

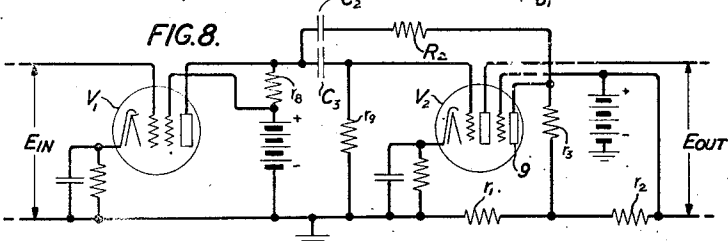
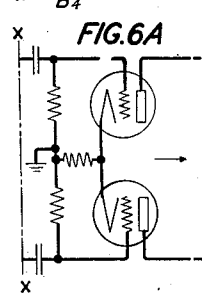
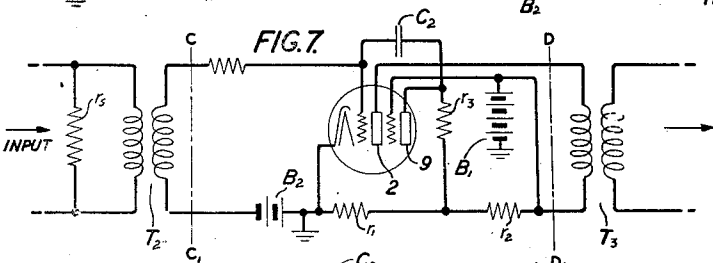
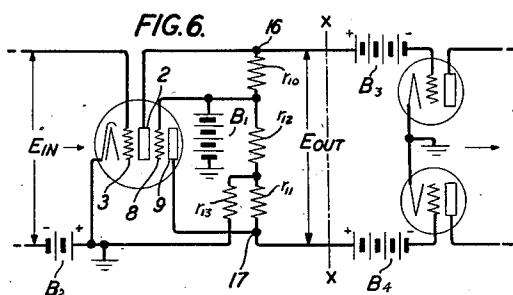
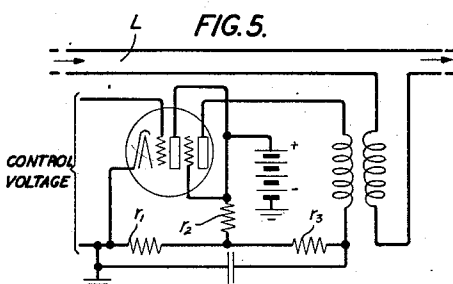
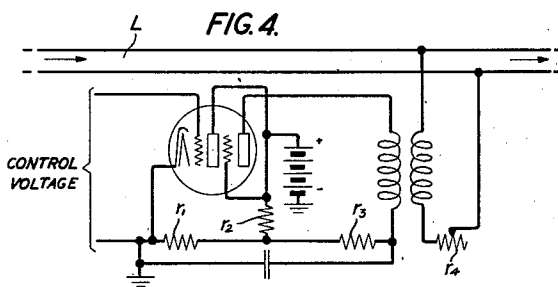
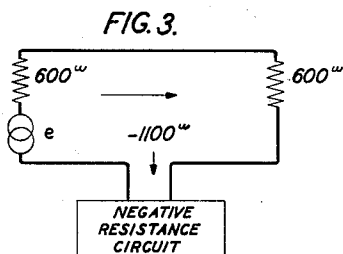
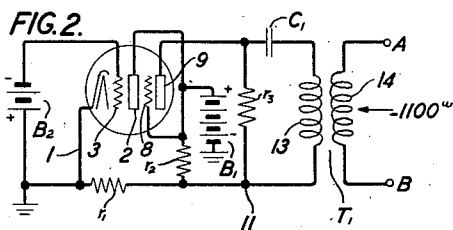
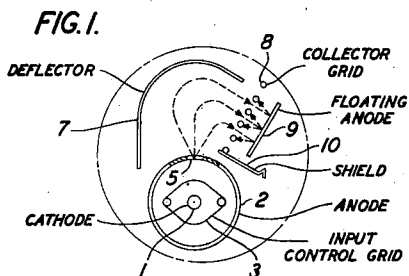
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H. L. BARNEY

2,370,221

ELECTRIC WAVE CIRCUIT

Filed July 22, 1942



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UNITED STATES PATENT OFFICE

2,370,221

ELECTRIC WAVE CIRCUITS

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3 Claims. (Cl. 179-171)

This invention relates to electric wave circuits and more particularly to an electronic device circuit including a vacuum tube of the secondary electron emission type.

