

# APPENDIX

## FUNDAMENTAL ELECTRICAL LAWS

### OHM'S LAW

When a continuous current is flowing thru a given conductor, whose temperature is maintained constant, the ratio of the potential difference or voltage existing between the conductor terminals and the current carried by the conductor is a constant, no matter what the value of the current may be. The mathematical formulae for Ohm's Law may be expressed in the following forms:

$$R = \frac{E}{I} \quad I = \frac{E}{R} \quad E = IR$$

Where  $R$  = resistance expressed in ohms

$I$  = current expressed in amperes

$E$  = potential difference or voltage in volts

A practical example is given to illustrate the use of Ohm's Law:

If the screen current for a certain tube is 2 milliamperes (0.002 ampere) what value of resistance should be used to reduce the screen voltage to 90 volts from a supply voltage of 250 volts?

Solution: The required voltage drop across the resistor would be 250 — 90 or 160 volts.

$$\text{Therefore } R = \frac{E}{I} = \frac{160 \text{ volts}}{0.002 \text{ ampere}} = 80,000 \text{ ohms}$$

### POWER

Power is the time rate of doing work. Since energy is the ability to do work, power may also be defined as the time rate of expending energy. From the fundamental definitions of power, electromotive force and current it is easy to show that power may be computed from the following expression:

$$P = EI$$

If  $E$  is expressed in volts and  $I$  in amperes then the power  $P$  will be given in watts. Using values for  $E$  or for  $I$  from Ohm's Law, the above expression becomes either:

$$P = I^2 R \quad \text{or} \quad P = \frac{E^2}{R}$$

If the first equation for power is used, the wattage rating of the resistor used for reducing the screen voltage may be computed.

$$P = EI = 160 \text{ volts} \times 0.002 \text{ ampere} = 0.32 \text{ watt}$$

A 0.5 watt resistor should be employed.

### RESISTORS CONNECTED IN SERIES AND IN PARALLEL:

When two or more resistors are connected in series, so that the same current flows through each resistor, the total effective resistance ( $R_t$ ) of the network will be the sum of the separate resistances. Thus:

$$R_t = R_1 + R_2 + R_3 + \dots$$

If a number of resistors are connected in parallel so that the voltage drop is the same across each resistor, then the current in each resistor will be inversely proportional to the resistances. The total effective resistance ( $R_t$ ) of the network, will be given by:

$$1/R_t = 1/R_1 + 1/R_2 + 1/R_3 + \dots$$

For the case of two resistors in parallel:

$$R_t = \frac{R_1 R_2}{R_1 + R_2}$$

### **CALCULATION OF CONDENSERS IN SERIES AND IN PARALLEL:**

When a number of condensers are connected in series, the total effective capacity ( $C_t$ ) is computed from the relation:

$$1/C_t = 1/C_1 + 1/C_2 + 1/C_3 + \dots$$

For the case of two condensers connected in series this expression reduces to the form:

$$C_t = \frac{C_1 C_2}{C_1 + C_2}$$

The total capacity ( $C_t$ ) of any number of condensers connected in parallel is the sum of the separate capacities:

$$C_t = C_1 + C_2 + C_3 + \dots$$

### **CALCULATION OF PROPER RESISTOR FOR SELF-BIASING:**

From Ohm's Law

$$R = \frac{\text{Grid Bias in Volts} \times 1000}{\text{Total Cathode Current in Ma.} \times \text{Number of Tubes Involved}}$$

For triodes the total cathode current is equal to the plate current.

For tetrodes and pentodes the total cathode current is the sum of the plate and screen currents.

For pentagrid converters the plate, screen and oscillator anode currents must be added to obtain the total cathode current.

Example: What biasing resistor is required for two Type 6L6G tubes operated in push-pull Class A with 250 volts applied to the plates?

The following data are taken from the characteristics shown for Type 6L6G:

- Grid Bias = -16 Volts
- Zero Signal Plate Current = 60.0 Ma. per tube
- Zero Signal Screen Current = 5.0 Ma. per tube
- Total Cathode Current = 65.0 Ma.

$$\text{Hence: } R = \frac{16 \times 1000}{65 \times 2} = \frac{16000}{130} = 125 \text{ ohms}$$

When over-biased operation is employed the recommended bias resistor values will be specified under Ratings or Circuit Application notes for the tube type involved.

# FUNDAMENTAL PROPERTIES OF VACUUM TUBES

The major operating characteristics of a vacuum tube can be expressed in terms of the amplification factor ( $\mu$ ), the dynamic plate resistance ( $R_P$ ) and the mutual conductance ( $G_M$ ). When these are known one can make quantitative calculations of the tube performance under many conditions.

