RIGHT—*From the Start*

PART 6. RECEIVING

by A. P. BLACKBURN

We have spent some time with audio amplifiers in previous articles, and arrived at the stage where further progress would entail a discussion of the deeper aspects of their operation and design. No introduction has yet been made to the "receiver" part of the radio system. By "receiver" is meant that part of the set which receives the broadcast signal, the tuning mechanism and so on.

This month, then, we will follow a signal from the transmitter to the input of the audio amplifier.

Modulation

The key to radio transmission lies, obviously, in how to get the signal from the studio to the receiving set. The early pioneers found that high frequency energy could be easily radiated through space to a distant point. The frequencies involved are, however, beyond the audible range, and some system had to be found which would enable the audible sounds to be superimposed on these high frequency "carriers." The process of superimposing one upon the other is called "modulation."

The carrier frequency is chosen to be many times higher than the highest modulating frequency. For example, the long wave B.B.C. Light Programme has a carrier frequency of 200 kc/s, and the highest audio frequency is probably 8 kc/s or so. The latter, of course, represents the highest musical note to be transmitted.

One of the methods of modulation is to cause the amplitude of the carrier to vary in sympathy with the loudness of the audio signal at a rate dependent upon the frequency of the audio signal. That may sound a little alarming, but Fig. 1 illustrates it. The audio modulating signal is represented by (a), and (b) stands for the carrier signal. After modulation of (b) by (a) the complete modulated signal (c) appears. This is fed to the aerial of the transmitter, and the carrier "transports" it to the receiving aerial.

So far, so good. But apart from the problem of reconverting the modulated signal into audible sounds, there are dozens of signals being transmitted at once. How is the receiver to pick out any particular one? Every one knows, of course, that the process of selecting one particular station is called "tuning." The real mechanism of tuning is, however, not so well known.

Tuned Circuits

There is a particular type of circuit which lends itself ideally to sorting out signals from one another. The simplest type is shown in Fig. 2, which consists simply of an inductance in parallel with a capacity. Now the behaviour of this simple circuit is quite remarkable, if an a.c. voltage of a particular frequency is applied between the points A and B. What happens is that at most frequencies, the circuit appears to be quite a low impedance, but at one frequency the circuit becomes high impedance.

This means that if an aerial and earth were connected as shown in Fig. 3, at one frequency an output voltage would appear, but not at any other frequency.

The values of the inductance and capacitance determine at what frequency this will occur. The effect is virtually that all signals but the required one may be rejected if the values of L and C are chosen correctly. Fortunately, it is a simple matter to calculate these values. The expression is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where f is the frequency in cycles/second,
L is the inductance in Henrys
C is the capacitance in Farads.

It is a simple matter now to make the circuit more flexible so that it may be set to any desired frequency. The most common method is to make C variable. One set of capacitor plates are moved relative to the other set and the movable ones connected to a shaft.

Having selected the required signal, we can now move on to separating carrier and modulation.

