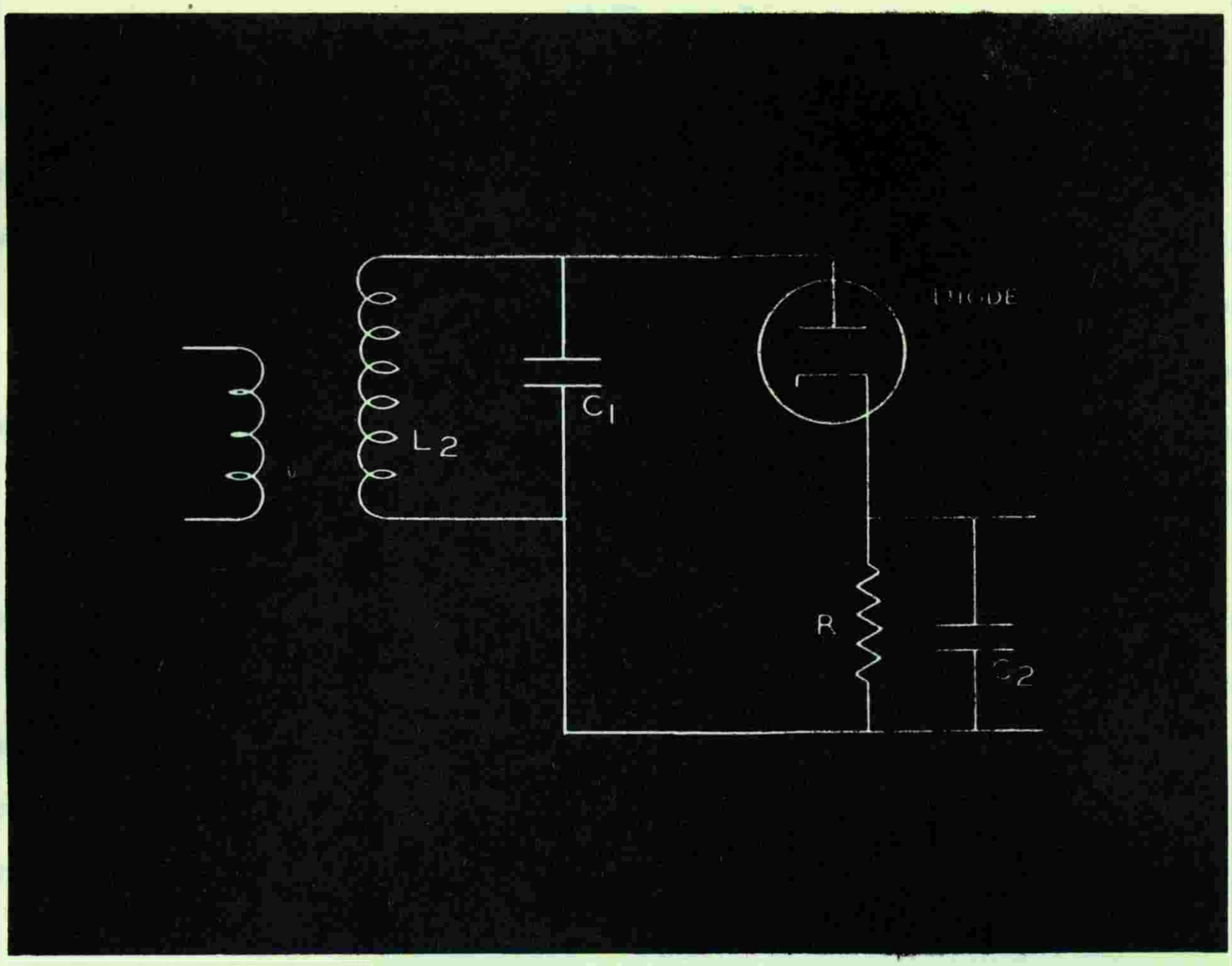

LESSON
25 RA

OPERATION OF A-M DETECTORS

RADIO-TELEVISION TRAINING SCHOOL, INC.
5100 SOUTH VERMONT AVENUE • LOS ANGELES 37, CALIFORNIA, U. S. A.