The **Amplification Factor** is defined as the ratio of a small increment in plate voltage to the corresponding change in grid voltage necessary to maintain constant plate current. In other words, it is the ratio of the effectiveness of the grid and plate voltages in producing electrostatic forces at the surface of the cathode. The amplification factor depends upon the configuration of the electrode system, especially the grid structure, and the electrode voltages. Changes which cause the grid to more completely shield the plate from the cathode will increase the value of  $\mu$ .

The **dynamic Plate Resistance** may be defined as the ratio of a small change in plate voltage to the corresponding change in plate current produced. The value will depend upon the grid and plate voltages at the operating point under consideration. It will not be equal to the ratio of total plate voltage to total plate current. The dimensions and relative positions of the tube electrodes will largely determine the value of plate resistance.

The **Mutual Conductance** ( $G_M$ ), sometimes called control grid-plate transconductance ( $S_M$ ), is the ratio of the amplification factor to the plate resistance and represents the rate of change in plate current with respect to the change in grid voltage when the other voltages remain constant.

**Interelectrode Capacities:** The electrodes of a vacuum tube form a complicated electrostatic system, and each element may be considered as forming one plate of a small condenser. In a three-element tube the capacitance between the cathode and grid, between the grid and plate, and between the plate and cathode, are known as the interelectrode capacitances of the tube. Of these, the grid-plate capacity is generally the most important. The effect of these capacitances depends upon the relationship between their reactances and the associated external circuit impedances. Their effect is, therefore, a function of frequency and external load.

In multi-electrode tubes the number of separate interelectrode capacitances is larger than for a triode. Fortunately, only three of these direct interelectrode capacitances are of great importance in most applications. These are:

1. Grid-plate capacity ( $C_{GP}$ ).
2. Direct input capacity from control grid to cathode plus all other electrodes except output plate.
3. Direct output capacity from plate to cathode plus all other electrodes except the input grid.

## AMPLIFIER CLASSIFICATION

All radio receiving tubes except the rectifiers may be conveniently considered as amplifiers. Oscillators and detectors or frequency converters may be thought of as special cases of amplifiers in which use is made of the non-linear relations between the input voltages and output currents of the tube under consideration.

There are three major classes of amplifier service. Definitions describing these have been standardized by the Institute of Radio Engineers.

## **Class A Amplifier**

A Class A, or Class A1, amplifier is one in which the grid bias and signal voltages are such that plate current in the tube, or in each tube of a push-pull stage flows at all times.

This is accomplished by operating at the center point of the plate current vs. grid voltage curve and using signal voltages which do not drive the grid into either the positive region or into the sharp bend near cut-off voltage.

## **Class A2 Amplifier**

A Class A2 amplifier is the same as a Class A1 amplifier except that the signal may drive the grid into the positive region. This is accomplished by operating at a lower bias than the center point which would have been selected for class A operation.

## **Class B Amplifier**

A Class B amplifier is an amplifier in which the grid bias is approximately equal to the cut-off value, so that the plate current is approximately zero when no signal voltage is applied and so that plate current in the tube or in each tube of a push-pull stage, flows for approximately one-half of each cycle when an alternating grid voltage is applied.

An important characteristic is that the grid circuit draws appreciable power which prevents it from being used with ordinary resistance coupled driver tubes.

## **Class AB1 Amplifier**

A Class AB1 amplifier permits greater output to be obtained from small tubes, but requires push-pull operation to reduce distortion. It is characterized by operation at a higher bias than for Class A and uses a signal large enough to drive the grid into the cut-off region but not into the positive region.

## **Class AB2 Amplifier**

A Class AB2 amplifier is the same as a Class AB1 above except that additional bias may be used, and the signal drives the grid into both the cut-off and grid current regions.

## **Class C Amplifier**

A Class C amplifier is one in which the tubes operate at a bias much greater than cut-off voltage so that plate power is drawn only on the peaks of the signal voltage. It is not used in audio amplifiers because the distortion is too high but is the most efficient circuit for R. F. power amplifiers where the harmonics can be reduced by use of resonant circuits.

# DEFINITIONS

## OF COMMON RADIO TERMS

**Anode Current:** The total current passing to or from an anode. In vacuum tube terminology this is called plate current. Symbol  $I_b$ .

**Cathode Current:** The total space current passing to or from the emitter. This should not be confused with filament current in filament type tubes. Symbol  $I_k$ .

**Conversion Transconductance:** (Formerly called Conversion Conductance). The ratio of the desired beat frequency component of the plate current to the signal voltage applied to the grid. It is expressed in micromhos. Symbol  $G_c$ .

