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. 11, NO. 11 | NOVEMBER, 1939 | 50c per year in U.S.A. 60c per year in Canada

Television Receivers

PART 4

By the Engineering Department, Aerovox Corporation

VIDEO AMPLIFIERS

AFTER detection, the television signal consists of alternating currents, varying in frequency from zero to four megacycles. These frequencies are sometimes called "video-frequencies" analogous to audio-frequencies. It must not be thought that these are "visible" frequencies for electrical currents and waves are neither visible nor audible. These are simply the frequencies needed to produce a picture with our present translating device. Its limits are 0-4 mc. today but they may become different when a greater detail is required or when any other change in the television system takes place.

The video amplifier differs from the audio amplifier in three ways:

1. Its frequency range is much greater, reaching up to 4 mc.
2. It must transmit a d.c. component.
3. The phase relations between the various components of a signal must be maintained. This point needs further clarification.

PHASE SHIFT

Reactances in tube coupling circuits cause a phase shift in the signal. This phase shift depends on frequency and usually causes a distortion of the wave shape as seen on an oscillograph. The magnitude of this distortion is considered unimportant in sound reception but will result in a distorted picture in television.

This might be visualized in the following way. Assume that the transmitted picture consists of alternate light and dark vertical bands and each of the dark bands has additional finer variations in light and dark. Then, if the finer variations (higher frequencies) were displaced with respect to the broad bands (lower frequencies) some of the detail belonging on the dark bands would appear on the light bands and in general the detail would be shifted over the picture as in a color picture with the different colors out of register.

Another effect is noted when there is a sharp line of demarcation between a light and dark picture area. This calls for a square waveform. Unless the different frequencies which make up this square wave remain in the same phase relations, the waveform is no longer square. The visual effect is a gradual change from dark to light in the picture, accompanied by some alternate light and dark bands on both sides of the line of demarcation.

Therefore, if there is a phase delay, which amounts to a time delay of the signal, this time delay should be the same for all components of the signal regardless of frequency. Or, which is the same thing, the phase delay, measured in degrees, should be proportional to frequency.

RESISTANCE-COUPLED AMPLIFIER

The direct-coupled amplifier best fulfills all the requirements for a good television amplifier since it transmits the d.c. component and eliminates some of the causes of phase shift. However, this type of amplifier is hard to handle when several stages are required.

The next best thing is the resistance-coupled amplifier; this type requires some re-designing to make the amplifier respond with reasonable uniformity to signals up to 4 mc. Consider a standard resistance-coupled amplifier stage employing a pentode of the 57 type as in Figure 1. If R_1 is 100,000 ohms, R_2, 0.5 meg., and a 300-volt supply is used, the gain of such a stage is about 90. At the low-frequency end the gain falls off due to the coupling condenser C_1 and the by-pass condenser C_2. Making these condensers larger will reduce the drop at the low end but it is not practical to go much below 30 cycles. These two condensers also cause a phase shift which is largest for the lowest frequencies and reduces to practically zero for frequencies above 1000 cycles. This is exactly opposite to what is desired. The increased size of both condensers will reduce this trouble but cannot entirely eliminate it. It may be desirable to eliminate C_2 altogether and to employ a correction circuit for the phase shift caused by C_1.

At the high-frequency end the response falls off because there is considerable capacity across the plate load resistance. This capacity is shown dotted in Figure 1; it consists of the plate-to-cathode capacity of the amplifier tube plus the grid-to-cathode capacity of the next tube plus the stray wiring capacity. In order to illustrate the effect of this capacity, C, let us assume that it amounts to 50 mmfd. This is probably too high but it will serve as an example.

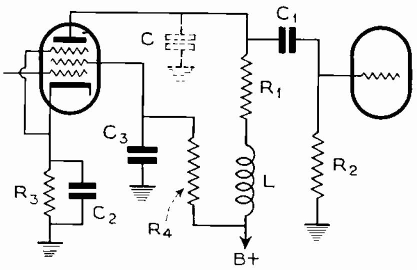


Figure 1

It was explained in the article on television tubes that the gain is proportional to the load impedance. Having a condenser across the load resistance, will shunt a reactance across the load, the reactance becoming lower and lower when the frequency goes up. So, in our example, the gain would be 30 percent less, or 3 db down when the reactance of C is equal to 100,000 ohms which is at 32 kc. When the reactance is one third of 100,000 ohms, at 96 kc., the gain is 10 db down, while at 320 kc. the gain would be 20 db down.