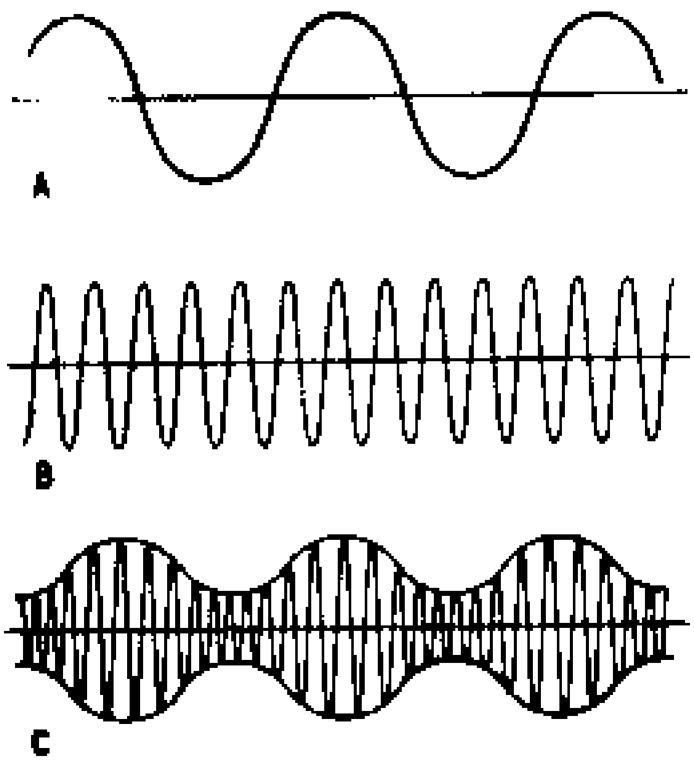


FIG. 1

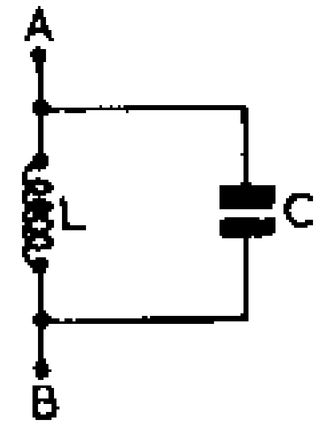


FIG. 2

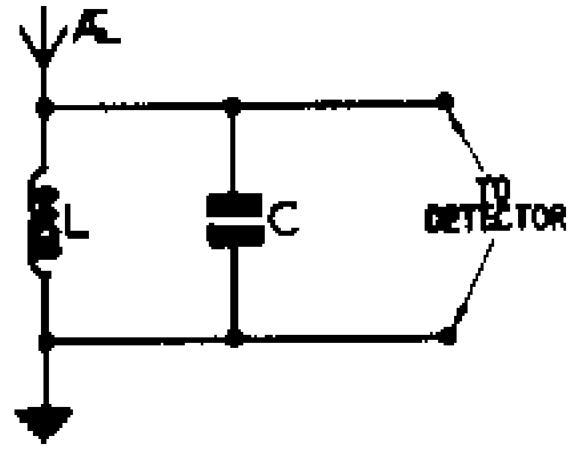