**Coupling:** The mutual relationship between circuits permitting a transfer of energy between them.

**Degeneration:** The result of a portion of the output signal appearing in the input circuit of a vacuum tube so as to reduce gain. It is sometimes introduced to stabilize the circuit and to improve the response. It may be called negative or inverse feedback.

**Demodulation:** The process of separating the modulation component from the carrier. It is commonly called detection.

**Diode:** A vacuum tube having two elements. It is usually used as a rectifier or detector. A duo diode is two diodes in one envelope; one element may or may not be common to both diodes.

**Distortion:** The change in wave form produced by the transmission device or amplifier.

**Discriminator:** A circuit which produces a DC voltage proportional in value and polarity to the variations in the applied frequency about the mean frequency, or which converts frequency modulated signals directly into audio frequency signals.

**Electron Emission:** The liberation of electrons from a surface into the surrounding space. If accomplished under the influence of heat it is called Thermionic Emission. If due to the impact of other electrons, it is called Secondary Emission. When emission occurs from a grid from any cause, it is called Grid Emission.

**Fidelity:** The degree of accuracy of reproduction of the original signal.

**Filter:** A selective network or circuit designed to pass a certain frequency or band of frequencies and reject all others.

**Frequency Deviation:** The amount of instantaneous carrier frequency shift from the mean frequency due to modulation in frequency modulated transmitters.

**Frequency Modulation:** A method of transmitting intelligence by means of varying the frequency of a transmitter about the mean frequency in accordance with the signal it is desired to transmit.

**Gain:** The ratio of output to input signal. It may be expressed in terms of power or voltage. Conversion gain is the ratio of intermediate frequency output to signal frequency input.

**Heptode:** A seven element vacuum tube containing an anode, cathode and five other electrodes, usually grids. It is chiefly used as a converter or mixer.

**Hexode:** A six element vacuum tube containing an anode, cathode and four other electrodes, usually grids. It is chiefly used as a converter or mixer.

**Limiter:** A circuit designed to prevent a signal from exceeding a pre-determined amplitude. The stage in a FM receiver used to remove any amplitude changes in the received signal.

**Load Resistance:** The total effective resistance in the plate circuit external to the tube.

**Modulation:** The process of varying the amplitude, phase, or frequency of a carrier in accordance with a signal. **Cross modulation** is an undesired process whereby the carrier of a desired signal combines with the modulation from an undesired signal. It usually occurs within the receiving device.

**Modulation Factor:** The ratio of half the difference between the maximum and minimum amplitudes of a modulated carrier to the average value. It is usually expressed in percent and called **modulation percentage**.

**Octode:** An eight element vacuum tube containing an anode, cathode and six other elements usually grids. It is usually used as a converter or mixer.

**Oscillator:** A vacuum tube device for generating alternating current. In superhetrodyne receivers it is the portion of the circuit generating the local signal required to beat with the incoming signal to produce the intermediate frequency.

**Peak Inverse Voltage:** The maximum instantaneous recurring voltage developed in the opposite direction to that in which an electron tube is designed to pass current. In half-wave rectifiers the value may be 2.8 times the rms value of AC plate voltage.

**Peak Plate Current:** The instantaneous maximum recurring current flowing in an anode or plate circuit.

**Pentagrid Converter:** A vacuum tube having five grids. It is usually used as an oscillator-mixer in a superhetrodyne receiver.

**Pentode:** A five element vacuum tube having an anode, a cathode and three grids.

**Perveance:** This is a figure of merit often used for diodes to express the ability to rectify high frequency current with low voltage drop. It corresponds roughly to  $1/R$  in a linear conductor, but in a non-linear conductor such as a vacuum tube which does not follow Ohm's Law the corresponding characteristic is called Perveance. **High Perveance:** means optimum design for both low capacitance and low diode voltage drop for currents within the tube rating.

**Phase Modulation:** A method of modulating a carrier by shifting the phase of the carrier with respect to the non-modulated carrier.

**Pip:** A strong short pulse appearing on the screen of a cathode ray tube. It is often used as a marker.

**Plate:** The common name of the principal anode element in a vacuum tube.

**Power Amplifier:** An amplifier designed to deliver power as distinguished from a voltage amplifier.

**Power Output:** The useful power developed in the output device or circuit. It is usually limited by permissible distortion.

**Pulse:** A single disturbance, such as half a square wave. **Grid pulsing** is a method of controlling a circuit by introducing a pulse into the grid circuit. **Plate Pulsing** is the same as grid pulsing except the pulse is introduced into the plate circuit.

**Reactance Tube:** A vacuum tube with operating conditions so chosen that the tube appears as an inductance or capacitance which can be varied by means of changes in the control voltage.