OPERATION OF A-M DETECTORS

Lesson 25 RA

When speech or music is transmitted from a radio station, the antenna system of the station radiates a radio-frequency carrier wave which is amplitude modulated, that is, its amplitude varies in accordance with the audio-frequency signal voltage being conveyed. The radio-frequency wave is said to be modulated by the audio-frequency signal. This process is known as amplitude modulation of the radio-frequency carrier wave. The effect of modulation on the steady r-f signal or wave-form of the radio-frequency carrier wave is shown at C in Fig. 1.

In analyzing Fig. 1 you will find the unmodulated r-f carrier wave shown at A, the audio-frequency signal used for modulating the r-f carrier wave shown at B, and the resultant modulated radio-frequency wave shown at C. Note the drawing at C shows that the radio-frequency wave is changed in its amplitude from that shown at A, however, notice also that there is no change in the number of radio frequency cycles. Only the amplitude of the r-f signal or carrier wave is changed and for the duration of one audio-frequency cycle.

In the standard broadcast A-M (amplitude modulated) radio receivers it is desired to reproduce the original audio-frequency which was used in modulating the r-f signal. This is the part of the signal containing the intelligence transmitted and it must be detected or removed from the modulated radio-frequency wave. In other words, it is desired to demodulate the the modulated radio-frequency. This action is known as detection in a radio receiver. This detection or demodulation is accomplished in a stage of the radio receiver called a demodulator or a detector.

There are a number of different types of detector circuits in general use, the crystal detector was extensively used in the early days of radio and now the diode tube detector is used extensively. The other types of detectors such as the grid-bias detector and the grid-leak detector are also used. These detector circuits are alike in that they remove or eliminate, either partially or completely, alternate half-cycles of the radio-frequency carrier wave. With the alternate half-cycles eliminated, the audio-frequency variations of half of the radio frequency carrier wave can be amplified the required amount to operate a set of head phones or a loudspeaker. We will learn more about the other characteristics of A-M detectors in this lesson.

CRYSTAL DETECTORS

A typical crystal detector circuit is shown in the drawing at E in Fig. 1. The modulated r-f signal current intercepted by receiving antenna is conveyed by the leadin through the primary winding L1 of the radio frequency transformer to the ground lead. The signal introduced in the secondary winding L2 is stepped up through the use of a tuning capacitor C1 whereby exact resonance is obtained with the frequency of the desired station. The voltage developed across C1 is applied directly to one terminal of the crystal detector and it is applied to the other terminal of the crystal detector through capacitor C2.

The action of this crystal detector circuit when a modulated radio-frequency wave is applied such as that shown at C in Fig. 1 is illustrated at D in Fig. 1. The radio-frequency voltage applied to the detector from the parallel resonant circuit formed by the coil L2 and the capacitor C1 is applied to the detector as stated above. The resistor R serving as the detector load across which there is very little radio-frequency voltage as the capacitor C2 has low reactance at this frequency and therefore tends to remove all of it. The detected audio-frequency signal will exist across R and C2. Between points 1 and 2 as shown at D in Fig. 1, the first positive half-cycle of the modulated radio-frequency voltage causes the capacitor C2 to charge up to the peak value of the first cycle of the radio-frequency voltage. Then as the radio-frequency voltage goes through its negative half-cycle, the voltage across C2 drops down, that is, drops from its peak value at point 2 to the valve at point 3. The capacitor C2 holds the voltage across the resistor R at a positive value for a short duration of time. This also means that the crystal detector does not pass current so long as the voltage across the parallel circuit formed by the resistor R and the capacitor C2 is more positive than the desired part of the signal voltage which is developed across the tuning capacitor C1. During the time that the crystal current is cut off, the capacitor C2 discharges from point 2 to 3 through the resistor R. Then when the radio-frequency voltage applied to the crystal rises again and is high enough to exceed the potential at which the capacitor C2 holds the voltage across the resistor R, current again flows, and the capacitor charges up to the peak value of the second positive half of the r-f cycle and as shown at point 4 in drawing D in Fig. 1. In this manner, the

