

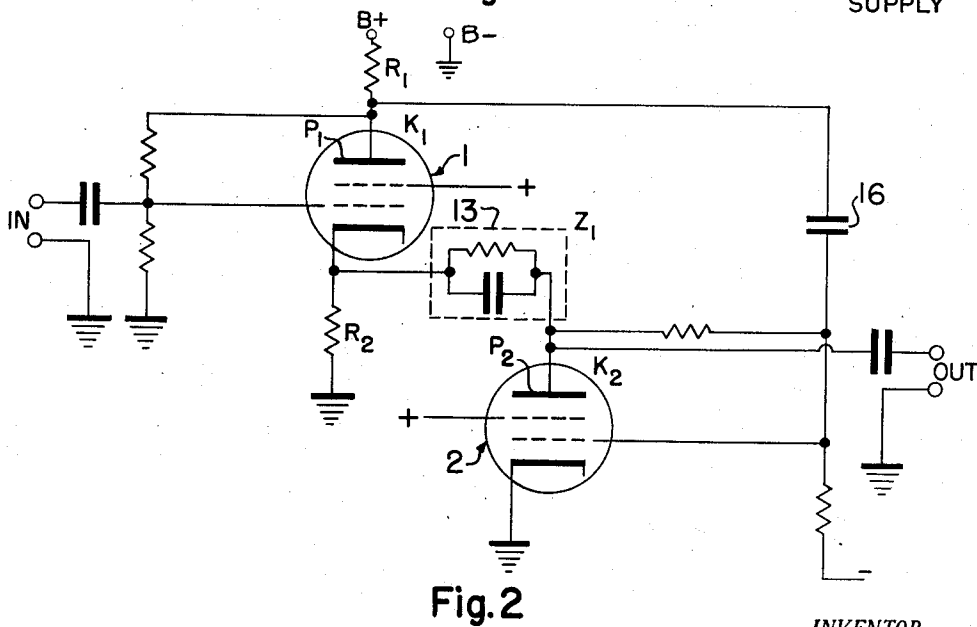
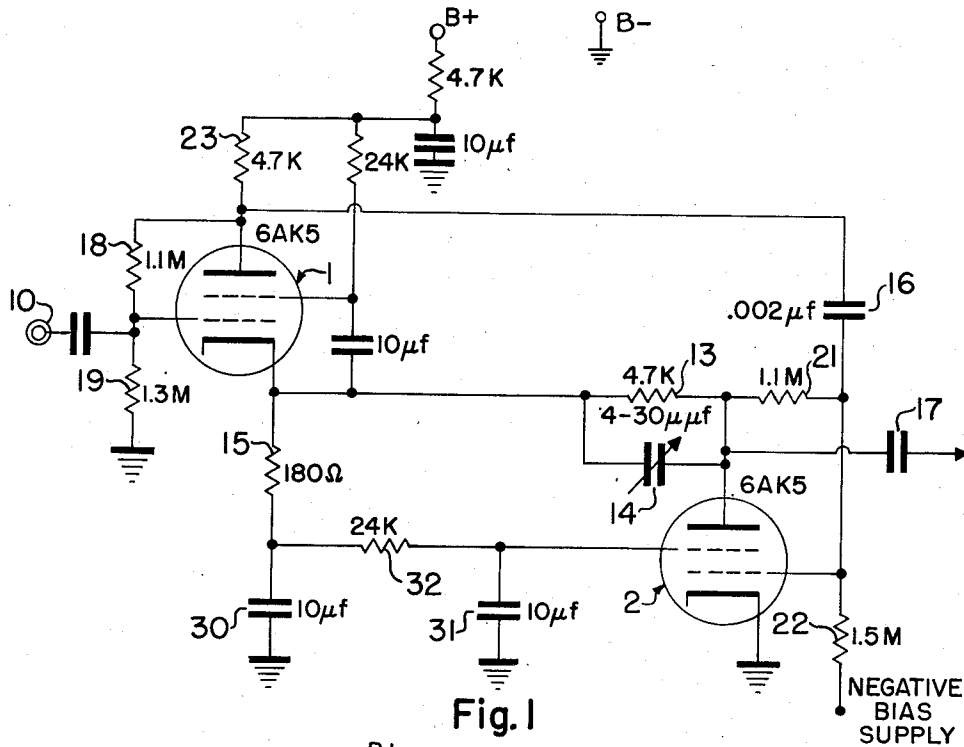
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STABILIZED FEEDBACK AMPLIFIER

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STABILIZED FEEDBACK AMPLIFIER

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This invention relates to negative feedback amplifiers, and more particularly to a negative feedback circuit which is economical of anode power consumption.

