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E. W. HEROLD

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NEGATIVE TRANSCONDUCTANCE AMPLIFIER CIRCUITS

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**Fig. 1**

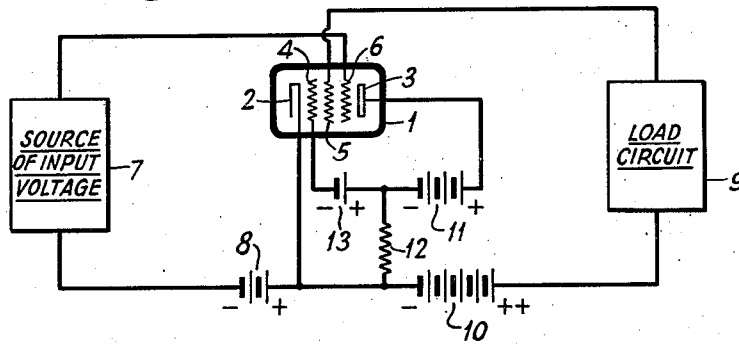


**Fig. 2**

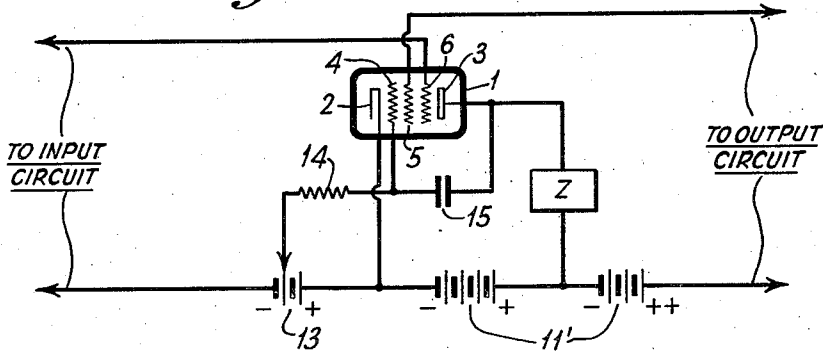
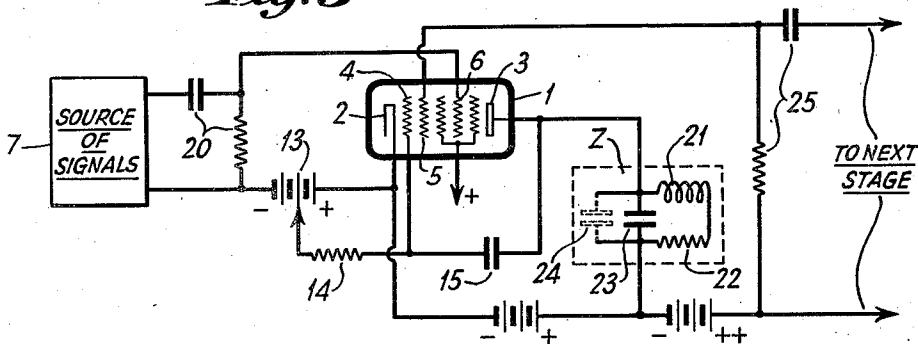


**Fig. 3**



INVENTOR.  
EDWARD W. HEROLD

BY

*H. S. Brown*  
ATTORNEY.

## UNITED STATES PATENT OFFICE

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Edward W. Herold, Verona, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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2 Claims. (Cl. 179—171)

My present invention relates to negative transconductance amplifier circuits, and more particularly to arrangements for improving the effective negative transconductance of negative transconductance tubes of the retarding field type.

In the ordinary negative transconductance tube of the retarding field type, a decrease in potential of a control electrode in the electron path is accompanied by an increase of current to some electrode located closer to the electron source than the said control electrode. The transconductance, in such case, between the two electrodes is said to be negative in sign. At the same time, the current to a cold electrode, or electrodes, situated further from the electron source than the aforesaid control electrode is decreased. The transconductance between the control electrode and the further cold electrode is positive in sign. Reference is made to my following article for a further discussion of devices of this type: "Negative resistance and devices for obtaining it" published in the Proceedings of the Institute of Radio Engineers, for October 1935, on pages 1201 to 1223.

