Radio Editors of magazines and newspapers are hereby given permission to reprint in whole or in part, with proper credit to the Aerovox Corporation, the contents of this issue of the Aerovox Research Worker.

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. 5 | MAY, 1937 | 50c per year in U.S.A. 60c per year in Canada

Hints on High Fidelity

By the Engineering Department, Aerovox Corporation

HIGH fidelity has been a much discussed subject during recent months and it is not the intention of repeating most of the information which has already appeared in print so often. There are however little known sources of distortion and methods of improvement which are often overlooked; these will be discussed here.

Contrary to popular opinion, high fidelity need not necessarily be identified with high cost. Although the expensive receivers have their points, surprisingly good fidelity is possible

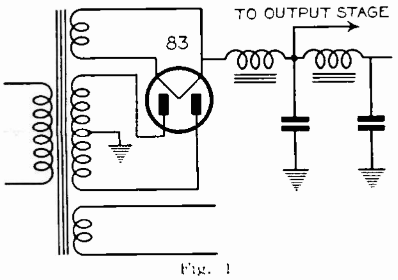


Fig. 1

with relatively simple and inexpensive equipment.

THE SPEAKER

Assuming that a good speaker is employed, it has to be mounted so as to obtain the best results. The usual recommendations of large cabinets or baffles are in order. It should be pointed out that all speakers have directional effects especially for the higher frequencies. Therefore, the speaker should be mounted so that the listener will be in the beam. This will never occur when the speaker is down near the floor unless the baffle is inclined but even then the beam will be at the proper height at only one point. The obvious solution is to place the speaker on a level with the head of a seated listener.

The use of vanes to distribute the higher frequencies is helpful but most vanes are designed to spread the beam in a horizontal plane only and not much is gained if this horizontal plane is at knee height.

In order to reproduce the lower frequencies, the cone should be large and the speaker should be on a large baffle board, or better yet in a completely closed large cabinet or closet. Those who cannot afford one of the large 18 inch speakers might be consoled by knowing that a considerable improvement in low frequency response can be obtained by operating two smaller speakers. They can be mounted side by side in the same cabinet and must then be correctly phased. Phasing is best accomplished by means of a 1½ volt battery connected across the voice coils in parallel or series; both cones should move in the same direction. If this is not the case, reverse the connections to one of the voice coils.

THE POWER SUPPLY

If the output stage is of the class AB type, the regulation of the power supply must be good. One of the troubles accompanying bad regulation is distortion in the r.f. and i.f. amplifiers due to the resulting changes in plate voltage. In addition, the output stages themselves do not deliver full output with minimum distortion when the power supply has too high a resistance.

The obvious remedy is, to employ low resistance chokes, a low impedance rectifier and a low resistance power transformer. For the above reasons, it is not recommended to have the speaker field in series with class AB power tubes. The best possible regulation is of course obtained with a mercury vapor rectifier and a choke input filter (such as shown in Fig. 1). However, in a radio receiver, the mercury vapor rectifier may have to be replaced with an 83V and an in-

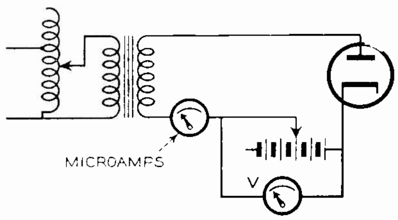


Fig. 2

put condenser may have to be used to boost the voltage. In any case, push-pull tubes can generally be supplied from a power pack with but one filter section. In fact, now that degeneration is here it has been suggested to connect the plate circuits of the output tubes directly to the output of the rectifier.

In the case of class A tubes, the regulation is not so important, but a single class A tube requires a low a.c. impedance of the pack. In receivers employing a single 2A3 or 6B5 or 6L6 as output tube, a considerable improvement of low frequency response can be had by increasing the size of the last condenser in the power pack.