**Rectifier:** A device for converting alternating current into direct current by permitting much more current to flow in one direction than the other. A **half-wave rectifier** permits current flow only during one half of the cycle. A **full-wave rectifier** permits current flow from both halves of the cycle.

**Regulation:** The ratio between a reference voltage and change of voltage caused by the load. It is usually expressed in percent.

**Ripple Voltage:** The alternating component of the DC voltage after rectification or from a generator.

**Selectivity:** The ability of a circuit to choose between desired and undesired signals on adjacent frequencies.

**Sensitivity:** Is the term used to denote the ratio between input signal and output power. Generally expressed as microvolts per watt.

**Side Bands:** Those frequencies adjacent to, and associated with a carrier.

**Space Charge:** A cloud of electrons between elements of a vacuum tube.

**Space Current:** The current consisting entirely of the electron flow from the cathode to the anode and other positive elements in a vacuum tube.

**Trigger Circuit:** A circuit having two stable operating conditions readily changed from one to the other by a small change in operating conditions.

**Triode:** A three element vacuum tube having an anode, cathode and a control electrode.

**Voltage Gain:** The ratio of the voltage developed in the plate circuit to the grid voltage necessary to produce it.

Voltage Gain per stage may be obtained from the formula:

$$\text{Gain} = \frac{\mu \times Z_P}{Z_P + R_P} = \frac{G_M \times R_P \times Z_P}{(Z_P + R_P) \times 10^6}$$

Where  $G_m$  is in micromhos;  $R_p$  and  $Z_p$  in ohms

# GENERAL TUBE AND CIRCUIT INFORMATION

Efficient tube performance requires that careful attention be given to proper installation and to circuit considerations. Numerous suggestions regarding tube ratings, voltage supplies for the various tube elements, volume controlling, shielding and filtering are discussed below. This information applies in a general way to all tube types and represents practical and approved methods employed in modern radio receivers. Additional instructions and precautions pertaining to a particular tube may be found under the **Circuit Application** for that type. Minor deviations from the information given may sometimes be desirable in special circuit designs, although in general it will be advisable to follow the recommendations.

## INTERPRETATION OF RECEIVING TUBE RATINGS

Interpretation of tube ratings published in this manual are in accordance with RMA standards. The ratings shall be interpreted according to the conditions outlined in the following paragraphs.

### 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.

### 1.4 Volt Battery Tube Types

**Dry Battery Operation:** The 1.4 volt line of battery tubes is designed to be operated from a dry cell battery rated at a terminal potential of 1.5 volts. In no case should the voltage across any 1.4 volt section of filament exceed 1.6 volts. In the case of series operation, shunting resistors may be required to obtain this condition.

**Operation from other Power Sources:** When other power supply sources are used the voltage drop across each 1.4 volt section should have a nominal value of 1.3 volts and should be maintained within a range of 1.25 and 1.4 volts at normal line voltage and for tubes of rated filament current. In the case of series operation shunting resistors may be required to obtain this condition. This assumes a normal line voltage of 117 volts, and a normal storage battery terminal voltage of 2.0 volts per cell.

### 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.

### Plate and Screen

In the case of plate voltage and screen voltage, however, recommended maximum values are given. The interpretation of this maximum value depends on the power source, as follows:

**A-C or D-C Power Line:** The maximum ratings of plate and screen voltages and dissipations given on the tube type data sheets are **Design Maximums**. For equipment designed for

use in the United States on nominal power-line services of 105 to 125 volts, satisfactory performance and serviceability may be anticipated, provided the equipment is designed so as not to exceed these **Design Maximums** at a line voltage of 117 volts.

**Automobile Storage Batteries:** When a tube is used in automobile receivers and other equipment operated from automobile storage batteries, consideration should be given to the larger percentage range over which the battery voltage varies as compared with the power-line voltage. The average voltage value of automobile batteries has been established as 6.6 volts. Automobile battery operated equipment should be designed so that when the battery voltage is 6.6 volts, the plate voltage, the plate dissipation, the screen voltage, the screen dissipation, and the rectifier load current will not exceed 90% of the respective recommended **Design Maximum** values given in the data for each tube type.

**"B" Batteries:** Equipment operated from "B" batteries should be designed so that under no condition of battery voltage will the plate voltage, the plate dissipation, the screen voltage, and the screen dissipation ever exceed the recommended respective maximum values shown in the data for each type by more than 10%.

### **Other Electrodes**

When a tube is of the multigrid type, the voltages applied to the additional positive electrodes will be governed by the considerations stated under Plate and Screen.