FIG. 3

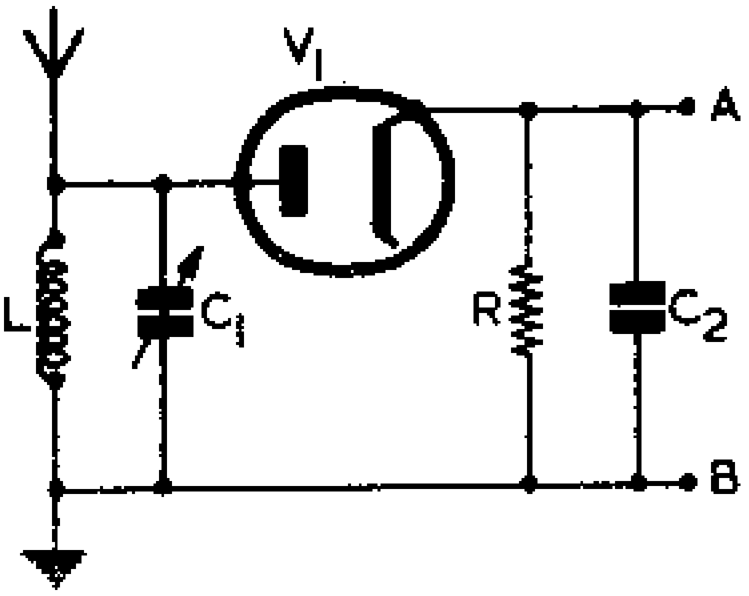


FIG. 4

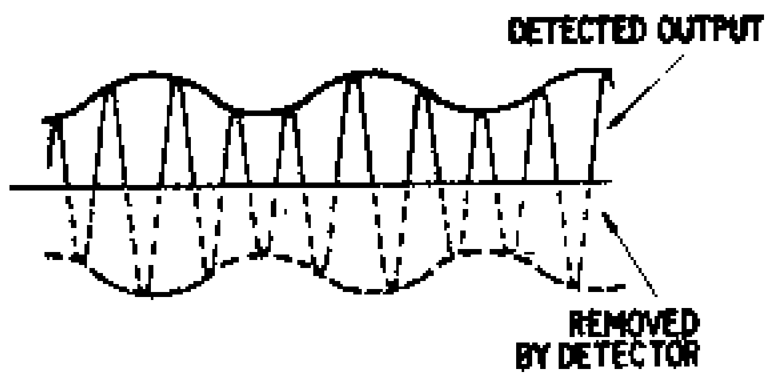
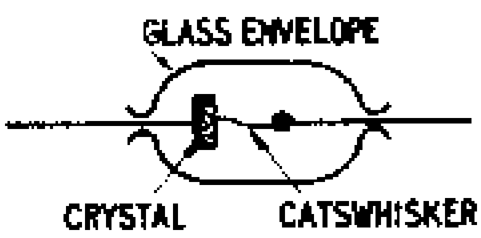


