inside back cover.

Filament or Heater Volts			1.25—1.4			2.0—5.0		6.3—117.0		
			Sub-miniature	Miniature	Other	Octal	Other	Miniature	Octal	Other
CONVERTERS & MIXERS (*For other types used as Mixers, see VOLTAGE AMPLIFIERS*).										
Converters	pentagrid		1E8	1L6 1R5	1A7-GT 1LA6 1LC6	1C7-G 1D7-G	1C6 1A6 2A7	6BE6 12BE6 12BA7 6BA7	6SA7 6SA7-GT 12SA7 12SA7-GT 6SB7-Y 6A8, 6A8-G 6A8-GT 6D8-G 12A8-GT	6A7 7B8 14B8 7Q7 14Q7
Converters	triode-pentode								6X8 19X8	
Converters	triode-hexode								6K8, 6K8-G 12K8	
Converters	triode-heptode								6J8-G	7S7 7J7 14J7
Converters	octode									7A8
Mixers	pentagrid								6L7, 6L7-G	
ELECTRON-RAY TUBES										
Single	with remote-cutoff triode									6AB5/6N5 6U5
Single	with sharp-cutoff triode						2E5			6E5
Twin	without triode								6AF6-G	
Triple									6AL7-GT	
VOLTAGE AMPLIFIERS with and without Diode Detectors; TRIODE, TETRODE, AND PENTODE DETECTORS; OSCILLATORS.										
Triodes	medium-mu	single unit			1G4-GT 1LE3 26	1H4-G	30 27 56	6AF4 6C4 6S4	6C5, 6C5-GT 6J5, 6J5-GT 12J5-GT 6AH4-GT 6L5-G 6P5-GT	7A4 14A4 76 37
Triodes	medium-mu	with rf pentode							6U8 6F7	
Triodes	medium-mu	with power pentode							6AD7-G	
Triodes	medium-mu	with pentode and diode			1D8-GT 3A8-GT*					
Triodes	medium-mu	with two diodes				1H6-G	1B5 25S 55	6BF6 12BF6	6R7, 6R7-GT 6SR7 6ST7 12SR7	7E6 14E6 85
Triodes	medium-mu	twin unit						6BQ7 12AU7▲ 6BQ7-A 6J6 12BH7▲ 19J6	6F8-G, 6SN7-GT 12SN7-GT 6C8-G 12AH7-GT 6BL7-GT	7AF7 14AF7 7F8 14F8 7N7 14N7
Triodes	high-mu	single unit						6AB4	6F5, 6F5-GT 12F5-GT 6SF5, 6SF5-GT 6K5-G 12SF5 25AC5-GT	7B4
Triodes	high-mu	with diode			1H5-GT 1LH4					
Triodes	high-mu	with two diodes					2A6	12AT6 6AT6 6AQ6 12AV6 6AV6	6Q7, 6Q7-G 6Q7-GT, 6SZ7 6SQ7, 6SQ7-GT 6B6-G 12Q7-GT 6T7-G 12SQ7 12SQ7-GT	7B6 14B6 7C6 75
Triodes	high-mu	with three diodes						6T8 19T8	6S8-GT 12S8-GT	
Triodes	high-mu	twin unit						12AT7▲ 12AX7▲	6SC7, 12SC7 6SL7-GT 12SL7-GT	7F7 14F7 7K7 7X7
Tetrodes	remote-cutoff						35			
Tetrodes	sharp-cutoff						24-A 32			36
Pentodes	remote-cutoff	single unit		1T4	1LG5 1P5-GT	1D5-GP	1A4-P 34 58	6BD6 12BD6 6BA6 12BA6 6BJ6	6SK7, 6SK7-GT 12SK7, 12SK7-GT 6SG7 6D6 12SG7 6U7-G 6AB7 6SS7 6K7, 6K7-G 6K7-GT 12K7-GT 6S7 6S7-G	78 7A7 14A7 7H7 14H7 7AH7 7B7 39/44
Pentodes	remote-cutoff	with triode								6F7
Pentodes	remote-cutoff	with diode							6SF7 12SF7	
Pentodes	remote-cutoff	with two diodes					2B7		12C8 6B8 6B8-G	6B7 7E7 14E7 6B7-S 7R7 14R7
Pentodes	sharp-cutoff	single unit	1AD5	1L4 1U4	1LC5 1LN5 1N5-GT	1E5-GP	1B4-P 57	6AG5 6AK5 6BC5 6CB6 6CF6 6AH6 6BH6 12AW6 6AU6 12AU6	6SJ7 6SJ7-GT 12SJ7 12SJ7-GT 6AC7 12J7-GT 6SH7 12SH7 6J7, 6J7-G, 6J7-GT 6C6 6W7-G	7AG7 7G7 7C7 14C7 7L7 7V7 77 7W7
Pentodes	sharp-cutoff	with diode	1T6	1S5 1U5	1LD5					
Pentodes	sharp-cutoff	with two diodes				1F7-G	1F6			

* Filament arranged for either 1.4 or 2.8-volt operation. ▲ Heater arranged for either 6.3 or 12.6-volt operation.



2½ times actual size

1 – Glass Envelope
2 – Internal Shield
3 – Plate
4 – Grid No. 3 (Suppressor)
5 – Grid No. 2 (Screen)
6 – Grid No. 1 (Control Grid)
7 – Cathode
8 – Heater
9 – Exhaust Tip
10 – Getter
11 – Spacer Shield Header
12 – Insulating Spacer
13 – Spacer Shield
14 – Inter-Pin Shield
15 – Glass Button-Stem Seal
16 – Lead Wire
17 – Base Pin
18 – Glass-to-Metal Seal

Structure of a Miniature Tube

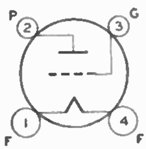
RCA Tube Types

This section contains technical descriptions of RCA tubes used in standard broadcast, FM, and television receivers. It includes data on current types, as well as information on those RCA discontinued types in which there may still be some interest as to characteristics.

In choosing tube types for the design of new electronic equipment, the designer is referred to the inside back cover for information regarding the availability of the latest **RCA Preferred Types List** and for a listing of **RCA Tube Types Not Recommended for New Equipment Design.**

Tube types are listed in this section according to the numerical-alphabetical sequence of their type designations. For **Key to Socket Connection Diagrams,** see inside front cover.

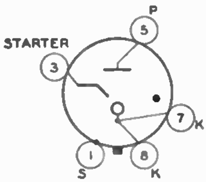
01-A



DETECTOR AMPLIFIER TRIODE

Storage-battery triode used as detector or amplifier. Outline 36, OUTLINES SECTION. Operating conditions as grid-resistor detector are: plate volts, 45 *max;* grid resistor, 2 to 3 megohms; grid capacitor, 250 μμf; grid return to (+) filament. As biased detector, type 01-A has plate volts of 135 *max;* bias of approximately −13.5 volts. As amplifier, it has plate volts of 135 *max;* bias of −9 volts. Filament volts, 5; amperes, 0.25. This is a DISCONTINUED type listed for reference only.

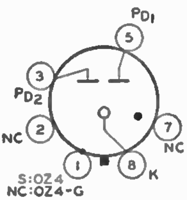
OY4



HALF-WAVE GAS RECTIFIER

Metal type used primarily in vibrator-type B-supply units of automobile receivers. Utilizes a starter electrode and an ionically heated cathode. Starter anode permits operation of OY4 directly from 117-volt ac line. Outline 3, OUTLINES SECTION. Tube requires octal socket. Pins 7 and 8 must be tied together at socket. RF filter circuits placed close to socket terminals are required to reduce rectifier noise. Ratings as half-wave rectifier with capacitor-input filter: peak inverse anode volts, 300 *max;* peak anode ma., 500 *max;* dc output ma., 75 *max,* 40 *min;* series anode resistance (117-volt line operation), 50 *min* ohms; tube voltage drop (approx.), 12 volts; minimum ac starting voltage when starter anode is connected to anode through a 10-megohm resistor bypassed with a 0.002-μf capacitor, 100 volts rms. This type is used principally for renewal purposes.

OZ4
OZ4-G



FULL-WAVE GAS RECTIFIER

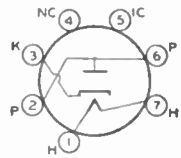
Metal type OZ4 and glass octal type OZ4-G are used in vibrator-type, B-supply units. Both have ionically heated cathodes, require octal sockets, and may be mounted in any position. OZ4 Outline 2, OUTLINES SECTION. OZ4-G dimensions: maximum overall length, 2-5/8 inches; maximum diameter, 1-1/16 inches; T-7 bulb; dwarf-shell octal 5-pin base. Base of OZ4-G has no pin No. 2. Shell of OZ4 and external shield of OZ4-G should be grounded. Filters may be necessary to eliminate objectionable noise. These types are used principally for renewal purposes.

Maximum Ratings: FULL-WAVE RECTIFIER

Peak Starting Supply Voltage Per Plate	300 *min*	volts
Peak Plate-To-Plate Voltage	1000 *max*	volts
Peak Plate Current	200 *max*	ma
DC Output Current	75 *max*	ma
	30 *min*	ma
DC Output Voltage	300 *max*	volts
Average Dynamic Tube Voltage Drop	24	volts

1A3

HF DIODE



Miniature type used as detector tube in portable FM receivers and in portable high-frequency measuring equipment. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket. Heater volts (ac/dc), 1.4; amperes, 0.15.

Maximum Ratings: HALF-WAVE RECTIFIER

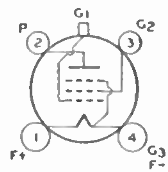
Peak Inverse Plate Voltage	330 *max*	volts
Peak Plate Current	5 *max*	ma
DC Output Current	0.5 *max*	ma
Peak Heater-Cathode Voltage	140 *max*	volts

Typical Operation (With Capacitor-Input Filter):

AC Plate-Supply Voltage (rms)	117	volts
Filter-Input Capacitor	2	μf
Minimum Total Effective Plate-Supply Impedance	0	ohms

1A4-P

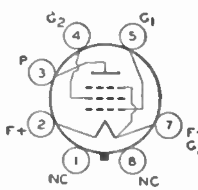
REMOTE-CUTOFF PENTODE



Glass type used in battery-operated receivers as rf or if amplifier. For ratings and operating data, refer to type 1D5-GP. Outline 34, OUTLINES SECTION. Tube requires four-contact socket. Filament volts (dc), 2.0; amperes, 0.06. This type is used principally for renewal purposes.

1A5-GT

POWER PENTODE



Glass octal type used in output stage of battery-operated receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For filament considerations, refer to 1U4.

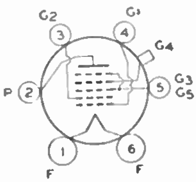
Filament Voltage (dc)	1.4	volts
Filament Current	0.05	ampere

Maximum Ratings: CLASS A_1 AMPLIFIER

Plate Voltage	110 *max*	volts
Grid-No.2 (Screen) Voltage	110 *max*	volts
Total Zero-Signal Cathode Current	6 *max*	ma

Typical Operation:

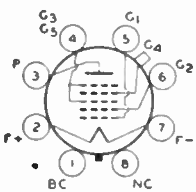
Plate Voltage	85	90	volts
Grid-No.2 Voltage	85	90	volts
Grid-No.1 (Control-Grid) Voltage	-4.5	-4.5	volts
Peak AF Grid-No.1 Voltage	4.5	4.5	volts
Zero-Signal Plate Current	3.5	4.0	ma
Maximum-Signal Plate Current	3.5	4.0	ma
Zero-Signal Grid-No.2 Current	0.7	0.8	ma
Maximum-Signal Grid-No.2 Current	1.0	1.1	ma
Plate Resistance (Approx.)	0.3	0.3	megohm
Transconductance	800	850	μmhos
Load Resistance	25000	25000	ohms
Total Harmonic Distortion	10	7	per cent
Maximum-Signal Power Output	100	115	mw



1A6

PENTAGRID CONVERTER

Glass type used in battery-operated receivers. Type 1A6 is identical electrically with type 1D7-G, except for interelectrode capacitances. Outline 34, OUTLINES SECTION. Tube requires six-contact socket. Filament volts (dc), 2.0; amperes, 0.06. This type is used principally for renewal purposes.



1A7-GT

PENTAGRID CONVERTER

Glass octal type used in superheterodyne circuits having battery power supplies. Outline 23, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For filament considerations, refer to 1U4.

FILAMENT VOLTAGE (DC)	1.4	volts
FILAMENT CURRENT	0.05	ampere

CONVERTER SERVICE

Maximum Ratings:

PLATE VOLTAGE	110 *max*	volts
GRIDS-NO.3-AND-NO.5 (SCREEN) VOLTAGE	60 *max*	volts
GRIDS-NO.3-AND-NO.5 SUPPLY VOLTAGE	110 *max*	volts
GRID-NO.2 (ANODE-GRID) VOLTAGE	110 *max*	volts
TOTAL ZERO-SIGNAL CATHODE CURRENT	6 *max*	ma

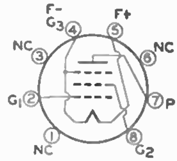
Typical Operation:

Plate Voltage	90	volts
Grids-No.3-and-No.5 Voltage*	45	volts
Grid-No.2 Voltage	90	volts
Grid-No.4 (Control-Grid) Voltage**	0	volts
Grid-No.1 (Oscillator-Grid) Resistor	0.2	megohm
Plate Resistance	0.6	megohm
Conversion Transconductance	250	μmhos
Conversion Transconductance with grid-No.4 bias of -3 volts (Approx.)	20	μmhos
Plate Current	0.6	ma
Grids-No.3-and-No.5 Current	0.7	ma
Grid-No.2 Current	1.2	ma
Grid-No.1 Current	0.035	ma
Total Cathode Current	2.5	ma

*Obtained preferably by using a bypassed 45000- to 75000-ohm voltage-dropping resistor in series with the 90-volt supply.

** A resistance of at least 1.0 megohm should be in the grid return to negative filament pin.

POWER PENTODE



1AC5

Subminiature type used in output stage of small, compact, battery-operated receivers for the standard AM broadcast band. It is capable of moderate power output with a very small input voltage. The 1AC5 and the other RCA subminiature types 1AD5, 1E8, and 1T6 comprise a complete tube complement for lightweight portable radio receivers having extremely low battery drain.

Filament Voltage (dc)	1.25	volts
Filament Current	0.04	ampere

Maximum Ratings: CLASS A_1 AMPLIFIER

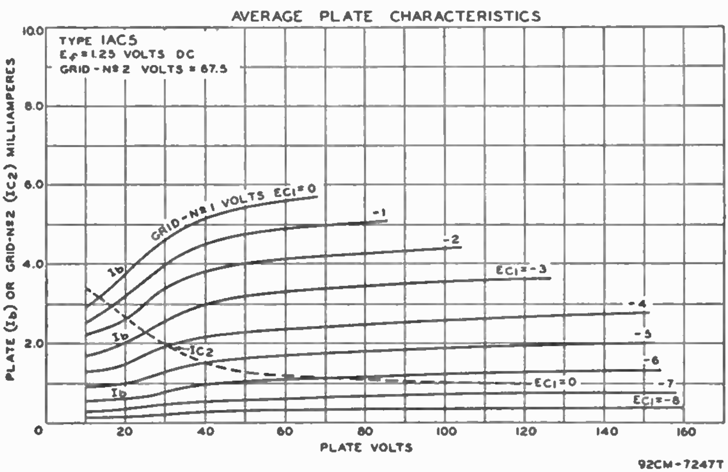
Plate Voltage	67.5 *max*	volts
Grid-No.2 (screen) Voltage	67.5 *max*	volts
Total Cathode Current	4.0 *max*	ma

Typical Operation:

Plate Voltage	30	45	67.5	volts
Grid-No.2 Voltage	30	45	67.5	volts
Grid-No.1 (Control-Grid) Voltage	−2	−3	−4.5	volts
Peak AF Grid-No.1 Voltage	2	3	4.5	volts
Zero-Signal Plate Current	0.5	1.0	2.0	ma
Zero-Signal Grid-No.2 Current	0.1	0.2	0.4	ma
Plate Resistance	0.2	0.17	0.15	megohm
Transconductance	450	600	750	μmhos
Load Resistance	50000	40000	25000	ohms
Total Harmonic Distortion	10	10	10	per cent
Maximum-Signal Power Output	5	15	50	mw

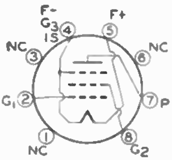
INSTALLATION AND APPLICATION

Type 1AC5 requires a subminiature eight-contact socket and may be mounted in any position. Do not attempt to solder the base pins to any circuit element because the heat of the soldering operation may crack the glass seal. Although the base pins are sturdy, they can be bent. It is essential, therefore, that the pins be



straight before they are inserted into the socket. Insertion will be facilitated if pins 1 and 8 are first aligned with their respective socket holes and the tube then gently pressed into the socket. Outline 8, OUTLINES SECTION.

The filament of the 1AC5 may be connected directly across a dry-cell battery rated at a terminal potential of 1.5 volts. In no case should the voltage across the filament ever exceed 1.6 volts. For additional filament considerations, refer to ELECTRON TUBE INSTALLATION SECTION.



SHARP-CUTOFF PENTODE

1AD5

Subminiature type used as rf or if amplifier in stages not controlled by avc in small, compact, battery-operated receivers for the standard AM broadcast band. Because of internal shielding feature, an external bulb shield is not needed, but socket shielding is essential if minimum grid-No.1-to-plate capacitance is to be obtained. The 1AD5 and the other RCA subminiature types 1AC5, 1E8, and 1T6 comprise a complete tube complement for lightweight portable radio receivers having extremely low battery drain. Outline 8, OUTLINES SECTION. Tube requires subminiature eight-contact socket and may be mounted in any position. For installation and application considerations, refer to type 1AC5.

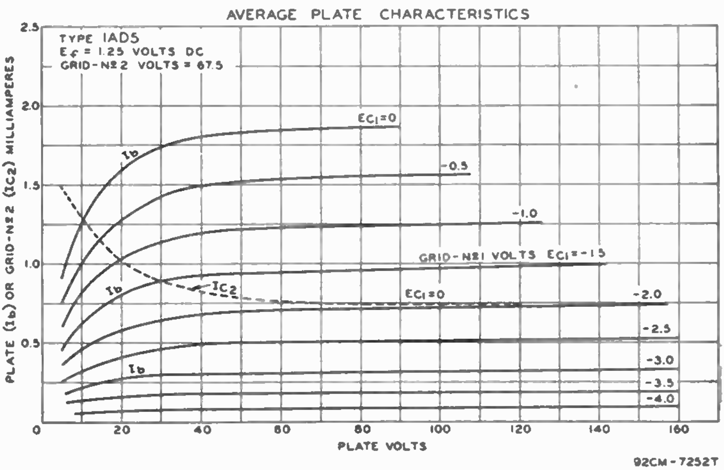
Filament Voltage (dc)	1.25	volts
Filament Current	0.04	ampere
Direct Interelectrode Capacitances (No external shields):		
Grid No.1 to Plate	0.010 *max*	μμf
Input	1.8	μμf
Output	2.8	μμf

Maximum Ratings: CLASS A_1 AMPLIFIER

Plate Voltage	67.5 *max*	volts
Grid-No.2 (screen) Voltage	67.5 *max*	volts
Total Cathode Current	4.0 *max*	ma

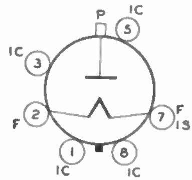
Typical Operation:

Plate Voltage	30	45	67.5	volts
Grid-No.2 Voltage	30	45	67.5	volts
Grid-No.1 (Control-Grid) Voltage	0	0	0	volts
Plate Resistance (Approx.)	0.7	0.7	0.7	megohm
Transconductance	430	580	735	μmhos
Grid-No.1 Bias (Approx.) for plate current of 10μa	-3	-4	-6	volts
Plate Current	0.45	0.9	1.85	ma
Grid-No.2 Current	0.16	0.35	0.75	ma



1B3-GT

HALF-WAVE VACUUM RECTIFIER



Glass octal type used in high-voltage, low-current applications such as the rectifier in a high-voltage, rf-operated power supply or as a rectifier of high-voltage pulses produced in television scanning systems. When used as an rf rectifier, one 1B3-GT in a half-wave circuit is capable of delivering a maximum dc output voltage of about 15000 volts. In a voltage-doubler circuit, two tubes will give about 30000 volts; and in a voltage-tripler circuit, three 1B3-GT's will deliver 45000 volts approximately.

FILAMENT VOLTAGE (AC)	1.25	volts
FILAMENT CURRENT	0.2	ampere
DIRECT INTERELECTRODE CAPACITANCE (No external shield):		
Plate to Filament (Approx.)	1.5	μμf

Maximum Ratings:	HALF-WAVE RECTIFIER	
PEAK INVERSE PLATE VOLTAGE	30000 *max*	volts
PEAK PLATE CURRENT	17 *max*	ma
AVERAGE PLATE CURRENT	2 *max*	ma
FREQUENCY OF SUPPLY VOLTAGE	300 *max*	Kc

INSTALLATION AND APPLICATION

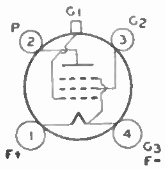
Type 1B3-GT requires an octal socket and may be mounted in any position. Plate connection is cap at top of bulb. Internal connections are made to pins 1, 3, 5, and 8. These pins may be connected to pin 7, otherwise, they should not be used. Outline 29, OUTLINES SECTION.

When the **filament** is to be operated on rf, it is recommended that the filament be connected first to a dc or low-frequency ac supply of 1.25 volts. The color temperature of the filament corresponding to this voltage may then be checked visually by observing in a darkened room the reflection of the incandescent filament upon the upper surface of the internal shield. A visual comparison of this color temperature with that obtained with the filament operated from an rf voltage provides a convenient means for adjusting the amount of rf excitation to produce 1.25 volts (rms) at the filament terminals. The filament must never, under any conditions of operation, be allowed to reach a temperature higher than that caused by operating the filament on dc or low-frequency ac at a voltage of 1.5 volts. Operation at higher temperatures, even momentarily during circuit adjustments, is certain to cause impaired performance of the tube even though the filament still lights.

The filament transformer, whether it is of the iron-core or the air-core type, must have sufficient insulation to withstand the maximum peak inverse plate voltage encountered in the installation.

The high voltages at which the 1B3-GT is operated are very dangerous. Great care should be taken to prevent coming in contact with these high voltages. In those circuits where the filament circuit is not grounded, the filament circuit operates at dc potentials which can cause fatal shock. Extreme precautions must be taken when the filament voltage is measured. These precautions must include safeguards which definitely eliminate all hazards to personnel.

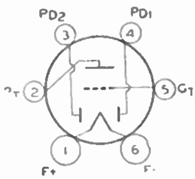
When used in television receivers and other equipment operating at 16000 volts or above, the 1B3-GT will produce X-rays which can constitute a health hazard unless the tube is adequately shielded.



SHARP-CUTOFF PENTODE

1B4-P

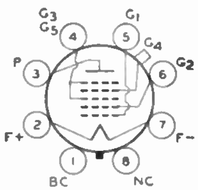
Glass type used as rf amplifier or detector in battery-operated receivers. Outline 34, OUTLINES SECTION. Tube requires four-contact socket. For typical operating conditions and maximum ratings as a class A_1 amplifier, refer to type 1E5-GP. Filament volts (dc), 2.0; amperes, 0.06. This type is used principally for renewal purposes.



TWIN DIODE—MEDIUM-MU TRIODE

1B5/25S

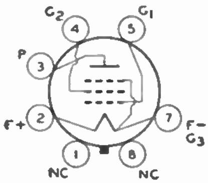
Glass type used as combined detector, amplifier, and avc tube in battery-operated receivers. Outline 32, OUTLINES SECTION. Tube requires six-contact socket. Filament volts (dc), 2.0; amperes, 0.06. Typical operation as class A_1 amplifier: plate volts, 135 *max;* grid volts, −3; plate ma., 0.8; plate resistance 35000, ohms; amplification factor, 20; transconductance, 575 µmhos. This type is used principally for renewal purposes.



PENTAGRID CONVERTER

1B7-GT

Glass octal type used in superheterodyne circuits having battery power supply. Outline 23, OUTLINES SECTION. Filament volts (dc), 1.4; amperes. 0.1. This is a DISCONTINUED type listed for reference only. The 1B7-GT may be replaced by the 1A7-GT if circuit adjustment is made for lower filament current of type 1A7-GT.



POWER PENTODE

1C5-GT

Glass octal type used in output stage of battery-operated receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For filament considerations, refer to 1U4. Type 1C5-GT is used principally for renewal purposes.

Filament Voltage (dc)	1.4	volts
Filament Current	0.1	ampere

Maximum Ratings: CLASS A_1 AMPLIFIER

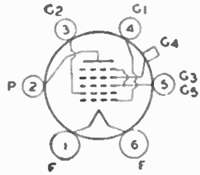
Plate Voltage	110 *max*	volts
Grid-No.2 (screen) Voltage	110 *max*	volts
Total Zero-Signal Cathode Current	12 *max*	ma

Typical Operation:

Plate Voltage	83	90	volts
Grid-No.2 Voltage	83	90	volts
Grid-No.1 (Control-Grid) Voltage	−7.0	−7.5	volts
Peak AF Grid-No.1 Voltage	7.0	7.5	volts
Zero-Signal Plate Current	7.0	7.5	ma
Maximum-Signal Plate Current	7.3	7.8	ma
Zero-Signal Grid-No.2 Current	1.6	1.6	ma
Maximum-Signal Grid-No.2 Current	3.5	3.5	ma
Plate Resistance (Approx.)	110000	115000	ohms
Transconductance	1500	1550	µmhos
Load Resistance	9000	8000	ohms
Total Harmonic Distortion	10	10	per cent
Maximum-Signal Power Output	200	240	mw

1C6

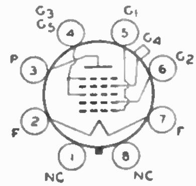
PENTAGRID CONVERTER



Glass type used in battery-operated receivers. Similar electrically to type 1C7-G except for interelectrode capacitances. Outline 34, OUTLINES SECTION. Tube requires six-contact socket. Filament volts (dc), 2.0; amperes, 0.12. For general discussion of pentagrid types, refer to Frequency Conversion in ELECTRON TUBE APPLICATIONS SECTION. This type is used principally for renewal purposes.

1C7-G

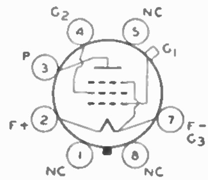
PENTAGRID CONVERTER



Glass octal type used in battery-operated receivers. Outline 33, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.12. Typical operation as converter: plate volts, 180 *max;* grids-No.3-and-No.5 (screen) volts, 67.5 *max;* grid-No.2 (anode grid) supply volts, 180 (applied through 20000-ohm dropping resistor bypassed by 0.01-μf capacitor); grid-No.4 (control-grid) volts, −3; grid-No.1 (oscillator-grid) resistor, 50000 ohms; plate ma., 1.5; grids-No.3-and-No.5 ma., 2; grid-No.2 ma., 4; grid-No.1 ma., 0.2. This type is used principally for renewal purposes.

1D5-GP

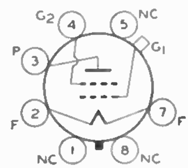
REMOTE-CUTOFF PENTODE



Glass octal type used in battery-operated receivers as rf or if amplifier. Outline 33, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.06. Typical operation as class A_1 amplifier: plate volts, 180 *max;* grid-No.2 (screen) volts, 67.5 *max;* grid-No.1 volts, −3 *min;* plate ma., 2.3; grid-No.2 ma., 0.8; plate resistance (approx.), 1.0 megohm; transconductance, 750 μmhos; transconductance at bias of −15 volts, 15 μmhos. This type is used principally for renewal purposes.

1D5-GT

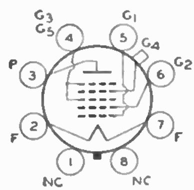
REMOTE-CUTOFF TETRODE



Glass octal type used in battery-operated receivers as rf or if amplifier. Outline 33, OUTLINES SECTION. Filament volts (dc), 2.0; amperes, 0.06. This is a DISCONTINUED type listed for reference only. It can be replaced by type 1D5-GP.

1D7-G

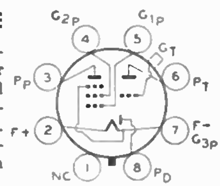
PENTAGRID CONVERTER



Glass octal type used in battery-operated receivers. Outline 33, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.06. Typical operation as converter: plate volts, grids-No.3-and-No.5 volts, grid-No.2 supply volts, grid-No.4 volts, and grid-No.1 resistor are same as for type 1C7-G; plate ma., 1.3; grids-No.3-and-No.5 ma., 2.4; grid-No.2 ma., 2.3; grid-No.1 ma., 0.2. This type is used principally for renewal purposes.

1D8-GT

DIODE—TRIODE—POWER PENTODE



Glass octal type used in compact battery-operated receivers. Diode unit is used as detector or avc tube, triode as first audio amplifier, and pentode as power output tube. Outline 20, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.1. Maximum plate volts of triode as well as maximum plate and grid-No.2 volts of pentode, 110.

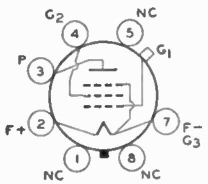
CLASS A_1 AMPLIFIER

Typical Operation (Pentode Unit):

Plate Voltage	45	67.5	90	volts
Grid-No.2 (Screen) Voltage	45	67.5	90	volts
Grid-No.1 (Control-Grid) Voltage	-4.5	-6	-9	volts
Plate Current	1.6	3.8	5	ma
Grid-No.2 Current	0.3	0.8	1.0	ma
Transconductance	650	875	925	µmhos
Load Resistance	20000	16000	12000	ohms
Total Harmonic Distortion	10	10	10	per cent
Power Output	35	100	200	mw

Typical Operation (Triode Unit):

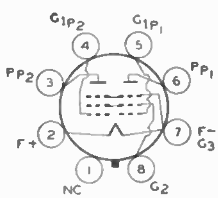
Plate Voltage	45	67.5	90	volts
Grid Voltage	0	0	0	volts
Amplification Factor	25	25	25	
Plate Resistance (Approx.)	77000	55500	43500	ohms
Transconductance	325	450	575	µmhos
Plate Current	0.3	0.6	1.1	ma



1E5-GP

SHARP-CUTOFF PENTODE

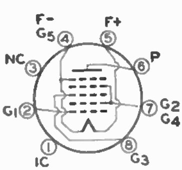
Glass octal type used as rf amplifier or detector in battery-operated receivers. Outline 33, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.06. Typical operation as class A_1 amplifier: plate volts, 180 *max;* grid-No.2 (screen) volts, 67.5 *max;* grid-No.1 volts, -3; plate ma., 1.7; grid-No.2 ma., 0.6; plate resistance, 1.5 megohms; transconductance, 650 µmhos; grid volts for plate-current cutoff (approx.), -8. This type is used principally for renewal purposes.



1E7-GT

TWIN POWER PENTODE

Glass octal type used in push-pull output stage of battery-operated receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.24. Typical operation as push-pull class A_1 amplifier: plate and grid-No.2 volts, 135 *max;* grid-No.1 volts, -7.5; plate ma., 10.5; grid-No.2 ma., 3.5; output watts, 0.575. The two units are used in the same manner as two separate tubes in conventional push-pull audio-frequency amplifier circuits. This type is used principally for renewal purposes.



1E8

PENTAGRID CONVERTER

Subminiature type used in small, compact, battery-operated receivers for the standard AM broadcast band. The 1E8 and the other RCA subminiature types 1AC5, 1AD5, and 1T6 comprise a complete tube complement for lightweight portable radio receivers having extremely low battery drain. Outline 8, OUTLINES SECTION. Tube requires subminiature eight-contact socket and may be mounted in any position. For general discussion of pentagrid types, see Frequency Conversion in ELECTRON TUBE APPLICATIONS SECTION. For installation and application considerations, refer to type 1AC5.

FILAMENT VOLTAGE (DC)	1.25	volts
FILAMENT CURRENT	0.04	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.3 to All Other Electrodes (RF Input)	6.0	μμf
Plate to All Other Electrodes (Mixer Input)	5.0	μμf
Grid No.1 to All Other Electrodes (Oscillator Input)	2.4	μμf
Grid No.3 to Plate	0.4 *max*	μμf
Grid No.3 to Grid No.1	0.2 *max*	μμf

CONVERTER SERVICE

Maximum Ratings:

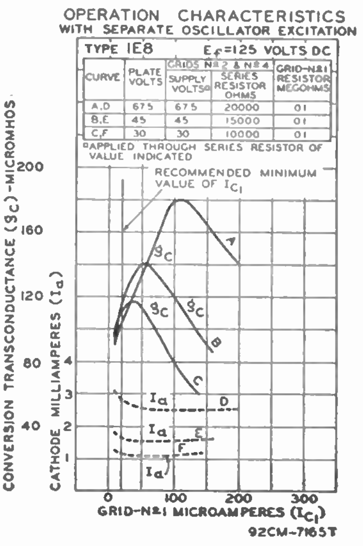
PLATE VOLTAGE	67.5 *max*	volts
GRIDS-NO.2 AND NO.4 (SCREEN) VOLTAGE	45 *max*	volts
GRIDS-NO.2 AND NO.4 SUPPLY VOLTAGE	67.5 *max*	volts
TOTAL CATHODE CURRENT	4.0 *max*	ma

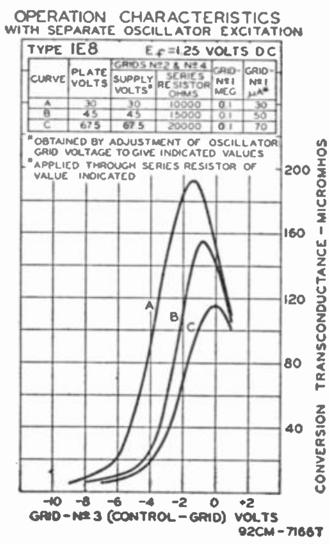
Characteristics (Separate Excitation): #

Plate Voltage	30	45	67.5	volts
Grids-No.2 and No.4 Supply Voltage	30	45	67.5	volts
Grids-No.2 and No.4 Resistor	10000	15000	20000	ohms
Grid-No.3 (Control-Grid) Voltage	0	0	0	volts
Grid-No.1 (Oscillator-Grid) Resistor	0.1	0.1	0.1	megohm
Plate Resistance (Approx.)	0.3	0.4	0.4	megohm
Conversion Transconductance	115	140	150	μmhos
Grid-No.3 Voltage for Conversion Transconductance of 5 μmhos (Approx.)	−7	−8	−9	volts
Plate Current	0.3	0.6	1.0	ma
Grids-No.2 and No.4 Current	0.8	1.1	1.5	ma
Grid-No.1 Current	30	50	70	μa
Total Cathode Current	1.1	1.7	2.5	ma

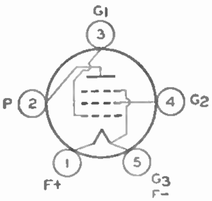
NOTE: The transconductance between grid No.1 and grids No.2 and No.4 connected to plate (not oscillating) is approximately 730 μmhos under the following conditions: signal applied to grid No.1 at zero bias; grids No.2 and No.4 and plate at 30 volts; and grid-No.3 grounded. Under the same conditions, the total cathode current is 3 milliamperes and the amplification factor is 3.9.

The characteristics shown under separate excitation approximate those obtained in a self-excited oscillator operating with zero bias.





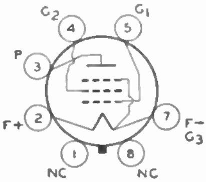
1F4



POWER PENTODE

Glass type used in output stage of battery-operated receivers. Outline 36, OUTLINES SECTION. Tube requires five-contact socket. Filament volts (dc), 2.0; amperes, 0.12. Type 1F4 is similar electrically to type 1F5-G. This type is used principally for renewal purposes.

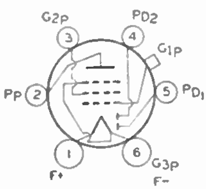
1F5-G



POWER PENTODE

Glass octal type used in output stage of battery-operated receivers. Outline 35, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.12. Typical operation as class A_1 amplifier: plate and grid-No.2 (screen) volts, 135 (180 *max*); grid-No.1 volts, –4.5; plate ma., 8; grid-No.2 ma., 2.4; cathode resistor, 432 ohms; output watts, 0.31. This type is used principally for renewal purposes.

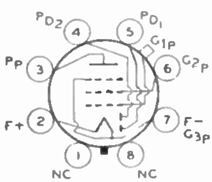
1F6



TWIN DIODE— SHARP-CUTOFF PENTODE

Glass type used as combined detector, amplifier, and avc tube in battery-operated receivers. Outline 34, OUTLINES SECTION. Tube requires six-contact socket. Filament volts (dc), 2.0; amperes, 0.06. This type is similar electrically to type 1F7-G, except for interelectrode capacitances. Typical operation of pentode unit as class A_1 amplifier: plate volts, 180 *max;* grid-No.2 (screen) volts, 67.5 *max;* grid-No.1 volts, –1.5; plate ma., 2.2; grid-No.2 ma., 0.7. This type is used principally for renewal purposes.

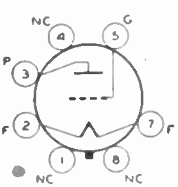
1F7-G



TWIN DIODE— SHARP-CUTOFF PENTODE

Glass octal type used as combined detector, amplifier, and avc tube in battery-operated receivers. Outline 33, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.06. Similar electrically to type 1F6 except for interelectrode capacitances. This type is used principally for renewal purposes.