Some will object that anything approaching high fidelity cannot be obtained from a single output tube. In this case, the 6L6 would have to be supplied with inverse feedback. However, the benefits of push-pull circuits has been exaggerated. It is well known that the plate impedance of the output tubes should be low in order to drive a speaker whose impedance varies widely. Using two tubes in push-pull increases the plate impedance while a decrease could be obtained by operating them in parallel. Now that the even harmonics can be reduced by degeneration the case of single stage vs. push-pull deserves further investigation.

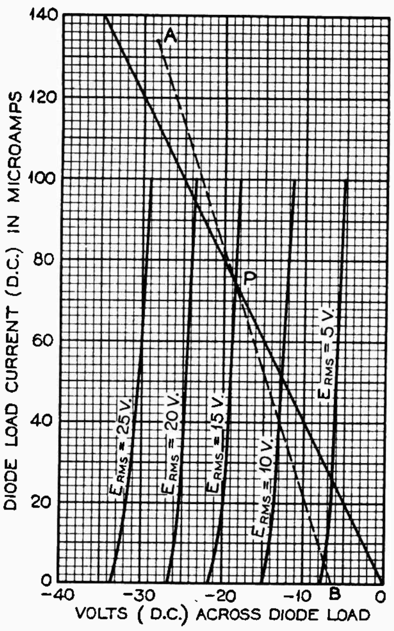


Fig. 3

AUDIO AMPLIFIER

The design of audio amplifiers has been discussed so often that we can hardly add any more. When resistance coupling is used, the high frequency response is limited by the effective grid-cathode capacitance and plate-cathode capacitance of the amplifier tubes. These form by-pass condensers across the coupling resistors and the ratio between their impedances determines the high-frequency response. The effective input capacitance of a triode is given by the expression:

$$C = Cgc + Cgp\ (A + 1)$$

where A is the gain of the stage. In case of a high-mu triode, like a 75, 2A6 or 6F5 this effective capacity becomes quite large—of the order of 100 mmfd. and more. Therefore, it is preferable to operate such a tube with low input grid resistors if possible. It is not recommended to employ several high-mu triodes in cascade. Low-mu triodes and pentodes are better in this respect.

When the amplifier has considerable gain, the first stage must be carefully designed so as to avoid hum and noise. One source of hum is in the grid bias and plate supply, especially if the grid bias is taken from a voltage divider. Some hum is then introduced in the grid supply, which is amplified, combines with that introduced in the plate supply, etc. The phase of these hum voltages can be controlled by the circuit constants and arranged so that they cancel each other. When this is done, a change of tube will usually upset the balance.

Self bias or battery bias from a bias cell or otherwise will be more desirable.

DETECTORS

More sins are probably committed in the detector circuit then anywhere else in the receiver, except perhaps the speaker. In the first place, the diode detector is linear only over a portion of its characteristic and this portion varies with the load resistance. Therefore, there is a best signal voltage for each load resistance.

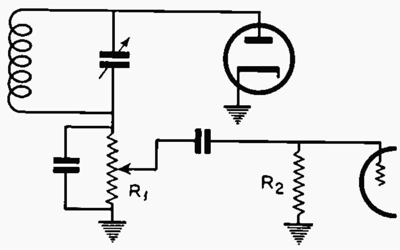


Fig. 4

When it comes to modulated signals there are more complications. Let us look at the trans-rectification diagram of a diode. This family of curves is analogous to the plate family of curves of a triode; load lines can be drawn on it to determine the linearity and to find the magnitude of the rectified voltages and currents. Such a set of curves can be obtained experimentally by applying known signal voltages to the tube in the circuit of Figure 2. The battery voltage is varied and plotted along the abscissa of the coordinate system.

Referring now to Figure 3, the set of curves, the load line has been drawn for a diode load of 0.25 meg. When the diode load is in parallel with several other resistors, coupled to it by means of condensers, the a.c. load becomes different and the load line for modulated signals for a signal voltage of 15 volts for instance would be centered at P and drawn at a slope equal to the a.c. resistance of the load. Let us assume that the grid leak of the following amplifier tube is 0.5 meg. and that the impedance of the coupling condenser is negligible. Then the a.c. load is 66.7 percent of the d.c. load and the actual value is 166.666 ohms. Drawing the load line for this value through the point P gives us the line A-B.