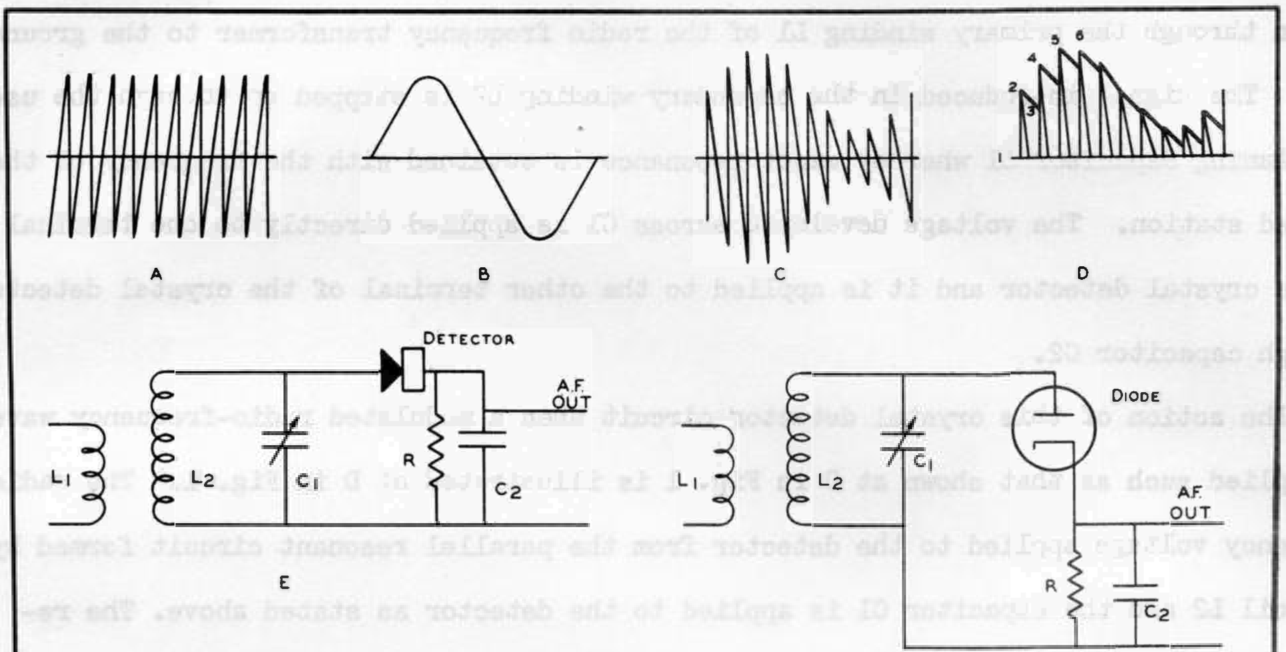

FIG. 1. This drawing shows the process of detection and two types of detector circuits.

voltage across the capacitor follows the peak value of the applied modulated r-f voltage and as a result we reproduce the audio-frequency signal. The waveform for the voltage across the capacitor, as shown at D in Fig. 1, is somewhat jagged. However, this jaggedness, which represents an r-f component in the voltage across the capacitor, is exaggerated in this drawing. In an actual circuit, the radio-frequency component of the voltage across the capacitor is negligible when the audio-voltage across the capacitor C2 is amplified. We can reproduce the music or speech originating in accordance with the signal being transmitted by transmitting station.

While we are discussing the operation of a crystal detector it may be well to point out another way of understanding the action of a crystal detector and that is to consider the circuit as a half-wave rectifier. When the radio-frequency signal applied to the anode terminal of the crystal detector is connected to the upper terminal of the capacitor C1 and when the signal swings through the positive half of the radio-frequency alternation, the crystal conducts and the rectified current flows through the load resistor R. Because the d-c output voltage of the rectifier depends upon the voltage of the a-c (alternating current) voltage at the input terminal of the detector, the d-c voltage across the capacitor C2 varies in accordance with the amplitude of the r-f carrier and thus reproduces the audio-frequency signal. The capacitor C2 should have low reactance so that it can smooth out the radio-frequency or intermediate frequency variations, in the case where the signal is obtained from an intermediate frequency amplifier of a superheterodyne, but should not be so large as to affect the audio variations. It is possible to employ two crystal detectors and thus obtain full-wave rectification to give us what is known as push-pull detection. In practice, however, the advantages of this connection generally do not justify the additional circuit complications. It is for this reason that we generally see but one crystal in a detector circuit.