FIG. 5



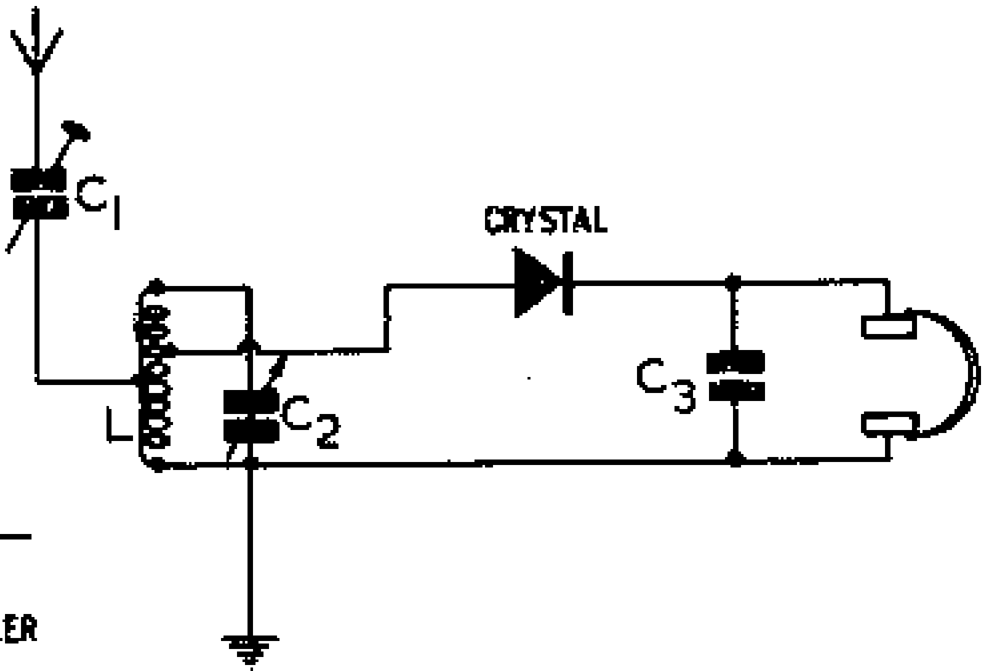


FIG. 6A

FIG. 6B

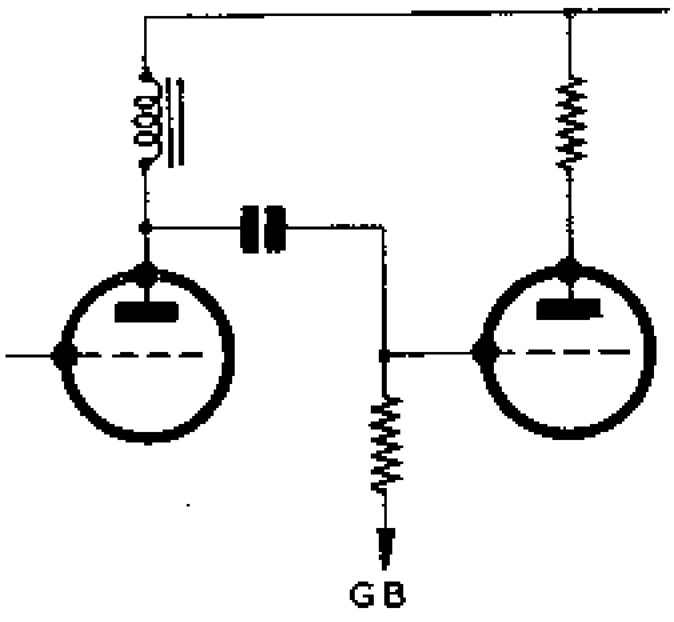


FIG.5.

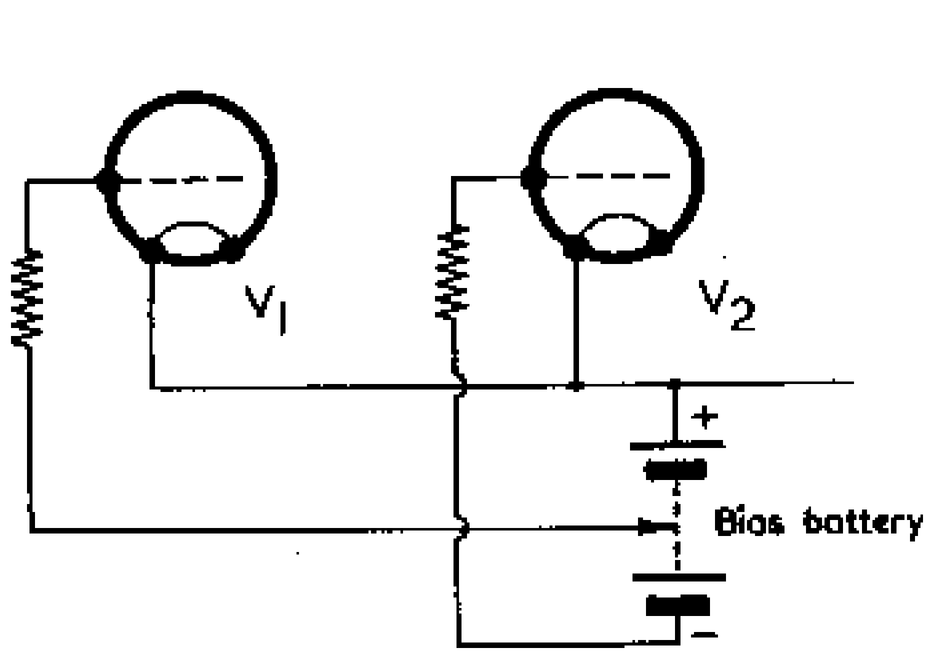


FIG.6.

