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The Aerovox Research Worker

The Aerovox Research Worker is a monthly house organ of the Aerovox Corporation. It is published to bring to the Radio Experimenter and Engineer authoritative, first hand information on condensers and resistances for radio work.

VOL. 9, NO. 6 | JUNE, 1937 | 50c per year in U.S.A. 60c per year in Canada

Amplifiers

PART 1

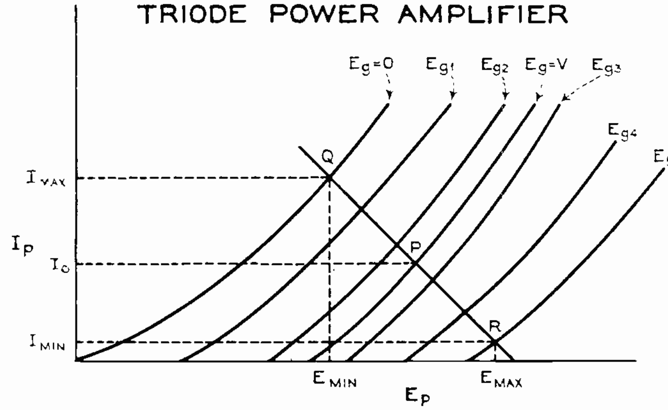
By the Engineering Department, Aerovox Corporation

AMPLIFIERS may be divided into two classifications, i.e., voltage amplifiers and power amplifiers. A voltage amplifier is an amplifier which is intended to deliver a large alternating voltage into a high resistance load. The power amplifier is designed to deliver appreciable power and may or may not require power to drive the grid circuit.

Amplifiers are also divided according to their method of operation in class A, class AB, class B, and class C amplifiers. In a class A amplifier the plate current is a faithful reproduction of the waveform of the applied grid voltage over a complete cycle; in a class AB amplifier this is the case for more than 180 degrees but less than 360 degrees; in a class B amplifier for only 180 degrees and in a class C amplifier for less than 180 degrees.

1. VOLTAGE AMPLIFIERS: Multi-stage amplifiers generally consist of several stages of voltage amplification followed by one or more stages of power amplification. The total amplification in amplifiers is limited by miscellaneous noises such as thermal agitation and shot effect which occur in the first stage and are amplified along with the signal. When the amplification becomes so much that these noises become a large part of the output, the amplifier becomes useless. Therefore, it is necessary to make attempts to keep the noise down, especially in the first stage. Operating them at lower voltages and

TRIODE POWER AMPLIFIER

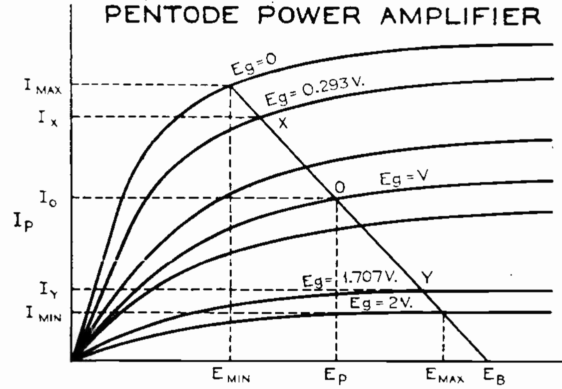


$$\text{POWER OUTPUT, WATTS} = \frac{(I_{MAX} - I_{MIN})\,(E_{MAX} - E_{MIN})}{8}$$

$$\text{PERCENT 2nd HARMONIC} = \frac{\frac{I_{MAX} + I_{MIN}}{2} - I_o}{I_{MAX} - I_{MIN}} \times 100$$

Fig. 1

PENTODE POWER AMPLIFIER



$$\text{POWER OUTPUT, WATTS} = \frac{\left[I_{MAX} - I_{MIN} + 1.41\,(I_X - I_Y)\right]^2 R_P}{32}$$

$$\text{PERCENT 2nd HARMONIC} = \frac{I_{MAX} + I_{MIN} - 2\,I_o}{I_{MAX} - I_{MIN} + 1.41\,(I_X - I_Y)} \times 100$$

$$\text{PERCENT 3rd HARMONIC} = \frac{I_{MAX} - I_{MIN} - 1.41\,(I_X - I_Y)}{I_{MAX} - I_{MIN} + 1.41\,(I_X - I_Y)} \times 100$$

Fig. 2

using special tubes are some of the remedies employed.