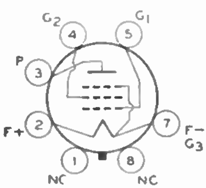
1G4-GT



MEDIUM-MU TRIODE

Glass octal type used in battery-operated receivers as detector or voltage amplifier. Outline 22, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation and characteristics as class A_1 amplifier: plate volts, 90 (110 *max*); grid volts, –6; plate ma., 2.3; plate resistance, 10700 ohms; amplification factor, 8.8; transconductance, 825 μmhos. This type has been used as a driver for type 1G6-GT.

1G5-G

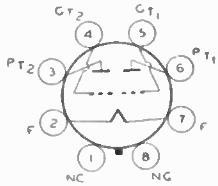


POWER PENTODE

Glass octal type used in output stage of battery-operated receivers. Outline 35, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.12. Typical operation as class A_1 amplifier: plate and grid-No.2 (screen) volts, 135 *max;* grid-No.1 volts, –13.5; plate ma., 9.7; output watts, 0.55. This type is used principally for renewal purposes.

1G6-GT

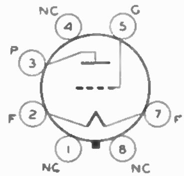
HIGH-MU TWIN POWER TRIODE



Glass octal type used in output stage of battery-operated receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.1. Typical operation as class B amplifier: plate volts, 90 (110 *max*); dc grid volts, 0; peak af grid-to-grid volts, 48; effective grid-circuit impedance per unit, 2530 ohms; plate ma. (zero signal), 2; plate ma. (maximum signal), 11; peak grid ma. per unit, 6; output watts (approx.), 0.35.

1H4-G

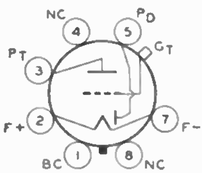
MEDIUM-MU TRIODE



Glass octal type used as detector or voltage amplifier in battery-operated receivers. Outline 31, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.06. Typical operation as class A_1 amplifier: plate volts, 180 *max;* grid volts, −13.5; amplification factor, 9.3; plate resistance, 10300 ohms; transconductance, 900 μmhos; plate ma., 3.1. For grid-bias detection, plate volts up to 180 *max* may be used and grid bias adjusted so that zero-signal plate ma. is about 0.2. This type is used principally for renewal purposes.

1H5-GT

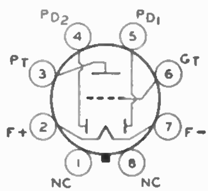
DIODE—HIGH-MU TRIODE



Glass octal type used as combined detector and amplifier in battery-operated receivers. Outline 23, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.05. Characteristics of triode unit as class A_1 amplifier: plate volts, 90 (110 *max*); grid volts, 0; plate ma., 0.15; plate resistance, 240000 ohms; amplification factor, 65; transconductance, 275 μmhos. Diode is located at negative end of filament.

1H6-G

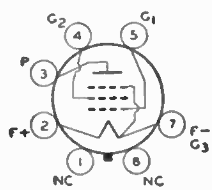
TWIN DIODE—MEDIUM-MU TRIODE



Glass octal type used as combined detector, amplifier, and avc tube in battery-operated receivers. Outline 31, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.06. Type 1H6-G is similar electrically to type 1B5/25S. This type is used principally for renewal purposes.

1J5-G

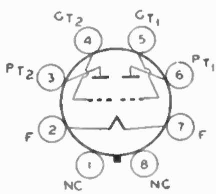
POWER PENTODE



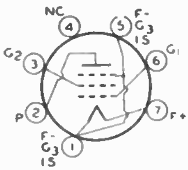
Glass octal type used in output stage of battery-operated receivers. Outline 35, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 2.0; amperes, 0.12. Typical operation as class A_1 amplifier: plate and grid-No.2 (screen) volts, 135 *max;* grid-No.1 volts, −16.5; plate ma., 7.0; grid-No.2 ma., 2.0; plate resistance, 105000 ohms; load resistance, 13500 ohms; output watts, 0.45. This is a DISCONTINUED type listed for reference only.

1J6-G
1J6-GT

HIGH-MU TWIN POWER TRIODE



Glass octal types used in output stage of battery-operated receivers. Type 1J6-G, Outline 31; type 1J6-GT, Outline 26, OUTLINES SECTION. Tubes require octal socket. Filament volts (dc), 2.0; amperes, 0.24. Typical operation as class B power amplifier: plate volts, 135 *max;* peak plate ma. per plate, 50 *max;* grid volts, 0; zero-signal plate ma. per plate, 5; effective plate-to-plate load resistance, 10000 ohms; average input watts, 0.17; output watts, 2.1. Type 1J6-G is a DISCONTINUED type listed for reference only; type 1J6-GT is used principally for renewal purposes.



SHARP-CUTOFF PENTODE

1L4

Miniature type used as rf or if amplifier in portable, battery-operated receivers particularly those not utilizing avc. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. Internal shield eliminates need for external bulb shield, but shielding the socket is essential if minimum grid-No.1-to-plate capacitance is required. For typical operation as a resistance-coupled amplifier, refer to Chart 1, RESISTANCE-COUPLED AMPLIFIER SECTION. For filament considerations, refer to type 1U4.

FILAMENT VOLTAGE (DC)	1.4	volts
FILAMENT CURRENT	0.05	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.01 *max*	μμf
Input	3.6	μμf
Output	7.5	μμf

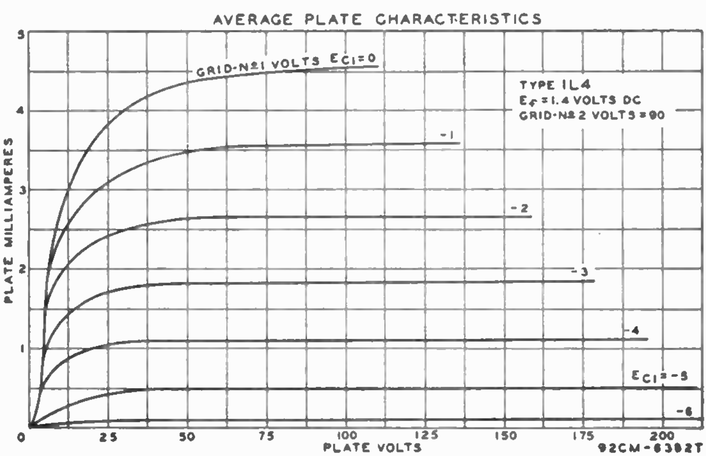
CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	110 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	90 *max*	volts
GRID-NO.2 SUPPLY VOLTAGE	110 *max*	volts
GRID-NO.1 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	volts
TOTAL CATHODE CURRENT	6.5 *max*	ma

Typical Operation:

Plate Voltage	90	90	volts
Grid-No.2 Voltage	67.5	90	volts
Grid-No.1 Voltage	0	0	volts
Plate Resistance	0.6	0.26	megohm
Transconductance	925	1025	μmhos
Grid-No. 1 Bias for plate current of 10 μa	−6	−10	volts
Plate Current	2.9	4.5	ma
Grid-No. 2 Current	1.2	2.0	ma



PENTAGRID CONVERTER

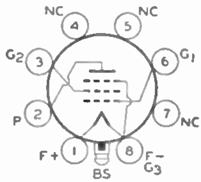
1L6

For technical data, see page 305.

1LA4

POWER PENTODE

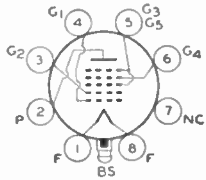
Glass lock-in type used in output stage of battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. For electrical characteristics and typical operation, refer to glass-octal type 1A5-GT.



1LA6

PENTAGRID CONVERTER

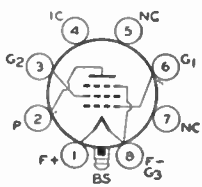
Glass lock-in type used in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation as converter is the same as for type 1A7-GT except that the maximum grid-No.2 volts is 65, the maximum total cathode ma. is 4.0, the plate resistance is 0.75 megohm, and the conversion transconductance for a grid-No.4 (control-grid) bias of −3 volts is 10 μmhos.



1LB4

POWER PENTODE

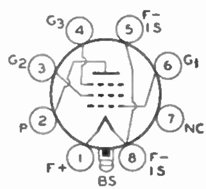
Glass lock-in type used in output stage of battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. For electrical characteristics, refer to pentode unit of glass-octal type 1D8-GT.



1LC5

SHARP-CUTOFF PENTODE

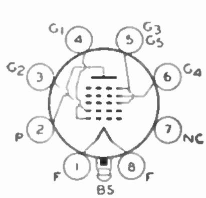
Glass lock-in type used as rf or if amplifier in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation as class A_1 amplifier: plate volts, 90 (110 *max*); grid-No.2 (screen) volts, 45 *max*; grid-No.1 volts, 0; plate resistance (approx.), greater than 1 megohm; transconductance, 775 μmhos; plate ma., 1.15; grid-No.2 ma., 0.3.



1LC6

PENTAGRID CONVERTER

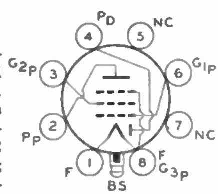
Glass lock-in type used in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation as converter: plate volts, 90 (110 *max*); grids-No.3-and-No.5 volts, 35 (45 *max*); grid-No.2 volts, 45; grid-No.1 volts, 0; plate resistance, 0.65 megohm; plate ma., 0.75; grids-No.3-and-No.5 ma., 0.70; grid-No.2 ma., 1.4; total cathode ma., 2.9; conversion transconductance (zero bias), 275 μmhos.

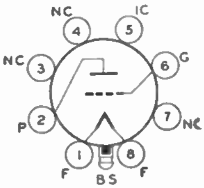


1LD5

DIODE—SHARP-CUTOFF PENTODE

Glass lock-in type used as combined detector and af voltage amplifier in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Characteristics of pentode unit: plate volts, 90 (110 *max*); grid-No.2 volts, 45; grid-No.1 volts, 0; plate ma., 0.6; grid-No.2 ma., 0.1; plate resistance, 0.75 megohm; transconductance, 575 μmhos.

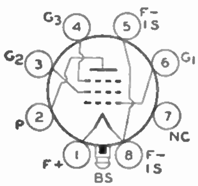




1LE3

MEDIUM-MU TRIODE

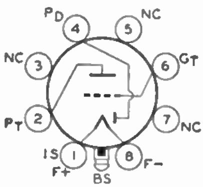
Glass lock-in type used as detector or voltage amplifier in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation as class A_1 amplifier: plate volts, 90 (110 *max*); grid volts, −3; plate ma., 1.4; plate resistance, 19000 ohms; transconductance, 760 μmhos; amplification factor, 14.5.



1LG5

REMOTE-CUTOFF PENTODE

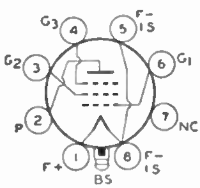
Lock-in type used as rf or if amplifier in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation and maximum ratings as class A_1 amplifier: plate volts, 90 (110 *max*); grid-No.2 volts, 45 (110 *max*); grid-No.1 volts, 0; plate resistance (approx.), greater than 1 megohm; transconductance, 800 μmhos; plate ma., 1.7; grid-No.2 ma., 0.4; grid-No.1 voltage for transconductance of 10 μmhos, −10 volts.



1LH4

DIODE—HIGH-MU TRIODE

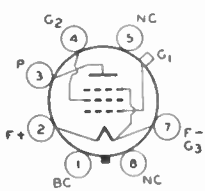
Glass lock-in type used as combined detector and amplifier in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. For electrical characteristics, refer to glass-octal type 1H5-GT.



1LN5

SHARP-CUTOFF PENTODE

Glass lock-in type used as rf or if amplifier in battery-operated receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation as class A_1 amplifier: plate and grid-No.2 (screen) volts, 90 (110 *max*); grid-No.1 volts, 0; plate ma., 1.6; grid-No.2 ma., 0.35; plate resistance (approx.), 1.1 megohms; transconductance, 800 μmhos.



1N5-GT

SHARP-CUTOFF PENTODE

Glass octal type used as rf or if amplifier in battery-operated receivers. Outline 23, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. When used in avc circuits, the 1N5-GT should be only partially controlled to avoid excessive reduction in receiver sensitivity with large signal input.

Filament Voltage (dc)	1.4	volts
Filament Current	0.05	ampere
Direct Interelectrode Capacitances:*		
Grid No.1 to Plate	0.007 *max*	μμf
Input	8	μμf
Output	10	μμf

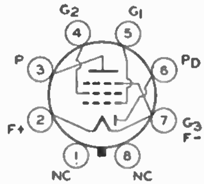
* With external shield connected to negative filament terminal.

Typical Operation: CLASS A_1 AMPLIFIER

Plate Voltage (110 volts *max*,	90	volts
Grid-No.2 (Screen) Voltage (1 .0 volts *max*)	90	volts
Grid-No.1 Voltage	0	volts
Plate Resistance (Approx.)	1.5	megohms
Transconductance	750	μmhos
Grid-No.1 Bias (Approx.) for transconductance of 5 μmhos	–4	volts
Plate Current	1.2	ma
Grid-No.2 Current	0.3	ma

1N6-G

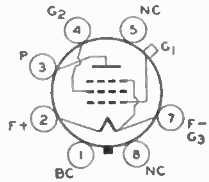
DIODE—POWER PENTODE



Glass octal type used as combined detector and power output tube in battery-operated receivers. Filament volts (dc), 1.4; amperes, 0.05. Typical operation of pentode unit as class A_1 amplifier: plate and grid-No.2 (screen) volts, 90 (110 *max*); grid-No.1 volts, –4.5; plate ma., 3.1; grid-No.2 ma. (zero-signal), 0.6; plate resistance (approx.), 0.3 megohm; transconductance, 800 μmhos; load resistance, 25000 ohms; output watts, 0.1. This is a DISCONTINUED type listed for reference only.

1P5-GT

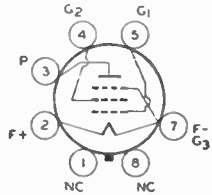
REMOTE-CUTOFF PENTODE



Glass octal type used as rf or if amplifier in battery-operated receivers. Outline 23, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.05. Typical operation as class A_1 amplifier: plate volts, 90 (110 *max*); grid-No.2 (screen) volts, 90 (110 *max*); grid-No.1 volts, 0; plate resistance (approx.), 0.8 megohm; transconductance, 750 μmhos; transconductance (approx.) with –12 volts on grid-No.1, 10 μmhos; plate ma., 2.3; grid-No.2 ma., 0.7.

1Q5-GT

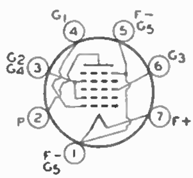
BEAM POWER AMPLIFIER



Glass octal type used in the output stage of battery-operated receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.1. For electrical characteristics and ratings, refer to type 3Q5-GT with parallel filament arrangement. This type is used principally for renewal purposes.

1R5

PENTAGRID CONVERTER



Miniature type used in lightweight, portable, compact, battery-operated receivers. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For general discussion of pentagrid types, see **Frequency Conversion** in ELECTRON TUBE APPLICATIONS SECTION. For filament considerations, refer to type 1U4.

FILAMENT VOLTAGE (DC)	1.4	volts
FILAMENT CURRENT	0.05	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.3 to All Other Electrodes (RF Input)	7.0	μμf
Plate to All Other Electrodes (Mixer Output)	7.5	μμf
Grid No.1 to All Other Electrodes (Osc. Input)	3.8	μμf
Grid No.3 to Plate	0.4 *max*	μμf
Grid No.3 to Grid No.1	0.2 *max*	μμf
Grid No.1 to Plate	0.1 *max*	μμf

CONVERTER SERVICE

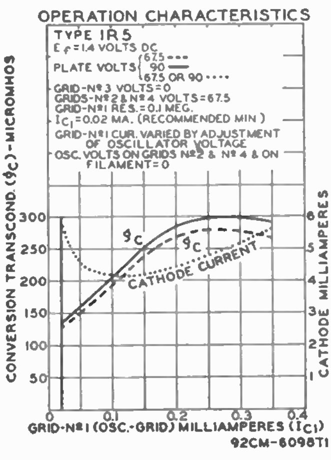
Maximum Ratings:

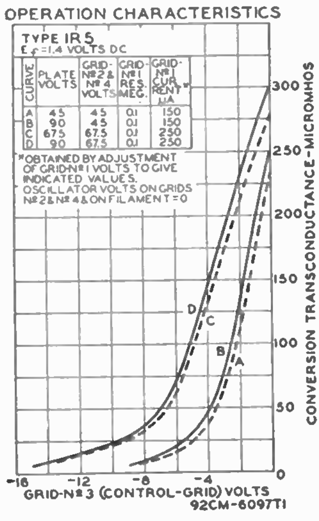
PLATE VOLTAGE	90 *max*	volts
GRIDS-NO.2-AND-NO.4 (SCREEN) VOLTAGE	67.5 *max*	volts
GRIDS-NO.2-AND-NO.4 SUPPLY VOLTAGE	90 *max*	volts
GRID-NO.3 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	volts
TOTAL ZERO-SIGNAL CATHODE CURRENT	5.5 *max*	ma

Typical Operation:

Plate Voltage	45	67.5	90	90	volts
Grids-No.2-and-No.4 Voltage	45	67.5	45	67.5	volts
Grid-No.3 Voltage	0	0	0	0	volts
Grid-No.1 Resistor	0.1	0.1	0.1	0.1	megohm
Plate Resistance (Approx.)	0.6	0.5	0.8	0.6	megohm
Conversion Transconductance	235	280	250	300	μmhos
Grid-No.3 Bias for conversion transconductance of approx. 5 μmhos	−9	−14	−9	−14	volts
Plate Current	0.7	1.4	0.8	1.6	ma
Grids-No.2-and-No.4 Current	1.9	3.2	1.9	3.2	ma
Grid-No.1 Current	0.15	0.25	0.15	0.25	ma
Total Cathode Current	2.75	5	2.75	5	ma

NOTE: The transconductance between grid No.1 and grids No.2 and No.4 tied to plate (not oscillating) is approximately 1400 μmhos under the following conditions: grids No.1 and No.3 at 0 volts; grids No.2 and No.4 and plate at 67.5 volts.



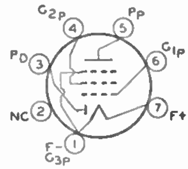


POWER PENTODE

1S4

Miniature type used in output stage of lightweight, compact, portable, battery-operated equipment. Types 1S4 and 3S4 are identical except for filament arrangement. Outline 12, OUTLINES SECTION. Type 1S4 requires miniature seven-contact socket and may be mounted in any position. For ratings, typical operation, and curves, refer to type 3S4 with parallel filament arrangement. For filament considerations, refer to type 1U4 and ELECTRON TUBE INSTALLATION SECTION. Filament volts (dc), 1.4; amperes, 0.1. This type is used principally for renewal purposes.

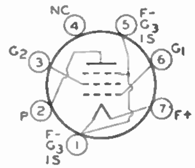
1S5



DIODE— SHARP-CUTOFF PENTODE

Miniature type used in lightweight, compact, portable, battery-operated receivers as combined detector and af voltage amplifier. Outline 12, OUTLINES SECTION. Filament volts (dc), 1.4; amperes, 0.05. Tube requires miniature seven-contact socket and may be mounted in any position. For electrical characteristics, curves, and application, refer to type 1U5.

1T4



REMOTE-CUTOFF PENTODE

Miniature type used in lightweight, compact, portable, battery-operated receivers as rf or if amplifier. Because of internal shielding feature, an external bulb shield is not needed, but socket shielding is essential if minimum grid-No.1-to-plate capacitance is to be obtained. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For curve of average plate characteristics, see next page. For filament considerations, refer to type 1U4.

FILAMENT VOLTAGE (DC)	1.4	volts
FILAMENT CURRENT	0.05	ampere
DIRECT INTERELECTRODE CAPACITANCES:*		
Grid No.1 to Plate	0.01 *max*	μμf
Input	3.6	μμf
Output	7.5	μμf

* With close-fitting shield connected to negative filament terminal.

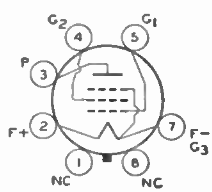
Maximum Ratings: CLASS A₁ AMPLIFIER

PLATE VOLTAGE	90 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	67.5 *max*	volts
GRID-NO.2 SUPPLY VOLTAGE	90 *max*	volts
GRID-NO.1 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	volts
TOTAL CATHODE CURRENT	5.5 *max*	ma

Typical Operation:

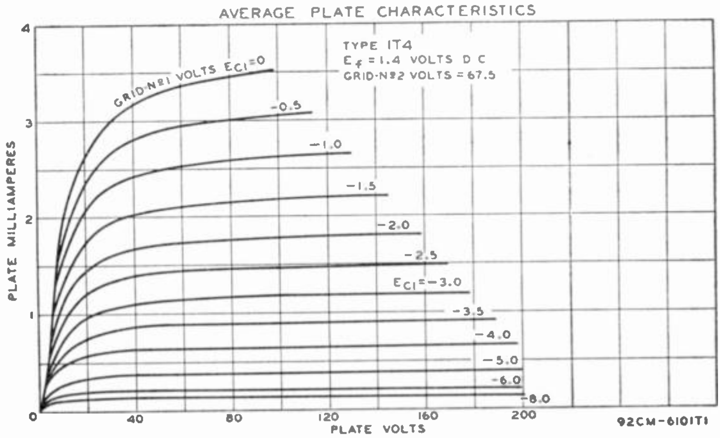
Plate Voltage	45	67.5	90	90	volts
Grid-No.2 Voltage	45	67.5	45	67.5	volts
Grid-No.1 Voltage	0	0	0	0	volts
Plate Resistance (Approx.)	0.35	0.25	0.8	0.5	megohm
Transconductance	700	875	750	900	μmhos
Grid-No.1 Bias for transconductance of 10 μmhos	−10	−16	−10	−16	volts
Plate Current	1.7	3.4	1.8	3.5	ma
Grid-No.2 Current	0.7	1.5	0.65	1.4	ma

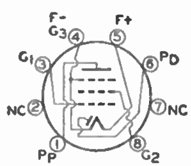
1T5-GT



BEAM POWER AMPLIFIER

Glass octal type used in output stage of battery-operated receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket. Filament volts (dc), 1.4; amperes, 0.05. For filament considerations, refer to type 1U4. Typical operation as class A_1 amplifier with fixed bias: plate and grid-No.2 (screen) volts, 90 (110 *max*); grid-No.1 volts, −6; peak af grid-No.1 volts, 6; plate ma. (maximum or zero-signal), 6.5; grid-No.2 ma.(zero-signal), 0.8; grid-No.2 ma. (maximum signal), 1.5; plate resistance, 0.25 megohm; transconductance, 1150 μmhos; load resistance, 14000 ohms; total harmonic distortion, 7.5 per cent; output watts, 0.17.





DIODE—SHARP-CUTOFF PENTODE

1T6

Subminiature type used as combined detector and audio amplifier in small, compact, battery-operated receivers for the standard AM broadcast band. The 1T6 and the other RCA subminiature types 1AC5, 1AD5, and 1E8 comprise a complete tube complement for lightweight portable radio receivers having extremely low battery drain. Outline 8, OUTLINES SECTION. Tube requires subminiature eight-contact socket and may be mounted in any position. For installation and application considerations, refer to type 1AC5.

Filament Voltage (dc)	1.25	volts
Filament Current	0.04	ampere

PENTODE UNIT AS CLASS A_1 AMPLIFIER

Maximum Ratings:

Plate Voltage	67.5 *max*	volts
Grid-No.2 (screen) Voltage	67.5 *max*	volts
Total Cathode Current	2.0 *max*	ma

Typical Operation:

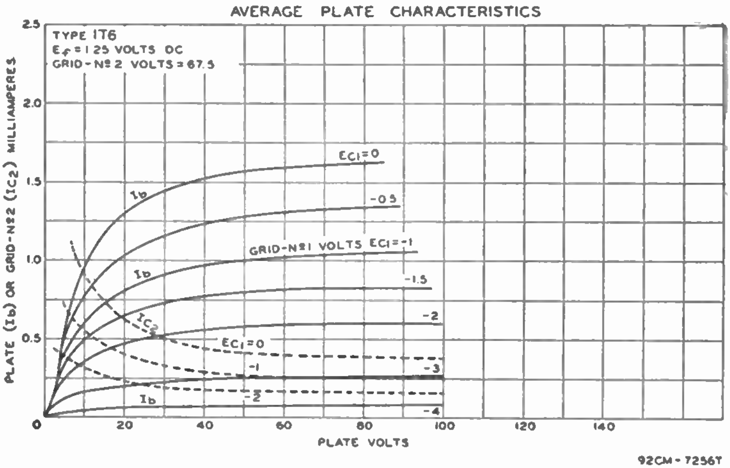
Plate Voltage	30	45	67.5	volts
Grid-No.2 (Screen) Voltage	30	45	67.5	volts
Grid-No.1 (Control-Grid) Voltage	0	0	0	volts
Plate Resistance (Approx.)	0.5	0.5	0.4	megohm
Transconductance	330	475	600	μmhos
Plate Current	0.33	0.75	1.6	ma
Grid-No.2 Current	0.10	0.21	0.4	ma

DIODE UNIT

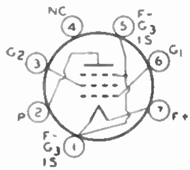
Maximum Rating:

Plate Current	0.25 *max*	ma

Diode unit is located at negative end of filament and is independent of the pentode unit except for the common filament.



SHARP-CUTOFF PENTODE



1U4

Miniature type used as rf or if amplifier in stages not controlled by avc in lightweight, compact, portable, battery-operated equipment. Because the screen can be operated at the same voltage as the plate, a voltage-dropping resistor is not needed. For typical operation as a resistance-coupled amplifier, refer to Chart 3, RESISTANCE-COUPLED AMPLIFIER SECTION.

FILAMENT VOLTAGE (DC)	1.4	volts
FILAMENT CURRENT	0.05	ampere
DIRECT INTERELECTRODE CAPACITANCES:*		
Grid No.1 to Plate	0.01 *max*	μμf
Input	3.6	μμf
Output	7.5	μμf

* External shield connected to negative filament terminal.

CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	110 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	110 *max*	volts
GRID-NO.1 (CONTROL-GRID) VOLTAGE:		
Negative bias value	30 *max*	volts
Positive bias value	0 *max*	volts
TOTAL CATHODE CURRENT	6 *max*	ma

Typical Operation:

Plate Voltage	90	volts
Grid-No.2 Voltage	90	volts
Grid-No.1 Voltage	0	volts
Plate Resistance (Approx.)	1.0	megohm
Transconductance	900	μmhos
Grid-No.1 Bias for transconductance of 10 μmhos	-4	volts
Plate Current	1.6	ma
Grid-No.2 Current	0.5	ma

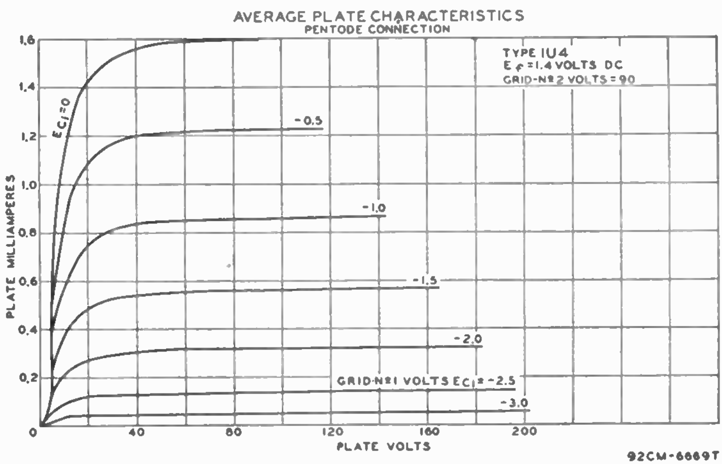
INSTALLATION AND APPLICATION

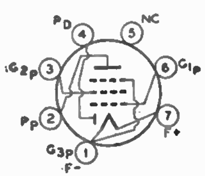
Type 1U4 requires a miniature seven-contact socket and may be mounted in any position. Outline 12, OUTLINES SECTION.

The filament power supply may be obtained from dry-cell batteries, from storage batteries, or from a power line. With dry-cell battery supply, the filament may be connected either directly across a battery rated at a terminal potential of 1.5 volts, or in series with the filaments of similar tubes across a power supply consisting of dry cells in series. In either case, the voltage across the filament should not exceed 1.6 volts.

With power-line or storage-battery supply, the filament may be operated in series with the filament of other tubes of the same filament-current rating. For such operation, design adjustments should be made so that, with tubes of rated characteristics, operating with all electrode voltages applied and on a normal line voltage of 117 volts or on a normal storage-battery voltage of 2.0 volts per cell (without a charger) or 2.2 volts per cell (with a charger), the voltage drop across the filament will be maintained within a range of 1.25 to 1.4 volts with a center of 1.3 volts.

In order to meet the recommended conditions for operating filaments in series from dry-battery, storage-battery, or power-line sources, it may be necessary to use shunting resistors across the individual 1.4-volt sections of filament. Refer to ELECTRON TUBE INSTALLATION SECTION for additional filament considerations.





DIODE—SHARP-CUTOFF PENTODE

1U5

Miniature type used in lightweight, compact, portable, battery-operated receivers as combined detector and af voltage amplifier. The 1U5 is similar to the 1S5 but utilizes an improved structure which greatly reduces any tendency toward microphonic effects. In addition, the diode unit is effectively shielded from the pentode unit to prevent "play-through." Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For typical operation as a resistance-coupled amplifier, refer to Chart 2, RESISTANCE-COUPLED AMPLIFIER SECTION. For filament consideration, refer to type 1U4.

FILAMENT VOLTAGE (DC)	1.4	volts
FILAMENT CURRENT	0.05	ampere

PENTODE UNIT AS CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	90 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	90 *max*	volts
GRID-NO.1 (CONTROL-GRID) VOLTAGE:		
Negative bias value	50 *max*	volts
Positive bias value	0 *max*	volts
TOTAL CATHODE CURRENT	3 *max*	ma

Characteristics:

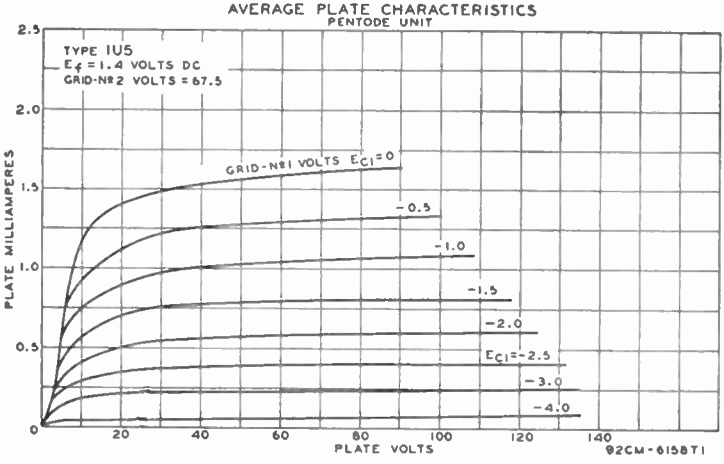
Plate Voltage	67.5	volts
Grid-No.2 Voltage	67.5	volts
Grid-No.1 Voltage	0	volts
Plate Resistance	0.6	megohm
Transconductance	625	μmhos
Grid-No.1 Bias for plate current of 10 μa	−5	volts
Plate Current	1.6	ma
Grid-No.2 Current	0.4	ma

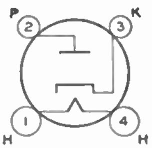
DIODE UNIT

Maximum Rating:

PLATE CURRENT	0.25 *max*	ma

Diode unit is located at negative end of filament and is independent of the pentode except for the common filament.

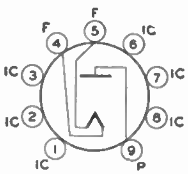




HALF-WAVE VACUUM RECTIFIER

1-v

Glass type used in ac/dc or automobile receivers. Outline 32, OUTLINES SECTION. Tube requires four-contact socket. For heater considerations, refer to type 6AT6. Heater volts (ac/dc), 6.3; amperes, 0.3. Maximum ratings as half-wave rectifier: peak inverse plate volts, 1000; peak plate ma., 270; peak heater-cathode volts, 500; dc output ma., 45. This type is used principally for renewal purposes.



HALF-WAVE VACUUM RECTIFIER

1V2

Miniature type used in high-voltage, low-current applications such as the rectifier in high-voltage, pulse-operated voltage-doubling power supplies for kinescopes. The very low power required by the filament permits the use of a rectifier transformer having small size and light weight.

Filament Voltage (ac)	0.625	volt
Filament Current	0.3	ampere
Direct Interelectrode Capacitance (No external shield):		
Plate to Filament (Approx.)	0.8	μμf

HALF-WAVE RECTIFIER

Pulsed Rectifier Service

Maximum Ratings:

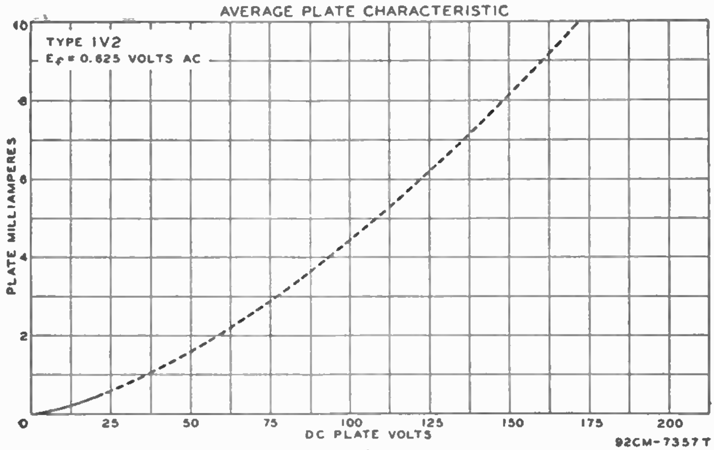
Peak Inverse Plate Voltage	7500 *max*	volts
Peak Plate Current	10 *max*	ma
Average Plate Current	0.5 *max*	ma

INSTALLATION AND APPLICATION

Type 1V2 requires a noval nine-contact socket and may be mounted in any position. The socket should be made of material having low leakage and should have adequate insulation between its filament and plate terminals to withstand the maximum peak inverse plate voltage. To provide the required insulation in noval nine-contact sockets designed with a cylindrical center shield, it is necessary to remove the center shield. In addition, it is recommended that the socket clips for pins 1, 6, and 7 be removed to reduce the possibility of arc-over and minimize leakage. Outline 13, OUTLINES SECTION.

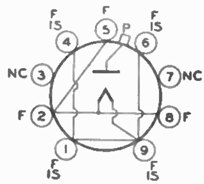
The filament is of the coated type and is designed for operation at 0.625 volt. The filament windings on the pulse transformer should be adjusted to provide the rated voltage under average line-voltage conditions. When the filament voltage is measured, it is recommended that an rms voltmeter of the thermal type be used. The meter and its leads must be insulated to withstand 15000 volts and the stray capacitances to ground should be minimized.

The high voltages at which the 1V2 is operated are very dangerous. Great care should be taken to prevent coming in contact with these high voltages. Particular care against fatal shock should be taken in measuring the filament voltage in those circuits where the filament is not grounded. Precautions must include safeguards which definitely eliminate all hazards to personnel.



1X2-A

HALF-WAVE VACUUM RECTIFIER



Miniature type used in high-voltage, low-current applications such as the rectifier in a high-voltage, rf-operated power supply, or as a rectifier of high-voltage pulses produced in television scanning systems. Outline 18, OUTLINES SECTION. Tube requires noval nine-contact socket and may be mounted in any position. Plate connection is cap at top of bulb. Pins 3 and 7 may be used as tie points for filament dropping resistor and high-voltage filter resistor, or may be connected to the filament. These pins should *not* be connected to low-potential circuits. For other filament and high-voltage considerations, refer to type 1B3-GT.

Filament Voltage (ac)	1.25	volts
Filament Current	0.2	ampere
Direct Interelectrode Capacitance (no external shield):		
Plate to Filament (Approx.)	1.0	$\mu\mu$f

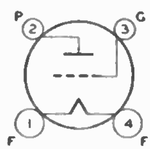
HALF-WAVE RECTIFIER

Maximum Ratings:

Peak Inverse Plate Voltage	18000 *max*	volts
Peak Plate Current	10 *max*	ma
Average Plate Current	1 *max*	ma
Frequency of Supply Voltage	300 *max*	Kc

2A3

POWER TRIODE



Glass type used in output stage of radio receivers and amplifiers. As a class A_1 power amplifier, the 2A3 is usable either singly or in push-pull combination.