When the signal is unmodulated, the rectified current will be 74 micro-amps. Now let us assume that it is 66.7% modulated or, that the input signal varies between 5 and 25 volts. The rectified current will then vary between zero and 134 micro-amps. It is now clear ,that an increase in modulation percentage will result in distortion because on the lower end, the current cannot become any less. The result is that the tops of the negative half-cycles will be cut off as soon as the modulation percentage exceeds 66.7%. In general, the modulation capability of the diode would be equal to (a.c. load):(d.c. load) if the characteristics were perfectly straight.

The above explanation shows that it is desirable to make the a.c. load approach the value of the d.c. load as much as possible. There are several schemes to accomplish this. The most obvious one is direct coupling between the diode load and the following audio amplifier. Such an arrangement will of course vary the bias of the amplifier tube with the strength of the incoming signal and the setting of the volume control. Yet this has been applied successfully. The gain of the audio amplifier is usually so high that a signal of but 0.25 to .5 volts will deliver full output. Consequently, if the added diode bias is only a small part of the normal bias of the tube, no harm will result.

Another scheme is shown in Figure 4. If the volume control is used as the diode load, the following grid leak is in parallel with the lower fraction of R1 only. Thus the equivalent resistance of R2 and R1 in parallel will approach R1 for low settings of the the volume control. Most strong stations which are suitable for high-fidelity reception require that the volume control be set low. In this way the modulation capability of the system is high for those signals which may require it. The advantage of placing of the volume control at R1 rather than at R2 is thus obvious.

Figure 5 shows another system which has been in use in several commercial receivers. The coupling resistor, R2 is the volume control but it is connected across a portion of the diode load only. A sacrifice of gain is made in this way but it maintains a favorable condition at all settings of the volume control.

It should not be forgotten that the a.v.c. system generally places a parallel resistor across the diode load. This is one of the arguments for disconnecting the a.v.c. circuit from the detector altogether by using a separate diode. If this is done, the a.v.c. diode should preferably be excited from the primary of the i.f. or r.f. transformer. This has the advantage of easier tuning since the primary is broader and also reduces the coupling between the a.v.c. diode and the detector.

Recently another type of "linear detector" has been suggested. This is the plate circuit detector with the load in the cathode circuit as shown in Figure 6. This detector has several advantages. It is an "infinite impedance" detector which does not load the tuned circuit. This makes it adaptable to t.r.f. receivers especially since the diode detector causes all sorts of difficulties with this type.

The biased detector when used with the load in the cathode circuit is said to have linear characteristics, comparable with those of a diode.

The main advantage of this type of detector is that its modulation capabilities are more favorable than those of the diode. Since there is some plate current flowing when no signal is received, a rectification diagram like Figure 3 would have its zero line moved up, making it possible to accommodate a greater part of the loadline A-B. The ratio between a.c. load and d.c. load may be less than unity for 100 percent modulation capablility but has a lower limit for each tube and plate voltage. In the case of the 6C5 with 250 volts applied to the plate, the ratio between a.c. load and d.c. load should be 0.6 or over in order to obtain 100% modulation capability regardless of the value of R1. Tubes with a low amplification factor are more suitable for this type of detection.

In circuits like the one of Figure 6, the volume control can be put in the place of the grid leak which has the advantage that it is not subjected to the direct current of the diode.

The biased detector has two disadvantages. It cannot be used as a.v.c. tube at the same time and it may be subject to hum since the cathode is "up in the air". Our experience has indicated no difficulty with the hum while the lack of a.v.c. facilities leads to the discussion of the sins of a.v.c.

A.V.C.