### **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.

## **VOLTAGE SUPPLIES**

The B-voltage supply includes voltage for the operation of plate circuits, screen circuits, and sometimes for bias circuits. The principal methods for obtaining each in various kinds of receivers will be described.

In battery receivers used in locations remote from power supply lines, B batteries are usually employed for the plate voltage. The screen voltage may be tapped off at the appropriate voltage; or for some cases a series dropping resistor and shunt filter condenser is applicable. Bias voltage was formerly obtained from separate batteries. However, with certain 1.4 volt battery types, such batteries are unnecessary since the tubes may be operated with no initial bias other than that developed across the a-v-c diode resistor.

For all other receivers screen voltages are obtained either by using a voltage divider or a series dropping resistor from the positive supply lead.

Grid bias is usually then supplied by means of an adequately by-passed resistor placed in the cathode circuit, or if a more stable bias is required, by means of a resistor in the negative lead of the plate supply and also adequately by-passed. Since this resistor carries the total plate supply load current, bias developed in this manner is much less affected by individual tube and circuit variations. As an economy measure a speaker field or filter choke having the proper resistance can be substituted for this resistor. In this case, resistance capacity filter circuits will be necessary to prevent hum voltage from appearing in the bias circuits, since the choke or speaker field will then often become part of the filter circuit.

In the cathode or "self-biased" circuit it is essential, except in push-pull circuits or where degeneration is desired, that the cathode resistor be by-passed with sufficient capacity so that no appreciable a-c impedance exists between cathode and grid return. With the other method of C-bias mentioned, adequate filtering must be used in order to keep at a minimum any power supply hum which might be applied to the tube grids.

For a-c operated receivers a step-up power transformer and rectifier tube are used to supply pulsating d.c. to an appropriate filter system, the output of which is essentially pure d.c. This supply can then be utilized for the recommended plate, screen and bias voltages.

In ac-dc radio sets the line voltage is applied directly across a rectifier tube and the associated filter system without using a power transformer. Whenever operation above 117 volts is required, a resistor of 50 to 100 ohms should be inserted in series with the rectifier plates to prevent damage to the tube or filter condenser. In many modern sets a filter capacity of 30 mf or more has been used which requires the addition of a peak current limiting resistor to prevent damage to the rectifier tube. The proper value will be found specified for each type under the various conditions of load. Except in circuits designed for voltage doubling, the rectified voltage will be relatively low and somewhat below the peak value of the impressed line voltage supply.

The r.f., converter and power output tubes suitable for use in this type of receiver are indicated by the inclusion of a rating of 100 volts for both plate and screen. The characteristics under these conditions show very little reduction in the mutual conductance but a great decrease in the plate resistance due to the plate and screen being at the same potential. The effect of this on performance can be estimated from the gain formula on page 14. The reasons for it can be seen from any of the plate characteristic curves and is discussed in the section on the Use of Curve Data.

Receivers operated directly on d.c. employ a hum or commutator-ripple filter that is connected across the line, the positive side being used for the plate supply voltage.

Automobile receivers utilize either a motor generator designed to deliver high d-c voltage, or a vibrator-transformer with a suitable rectifier and filter system to supply the set with B voltages. Either method depends upon the car storage battery as the primary source.

## HEATER VOLTAGE SUPPLIES

To obtain satisfactory performance it is important that proper voltages be supplied to the heaters or filaments at all times. The life of the tubes will be greatly shortened if excessive voltages are applied because the active or electron emitting material will be evaporated at a faster rate than required. If, on the other hand, the voltages are too low, the operating temperature of the cathode or filament will be inadequate to supply sufficient emission for proper operation.

The following sources of filament power supply are generally used:

- Dry batteries
- "Air Cell" batteries
- Storage batteries
- Direct Current 32 volt farm lighting power
- Alternating Current power line

The voltage delivered by dry batteries falls off during life so that it is necessary to provide a rheostat or ballast tube in order that constant voltage may be supplied to the tubes during the life of the batteries.

The voltage delivered by an "air cell" battery remains quite constant until final exhaustion, when it drops very rapidly. A fixed series resistor used in connection with this battery supply device will usually prove entirely satisfactory.

Exceptions to the two preceding paragraphs exist when 1.4 volt battery tubes are employed. These types will operate directly from a suitable 1.5 volt dry battery without the use of a series dropping resistor or ballast tube since the filament design provides satisfactory performance over the useful range normally encountered during the life of the battery. Single cell "air cells" also provide satisfactory operation without the use of a fixed series resistor since the constant terminal battery voltage is within the normal operating range for these tubes.