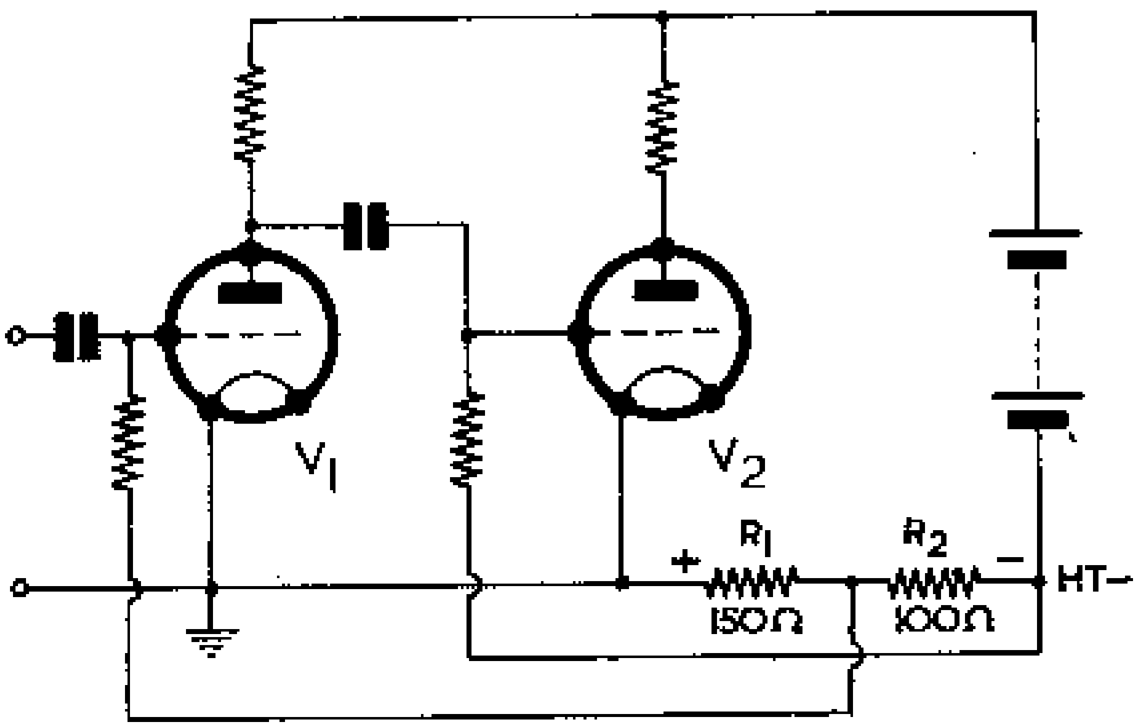


FIG.7.

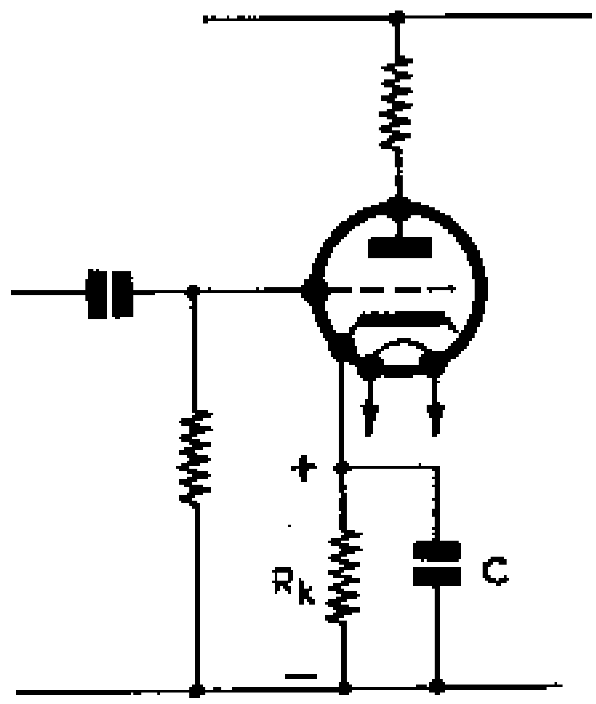


FIG.8.

an "auto bias" circuit appeared. The total valve h.t. current is caused to flow through a series of resistors as shown in Fig. 7. This means that the filaments are *positive* with respect to h.t.−, due to the valve current producing a voltage across R_1 and R_2. The grids can now be connected to the points shown which are *negative* with respect to the filaments.

Say, for example, that the total valve current were 20mA and V_2 required a grid bias of 5 volts. Then the total resistance (R_1+R_2) would be by Ohms Law:

$$R=\frac{E}{I}=\frac{5}{0.02}=250\Omega;$$

but if V_1 only required a bias of 3 volts, a resistance of

$$R=\frac{3}{0.02}=150\Omega$$

would be required.