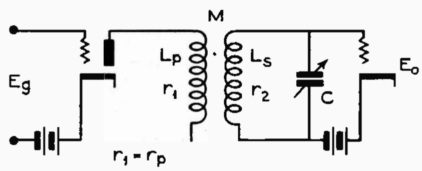
In multi-stage design it is important to proportion the stages so that none of the early stages can become overloaded before maximum output is obtained in later stages. Such a condition may occur if the volume control is placed in the second stage and the input device delivers more voltage than the bias of the first stage. Placing the volume control in a still later stage will make the condition worse unless the amplifier is to be used for but one input device of very low output. In general, it is best to put the volume control in earliest stage possible and to place tubes with low bias and high gain first.

A tube used as a voltage amplifier delivers maximum amplification (equal to mu) if the a.c. load is infinite and the actual plate voltage remains at the rated value. The gain drops with the plate load and with the plate voltage, so that the best compromise of plate load and plate voltage must be determined. Other considerations such as the parallel capacitance must be taken into consideration; they are treated in the design charts below.

The obtainable gain and the maximum output as well as the distortion of any tube can be determined for any load and power supply by a geometrical construction on the plate family of curves (Ep — Ip curves). When the load has the same a.c. and d.c. resistance, the load line is drawn from the plate supply point on the X axis at a slope equal to 1 R or I/E, taking into consideration the scale of units employed along the coordinate axes. An operating point is then selected, representing the fixed grid bias; variations in plate current and plate voltage for any grid voltage can then be read. The load should be so selected that the intersections of grid voltage lines are regularly spaced.

When the a.c. load is different from the d.c. load, a load line should first be drawn corresponding in slope to the d.c. load and starting from the plate voltage point on the X axis. At the chosen operating point the real loadline should be constructed at a slope corresponding to the a.c. load resistance. Maximum output and gain are immediately apparent from the curves.

R.F. AMPLIFIERS

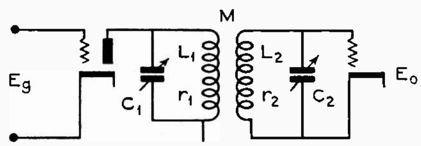


GAIN AT RESONANCE $= \dfrac{\mu\omega M}{r_1 r_2 + \omega^2 M^2}\,\omega L_s$

MAXIMUM GAIN, WHEN $\omega M = \sqrt{r_1 r_2}$

$$= \frac{\mu\omega L_s}{2\sqrt{r_1 r_2}}$$

GAIN AT RESONANCE FOR PENTODES $= \dfrac{\mu\omega M\omega L_s}{r_1 r_2} = G_m Q_2 \omega M$



WHEN BOTH CIRCUITS ARE TUNED TO THE SAME FREQUENCY

$$\text{GAIN} = \frac{\mu \frac{M}{C_2}}{\sqrt{(r_1 r_2 + \omega^2 M^2)^2 + \left(\omega L_1 r_2 + r_p \frac{r_1 r_2 + \omega^2 M^2}{\omega L_1}\right)^2}}$$

Fig.3

2. POWER AMPLIFIERS: Maximum undistorted output is obtained from triodes when the load equals 2 Rp, for pentodes when the load is approximately 1/5th Rp. The performance as a single ended class A amplifier can be predicted from the Ep-Ip curves as shown in the example of Figure 1. Draw the loadline through the chosen operating point at the slope corresponding to the a.c. load (the d.c. resistance is usually negligible). For minimum distortion, the segments of the load line, PQ and PR should be equal. When the ratio of their respective lengths is 9 : 11, the harmonic distortion is five per-cent.