The voltage delivered by a storage battery varies widely, depending upon the condition of charge. If 5 volt tubes are employed, it will be necessary to employ a rheostat to reduce the voltage at the socket terminals to 5 volts. If 6.3 volt heater type tubes are employed, it will be unnecessary to use a series resistor unless the voltage range exceeds the normal value by more than 10%.

Receivers designed to operate on 115 volt d-c lines usually employ tubes connected in series, and with sufficient fixed resistance introduced the heater current is kept normal with 117 volts applied. Under normal line voltage variations from 105 volts to 130 volts no additional adjustable resistors will be necessary.

The universal type of receiver so common at the present time employs the series filament method of connection described in the previous paragraph. In general, no special precautions are necessary to take care of line voltage fluctuations.

Receivers designed for use on a-c power lines of a specified frequency employ step-down transformers to supply the proper filament voltages. If extremely high line voltages are encountered it may be desirable to incorporate an added resistor to reduce the voltage applied to the primary to a nominal value.

## VOLUME CONTROL CONSIDERATIONS

The method employed in older type receivers to control the volume was that of varying the screen voltage applied to the tubes. Later, with the advent of remote cut-off tubes, the system of C-bias variation was universally adopted. The bias voltage was obtained either from a potentiometer across the negative portion of the bleeder, or by inserting a variable resistance in the common cathode lead of several tubes when manual control of sensitivity was desired.

Most modern receivers employ automatic volume control. The function of the a-v-c circuit is to properly regulate the bias applied to the control grids of the r-f, converter and i-f tubes so that, in-so-far as the inherent limitations of the receiver permit, a nearly constant signal will be delivered to the input of the second detector. This is accomplished by utilizing the rectified voltage developed across the load resistor in the diode circuit for the control voltage impressed on the grids of the amplifier tubes. The diode current flowing through the resistor will place the cathode end at positive potential and the opposite end at negative potential. The negative voltage for biasing the grids is obtained from the negative end of this resistor. The value of the resistor should be such that for a given signal the drop in voltage across it will be sufficient to bias the tubes being controlled to a sensitivity consistent with the volume desired. An increase in the r-f signal input will raise the voltage drop, thereby applying more bias to the control tubes. This will decrease the receiver sensitivity and

maintain the receiver output at normal volume. On the other hand, a decrease in r-f signal input reduces the voltage drop and thus lowers the bias on the control tubes. This increases the receiver sensitivity and automatically maintains the volume constant.

With sharp cut-off tubes the cut-off voltage may be extended by feeding the screen through a series resistor from the full B-voltage source. The tube will then act somewhat similar to a remote cut-off type where the volume is controlled by varying the C-bias. The extended cut-off feature thus obtained is intermediate in magnitude between sharp and remote cut-off tubes. Such service is not recommended where the signal voltage is apt to be large since the sharpness of the knee of the dynamic characteristic is not materially reduced. In no case will the dynamic curve become similar to the characteristic of true remote cut-off tubes.

## SHIELDING

In order to obtain stable amplification which will be comparable with the theoretical limit it is essential that ample consideration be given to proper shielding. This is especially necessary in high gain circuits.

Each receiver layout will present different shielding problems. These become more complicated in small compact radios. Much can be done to minimize the necessity for shielding by using a layout scheme such that critical feed-back points are separated as far from each other as is conveniently possible. Over-all feed-back from the output tube to the antenna circuit should always be avoided.

## FILTERING

There are two major classes of filters, the high frequency and the low frequency types. In the former, very good condensers having low resistance and inductance components are required. Electrolytic condensers are not generally satisfactory for high frequency work.

At low frequencies it is necessary to consider the peak voltage that may be impressed on the condensers, since this is considerably greater than the d-c voltage measured across them. If considerable power is to be delivered from the filter an inductance-capacity filter should be used. Whenever the load current from the filter is not excessive, a resistance-capacity filter can be used. This type is more economical and requires less space.

AVC filter systems usually employ resistance and capacity networks. Careful consideration must be given to the time constant. If this is made too long, a sudden disturbance such as static may cause the receiver to become inoperative for a noticeable period of time. When the constant is too short, low frequency degeneration and modulation distortion may occur. A suitable value for the time constant is of the order of one-tenth second.

Screen circuits usually require more careful filtering than the plate circuits, since the screen grid has a control effect quite similar to any other grid in the tube. Instability and general interaction between circuits often result from inadequately filtered screen grids.

C-bias filtering has been discussed in detail under Voltage Sources. The usual circuit elements involved are series resistors and low-voltage shunt condensers.