Crystal detectors have one outstanding disadvantage over diode detectors employing an anode and a cathode within a vacuum such as the diodes used in regular radio receivers and that is the fact that they may become intermittent. The point of connection to the crystal surface may not be good and furthermore the degree of rectification may not be the same at all times. This causes an undesirable change in receiver sensitivity. It is for this reason that the diode detectors of the vacuum type are employed and have proven most satisfactory in radio receivers.

A diode detector circuit is shown at F in Fig. 1. The crystal detector has been removed and a diode consisting of an anode and a cathode has been inserted. The heater circuit is not shown here. The diode will allow all positive alternations of the modulated r-f signal voltage to cause the flow of electrons from the cathode to the anode. This will make the upper terminal of the resistor R positive with respect to its lower terminal and we will again have the type of waveform shown at D in Fig. 1. The A.F. (audio-frequency) output voltage varying in accordance with the modulated wave received.

The diode method of detection has an outstanding advantage over many other methods in that it introduces less distortion. This is due to the fact that its dynamic characteristic is more linear than that of other detectors. This means that its output

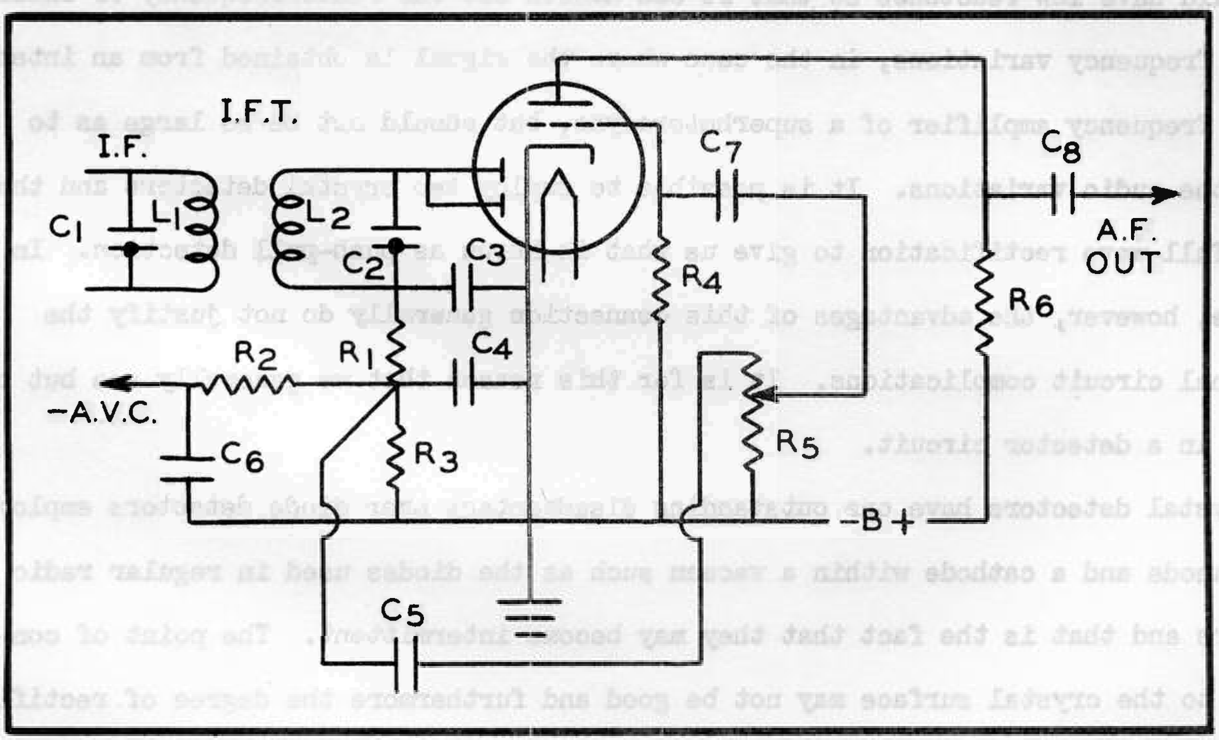

FIG. 2. A duplex-diode triode detector circuit

voltage is directly proportional to its input voltage. It has the disadvantage, however, that it does not amplify the signal, and that it draws current from the r-f input circuit and therefore reduces the selectivity of the input circuit. The diode method of detection also permits the use of simple automatic volume control circuits without the necessity of an additional voltage suppl. These are some of the reasons why the diode detection method is most widely used in broadcast and communication radio receivers.