Filament Voltage (ac/dc)	2.5	volts
Filament Current	2.5	amperes
Direct Interelectrode Capacitances (Approx.):		
Grid to Plate	16.5	$\mu\mu$f
Input	7.5	$\mu\mu$f
Output	5.5	$\mu\mu$f

CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
PLATE DISSIPATION	15 *max*	watts

Typical Operation:

Plate Voltage	250	volts
Grid Voltage#	-45	volts
Plate Current	60	ma
Amplification Factor	4.2	
Plate Resistance	800	ohms
Transconductance	5250	μmhos
Load Resistance	2500	ohms
Second Harmonic Distortion	5	per cent
Power Output	3.5	watts

PUSH-PULL CLASS AB_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
PLATE DISSIPATION	15 *max*	watts

Typical Operation (Values Are For Two Tubes):	*Fixed Bias*	*Cathode Bias*	
Plate Voltage	300	300	volts
Grid Voltage* #	-62	–	volts
Cathode-Bias Resistor	–	780	ohms
Peak AF Grid-to-Grid Voltage	124	156	volts
Zero-Signal Plate Current	80	80	ma
Maximum-Signal Plate Current	147	100	ma
Effective Load Resistance (Plate-to-plate)	3000	5000	ohms
Total Harmonic Distortion	2.5	5.0	per cent
Power Output	15	10	watts

* Grid voltage referred to mid-point of ac-operated filament.
# When a single 2A3 is operated cathode-biased, the cathode-biasing resistor value should be 750 ohms.

INSTALLATION AND APPLICATION

Type 2A3 requires a four-contact socket and may be mounted in any position. Outline 41, OUTLINES SECTION. It is especially important that this tube, like other power-handling tubes, should be adequately ventilated.

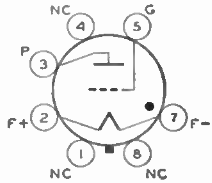
The values recommended for push-pull operation are different from the conventional ones usually given on the basis of characteristics for a single tube. The values shown for Push-Pull Class AB_1 operation cover operation with fixed bias and with cathode bias, and have been determined on the basis of no grid current flow during the most positive swing of the input signal and of cancellation of second-harmonic distortion by virtue of the push-pull circuit. The cathode resistor should preferably be shunted by a suitable filter network to minimize grid-bias variations produced by current surges in the cathode resistor.

When 2A3's are operated in push-pull, it is desirable to provide means for adjusting independently the bias on each tube. This requirement is a result of the very high transconductance of these tubes—5250 micromhos. This very high value makes the 2A3 somewhat critical as to grid-bias voltage, since a very small bias-voltage change produces a very large change in plate current. It is obvious, therefore, that the difference in plate current between two tubes may be sufficient to unbalance the system seriously. To avoid this possibility, simple methods of independent cathode-bias adjustment may be used, such as (1) input transformer with two independent secondary windings, or (2) filament transformer with two independent filament windings. With either of these methods, each tube can be biased separately so as to obtain circuit balance.

Any conventional type of **input coupling** may be used provided the resistance added to the grid circuit by this device is not too high. *Transformers or impedances are recommended.* When cathode bias is used, the dc resistance in the grid circuit should not exceed 0.5 megohm. With fixed bias, however, the dc resistance should not exceed 50000 ohms.

2A4-G

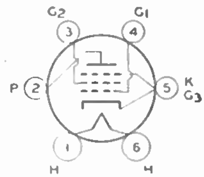
GAS TRIODE



Glass octal type used in relay-control equipment such as motor-controlled tuning mechanisms of radio receivers. It is a grid-controlled gaseous-discharge tube. Outline 31, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. Filament volts (ac/dc), 2.5; amperes, 2.5. Filament voltage should be applied for 2 seconds before start of tube conduction. Characteristics: peak inverse anode volts, 200 *max;* peak forward anode volts, 200 *max;* peak volts between any two electrodes, 250 *max;* peak anode amperes, 1.25 *max;* average anode amperes (over any 45-second period), 0.10 *max;* anode voltage drop, 15 volts. This type is used principally for renewal purposes.

2A5

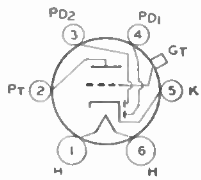
POWER PENTODE



Glass type used in output stage of ac-operated receivers. Outline 36, OUTLINES SECTION. Tube requires six-contact socket. Except for its heater rating (2.5 volts ac/dc; 1.75 amperes), the 2A5 has electrical characteristics identical with type 6F6. This type is used principally for renewal purposes.

2A6

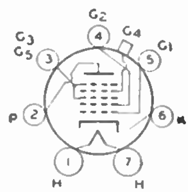
TWIN DIODE—HIGH-MU TRIODE



Glass type used in ac-operated receivers chiefly as a combined detector, amplifier, and avc tube. Outline 34, OUTLINES SECTION. Tube requires six-contact socket. Except for its heater rating (2.5 volts ac/dc; 0.8 ampere), and within its 250-volt maximum plate rating, the 2A6 has electrical characteristics identical with type 6SQ7. This type is used principally for renewal purposes.

2A7

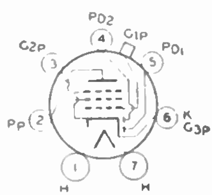
PENTAGRID CONVERTER



Glass type used in ac-operated receivers. Outline 34, OUTLINES SECTION. Tube requires small seven-contact (0.75-inch, pin-circle diameter) socket. Except for its heater rating (2.5 volts ac/dc; 0.8 ampere) and its interelectrode capacitances, the 2A7 has electrical characteristics identical with type 6A8. Complete shielding of this tube is generally necessary. This type is used principally for renewal purposes.

2B7

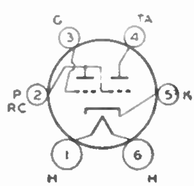
TWIN DIODE—REMOTE-CUTOFF PENTODE



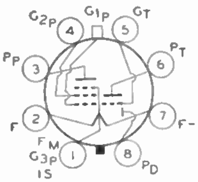
Glass type used as combined detector, avc tube, and amplifier. Outline 34, OUTLINES SECTION. Tube requires small seven-contact (0.75-inch, pin-circle diameter) socket. Except for its heater rating (2.5 volts ac/dc; 0.8 ampere) and its interelectrode capacitances, the 2B7 has electrical characteristics identical with type 6B8-G. This type is used principally for renewal purposes.

2E5

ELECTRON-RAY TUBE



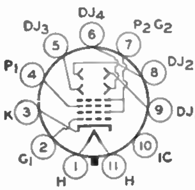
Glass type used to indicate visually by means of a fluorescent target the effects of a change in a controlling voltage. It is used as a convenient means of indicating accurate radio receiver tuning. Outline 32, OUTLINES SECTION. Tube requires six-contact socket. Except for its heater rating (2.5 volts ac/dc; 0.8 ampere), the 2E5 has electrical characteristics identical with type 6E5. This type is used principally for renewal purposes.



DIODE—TRIODE—PENTODE

3A8-GT

Glass octal type used as combined detector, af amplifier, and rf amplifier in battery-operated receivers. Filament has mid-tap so that tube may be used with either 1.4- or 2.8-volt dc filament supplies. Filament volts 1.4 (parallel), 2.8 (series); amperes 0.1 (parallel), 0.05 (series). Typical operation of triode unit as class A_1 amplifier: plate volts, 90 (110 *max*); grid volts, 0; amplification factor, 65; plate resistance, 0.2 megohm; transconductance, 325 μmhos; plate ma., 0.2. Typical operation of pentode unit as class A_1 amplifier: plate volts, 90 (110 *max*); grid-No.2 volts, 90 (110 *max*); grid-No.1 volts, 0; plate resistance, 0.8 megohm; transconductance, 750 μmhos; plate ma., 1.5; grid-No.2 ma., 0.5. This type is used principally for renewal purposes.



KINESCOPE

3KP4

Directly viewed picture tube used in compact, low-cost television receivers. Employs a white fluorescent screen having medium persistence and high efficiency. It utilizes electrostatic focus and deflection to provide a rectangular picture with rounded corners about 2½ x 1⅞ inches. Maximum diameter is 3-1/16 inches; maximum overall length is 11¾ inches. Tube requires magnal eleven-contact socket and may be mounted in any position. For installation and handling considerations, refer to ELECTRON TUBE INSTALLATION SECTION. This type is used principally for renewal purposes.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.6	ampere

Maximum Ratings:

ANODE-NO.2 AND GRID-NO.2 VOLTAGE	2500 *max*	volts
ANODE-NO.1 VOLTAGE	1000 *max*	volts
GRID-NO.1 VOLTAGE:		
Negative bias value	200 *max*	volts
Positive bias value	0 *max*	volts
Positive peak value	2 *max*	volts
PEAK VOLTAGE BETWEEN ANODE NO.2 AND ANY DEFLECTING ELECTRODE	500 *max*	volts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	125 *max*	volts
Heater positive with respect to cathode	125 *max*	volts

Typical Operation:

Anode-No.2 Voltage*	2000	volts
Anode-No.1 Voltage for Focus°	320 to 600	volts
Grid-No.1 Voltage for Visual Cutoff of Undeflected Focused Spot	-38 to -90	volts
Deflection Factors#:		
DJ1 and DJ2	100 to 136	volts dc/in
DJ3 and DJ4	76 to 104	volts dc/in

Maximum Circuit Values:

Grid-No.1 Circuit Resistance	1.5 *max*	megohms
Resistance in any Deflecting Electrode Circuit	5 *max*	megohms

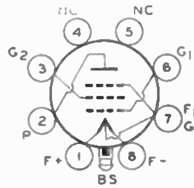
* Brilliance and definition decrease with decreasing anode-No.2 voltage.

° With the combined grid-No.1-bias voltage and video-signal voltage adjusted for a highlight brightness of 2 foot-lamberts on a 2½" x 1⅞" picture area.

Deflecting electrodes DJ1 and DJ2 are nearer the screen; deflecting electrodes DJ3 and DJ4 are nearer the base. When DJ1 is positive with respect to DJ2, the spot is deflected toward pin 4; when DJ3 is positive with respect to DJ4, the spot is deflected toward pin 1.

3LF4

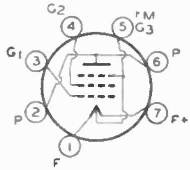
BEAM POWER AMPLIFIER



Glass lock-in type used in output stage of ac/dc/battery portable receivers. Outline 14, OUTLINES SECTION. Tube requires lock-in socket. Filament volts (dc) 1.4 (parallel), 2.8 (series); amperes 0.1 (parallel), 0.05 (series). For electrical characteristics, refer to glass-octal type 3Q5-GT.

3Q4

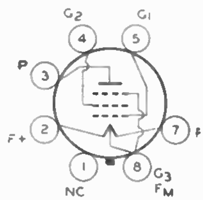
POWER PENTODE



Miniature type used in output stage of lightweight, compact, portable, battery-operated equipment. Outline 12, OUTLINES SECTION. Except for terminal connections, types 3Q4 and 3V4 are identical. Refer to type 3V4 for ratings, typical operation, curves, and installation considerations.

3Q5-GT

BEAM POWER AMPLIFIER



Glass octal type used in output stage of ac/dc/battery portable receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For series filament arrangement, filament voltage is applied between pins 2 and 7. For parallel filament arrangement, filament voltage is applied between pin 8 and pins 2 and 7 connected together. For additional filament considerations, refer to type 3V4 and ELECTRON TUBE INSTALLATION SECTION.

Filament Arrangement	*Series*	*Parallel*	
FILAMENT VOLTAGE (DC)	2.8	1.4	volts
FILAMENT CURRENT	0.05	0.1	ampere

CLASS A_1 AMPLIFIER

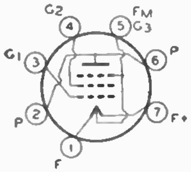
Maximum Ratings:

	Series	*Parallel*	
PLATE VOLTAGE	110 *max*	110 *max*	volts
GRID-NO. 2 (SCREEN) VOLTAGE	110 *max*	110 *max*	volts
TOTAL ZERO-SIGNAL CATHODE CURRENT	6 *max*	12 *max*	ma

Typical Operation:

	Series		*Parallel*			
Plate Voltage	90	110	85	90	110	volts
Grid-No. 2 Voltage	90	110	85	90	110	volts
Grid-No. 1 Voltage*	-4.5	-6.6	-5	-4.5	-6.6	volts
Peak AF Grid-No. 1 Voltage	4.5	5.1	5	4.5	5.4	volts
Plate Current	8.0	8.5	7.0	9.5	10	ma
Grid-No. 2 Current (Approx.)	1.0	1.1	0.8	1.3	1.4	ma
Plate Resistance (Approx.)	0.08	0.11	0.07	0.09	0.1	megohm
Transconductance	2000	2000	1950	2200	2200	μmhos
Load Resistance	8000	8000	9000	8000	8000	ohms
Total Harmonic Distortion	8.5	8.5	5.5	6.0	6.0	per cent
Maximum-Signal Power Output	230	330	250	270	400	mw

*The grid-No.1-circuit resistance should not exceed 1.0 megohm for either cathode- or fixed-bias operation.



POWER PENTODE

3S4

Miniature type used in output stage of lightweight, compact, portable, battery-operated equipment. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. Types 3S4 and 1S4 are identical except for filament arrangement. Type 3S4 features a filament mid-tap so that tube may be used either with a 1.4-volt battery supply or in series with other miniature tubes having 0.050-ampere filaments. For filament considerations, refer to type 3V4 and ELECTRON TUBE INSTALLATION SECTION.

Filament Arrangement	*Series*	*Paralle*	
Filament Voltage (dc)	2.8	1.4	volts
Filament Current	0.05	0.1	ampere

CLASS A_1 AMPLIFIER

Maximum Ratings:

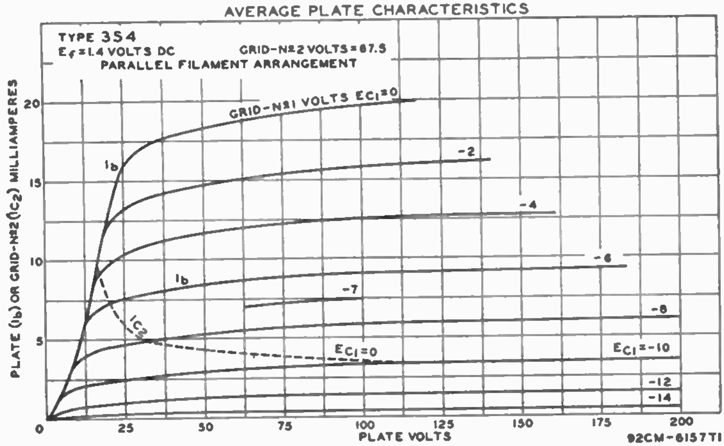
	Series	*Parallel*	
Plate Voltage	90 *max*	90 *max*	volts
Grid-No. 2 (screen) Voltage	67.5 *max*	67.5 *max*	volts
Total Cathode Current	6.0# *max*	12 *max*	ma

For each 1.4-volt filament section.

Typical Operation:

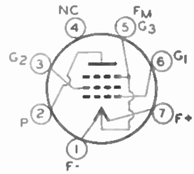
	Series		*Parallel*		
Plate Voltage	67.5	90	67.5	90	volts
Grid-No. 2 Voltage	67.5	67.5	67.5	67.5	volts
Grid-No. 1 (Control-Grid) Voltage	−7	−7	−7	−7	volts
Peak AF Grid-No. 1 Voltage	7	7	7	7	volts
Zero-Signal Plate Current	6.0	6.1	7.2	7.4	ma
Zero-Signal Grid-No. 2 Current	1.2	1.1	1.5	1.4	ma
Plate Resistance	0.1	0.1	0.1	0.1	megohm
Transconductance	1400	1425	1550	1575	µmhos
Load Resistance	5000	8000	5000	8000	ohms
Total Harmonic Distortion	12	13	10	12	per cent
Maximum-Signal Power Output	160	235	180	270	mw

AVERAGE PLATE CHARACTERISTICS



3V4

POWER PENTODE



Miniature type used in output stage of lightweight, compact, portable, battery-operated equipment. Except for terminal connections, types 3V4 and 3Q4 are identical. Both feature filament mid-tap so that tubes may be used either with a 1.4-volt battery supply or in series with other miniature tubes having 0.050-ampere filaments.

Filament Arrangement	*Series*	*Parallel*	
FILAMENT VOLTAGE (DC)	2.8	1.4	volts
FILAMENT CURRENT	0.05	0.1	ampere
DIRECT INTERELECTRODE CAPACITANCES (Approx. With no external shield):			
Grid No. 1 to Plate	0.2		$\mu\mu$f
Input	5.5		$\mu\mu$f
Output	3.8		$\mu\mu$f

CLASS A_1 AMPLIFIER

Maximum Ratings:	*Series*	*Parallel*	
PLATE VOLTAGE	90 *max*	90 *max*	volts
GRID-NO. 2 (SCREEN) VOLTAGE	90 *max*	90 *max*	volts
TOTAL CATHODE CURRENT	6# *max*	12 *max*	ma

For each 1.4-volt filament section.

Typical Operation:	*Series*	*Parallel*		
Plate Voltage	90	85	90	volts
Grid-No. 2 Voltage	90	85	90	volts
Grid-No. 1 (Control-Grid) Voltage	-4.5	-5	-4.5	volts
Peak AF Grid-No. 1 Voltage	4.5	5	4.5	volts
Zero-Signal Plate Current	7.7	6.9	9.5	ma
Zero-Signal Grid-No. 2 Current	1.7	1.5	2.1	ma
Plate Resistance (Approx.)	0.12	0.12	0.1	megohm
Transconductance	2000	1975	2150	μmhos
Load Resistance	10000	10000	10000	ohms
Total Harmonic Distortion	7	10	7	per cent
Maximum-Signal Power Output	240	250	270	mw

INSTALLATION AND APPLICATION

Type 3V4 requires miniature seven-contact socket and may be mounted in any position. Outline 12, OUTLINES SECTION.

The **filament** power supply may be obtained from dry-cell batteries, from storage batteries, or from a power line. With dry-cell battery supply, the filament may be connected either directly across a battery rated at a terminal potential of 1.5 volts, or in series with the filaments of similar tubes across a power supply consisting of dry cells in series. In any case, the voltage across each 1.4-volt section of filament should not exceed 1.6 volts.

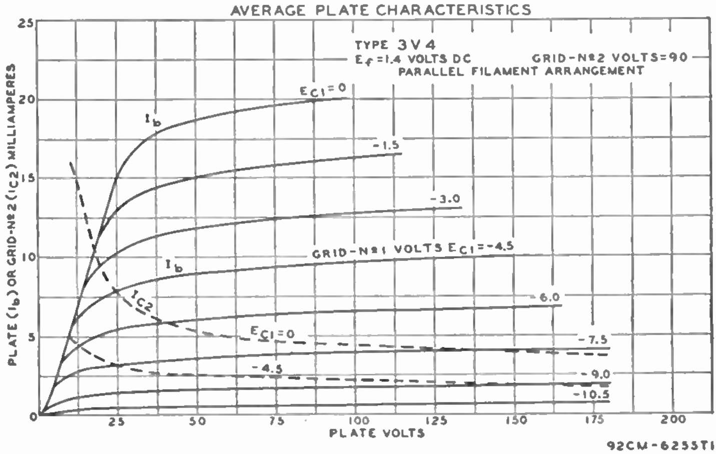
With power-line or storage-battery supply, the filament may be operated in series with the filaments of other tubes of the same filament-current rating. For such operation, design adjustments should be made so that, with tubes of rated characteristics operating with all electrode voltages applied and on a normal line voltage of 117 volts or on a normal storage-battery voltage of 2.0 volts per cell (without a charger) or 2.2 volts per cell (with a charger), the voltage drop across each 1.4-volt section of filament will be maintained within a range of 1.25 to 1.4 volts with a center of 1.3 volts.

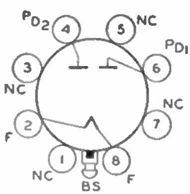
For series operation of the sections, a shunting resistor must be connected across the section between the F- and F_m, the filament mid-tap, to bypass any cathode current in this section which is in excess of the rated maximum per section.

When other tubes in a series-filament arrangement contribute to the filament current of the 3V4, an additional shunting resistor may be required across the entire filament (F- to F+).

For series filament arrangement, filament voltage is applied between pins No.1 and No.7. For parallel filament arrangement, filament voltage is applied between pin No.5 and pins No.1 and No.7 connected together. Refer to ELECTRON TUBE INSTALLATION SECTION for additional filament considerations.

In series filament arrangement, the grid-No.1 voltage is referred to F-. In parallel filament arrangement, the grid-No.1 voltage is referred to F_M, the filament mid-tap.

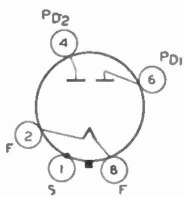




FULL-WAVE VACUUM RECTIFIER

5AZ4

Lock-in type used in power supply of radio equipment having moderate dc requirements. Outline 19, OUTLINES SECTION. Tube requires lock-in socket. Filament volts, 5; amperes, 2. For maximum ratings, typical operation, and curves, refer to glass-octal type 5Y3-GT.



FULL-WAVE VACUUM RECTIFIER

5T4

Metal type used in power supply of radio equipment having large dc requirements. Outline 7, OUTLINES SECTION. Tube requires octal socket. Vertical tube mounting is preferred but horizontal mounting is permissible if pins 2 and 8 are in vertical plane. Filament volts (ac), 5.0; amperes, 2.0. This type is used principally for renewal purposes.

Maximum Ratings: FULL-WAVE RECTIFIER

PEAK INVERSE PLATE VOLTAGE	1550 *max*	volts
PEAK PLATE CURRENT	675 *max*	ma
DC OUTPUT CURRENT	225 *max*	ma

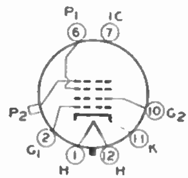
Typical Operation:

Filter Input	*Capacitor*	*Choke*	
AC Plate-to-Plate Supply Voltage (rms)	900	1100	volts
Filter-Input Capacitor	4	–	μf
Total Effective Plate-Supply Impedance Per Plate†	150	–	ohms
Filter-Input Choke	–	10	henries
DC Output Current	225	225	ma
DC Output Voltage at Input to Filter (Approx.):			
At half-load current (112.5 ma.)	530	465	volts
At full-load current (225 ma.)	480	450	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	50	15	volts

† When a filter-input capacitor larger than 40 μf is used, it may be necessary to use more plate-supply impedance than the value shown in order to limit the peak plate current to the rated value.

5TP4

PROJECTION KINESCOPE



Projection-type kinescope used in television receivers having a reflective optical system. Features high-efficiency, metal-backed white fluorescent screen utilizing phosphor No.4 of the silicate type. Highlight brightness of the projected picture is about 15 foot-lamberts when the 5TP4 is operated at 27 kilovolts. Utilizes electrostatic focusing and magnetic deflection. Has deflection angle of about 50°.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.6	ampere
Direct Interelectrode Capacitances:		
Grid No.1 to All Other Electrodes	8	μμf
Cathode to All Other Electrodes	5	μμf
External Conductive Coating to Anode No. 2	500 *max*	μμf
	100 *min*	μμf

Maximum Ratings:

Anode-No.2 Voltage	27000 *max*	volts
Anode-No.1 Voltage	6000 *max*	volts
Grid-No.2 Voltage	350 *max*	volts
Grid-No.1 Voltage:		
Negative bias value	150 *max*	volts
Positive bias value	0 *max*	volts
Positive peak value	2 *max*	volts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode:		
During equipment warm-up period not exceeding 15 seconds	410 *max*	volts
After equipment warm-up period	175 *max*	volts
Heater positive with respect to cathode	10 *max*	volts

Typical Operation:

Anode-No.2 Voltage*	27000	volts
Anode-No.1 Voltage Range for Focus when Anode-No.2 Current is 200 μa	4320 to 5400	volts
Grid-No.2 Voltage	200	volts
Grid-No.1 Voltage for Visual Cutoff of undeflected focused spot	–42 to –98	volts
Anode-No.2 Current	200	μa
Maximum Anode-No.1 Current	55	μa
Grid-No.2 Current Range	–15 to +15	μa

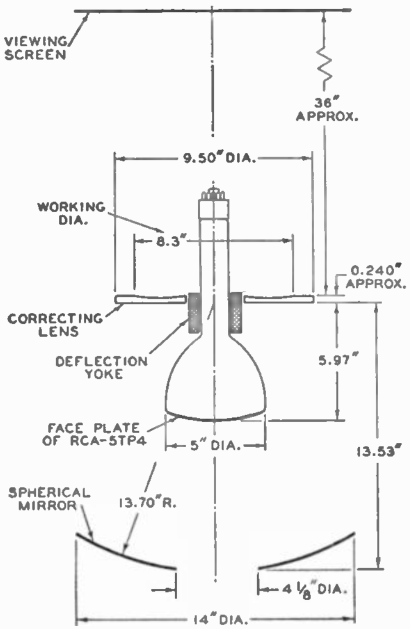
Maximum Circuit Value:

Grid-No.1-Circuit Resistance	1.5 *max*	megohms

* Brilliance and definition decrease with decreasing anode voltages. In general, anode-No. 2 voltage should not be less than 20000 volts.

INSTALLATION AND APPLICATION

The **base pins** of the 5TP4 fit the duodecal seven-contact socket. In order to provide the maximum socket insulation for high-voltage pins 6 and 7, the socket contacts for pins 3, 4, 5, 8, and 9 should be removed. The socket should be made of high-grade, arc-resistant insulating material and should preferably be designed with baffles. The tube should be supported by a metal holder at the large end of the tube. The 5TP4 may be operated in any position. Outline 44, OUTLINES SECTION.



A typical **reflective optical system** for use with the 5TP4 is illustrated in the accompanying sketch. It consists of a spherical collecting mirror and a correcting lens located at the center of curvature of the mirror. The illustration also shows the location of the face plate of the 5TP4 and the location of the viewing screen with respect to the mirror and the correcting lens.

The **neck external conductive coating** must be grounded. Connection to the coating may be made by a flexible band around the base end of the coating, or by a soft brush contact attached to the bottom of the yoke. Unless the coating is grounded, it may assume the potential of anode No.2 and thus break down the yoke insulation.

The coating serves to prevent corona between the neck (which has an internal coating at anode-No.2 potential) and the yoke. Corona would act to damage the yoke insulation and to produce breakdown in the glass of the neck. It is important that the yoke insulation be adequate for operation of the yoke against the external grounded coating.

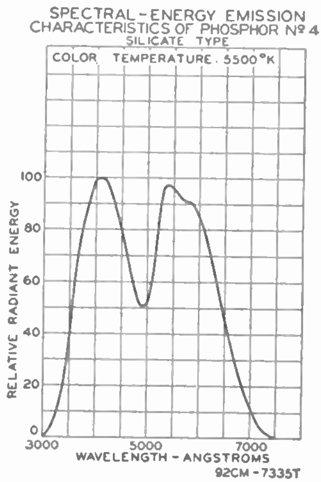
The **bulb insulating (moisture-repellent) coating** serves to prevent formation of a continuous film of moisture over the glass surface when humidity is high. Such a film, when a high-voltage gradient is present, is conducive to the formation of corona and tends to produce sparking over the glass surface. Care must be taken not to scratch the insulating coating, nor to wash or wipe it with any liquid likely to soften or dissolve lacquers.

Grid No. 2 is incorporated in the design of the 5TP4 to prevent interaction between the fields produced by grid No.1 and anode No.1. However, grid No.2 may also be used to compensate for the normal variation to be expected in the grid-No.1 voltage for cutoff in individual tubes. By adjusting the voltage applied to grid No.2 with due consideration to its maximum rated value, it is possible to fix the grid-No.1 bias at a desired value, and obtain almost the same maximum anode current for individual tubes having different cutoff voltages. Adjusting grid-No.1 cutoff in this way not only makes grid drive more uniform, but also reduces variations in anode-No.1 current. Since grid-No.2 draws at most only a negligible leakage current, its voltage may be obtained from a potentiometer inserted in the anode-No.1 voltage divider.

The high voltage at which the 5PT4 is operated is very dangerous. Great care should be taken in the design of apparatus to prevent the operator from coming in contact with the high voltages. Precautions include the enclosing of high-potential terminals and the use of inter-locking switches to break the primary circuit of the power supply when access to the equipment is required. To minimize the danger of these high voltages, it is recommended that the high-voltage supply for the 5TP4 be one in which the peak current even under short-circuit conditions is well below the value dangerous to life.

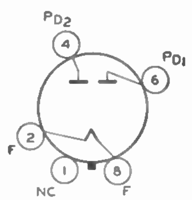
For additional installation and handling considerations, refer to ELECTRON TUBE INSTALLATION SECTION.

Occasionally, after a tube has been transported, fine loose particles inside the tube may get on the anode-No.1 surface. When voltage is applied, there will be a momentary spark which fuses or removes the particles, so that no further sparking occurs. Such sparking causes no harm to the tube provided the maximum energy dissipated in the spark is kept small by use of a suitable high-voltage power supply as recommended above.



5U4-G

FULL-WAVE VACUUM RECTIFIER



Glass octal type used in power supply of radio equipment having high dc requirements. Outline 40, OUTLINES SECTION. Tube requires octal socket. Vertical mounting is preferred but horizontal mounting is permissible if pins 1 and 4 are in vertical plane. The coated filament is designed to operate from the ac line through a step-down transformer. The voltage at the filament terminals should be 5.0 volts under operating conditions at an average line voltage of 117 volts. It is especially important that this tube, like other power-handling tubes, should be adequately ventilated. For discussion of Rating Chart and Operation Characteristics, refer to type 6AX5-GT.

Filament Voltage (AC)	5.0	volts
Filament Current	3.0	amperes

FULL-WAVE RECTIFIER

Maximum Ratings:

PEAK INVERSE PLATE VOLTAGE	1550 *max*	volts
PEAK PLATE CURRENT PER PLATE	675 *max*	ma
HOT-SWITCHING TRANSIENT PLATE CURRENT for duration of 0.2 second maximum	2.35 *max*	amperes
AC PLATE SUPPLY VOLTAGE PER PLATE (RMS)	*See Rating Chart*	
DC OUTPUT CURRENT PER PLATE (RMS)	*See Rating Chart*	

Typical Operation with Capacitor Input to Filter:

AC Plate-to-Plate Supply Voltage (rms)	900	1100	volts
Filter Input Capacitor*	10	10	μf
Effective Plate-Supply Impedance Per Plate	170	230	ohms
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of 112.5 ma	510	–	volts
At half-load current of 78 ma	–	660	volts
At full-load current of 225 ma	430	–	volts
At full-load current of 156 ma	–	590	volts
Voltage Regulation (Approx.): Half-load to full-load current	80	70	volts

Typical Operation with Choke Input to Filter:

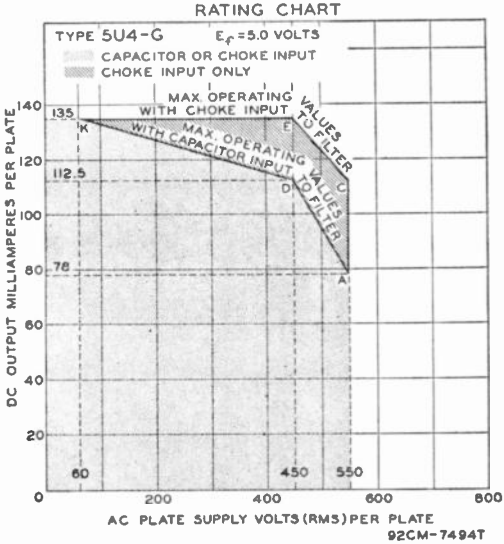
AC Plate-to-Plate Supply Voltage (rms)	900	1100	volts
Filter Input Choke	10#	10##	henries
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of 135 ma	365	–	volts
At half-load current of 112.5 ma	–	460	volts
At full-load current of 270 ma	345	–	volts
At full-load current of 225 ma	–	440	volts
Voltage Regulation (Approx.): Half-load to full-load current	20	20	volts

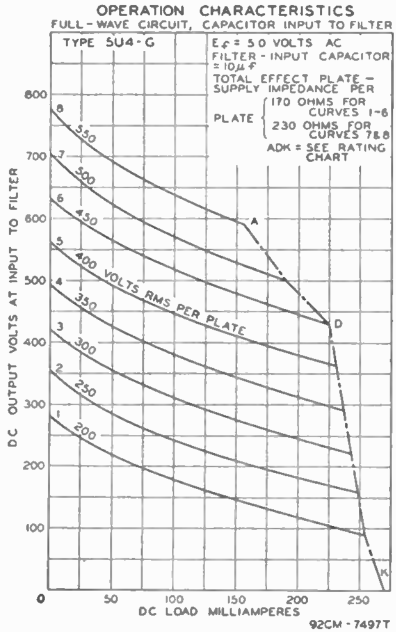
* Higher values of capacitance than indicated may be used but the effective plate-supply impedance may have to be increased to prevent exceeding the maximum rating for hot-switching transient plate current.

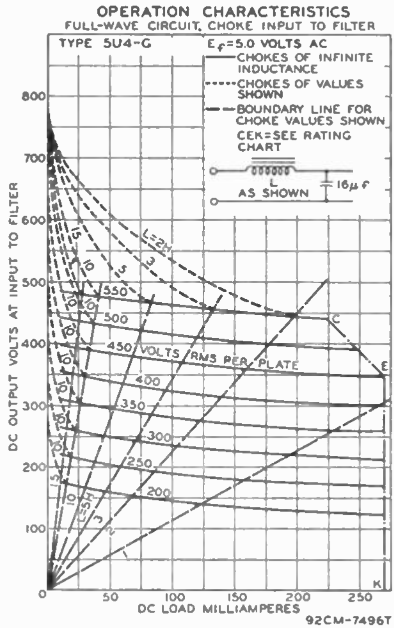
This value is adequate to maintain optimum regulation in the region to the right of line L=10H on curve OPERATION CHARACTERISTICS with Choke Input to Filter, provided the load current is not less than 35 ma. For load currents less than 35 ma, a larger value of inductance is required for optimum regulation.

This value is adequate to maintain optimum regulation in the region to the right of line L=10H on curve OPERATION CHARACTERISTICS with Choke Input to Filter, provided the load current is not less than 45 ma. For load currents less than 45 ma, a larger value of inductance is required for optimum regulation.

RATING CHART

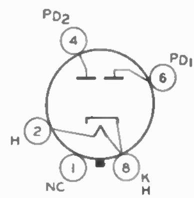






5V4-G

FULL-WAVE VACUUM RECTIFIER



Glass octal type used in power supply of radio equipment having high dc requirements. Outline 35, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. The heater is designed to operate from the ac line through a step-down transformer. The voltage at the heater terminals should be 5.0 volts under operating conditions at an average line voltage of 117 volts. It is especially important that this tube, like other power-handling tubes, should be adequately ventilated.

HEATER VOLTAGE (AC)	5.0	volts
HEATER CURRENT	2.0	amperes

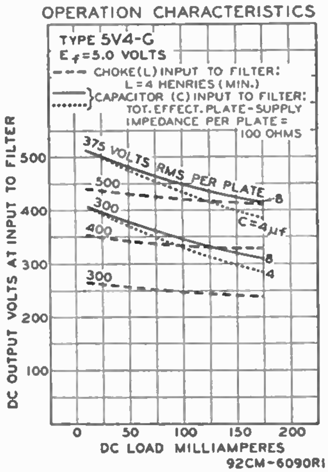
Maximum Ratings: FULL-WAVE RECTIFIER

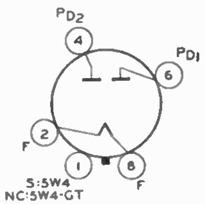
PEAK INVERSE PLATE VOLTAGE	1400 *max*	volts
PEAK PLATE CURRENT	525 *max*	ma
DC OUTPUT CURRENT	175 *max*	ma

Typical Operation:

Filter Input	*Capacitor*	*Choke*	
AC Plate-to-Plate Supply Voltage (rms)	750	1000	volts
Filter-Input Capacitor	8	–	μf
Total Effective Plate-Supply Impedance per Plate*	100	–	ohms
Min. Filter-Input Choke	–	4	henries
DC Output Current	175	175	ma
DC Output Voltage at Input to Filter (Approx.):			
At half-load current (87.5 ma.)	455	425	volts
At full-load current (175 ma.)	415	415	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	40	10	volts

* When a filter-input capacitor larger than 40 μf is used, it may be necessary to use more plate-supply impedance than the value shown to limit the peak plate current to the rated value.

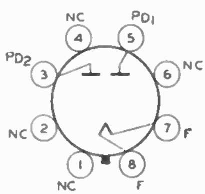




FULL-WAVE VACUUM RECTIFIER

5W4
5W4-GT

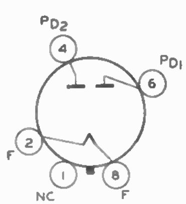
Metal type 5W4 and glass-octal type 5W4-GT are used in power supply of radio equipment having low dc requirements. Outlines 6 and 25, respectively, OUTLINES SECTION. Both types require octal socket. Filament volts (ac), 5.0; amperes, 1.5. Maximum ratings: peak inverse plate volts, 1400 *max;* peak plate ma., 300 *max;* dc output ma., 100 *max*. The 5W4 is a DISCONTINUED type listed for reference only. Type 5W4-GT is used principally for renewal purposes.



FULL-WAVE VACUUM RECTIFIER

5X4-G

Glass octal type used in power supply of radio equipment having large dc requirements. Outline 40, OUTLINES SECTION. Filament volts, 5.0; amperes, 3.0. Except for basing arrangement, this type is identical with type 5U4-G. Type 5X4-G is used principally for renewal purposes.