## LOCK-IN TYPE TUBES

Sylvania Lock-Ins are small "all-glass" tubes without the familiar bakelite base. The contact pins are sealed into the glass bottom, thus eliminating soldered connections. This type of construction permits single-ended operation, as no top cap connections are present, and provides compactness, suitable shielding, and a special lock-in feature. Numerous types are especially suitable for use in UHF applications because of low lead inductances, low inter-electrode capacitances, and low dielectric losses. The lower portion of the tube is fitted with a metal shell and guide pin. This unit acts as a shield and makes possible the lock-in feature by employing a groove around the bottom of the locating pin which fits into a catch on the socket.

The locking arrangement holds the tubes in the sockets securely, assuring good contact at all times. Removal of these tubes from the sockets may be somewhat difficult when done by a direct upward pull. With a slight off-side pressure, the socket lock is released and the tube is readily removed.

These tubes are not directly interchangeable with other designs of receiving tubes because of the socket requirements. In many instances the electrical characteristics and applications are similar to other well known types. Adequate information is supplied under the various lock-in types shown elsewhere in this Manual.

## METAL TUBES

Metal tubes are somewhat smaller than the regular types of glass tubes. The bulb or shell diameter is one inch except at the base where the maximum diameter is one and five-sixteenths inches. The shell is all metal and the lead wires are brought out through the "header", which seals the shell at the bottom. The shell is connected to a base pin and operates at ground potential to eliminate any danger of electric shocks. The over-all length of the tube is reduced and an octal base is provided.

The octal base has provisions for eight pins uniformly spaced. Where fewer than eight pins are required, they are omitted and the spacing of the remaining pins is unchanged. The pin numbering is in accordance with the RMA standard numbering system. In this system, numbers are assigned to each of the eight possible pin positions. Numbering begins at the shell connection, which is always the first pin to the left of the locating lug when the base is viewed from the bottom with the lug toward the observer. The direction of numbering is clockwise on the basis of possible pin position.

## G, GT AND GT/G TUBES

Tubes are often classified according to their general design and construction. Lock-In and metal types have been briefly described. The so-called "regular" glass types are characterized by the style of glass envelope and particularly by the standard bakelite base equipped with four, five, six or seven pins as required, and the absence of any locating base lug.

G type tubes are glass tubes which are, in most cases, identical or very similar in operating characteristics to many of the regular types. The bases are of octal design with a bakelite locating lug while the top caps, if required, are of the miniature style. In these respects the G tubes resemble metal tubes.

A smaller version of the G tube is the GT style designed for use where tubes of this size are desired. For most GT types the characteristics are essentially the same as for the G type equivalent. All GT tubes are equipped with octal bases and a tubular bulb is employed. The suffix GT is derived from the base used on G types and tubular T style bulb. Reduction in physical size is secured through the use of a shorter stem.

Because of the similarity in characteristics between G tubes and the corresponding GT types it is usually possible to interchange GT for G tubes and vice versa if space permits. Consequently, many G types have been discontinued as such, the GT style adopted, and the tubes bulb-etched GT/G.

Two kinds of octal bases are employed on GT and GT/G types. Rectifier and output types are equipped with an all bakelite base as on G tubes. Converters, r-f and i-f types have metal shell bases, that is, a combination of a bakelite wafer to which is fastened a metal shell which is cemented to the glass bulb. The metal shell serves as a part of the shielding and is connected to pin No. 1. This arrangement often permits GT/G or GT tubes to be substituted for equivalent metal types. Slight realignment of tuned circuits may be required to secure correct performance. If additional shielding is necessary on GT/G tubes an external shield can be slipped over the metal shell. Other GT/G types may have one or the other style of base described above, this being optional with the manufacturer.

## MINIATURE TUBES

One of the recent trends in radio tube manufacture is the reduction in size of the tube required for given performance. The group of tubes known as miniatures are good examples of the results which may be obtained in a small T-5½ bulb. Many of these types are particularly useful at high frequencies because of the short leads and the absence of the old style phenolic insulation. Some well-known types of this design are Types 12AU6, 12AT6, 12BA6, 12BE6, 35W4 and 50B5.

## BATTERY TUBES

There are two general groups of battery tubes: the group designed for 2-volt operation and the newer group of 1.4 volt types. The former are now employed primarily for replacement purposes and their characteristics are quite well known. The latter both in GT/G and Lock-In construction are widely used in all forms of battery receivers and several special features are outlined below.

The 1.4 volt group of battery tubes is of particular interest because of the economy afforded in power supply requirements and the reduction in space which is possible. These tubes have been designed especially for economical operation, non-microphonic action and long life. With the exception of the output types, the tubes are designed for zero bias operation, thus simplifying circuit applications and reducing couplings to some extent.