Nearly all diode detector circuits employ an arrangement whereby the cathode is at ground potential. With this type of circuit no hum or heater circuit noise voltages can enter the detector circuit. This diode detector circuit is shown in Fig. 2. Here the cathode lead is connected directly to ground or chassis.

The diode-detector circuit shown in Fig. 2 is a typical duplex-diode triode tube arrangement. In analyzing the circuit employed we will find that the I.F.T. (intermediate frequency transformer) formed by the coils L1 and L2 as well as their respective tuning capacitors C1 and C2 is the last transformer in the radio receiver. The voltage across C2 is applied to the two diodes which are connected together and in parallel. The capacitor C3 in this circuit serves the same purpose as capacitor C2 as shown at E and F in Fig. 1. The combined resistance of the resistors R1 and R3 form the diode load resistor in this circuit and serve the same purpose as the resistor R as shown at E and F in Fig. 1. Then the resistor R1 in Fig. 2 serves the dual purpose of conveying the demodulated audio-frequency signal to the top terminal of the resistor R3 and providing additional filtering along with capacitor C4 to remove all of the high frequencies that may still exist across the capacitor C3. Both the capacitors C3 and C4 have a relatively small amount of capacitance which is just enough to remove the high frequency (carrier) but not enough capacitance to affect the audio-frequency voltage in the circuit. The audio-frequency voltage which appears across the resistor R3 is conveyed by the coupling capacitor C5, which has low reactance to the audio-frequency variations, to the volume control resistor R5. Then the voltage at the moving point on the resistor R5 is conveyed to the grid of the triode section of the tube through the coupling capacitor C7. The value of the resistor R5 being of any value between 250,000 and 2,000,000 ohms. The values of the capacitors C5 and C7 being of any value between .01 and .1 mfd. The resistor R4 provides the necessary bias voltage for the operation of the triode section of the amplifier tube. This resistor generally has a resistance in excess of 5 megohms. The electrons that leave the cathode strike the individual wires of the grid electrode in the tube and thereby provide the necessary electron flow through the resistor R4 to give the required no signal operating bias voltage of approximately .5 volts. The resistor R6 provides the plate load resistance for the triode section of the tube. The amplified audio-frequency voltage across this resistor is transferred to the following stage through the coupling capacitor C8. The value of the capacitance of this capacitor may be of any value between .01 and .1 mfd.

In further aalyzing the circuit shown in Fig. 2 you will find that the resistor R2 and the capacitor C6 provide the necessary filtering for the purpose of removing the audio-frequency variations which appear across the resistor R3. Only the d-c voltage across R3 caused by the carrier wave appears at the upper terminal of the capacitor C6. This voltage varies in accordance with the average signal intensity of the carrier wave received. This voltage does not vary with the amplitude of the audio-frequency signal but only varies with the average signal level. This voltage can therefore be used for automatic volume controlling purposes. The minus a.v.c. lead as shown in Fig. 2 is connected to the grid return circuits of the various r-f and i-f amplifier tubes receiving this automatic volume control voltage.

The circuit combination shown in Fig. 2 may easily be modified to employ a duplex-diode pentode tube by the simple insertion of a screen grid element in the tube. Greater over all a-f signal voltage amplication will be obtained from such a circuit.

It is possible to employ a modified duplex-diode triode tube as a detector. The circuit arrangement in this instance is very similar to the one shown in Fig. 2, however, the lower diode instead of being connected to the upper diode is connected to the upper terminal of the capacitor C6. In this case this diode tends to remove all positive variations in the voltage which may be developed across the capacitor C6. This diode therefore prevents the application of a positive signal to the grid return circuits of those tubes which are a.v.c. controlled and greater stability is obtained in the receiver.