FULL-WAVE VACUUM RECTIFIER

5Y3-G
5Y3-GT

Glass octal types used in power supply of radio equipment having moderate dc requirements. Type 5Y3-G, Outline 35; type 5Y3-GT, Outline 25, OUTLINES SECTION. Tubes require octal socket. Vertical tube mounting is preferred, but horizontal operation is permissible if pins 2 and 8 are in horizontal plane. It is especially important that these tubes, like other power-handling tubes, should be adequately ventilated. Type 5Y3-G is used principally for renewal purposes. For discussion of Rating Chart and Operation Characteristics, refer to type 6AX5-GT.

FILAMENT VOLTAGE (AC)	5.0	volts
FILAMENT CURRENT	2.0	amperes

Maximum Ratings: FULL-WAVE RECTIFIER

PEAK INVERSE PLATE VOLTAGE	1400 *max*	volts
PEAK PLATE CURRENT PER PLATE	400 *max*	ma
HOT-SWITCHING TRANSIENT PLATE CURRENT		
For duration of 0.2 second maximum	2.2 *max*	amperes
AC PLATE SUPPLY VOLTAGE PER PLATE (RMS)	*See Rating Chart*	
DC OUTPUT CURRENT PER PLATE (RMS)	*See Rating Chart*	

Typical Operation with Capacitor Input to Filter:

AC Plate-to-Plate Supply Voltage (rms)	700	1000	volts
Filter Input Capacitor*	10	10	μf
Effective Plate-Supply Impedance Per Plate	50	140	ohms
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of 62.5 ma	390	–	volts
At half-load current of 42 ma	–	610	volts
At full-load current of 125 ma	350	–	volts
At full-load current of 84 ma	–	560	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	40	50	volts

Typical Operation with Choke Input to Filter:

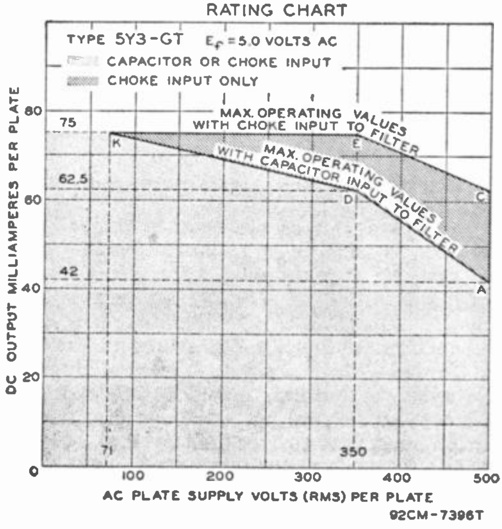
AC Plate-to-Plate Supply Voltage (rms)	700	1000	volts
Filter Input Choke	10#	10##	henries
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of 75 ma	270	–	volts
At half-load current of 62.5 ma	–	405	volts
At full-load current of 150 ma	245	–	volts
At full-load current of 125 ma	–	390	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	25	15	volts

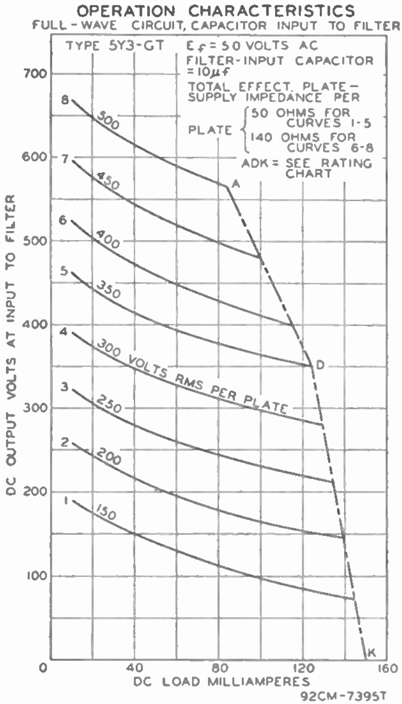
* Higher values of capacitance than indicated may be used but the effective plate supply impedance may have to be increased to prevent exceeding the maximum rating for hot-switching transient plate current.

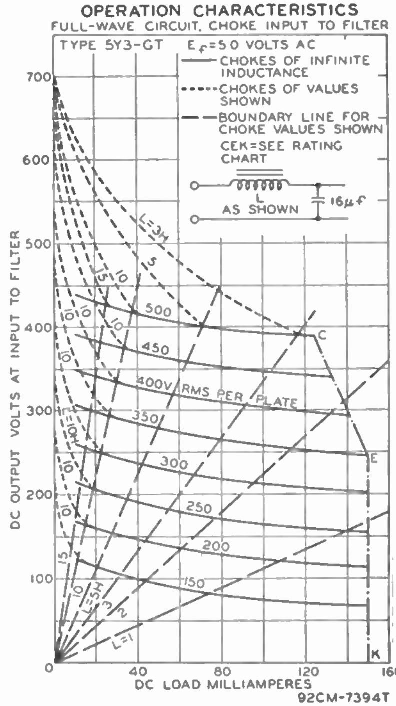
This value is adequate to maintain optimum regulation in the region to the right of line L=10H on curve OPERATION CHARACTERISTICS with Choke Input to Filter, provided the load current is not less than 35 ma. For load currents less than 35 ma, a larger value of inductance is required for optimum regulation.

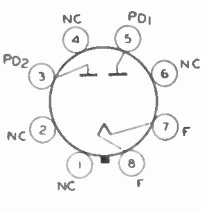
This value is adequate to maintain optimum regulation in the region to the right of line L=10H on curve OPERATION CHARACTERISTICS with Choke Input to Filter, provided the load current is not less than 50 ma. For load currents less than 50 ma, a larger value of inductance is required for optimum regulation.

RATING CHART





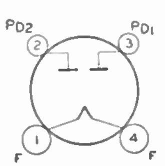




FULL-WAVE VACUUM RECTIFIER

5Y4-G

Glass octal type used in power supply of radio equipment having moderate dc requirements. Outline 35, OUTLINES SECTION. Tube requires octal socket. Vertical tube mounting is preferred, but horizontal mounting is permissible if pins 2 and 7 are in horizontal plane. Filament volts (ac), 5.0; amperes, 2.0. For maximum ratings, typical operation, and curves, refer to type 5Y3-GT. Type 5Y4-G is used principally for renewal purposes.



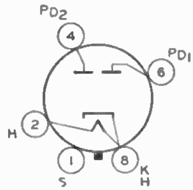
FULL-WAVE VACUUM RECTIFIER

5Z3

Glass type used in power supply of radio equipment having large dc requirements. Outline 41, OUTLINES SECTION. Tube requires four-contact socket. Vertical mounting is preferred but horizontal mounting is permissible if pins 1 and 4 are in horizontal plane. Filament volts (ac), 5.0; amperes, 3.0. For maximum ratings, typical operation, and curves, refer to type 5U4-G.

5Z4

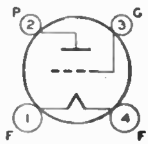
FULL-WAVE VACUUM RECTIFIER



Metal type used in power supply of radio equipment having moderate dc requirements. Outline 6, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. Heater volts (ac), 5.0; amperes, 2.0. Maximum ratings: peak inverse plate volts, 1400 *max;* peak plate ma. per plate, 375 *max.* Typical operation as full-wave rectifier with capacitor-input filter: ac plate-to-plate supply volts (rms), 700; total effective plate-supply impedance per plate, 50 ohms; dc output ma., 125. Typical operation with choke-input filter: ac plate-to-plate supply volts, 1000; minimum filter-input choke, 5 henries; dc output ma., 125.

6A3

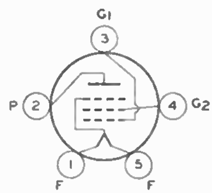
POWER TRIODE



Glass type used in output stage of radio receivers. Outline 41, OUTLINES SECTION. Tube requires four-contact socket. Filament volts (ac/dc), 6.3; amperes, 1.0. This type is identical electrically with type 6B4-G. The 6A3 is used principally for renewal purposes.

6A4/LA

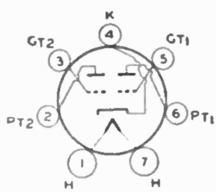
POWER PENTODE



Glass type used in output stage of automobile receivers. Outline 36, OUTLINES SECTION. Tube requires five-contact socket. Filament volts (ac/dc), 6.3; amperes, 0.3. Typical operation: plate and grid-No. 2 volts, 180 *max;* grid-No. 1 volts, -12; plate ma., 22; grid-No. 2 ma., 3.9; plate resistance, 45500 ohms approx.; transconductance, 2200 μmhos; load resistance, 8000 ohms; cathode-bias resistor, 465 ohms; output watts, 1.4. This is a DISCONTINUED type listed for reference only.

6A6

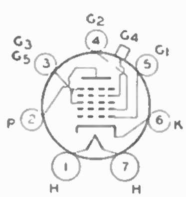
HIGH-MU TWIN POWER TRIODE



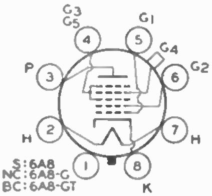
Glass type used in output stage of ac-operated receivers as a class B power amplifier or with units in parallel as a class A_1 amplifier to drive a 6A6 as class B amplifier. Outline 36, OUTLINES SECTION. Tube requires medium seven-contact (0.855-inch, pin-circle diameter) socket. Filament volts (ac/dc), 6.3; amperes, 0.8. This type is electrically identical with type 6N7. The 6A6 is used principally for renewal purposes.

6A7
6A7S

PENTAGRID CONVERTER



Glass types used in superheterodyne circuits. Outline 34, OUTLINES SECTION. These types require the small seven-contact (0.75-inch, pin-circle diameter) socket. Except for interelectrode capacitances, the 6A7 is identical electrically with type 6A8. Type 6A7S, now DISCONTINUED, has the external shield connected to cathode. In general, its electrical characteristics are similar to those of the 6A7, but the two types are usually not directly interchangeable. Type 6A7 is used principally for renewal purposes.



PENTAGRID CONVERTER

6A8
6A8-G
6A8-GT

Metal type 6A8 and glass-octal types 6A8-G and 6A8-GT used in superheterodyne circuits. Type 6A8, Outline 4; type 6A8-G, Outline 33; type 6A8-GT, Outline 23, OUTLINES SECTION. Type 6A8-G is used principally for renewal purposes. All require octal socket. For general discussion of pentagrid types, see **Frequency Conversion** in ELECTRON TUBE APPLICATIONS SECTION. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere

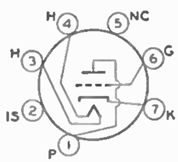
Maximum Ratings: CONVERTER SERVICE

Plate Voltage	300 *max*	volts
Grids-No. 3-and-No. 5 (screen) Voltage	100 *max*	volts
Grids-No. 3-and-No. 5 Supply Voltage	300 *max*	volts
Grid-No. 2 (anode-grid) Voltage	200 *max*	volts
Grid-No. 2 Supply Voltage	300 *max*	volts
Grid-No. 4 (control-grid) Voltage, Positive Bias Value	0 *max*	volts
Plate Dissipation	1.0 *max*	watt
Grids-No.3-and-No.5 Input	0.3 *max*	watt
Grid-No.2 Input	0.75 *max*	watt
Total Cathode Current	14 *max*	ma
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate Voltage	100	250	volts
Grids-No. 3-and-No. 5 Voltage	50	100	volts
Grid-No. 2 Voltage	100	–	volts
Grid-No. 2 Supply Voltage	–	250*	volts
Grid-No. 4 Voltage	–1.5	–3	volts
Grid-No. 1 (Oscillator-Grid) Resistor	50000	50000	ohms
Plate Resistance (Approx.)	0.6	0.36	megohm
Conversion Transconductance	360	550	μmhos
Conversion Transconductance (Approx.) with control-grid bias of –20 volts	3	–	μmhos
Conversion Transconductance (Approx.) with control-grid bias of –35 volts	–	6	μmhos
Plate Current	1.1	3.5	ma
Grids-No. 3-and-No. 5 Current	1.3	2.7	ma
Grid-No. 2 Current	2	4	ma
Grid-No. 1 Current	0.25	0.4	ma
Total Cathode Current	4.6	10.6	ma

* Grid-No. 2 supply voltages in excess of 200 volts require use of 20000-ohm voltage-dropping resistor bypassed by 0.1-μf capacitor.



HIGH-MU TRIODE

6AB4

Miniature type used as grounded-grid amplifier, frequency converter, or oscillator at frequencies up to about 300 megacycles per second particularly in television and FM receivers. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For maximum ratings, characteristics, and curves, refer to type 12AT7. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.15	ampere
Direct Interelectrode Capacitances (No external shield):		
	Grounded-Cathode Operation	
Grid to Plate	1.5	μμf
Input	2.2	μμf
Output	0.5	μμf
Heater to Cathode	2.9	μμf

Direct Interelectrode Capacitances (No external shield):

	Grounded-Grid Operation	
Plate to Cathode	0.24	μμf
Input	5.0	μμf
Output	1.7	μμf

Maximum Ratings: CLASS A_1 AMPLIFIER

Plate Voltage	300 *max*	volts
Plate Dissipation	2.5 *max*	watts
Grid Voltage, Negative Bias Value	−50 *max*	volts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

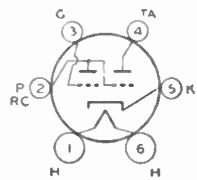
Characteristics:

Plate Voltage	100	250	volts
Internal Shield	Connected to ground		
Cathode Resistor	270	200	ohms
Amplification Factor	60	60	
Plate Resistance (Approx.)	15500	10900	ohms
Transconductance	4000	5500	μmhos
Grid Bias (Approx.) for plate current of 10 μa	−5	−12	volts
Plate Current	3.7	10	ma

6AB5/ 6N5

ELECTRON-RAY TUBE

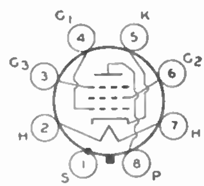
Glass type used to indicate visually by means of a fluorescent target the effects of a change in a controlling voltage. It is used as a convenient means of indicating accurate radio-receiver tuning. Outline 30, OUTLINES SECTION. Tube requires six-contact socket. For heater and cathode considerations, refer to type 6AV6. Heater volts (ac/dc), 6.3; amperes, 0.15. Ratings: plate-supply volts, 180 *max;* target volts, 180 *max*, 125 *min.*



6AB7

REMOTE-CUTOFF PENTODE

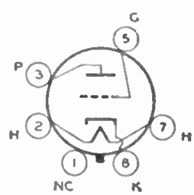
Metal type used in rf and if stages of picture amplifier of television receivers particularly those employing automatic-gain control. Outline 3, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.45. Maximum ratings as class A_1 amplifier: plate and grid-No. 2 supply volts, 300 *max;* grid-No. 2 volts, 200 *max;* plate dissipation, 3.75 *max* watts; grid-No.2 input, 0.7 *max* watt. Typical operation: plate and grid-No.2 supply volts, 300; grid-No.3 volts, 0; grid-No.2 series resistor, 30000 ohms; grid-No.1 volts, −3; plate resistance (approx.), 0.7 megohm; transconductance, 5000 μmhos; grid-No.1 volts for transconductance of 50 μmhos, −15; plate ma., 12.5; grid-No.2 ma., 3.2.

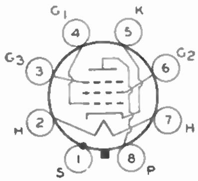


6AC5-GT

HIGH-MU POWER TRIODE

Glass octal type used in single-ended or push-pull audio-frequency power amplifiers of the direct-coupled type in which a driver tube develops positive grid bias for the 6AC5-GT output stage. Outline 22, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.4. Maximum ratings: plate volts, 250 *max;* peak plate ma. (per tube), 110 *max:* average plate dissipation, 10 *max* watts. This type is used principally for renewal purposes.





SHARP-CUTOFF PENTODE

6AC7

Metal type used in rf and if stages of picture amplifier and the first stages of the video amplifier of television receivers. It is also used as a mixer or oscillator tube in low-frequency applications. Outline 3, OUTLINES SECTION. Tube requires octal socket. When tube is used as a high-gain audio amplifier, heater should be operated from a battery source. For other heater considerations, refer to type 6AQ5.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.45	ampere
DIRECT INTERELECTRODE CAPACITANCES (Shell connected to cathode):		
Grid No.1 to Plate	0.015 *max*	μμf
Input	11	μμf
Output	5	μμf

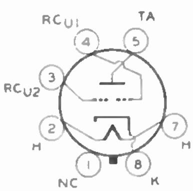
Maximum Ratings: CLASS A_1 AMPLIFIER

PLATE VOLTAGE	300 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	150 *max*	volts
GRID-NO.2 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	3 *max*	watts
GRID-NO.2 INPUT	0.4 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:	*Condition I**	*Condition II***	
Plate Voltage	300	300	volts
Grid-No. 3 Voltage	0	0	volts
Grid-No. 2 Supply Voltage	150	300#	volts
Grid-No. 2 Series Resistor	–	60000	ohms
Min. Cathode-Bias Resistor	160	160	ohms
Plate Resistance (Approx.)	1	1	megohm
Transconductance	9000	9000	μmhos
Plate Current	10	10	ma
Grid-No. 2 Current	2.5	2.5	ma

* With fixed grid-No.2 supply. ** With series grid-No. 2 resistor.

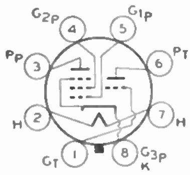
Grid-No.2 supply voltages in excess of 150 volts require use of a series dropping resistor to limit the voltage at grid No. 2 to 150 volts when the plate current is at its normal value of 10 milliamperes.



ELECTRON-RAY TUBE

6AD6-G

Glass octal type used to indicate visually, by means of two shadows on the fluorescent target, the effects of changes in the controlling voltages. It is a twin-indicator type and is used as a convenient means of indicating accurate radio-receiver tuning. Heater volts (ac/dc), 6.3; amperes, 0.15. Maximum target volts, 150. This is a DISCONTINUED type listed for reference only.



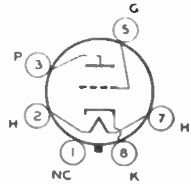
TRIODE—POWER PENTODE

6AD7-G

Glass octal type used in a push-pull amplifier circuit in conjunction with type 6F6-G. Triode unit serves as phase inverter. Outline 35, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.85. For typical operation of pentode unit, refer to type 6F6-G. Maximum ratings of pentode unit as class A_1 or push-pull class AB_1 amplifier: plate volts, 375 *max;* grid-No. 2 volts, 285 *max;* plate dissipation, 8.5 *max* watts; grid-No.2 input, 2.7 *max* watts. Maximum ratings of triode unit as class A_1 amplifier: plate volts, 285 *max;* plate dissipation, 1.0 *max* watt.

6AE5-GT

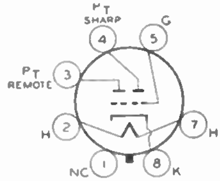
LOW-MU TRIODE



Glass octal type used as class A_1 amplifier in ac/dc radio receivers. Outline 22, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.3. Maximum ratings as class A_1 amplifier: plate volts, 300 *max;* plate dissipation, 2.5 *max* watts. This is a DISCONTINUED type listed for reference only.

6AE6-G

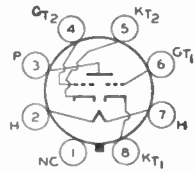
TWIN-PLATE CONTROL TUBE



Glass octal type used as a control tube for twin-indicator type electron-ray tubes. Outline 31, OUTLINES SECTION. Contains two triodes with different cutoff characteristics. If avc voltage is applied to the common control grid in suitable circuit, one triode section operates on weak signals while the other operates on strong signals. Heater voltage (ac/dc), 6.3; amperes, 0.15. This is a DISCONTINUED type listed for reference only.

6AE7-GT

TWIN-INPUT TRIODE



Glass octal type used as a voltage amplifier or as a driver for two type 6AC5-GT tubes in dynamic-coupled, push-pull amplifiers. In the latter service, type 6AE7-GT replaces two tubes ordinarily required as drivers. Outline 22, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.5. This is a DISCONTINUED type listed for reference only.

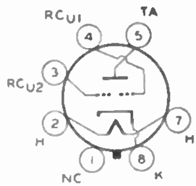
6AF4

UHF OSCILLATOR TRIODE

For technical data, see page 305.

6AF6-G

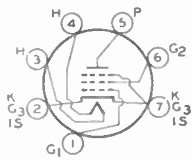
ELECTRON-RAY TUBE



Glass octal type used to indicate visually, by means of two shadows on the fluorescent target, the effects of changes in the controlling voltages. It is a twin-indicator type and is used as a convenient means of indicating accurate radio-receiver tuning. Outline 11, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.15. Ratings: target volts, 250 *max*, 125 *min;* ray-control-electrode supply volts, 250 *max;* peak heater-cathode volts, 90 *max*. Typical operation: target volts, 250; target ma., 2.2; series resistor, 1 megohm; ray-control electrode volts (approx. for 0° shadow angle), 160; ray-control electrode volts (approx. for 90° shadow angle), 0.

6AG5

SHARP-CUTOFF PENTODE



Miniature type used in compact radio equipment as an rf or if amplifier up to 400 megacycles per second. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. The two cathode leads facilitate isolation of the input and output circuits thus helping to minimize degeneration. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere
Direct Interelectrode Capacitances (No external shield):		
Grid No. 1 to Plate	0.030 *max*	μμf
Input	6.5	μμf
Output	1.8	μμf

CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
GRID-NO. 2 (SCREEN) VOLTAGE	150 *max*	volts
PLATE DISSIPATION	2 *max*	watts
GRID-NO. 2 INPUT	0.5 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate Voltage	100	125	250	volts
Grid-No. 2 Voltage	100	125	150	volts
Cathode-Bias Resistor	180	100	180	ohms
Plate Resistance (Approx.)	0.6	0.5	0.8	megohm
Transconductance	4500	5100	5000	µmhos
Grid-No.1 Bias for plate current of 10 µa	–5	–6	–8	volts
Plate Current	4.5	7.2	6.5	ma
Grid-No. 2 Current	1.4	2.1	2	ma

Maximum Ratings (Triode Connection):*

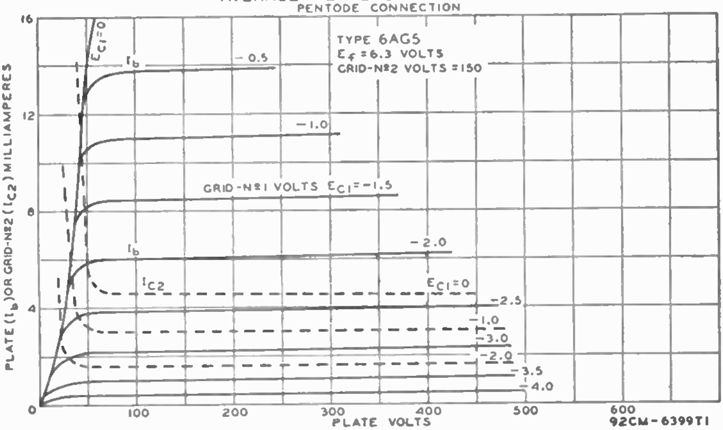
PLATE VOLTAGE	300 *max*	volts
PLATE DISSIPATION	2.5 *max*	watts

Typical Operation (Triode Connection):*

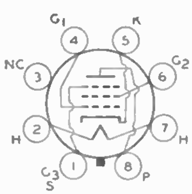
Plate Voltage	180	250	volts
Cathode-Bias Resistor	330	820	ohms
Plate Resistance	8000	10000	ohms
Amplification Factor	45	42	
Transconductance	5700	3800	µmhos
Plate Current	7.0	5.5	ma

*Grid No. 2 tied to plate.

AVERAGE PLATE CHARACTERISTICS
PENTODE CONNECTION



POWER PENTODE



6AG7

Metal type used in output stage of video amplifier of television receivers. Outline 6, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.65. Maximum ratings as class A_1 video voltage amplifier: plate volts, 300 *max;* grid-No. 2 volts, 300 *max;* plate dissipation, 9.0 *max* watts; grid-No. 2 input, 1.5 *max* watts. Typical operation as a class A_1 amplifier: plate volts, 300; grid-No. 2 volts, 150; grid-No. 1 volts, –3; peak af grid-No. 1 volts, 3; zero-signal plate ma., 30; maximum-signal plate ma., 30.5; zero-signal grid-No. 2 ma., 7; maximum-signal grid-No. 2 ma., 9; plate resistance, 130000 ohms; transconductance, 11000 µmhos; load resistance 10000 ohms; total harmonic distortion, 7 per cent; maximum-signal output watts, 3.

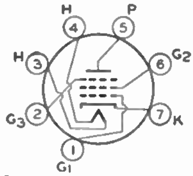
POWER TRIODE

For technical data, see page 306.

6AH4-GT

6AH6

SHARP-CUTOFF PENTODE



Miniature type used in the intermediate-frequency stages of the picture amplifier and the first stages of the video amplifier of television receivers. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AQ5.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.45	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.030 *max*	μμf
Input	10	μμf
Output	2	μμf

Maximum Ratings: CLASS A_1 AMPLIFIER

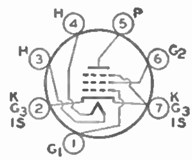
PLATE VOLTAGE	300 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	150 *max*	volts
PLATE DISSIPATION	3.2 *max*	watts
GRID-No.2 INPUT	0.4 *max*	watt
TOTAL CATHODE CURRENT	13 *max*	ma
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation and Characteristics:	*Triode* Connection*	*Pentode Connection*	
Plate Voltage	150	300	volts
Grid-No.3 (Suppressor)	–	Connected to cathode at socket	
Grid-No.2 Voltage	–	150	volts
Cathode Resistor	160	160	ohms
Amplification Factor	40	–	
Plate Resistance (Approx.)	3600	500000	ohms
Transconductance	11000	9000	μmhos
Grid-No.1 Bias (Approx.) for plate current of 10 μa	–7	–7	volts
Plate Current	12.5	10	ma
Grid-No.2 Current	–	2.5	ma

* Grid No.2 and Grid No.3 tied to plate.

6AK5

SHARP-CUTOFF PENTODE



Miniature type used as an rf or if amplifier especially in high-frequency wide-band applications. It is useful as an amplifier at frequencies up to 400 megacycles per second. Outline 9, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.175	ampere
DIRECT INTERELECTRODE CAPACITANCES (Approx. With external shield):		
Grid No.1 to Plate	0.02 *max*	μμf
Input	4.0	μμf
Output	2.8	μμf

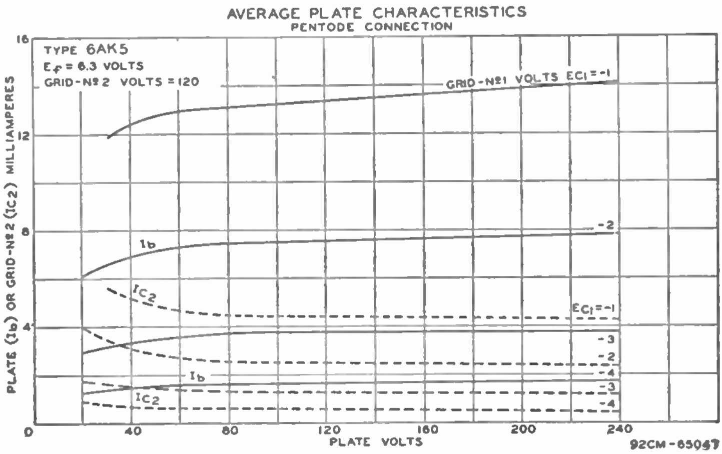
Maximum Ratings: CLASS A_1 AMPLIFIER

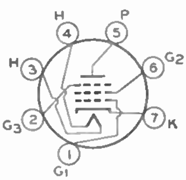
PLATE VOLTAGE	180 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	140 *max*	volts
PLATE DISSIPATION	1.7 *max*	watts
GRID-No.2 INPUT	0.5 *max*	watt
CATHODE CURRENT	18 *max*	ma
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation and Characteristics:

Plate Voltage	120	180	volts
Grid-No.2 Voltage	120	120	volts
Cathode-Bias Resisto *	180	200	ohms
Plate Resistance (Approx.)	0.3	0.5	megohm
Transconductance	5000	5100	μmhos
Grid-No.1 Bias for plate current of 10 μa	-8.5	-8.5	volts
Plate Current	7.5	7.7	ma
Grid-No.2 Current	2.5	2.4	ma

* Fixed-bias operation is not recommended.





POWER PENTODE

6AK6

Miniature type used in compact equipment as a power amplifier. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.15	ampere
DIRECT INTERELECTRODE CAPACITANCES (Approx. With no external shield):		
Grid No. 1 to Plate	0.12	μμf
Input	3.6	μμf
Output	4.2	μμf

CLASS A_1 AMPLIFIER

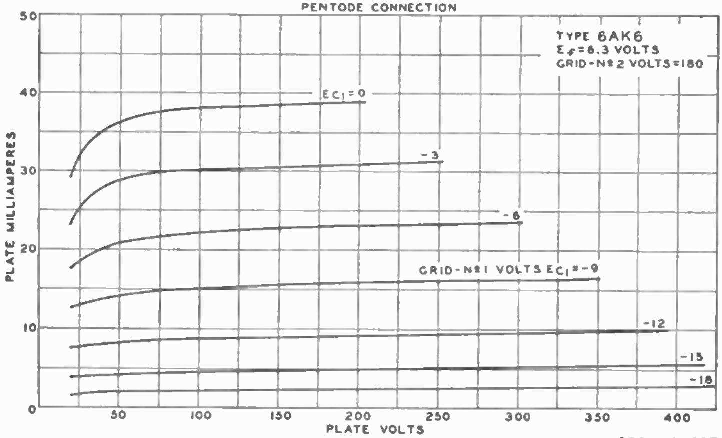
Maximum Ratings:	*Triode# Connection*	*Pentode Connection*	
PLATE VOLTAGE	300 *max*	300 *max*	volts
GRID NO. 2 (SCREEN) VOLTAGE	-	300 *max*	volts
PLATE DISSIPATION	3.5 *max*	2.75 *max*	watts
GRID-NO.2 INPUT	-	0.75 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:			
Heater negative with respect to cathode	90 *max*	90 *max*	volts
Heater positive with respect to cathode	90 *max*	90 *max*	volts

Typical Operation:	*Triode# Connection*	*Pentode Connection*	
Plate Voltage	180	180	volts
Grid No. 3 (Suppressor)	–	Connected to cathode at socket	
Grid-No. 2 Voltage	–	180	volts
Grid-No. 1 Voltage‡	–12	–9	volts
Peak AF Grid-No. 1 Voltage	12	9	volts
Zero-Signal Plate Current	12	15	ma
Zero-Signal Grid-No. 2 Current	–	2.5	ma
Plate Resistance	0.0044	0.2	megohm
Amplification Factor	9.3	–	
Transconductance	2100	2300	μmhos
Load Resistance	12000	10000	ohms
Total Harmonic Distortion	5	10	per cent
Maximum-Signal Power Output	0.26	1.1	watts

Grid No. 2 and grid No. 3 tied to plate.

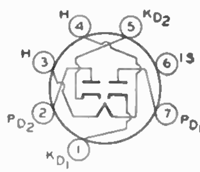
‡ The dc resistance in the grid-No.1 circuit under maximum rated conditions should not exceed 0.5 megohm for cathode-bias operation and 0.1 megohm for fixed-bias operation.

AVERAGE PLATE CHARACTERISTICS
PENTODE CONNECTION



92CM-6450T

TWIN DIODE



6AL5

Miniature, high-perveance type used as detector in FM and television circuits. It is especially useful as a ratio detector in ac-operated FM receivers. Each diode can be used independently of the other or combined in parallel or full-wave arrangement. Resonant frequency of each unit is approximately 700 megacycles per second. Outline 9, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES:		
Plate No. 1 to Cathode No. 1, Heater, and Internal Shield*	3.2	μμf
Plate No. 2 to Cathode No. 2, Heater, and Internal Shield**	3.2	μμf
Cathode No. 1 to Plate No. 1, Heater, and Internal Shield°	3.6	μμf
Cathode No. 2 to Plate No. 2, Heater, and Internal Shield°°	3.6	μμf
Plate No. 1 to Plate No. 2†	0.026 *max*	μμf

* With close-fitting external shield connected to Cathode No. 1.
** With close-fitting external shield connected to Cathode No. 2.
° With close-fitting external shield connected to Plate No. 1.
°° With close-fitting external shield connected to Plate No. 2.
† With close-fitting external shield connected to ground.

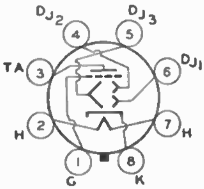
HALF-WAVE RECTIFIER

Maximum Ratings:

PEAK INVERSE PLATE VOLTAGE	330 *max*	volts
PEAK PLATE CURRENT PER PLATE	54 *max*	ma
DC OUTPUT CURRENT PER PLATE	9 *max*	ma
PEAK HEATER-CATHODE VOLTAGE:	330 *max*	volts
Heater negative with respect to cathode	330 *max*	volts
Heater positive with respect to cathode	330 *max*	volts

Typical Operation:

AC Plate Voltage per Plate (rms)	117	volts
Min. Total Effective Plate-Supply Impedance	300	ohms



ELECTRON-RAY TUBE

6AL7-GT

Glass octal type used to indicate visually on a pair of rectangular fluorescent patterns the effects of changes in voltages applied to its grid and three deflecting electrodes. It is especially useful in meeting the requirements for accurate tuning in FM receivers. Outline 17, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.15	ampere

INDICATOR SERVICE

Maximum Ratings:

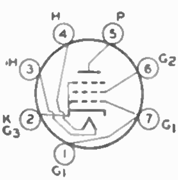
TARGET VOLTAGE	365 *max*	volts
	220 *min*	volts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Target Voltage	315	volts
Deflecting-Electrode-No.1 Voltage	0	volts
Deflecting-Electrode-No.2 Voltage	0	volts
Deflecting-Electrode-No.3 Voltage	0	volts
Cathode Resistor (Approx.)	3300	ohms
Deflection Sensitivity (Approx.)#	1	mm/volt
Grid Voltage for Fluorescence Cutoff (Approx.)*	–6	volts

#For first millimeter of unbalance in FM application.

*The grid should be connected to the cathode when not used for fluorescence control.



BEAM POWER AMPLIFIER

6AQ5

Miniature type used as output amplifier primarily in automobile receivers and in ac-operated receivers. Within its maximum ratings, the performance of the 6AQ5 is equivalent to that of larger types 6V6 and 6V6-GT. For typical circuits employing type 6AQ5, both singly and in push-pull, refer to CIRCUIT SECTION.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.45	ampere
Direct Interelectrode Capacitances:*		
Grid No. 1 to Plate	0.35	μμf
Input	7.6	μμf
Output	6.0	μμf

* No external shield. Approximate values.

CLASS A_1 AND CLASS AB_1 PUSH-PULL AMPLIFIER

Maximum Ratings:

Plate Voltage	250 *max*	volts
Grid-No. 2 Voltage	250 *max*	volts
Plate Dissipation	12 *max*	watts
Grid-No.2 Input	2 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Same as for type 6V6-GT within the limitations of the maximum ratings.

INSTALLATION AND APPLICATION

Type 6AQ5 requires a miniature seven-contact socket and may be mounted in any position. Outline 15, OUTLINES SECTION.

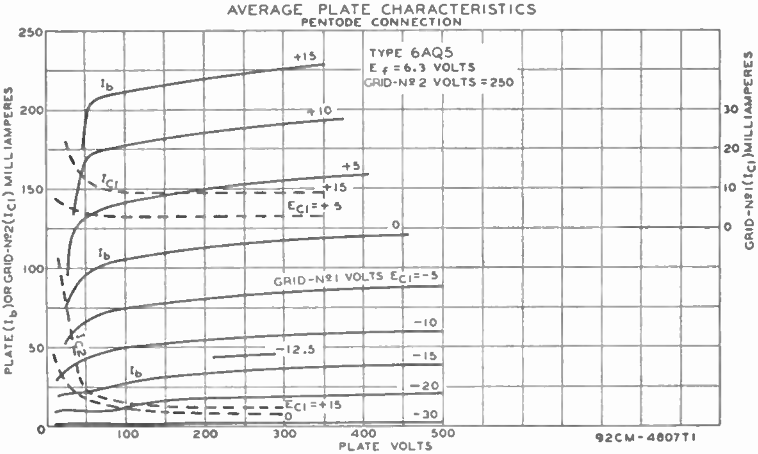
When the **heater** is operated on ac with a transformer, the winding of the transformer which supplies the heater circuit should operate the heater at the recommended value for full-load operating conditions at average line voltage. Under any condition of operation, the heater voltage should not be allowed to vary more than 10% from the rated value. When the 6AQ5 is used in automobile receivers, the heater terminals should be connected directly across the 6-volt battery.

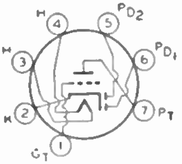
Use of type 6AQ5 in a series string arrangement should be limited to tubes with the same heater-current rating. If it is necessary to use the 6AQ5 in series with tubes having different heater ratings, shunt resistors are required. Refer to ELECTRON TUBE INSTALLATION SECTION for additional heater considerations.

The **cathode** of the 6AQ5 should preferably be connected directly to the electrical mid-point of the heater circuit when the heater voltage is supplied from a transformer. When the 6AQ5 is operated in receivers employing a 6-volt storage battery for the heater supply, its cathode circuit is tied in either directly or through bias resistors to the negative side of the dc plate supply which is furnished either by the dc power line or the ac line through a rectifier. Under any circumstances, the heater-cathode voltage should be kept within ratings. If the use of a large resistor is necessary in some circuit designs, it should be bypassed by a suitable filter network or objectionable hum may develop.