An object of this invention is to so interconnect the various elements of the circuit as to produce an effective and stable negative resistance device.

A further object of the invention is to apply this negative resistance device to various useful purposes in a manner to be hereinafter described.

In accordance with this invention these objects are realized by the use of an electronic device comprising an electron source or cathode, a primary anode, an input control electrode or grid, a secondary electron emitting electrode adapted to emit secondary electrons in a ratio greater than unity when bombarded with electrons from the primary electron source, and a secondary electron collecting electrode. This device is associated with certain sources of potential and certain circuit elements to give the desired negative resistance.

A more complete understanding of this invention will be obtained from the following specification read with reference to the figures of the accompanying drawing wherein:

Fig. 1 shows in cross section one form of a vacuum tube especially adapted for the purpose of my invention;

Fig. 2 shows one circuit connection with such a device to produce a negative resistance circuit; and

Figs. 3 to 8 show various applications of the negative resistance circuit.

While the electronic device for producing the results which are desired may take on various forms, Fig. 1 shows one form of tube which I find particularly well suited. This tube is described in detail in the copending application of A. M. Skellett, Serial No. 321,852, filed March 2, 1940 issued as Patent No. 2,293,177 dated August 18, 1942, and will herein be described briefly only, inasmuch as it represents but one type of tube with which to carry out my invention. In the said Fig. 1 there is shown at 1 a primary electron source or cathode. Surrounding this cathode is an anode 2. Between these two there is a grid 3 which serves as a control grid. The anode 2 completely encloses the cathode and the control grid except for an aperture or window 5 through which, when the tube is in operation, a fractional part of the electrons from the cathode 1 may pass. In the approximate path of these electrons

is a deflecting plate 7 which diverts the stream of electrons to a secondary or floating anode 9. This anode has its surface so treated that it is a ready emitter of secondary electrons. Near to and in front of the anode 9 is a collector grid 8. A shield 10 is preferably provided so positioned, as shown, to prevent the flow of electrons in undesired directions.

Fig. 2 shows one circuit arrangement yielding a two-terminal negative resistance circuit. In this circuit the primary anode 2 and the collector grid 8 are connected directly to the positive terminal of the potential source B₁. The secondary anode 9 is connected at 11 to a point of intermediate potential, such as that on a bleeder circuit comprising resistances r₁ and r₂. Included between the secondary anode 9 and the point 11 is a resistance r₃ of relatively high value and shunted around this resistance is an alternating current circuit comprising the condenser C₁ and the primary 13 of a transformer T₁. The control grid is shown as being connected to the cathode through a biasing battery B₂.

With appropriate values of potentials and element constants there will appear across the terminals A, B of the secondary 14 a negative resistance and as such this circuit constitutes a part of my invention.

As an illustration of typical values for the circuit elements when used with the particular tube to which reference has been made, the following information is given:

B ₁ =135 volts	r ₂ =20,000 ohms
B ₂ =9 volts	r ₃ =60,000 ohms
r ₁ =10,000 ohms	C ₁ =1 microfarad

Transformer impedance ratio 75,000 to 600

Under these circumstances the resistance of the circuit looking into the terminals A, B was of the order of -1100 ohms.

Fig. 3 shows an application of this negative resistance circuit used as an amplifier in a 600 ohm line. Its insertion is equivalent to the reduction of the resistance of the circuit by 1100 ohms. Thus, when this negative resistance was placed in series with one side of the 600-ohm line it inserted a gain of approximately 21 decibels to either direction of transmission.