The benefits of negative feedback in amplifiers are well known in the art and in general include improvements in stability, linearity and noise reduction.

The usual negative feedback amplifier is a multi-stage arrangement with signal-back coupling in the degenerative phase from a selected stage to a selected preceding stage. Various techniques are available for single stage amplifiers, as shown in "Radio Engineering" by Terman, third edition, page 322. However, these techniques are deficient in controllability of the amount of feedback, or stability, or flatness of response for the purposes of laboratory measuring equipment. The multi-stage amplifier admits of better flexibility, but has the inherent disadvantage of high anode power demand particularly if used in portable battery operated equipment.

Accordingly, it is a prime object of this invention to provide a feedback amplifier circuit having the advantages of a two-stage device, yet having the anode current consumption of but one.

It is a further object to provide series connected tubes in a feedback arrangement in which the potential for the acceleration or screen grid of the feedback tube is provided in an economical manner.

Other objects and advantages of this invention will become apparent from the specification, taken in connection with the accompanying drawing made a part thereof.

In the drawings:

Figure 1 is a circuit diagram of a practical embodiment of a species in accordance with this invention; and

Figure 2 is a simplified equivalent version of the circuit of Figure 1 provided to facilitate the explanation of operation thereof.

Referring to Figure 1, a single stage amplifier having the novel features of this invention comprises two grid controlled thermionic tubes 1 and 2. These tubes are shown as tetrodes for purposes of illustration, but may be grid controlled tubes having any number of electrodes.

The interelectrode space of tube 1 is electrically connected in series with the interelectrode space of tube 2. It follows that the cathode current of tube 1 must equal the current flowing to at least the anode of tube 2. In the embodiment shown, in order to provide screen potential for tube 2 in an economical fashion, the screen current is also provided by the cathode circuit of tube 1. To accomplish this a pair of electrical paths in tube 2 are provided for the cathode of tube 1. A first of these paths includes at least a resistive network and preferably a resistive-capacitive network 13 connected between the cathode of tube 1 and the anode of tube 2. A second path includes resistors 15 and 32 connected between the cathode of tube 1 and the screen grid of tube 2.

The condenser 14 is made adjustable in order to permit adjustment of the band width and rise time of the amplifier. It is desirable to select an adjustment of this

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capacitor which gives maximum bandwidth while maintaining a selected pulse characteristic.

The screen potential for tube 2 is maintained at a constant value by a long time constant filter network comprising resistor 32 and capacitors 30 and 31. The value of capacitor 30 is selected of any large value such as to effectively by-pass all variations of signal nature appearing at the lower end of resistor 15. Consequently, to all intents and purposes, as far as signal is concerned, the cathode load resistor of tube 1 terminates at an equipotential plane or ground.

The anode of tube 1 is provided with a selected load impedance 23 and a capacitor 16 of negligible impedance at signal frequencies coupling it to the control grid of tube 2. The anode load resistor 23 of tube 1 is connected through a filter or decoupling network to the positive pole of an anode potential source and the circuit is completed through the potential source to the ground connection of the cathode of tube 2.

The ambient bias on the grids of tubes 1 and 2 is determined by series resistors 18—19 connected between the anode of tube 1 and ground, and by series resistors 21—22 connected between the anode of tube 2 and a source of negative bias potential. This feature is utilized to stabilize the transconductance of the tubes in the practical embodiment shown. It is apparent from inspection that an increase of internal resistance in tube 1 or 2 tends to result in decreased anode current. The potential at the anode tends to rise thereby decreasing the grid bias and thereby restoring the original internal resistance.

It is apparent that well known biasing methods can be substituted although the advantage of transconductance stabilization will be sacrificed.

The operation of the circuit is readily apparent from inspection of Figure 2. For a degenerative effect, the potential excursions due to signals on the cathode and on the anode of a tube move in opposite directions. The anode of tube 1 is coupled to the control grid of tube 2 through capacitor 16. Phase reversal is obtained on the anode of tube 2 which is coupled through network 13 to the cathode of tube 1.

To facilitate the practical utilization of this invention, the values of the final gain of the amplifier, herein termed A_f can be determined in the manner well known in the art. The actual expression for A_f is algebraically awkward but can be simplified by the use of several reasonable assumptions which are, $A \gg 1$; $u_1 \gg 1$; $r_{p1} \gg R_1$; $r_{p2} \gg Z_1$; $r_{p2} \gg (R_2 + Z_1)$;

$$R_1 \gg \frac{1}{g_{m2}} \left(1 + \frac{1}{g_{m1} R_2} \right) \text{ and } \left(\frac{R_2 + Z_1}{R_2} \right) \gg \frac{1}{g_{m2} R_1}$$

wherein A is the unfeedback gain of the amplifier, g_{m1} is the mutual conductance of tube 1, g_{m2} is the mutual conductance of tube 2, and the rest of the terms are those commonly used in the art.