In all services, precautions should be taken to insure that the dissipation rating is not exceeded with expected line-voltage variations, especially in the cases of fixed-bias operation. When the push-pull connection is used, fixed-bias values up to 10% of each typical screen voltage can be used without increasing distortion.

The type of input coupling used in class A_1 and class AB_1 service should not introduce too much resistance in the grid-No.1 circuit. Transformer- or impedance-coupling devices are recommended. When the grid-No.1 circuit has a resistance not higher than 0.1 megohm, fixed bias may be used; for higher values, cathode bias is required. With cathode bias, the grid-No.1 circuit may have a resistance as high as, but not greater than, 0.5 megohm.





TWIN DIODE—HIGH-MU TRIODE

6AQ6

Miniature type used as a combined detector, amplifier, and avc tube in compact radio receivers. This type is similar to metal type 6Q7 in many of its electrical characteristics. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For typical operation as resistance-coupled amplifier, refer to Chart 7, RESISTANCE-COUPLED AMPLIFIER SECTION. For heater considerations, refer to type 6AV6.

Heater Voltage (AC/DC)	6.3	volts
Heater Current	0.15	ampere
Direct Interelectrode Capacitances (Triode Unit):°		
Grid to Plate	1.8	μμf
Input	1.7	μμf
Output	1.5	μμf

° With close-fitting shield connected to cathode.

TRIODE UNIT AS CLASS A_1 AMPLIFIER

Maximum Ratings:

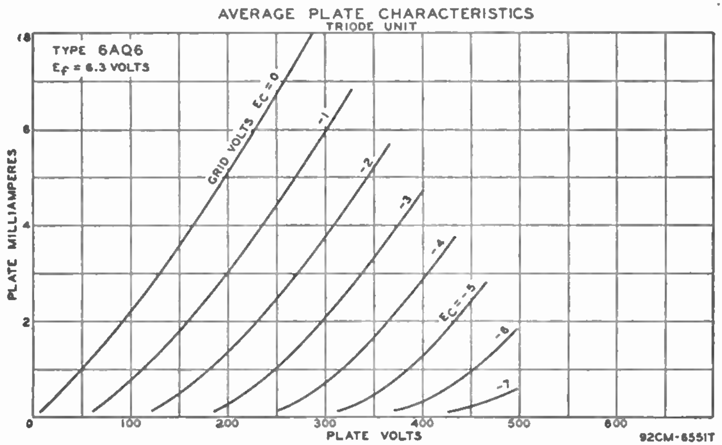
Plate Voltage	300 *max*	volts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Characteristics:

Plate Voltage	100	250	volts
Grid Voltage	−1	−3	volts
Amplification Factor	70	70	
Plate Resistance	61000	58000	ohms
Transconductance	1150	1200	μmhos
Plate Current	0.8	1.0	ma

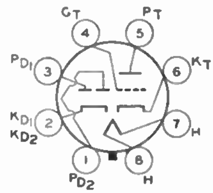
DIODE UNITS

Two diode plates are placed around a cathode, the sleeve of which is common to the triode unit. Diode biasing of the triode unit of the 6AQ6 is not suitable. For diode operation curves, refer to type 6SQ7.



6AQ7-GT

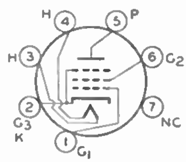
TWIN DIODE—HIGH-MU TRIODE



Glass octal type used as FM detector and audio amplifier in circuits which require diode and triode units with separate cathodes. Outline 22, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.3. Ratings and characteristics of triode unit as class A_1 amplifier: plate volts, 250 *max;* grid volts, -2; amplification factor, 70; plate resistance (approx.), 44000 ohms; transconductance, 1600 μmhos; plate ma., 2.3. For typical operation as a resistance-coupled amplifier, refer to Chart 7, RESISTANCE-COUPLED AMPLIFIER SECTION.

6AR5

POWER PENTODE



Miniature type used as output tube primarily in automobile receivers and ac-operated receivers. Outline 15, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to miniature type 6AQ5. Within its maximum ratings, type 6AR5 is equivalent in performance to glass-octal type 6K6-GT. Refer to type 6K6-GT for characteristic curves.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.4	ampere

CLASS A_1 AMPLIFIER

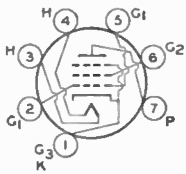
Maximum Ratings:		
Plate Voltage	250 *max*	volts
Grid-No.2 (screen) Voltage	250 *max*	volts
Plate Dissipation	8.5 *max*	watts
Grid-No.2 Input	2.5 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation and Characteristics:

Plate Voltage	250	250	volts
Grid-No.2 Voltage	250	250	volts
Grid-No.1 (Control-Grid) Voltage	−16.5	−18	volts
Peak AF Grid-No.1 Voltage	16.5	18	volts
Zero-Signal Plate Current	34	32	ma
Maximum-Signal Plate Current	35	33	ma
Zero-Signal Grid-No.2 Current	5.7	5.5	ma
Maximum-Signal Grid-No.2 Current	10	10	ma
Plate Resistance (Approx.)	65000	68000	ohms
Transconductance	2400	2300	μmhos
Load Resistance	7000	7600	ohms
Total Harmonic Distortion	7	11	per cent
Maximum-Signal Power Output	3.2	3.4	watts

Maximum Circuit Values (For maximum rated conditions):

Grid-No.1-Circuit Resistance	Fixed Bias	0.1 *max*	megohm
	Cathode Bias	0.5 *max*	megohm



BEAM POWER AMPLIFIER

6AS5

Miniature type used as output amplifier primarily in automobile and in ac-operated receivers. Outline 15, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AQ5. For curves, refer to type 35C5.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.8	ampere
DIRECT INTERELECTRODE CAPACITANCES (Approx.):°		
Grid No.1 to Plate	0.6	μμf
Input	12	μμf
Output	8.4	μμf

° With no external shield.

Maximum Ratings: CLASS A_1 AMPLIFIER

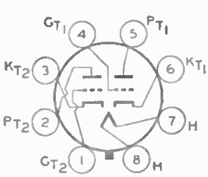
PLATE VOLTAGE	150 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	117 *max*	volts
PLATE DISSIPATION	5.5 *max*	watts
GRID-NO.2 INPUT	1.0 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts
BULB TEMPERATURE (At hottest point on bulb surface)	250 *max*	°C

Typical Operation:

Plate Voltage	150	volts
Grid-No.2 Voltage	110	volts
Grid-No.1 (Control-Grid) Voltage	−8.5	volts
Peak AF Grid-No.1 Voltage	8.5	volts
Zero-Signal Plate Current	35	ma
Maximum-Signal Plate Current	36	ma
Zero-Signal Grid-No.2 Current (Approx.)	2	ma
Maximum-Signal Grid-No.2 Current (Approx.)	6.5	ma
Transconductance	5600	μmhos
Load Resistance	4500	ohms
Total Harmonic Distortion	10	per cent
Maximum-Signal Power Output	2.2	watts

Maximum Circuit Values (For maximum rated conditions):

Grid-No.1-Circuit Resistance	Fixed Bias	0.1 *max*	megohm
	Cathode Bias	0.5 *max*	megohm



LOW-MU TWIN POWER TRIODE

6AS7-G

Glass octal type used as a regulator tube in dc power-supply units, as a booster tube in the scanning circuit of television receivers, and as a push-pull class A output tube in high-fidelity audio amplifiers. Outline 40, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. It is especially important that this tube, like other power-handling tubes, should be adequately ventilated. For an audio amplifier circuit employing this tube, refer to the CIRCUIT SECTION. An operation characteristic curve for the 6AS7-G in this amplifier circuit, is given on the next page.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	2.5	amperes
DIRECT INTERELECTRODE CAPACITANCES (Approx.):		
Grid to Plate	10.5	μμf
Input	6.8	μμf
Output	2.3	μμf
Heater to Cathode	6.7	μμf
Grid to Grid	0.70	μμf
Plate to Plate	1.65	μμf

Maximum Ratings: **DC AMPLIFIER (Each Unit)**

PLATE VOLTAGE	250 *max*	volts
PLATE CURRENT	125 *max*	ma
PLATE DISSIPATION	13 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	300 *max*	volts
Heater positive with respect to cathode	300 *max*	volts

Characteristics:

Plate-Supply Voltage	135	volts
Cathode-Bias Resistor*	250	ohms
Amplification Factor	2.0	
Plate Resistance	280	ohms
Transconductance	7000	μmhos
Plate Current	125	ma

Maximum Circuit Value (For maximum rated conditions):

Grid-Circuit Resistance for Cathode-Bias Operation*	1.0	megohm

Maximum Ratings: **BOOSTER SCANNING SERVICE (Each Unit)**

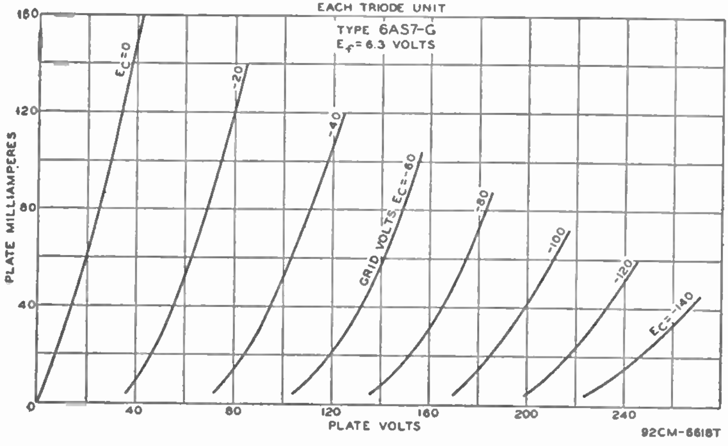
PEAK NEGATIVE-PULSE PLATE VOLTAGE	1700 *max*	volts
DC PLATE CURRENT	125 *max*	ma
PLATE DISSIPATION	13 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	300 *max*	volts
Heater positive with respect to cathode	300 *max*	volts

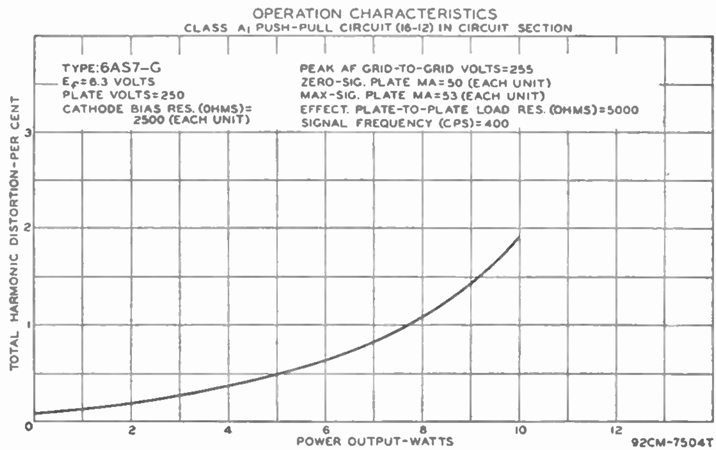
Maximum Circuit Value (For maximum rated conditions):

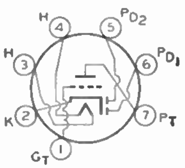
Grid-Circuit Resistance for Cathode-Bias Operation*	1.0	megohm

* Operation with fixed bias is not recommended.

AVERAGE PLATE CHARACTERISTICS
EACH TRIODE UNIT







TWIN DIODE—HIGH-MU TRIODE

6AT6

Miniature type used as a combined detector, amplifier, and avc tube in automobile and ac-operated radio receivers. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For typical operation as resistance-coupled amplifier, refer to Chart 7, RESISTANCE-COUPLED AMPLIFIER SECTION. For heater considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere
Direct Interelectrode Capacitances (No external shield):		
Triode Grid to Plate	2.0	μμf
Triode Input	2.2	μμf
Triode Output	0.8	μμf
Diode Plate No.2 to Triode Grid	0.04 *max*	μμf

TRIODE UNIT AS CLASS A1 AMPLIFIER

Maximum Ratings:

Plate Voltage	300 *max*	volts
Plate Dissipation	0.5 *max*	watt
Grid Voltage, Positive Bias Value	0 *max*	volts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Characteristics:

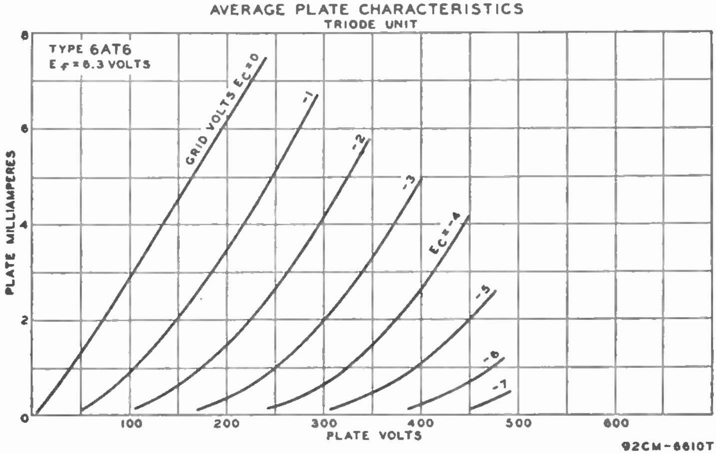
Plate Voltage	100	250	volts
Grid Voltage	-1	-3	volts
Amplification Factor	70	70	
Plate Resistance	54000	58000	ohms
Transconductance	1300	1200	μmhos
Plate Current	0.8	1.0	ma

DIODE UNITS

Maximum Rating:

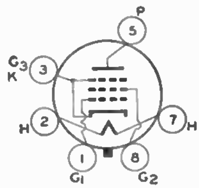
Plate Current (each unit)	1.0 *max*	ma

The two diode plates are placed around a cathode, the sleeve of which is common to the triode unit. Each diode plate has its own base pin. For diode operation curves, refer to type 6SQ7.



6AU5-GT

BEAM POWER AMPLIFIER



Glass octal type used as horizontal deflection amplifier in low-cost, high-efficiency deflection circuits of television receivers employing either transformer coupling or direct coupling to the deflecting yoke. Outline 21, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	1.25	amperes
Direct Interelectrode Capacitances (No external shield):		
Grid No.1 to Plate	0.5	μμf
Input	11.3	μμf
Output	7.0	μμf
Transconductance#	6000	μmhos
Mu-Factor, Grid No.2 to Grid No.1†	5.9	

For plate volts, 115; grid-No.2 volts, 175; grid-No.1 volts, –20.
† For plate volts, 100; grid-No.2 volts, 100; grid-No.1 volts, –4.5.

HORIZONTAL DEFLECTION AMPLIFIER

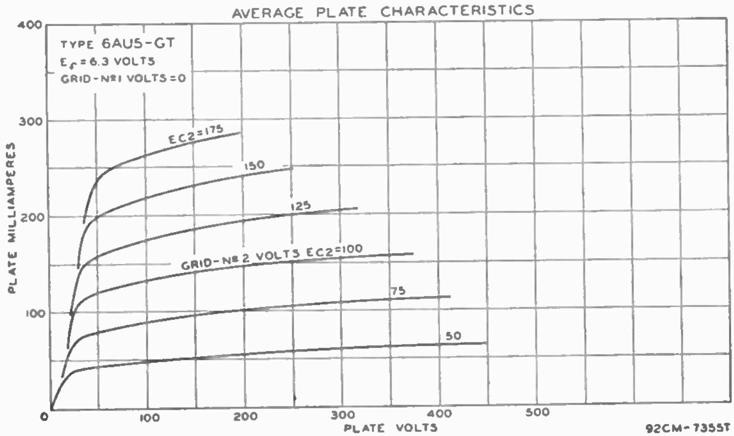
For operation in a 525-line, 30-frame system.

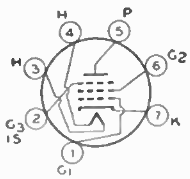
Maximum Ratings:

DC Plate Voltage	450 *max*	volts
Peak Positive-Pulse Plate Voltage*	5000 *max*	volts
Peak Negative-Pulse Plate Voltage*	–1000 *max*	volts
DC Grid-No.2 (screen) Voltage°	200 *max*	volts
DC Grid-No.1 (control-grid) Voltage	–50 *max*	volts
Peak Negative-Pulse Grid-No.1 Voltage	–100 *max*	volts
DC Plate Current	100 *max*	ma
Plate Dissipation	10 *max*	watts
Grid-No.2 Input	2.5 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	180 *max*	volts
Heater positive with respect to cathode	180 *max*	volts

* The duration of the voltage pulse must not exceed 15% of one horizontal scanning cycle. In a 525-line, 30-frame system, 15% of one horizontal scanning cycle is 10 microseconds.

° Preferably obtained through a series dropping resistor of sufficient magnitude to limit the grid-No.2 input to the rated maximum value.





SHARP-CUTOFF PENTODE

6AU6

Miniature type used in compact radio equipment as an rf amplifier especially in high-frequency, wide-band applications. It is also used as a limiter tube in FM equipment. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For a discussion of limiters, refer to ELECTRON TUBE APPLICATIONS SECTION. For typical operation as resistance-coupled amplifier, refer to Chart 8, RESISTANCE-COUPLED AMPLIFIER SECTION. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere
Direct Interelectrode Capacitances (No external shield):		
Grid No.1 to Plate	0.0035 *max*	μμf
Input	5.5	μμf
Output	5.0	μμf

CLASS A_1 AMPLIFIER

Maximum Ratings:	*Triode† Connection*	*Pentode Connection*	
Plate Voltage	250 *max*	300 *max*	volts
Grid-No.2 (screen) Voltage	–	150 *max*	volts
Grid-No.2 Supply Voltage	–	300 *max*	volts
Plate Dissipation	3.2 *max*	3 *max*	watts
Grid-No.2 Input	–	0.65 *max*	watt
Grid-No.1 (control-grid) Voltage:			
Negative bias value	50 *max*	50 *max*	volts
Positive bias value	0 *max*	0 *max*	volts
Peak Heater-Cathode Voltage:			
Heater negative with respect to cathode	90 *max*	90 *max*	volts
Heater positive with respect to cathode	90 *max*	90 *max*	volts

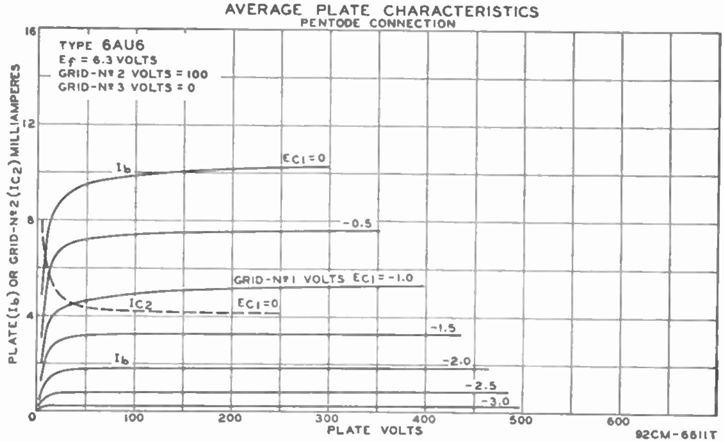
Typical Operation (Pentode Connection):

Plate Voltage	100	250	250	volts
Grid No.3 (Suppressor)	Connected to cathode at socket			
Grid-No.2 Voltage	100	125	150	volts
Cathode Resistor	150	100	68	ohms
Plate Resistance (Approx.)	0.5	1.5	1.0	megohms
Transconductance	3900	4500	5200	μmhos
Grid-No.1 Bias for plate current of 10 μa.	−4.2	−5.5	−6.5	volts
Plate Current	5.0	7.6	10.6	ma
Grid-No. 2 Current	2.1	3.0	4.3	ma

Typical Operation (Triode Connection):†

Plate Voltage	250	volts
Cathode Resistor	330	ohms
Amplification Factor	36	
Plate Resistance	7500	ohms
Transconductance	4800	μmhos
Plate Current	12.2	ma

† Grid No. 2 and grid No. 3 tied to plate.



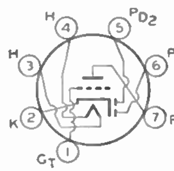
6AV5-GT

BEAM POWER AMPLIFIER

For technical data, see page 307.

6AV6

TWIN DIODE— HIGH-MU TRIODE



Miniature type used as combined detector, amplifier, and avc tube in automobile and ac-operated radio receivers. The 6AV6 may be substituted directly for the 6AT6 in applications where the higher amplification of the 6AV6 is advantageous.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Triode Grid to Triode Plate	2.0	μμf
Triode Input	2.2	μμf
Triode Output	0.8	μμf
Diode No.2 Plate to Triode Grid	0.04 *max*	μμf

Maximum Ratings: TRIODE UNIT AS CLASS A_1 AMPLIFIER

PLATE VOLTAGE	300 *max*	volts
GRID VOLTAGE, Positive Bias Value	0 *max*	volts
PLATE DISSIPATION	0.5 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Characteristics:

Plate Voltage	100	250	volts
Grid Voltage	–1	–2	volts
Amplification Factor	100	100	
Plate Resistance	80000	62500	ohms
Transconductance	1250	1600	μmhos
Plate Current	0.50	1.2	ma

Maximum Rating: DIODE UNITS

PLATE CURRENT (Each Unit)	1.0 *max*	ma

The two diode plates are placed around a cathode, the sleeve of which is common to the triode unit. Each diode plate has its own base pin. Diode biasing of the triode unit is not recommended. For diode operation curves, refer to type 6SQ7.

INSTALLATION AND APPLICATION

Type 6AV6 requires miniature seven-contact socket and may be mounted in any position. Outline 12, OUTLINES SECTION.

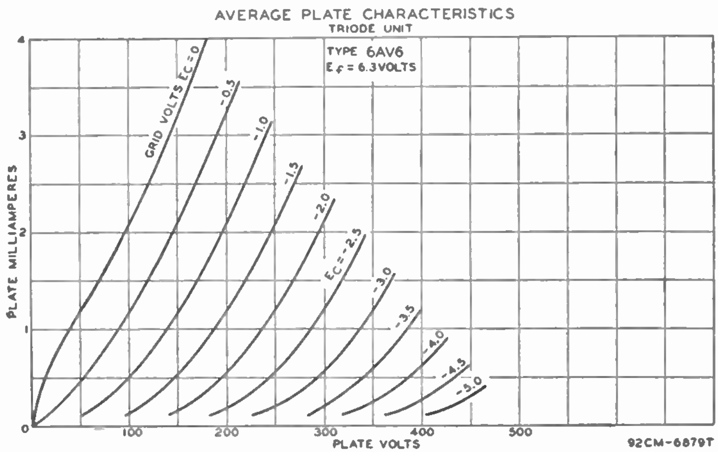
When the **heater** is operated on ac with a transformer, the winding of the transformer which supplies the heater circuit should operate the heater at the recommended value for full-load operating conditions at average line voltage. Under any condition of operation, the heater voltage should not be allowed to rise more than 10% above the rated value. When the 6AV6 is used in automobile receivers, the heater terminals should be connected directly across a 6-volt battery.

In receivers that employ a series-heater connection, the heater of the 6AV6 may be operated in series with the heater of other types having the same heater-current rating. The current in the heater circuit of the 6AV6 should be adjusted to the rated value for the normal supply voltage. Refer to ELECTRON TUBE INSTALLATION SECTION, **Filament and Heater Power Supply**, for a discussion of arrangement of heaters in series-heater or "string" connection.

The **cathode** of the 6AV6 when operated from a transformer, should preferably be connected directly to the electrical mid-point of the heater circuit. When operated in receivers employing a 6-volt storage battery for the heater supply, the cathode circuit is tied in either directly or through bias resistors to the negative side of the dc plate supply which is furnished either by the dc power line or the ac line through a rectifier. In circuits where the cathode is not connected directly to the heater, such as in a series-heater connection, the voltage difference between the heater and cathode should be kept within the tube ratings. If the use of a large resistor is necessary between the heater and cathode in some circuit designs, it should be bypassed by a suitable filter network or objectionable hum may develop.

The triode unit of the 6AV6 is recommended for use only in resistance-coupled circuits. Refer to the RESISTANCE-COUPLED AMPLIFIER SECTION, Chart 25 for typical operating conditions.

Grid bias for the triode unit of the 6AV6 may be obtained from a fixed source, such as a fixed-voltage tap on the dc power supply or from a cathode-bias resistor. It should not be obtained by the diode-biasing method because of the probability of plate-current cutoff, even with relatively small signal voltages applied to the diode circuit.



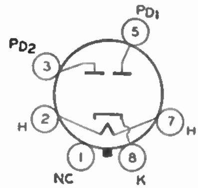
6AX4-GT

HALF-WAVE VACUUM RECTIFIER

For technical data, see page 308.

6AX5-GT

FULL-WAVE VACUUM RECTIFIER



Glass octal type used in power supply of radio equipment having moderate dc requirements. The heater of this tube can be operated from the same transformer winding that supplies other 6.3-volt tubes in the receiver. In addition, because its heater-cathode construction gives the same heating time as that of other heater-cathode types in the receiver, use of the 6AX5-GT prevents excessive voltages from appearing across filter capacitors during warmup, and, as a result, permits the use of electrolytic filter capacitors having lower peak voltage ratings than required for a filament-type rectifier tube.

HEATER VOLTAGE (AC)	6.3	volts
HEATER CURRENT	1.2	amperes

FULL-WAVE RECTIFIER

Maximum Ratings:

PEAK INVERSE PLATE VOLTAGE	1250 *max*	volts
PEAK PLATE CURRENT PER PLATE	375 *max*	ma
HOT-SWITCHING TRANSIENT PLATE CURRENT		
For duration of 0.2 second maximum	2.6 *max*	amperes
AC PLATE SUPPLY VOLTAGE PER PLATE (RMS)	*See Rating Chart*	
DC OUTPUT CURRENT PER PLATE (RMS)	*See Rating Chart*	
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	450 *max*	volts
Heater positive with respect to cathode	450 *max*	volts

Typical Operation with Capacitor Input to Filter:

AC Plate-to-Plate Supply Voltage (rms)	700	900	volts
Filter Input Capacitor*	10	10	µf
Effective Plate-Supply Impedance Per Plate	50	105	ohms
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of 62.5 ma	395	–	volts
At half-load current of 40 ma	–	540	volts
At full-load current of 125 ma	350	–	volts
At full-load current of 80 ma	–	490	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	45	50	volts

Typical Operation with Choke Input to Filter:

AC Plate-to-Plate Supply Voltage (rms)	700	900	volts
Filter Input Choke	10#	10##	henries
DC Output Voltage at Input to Filter (Approx.):			
At half-load current of 75 ma	270	–	volts
At half-load current of 62.5 ma	–	365	volts
At full-load current of 150 ma	250		volts
At full-load current of 125 ma	–	350	volts
Voltage Regulation (Approx.):			
Half-load to full-load current	20	15	volts

* Higher values of capacitance than indicated may be used but the effective plate-supply impedance may have to be increased to prevent exceeding the maximum rating for hot-switching transient plate current.

This value is adequate to maintain optimum regulation in the region to the right of line L=10H on curve OPERATION CHARACTERISTICS With Choke Input to Filter, provided the load current is not less than 30 ma. For load currents less than 30 ma, a larger value of inductance is required for optimum regulation.

This value is adequate to maintain optimum regulation in the region to the right of line L=10H on curve OPERATION CHARACTERISTICS With Choke Input to Filter, provided the load current is not less than 35 ma. For load currents less than 35 ma, a larger value of inductance is required for optimum regulation.

INSTALLATION AND APPLICATION

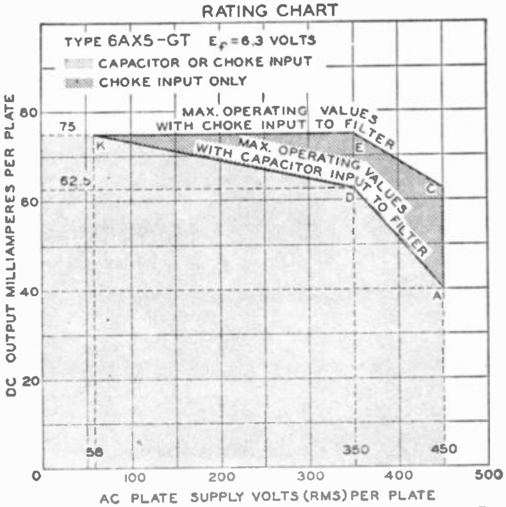
Type 6AX5-GT requires an octal socket and may be mounted in any position. Outline 21, OUTLINES SECTION. It is especially important that this tube, like other power-handling tubes, should be adequately ventilated.

The *Rating Chart* presents graphically the relationships between maximum ac voltage input and maximum dc output current derived from the fundamental ratings for conditions of capacitor-input and choke-input filters. This graphical presentation provides for considerable latitude in choice of operating conditions.

The *Operation Characteristics* for a full-wave rectifier with capacitor-input filter, show by means of boundary line "ADK" the limiting current and voltage relationships presented in the Rating Chart.

The *Operation Characteristics* for a full-wave rectifier with choke-input filter not only show by means of boundary line "CEK" the limiting current and voltage relationships presented in the Rating Chart, but also give information as to the effect on regulation of various sizes of chokes. The solid-line curves show the dc voltage outputs which would be obtained if the filter chokes had infinite inductance. The long-dash lines radiating from the zero position are boundary lines for various sizes of chokes as indicated. The intersection of one of these lines with a solid-line curve indicates the point on the curve at which the choke no longer behaves as though it had infinite inductance. To the left of the choke boundary line, the regulation curves depart from the solid-line curves as shown by the representative short-dash regulation curves.

RATING CHART



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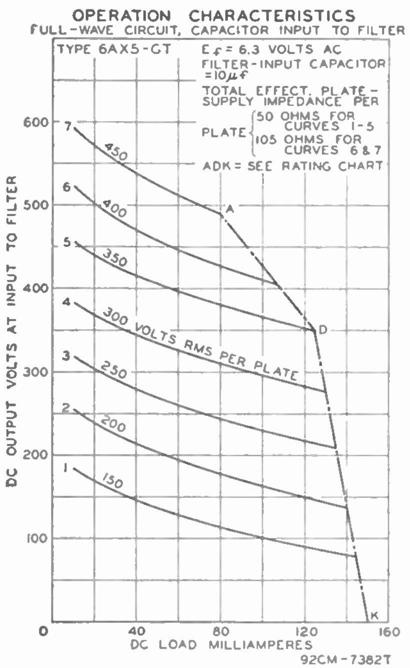
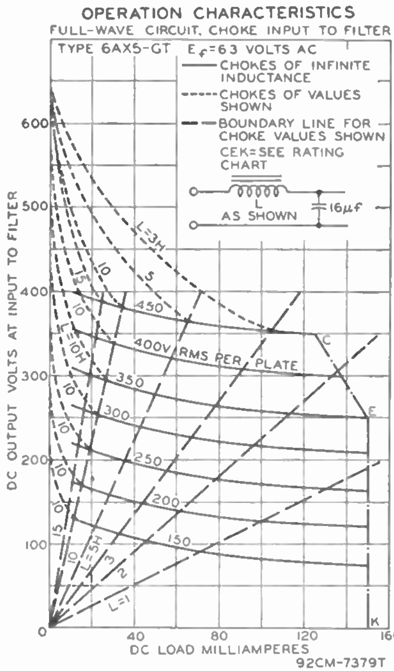
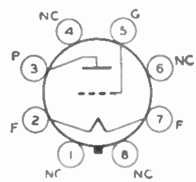




6B4-G

POWER TRIODE



Glass octal type used in output stage of radio receivers and amplifiers. Outline 40, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For installation and application information, and typical operation as a single-tube class A amplifier, refer to type 2A3.

Filament Voltage (ac/dc)	6.3	volts
Filament Current	1.0	ampere

PUSH-PULL CLASS AB_1 AMPLIFIER

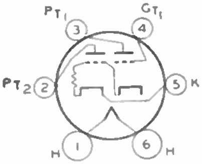
Maximum Ratings:

Plate Voltage	325 *max*	volts
Plate Dissipation	15 *max*	watts

Typical Operation (Values are for Two Tubes):

	Fixed Bias	*Cathode Bias*	
Plate Voltage	325	325	volts
Grid Voltage*	–68	–	volts
Cathode-Bias Resistor	–	850	ohms
Plate Current	80	80	ma
Effective Load Resistance (Plate-to-plate)	3000	5000	ohms
Total Harmonic Distortion	2.5	5	per cent
Power Output	15	10	watts

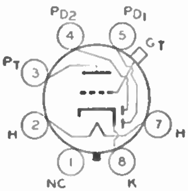
* Grid voltage referred to mid-point of ac-operated filament.



DIRECT-COUPLED POWER TRIODE

6B5

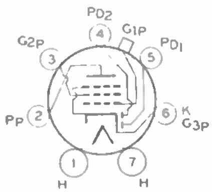
Glass type used as class A_1 power amplifier. One triode, the driver, is directly connected within the tube to the second, or output, triode. Outline 36, OUTLINES SECTION. Tube requires six-contact socket. Heater volts (ac/dc), 6.3; amperes, 0.8. Characteristics of input and output triodes as class A_1 amplifier follow. Input triode: plate volts, 300 *max;* grid volts, 0; plate ma., 8. Output triode: plate volts, 300 *max;* plate ma., 45; plate resistance, 24000 ohms; load resistance, 7000 ohms; output watts, 4. This type is used principally for renewal purposes.



TWIN-DIODE—HIGH-MU TRIODE

6B6-G

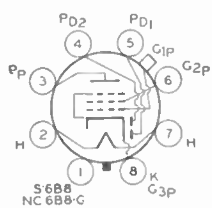
Glass octal type used as combined detector, amplifier, and avc tube. Outline 33, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.3. Within its triode maximum plate-voltage rating of 250 volts, this type is similar electrically to type 6SQ7 and curves under that type apply to the 6B6-G. This type is used principally for renewal purposes.



TWIN-DIODE— REMOTE-CUTOFF PENTODE

6B7
6B7S

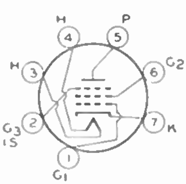
Glass types used as combined detector, amplifier, and avc tubes. Outline 34, OUTLINES SECTION. These types fit the small seven-contact (0.75-inch, pin-circle diameter) socket. Except for interelectrode capacitances, the electrical characteristics of the 6B7 are identical with those of type 6B8-G. Type 6B7 is used principally for renewal purposes. Type 6B7S, now DISCONTINUED, has the external shield connected to the cathode. In general, its electrical characteristics are similar to those of the 6B7, but the two types are usually not directly interchangeable.



TWIN-DIODE— REMOTE-CUTOFF PENTODE

6B8
6B8-G

Metal type 6B8 and glass octal type 6B8-G are used as combined detector, amplifier, and avc tubes. Outlines 4 and 33, respectively, OUTLINES SECTION. Type 6B8-G is used principally for renewal purposes. Tubes require octal socket. Type 6B8-G requires complete shielding of detector circuits. Heater volts (ac/dc), 6.3; amperes, 0.3. Maximum ratings of pentode unit as class A_1 amplifier: plate volts, 300 *max;* grid-No.2 (screen) volts, 125 *max;* grid-No.2 supply volts, 300 *max;* grid-No.1 volts, 0 *min;* plate dissipation, 3.0 *max* watts (6B8), 2.25 *max* watts (6B8-G); grid-No.2 input, 0.3 *max* watt. For typical operation as a resistance-coupled amplifier, refer to Chart 5, RESISTANCE-COUPLED AMPLIFIER SECTION.



REMOTE-CUTOFF PENTODE

6BA6

Miniature type used as rf amplifier in standard broadcast and FM receivers, as well as in wide-band, high-frequency applications. This type is similar in performance to metal type 6SG7. The low value of grid-No.1-to-plate capacitance minimizes regenerative effects, while the high transconductance makes possible high signal-to-noise ratio.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.0035 *max*	μμf
Input	5.5	μμf
Output	5.0	μμf

CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	125 *max*	volts
GRID-No.2 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	3 *max*	watts
GRID-No.2 INPUT	0.6 *max*	watt
GRID-No.1 (CONTROL-GRID) VOLTAGE:		
Negative bias value	50 *max*	volts
Positive bias value	0 *max*	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:

Plate Voltage	100	250	volts
Grid No.3 (Suppressor)	Connected to cathode at socket		
Grid-No.2 Voltage	100	100	volts
Cathode-Bias Resistor	68	68	ohms
Plate Resistance (Approx.)	0.25	1.0	megohm
Transconductance	4300	4400	μmhos
Grid-No.1 Bias (Approx.) for transconductance of 40 μmhos	-20	-20	volts
Plate Current	10.8	11	ma
Grid-No.2 Current	4.4	4.2	ma

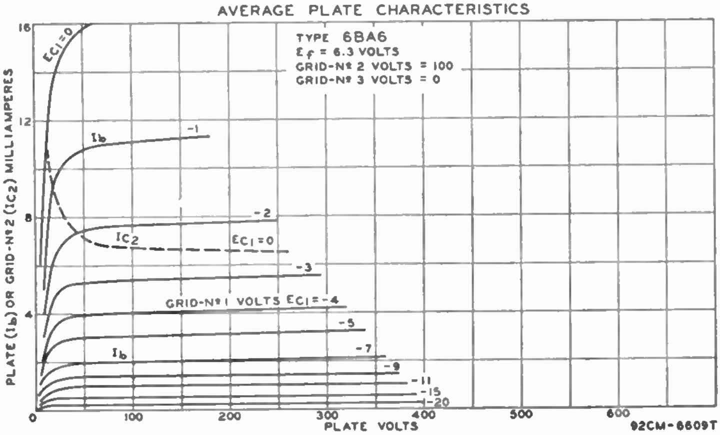
INSTALLATION AND APPLICATION

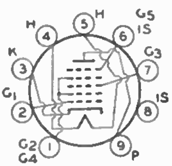
Type 6BA6 requires miniature seven-contact socket and may be mounted in any position. Outline 12, OUTLINES SECTION. For heater and cathode considerations, refer to type 6AV6.