Assume, now, a tube of the aforescribed type and wherein the current in the positive transconductance output electrode is passed through a resistance, and the resulting potential drop across the latter is applied to an auxiliary control electrode close to, or surrounding, the electron source. It will be found that as the current decreases in the positive transconductance output electrode, the auxiliary electrode rises in potential and causes the flow of current in the negative transconductance output electrode to rise. The negative transconductance action is thus augmented; it is possible to increase the action five-fold or more.

One of the main objects of my present invention is to augment the amplifying action of a negative transconductance amplifier in such a manner that the latter remains stable under most operating conditions.

Another important object of this invention is to provide in a negative transconductance amplifier a method of augmenting the negative transconductance action; the method including deriving from current flowing in a positive transconductance section of the amplifier an alternating potential, and applying the latter to an auxiliary electrode in a sense to increase the current flow to the negative transconductance output electrode.

Still another object of my invention is to provide a tube having positive and negative transconductance sections including a common control electrode; the positive transconductance section having an output load impedance capable of developing a high frequency potential thereacross, and the potential being utilized to

increase the current flow to the negative transconductance output electrode.

Still other objects of the invention are to improve generally the efficiency and reliability of negative transconductance amplifiers, and more especially to produce such amplifiers in an economical manner.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

Fig. 1 shows a circuit embodying a form of the invention.

Fig. 2 illustrates a modification of the circuit, Fig. 3 shows still another modification.

Referring now to the accompanying drawing, wherein like reference characters in the different figures denote similar circuit elements, there is shown in Fig. 1 a simple amplifier circuit illustrating the manner of improving the negative transconductance action. Thus, tube 1, which may be of the pentode type, includes a cathode 2, a plate 3 and three grids 4, 5, 6, arranged in succession in the electron stream. Numeral 7 designates any well known source of input voltage; the source is connected between grid 6 and cathode 2. The potential source 8 applies a negative bias to grid 6. The load circuit 9 may be of any conventional type; it is connected between grid 5 and cathode. The current source 10 maintains the grid 5, or negative transconductance output electrode, at a positive voltage. It will be noted that plate 3 is connected to the end of cathode resistor 12 by current source 11. The auxiliary grid 4 is connected to the same end of resistor 12 by the negative biasing source 13.

To explain the action of the amplifier, assume that an input voltage applied to 7 renders the grid 6 more negative than the normal biasing voltage established by source 8. In that case the current flow through plate 3 decreases; on the other hand the current flow through the circuit of grid 5 increases. This is due to the fact that the transconductance between grid 6 and plate 3 is positive, while it is negative between grid 6 and grid 5. Now, if a voltage were to be applied to grid 4 so as to make it positive, the total current flow will be increased so that the current through the circuit of grid 5 will be augmented. This is accomplished by means of the current variations in the circuit of plate 3. The variations develop across resistive impedance 12 a varying potential; the latter is applied to grid 4. When the

current flow through the circuit of plate 3 decreases, the grid 4 assumes a potential which becomes increasingly greater in a positive polarity sense. This results in a greater current flow through the circuit of grid 5. In other words while the transconductance is negative between grids 6 and 5, yet it is positive between grids 4 and 5.

While the circuit of Fig. 1 is well suited for amplifying of direct current, or low frequency alternating, potential variations applied to grid 6, yet for high frequency amplification the high capacitance of the anode battery to cathode is a limitation. To overcome the latter, and to simplify battery requirements, there is shown in Fig. 2 a circuit modification suitable for improving the amplification solely of alternating voltages. Here the plate 3 is connected, through impedance Z, to an intermediate point on current source 11'. The auxiliary grid 4 is connected to a desired negative potential point on source 13 through the high resistance 14. Alternating potential variations across Z are impressed on grid 4 through a large condenser 15. Otherwise, the circuit is similar to that shown in Fig. 1.