From this it follows, that better high-frequency response can be had if we are willing to sacrifice gain by lowering the plate load. For instance, if R_1 is only 10,000 ohms, the gain will be only 9 at 400 cycles. It will be 3 db down at 320 kc., 10 db down at 960 kc. and 20 db down at 3.2 mc. Even this is not good enough; in order to make the loss in gain at 4 mc. only 30 percent or 3 db., the load resistance of the tube would have to be reduced to 800 ohms and there would be no more gain but a loss instead.

The remedy for this condition is the use of a tube with a higher mutual conductance. For instance, with an 1852 instead of a 57, the gain will be 7 with an 800 ohm load. Remember that a value of C equal to 50 mmfd. was assumed and that a reduction in this capacity will allow a higher plate load and a higher gain.

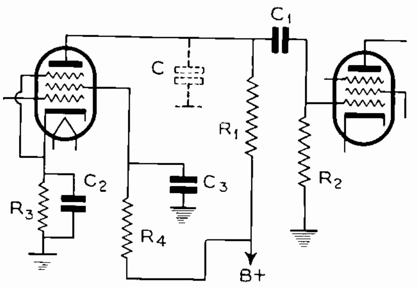


Figure 2

Even the extreme measure of reducing the load to 800 ohms still will result in a 3 db loss at 4 mc. This drop, however, can be eliminated and a fairly uniform response curve can be obtained by including a small inductance in series with the load resistance. This circuit is shown in Figure 2; C, R_1 and L might be considered as a parallel tuned circuit which resonates at a frequency above the highest frequency to be received. When the resonant frequency is approached, the impedance of the parallel circuit increases and compensates for the reduction due to the capacity C. The most uniform response characteristic is obtained when at the highest frequency to be received, the reactance of C equals the load resistance and the reactance of the coil equals half the load resistance. For an upper frequency of 4 mc. and the same values as described above, 800 ohm load and 50 mmfd. capacity, the coil should be 16 microhenries.

Ordinary power tubes such as the 6V6, 6L6 and 42 may be found useful as video amplifier tubes. Tubes having a high mutual conductance and a low output capacity are suitable for the purpose.

The design procedure is now as follows. First choose the tube to be used which shows promise of giving satisfactory gain. Then determine the value of C by actual measurement. This can be done by connecting an arbitrary plate load in the circuit of Figure 1, as 5000 ohms. Measure the gain by adjusting the next tube as a vacuum-tube voltmeter and using an audio oscillator. Then find the frequency where the gain has dropped 30 percent. The reactance of C at this frequency is equal to the plate load resistance and C can be calculated. The values of the load resistance and the coil are then found by the rules given above.

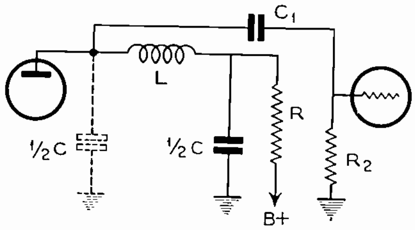


Figure 3

FILTER THEORY

It is sometimes convenient to consider the interstage coupling circuit as a filter and to obtain the values of the constants from the well known filter theory. Figure 3 shows the tube with a low-pass filter section as a load. In this case the stray capacity has been called ½C because this allows the standard filter equations to be used but ½C in Figure 3 is equivalent to C in Figures 1 and 2. When this filter section is terminated in its characteristic resistance, R, as in Figure 3, the input impedance (the tube's load impedance) is also equal to R over the pass band of the filter. Outside this pass band the impedance changes radically either to zero or to infinity. Here then, is a method of obtaining a uniform load impedance and consequent uniform gain over the required range. In the case we are considering the filter would be of the low-pass type and the parallel element on the input side can consist of the stray capacity.