Control-grid bias variation will be found effective in changing the volume of the receiver. In order to obtain adequate volume control, an available grid-No.1-bias voltage of approximately 50 volts will be required. The exact value will depend upon the circuit design and operating conditions. This voltage may be obtained, depending on the receiver requirements, from a potentiometer across a fixed supply voltage, from a variable cathode-bias resistor, from the avc system, or from a combination of these methods.

The **grid-No. 2 (screen)** voltage may be obtained from a potentiometer or bleeder circuit across the B-supply source, or through a dropping resistor from the plate supply. The use of series resistors for obtaining satisfactory control of grid-No.2 voltage in the case of four-electrode tubes is usually impossible because of secondary-emission phenomena. In the 6BA6, however, because grid No.3 practically removes these effects, it is practical to obtain grid-No.2 voltage through a series-dropping resistor from the plate supply or from some high intermediate voltage, providing these sources do not exceed the plate-supply voltage. With this method, the grid-No.2-to-cathode voltage will fall off very little from minimum to maximum value of the resistor controlling cathode bias. In some cases, it may actually rise. This rise of grid-No.2-to-cathode voltage above the normal maximum value is allowable because both the grid-No.2 current and the plate current are reduced simultaneously by a sufficient amount to prevent damage to the tube. It should be recognized that, in general, the series-resistor method of obtaining grid-No.2 voltage from a higher voltage supply necessitates the use of the variable cathode-resistor method of controlling volume in order to prevent too high a voltage on grid No.2. When grid-No.2 and control-grid voltage are obtained in this manner, the remote "cutoff" advantage of the 6BA6 can be fully realized. However, it should be noted that the use of a resistor in the grid-No.2 circuit will have an effect on the change in plate resistance with variation in grid-No.3 (suppressor) voltage in case grid No.3 is utilized for control purposes.

Grid No. 3 (suppressor) may be connected directly to the cathode or it may be made negative with respect to the cathode. For the latter condition, the grid-No.3 voltage may be obtained from a potentiometer or bleeder circuit, or from the avc system.





PENTAGRID CONVERTER

6BA7

Miniature type used as converter in superheterodyne circuits especially those for the FM broadcast band. Outline 16, OUTLINES SECTION. Tube requires noval nine-contact socket and may be mounted in any position. Its characteristics are similar to those of metal type 6SB7-Y. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (Without shield):		
Grid No.3 to All Other Electrodes (RF Input)	9.5	μμf
Plate to All Other Electrodes (Mixer Output)	8.3	μμf
Grid No.1 to All Other Electrodes (Oscillator Input)	6.7	μμf
Grid No.3 to Plate	0.19 *max*	μμf
Grid No.1 to Grid No.3	0.1 *max*	μμf
Grid No.1 to Plate	0.05 *max*	μμf
Grid No.1 to All Other Electrodes Except Cathode	3.4	μμf
Grid No.1 to Cathode	3.3	μμf
Cathode to All Other Electrodes Except Grid No.1	4.0	μμf

Maximum Ratings: CONVERTER SERVICE

PLATE VOLTAGE	300 *max*	volts
GRID-NO.5-AND-INTERNAL-SHIELD VOLTAGE▲	0 *max*	volts
GRIDS-NO.2-AND-NO.4 VOLTAGE	100 *max*	volts
GRIDS-NO.2-AND-NO.4 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	2.0 *max*	watts
GRIDS-NO.2-AND-NO.4 INPUT	1.5 *max*	watts
TOTAL CATHODE CURRENT	22 *max*	ma
GRID-NO.3 VOLTAGE:		
Negative bias value	100 *max*	volts
Positive bias value	0 *max*	volts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Characteristics (Separate Excitation):*

Plate Voltage	100	250	volts
Grid No.5 and Internal Shield▲	Connected directly to ground		
Grids-No.2-and-No.4 (Screen) Voltage	100	100	volts
Grid-No.3 (Control-Grid) Voltage	−1.0	−1.0	volt
Grid-No.1 (Oscillator-Grid) Resistor	20000	20000	ohms
Plate Resistance (Approx.)	0.5	1.0	megohm
Conversion Transconductance	900	950	μmhos
Conversion Transconductance (Approx.)**	3.5	3.5	μmhos
Plate Current	3.6	3.8	ma
Grids-No 2-and-No.4 Current	10.2	10	ma
Grid-No.1 Current	0.35	0.35	ma
Total Cathode Current	14.2	14.2	ma

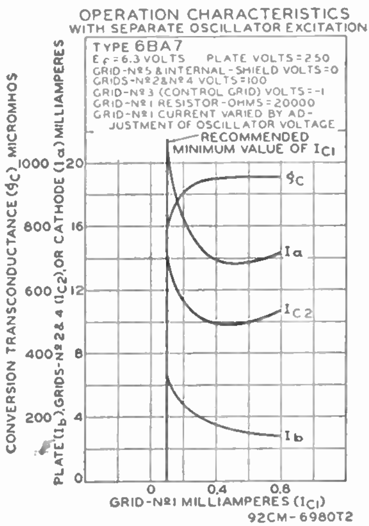
NOTE: The transconductance between grid No.1 and grids No.2 and No.4 connected to plate (not oscillating) is approximately 8000 μmhos under the following conditions: signal applied to grid No.1 at zero bias; grids No.2 and No.4 and plate at 100 volts; grid No.3 grounded. Under the same conditions, the plate current is 32 milliamperes, and the amplification factor is 16.5.

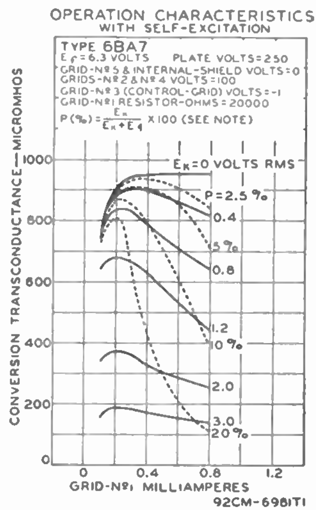
*The characteristics shown with separate excitation correspond very closely with those obtained in a self-excited oscillator circuit operating with zero bias.

**With grid-No.3 bias of −20 volts.

▲Internal Shield (pins No.6 and No.8) connected directly to ground.

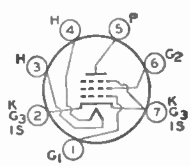
NOTE ON CURVES: In the 6BA7 operation characteristics with self-excitation, E_k is the voltage across the oscillator-coil section between cathode and ground; E_g is the oscillator voltage between cathode and grid.



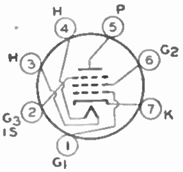


6BC5

SHARP-CUTOFF PENTODE



Miniature type used in compact radio equipment as an rf or if amplifier at frequencies up to 400 megacycles per second. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. Except for a slightly higher transconductance, this type is similar electrically to type 6AG5. Heater volts (ac/dc), 6.3; amperes, 0.3. For heater and cathode considerations, refer to type 6AV6.



REMOTE-CUTOFF PENTODE

6BD6

Miniature type used as rf or if amplifier in radio receivers. This type is similar in performance to metal type 6SK7. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.005 *max*	μμf
Input	4.3	μμf
Output	5.0	μμf

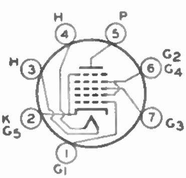
CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	125 *max*	volts
PLATE DISSIPATION	3.0 *max*	watts
GRID-No.2 INPUT	0.65 *max*	watt
TOTAL CATHODE CURRENT	14 *max*	ma
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate Voltage	100	125	250	volts
Grid-No.2 Voltage	100	125	100	volts
Grid-No.1 (Control-Grid) Voltage	−1	−3	−3	volts
Plate Resistance (Approx.)	0.15	0.18	0.8	megohm
Transconductance	2550	2350	2000	μmhos
Grid-No.1 Bias (Approx.) for transconductance of 10 μmhos	−35	−45	−35	volts
Plate Current	13	13	9	ma
Grid-No.2 Current	5	5	3	ma



PENTAGRID CONVERTER

6BE6

Miniature type used as converter in superheterodyne circuits in both the standard broadcast and FM bands. The 6BE6 is similar in performance to metal type 6SA7. For general discussion of pentagrid types, see **Frequency Conversion** in ELECTRON TUBE APPLICATION SECTION.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.3 to All Other Electrodes (RF Input)	7.0	μμf
Plate to All Other Electrodes (Mixer Output)	8.0	μμf
Grid No.1 to All Other Electrodes (Osc. Input)	5.5	μμf
Grid No.3 to Plate	0.30 *max*	μμf
Grid No.1 to Grid No.3	0.15 *max*	μμf
Grid No.1 to Plate	0.1 *max*	μμf
Grid No.1 to All Other Electrodes Except Cathode	2.7	μμf
Grid No.1 to Cathode	2.8	μμf
Cathode to All Other Electrodes Except Grid No.1	15	μμf

CONVERTER SERVICE

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
GRIDS-NO.2-AND-NO.4 VOLTAGE	100 *max*	volts
GRIDS-NO.2-AND-NO.4 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	1.0 *max*	watt
GRIDS-NO.2-AND-NO.4 INPUT	1.0 *max*	watt
TOTAL CATHODE CURRENT	14 *max*	ma
GRID-NO.3 VOLTAGE:		
Negative bias value	50 *max*	volts
Positive bias value	0 *max*	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 (Separate Excitation):*

Plate Voltage	100	250	volts
Grids-No.2-and-No.4 (Screen) Voltage	100	100	volts
Grid-No.3 (Control-Grid) Voltage	−1.5	−1.5	volts
Grid-No.1 (Oscillator-Grid) Resistor	20000	20000	ohms
Plate Resistance (Approx.)	0.4	1.0	megohm
Conversion Transconductance	455	475	μmhos
Grid-No. 3 Voltage for conversion transconductance of 10 μmhos	−30	−30	volts
Plate Current	2.6	2.9	ma
Grids-No.2-and-No.4 Current	7.0	6.8	ma
Grid-No.1 Current	0.5	0.5	ma
Total Cathode Current	10.1	10.2	ma

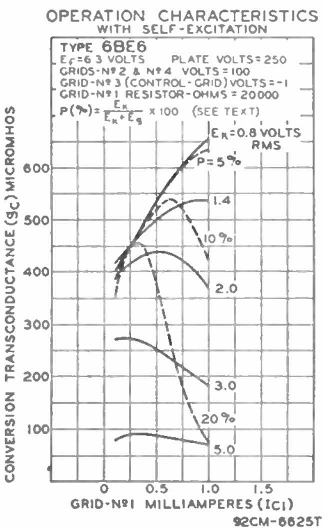
Note: The transconductance between grid No.1 and grids No.2 and No.4 connected to plate (not oscillating) is approximately 7250 μmhos under the following conditions: grids No.1 and No.3 at 0 volts; grids No.2 and No.4 and plate at 100 volts. Under the same conditions, the plate current is 25 ma., and the amplification factor is 20.

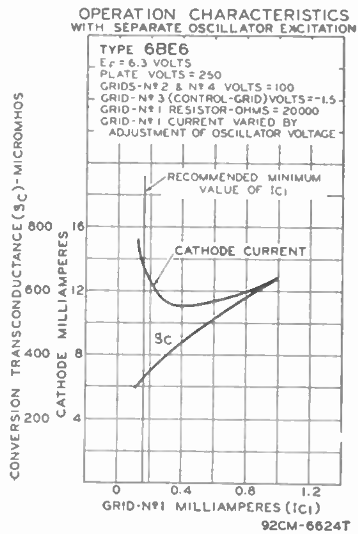
* The characteristics shown with separate excitation correspond very closely with those obtained in a self-excited oscillator circuit operating with zero bias.

INSTALLATION AND APPLICATION

Type 6BE6 requires miniature seven-contact socket and may be mounted in any position. Outline 12, OUTLINES SECTION. For heater and cathode considerations, refer to type 6AV6.

Because of the special structural arrangement of the 6BE6, a change in signal-grid voltage produces little change in cathode current. Consequently, an rf voltage





on the signal grid produces little modulation of the electron current flowing in the cathode circuit. This feature is important because it is desirable that the impedance in the cathode circuit should produce little degeneration or regeneration of the signal-frequency input and intermediate-frequency output. Another important feature is that, because signal-grid voltage has very little effect on the space charge near the cathode, changes in avc bias produce little change in oscillator transconductance and in the input capacitance of grid No.1. There is, therefore, little detuning of the oscillator by avc bias.

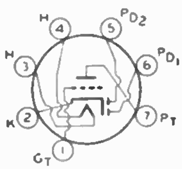
A typical self-excited oscillator circuit employing the 6BE6 is given in the CIRCUIT SECTION.

In the 6BE6 operation characteristics curves with self-excitation, E_k is the voltage across the oscillator-coil section between cathode and ground; E_g is the oscillator voltage between cathode and grid.

BEAM POWER AMPLIFIER — 6BF5

For technical data, see page 308

TWIN DIODE— MEDIUM-MU TRIODE — 6BF6



Miniature type used in compact radio equipment as combined detector, amplifier, and avc tube. The triode unit is particularly useful as a driver for impedance- or transformer-coupled output stages in automobile receivers. It is equivalent in performance to metal type 6SR7. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For typical operation as a resistance-coupled amplifier, refer to Chart 9, RESISTANCE-COUPLED AMPLIFIER SECTION. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (Triode Unit):		
Grid to Plate	2.0	μμf
Grid to Cathode	1.8	μμf
Plate to Cathode	1.4	μμf

* With external shield connected to cathode.

TRIODE UNIT AS CLASS A_1 AMPLIFIER

Maximum Ratings:

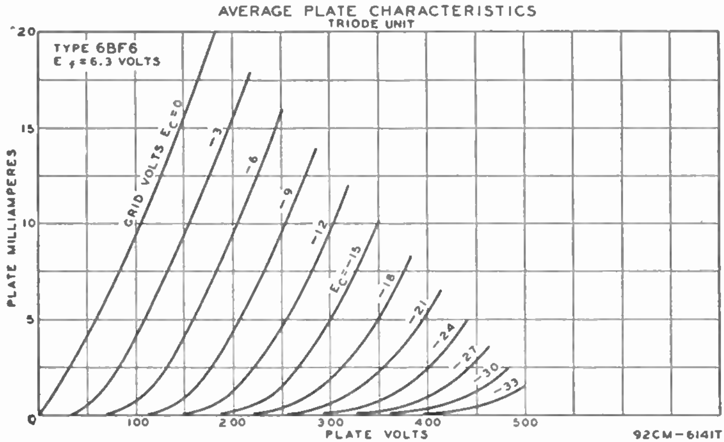
PLATE VOLTAGE	300 *max*	volts
PLATE DISSIPATION	2.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation (With Transformer Coupling):

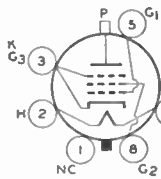
Plate Voltage	250	volts
Grid Voltage	-9	volts
Amplification Factor	16	
Plate Resistance	8500	ohms
Transconductance	1900	μmhos
Plate Current	9.5	ma
Load Resistance	10000	ohms
Total Harmonic Distortion	6.5	per cent
Power Output	300	mw

DIODE UNITS

The two diode plates and the triode unit have a common cathode. Diode biasing of the triode unit of the 6BF6 is not suitable. For diode operation curves, refer to type 6SQ7.



BEAM POWER AMPLIFIER



6BG6-G

Glass octal type used as output amplifier in horizontal-deflection circuits of television equipment and other applications where high pulse voltages occur during short duty cycles. Outline 42, OUTLINES SECTION. Tube requires octal socket. Vertical tube mounting is preferred but horizontal operation is permissible if pins No.2 and 7 are in vertical plane.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.9	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.65 *max*	μμf
Input	11	μμf
Output	6.5	μμf
TRANSCONDUCTANCE°	6000	μmhos
MU-FACTOR, Grid No.2 to Grid No.1°°	8	

° For plate volts, 250; grid-No.2 volts, 250; grid-No.1 volts, –15.

°° For plate volts, 250; grid-No.2 volts, 250; grid-No.1 volts, –20.

HORIZONTAL DEFLECTION AMPLIFIER

For operation in a 525-line, 30-frame system

Maximum Ratings:

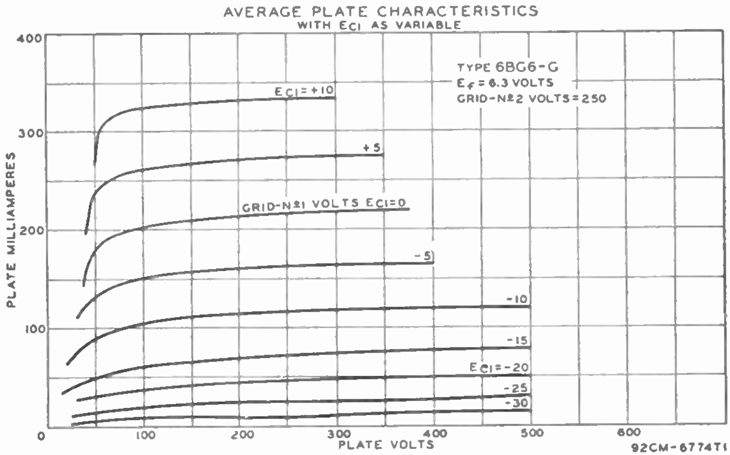
DC PLATE VOLTAGE	700 *max*	volts
PEAK POSITIVE PULSE PLATE VOLTAGE*	6000 *max*	volts
PEAK NEGATIVE PULSE PLATE VOLTAGE*	–1500 *max*	volts
DC GRID-NO.2 (SCREEN) VOLTAGE†	350 *max*	volts
DC GRID-NO.1 (CONTROL-GRID) VOLTAGE	–50 *max*	volts
PEAK NEGATIVE PULSE GRID-NO.1 VOLTAGE*	–400 *max*	volts
DC PLATE CURRENT	100 *max*	ma
PLATE DISSIPATION	20 *max*	watts
GRID-NO.2 INPUT	3.2 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	135 *max*	volts
Heater positive with respect to cathode	135 *max*	volts

Maximum Circuit Value:

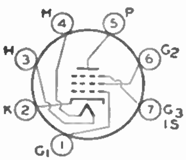
GRID-NO.1 CIRCUIT RESISTANCE	1.0 *max*	megohm

* The duration of the voltage pulse must not exceed 15% of one horizontal scanning cycle. In a 525-line, 30-frame system, 15% of one horizontal scanning cycle is 10 microseconds.

† Preferably obtained through a series dropping resistor of sufficient magnitude to limit the grid-No.2 input to the rated maximum value.



SHARP-CUTOFF PENTODE



6BH6

Miniature type used as rf amplifier particularly in ac/dc receivers and in mobile equipment where low heater-current drain is important. It is particularly useful in high-frequency, wide-band applications. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

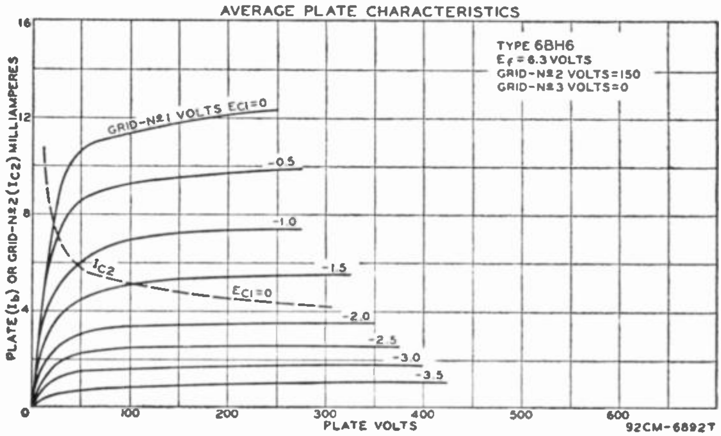
HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.15	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.0035 *max*	μμf
Input	5.4	μμf
Output	4.4	μμf

Maximum Ratings: CLASS A_1 AMPLIFIER

PLATE VOLTAGE	300 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	150 *max*	volts
GRID-No.2 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	3 *max*	watts
GRID-No.2 INPUT	0.5 *max*	watt
GRID-No.1 (CONTROL-GRID) VOLTAGE:		
Negative bias value	50 *max*	volts
Positive bias value	0 *max*	volts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

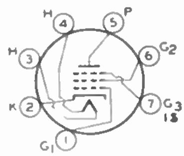
Typical Operation and Characteristics:

Plate Voltage	100	250	volts
Grid-No.3 (Suppressor)	Connected to cathode at socket		
Grid-No.2 Voltage	100	150	volts
Grid-No.1 Voltage	-1	-1	volt
Plate Resistance (Approx.)	0.7	1.4	megohms
Transconductance	3400	4600	μmhos
Grid-No.1 Bias for plate current of 10 μa	-5	-7.7	volts
Plate Current	3.6	7.4	ma
Grid-No.2 Current	1.4	2.9	ma



REMOTE-CUTOFF PENTODE

6BJ6



Miniature type used as rf amplifier in high-frequency and wide-band applications. Features high transconductance and low grid-to-plate capacitance. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

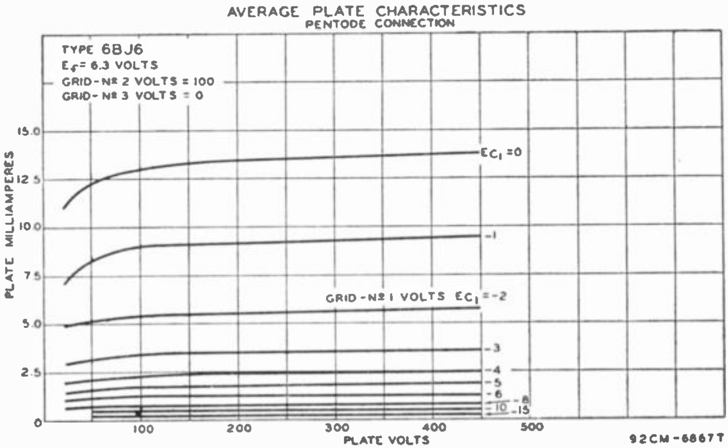
HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.15	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid No.1 to Plate	0.0035 *max*	μμf
Input	4.5	μμf
Output	5.5	μμf

Maximum Ratings: CLASS A_1 AMPLIFIER

PLATE VOLTAGE	300 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	125 *max*	volts
GRID-No.2 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	3 *max*	watts
GRID-No.2 INPUT	0.6 *max*	watt
GRID-No.1 (CONTROL-GRID) VOLTAGE:		
Negative bias value	50 *max*	volts
Positive bias value	0 *max*	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:

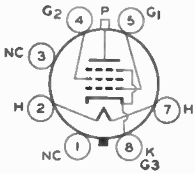
Plate Voltage	100	250	volts
Grid No.3 (Suppressor)	Connected to cathode at socket		
Grid-No.2 Voltage	100	100	volts
Grid-No.1 Voltage	−1.0	−1.0	volt
Plate Resistance (Approx.)	0.25	1.3	megohms
Transconductance	3650	3600	μmhos
Grid-No.1 Bias (Approx.) for transconductance of 15 μmhos	−20	−20	volts
Plate Current	9.0	9.2	ma
Grid-No.2 Current	3.5	3.3	ma



MEDIUM-MU TWIN TRIODE — 6BL7-GT

For technical data, see page 309.

BEAM POWER AMPLIFIER — 6BQ6-GT



Glass octal type used as horizontal deflection amplifier in television receivers employing either transformer coupling or direct coupling to the deflecting yoke. Outline 28, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	1.2	amperes
Direct Interelectrode Capacitances (No external shield):		
Grid No.1 to Plate	0.95	μμf
Input	14	μμ
Output	9.5	μμf
Transconductance*	5500	μmhos
Mu-Factor, Grid No.2 to Grid No.1*	4.5	

* For plate volts, 250; grid-No.2, volts, 150; grid-No.1 volts, -22.5; plate ma, 55, grid-No.2 ma, 2.1.

HORIZONTAL DEFLECTION AMPLIFIER

For operation in a 525-line, 30-frame system

Maximum Ratings:

DC Plate Voltage	550 *max*	volts
Peak Positive-Pulse Plate Voltage#	5000 *max*	volts
DC Grid-No.2 (screen) Voltage	200 *max*	volts
DC Grid-No.1 (control-grid) Voltage	-50 *max*	volts
Peak Negative-Pulse Grid-No.1 Voltage#	-135 *max*	volts
DC Plate Current	100 *max*	ma
Plate Dissipation†	10 *max*	watts
Grid-No.2 Input	2.5 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	180 *max*	volts
Heater positive with respect to cathode	180 *max*	volts

Maximum Circuit Values:

Grid-No.1 Circuit Resistance	0.5 *max*	megohm

#The duration of the voltage pulse must not exceed 15% of one horizontal scanning cycle. In a 525-line, 30-frame system, 15% of one horizontal scanning cycle is 10 microseconds.

†In the event of loss of excitation, a plate dissipation up to 30 watts for a duration not exceeding three minutes will not result in permanent damage to the tube. A cathode resistor of suitable value should be used to limit the no-signal plate dissipation to 30 watts.

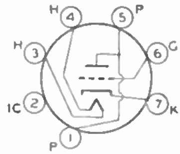
6BQ7
6BQ7-A

MEDIUM-MU TWIN TRIODE

For technical data, see page 310.

6C4

HF TRIODE



Miniature type used in compact radio equipment as a local oscillator in FM and other high-frequency circuits. It may also be used as a class C rf amplifier. In such service, it delivers a power output of 5.5 watts at moderate frequencies, and 2.5 watts at 150 megacycles per second. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For typical operation as a resistance-coupled amplifier, refer to Chart 10, RESISTANCE-COUPLED AMPLIFIER SECTION. For curve of average plate characteristics, see next page. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.15	ampere
DIRECT INTERELECTRODE CAPACITANCES (No external shield):		
Grid to Plate	1.6	μμf
Input	1.8	μμf
Output	1.3	μμf

CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
PLATE DISSIPATION	3.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	200 *max*	volts
Heater positive with respect to cathode	200 ■ *max*	volts

Characteristics:

Plate Voltage	100	250	volts
Grid Voltage*	0	-8.5	volts
Amplification Factor	19.5	17	
Plate Resistance	6250	7700	ohms
Transconductance	3100	2200	μmhos
Plate Current	11.8	10.5	ma

■ The dc component must not exceed 100 volts.

* The type of input coupling used should not introduce too much resistance in the grid circuit. Transformer- or impedance-coupling devices are recommended. Under maximum rated conditions, the resistance in the grid circuit should not exceed 0.25 megohm with fixed bias, or 1.0 megohm with cathode bias.

RF POWER AMPLIFIER AND OSCILLATOR—Class C Telegraphy

Maximum Ratings:

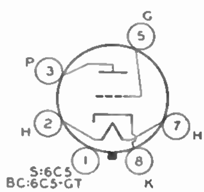
DC PLATE VOLTAGE	300 *max*	volts
DC GRID VOLTAGE	-50 *max*	volts
DC PLATE CURRENT	25 *max*	ma
DC GRID CURRENT	8 *max*	ma
PLATE DISSIPATION	5 *max*	watts

Typical Operation (At Moderate Frequencies):

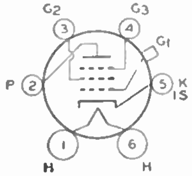
DC Plate Voltage	300	volts
DC Grid Voltage	-27	volts
DC Plate Current	25	ma
DC Grid Current (Approx.)	7	ma
Driving Power (Approx.)	0.35	watt
Power Output (Approx.)	5.5	watts

6C5
6C5-GT

MEDIUM-MU TRIODE



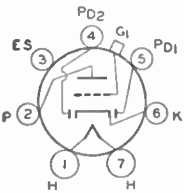
Metal type 6C5 and glass-octal type 6C5-GT used as audio amplifier and oscillator. They are also used as detectors of grid-resistor-and-capacitor type or grid-bias type. Outlines 3 and 24, respectively, OUTLINES SECTION. Tubes require octal socket and may be mounted in any position. Heater volts (ac/dc), 6.3; amperes, 0.3. Maximum ratings as class A_1 amplifier: plate volts, 300 *max*; plate dissipation, 2.5 *max* watts; grid volts, 0 *min*. Typical operation: plate volts, 250; grid volts, −8 (grid-circuit resistance should not exceed 1.0 megohm); amplification factor, 20; plate resistance, 10000 ohms; transconductance, 2000 μmhos; plate ma., 8. For typical operation as a resistance-coupled amplifier, refer to Chart 11, RESISTANCE-COUPLED AMPLIFIER SECTION.



6C6

SHARP-CUTOFF PENTODE

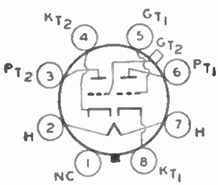
Glass type used as biased detector and as a high-gain amplifier in radio equipment. Outline 38, OUTLINES SECTION. Tube requires six-contact socket. Heater volts (ac/dc), 6.3; amperes, 0.3. For ratings and typical operation data, refer to type 6J7. This type is used principally for renewal purposes.



6C7

TWIN DIODE— MEDIUM-MU TRIODE

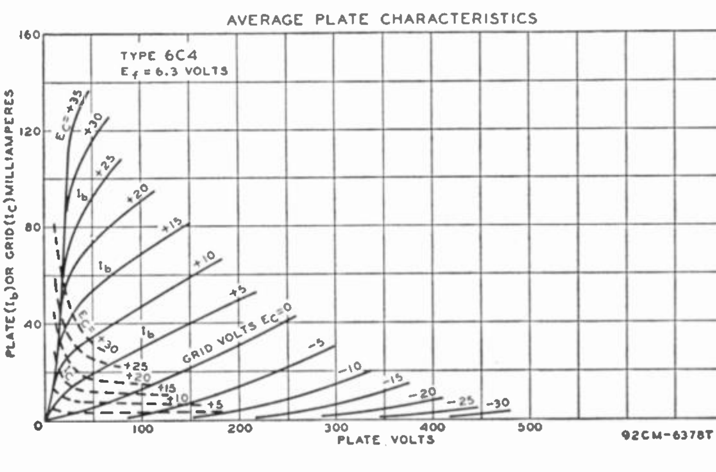
Glass type used as combined detector, amplifier, and avc tube. Outline 34, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.3. This type is similar to, but not interchangeable with, type 85. The 6C7 is a DISCONTINUED type listed for reference only.



6C8-G

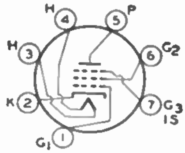
MEDIUM-MU TWIN TRIODE

Glass octal type used as a voltage amplifier and phase inverter in radio equipment. Outline 33, OUTLINES SECTION. When this type is used in a high-gain amplifier, hum may be reduced or eliminated by grounding pin No.7 or by grounding the arm of a 100-to-500-ohm potentiometer across the heater terminals. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.3. Maximum ratings for each triode unit as class A_1 amplifier: plate volts, 250 *max;* grid volts, 0 *min;* plate dissipation, 1.0 *max* watt. Typical operation: plate volts, 250; grid volts, −4.5; plate ma., 3.2; plate resistance, 22500 ohms; amplification factor, 36; transconductance, 1600 μmhos. For typical operation as a resistance-coupled amplifier, refer to Chart 12, RESISTANCE-COUPLED AMPLIFIER SECTION. This type is used principally for renewal purposes.



6CB6

SHARP-CUTOFF PENTODE



Miniature type used in television receivers as an intermediate-frequency amplifier at frequencies up to about 45 megacycles per second and as an rf amplifier in vhf television tuners. Tube features very high transconductance combined with low interelectrode capacitance values, and is provided with separate base pins for grid No.3 and the cathode to permit the use of an unbypassed cathode resistor to minimize the effects of regeneration. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

Heater Volts (ac/dc)	6.3	volts
Heater Current	0.3	ampere
Direct Interelectrode Capacitances (No external shield):		
Grid No.1 to Plate	0.020 *max*	μμf
Input	6.3	μμf
Output	1.9	μμf

CLASS A_1 AMPLIFIER

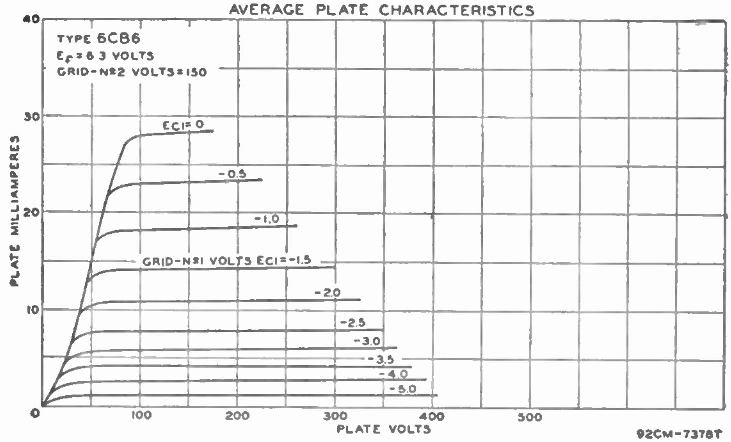
Maximum Ratings:

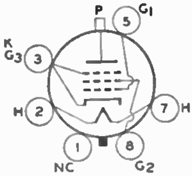
Plate Voltage	300 *max*	volts
Grid-No.2 (screen) Voltage	150 *max*	volts
Plate Dissipation	2.0 *max*	watts
Grid-No.2 Input	0.5 *max*	watt
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation and Characteristics:

Plate Voltage	200	volts
Grid-No.3 (Suppressor)	Connected to cathode at socket	
Grid-No.2 Voltage	150	volts
Cathode-Bias Resistor	180	ohms
Plate Resistance (Approx.)	0.6	megohm
Transconductance	6200	μmhos
Grid-No.1 Bias (Approx.) for plate current of 10 μa	-8	volts
Plate Current	9.5	ma
Grid-No.2 Current	2.8	ma

AVERAGE PLATE CHARACTERISTICS





BEAM POWER AMPLIFIER

6CD6-G

Glass octal type used as horizontal deflection amplifier in high-efficiency deflection circuits of television receivers employing either transformer coupling or direct coupling to the deflection yoke. Outline 42, OUTLINES SECTION. Tube requires octal socket. Vertical tube mounting is preferred but horizontal operation is permissible if pins No.2 and 7 are in vertical plane.

Heater Voltage (AC/DC)	6.3	volts
Heater Current	2.5	amperes
Direct Interelectrode Capacitances (No external shield):		
Grid No.1 to Plate	1.0 *max*	μμf
Input	26	μμf
Output	10	μμf
Transconductance°	7500	μmhos
Mu-Factor, Grid No.2 to Grid No.1°	3.8	

° For plate volts, 175; grid-No.2 volts, 175; grid-No.1 volts, −30.

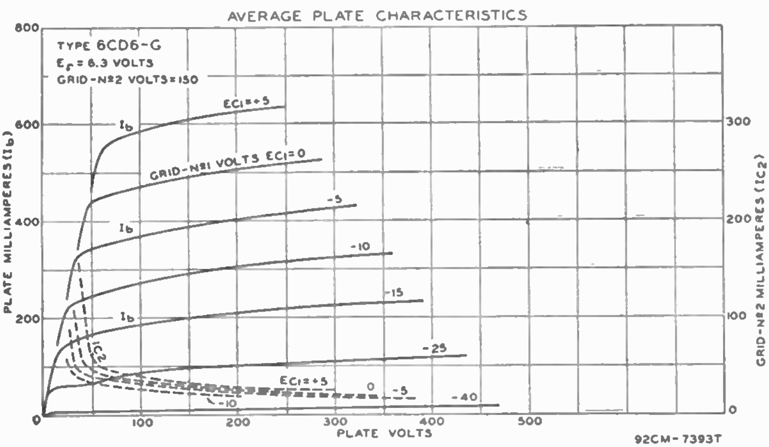
HORIZONTAL DEFLECTION AMPLIFIER

For operation in a 525-line, 30-frame system

Maximum Ratings:

DC Plate Voltage	700 *max*	volts
Peak Positive-Pulse Plate Voltage*	6000 *max*	volts
Peak Negative-Pulse Plate Voltage*	−1500 *max*	volts
DC Grid-No.2 (screen) Voltage	175 *max*	volts
DC Grid-No.1 (control-grid) Voltage	−50 *max*	volts
Peak Negative-Pulse Grid-No.1 Voltage*	−150 *max*	volts
DC Plate Current	170 *max*	ma
Plate Dissipation	15 *max*	watts
Grid-No.2 Input	3 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	135 *max*	volts
Heater positive with respect to cathode	135 *max*	volts
Bulb Temperature (At hottest point)	210 *max*	°C

* The duration of the voltage pulse must not exceed 15% of one horizontal scanning cycle. In a 525-line, 30-frame system, 15% of one horizontal scanning cycle is 10 microseconds.



SHARP-CUTOFF PENTODE

6CF6

For technical data, see page 311.