In Figure 1 maximum power output and harmonic distortion is given in the equation. Figure 2 gives the same data for pentodes. The gain of amplifiers is often given in decibels. The decibels is a logarithmic unit, expressing the ratio between two magnitudes of power. Mathematically—

$$\text{db} = 10 \log \frac{P_1}{P_2} \quad \frac{\text{watts}}{\text{watts}}$$

where P_1 and P_2 are the output and input power respectively of the amplifier.

When the impedance at input and output are equal, the decibel may also be expressed in terms of voltages or currents:

$$\text{db} = 20 \log \frac{E_1}{E_2} \quad 20 \log \frac{I_1}{I_2}$$

The decibel is used in addition as a unit of loss and gain in networks. Although the decibel is not an absolute unit of power level it can be used to indicate the power level in decibels above or below an arbitrary "zero level". One of the most frequently employed zero levels is 6 milliwatts. In acoustical measurements a zero level of 10^{-16} watts per square cm. has been accepted.

When rating microphones, the zero level is: "1 volt output at open circuit when the soundpressure is 1 dyne per square centimeter". From this information it is possible to calculate all necessary data if the generator (microphone) impedance is known and the circuit has been determined. A zero level in milliwatts would be ambiguous since the rating depends on the say measurements are made, the volume of the sound, the impedance of the load, etc.

There is also an ambiguity in rating resistance coupled amplifiers. There appears to be no standard way of measuring input power and consequently different individuals get different results. Since the decibel is a power ratio and the grid of the input stage takes no power, it appears that some other type of rating would be desirable. It is suggested that the rating would be in terms of power sensitivity:

$$\frac{\text{watts output}}{\text{input volts squared}}$$

This would leave no possibility for misunderstanding.

3. RADIO-FREQUENCY AMPLIFIERS: Practically all r.f. amplifiers used at present are tuned radio-frequency amplifiers. The chart of Figure 3 shows a typical circuit and gives the equations for gain at resonance.

These equations refer to a circuit where the only coupling between primary and secondary is inductive. Since the equation shows that the gain is proportional to frequency, some effort is usually made to minimize this effect in tunable amplifiers for receivers. A combination of capacity coupling and inductive coupling may be used and the primary may be resonated at or slightly below the low frequency end of the tuning range.

The equation is good only for a single stage because in multi-stage amplifiers the accidental feedback between stages is never completely eliminated and greatly modifies the calculated value. This will then necessitate lowering the gain in order to obtain stability. A gain of 30 per stage is considered excellent for pentodes while triodes may deliver only a gain of 10.

4. INTERMEDIATE FREQUENCY AMPLIFIERS: Intermediate frequency amplifiers are nothing but radio frequency amplifiers designed for but one single frequency. The chart of Figure 3 shows the gain and other essential data on such amplifiers if both the plate circuit and grid circuit are tuned and when only the grid circuit is tuned. In spite of the fact that the gain is higher with an untuned primary, the double tuned circuit is generally employed in order to obtain a more desirable selectivity curve.

I.f. amplifiers have been made with a gain of as much as 250 in one stage. As in the case of r.f. amplifiers, it is not possible to maintain this gain in multistage amplifiers, and the gain in two stages may not be much more than in one stage, but the selectivity may be considerably improved.