Therefore R_1 would be 150Ω and R_2 100Ω, thus making the total of 250Ω for the bias of V_2. The arrival of indirectly heated valves produced another "automatic" biasing system. First, however, it should be explained that the indirectly heated valve is so called because the surface emitting the electrons is a tubular cathode placed around the filament. This enables an a.c. voltage to be used for the filament, as the cathode is electrically insulated from the filament. If a.c. were applied to the filament of a directly heated valve, some of the a.c. would be superimposed on the signal, resulting in an objectionable hum.

The method of automatic bias mostly used with indirectly heated valves to-day is shown in Fig. 8. The principle of operation is rather similar to that of Fig. 7. Here, however, only the current in individual valves is used to produce the bias voltage. The current flowing in R_K produces a voltage which is positive at the cathode. The grid, which is returned via its grid leak to the other end of R_K, is therefore negative with respect to the cathode.

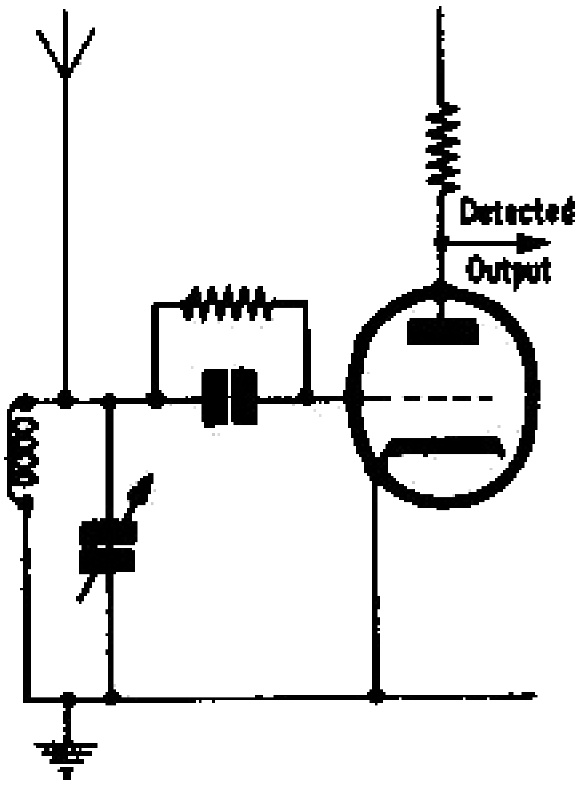


FIG. 7A

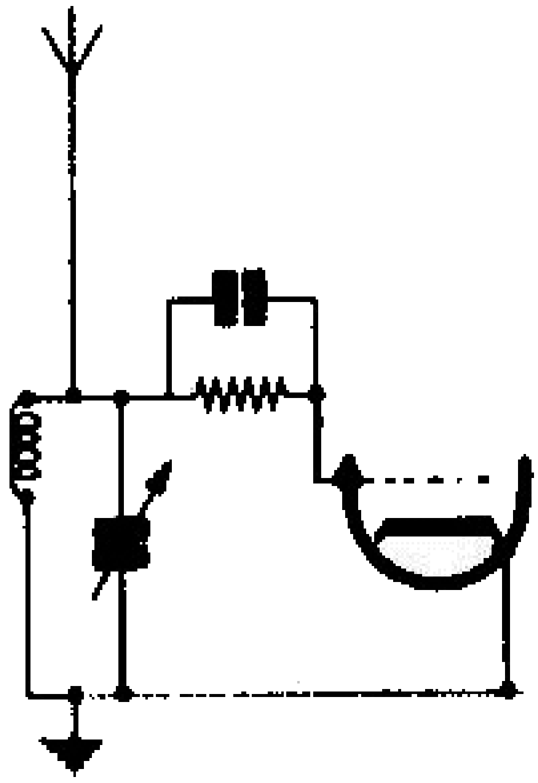


FIG. 7B

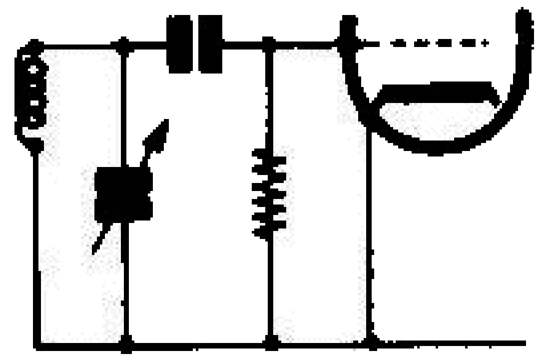


FIG. 7C

FIG. 8

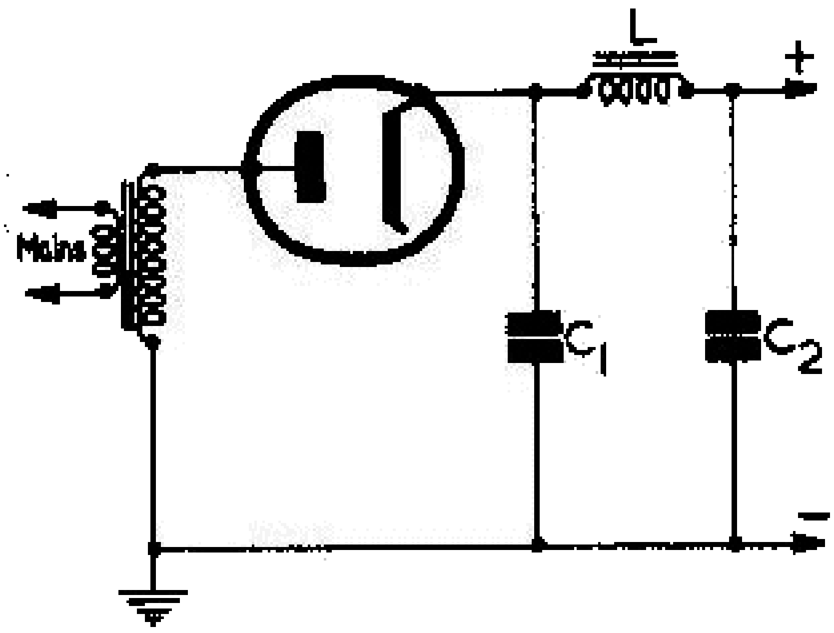


FIG. 9

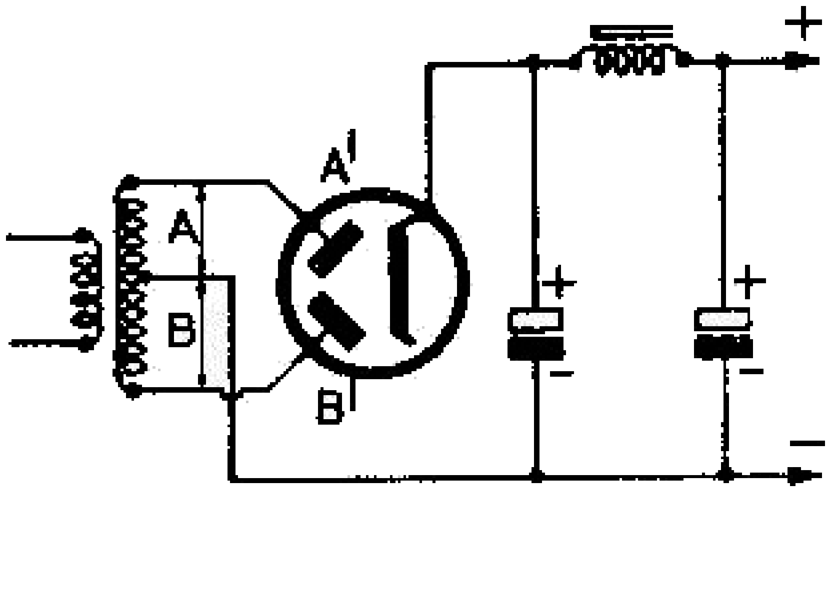


FIG. 10A

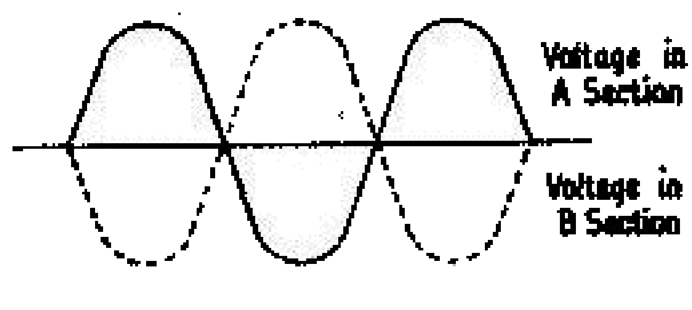


FIG. 10B

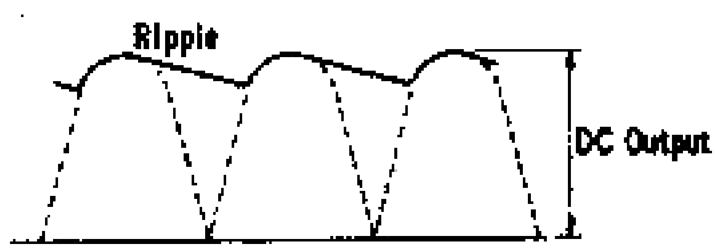


FIG 10C