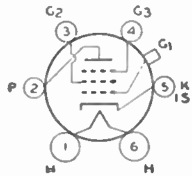
POWER PENTODE

6CL6

For technical data, see page 311.

6D6

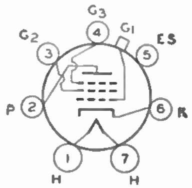
REMOTE-CUTOFF PENTODE



Glass type used in rf and if stages of radio receivers employing avc. Outline 38, OUTLINES SECTION. Tube requires six-contact socket. Except for interelectrode capacitances, this type is identical electrically with type 6U7-G. Refer to type 6SK7 for general application information. Heater volts (ac/dc), 6.3; amperes, 0.3. This type is used principally for renewal purposes.

6D7

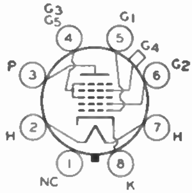
SHARP-CUTOFF PENTODE



Glass type used as detector or amplifier in radio receivers. Outline 38, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.3. For electrical characteristics, refer to type 6J7. This is a DISCONTINUED type listed for reference only.

6D8-G

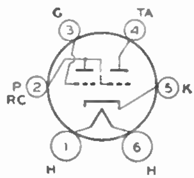
PENTAGRID CONVERTER



Glass octal type used in superheterodyne circuits. Outline 33, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.15. Except for interelectrode capacitances and heater rating, the 6D8-G is similar electrically to type 6A8-G. The 6D8-G is used principally for renewal purposes.

6E5

ELECTRON-RAY TUBE



Glass type used to indicate visually by means of a fluorescent target the effects of a change in a controlling voltage. It is used as a convenient means of indicating accurate radio-receiver tuning. Outline 30, OUTLINES SECTION. Tube requires six-contact socket. Heater volts (ac/dc), 6.3; amperes, 0.3. For additional considerations, refer to **Tuning Indication with Electron-Ray Tubes** in ELECTRON TUBE APPLICATIONS SECTION.

TUNING INDICATOR

Maximum Ratings:

PLATE-SUPPLY VOLTAGE	250 *max*	volts
TARGET VOLTAGE	250 *max*	volts
	125 *min*	volts

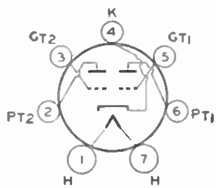
Typical Operation:

Plate and Target Supply	200	250	volts
Series Triode-Plate Resistor	1	1	megohm
Target Current*†	3	4	ma
Triode-Plate Current*	0.19	0.24	ma
Triode-Grid Voltage (Approx.):			
For shadow angle of 0°	−6.5	−8.0	volts
For shadow angle of 90°	0	0	volts

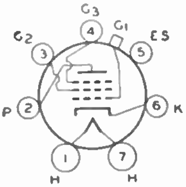
* For zero triode-grid voltage. † Subject to wide variations.

6E6

TWIN POWER TRIODE



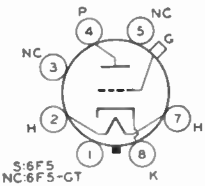
Glass type used as class A_1 amplifier in either push-pull or parallel circuits. Outline 36, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.6. With plate volts of 250 and grid volts of −27.5, characteristics for each unit are: plate ma., 18; plate resistance, 3500 ohms; transconductance, 1700 μmhos; amplification factor, 6. With plate-to-plate load resistance of 14000 ohms, output watts for two tubes is 1.6. This is a DISCONTINUED type listed for reference only.



REMOTE-CUTOFF PENTODE

6E7

Glass type used in rf and if stages of radio receivers employing avc. Outline 38, OUTLINES SECTION. Except for interelectrode capacitances, this type is identical electrically with type 6U7-G. Heater volts (ac/dc), 6.3; amperes, 0.3. This is a DISCONTINUED type listed for reference only.



HIGH-MU TRIODE

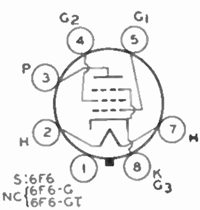
6F5
6F5-GT

Metal type 6F5 and glass-octal type 6F5-GT used in resistance-coupled amplifier circuits. Outlines 4 and 20, respectively, OUTLINES SECTION. Tubes require octal socket and may be mounted in any position. For typical operation as a resistance-coupled amplifier, refer to Chart 18, RESISTANCE-COUPLED AMPLIFIER SECTION. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere

Characteristics: CLASS A_1 AMPLIFIER

Plate Voltage (300 volts *max*)	100	250	volts
Grid Voltage	−1	−2	volts
Amplification Factor	100	100	
Plate Resistance	85000	66000	ohms
Transconductance	1150	1500	μmhos
Plate Current	0.4	0.9	ma



POWER PENTODE

6F6
6F6-G
6F6-GT

Metal type 6F6 and glass-octal types 6F6-G and 6F6-GT are used in the audio output stage of ac receivers. They are capable of large power output with relatively small input voltage. Outlines 6, 35, and 26, respectively, OUTLINES SECTION. Tubes require octal socket and may be mounted in any position. It is especially important that these tubes, like other power-handling tubes, should be adequately ventilated.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.7	ampere

Maximum Ratings: SINGLE-TUBE CLASS A_1 AMPLIFIER

Plate Voltage	375 *max*	volts
Grid-No.2 (screen) Voltage	285 *max*	volts
Plate Dissipation	11 *max*	watts
Grid-No.2 Input	3.75 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

	Fixed Bias		Cathode Bias		
Plate Voltage	250	285	250	285	volts
Grid-No.2 Voltage	250	285	250	285	volts
Grid-No.1 (Control-Grid) Voltage	−16.5	−20	–	–	volts
Cathode Resistor	–	–	410	440	ohms
Peak AF Grid-No.1 Voltage	16.5	20	16.5	20	volts
Zero-Signal Plate Current	34	38	34	38	ma
Maximum-Signal Plate Current	36	40	35	38	ma
Zero-Signal Grid-No.2 Current	6.5	7	6.5	7	ma
Maximum-Signal Grid-No.2 Current	10.5	13	9.7	12	ma
Plate Resistance (Approx.)	80000	78000	–	–	ohms
Transconductance	2500	2550	–	–	μmhos
Load Resistance	7000	7000	7000	7000	ohms
Total Harmonic Distortion	8	9	8.5	9	per cent
Maximum-Signal Power Output	3.2	4.8	3.1	4.5	watts

PUSH-PULL CLASS A_1 AMPLIFIER

Maximum Ratings:

(Same as for single-tube class A_1 amplifier)

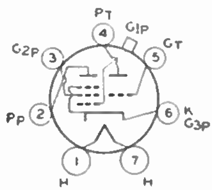
Typical Operation (Values are for two tubes):

	Fixed Bias	Cathode Bias	
Plate Voltage	315	315	volts
Grid-No.2 Voltage	285	285	volts
Grid-No.1 (Control-Grid) Voltage	−24	–	volts
Cathode Resistor	–	320	ohms
Peak AF Grid-No.1-to-Grid-No.1 Voltage	48	58	volts
Zero-Signal Plate Current	62	62	ma
Maximum-Signal Plate Current	80	73	ma
Zero-Signal Grid-No.2 Current	12	12	ma
Maximum-Signal Grid-No.2 Current	19.5	18	ma
Effective Load Resistance (Plate-to-plate)	10000	10000	ohms
Total Harmonic Distortion	4	3	per cent
Maximum-Signal Power Output	11	10.5	watts

6F7

MEDIUM-MU TRIODE— REMOTE-CUTOFF PENTODE

Glass type adaptable to circuit design in several ways. Except for common cathode, the triode and pentode units are independent of each other. Outline 34, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.3. This type is used principally for renewal purposes.



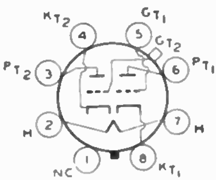
CLASS A_1 AMPLIFIER

Maximum Ratings:

	Triode Unit	Pentode Unit	
PLATE VOLTAGE	100 *max*	250 *max*	volts
PLATE-SUPPLY VOLTAGE	250 *max*	250 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	-	100 *max*	volts
GRID-NO.1 (CONTROL-GRID) VOLTAGE	−3 *min*	−3 *min*	volts
PEAK HEATER-CATHODE VOLTAGE:			
Heater negative with respect to cathode	90 *max*	90 *max*	volts
Heater positive with respect to cathode	90 *max*	90 *max*	volts

Typical Operation and Characteristics:

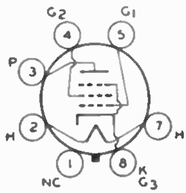
	Triode Unit	Pentode Unit		
Plate Voltage	100	100	250	volts
Grid-No.2 Voltage	–	100	100	volts
Grid-No.1 Voltage	−3	−3	−3	volts
Amplification Factor	8	–	–	
Plate Resistance	0.016	0.29	0.85	megohm
Transconductance	500	1050	1100	μmhos
Transconductance at −35-volts bias	–	9	10	μmhos
Plate Current	3.5	6.3	6.5	ma
Grid-No.2 Current	–	1.6	1.5	ma



MEDIUM-MU TWIN TRIODE

6F8-G

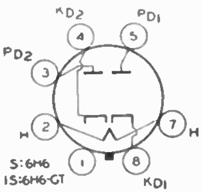
Glass octal type used as voltage amplifier or phase inverter in radio equipment. Except for common heater each triode is independent of the other. Outline 33, OUTLINES SECTION. Tube requires octal socket. Except for the heater rating of 6.3 volts (ac/dc) and 0.6 ampere and interelectrode capacitances, each triode unit is identical electrically with type 6J5. For typical operation as a resistance-coupled amplifier, refer to Chart 13, RESISTANCE-COUPLED AMPLIFIER SECTION.



POWER PENTODE

6G6-G

Glass octal type used in output stage of radio receivers where moderate power output is required. This type is economical because of its low plate-power requirements and low heater current. Outline 31, OUTLINES SECTION. Tube requires octal socket. Except for interelectrode capacitances and a plate resistance of 175000 ohms, this type is electrically identical with type 6AK6. Heater volts (ac/dc), 6.3; amperes, 0.15.



TWIN DIODE

6H6
6H6-GT

Metal type 6H6 and glass-octal type 6H6-GT are used as detectors, low-voltage rectifiers, and avc tubes. Except for the common heater, the two diode units are independent of each other. For diode detector considerations, refer to ELECTRON TUBE APPLICATIONS SECTION.

HEATER VOLTAGE (AC/DC)	6.3		volts
HEATER CURRENT	0.3		ampere
DIRECT INTERELECTRODE CAPACITANCES:†			
	6H6	*6H6-GT*	
Plate No.1 to Cathode No.1	3.0	3.0	μμf
Plate No.2 to Cathode No.2	3.4	4.0	μμf
Plate No.1 to Plate No.2	0.1 *max*	0.1 *max*	μμf

† With shell or external and internal shields connected to cathode.

Maximum Ratings: RECTIFIER OR DOUBLER

PEAK INVERSE PLATE VOLTAGE	420 *max*	volts
PEAK PLATE CURRENT PER PLATE	48 *max*	ma
DC OUTPUT CURRENT PER PLATE	8 *max*	ma
PEAK HEATER-CATHODE VOLTAGE	330 *max*	volts

Typical Operation (As Half-Wave Rectifier):*

AC Plate Voltage per Plate (rms)	117	150	volts
Min. Total Effective Plate-Supply Impedance per Plate°	15	40	ohms
DC Output Current per Plate	8	8	ma

Typical Operation (As Voltage Doubler):

	Half-Wave	*Full-Wave*	
AC Plate Voltage per Plate (rms)	117	117	volts
Min. Total Effective Plate-Supply Impedance per Plate°	30	15	ohms
DC Output Current	8	8	ma

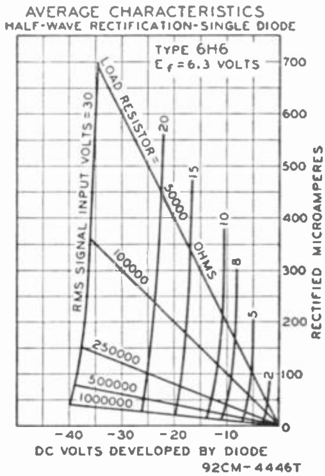
* In half-wave service, the two units may be used separately or in parallel.

° When a filter-input capacitor larger than 40 μf is used, it may be necessary to use more plate-supply impedance than the value shown to limit the peak plate current to the rated value.

INSTALLATION AND APPLICATION

Types 6H6 and 6H6-GT require an octal socket and may be mounted in any position. Outlines 1 and 22 respectively, OUTLINES SECTION. For heater and cathode considerations, refer to type 6AV6.

For detection, the diodes may be utilized in a full-wave circuit or in a half-wave circuit. In the latter case, one plate only, or the two plates in parallel, may be employed. For the same signal voltage, the use of the half-wave arrangement will provide approximately twice the rectified voltage as compared with the full-wave arrangement.

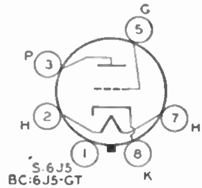


For automatic-volume control, the 6H6 and 6H6-GT may be used in circuits similar to those employed for any of the twin-diode types of tubes. The only difference is that the 6H6 and 6H6-GT are more adaptable because each diode has its own separate cathode.

Since the diodes by themselves do not provide any amplification, it is usually necessary to provide gain by means of a supplementary tube. Types such as the 6J5, 6SJ7, and 6AU6 are very suitable for this purpose. Their use in combination with the 6H6 or 6H6-GT is similar to that of the amplifier sections of twin-diode triode or pentode types.

6J5
6J5-GT

MEDIUM-MU TRIODE



Metal type 6J5 and glass-octal type 6J5-GT used as detectors, amplifiers, or oscillators in radio equipment. These types feature high transconductance together with comparatively high amplification factor. Outlines 3 and 24, respectively, OUTLINES SECTION. Tubes require octal socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6. For typical operation as a resistance-coupled amplifier, refer to Chart 13, RESISTANCE-COUPLED AMPLIFIER SECTION.

Heater Voltage (ac/dc)		6.3	volts
Heater Current		0.3	ampere
Direct Interelectrode Capacitances (Approx.):	*6J5**	*6J5-GT***	
Grid to Plate	3.4	3.8	μμf
Input	3.4	4.2	μμf
Output	3.6	5.0	μμf

* Shell connected to cathode. ** Close-fitting shield connected to cathode.

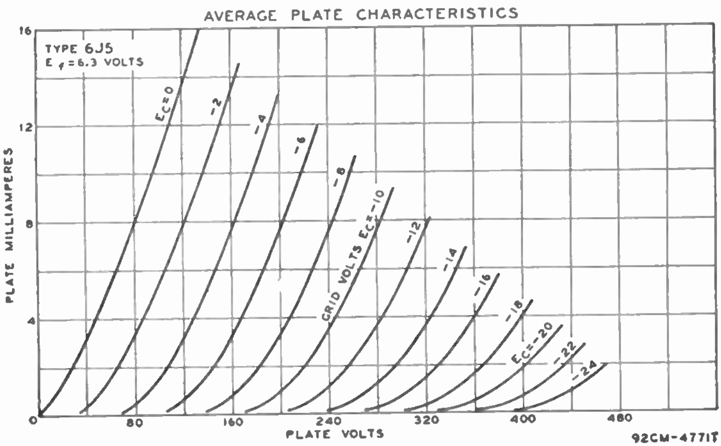
Maximum Ratings: CLASS A_1 AMPLIFIER

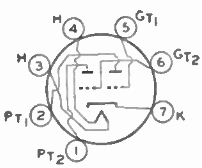
Plate Voltage	300 *max*	volts
Grid Voltage, Positive Bias Value	0 *max*	volts
Plate Dissipation	2.5 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts
Cathode Current	20 *max*	ma

Typical Operation:

Plate Voltage	90	250	volts
Grid Voltage†	0	−8	volts
Amplification Factor	20	20	
Plate Resistance	6700	7700	ohms
Transconductance	3000	2600	µmhos
Grid Bias (Approx.) for plate current of 10 µa	−7	−18	volts
Plate Current	10	9	ma

† Under maximum rated conditions, the dc resistance in the grid circuit should not exceed 1.0 megohm.





MEDIUM-MU TWIN TRIODE

6J6

Miniature type used as an rf power amplifier and oscillator or as an af amplifier. With a push-pull arrangement of the grids and with the plates in parallel, it is also used as a mixer at frequencies as high as 600 megacycles per second. Outline 12, OUTLINES SECTION. Tube requires miniature seven-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AQ5.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.45	ampere
DIRECT INTERELECTRODE CAPACITANCES: *		
Grid to Plate	1.6	µµf
Input	2.2	µµf
Output	0.4	µµf

* No external shield. Approximate values for each unit.

CLASS A_1 AF AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
PLATE DISSIPATION (PER UNIT)	1.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	100 *max*	volts
Heater positive with respect to cathode	100 *max*	volts

Typical Operation (Each Unit):

Plate Voltage	100	volts
Cathode-Bias Resistor**	50†	ohms
Amplification Factor	38	
Plate Resistance	7100	ohms
Transconductance	5300	μmhos
Plate Current	8.5	ma

** Under maximum rated conditions, the resistance in the grid circuit should not exceed 0.5 megohm with cathode bias. Operation with fixed bias is not recommended.
† Value is for both units operating at the specified conditions.

RF POWER AMPLIFIER AND OSCILLATOR—Class C Telegraphy

Values are for both units, unless otherwise specified.

Maximum Ratings:

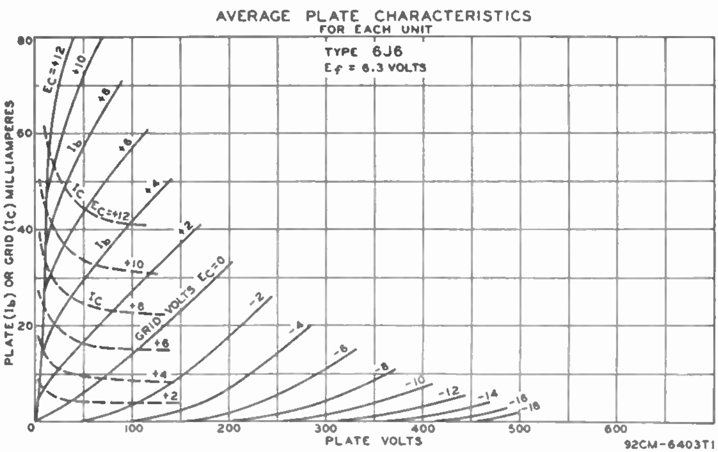
DC PLATE VOLTAGE	300 *max*	volts
DC GRID VOLTAGE	-40 *max*	volts
DC PLATE CURRENT (PER UNIT)	15 *max*	ma
DC GRID CURRENT (PER UNIT)	8 *max*	ma
DC PLATE INPUT (PER UNIT)	4.5 *max*	watts
PLATE DISSIPATION (PER UNIT)	1.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	100 *max*	volts
Heater positive with respect to cathode	100 *max*	volts

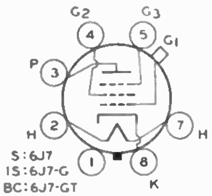
Typical Operation:‡

DC Plate Voltage	150	volts
DC Grid Voltage°	-10	volts
DC Plate Current	30	ma
DC Grid Current (Approx.)	16	ma
Driving Power (Approx.)	0.35	watt
Power Output (Approx.)	3.5	watts

‡ At moderate frequencies in push-pull. Key-down conditions without modulation. At 250 Mc, approximately 1.0 watt can be obtained when the 6J6 is used as a push-pull oscillator with a plate voltage of 150 volts, with maximum rated plate dissipation, and with a grid resistor of 2000 ohms common to both units.

° Obtained by grid resistor (625 ohms), cathode resistor (220 ohms), or fixed supply.





SHARP-CUTOFF PENTODE

6J7
6J7-G
6J7-GT

Metal type 6J7 and glass-octal types 6J7-G and 6J7-GT are used as biased detectors or high-gain audio amplifiers in radio receivers. Outlines 4,33, and 23, respectively. OUTLINES SECTION. Type 6J7-G is used principally for renewal purposes. All types require octal socket and may be mounted in any position. For typical operation as resistance-coupled amplifiers, refer to Charts 11 and 14, RESISTANCE-COUPLED AMPLIFIER SECTION. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere

Maximum Ratings: CLASS A_1 AMPLIFIER (Pentode Connection)

Plate Voltage	300 *max*	volts
Grid-No.2 (screen) Voltage	125 *max*	volts
Grid-No.2 Supply Voltage	300 *max*	volts
Grid-No.1 (control-grid) Voltage, Positive Bias Value	0 *max*	volts
Plate Dissipation	0.75 *max*	watt
Grid-No.2 Input	0.10 *max*	watt
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate Voltage	100	250	volts
Grid No.3 (Suppressor)	Connected to cathode at socket		
Grid-No.2 Voltage	100	100	volts
Grid-No.1 Voltage*	−3	−3	volts
Plate Resistance	1.0	+	megohm
Transconductance	1185	1225	μmhos
Grid-No.1 Bias (Approx.) for cathode-current cutoff	−7	−7	volts
Plate Current	2	2	ma
Grid-No.2 Current	0.5	0.5	ma

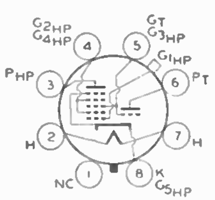
Maximum Ratings: CLASS A_1 AMPLIFIER (Triode Connection)°

Plate Voltage	250 *max*	volts
Grid-No.1 Voltage, Positive Bias Value	0 *max*	volts
Plate and Grid-No.2 Dissipation (total)	1.75 *max*	watts

Typical Operation:

Plate Voltage	180	250	volts
Grid-No.1 Voltage*	−5.3	−8	volts
Amplification Factor	20	20	
Plate Resistance	11000	10500	ohms
Transconductance	1800	1900	μmhos
Plate Current	5.3	6.5	ma

* DC resistance in grid circuit should not exceed 1.0 megohm.
+ Greater than 1.0 megohm.
° Grids No.2 and No.3 connected to plate.



TRIODE—HEPTODE CONVERTER

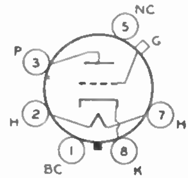
6J8-G

Glass octal type used as a combined triode oscillator and heptode mixer in radio receivers. Outline 33, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.3. Typical operation—Heptode unit: plate volts, 250 (300 *max*); grids-No.2-and-No.4 volts, 100 *max;* grid-No.1 volts, −3; plate resistance, 4 megohms; conversion transconductance, 290 μmhos; plate ma., 1.3; grids-No.2-and-No.4 ma., 3.5. Triode unit: plate volts, 250 *max* (applied through 20000-ohm dropping resistor); grid resistor, 50000 ohms; plate ma., 5.8. This type is used principally for renewal purposes.

6K5-GT

HIGH-MU TRIODE

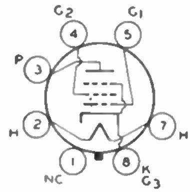
Glass octal type used as voltage amplifier in radio equipment. Outline 23, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.3. Characteristics as class A_1 amplifier: plate volts, 250 *max;* grid volts, −3; amplification factor, 70; plate resistance, 50000 ohms; transconductance, 1400 μmhos; plate ma., 1.1. This type is used principally for renewal purposes



6K6-GT

POWER PENTODE

Glass octal type used in output stage of radio receivers. It is capable of delivering moderate power output with relatively small input voltage. Tube may be used singly or in push-pull.



Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.4	ampere
Direct Interelectrode Capacitances (Approx. With no external shield):		
Grid No.1 to Plate	0.5	μμf
Input	5.5	μμf
Output	6.0	μμf

Maximum Ratings: SINGLE-TUBE CLASS A_1 AMPLIFIER

Plate Voltage	315 *max*	volts
Grid-No.2 (screen) Voltage	285 *max*	volts
Plate Dissipation	8.5 *max*	watts
Grid-No.2 Input	2.8 *max*	watts
Grid-No.1 (control-grid) Voltage, Positive Bias Value	0 *max*	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:

Plate Voltage	100	250	315	volts
Grid-No.2 Voltage	100	250	250	volts
Grid-No.1 (Control-Grid) Voltage	−7	−18	−21	volts
Peak AF Grid-No.1 Voltage	7	18	21	volts
Zero-Signal Plate Current	9	32	25.5	ma
Maximum-Signal Plate Current	9.5	33	28	ma
Zero-Signal Grid-No.2 Current	1.6	5.5	4.0	ma
Maximum-Signal Grid-No.2 Current	3	10	9	ma
Plate Resistance (Approx.)	104000	90000	110000	ohms
Transconductance	1500	2300	2100	μmhos
Load Resistance	12000	7600	9000	ohms
Total Harmonic Distortion	11	11	15	per cent
Maximum-Signal Power Output	0.35	3.4	4.5	watts

Maximum Ratings: PUSH-PULL CLASS A_1 AMPLIFIER

(Same as for Single-Tube Class A_1 Amplifier.)

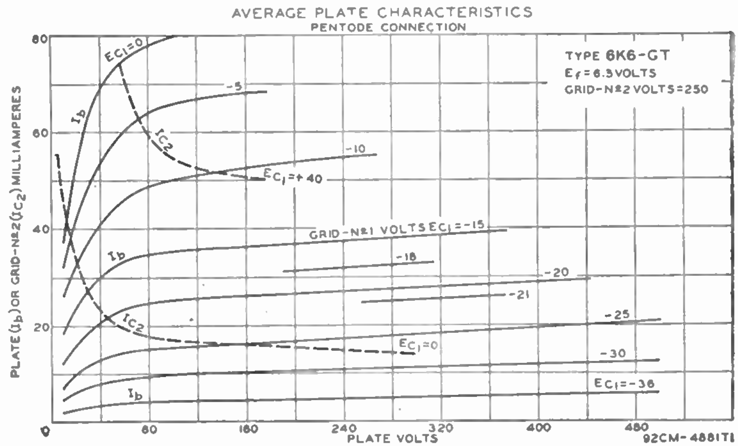
Typical Operation (Values are for two tubes):

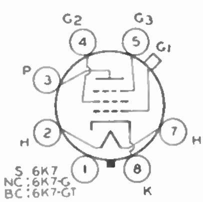
	Fixed Bias	*Cathode Bias*	
Plate Voltage	285	285	volts
Grid-No.2 Voltage	285	285	volts
Grid-No.1 (Control-Grid) Voltage	−25.5	–	volts
Cathode Resistor	–	400	ohms
Peak AF Grid-No.1-to-Grid-No.1 Voltage	51	51	volts
Zero-Signal Plate Current	55	55	ma
Maximum-Signal Plate Current	72	61	ma
Zero-Signal Grid-No.2 Current	9	9	ma
Maximum-Signal Grid-No.2 Current	17	13	ma
Effective Load Resistance (Plate-to-plate)	12000	12000	ohms
Total Harmonic Distortion	6	4	per cent
Maximum-Signal Power Output	10.5	9.8	watts

INSTALLATION AND APPLICATION

Tube requires octal socket and may be mounted in any position. Outline 22, OUTLINES SECTION. It is especially important that this tube, like other power-handling tubes, should be adequately ventilated.

Any conventional type of input coupling may be used provided the resistance added to the grid-No.1 circuit by this device is not too high. Transformer- or impedance-coupling devices are recommended. When the grid-No.1 circuit has a resistance not higher than 0.1 megohm, fixed bias may be used; for higher values, cathode bias is required. With cathode bias, the grid-No.1 circuit may have a resistance as high as but not higher than 0.5 megohm, provided the heater voltage does not rise more than 10% above the rated value under any condition of operation.





REMOTE-CUTOFF PENTODE

6K7
6K7-G
6K7-GT

Metal type 6K7 and glass-octal types 6K7-G and 6K7-GT used in rf and if stages of radio receivers, particularly in those employing avc. Outlines 4, 33, and 23, respectively, OUTLINES SECTION. Type 6K7-G is used principally for renewal purposes. These tubes require octal socket and may be mounted in any position. For electrode voltage supplies and application, refer to type 6SK7. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere

CLASS A_1 AMPLIFIER

Maximum Ratings:

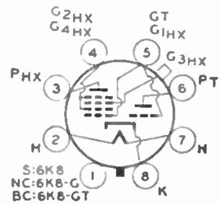
PLATE VOLTAGE	300 *max*	volts
GRID-No.2 (SCREEN) VOLTAGE	125 *max*	volts
GRID-No.2 SUPPLY VOLTAGE	300 *max*	volts
GRID-No.1 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	volts
PLATE DISSIPATION	2.75 *max*	watts
GRID-No.2 INPUT	0.35 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate Voltage	100	250	250	volts
Grid No.3 (Suppressor)	Connected to cathode at socket			
Grid-No.2 Voltage	100	100	125	volts
Grid-No.1 Voltage	−1	−3	−3	volts
Plate Resistance (Approx.)	0.15	0.8	0.6	megohm
Transconductance	1650	1450	1650	μmhos
Grid-No.1 Bias for transconductance of approx. 2 μmhos	−38.5	−42.5	−52.5	volts
Plate Current	9.5	7.0	10.5	ma
Grid-No.2 Current	2.7	1.7	2.6	ma

6K8
6K8-G
6K8-GT

TRIODE-HEXODE CONVERTER



Metal type 6K8 and glass-octal types 6K8-G and 6K8-GT used as combined triode oscillator and hexode mixer in radio receivers. Type 6K8, Outline 5, type 6K8-G, Outline 33, OUTLINES SECTION. Types 6K8-G and 6K8-GT are DISCONTINUED types listed for reference only. Tubes require octal socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6. For application, refer to **Frequency Conversion** in ELECTRON TUBE APPLICATIONS SECTION.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere

Maximum Ratings: CONVERTER SERVICE

HEXODE PLATE VOLTAGE	300 *max*	volts
HEXODE GRIDS-NO.2-AND-NO.4 (SCREEN) VOLTAGE	150 *max*	volts
HEXODE GRIDS-NO.2-AND-NO.4 SUPPLY VOLTAGE	300 *max*	volts
HEXODE GRID-NO.3 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	volts
TRIODE PLATE VOLTAGE	125 *max*	volts
HEXODE PLATE DISSIPATION	0.75 *max*	watt
HEXODE GRIDS-NO.2-AND-NO.4 INPUT	0.7 *max*	watt
TRIODE PLATE DISSIPATION	0.75 *max*	watt
TOTAL CATHODE CURRENT	16 *max*	ma
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

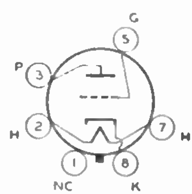
Typical Operation:

Hexode Plate Voltage	100	250	volts
Hexode Grids-No.2-and-No.4 Voltage	100	100	volts
Hexode Grid-No.3 Voltage	−3	−3	volts
Triode Plate Voltage	100	100	volts
Triode Grid Resistor	50000	50000	ohms
Hexode Plate Resistance (Approx.)	0.4	0.6	megohm
Conversion Transconductance	325	350	μmhos
Hexode Grid-No.3 Voltage (Approx.) for conversion transconductance of 2 μmhos	−30	−30	volts
Hexode Plate Current	2.3	2.5	ma
Hexode Grids-No.2-and-No.4 Current	6.2	6.0	ma
Triode Plate Current	3.8	3.8	ma
Triode Grid and Hexode Grid-No.1 Current	0.15	0.15	ma
Total Cathode Current	12.5	12.5	ma

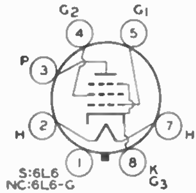
The transconductance of the triode section, not oscillating, of the 6K8 is approximately 3000 μmhos when the triode plate voltage is 100 volts, and the triode grid voltage is 0 volts.

6L5-G

MEDIUM-MU TRIODE



Glass octal type used as detector, amplifier, or oscillator in radio receivers. Outline 31, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.15. Typical operation and characteristics: plate volts, 250 *max*; grid volts, -9; plate ma., 8; plate resistance, 9000 ohms; amplification factor, 17; transconductance, 1900 μmhos; grid-bias volts for cathode-current cutoff, -20. As a class A_1 amplifier, the 6L5-G may be operated in resistance-coupled circuits as shown in Chart 15, RESISTANCE-COUPLED AMPLIFIER SECTION. This type is used principally for renewal purposes.



BEAM POWER AMPLIFIER

6L6
6L6-G

Metal type 6L6 and glass-octal type 6L6-G are used in output stage of radio receivers and amplifiers, especially those designed to have ample reserve of power-delivering ability. These types provide high power output, sensitivity, and high efficiency. Power output at all levels has low third and negligible higher-order harmonics. For discussion of beam power amplifier considerations, refer to ELECTRONS, ELECTRODES, AND ELECTRON TUBES SECTION.

HEATER VOLTAGE (AC/DC)		6.3	volts
HEATER CURRENT		0.9	ampere
DIRECT INTERELECTRODE CAPACITANCES (Approx.):	*6L6*	*6L6-G*	
Grid No.1 to Plate	0.4	0.9	μμf
Input	10	11.5	μμf
Output	12	9.5	μμf

SINGLE-TUBE CLASS A_1 AMPLIFIER

Maximum Ratings:

PLATE VOLTAGE	360 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	270 *max*	volts
PLATE DISSIPATION	19 *max*	watts
GRID-NO.2 INPUT	2.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	180 *max*	volts
Heater positive with respect to cathode	180 *max*	volts

Typical Operation:

	Fixed Bias		*Cathode Bias*		
Plate Voltage	250	350	250	300	volts
Grid-No.2 Voltage	250	250	250	200	volts
Grid-No.1 (Control-Grid) Voltage	−14	−18	–	–	volts
Cathode Resistor	–	–	170	220	ohms
Peak AF Grid-No.1 Voltage	14	18	14	12.5	volts
Zero-Signal Plate Current	72	54	75	51	ma
Maximum-Signal Plate Current	79	66	78	54.5	ma
Zero-Signal Grid-No.2 Current	5	2.5	5.4	3	ma
Maximum-Signal Grid-No.2 Current	7.3	7	7.2	4.6	ma
Plate Resistance	22500	33000	–	–	ohms
Transconductance	6000	5200	–	–	μmhos
Load Resistance	2500	4200	2500	4500	ohms
Total Harmonic Distortion	10	15	10	11	per cent
Maximum-Signal Power Output	6.5	10.8	6.5	6.5	watts

SINGLE-TUBE CLASS A_1 AMPLIFIER (Triode Connection)†

Maximum Ratings:

PLATE VOLTAGE	275 *max*	volts
PLATE AND GRID-NO.2 DISSIPATION (TOTAL)	12.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	180 *max*	volts
Heater positive with respect to cathode	180 *max*	volts

Typical Operation:

	Fixed Bias	*Cathode Bias*	
Plate Voltage	250	250	volts
Grid-No.1 (Control-Grid) Voltage	−20	–	volts
Cathode Resistor	–	490	ohms
Peak AF Grid-No.1 Voltage	20	20	volts
Zero-Signal Plate Current	40	40	ma
Maximum-Signal Plate Current	44	42	ma
Plate Resistance	1700	–	ohms
Amplification Factor	8	–	
Transconductance	4700	–	μmhos
Load Resistance	5000	6000	ohms
Total Harmonic Distortion	5	6	per cent
Maximum-Signal Power Output	1.4	1.3	watts

† Grid No.2 connected to plate.

Maximum Ratings: PUSH-PULL CLASS A_1 AMPLIFIER

(Same as for single-tube class A_1 amplifier)

Typical Operation (Values are for two tubes)	*Fixed Bias*		*Cathode Bias*	
Plate Voltage	250	270	270	volts
Grid-No.2 Voltage	250	270	270	volts
Grid-No.1 (Control-Grid) Voltage	-16	-17.5	–	volts
Cathode Resistor	–	–	125	ohms
Peak AF Grid-No.1-to-Grid-No.1 Voltage	32	35	40	volts
Zero-Signal Plate Current	120	134	134	ma
Maximum-Signal Plate Current	140	155	145	ma
Zero-Signal Grid-No.2 Current	10	11	11	ma
Maximum-Signal Grid-No.2 Current	16	17	17	ma
Plate Resistance	24500	23500	–	ohms
Transconductance	5500	5700	–	µmhos
Effective Load Resistance (Plate-to-plate)	5000	5000	5000	ohms
Total Harmonic Distortion	2	2	2	per cent
Maximum-Signal Power Output	14.5	17.5	18.5	watts

Maximum Ratings: PUSH-PULL CLASS AB_1 AMPLIFIER

(Same as for single-tube class A_1 amplifier)

Typical Operation (Values are for two tubes):	*Fixed Bias*		*Cathode Bias*	
Plate Voltage	360	360	360	volts
Grid-No.2 Voltage	270	270	270	volts
Grid-No.1 (Control-Grid) Voltage	-22.5	-22.5	–	volts
Cathode Resistor	–	–	250	ohms
Peak AF Grid-No.1-to-Grid-No.1 Voltage	45	45	57	volts
Zero-Signal Plate Current	88	88	88	ma
Maximum-Signal Plate Current	132	140	100	ma
Zero-Signal Grid-No.2 Current	5	5	5	ma
Maximum-Signal Grid-No.2 Current	15	11	17	ma
Effective Load Resistance (Plate-to-plate)	6600	3800	9000	ohms
Total Harmonic Distortion	2	2	4	per cent
Maximum-Signal Power Output	26.5	18	24.5	watts

Maximum Ratings: PUSH-PULL CLASS AB_2 AMPLIFIER

(Same as for single-tube class A_1 amplifier)

Typical Operation (Values are for two tubes):	*Fixed Bias*		
Plate Voltage	360	360	volts
Grid-No.2 Voltage	225	270	volts
Grid-No.1 (Control-Grid) Voltage	-18	-22.5	volts
Peak AF Grid-No.1-to-Grid-No.1 Voltage	52	72	volts
Zero-Signal Plate Current	78	88	ma
Maximum-Signal Plate Current	142	205	ma
Zero-Signal Grid-No.2 Current	3.5	5	ma
Maximum-Signal Grid-No.2 Current	11	16	ma
Effective Load Resistance (Plate-to-plate)	6000	3800	ohms
Peak Grid-Input Power	140	270	mw
Total Harmonic Distortion	2	2	per cent
Maximum-Signal Power Output	31	47	watts

INSTALLATION AND APPLICATION

Types 6L6 and 6L6-G require an octal socket and may be mounted in any position. Outlines 7 and 40, respectively, OUTLINES SECTION. It is especially important that these tubes, like other power-handling tubes, should be adequately ventilated.