(To be continued in the July 1937 issue)

Diagnosing Line Radio Noises

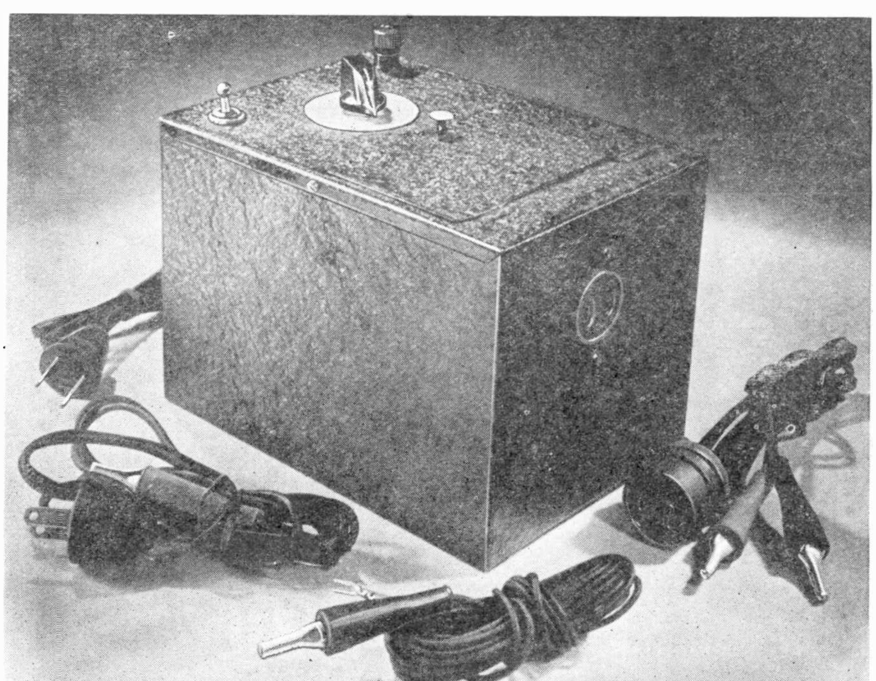
THE increased sensitivity of present-day radio sets introduces the problem of excessive background noises to many set owners and in many localities. Especially so in the short-wave band. Yet with proper diagnosis followed up with the installation of proper equipment, most background noises can be cleaned up.

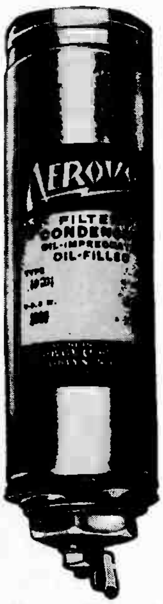
There are two broad classes of radio noises: first, those reaching the set through space and via the antenna system, which are readily suppressed by a noise-reducing antenna; second, those reaching the set via the power line, which are suppressed preferably at the noise source but otherwise at the set. It is with the latter class that we are concerned here.

Of line noise interference filters, there are several types made up of condensers alone or condensers and inductances in various combinations. Some noise-producing devices are best suppressed with a condenser type filter device. Others require inductance as well as capacitance. Some require grounding and others do not. It is almost guesswork to decide on this or that of the inexpensive filters for any given noise-producing device, without actual test under working conditions.

To facilitate a satisfactory test of various types of filters, there is now made available the AEROVOX line noise analyzer. This handy, portable, inexpensive test instrument comprises a variety of interference filters any one of which can be introduced in a power circuit by the setting of a switch. In other words, when the instrument is plugged between power line and noise-producing device, the switch handle is turned to each position and the noise-reducing effect noted on a nearby set. By means of test cords and connectors, various grounding means can also be tried out. When the maximum noise reduction is attained, the operator can determine at a glance the type of filter which has been used, as well as the most satisfactory ground arrangement. It only remains for him to install permanently the corresponding line noise filter with the indicated ground arrangement to duplicate those results in actual service.

Of course it is possible to introduce the line-noise filter at the receiver, or between set and line. This is usually satisfactory. But due to the possibility of troublesome re-radiation of noise-producing disturbances by transmission line and house wiring, there is always the danger that noises may now reach the set via the air. The use of a noise-reducing antenna system, of course, takes care of this contingency.





Also available in this inverted screw mounting style, with can grounded. Insulating washer if desired.

A lot of high-voltage capacity in small bulk at a low price.

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