It is questionable whether a.v.c. is desirable at all in a high-fidelity receiver. If the receiver is used also for general reception and for short-wave reception, a.v.c. is practically imperative but for a receiver which is intended to receive but a few local stations with high fidelity would be better without it. Assuming that the a.v.c. circuit has been divorced from the detector, as described above, it still can

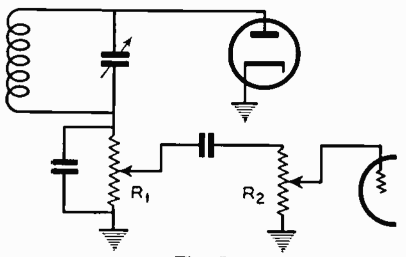


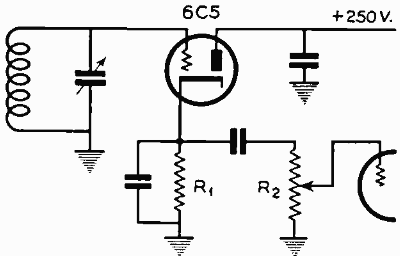
Fig. 5

be the cause of distortion due to insufficient filtering and due to improper design. When the signal is modulated at high percentage with a low audio frequency, a portion of the audio signal may be fed back to the grid of the r.f. or i.f. stages and thus cause distortion. The remedy would be better filtering but that would make the time constant too large and the action of the a.v.c. would be sluggish. The present compromise still causes some distortion.

The design of the a.v.c. system must be such that none of the tubes will draw grid current for any value of input signal. Examination of some receivers with uncontrolled mixers have shown the mixer drew grid current if the input signal had certain signal strength. When a receiver has unexplained distortion it is recommended to check for this.

MULTI-PURPOSE TUBES

Tubes of the duo-diode triode type and those with a pentode section have some coupling between the diode plates and the elements of the amplifier tube. This results in an r.f. signal being applied to the grid and plate of the tube which may then be rectified there or in the next tube. The result is that the volume will not be zero even when the volume control is set for zero. Moreover these spurious signals may be out of phase with the