line *ab* some way from the base line, as shown in Fig. 8. This line represents the average d.c. level from the detector.

Summarising this, it means that the diode or crystal detectors give an output composed of an audio signal superimposed on a d.c. voltage, where the value of the d.c. voltage depends upon the amplitude of the carrier only.

Although this has no application to the simple sets we are dealing with at the moment, it is of immense use for providing automatic volume control in more complex receivers, as we shall see later.

Rectification

Another name for the process of detection is "rectification." The latter name is not so commonly applied to the process of separating modulation from carriers, but it is used for another application of the same process. That is, changing a.c. voltages to d.c. voltages. In this series, valves have always been shown with batteries for the h.t. supplies. In mains receivers, some method has to be used to convert the mains 50 c/s a.c. supply to d.c. to replace the batteries.

This is done by using diodes very much in the same way as for detection, except that this time it is the d.c. component only that we are interested in. Even after rectification a considerable amount of a.c. is still present on the d.c. output voltage, and therefore a filter has to be used.

Fig. 9 shows a simple half-wave power rectifier circuit. The capacitor C_1 is the reservoir capacitor. It is charged by the rectifier and retains its charge until the next conducting half-cycle. The remaining ripple is smoothed by the choke L and the smoothing capacitor C_2. Excessive amounts of ripple can be the cause of hum at the output of the receiver.

A system that produces less ripple is the "full-wave" rectifier. This is shown in Fig. 10A. Here two rectifiers are used, and a centre-tapped transformer. The voltages appearing at the secondary of the transformer are shown in Fig. 10B. The full line represents the voltage in the section A in Fig. 10A, and the dotted line the voltage in section B. Now when section A is positive, diode A' will conduct. Diode B' will not be conducting because the voltage in section B is negative. However, when B becomes positive, A becomes negative and diode A' ceases conducting, when B' commences.

Now we have rectification taking place over the whole cycle instead of only half the cycle as in Fig. 9. The output waveform is shown in Fig. 10C. It can be seen that the ripple frequency is twice the mains frequency, i.e. 100 c/s for 50 c/s mains. This has the advantage that smoothing is easier and less ripple can result.

The two rectifier circuits Figs. 9 and 10 give a positive output voltage. The diodes could be reversed, i.e. the output taken from the anode and the cathode connected to the transformer, and the output would become negative.

For most ordinary radio work, of course, a positive voltage is required, so the figures are as usually found in radio circuits.