The heater is designed to operate at 6.3 volts. The transformer supplying this voltage should be designed to operate the heater at this recommended value for full-load operating conditions at average line voltage. Under the maximum screen- and plate-dissipation conditions, the heater voltage should never fluctuate so that it exceeds 7.0 volts. For cathode connection, refer to type 6AQ5.

In all services, precautions should be taken to insure that the dissipation rating is not exceeded with expected line-voltage variations, especially in the cases of fixed-bias operation. When the push-pull connection is used, fixed-bias values up to 10% of each typical grid-No.2 voltage can be used without increasing distortion.

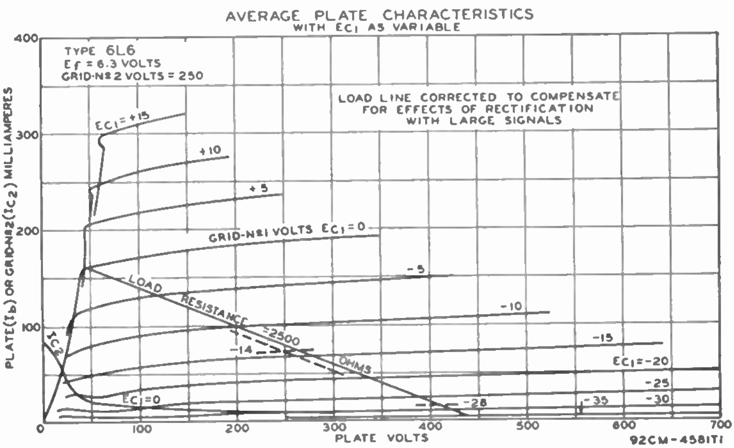
As **class A_1 power amplifiers**, the 6L6 and 6L6-G may be operated as shown in the tabulated data. The values cover cathode- and fixed-bias operation for both types where used as beam power tubes as well as where they are connected as triodes and have been determined on the basis that no grid current flows during any part of the input-signal swing. The second harmonics can easily be eliminated by the use of push-pull circuits. In single-tube amplifiers with resistance-coupled input, the second harmonics can be minimized by generating out-of-phase second harmonics in the pre-amplifier.

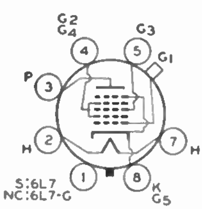
As **push-pull class AB_1 power amplifiers**, the 6L6 and 6L6-G may be operated as shown in the tabulated data. The values shown cover cathode- and fixed-bias operation and have been determined on the basis that no grid current flows during any part of the input-signal swing.

The type of input coupling used in class A_1 and class AB_1 service should not introduce too much resistance in the grid-No.1 circuit. Transformer- or impedance-coupling devices are recommended. When the grid-No.1 circuit has a resistance not higher than 0.1 megohm, fixed bias may be used; for higher values, cathode bias is required. With cathode bias the grid-No.1 circuit may have a resistance as high as, but not higher than, 0.5 megohm provided the heater voltage is not allowed to rise more than 10% above the rated value under any condition of operation.

As **push-pull class AB_2 power amplifiers**, the 6L6 and the 6L6-G may be operated as shown in the tabulated data. The values cover operation with fixed bias and have been determined on the basis that some grid current flows during the most positive swing of the input signal.

Refer to CIRCUIT SECTION for circuits employing the 6L6 or 6L6-G, and to the ELECTRON TUBE APPLICATIONS SECTION for discussion of inverse-feedback arrangements.





PENTAGRID MIXER

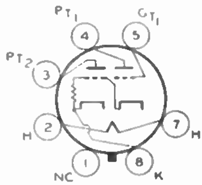
6L7
6L7-G

Metal type 6L7 and glass-octal type 6L7-G are used as mixers in superheterodyne circuits having a separate oscillator stage as well as in other applications where dual control is desirable in a single stage. The two separate control grids are shielded from each other and the coupling effects between oscillator and signal circuits are very small. For additional information, refer to **Frequency Conversion**, ELECTRON TUBE APPLICATIONS SECTION. Outlines 4 and 33, respectively, OUTLINES SECTION. Type 6L7-G is used principally for renewal purposes. Heater volts (ac/dc), 6.3; amperes, 0.3. Maximum ratings as mixer: plate volts, 300; grids-No.2-and-No.4 volts, 150; plate dissipation, 1.0 watt; grids-No.2-and-No.4 input, 1.5 watts. Typical operation as mixer (values recommended for all-wave receivers): plate volts, 250; grids-No.2-and-No.4 volts, 150; grid-No.1 (signal-grid) volts, −6 *min;* grid-No.3 (oscillator-grid) volts*, −15; peak oscillator volts applied to grid-No.3, 18 *min;* plate ma, 3.3; grids-No.2-and-No.4 ma, 9.2; plate resistance, greater than 1 megohm; conversion transconductance, 350 µmhos; grid-No.1 volts for 5 µmhos conversion transconductance, −45.

* The dc resistance in the grid-No.3 circuit should be limited to 50000 ohms.

6N6-G

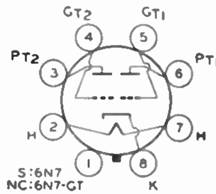
DIRECT-COUPLED POWER TRIODE



Glass octal type used as class A_1 power amplifier. Outline 35, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.8. For electrical characteristics, refer to type 6B5. Type 6N6-G is used principally for renewal purposes.

6N7
6N7-GT

HIGH-MU TWIN POWER TRIODE



Metal type 6N7 and glass-octal type 6N7-GT used in output stage of radio receivers as class B power amplifier or with units in parallel as a class A_1 amplifier to drive a 6N7 or 6N7-GT as a class B amplifier. Outlines 6 and 22, respectively, OUTLINES SECTION. Tubes require octal socket and may be mounted in any position. For typical operation as a resistance-coupled amplifier, refer to Chart 6, RESISTANCE-COUPLED AMPLIFIER SECTION. For class B amplifier considerations, refer to ELECTRON TUBE APPLICATIONS SECTION.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.8	ampere

CLASS B POWER AMPLIFIER

Values are for both units, unless otherwise specified.

Maximum Ratings:

Plate Voltage	300 *max*	volts
Peak Plate Current (Each Unit)	125 *max*	ma
Average Plate Dissipation (Each Unit)	5.5 *max*	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate-Supply Impedance	0	1000	ohms
Effective Grid-Circuit Impedance	0	516**	ohms
Plate Voltage	300	300	volts
Grid Voltage	0	0	volts
Peak AF Grid-to-Grid Voltage	58	82	volts
Zero-Signal DC Plate Current	35	35	ma
Maximum-Signal DC Plate Current	70	70	ma
Peak Grid Current (Each Unit)	20	22	ma
Effective Load Resistance (Plate-to-plate)	8000	8000	ohms
Total Harmonic Distortion	4	8	per cent
Third Harmonic Distortion	3.5	7.5	per cent
Fifth Harmonic Distortion	1.5	2.5	per cent
Maximum-Signal Power Output	10	10	watts

** At 400 cycles per second for class B stage in which the effective resistance per grid circuit is 500 ohms, and the leakage reactance of the coupling transformer is 50 millihenries. The driver stage should be capable of supplying the grids of the class B stage with the specified values at low distortion.

CLASS A_1 AMPLIFIER

Both grids connected together at socket; likewise, both plates.

Maximum Ratings:

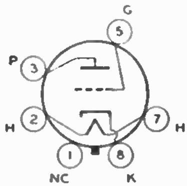
Plate Voltage	300 *max*	volts
Plate Dissipation (per plate)	1.0 *max*	watt

PEAK HEATER-CATHODE VOLTAGE:			
Heater negative with respect to cathode		90 *max*	volts
Heater positive with respect to cathode		90 *max*	volts

Typical Operation:

Plate Voltage	250	300	volts
Grid Voltage	–5	–6	volts
Amplification Factor	35	35	
Plate Resistance	11300	11000	ohms
Transconductance	3100	3200	μmhos
Plate Current	6	7	ma

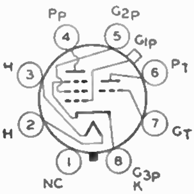
Plate Load—Depends largely on the design factors of the class B amplifier. In general, the load will be between 20000 and 40000 ohms.
Power Output—Under maximum voltage conditions, upwards of 400 milliwatts can be obtained.



6P5-GT

MEDIUM-MU TRIODE

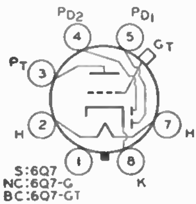
Glass octal type used as detector, amplifier, or oscillator in radio receivers. Outline 22, OUTLINES SECTION. Tube requires octal socket. Heater volts (ac/dc), 6.3; amperes, 0.3. Except for interelectrode capacitances, this type is identical electrically with type 76. Type 6P5-GT is used principally for renewal purposes.



6P7-G

TRIODE—PENTODE

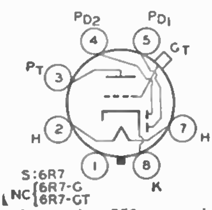
Glass octal type used as an amplifier. Outline 33, OUTLINES SECTION. Heater volts (ac/dc), 6.3; amperes, 0.3. Except for interelectrode capacitances, this type is identical electrically with type 6F7. Type 6P7-G is a DISCONTINUED type listed for reference only.



6Q7
6Q7-G
6Q7-GT

TWIN DIODE—HIGH-MU TRIODE

Metal type 6Q7 and glass-octal types 6Q7-G and 6Q7-GT used as a combined detector, amplifier, and avc tube in radio receivers. Outlines 4, 33, and 23, respectively, OUTLINES SECTION. Type 6Q7-G is used principally for renewal purposes. Tubes require octal socket and may be mounted in any position. Heater volts (ac/dc), 6.3; amperes, 0.3. For heater and cathode considerations, refer to type 6AV6. These types are similar electrically in most respects to types 6SQ7 and 6AT6. Maximum ratings and typical operation of the triode unit as a class A_1 amplifier are the same as those for type 6AT6 except that with a plate voltage of 100 volts, the transconductance is 1200 μmhos and the plate resistance 58000 ohms. The triode unit is recommended for use only in resistance-coupled circuits; refer to Chart 7, RESISTANCE-COUPLED AMPLIFIER SECTION. For triode-unit, grid-bias considerations, refer to type 6AV6. For diode curves, refer to type 6SQ7.

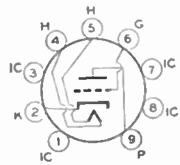


6R7
6R7-G
6R7-GT

TWIN DIODE—MEDIUM-MU TRIODE

Metal type 6R7 and glass-octal types 6R7-G and 6R7-GT used as combined detector, amplifier, and avc tubes. Outlines 4, 33, and 20, respectively, OUTLINES SECTION. Tubes require octal sockets. Within their maximum ratings, these types are identical electrically with type 6BF6 except for capacitances. Maximum ratings of triode unit as class A_1 amplifier: plate volts, 250 *max;* plate dissipation, 2.5 *max* watts. For typical operation as a resistance-coupled amplifier, refer to Chart 9, RESISTANCE-COUPLED AMPLIFIER SECTION. Type 6R7-G is a DISCONTINUED type listed for reference only.

MEDIUM-MU TRIODE



6S4

Miniature type having high perveance used as vertical deflection amplifier in television receivers. Outline 16, OUTLINES SECTION. Tube requires noval nine-contact socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AQ5.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.6	ampere

Characteristics: CLASS A_1 AMPLIFIER

Plate Voltage	250	volts
Grid Voltage	−8	volts
Amplification Factor	16	
Plate Resistance (Approx.)	3600	ohms
Transconductance	4500	μmhos
Plate Current	26	ma

VERTICAL DEFLECTION AMPLIFIER

For operation in a 525-line, 30-frame system

Maximum Ratings:

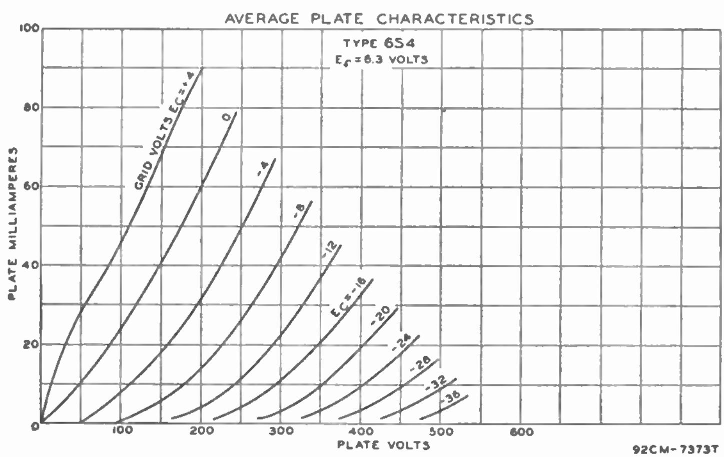
DC PLATE VOLTAGE	500 *max*	volts
PEAK POSITIVE-PULSE PLATE VOLTAGE°	2000 *max*	volts
DC GRID VOLTAGE	−50 *max*	volts
PEAK NEGATIVE-PULSE GRID VOLTAGE	−200 *max*	volts
DC CATHODE CURRENT	30 *max*	ma
PLATE DISSIPATION	7.5 *max*	watts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	200 *max*	volts
Heater positive with respect to cathode	200 *max*	volts

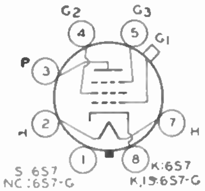
Circuit Values:

Grid-Circuit Resistance	2.2 *max*	megohms
Cathode-Bias Resistance #	220 *min*	ohms

° The duration of the voltage pulse must not exceed 15% of one scanning cycle. In a 525-line, 30-frame system, 15% of one scanning cycle is 2.5 milliseconds.

Indicated minimum value of this resistor is required to protect the tube in the event of temporary failure of excitation and resultant loss in developed bias.

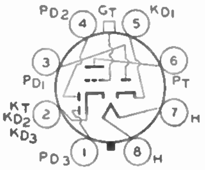




REMOTE-CUTOFF PENTODE

6S7
6S7-G

Metal type 6S7 and glass-octal type 6S7-G are used in rf and if stages of automobile receivers employing avc. Outlines 5 and 33, respectively, OUTLINES SECTION. Type 6S7-G is used principally for renewal purposes. Tubes require octal socket and may be mounted in any position. Heater volts, 6.3; amperes, 0.15. Typical operation and maximum ratings as Class A_1 amplifier: plate volts, 250 (300 *max*); grid-No.2 volts, 100 *max*; grid-No.1 volts, −3 (0 *min*); grid No.3 connected to cathode at socket; plate ma., 8.5; grid-No.2 ma., 2; plate resistance, 1.0 megohm; transconductance, 1750 μmhos; grid-No.1 volts for transconductance of 10 μmhos, −38.5. Plate dissipation, 2.25 *max* watts; grid-No.2 input, 0.25 *max* watt. For typical operation as a resistance-coupled amplifier, refer to Chart 16, RESISTANCE-COUPLED AMPLIFIER SECTION.



TRIPLE DIODE—HIGH-MU TRIODE

6S8-GT

Glass octal type used as audio amplifier, AM detector, and FM detector in AM/FM receivers. Diode unit No.2 is used for AM detection, and diode units No.1 and No.3 are used for FM detection. The grid of the high-mu triode is brought out to a top cap. Outline 27, OUTLINES SECTION. Tube may be mounted in any position. For heater and cathode considerations, refer to type 6AV6. For typical operation of triode unit as a resistance-coupled amplifier, refer to Chart 4, RESISTANCE-COUPLED AMPLIFIER SECTION.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (With external shield):		
Triode Grid to Triode Plate	1.2	μμf
Triode Input	2.0	μμf
Triode Output	5.0	μμf
Triode Grid to any Diode Plate	0.005 *max*	μμf
Diode Plate to Cathode (Approx. for each unit)	1.0	μμf

TRIODE UNIT AS CLASS A_1 AMPLIFIER

Maximum Ratings:

TRIODE PLATE VOLTAGE	300 *max*	volts
TRIODE PLATE DISSIPATION	0.5 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Characteristics:

Plate Voltage	50	100	250	volts
Grid Voltage	–	−1	−2	volts
Grid Resistor	10	0	0	megohms
Amplification Factor	85	100	100	
Plate Resistance	285000	110000	91000	ohms
Transconductance	300	900	1100	μmhos
Plate Current	0.07	0.4	0.9	ma

DIODE UNITS

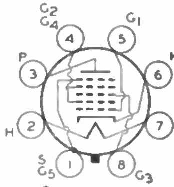
Maximum Rating:

PLATE CURRENT (EACH UNIT)	1.0 *max*	ma

Diode units No.2 and No.3 and the triode unit have a common cathode. Diode unit No.1 has a separate cathode. For diode operation curves, refer to type 6SQ7.

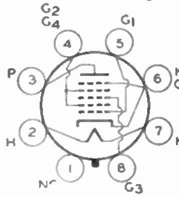
6SA7

PENTAGRID CONVERTER



Metal type 6SA7 and glass-octal type 6SA7-GT used as converter in superheterodyne circuits. They are similar in performance to type 6BE6. For general discussion of pentagrid types, see **Frequency Conversion** in ELECTRON TUBE APPLICATIONS SECTION. Both tubes have excellent frequency stability.

6SA7-GT



HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere

DIRECT INTERELECTRODE CAPACITANCES:	*6SA7*	*6SA7-GT*	
Grid No.3 to All Other Electrodes (RF Input)	9.5*	11**	μμf
Plate to All Other Electrodes (Mixer Output)	9.5*	11**	μμf
Grid No.1 to All Other Electrodes (Osc. Input)	7*	8**	μμf
Grid No.2 to Plate	0.13 *max**	0.5 *max***	μμf
Grid No.3 to Grid No.1	0.15 *max**	0.4 *max***	μμf
Grid No.1 to Plate	0.06 *max**	0.2 *max***	μμf
Grid No.1 to Shell, Grid No.5, and All Other Electrodes except Cathode	4.4	–	μμf
Grid No.1 to All Other Electrodes except Cathode and Grid No.5	–	5	μμf
Grid No.1 to Cathode	2.6	–	μμf
Grid No.1 to Cathode and Grid No.5	–	3	μμf
Cathode to Shell, Grid No.5, and All Other Electrodes except Grid No.1	5	–	μμf
Cathode and Grid No.5 to All Other Electrodes except Grid No.1	–	14	μμf

* With shell connected to cathode. ** With external shield connected to cathode.

CONVERTER SERVICE

Maximum Ratings:

PLATE VOLTAGE	300 *max*	volts
GRIDS-NO.2-AND-NO.4 VOLTAGE	100 *max*	volts
GRIDS-NO.2-AND-NO.4 SUPPLY VOLTAGE	300 *max*	volts
GRID-NO.3 VOLTAGE:		
Negative bias value	-50 *max*	volts
Positive bias value	0 *max*	volts
PLATE DISSIPATION	1.0 *max*	watt
GRIDS-NO.2-AND-NO.4 INPUT	1.0 *max*	watt
TOTAL CATHODE CURRENT	14 *max*	ma
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

	Self-Excitation†		*Separate Excitation*		
Plate Voltage	100	250	100	250	volts
Grids-No.2-and-No.4 Voltage	100	100	100	100	volts
Grid-No.3 (Control-Grid) Voltage	0	0	-2	-2	volts
Grid-No.1 Resistor	20000	20000	20000	20000	ohms
Plate Resistance (Approx.)	0.5	1.0	0.5	1.0	megohm
Conversion Transconductance	425	450	425	450	μmhos
Grid-No.3 Voltage (Approx.) for transconductance of 10 μmhos	-25	-25	-25	-25	volts
Grid-No.3 Voltage (Approx.) for conversion transconductance of 100 μmhos	-9	-9	-9	-9	volts
Plate Current	3.3	3.5	3.3	3.5	ma
Grids-No.2-and-No.4 Current	8.5	8.5	8.5	8.5	ma
Grid-No.1 Current	0.5	0.5	0.5	0.5	ma
Total Cathode Current	12.3	12.5	12.3	12.5	ma

NOTE: The transconductance between grid No.1 and grids No.2 and No.4 connected to plate (not oscillating) is approximately 4500 μmhos under the following conditions: grids No.1, No.3, and shell at 0 volts; grids No.2 and No.4 and plate at 100 volts.

† Characteristics are approximate only and are shown for a Hartley circuit with a feedback of approximately 2 volts peak in the cathode circuit.

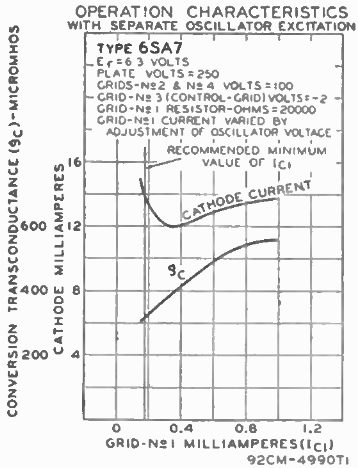
INSTALLATION AND APPLICATION

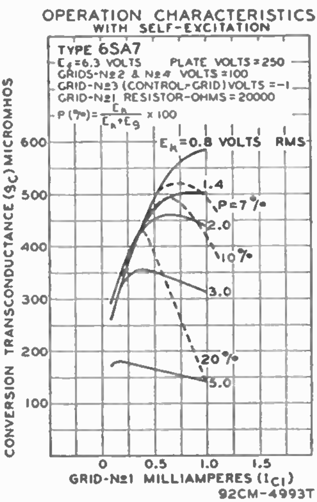
Types 6SA7 and 6SA7-GT require octal socket and may be mounted in any position. Outlines 3 and 22, respectively, OUTLINES SECTION. For heater and cathode considerations, refer to type 6AV6.

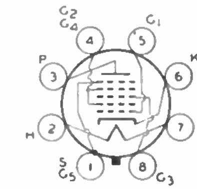
Because of the special structural arrangement of the 6SA7 and 6SA7-GT, a change in signal-grid voltage produces little change in cathode current. Consequently, an rf voltage on the signal grid produces little modulation of the electron current flowing in the cathode circuit. This feature is important because it is desirable that the impedance in the cathode circuit should produce little degeneration or regeneration of the signal-frequency input and intermediate-frequency output. Another important feature is that, because signal-grid voltage has little effect on the space charge near the cathode, changes in avc bias produce little change in oscillator transconductance and in the input capacitance of the No.1 grid. There is, therefore, little detuning of the oscillator by avc bias.

A typical self-excited oscillator circuit for use with the 6SA7 will be similar to that for the 6BE6 in the CIRCUIT SECTION. For operation in frequency bands lower than approximately 6 megacycles per second, the circuit should generally be adjusted to provide, with recommended values of plate and grids-No.2-and-No.4 voltage, a cathode voltage of approximately 2 volts peak, and an oscillator-grid current of 0.5 milliampere through a grid resistor of 20000 ohms. In the low- and medium-frequency bands, the recommended oscillator conditions can be readily met. However, in the band covering frequencies higher than approximately 6 megacycles per second, the tank-circuit impedance is generally so low that it is not easy to obtain these oscillator conditions. For optimum performance in this band, it is generally best to adjust the oscillator circuit for maximum conversion gain at the low-frequency end of the band. Maximum conversion gain at this end of the band is usually obtained by adjustment of the oscillator circuit to give a cathode voltage of approximately 2 volts peak and an oscillator-grid current of 0.20 to 0.25 milliampere, with a grid resistor of 20000 ohms.

In the 6SA7 and 6SA7-GT operation characteristics curves with self-excitation, E_k is the voltage across the oscillator-coil section between cathode and ground; E_g is the oscillator voltage between cathode and grid.







PENTAGRID CONVERTER

6SB7-Y

Metal type used as converter in superheterodyne circuits. Because of its high conversion and oscillator transconductance, it is especially useful in FM converter service in the 100-megacycle region. The 6SB7-Y has a micanol base which minimizes drift in oscillator frequency during warm-up period. For general discussion of pentagrid types, see **Frequency Conversion** in ELECTRON TUBE APPLICATIONS SECTION. Outline 3, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere

Maximum Ratings: CONVERTER SERVICE

Plate Voltage	300 *max*	volts
Grids-No.2-and-No.4 Voltage	100 *max*	volts
Grids-No.2-and-No.4 Supply Voltage	300 *max*	volts
Plate Dissipation	2.0 *max*	watts
Grids-No.2-and-No.4 Input	1.5 *max*	watts
Total Cathode Current	22 *max*	ma
Grid-No.3 Voltage:		
Negative bias voltage	100 *max*	volts
Positive bias voltage	0 *max*	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 (Separate Excitation):*

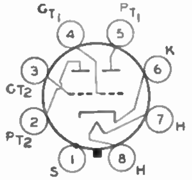
Plate Voltage	100	250	volts
Grids-No.2-and-No.4 (Screen) Voltage	100	100	volts
Grid-No.3 (Control-Grid) Voltage	−1.0	−1.0	volt
Grid-No.1 (Oscillator Grid) Resistor	20000	20000	ohms
Plate Resistance (Approx.)	0.5	1.0	megohm
Conversion Transconductance	900	950	μmhos
Conversion Transconductance with grid-No.3 bias of −20 volts	3.5	3.5	μmhos
Plate Current	3.6	3.8	ma
Grids-No.2-and-No.4 Current	10.2	10	ma
Grid-No.1 Current	0.35	0.35	ma
Total Cathode Current	14.2	14.2	ma

* The characteristics shown with separate excitation correspond very closely with those obtained in a self-excited oscillator circuit operating with zero bias.

Typical Operation in FM Band (88-108 Mc):

Plate Voltage		250	volts
Grids-No.2-and-No.4 Supply Voltage		250	volts
Grids-No.2-and-No.4 Resistor		12000	ohms
Grid-No.1 Resistor		22000	ohms
Signal Frequency	88	108	Mc
Oscillation Frequency	98.7	118.7	Mc
Plate Current	6.8	6.5	ma
Grids-No.2-and-No.4 Current	12.6	12.5	ma
Grid-No.1 Current	0.130	0.140	ma

NOTE: The transconductance between grid No.1 and grids No.2 and No.4 connected to plate (not oscillating) is approximately 8000 μmhos under the following conditions: signal applied to grid No.1 at zero bias; grids No.2 and No.4 and plate at 100 volts; grid No.3 grounded. Under the same conditions, the plate current is 32 milliamperes and the amplification factor is 16.5.



HIGH-MU TWIN TRIODE

6SC7

Metal type used as phase inverter or voltage amplifier in radio equipment. Except for common cathode, each triode is independent of the other. Outline 3, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6. For typical operation as a resistance-coupled amplifier, refer to Chart 17, RESISTANCE-COUPLED AMPLIFIER SECTION.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (Shell connected to cathode):*		
Grid to Plate	2	μμf
Input	2	μμf
Output	3	μμf

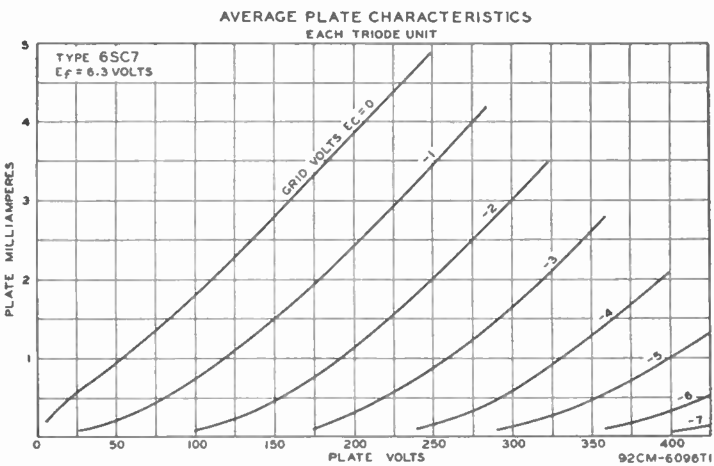
* Approximate values for each unit.

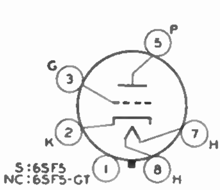
Maximum Ratings: CLASS A_1 AMPLIFIER

PLATE VOLTAGE	250 *max*	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 (Each Unit):

Plate Voltage	250	volts
Grid Voltage	–2	volts
Amplification Factor	70	
Plate Resistance (Approx.)	53000	ohms
Transconductance (Approx.)	1325	μmhos
Plate Current	2	ma





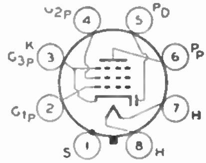
HIGH-MU TRIODE

6SF5
6SF5-GT

Metal type 6SF5 and glass-octal type 6SF5-GT are used in resistance-coupled amplifier circuits. Outlines 3 and 22, respectively, OUTLINES SECTION. Tubes require octal socket and may be mounted in any position. Characteristics, application, and references under type 6F5 apply to types 6SF5 and 6SF5-GT. Heater volts (ac/dc), 6.3; amperes, 0.3.

6SF7

DIODE— REMOTE-CUTOFF PENTODE



Metal type used as combined rf or if amplifier and detector or avc tube in radio receivers. Also used as resistance-coupled af amplifier. Outline 3, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6. For typical operation as a resistance-coupled amplifier, refer to Chart 19, RESISTANCE-COUPLED AMPLIFIER SECTION.

Heater Voltage (ac/dc)	6.3	volts
Heater Current	0.3	ampere
Direct Interelectrode Capacitances (Shell connected to cathode):		
Pentode Unit:		
Grid No. 1 to Plate	0.004 *max*	μμf
Input	5.5	μμf
Output	6.0	μμf
Pentode Grid No.1 to Diode	0.002 *max*	μμf
Pentode Plate to Diode	0.8	μμf

PENTODE UNIT AS CLASS A_1 AMPLIFIER

Maximum Ratings:

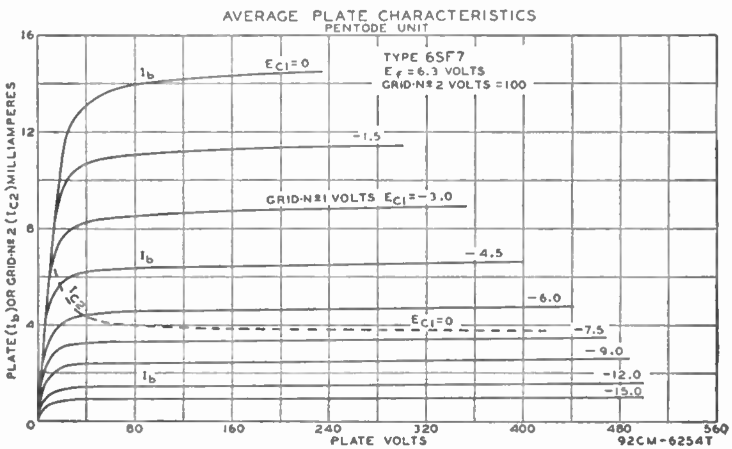
Plate Voltage	300 *max*	volts
Grid-No.2 (screen) Voltage	100 *max*	volts
Grid-No.2 Supply Voltage	300 *max*	volts
Grid-No.1 (control-grid) Voltage, Positive Bias Value	0 *max*	volts
Plate Dissipation	3.5 *max*	watts
Grid-No.2 Input	0.5 *max*	watt
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

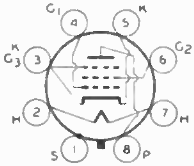
Typical Operation:

Plate Voltage	100	250	volts
Grid-No.2 Voltage	100	100	volts
Grid-No.1 Voltage	−1	−1	volt
Plate Resistance (Approx.)	0.2	0.7	megohm
Transconductance	1975	2050	μmhos
Grid-No.1 Bias (Approx.) for transconductance of 10 μmhos	−35	−35	volts
Plate Current	12	12.4	ma
Grid-No. 2 Current	3.4	3.3	ma

DIODE UNIT

The diode plate is placed around the cathode, the sleeve of which is common to the pentode unit. For diode operation curves, refer to type 6SQ7.





REMOTE-CUTOFF PENTODE

6SG7

Metal type used as rf amplifier in high-frequency and wide-band applications. Features high transconductance with low grid-No.1-to-plate capacitance. Suitable for frequencies up to 18 megacycles per second (approx.). Two separate cathode terminals enable the input and output circuits to be effectively isolated from each other. Outline 3, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. For heater and cathode considerations, refer to type 6AV6.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (Shell connected to cathode):		
Grid No.1 to Plate	0.003 *max*	μμf
Input	8.5	μμf
Output	7.0	μμf

CLASS A_1 AMPLIFIER

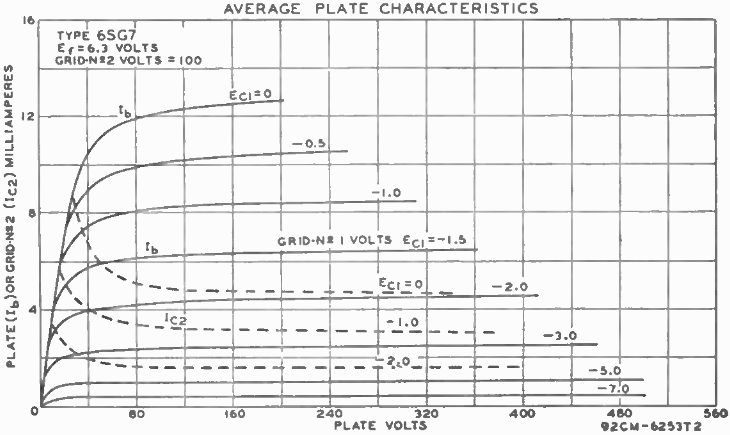
Maximum Ratings:

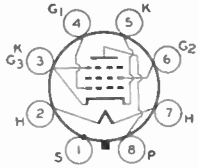
PLATE VOLTAGE	300 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	200 *max*	volts
GRID-NO.2 SUPPLY VOLTAGE	300 *max*	volts
GRID-NO.1 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	volts
PLATE DISSIPATION	3 *max*	watts
GRID-NO.2 INPUT	0.6 *max*	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	90 *max*	volts
Heater positive with respect to cathode	90 *max*	volts

Typical Operation:

Plate Voltage	100	250	250	volts
Grid-No.2 Voltage	100	125	150	volts
Grid-No.1 Voltage	-1	-1	-2.5	volts
Grid No.3 (Suppressor)	Connected to pin No. 3 internally			
Plate Resistance (Approx.)	0.25	0.9	+	megohm
Transconductance	4100	4700	4000	μmhos
Grid-No.1 Bias (Approx.) for transconductance of 40 μmhos	-11.5	-14	-17.5	volts
Plate Current	8.2	11.8	9.2	ma
Grid-No.2 Current	3.2	4.4	3.4	ma

+ Greater than 1 megohm.





6SH7

SHARP-CUTOFF PENTODE

Metal type used as rf amplifier in high-frequency, wide-band applications and as a limiter tube in FM equipment. Similar electrically to miniature type 6AU6. It features high transconductance and low grid-No.1-to-plate capacitance. Outline 3, OUTLINES SECTION. Tube requires octal socket and may be mounted in any position. Two separate cathode terminals enable the input and output circuits to be isolated effectively from each other. This type is not recommended for high-gain, audio-amplifier applications because undesirable hum may be encountered. For heater and cathode considerations, refer to type 6AV6. For typical operation as a resistance-coupled amplifier, refer to Chart 8, RESISTANCE-COUPLED AMPLIFIER SECTION.

HEATER VOLTAGE (AC/DC)	6.3	volts
HEATER CURRENT	0.3	ampere
DIRECT INTERELECTRODE CAPACITANCES (Shell connected to cathode):		
Grid No.1 to Plate	0.003 *max*	μμf
Input	8.5	μμf
Output	7.0	μμf

Maximum Ratings: CLASS A₁ AMPLIFIER

PLATE VOLTAGE	300 *max*	volts
GRID-NO.2 (SCREEN) VOLTAGE	150 *max*	volts
GRID-NO.2 SUPPLY VOLTAGE	300 *max*	volts
PLATE DISSIPATION	3 *max*	watts
GRID-NO.2 INPUT	0.7 *max*	watt
GRID-NO.1 (CONTROL-GRID) VOLTAGE, Positive Bias Value	0 *max*	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:

Plate Voltage	100	250	volts
Grid-No.2 Voltage	100	150	volts
Grid-No.1 Voltage	-1	-1	volt
Plate Resistance (Approx.)	0.35	0.9	megohm
Transconductance	4000	4900	μmhos
Grid-No.1 Bias for plate current of 10 μa	-4.0	-5.5	volts
Plate Current	5.3	10.8	ma
Grid-No.2 Current	2.1	4.1	ma

AVERAGE PLATE CHARACTERISTICS