With these assumptions, the conventional expression

$$A_f = \frac{A}{1 + AB}$$

for the gain of an amplifier with feedback, becomes for the amplifier of the present invention:

$$A_f = \frac{R_2 + Z_1}{R_2}$$

Accordingly, it follows that to a reasonable approximation (within 20%), the final gain of the amplifier is equal to the ratio between the sum of R_2 and Z_1 , and R_2 . Since Z_1 can be high relative to cathode resistor 15, i. e. R_2 , this amplifier can be given considerable feedback and have a gain higher than 1.

Thus, it is seen that a novel type of inverse feedback amplifier, which consumes a minimum of anode power,

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has been described. The techniques employed are readily applicable to other tubes having any number of electrodes. Since many changes could be made in the construction above shown and described, and other embodiments of this invention could be made without departing from the scope thereof, it is intended that the invention shall be restricted only by the scope of the appended claims as interpreted in view of the prior art.

What is claimed is:

1. A feedback amplifier comprising a first and a second thermionic tube each having at least a cathode, a control grid and an anode, first resistance means coupling the cathode of the first tube to the anode of the second tube, a second resistance of low ohmic value compared to said first resistance connected at one end to the cathode of the first tube and at the other end to one side of a large capacitance of negligible reactance at the lowest working frequency, said capacitance being connected on its other side to the cathode of the second tube, a load impedance connected between the anode of the first tube and the positive pole of a source of anode potential, a gridleak connecting the grid of the first tube to ground, means coupling the anode of the first tube to the control grid of the second tube and means electrically connecting the cathode of the second tube to the negative pole of said source of anode potential.

2. A feedback amplifier device comprising two grid controlled thermionic tubes having their cathode-anode interelectrode spaces electrically connected in series through a first resistance connected between the cathode of a first one of said tubes and the anode of the second one of said tubes, means electrically coupling the anode of the first one of said tubes to the control grid of the second one of said tubes, a source of anode potential, impedance means electrically connecting the positive pole of said source of anode potential to the anode of the said first one of said tubes and means connecting the negative pole of said source of anode potential to the cathode of the second one of said tubes, input signal means coupled to the grid of said first one of said tubes, and a gridleak resistor connecting the grid of said first one of said tubes to ground, and output signal means coupled to the anode of the said second one of said tubes.

3. The device of claim 2 in which an impedance comprising a second resistance of low ohmic value compared to the ohmic value of the first resistance connected in series with a capacitance of negligible reactance at the lowest working frequency is connected between the cathode of the said first one of said tubes and to ground.

4. A feedback amplifier comprising a first and second vacuum tube each having at least an anode, cathode and control electrode, signal input means electrically coupled to the control electrode of the first tube, an anode load impedance having an end connected to the anode of the first tube, means electrically coupling the control electrode of the second tube to the anode of the first tube,

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means including a parallel resistance-capacitance network electrically connecting the cathode of the first tube in series with the anode of the second tube, a series resistance-capacitance network, of substantially lower impedance than the impedance of said parallel network, connected between the cathode of the first tube and the cathode of the second tube and means electrically connecting the free end of the first tube anode load impedance and the cathode of the second tube, respectively, to the positive and negative terminals of a potential source.

5. The device of claim 4 in which at least the second tube contains a screen grid, a decoupling network electrically connected between the junction of the resistor and capacitor of said series resistance-capacitance network and said screen grid.

6. The device of claim 4 in which a high resistance voltage divider having a substantially higher value of resistance than the input impedance of said first vacuum tube and having a tap thereon is electrically connected between the anode of said first vacuum tube and the negative terminal of said potential source, and said tap is electrically connected to the control electrode of said first tube.

7. The device of claim 4 in which a high resistance voltage divider having a substantially higher value of resistance than the input impedance of said second tube having a tap thereon is electrically connected between the anode of the second tube and a source of negative bias more negative than the potential of the negative terminal of said potential source, and the control electrode of said second tube being connected to the tap on said voltage divider.

8. In a stabilized amplifier including a thermionic tube having at least a cathode, a control grid and an anode, means for stabilizing the transconductance of said tube comprising a load resistance connected between the anode of said tube and a source of anode potential and a high resistance voltage divider electrically connected between the anode of said tube and a source of potential of value more negative than the desired bias for said control grid, a tap on said voltage divider at a point of desired bias for the control grid, and an electrical connection directly connecting the tap of the voltage divider to the control grid, said voltage divider having a resistance of substantially great ohmic value than the input impedance of said thermionic tube.

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