The nature of impedance Z will depend on the use to which the circuit is to be put. In its simplest form it may consist of a pure resistance; the amplifier will then be suitable for amplification of currents of low frequencies. Because of the unavoidable shunting capacitance across the resistance, however, the amplification drops off at higher frequencies. In Fig. 3 there is shown an amplifier, constructed according to this invention, capable of operating over a wide band of frequencies extending up to frequencies of the order of 1 megacycle (mc.). The source 7 is to be understood as being a signal source covering a wide band of frequencies. Tube 1 may be of the 2A7, 6A7 or 6A8 type; in general, they include positive screen grids on either side of grid 6 to increase the gain of the output electrode 5 and the gain to the auxiliary anode 3. If desired, a shielding electrode between electrodes 4 and 5 may be employed.

The signal source 7 is coupled to the input electrodes 6-2 by the resistance-capacity coupling 20. The impedance Z, represented by a dotted rectangle, includes coil 21 and resistor 22 in series in the plate circuit; the unavoidable circuit and tube capacitance being represented in dotted line by numeral 24 as being in shunt with the series path 21-22. Numeral 23 denotes any external capacitance which may be added. The numeral 25 designates the coupling to the following amplifier state, assuming, for example, that the amplifier network is of the resistance-capacity coupled type.

If the capacity 23 is made equal to zero, and the square of resistance 22 made approximately equal to twice the value of coil 21 divided by capacitance 24, the impedance Z becomes practically constant at a value of resistance 22 from zero frequency to a frequency=

$$\frac{1}{2\pi R_{22} C_{24}}$$

This permits a uniform improvement in amplification over this whole band of frequencies. If, now, resistor 22 is shortened, the impedance of Z has a sharp maximum at a frequency=

$$\frac{1}{2\pi \sqrt{L_{21} C_{24}}}$$

The improvement, in that case, occurs only over a very narrow band about this frequency. Regardless of the construction of impedance Z, the potential thereacross is fed back, or impressed, through condenser 15 to the auxiliary grid 4. The functioning of the circuit is similar to that described in connection with Fig. 2. In brief, the alternating potential developed across impedance Z is employed to augment the negative transconductance action between grid 6 and output electrode 5.

The impedance Z may assume various other forms besides those enumerated above. For example, it may consist of a small inductance in series with a relatively high resistance; or it may comprise an inductance shunted by a capacitance in series with a resistance; or an inductance in series with a resistance with a series connection of inductance and capacitance shunted across the resistance. The use of other wave filter networks for Z permits increased amplification over any specified band of frequencies. It is believed that those skilled in the art will be able to select the proper construction for the impedance Z to suit any specific requirement.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In an amplifier provided with a cathode and a cold electrode spaced therefrom, at least three auxiliary electrodes arranged in succession therebetween, a source of alternating input voltage connected between the cathode and the third of said auxiliary electrodes, an output circuit connected between the cathode and solely the second of said auxiliary electrodes, means for establishing said cold electrode and second auxiliary electrode at positive potentials, means establishing the first auxiliary electrode at a negative potential relative to said cathode, an impedance in circuit with said cold electrode, and a path of low impedance to alternating voltage connected between the first auxiliary electrode and said impedance, said impedance including a network which comprises inductance, resistance and capacity so related as to impart a constant value thereto over a wide frequency range.

2. An amplifier including an electron discharge device having a cathode, a first control electrode, an output anode, a second control electrode and an auxiliary anode in the order named, means for shielding said second control electrode from said output anode and from said auxiliary anode, a source of signals connected between the said second control electrode and the cathode, an output circuit between said output anode and cathode, an impedance which is resistive in nature over the range of frequencies to be amplified connected between said auxiliary anode and cathode, means for impressing alternating potential variations across said impedance on said first control electrode for the purpose of increasing the amplification of frequencies within the desired range and including means for biasing said first control electrode negative with respect to the cathode.

EDWARD W. HEROLD.