Since these tubes are of the directly heated filament type there may be some small variation in contact potential which, in some instances, may result in slight variation in sensitivity between tubes of the same type if the grid return is made directly to minus filament. It is recommended that a resistance of at least 0.5 megohm, suitably by-passed, be connected between the grid return and minus filament. If these tubes are employed so that a-v-c voltage is applied to the grids, the resistors used for isolation and diode load will be sufficient.

Since the filament wire employed in these tubes is extremely small in diameter, some precautions may be necessary to prevent filament vibrations resulting mainly from acoustic and mechanical feed-back from the speaker to the tubes and chassis. Therefore, it is preferable not to mount the speaker directly on the chassis. A further point to bear in mind is the fact that the permanent magnet of the speaker produces a strong magnetic field which may influence the electron stream in tubes that are in close proximity to the magnet. With moderate care in lay-out this difficulty can be readily avoided.

## TUBE AND BASE DIAGRAM SYMBOLS

A —Anode	IS —Internal Shield
Dp —Diode Plate	J —Jumper
F —Filament	K —Cathode
Fc —Filament Center Tap	NC—No Connection
G —Control Grid	P —Plate
Ga —Anode Grid	Rc —Ray Control
Gm—Modulator Grid	S —Metal Shell
Go —Oscillator Grid	SA—Starter Anode
Gs —Screen Grid	Su —Suppressor Grid
H —Heater	T —Target
Hc —Heater Center Tap	XS—External Shield
Ht—Heater Tap	□ —Top Cap
Ic —Internal Connection	→ —Locating Pin

The symbols listed above are those employed in connection with the tube and base diagrams accompanying the characteristics on individual types of Sylvania tubes shown in the following section of this Technical Manual. All base diagrams are illustrated as viewed from bottom of base and numbers are in accordance with the RMA standard numbering system. Basing diagrams are purely symbolic and are not to be interpreted as exact representations of tube structure.

## BASE CONNECTION DIAGRAMS

The Radio and Television Manufacturer's Association have standardized on an improved method of designating the base connections. Formerly every minor change of shielding, really required a new drawing but now the location of the shielding elements is indicated by two following numbers (or letters) according to the following rules:

- (1) The first group of 2 or 3 digits, one figure and one or more letters, indicates the basing arrangements as far as the more important elements are concerned. This is the same group formerly given in the manual.
- (2) Following the dash separating it from the preceding group is a single numeral indicating the base pin to which is connected any external shielding such as base shielding or shell of metal tubes. The letter "L" means locking lug as on lock-in type tubes.

- (3) Following the second dash is a figure (or figures) indicating to which pin any internal shielding is connected. In case connection is made to two pins both numbers appear, connected by the symbol &.

Examples are: Type 6SK7GT, basing symbol 8N-1-5 which means base diagram number 8N with base shield connected to Pin No. 1 and internal shield to pin No. 5. Type 7E6 basing symbol 8W-L-7 which means base diagram 8W with base shield connected to locking lug and internal shield connected to pin No. 7.

## CATHODE RAY TUBES

Sylvania manufactures a line of television picture tubes and general purpose cathode ray tubes for a wide variety of initial equipment and renewal applications. Technical characteristics of the more popular types are provided in this tube manual. If additional data are required, write the Technical Publications Section, Sylvania Electric Products Inc., Emporium, Pennsylvania.

In radio servicing, as in any other work, certain precautions must be observed in order to work safely. With television receiver servicing the major dangers are from possible high voltage shock or injury from flying glass if a tube is carelessly or accidentally broken. To avoid shock we recommend taking no chances or short cuts; turn the power off and discharge the condenser before making changes. Be sure the interlocks and high voltage insulation in the set are in order. Also, use a dry linoleum or rubber mat to stand on and keep one hand in your pocket when making adjustments in a live set.

To avoid injury from broken glass it is recommended that gloves and goggles be worn when handling the larger picture tubes (over 5 inches in diameter) and that tubes not in a set be kept in their cartons. Be careful not to scratch the tube with tools or let it roll off the table. Worn out tubes should be disposed of by breaking the tip to let air in, making them safe for handling since only high vacuum makes implosion possible.

**WARNING:** X-ray radiation shielding may be necessary to protect against possible danger of personal injury from prolonged exposure at close range if this tube is operated at higher than the manufacturer's Maximum Rated Anode Voltage or 16,000 volts, whichever is less.

Some types have an external conductive coating on the glass shell. This coating should be grounded as a precaution against dangerously high potentials being developed on the coating.

The anode voltage is applied to the shell of the metal cone type tubes, making it necessary for such types to be operated only within an enclosure to prevent accidental contact or grounding.