Since the circuit of Fig. 2 yields a negative resistance, it is obviously possible to obtain a zero resistance by adjustment of the circuit or simply by adding positive resistance in series with the negative resistance. If this zero resistance circuit was shunted across a transmission line L,

it would block transmission and this effective short circuit would be under control of the control grid of the tube. Such a circuit arrangement is shown in Fig. 4. In this circuit the resistance r_4 is shown, this being adjusted to such a value for a given control grid potential that the resistance of the tube circuit as seen looking in from the line is zero. If the control grid were made so negative that no electrons could get to the secondary anode, the impedance seen at the output of the negative resistance circuit, instead of being -1100 ohms, would be a large positive reactive value, depending on the characteristics of the output transformer. This positive reactive value is sufficiently high so that it would introduce substantially no loss on the transmission line.

In Fig. 5 is shown a series control of transmission in which the impedance introduced in series with the line may be made positive, negative or zero by varying the potential of the control grid of the tube. Thus, this switching amplifier may be made to introduce a gain or a loss according to the control grid bias. Applications of these types of switching amplifiers may be made to echo suppressors and other types of switching and suppressing devices.

It is to be noted that one of the characteristics of the circuit described in Fig. 2 is that voltage variations on the secondary anode 9 are 180 degrees out of phase with those on the conventional or primary anode 2. By virtue of this, certain other useful applications may be made. One of these is illustrated in Fig. 6 which is a phase inverter and amplifier stage of a design to couple between a single-sided and a push-pull vacuum tube stage. In this circuit, as in Fig. 3, the collector grid 8 is shown connected directly to the positive terminal of the potential source B_1 . The primary anode is connected to this same potential point through a resistance r_{10} . The secondary or floating anode 9 is connected through a resistance r_{11} to an intermediate potential point between the resistances r_{12} and r_{13} .

In this circuit if the control grid 3 goes more positive, then anode 2 falls in potential but the anode 9 rises in potential. The points 16, 17 may therefore be connected directly as shown in Fig. 6 to the control grids of a push-pull circuit comprising two amplifying tubes, here shown as triodes. Biasing batteries B_3 and B_4 would normally be introduced to offset direct current potentials between the points 16, 17. In view of the fact that the current variations through resistances r_{11} and r_{12} are not the same as those through r_{10} it would be necessary to give $r_{11} + r_{12}$ a different value from r_{10} .

As a further concrete example of values appropriate for a particular tube to which reference has been made, the following constants are recited:

$B_1=135$ volts	$r_{11}=60,000$ ohms
$B_2=4$ volts	$r_{12}=10,000$ ohms
$r_{10}=8,000$ ohms	$r_{13}=10,000$ ohms

In the circuit with these constants, the alternating current voltages to ground from the two anodes are equal and, therefore, the alternating current output of the stage is balanced. In actual performance in one instance, the voltage amplification from single-sided input to the output at 16, 17 was 8.3 as compared with the conventional phase inverter and amplifier circuit in which the phase inverter tube normally gives no amplification. Since there are no coupling con-

densers or transformers involved in this circuit the frequency range over which it will operate extends from direct current to the frequency at which parasitic capacitances in the tube become limiting. For this circuit the grid batteries B_3 and B_4 would not be the same in voltage since the direct current potentials to ground of the output leads from the first tube are not necessarily equal, although the alternating current potentials to ground are balanced.

Instead of the direct current coupling to the push-pull circuit of Fig. 6 it is obvious that a condenser coupling may be used as indicated in the circuit of Fig. 6A, this circuit being substituted at $x-x$.