GRID-BIASED DETECTORS

A grid-biased detector circuit is shown in Fig. 3. In this circuit, the grid of the tube is biased almost to the point where plate current is completely cut-off. This means that the plate current will be very low with zero r-f carrier signal. The bias voltage is obtained from the cathode-biased resistor R1 as shown in Fig. 3. However, this bias voltage may be obtained from a C battery or a tap on a voltage divider of the power supply. Because of the high negative bias, only the positive half cycles of the radio-frequency signal which is being received will therefore be amplified by the triode tube. The signal is, therefore, detected in the plate circuit. The advantages of this method of detection are that it amplifies the signal, besides detecting it, and that it does not draw current from the input circuit and therefore does not lower the selectivity of the secondary circuit formed by L2 and C1.

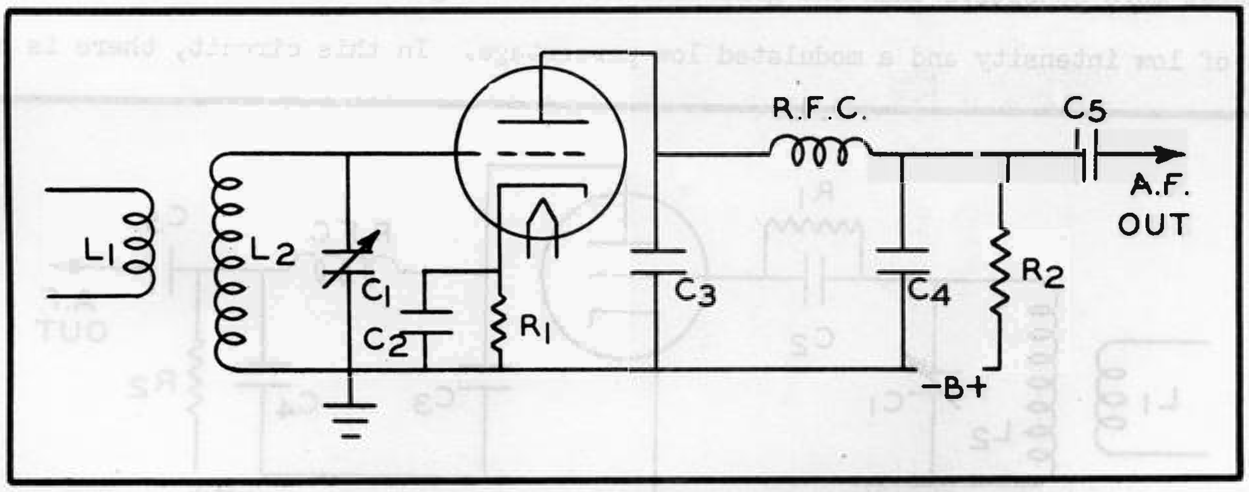

FIG. 3. A grid-biased detector circuit.

In further analyzing the circuit shown in Fig. 3 we will find that the capacitor C1 may be the last capacitor of a bank or a group of capacitors in a tuned radio-frequency amplifier receiver. The capacitor C2 has a low reactance and is used to prevent radio-frequency variations during modulation from changing the cathode-to-chassis voltage. This prevents a variation of the bias voltage applied to the tube. This capacitor generally has a value of 1 mfd. The resistor R1 may be of any value from 20,000 to 50,000 ohms, depending upon the tube characteristics. In analyzing the plate circuit of this detector circuit we will find that a radio-frequency choke shown as R.F.C. is used because a resistor may cause excessive d-c voltage drop in the circuit during high percentages of signal modulation and may introduce distortion. The capacitors C3 and C4 again have enough reactance to smooth out or remove the r-f variations that are amplified along with the desired signal. The reactance of these capacitors is high so that they do not affect the audio variations. The audio-frequency voltage which has been detected is developed across the resistor R2 and is conveyed through the coupling capacitor C5 to the input of the following stage.