The design equations for this type of filter are:

$$f = \frac{1}{\pi\sqrt{LC}} \qquad (1)$$

$$R = \sqrt{\frac{L}{C}} \qquad (2)$$

$$C = \frac{1}{\pi f R} \qquad (3)$$

$$L = \frac{R}{\pi f} \qquad (4)$$

where f is the cut-off frequency or highest frequency to be transmitted (in cycles), the other constants are in ohms, henries and farads.

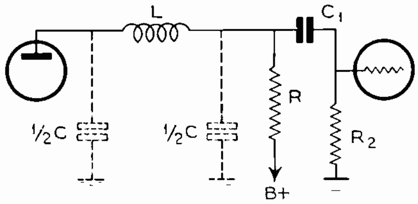


Figure 4

Using again the same value of stray capacity, 50 mmfd., ½C equals 50 mmfd. or C equals 100 mmfd. Since f equals 4 mc. we then find R to be 800 ohms as before and L equals 128 microhenries. With an 1852 the gain is again 7.

These examples have shown that the gain is limited by the stray capacity and the mutual conductance of the tube. For a given tube, the gain can be increased if this value of ½C can be reduced. It is possible to arrange the circuit as in Figure 4 where the stray capacity has been split into two parts, each being considerably smaller. At the input of the filter, the capacity consists of the plate-to-cathode capacity of the tube plus wiring capacity and at the output of the filter it consists of the grid-cathode capacity of the next tube plus wiring capacity. These two values must be made equal by adding a small trimmer across the smaller one. Then, ½C would be perhaps 30 mmfd. and the gain would become 12, the resistance R would become 1350 ohms and L would be 215 microhenries.

This method can be extended one step farther. If a double section filter is used the middle capacity is twice as large as the input or output capacity. It happens that the input capacity of an 1852 is about twice the output capacity and for other reasons, such as the size of C_1, this circuit more nearly fits the actual conditions. In this way it is possible to reduce the effect of stray capacity as much as possible and to get the highest gain for any given frequency range or the highest frequency range for any desired gain.

PHASE CORRECTION

It may be necessary to correct for the phase shifts introduced by the combination of C_1 and R_2. This can be done by connecting a resistance and condenser in series from the plate side of C_1 to the chassis.

POLARITY

If the signal is to have proper polarity and cause a positive picture to appear on the screen, one must watch the detector connections and the number of video stages. The usual connections of a diode detector, with the cathode grounded, causes the signal at the detector to be of proper polarity for direct application to the picture tube grid. If there are video stages it will have to be an even number, for each stage reverses the picture.

When an odd number of video stages is desired, the diode detector should have the cathode "up in the air" and the other side of the load resistance grounded.

THE OUTPUT STAGE

Since the gain per stage is rather low the output obtainable wtih certain tubes cannot be made large enough to modulate the cathode-ray beam completely. A special output tube for this purpose was made available, the 6AG7. Some of the power tubes may also be found suitable; the requirements are a large mutual conductance together with the ability to take a large signal on the grid.

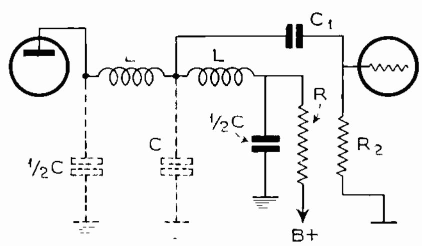


Figure 5

THE D. C. RESTORER

When the coupling circuit between two amplifiers contains a coupling condenser (such as C_1 in Figures 1 to 5) or a transformer, the next amplifier grid receives only the variations in the signal or the a.c. component and not the d.c. component. Unfortunately, television requires that the d.c. component be transmitted as well. This is perhaps best illustrated by Figure 6. Figure 6A shows the picture signal as it was transmitted. The upper impulses represent the synchronizing signals and the bottom of these represents the shade "black". First come several lines of a brilliant image then some lines of a darker section. In both cases the level of the points representing black fall at the same height above the axis or at the same voltage. This is not the case in Figure 6B where the signal is shown after having travelled through a coupling condenser. Here the darkest parts of the picture do not remain black but vary with the average brilliance of the picture. Thus to restore the original condition, the upper impulses must be brought into line again as in Figure 6A; this is done by the d.c. restorer.