Another circuit in which I make use of the negative resistance characteristic of my circuit and the opposite potential phasing of the primary and secondary anodes is shown in Fig. 7. Here an input circuit is shown as connected through the transformer T_2 to the input circuit of the tube. The collector grid is again connected to positive of battery. The primary anode 2 is connected to battery through a load circuit comprising the primary of transformer T_3 . The secondary or floating anode 9 is connected through a resistance r_3 to an intermediate potential point determined by resistances r_1 and r_2 . A feedback path comprising condenser C_2 connects from the floating anode to the control grid. In view of the fact that the potential variations on the anode 9 are 180 degrees out of phase with those of anode 2, this feedback path gives positive feedback or regeneration.

The following circuit constants illustrate appropriate values to use in connection with the particular type of tube shown:

$B_1=135$ volts	$r_2=20,000$ ohms
$B_2=5$ volts	$r_3=60,000$ ohms
$r_1=10,000$ ohms	$C_2=8$ microfarads

With the constants as given the input and output impedances in one instance were 600 ohms and the over-all gain between 600 ohms sending and receiving circuits was 10.2 decibels. If the circuit between points C-C' and D-D' is considered as the equivalent of a conventional vacuum tube circuit without feedback, its transfer conductance G_m and its amplification factor μ are 7500 micromhos and 8.9, respectively. The G_m and μ of the triode section of the tube with the feedback from the floating grid are 820 micromhos and 10.9, respectively, the same triode plate current of 4 milliamperes being used in both instances. The internal resistance r_0 of the triode part of the tube under the former condition was 13,300 ohms. The application of the regenerative feedback reduced the effective r_0 of the triode plate circuit from 13,300 ohms to 1,000 ohms.

It is of interest to note that in order to obtain a 600-ohm input impedance for the amplifier of Fig. 7, a resistance r_5 , which in the particular case referred to took on a value of 460 ohms, had to be shunted across the input terminals of the primary of transformer T_2 . This arises because of the fact that through the condenser coupling C_2 there is effectively placed across the input circuit a negative resistance. In the particular instance it develops that the impedance looking into the primary of the transformer T_2 without the shunting resistance r_5 is approximately -2,000 ohms.

Another amplifier circuit using the same type of tube is shown in Fig. 8 with a resistance capac-

ity coupling from a preceding screen grid tube V_1 . The feedback from the floating anode again effectively results in a negative resistance being shunted across the resistance r_s , the feedback connection including condenser C_2 and resistance R_2 . Thus the plate load impedance on V_1 is greater than simply that of r_s and r_p in parallel, being in fact the resultant of a negative resistance in shunt with r_s and r_p . Therefore the resistances r_s and r_p may be made comparatively low with correspondingly small direct current voltage drop due to r_s while the alternating current plate load impedance of V_1 may be made so high as to obtain maximum voltage amplification from the first stage.

While I have described certain applications of my negative resistance circuit it is to be understood that these are for illustrative purposes only and many variations may be made therein without departing from the spirit of my invention.

What is claimed is:

1. A high vacuum tube circuit possessing negative resistance properties over a portion of its characteristic, the vacuum tube comprising a cathode and a primary anode, a control grid between the cathode and the primary anode, a secondary anode adapted to receive a limited number of primary electrons from the cathode, a collector grid adjacent the secondary anode and adapted to receive secondary electrons from the

secondary anode, a source of potential with the negative terminal connected to the cathode and the positive terminal connected to the collector grid, a load circuit from the primary anode to a positive point on the potential source, a connection from the secondary anode through a resistance to an intermediate potential point with respect to the cathode, the potentials being so adjusted that the volt-ampere characteristic from cathode to secondary anode has a negative slope over its operating range, means for impressing a signal to be amplified between the control grid and the cathode, and a regenerative feedback connection consisting of an impedance connected from the secondary anode to the control grid.

2. The combination of claim 1 characterized by the fact that the feedback connection comprises a condenser.

3. The combination of claim 1 characterized by the fact that the input circuit is coupled to a preceding amplifier circuit through a resistance coupling, the direct current resistance load of the said preceding tube being held to a relatively low value while the alternating current impedance of the load of the said preceding tube is maintained at a high value by virtue of the negative resistance of the secondary anode circuit from which the feedback connection is derived.

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