GRID-LEAK AND CONDENSER DETECTORS

The grid-leak and condenser detector circuit is shown in Fig. 4. This circuit is somewhat more sensitive than the grid-bias method and gives its best results on signals of low intensity and a modulated low percentage. In this circuit, there is no

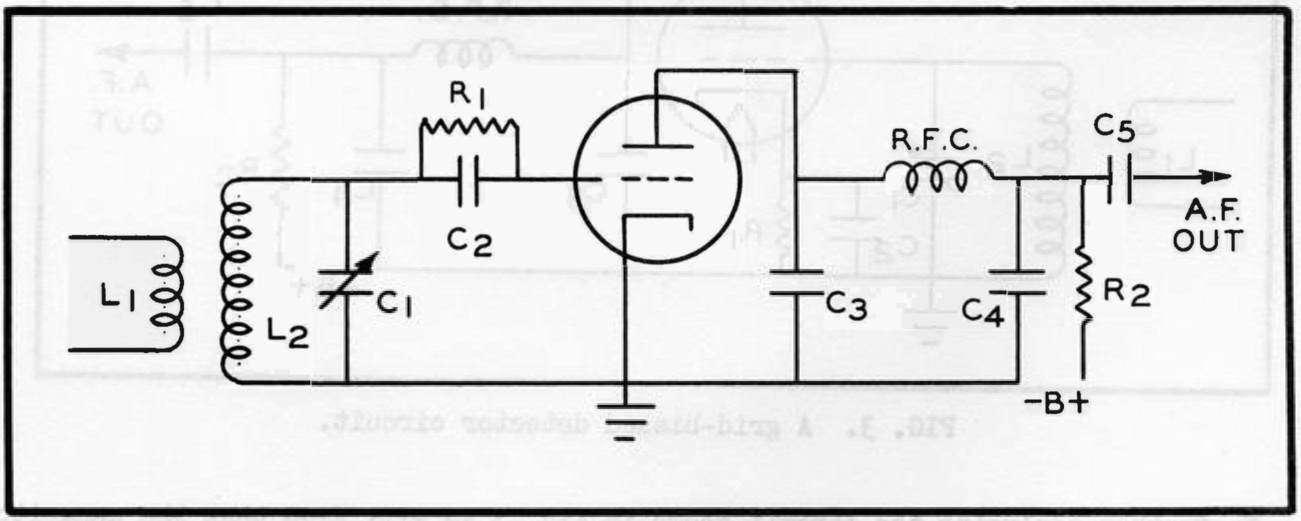

FIG. 4. A grid-leak and condenser detector circuit.

external negative bias voltage applied to the grid of the tube. The positive-half of the r-f cycle of the incoming signal causes electrons to flow from the cathode to the grid. This causes the grid to become negative with respect to the cathode. That is, the grid and cathode act as a diode detector, with the grid-leak resistor serving as the diode load resistor and the grid capacitor C2 as the r-f bypass and coupling capacitor. The voltage across this capacitor C2 varies with the audio-frequency modulation in the same manner as has been explained for the crystal and diode detector circuits. Since desired A.F. voltage appears between the grid and cathode, detection occurs in the grid circuit. The signal is amplified in the plate circuit as the tube operates as a class A amplifier because the R.F. signal level is limited so that the average rectified d-c voltage across R1 allows the tube to operate on the straight portion of its grid voltage-plate current curve.

In further analyzing the circuit shown in Fig. 4 note the similarity between the input and output circuit as shown in Fig. 3. This means that many of the parts serve the same purpose. In this detector circuit, the use of a high resistance grid-leak increases selectivity and sensitivity. However, improved a-f response and stability are obtained with lower values of grid-leak resistance. This detector circuit has the advantage that it amplifies the signal but has the disadvantage that it draws current from the input circuit and therefore lowers the selectivity of the input circuit. This circuit also introduces considerable distortion during high percentages of modulation (loud volume passages). The values for the capacitors C1 range from 100 mmfd to 500 mmfd and values of the resistor R1 vary from 100,000 to 2,000,000 ohms. The lower the values of these two parts the better the amplification of higher audio-frequency variations.

In comparing the performance characteristics of the circuit shown in Figures 3 and 4 we will generally find that the circuit arrangement shown in Fig. 3 is capable of giving less distortion as it is capable of handling signals that are modulated at high percentages. This means better amplitude variation as heard from the loudspeaker.

The circuit shown in Fig. 2 has excellent characteristics in that it will handle high signal levels as well as signals that are modulated to a high level or percentage.

Again in referring to the detector circuit shown in Figures 3 and 4 we may state that the circuit shown in Fig. 3 has excellent detection characteristics, however, the signal must be great enough to cause the plate current of the tube to swing up and off the straight portion of its grid-voltage-plate current curve.

EXAMINATION QUESTIONS ON FOLLOWING PAGES.