A New Negative Resistance Thermionic Device

By John Scott-Taggart

ONE of the most interesting physical phenomena is that of negative resistance. This property of certain devices is a very extraordinary one. The current through such conductors does not increase as the potential difference across the conductor increases but actually becomes less. Conversely, a decrease of potential produces an increase of current. This remarkable effect may be utilized in an infinite variety of ways. The chief application of a negative resistance device is its use to neutralize the positive or ordinary resistance of a circuit. In this way it is possible to overcome the losses in a circuit due to its ohmic resistance.

The arc and vapor lamp possess negative resistance characteristics and the properties of the former have enabled it to be used as a generator of continuous waves.

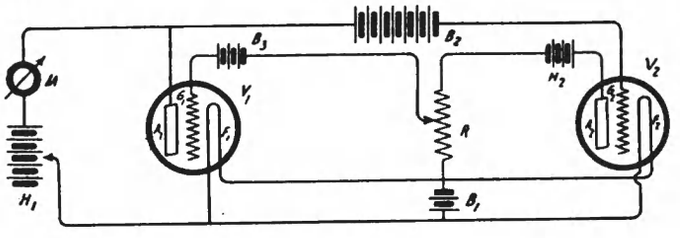

Figure 1—One form of the Biotron circuit

The device which has, however, become best known as a negative resistance for use in wireless receiving systems is the Dynatron vacuum tube. This tube takes advantage of the emission of secondary electrons from a bombarded anode.

Realizing the inherent possibilities of any device possessing stable and readily-obtained negative characteristics, the writer tackled the problem with a view to making use of the ordinary three-electrode tube. The purpose of this article is to give a short account of the principles on which the resultant device works.

The popular tendency being to give negative resistance devices distinctive names with the suffix "-tron," it has been decided to call the present arrangement the "Biotron," which, as its name almost implies, involves the use of two tubes. The Biotron circuit is shown in one form in figure 1. The anode circuit of a three-electrode tube V_1 contains a milliammeter M and a variable anode battery H_1. An electron current will take the path F_1 A_1 M H_1 F_1, giving a steady reading in M.

Let us confine ourselves for a moment to this circuit. If we increased the voltage of the battery H_1, the potential of the anode A_1 would increase and the anode current would be augmented. The circuit across which M and H_1 are connected possesses ordinary resistance. An increase of voltage produces an increase of current, while decreasing the value of H_1 would cause a decrease of current through H_1. The problem before us is to arrange matters so that the reverse effect is obtained.

Now, supposing that the increase of potential applied to A_1 be reversed in sign and applied to G_1, we will see that the negative potential on G_1 will tend to decrease the anode current of V_1. There would thus be two simultaneous effects: an increase in anode potential tending to increase the anode current and a decrease of grid potential tending to decrease the anode current. Since the potential on the grid has a much greater controlling effect than the same potential on the anode (about 5 to 10 times, usually) it is clear that the final result would be a decrease of anode current. This negative resistance effect is obtained in the Biotron by the use of a second three-electrode tube.

This tube is necessary to reverse the sign of the potential increase before applying it to the grid G_1. The filament F_2 of the second tube is connected to the filament of the first tube (preferably by using the same accumulator B_1) and the anode A_1 is connected through B_2 to the second grid G_2. The battery B_2 is used to neutralize the high potential of A_1 so that the potential of G_2 will be in the neighborhood of zero volts. It is to be understood that the circuits given here are those which most clearly indicate the theoretical action of the device. More practical circuits may be arranged for actual working.

The anode circuit of the second tube contains an anode battery H_2 and a high resistance R of about 50,000 ohms. The electron current of this valve takes the path F_2 A_2 H_2 R F_2. The steady current of about one milliampere through R will result in a steady potential drop across this

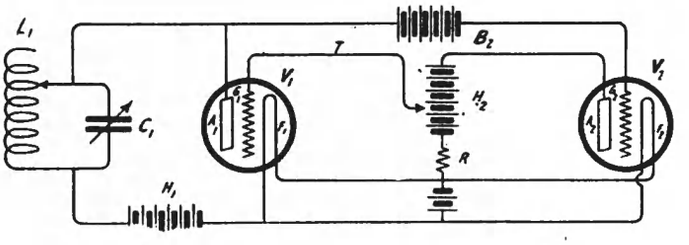

Figure 2—The Biotron used as a generator of oscillations

resistance, the potential of the top end of R being about — 50 volts. This end of R is connected to the grid of the first tube through a battery B_3 which is so connected as to bring G_1 to a suitable potential in the neighborhood of zero volts. Under normal conditions, the current through M will have a steady value. If now, we increase the E.M.F. of the battery H_1, the anode A_1 becomes more positive. At the same time, the grid G_2, which is connected to the anode A_1, also becomes more positive with respect to the filaments. The effect of G_2 becoming positive is to incerase the electron current flowing through R in the anode circuit of the second tube. This increase of current will cause an increase in the potential difference across R, making the top end of R and therefore the grid G_1 more negative with respect to the filaments. The negative potential applied to G_1 will tend to decrease the anode current of V_1. This anode current will decrease because the increase in the anode potential is greatly outweighed by the decrease in the grid potential. Moreover, the potential changes in H_1 have not only been reversed by the second tube, but also magnified on the usual principle of a resistance amplifier.

From the foregoing description it will be seen that the circuit A_1 M H_1 F_1 possesses negative resistance characteristics. A decrease of the potential of H_1 will make G_2 negative and G_1 positive. The anode current of the first tube will thus increase. In order to neutralize the ohmic resistance of a circuit all that is necessary is to include the circuit somewhere in series with H_1. The actual value of the negative resistance produced may be varied by altering the value of R or the position of the tapping T. If the resistance is of very low value or T is near the foot of R, it will be clear that the potentials communicated to G_1 will be very small and their effect may be so little as to be completely outweighed by the effect of the potential on the anode. Under these conditions the device acts in the ordinary way as a positive resistance. By suitably adjusting R, conditions are obtained so that variations of the voltage of H_1 produce no change in the current through H_1.

The second figure shows the Biotron as a negative resistance generator of oscillations, the resistance of the oscillatory circuit L_1 C_1 being neutralized by the negative resistance of the device, thus producing continuous oscil-