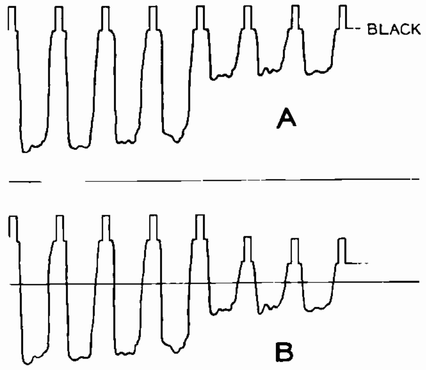


Figure 6

In its simplest form the d.c. restorer consists of a rectifier, see Figure 7A. If the signal of Figure 6B is applied to the rectifier the plate will draw current at every one of the synchronizing pulses. This will cause a charge on condenser C and a current through R which will bias the plate of the diode so that only the tops of the synchronizing pulses make the plate positive. The other part of the cycle does not have any effect for then the plate is beyond cut-off. When the amplitude of the signal varies as in the case where the average brilliance has varied, the tops of the waves will still be just high enough to draw some plate current because the bias will re-adjust itself. So this device lines up all the synchronizing impulses and the black level as desired.

The signal as supplied by Figure 7A is of the wrong polarity for application to the picture tube. It can be inverted by using a triode with the grid serving as the rectifier as in Figure 7C or the signal can be applied to the rectifier last as in Figure 7B. The rectifier must then be "upside down" and the signal must be applied to it in the proper polarity, opposite to that shown in Figure 6.

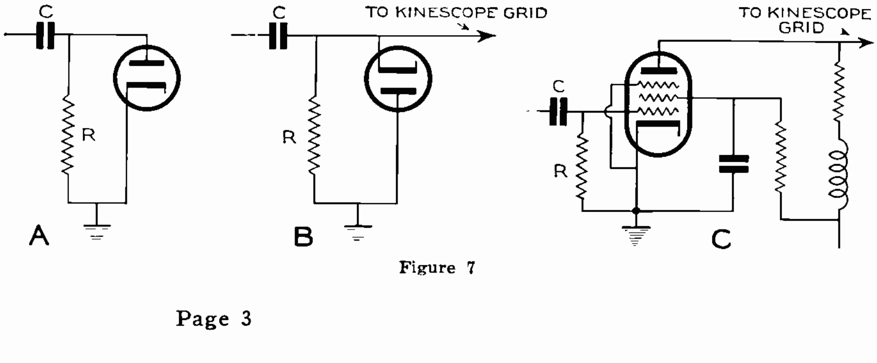
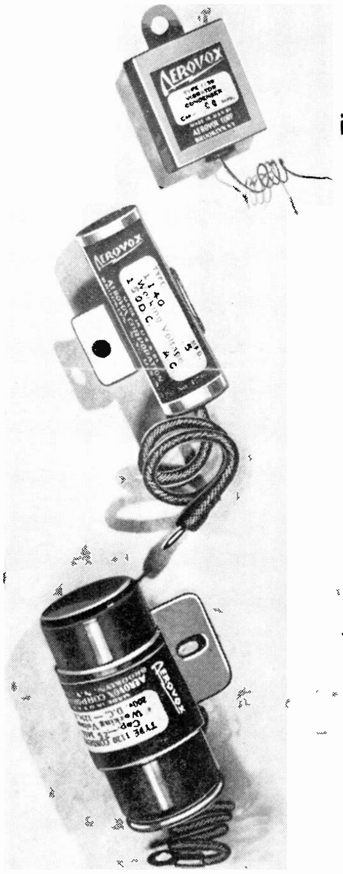


Figure 7

AUTO-RADIO Condensers



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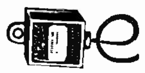

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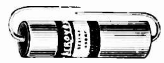

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