MODULATION CAPABILITY IS 100 % IF $\frac{R_2}{R_1+R_2} > 0.6$

Fig. 6

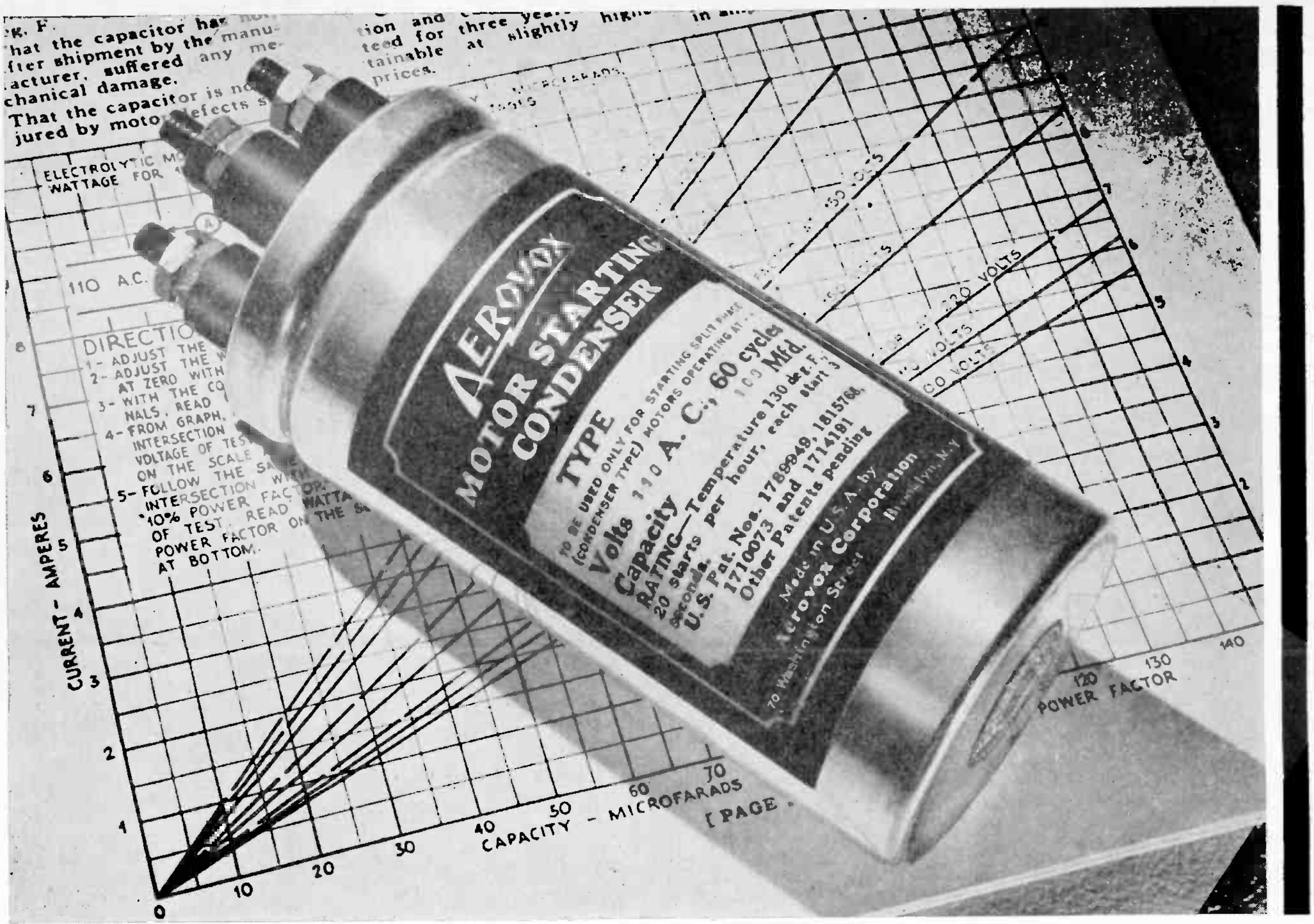
regular signal and cause distortion. The tube manufacturers recommend the use of bypass condensers across plate and grid circuits of the triode; the value recommended is 200 mmfd. This, however will reduce the high frequencies.

TUNER

Discussion of band-pass filters for receivers have been so numerous that we do not have any more to add. It should not be supposed that the r.f. or i.f. amplifier tubes are innocent of distortion. Like all other tubes, the characteristic is not perfectly linear and they will distort the modulation envelope along with the carrier. There are those who maintain that the superheterodyne introduces some special distortions of its own. These are ascribed to irregular variations in the oscillator frequency which distorts the low notes especially. Another accusation is that the mixer contributes more than its share of envelope distortion and noise.

ANTENNA

Finally, a good antenna is recommended so as to start out with a healthy signal and a good signal to noise ratio. Antenna, ground connections and metal objects should be watched for corroded joints or vibrating contacts since these have been found to cause cross modulation and noise. Generally everything else is suspected before this possibility is investigated.



Motor-Starting Capacitors

OF the millions of motor-starting capacitors now in use, AEROVOX has supplied the major portion. That is why AEROVOX is pre-eminently fitted to advise and to collaborate in any motor-starting problem, whether it be the production of new equipment or the servicing of old.

AEROVOX produces every type of capacitor for motor-starting requirements. ● There are electrolytics for maximum capacity in minimum bulk, intended for intermittent operation in starting.

There are oil-filled paper capacitors for constant service and particular power factor correction. ● The production of many types for many manufacturers has produced many standard types, many of which are stocked by leading jobbers.

Ask for this DATA It's the new Industrial Capacitor Replacements Catalog listing capacitor-starting motors and their capacitor requirements. Helps you service such equipment. Ask your jobber for copy—or write us direct.

AEROVOX CORPORATION

70 WASHINGTON STREET, BROOKLYN, N. Y.

Sales Offices in All Principal Cities