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STABILIZED HIGH-GAIN AMPLIFIER

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FIG. 1.

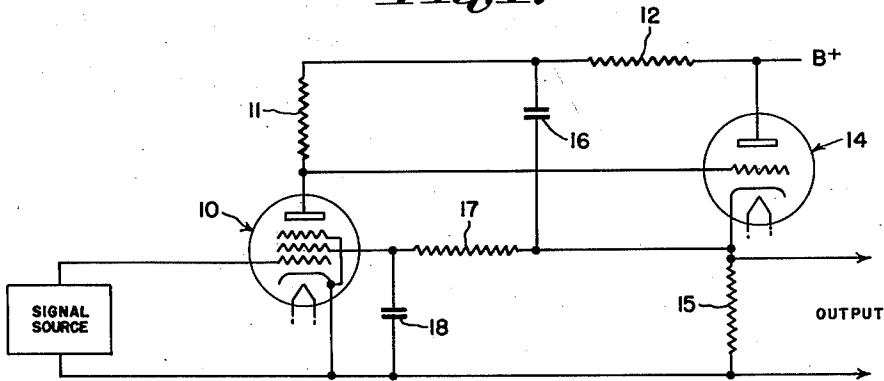


FIG. 2.

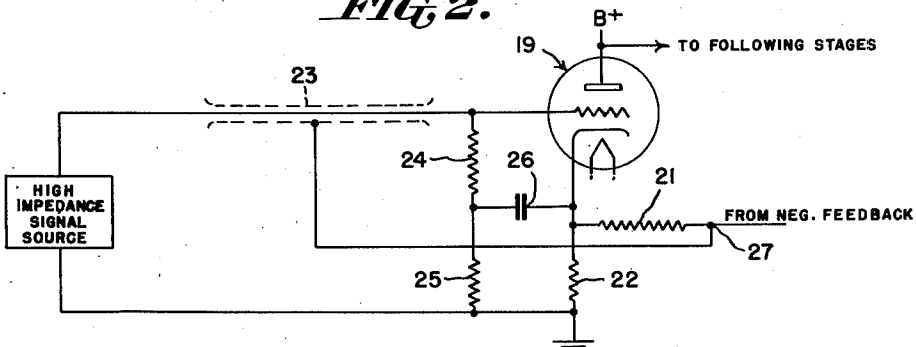


FIG. 3.

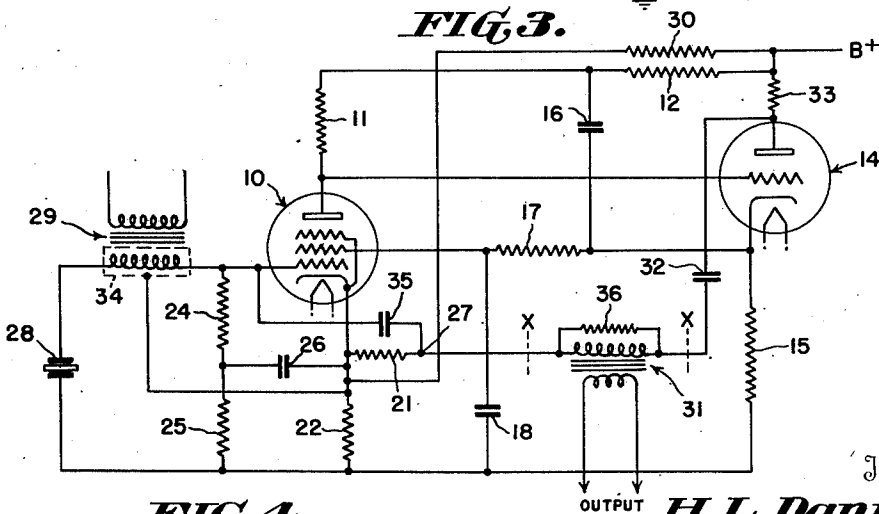
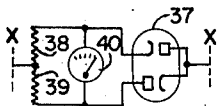


FIG. 4.



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STABILIZED HIGH GAIN AMPLIFIER

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This invention relates generally to vacuum tube amplifiers and more particularly to high gain amplifiers having means for stabilizing the operation thereof, the principal object being to provide a circuit arrangement, including a cathode follower, for a conventional pentode whereby a voltage gain which closely approaches the amplification factor of the pentode may be obtained therefrom.

Another object is to provide a means of coupling between the pentode and cathode follower which is adapted to maintain a flat frequency response of the pentode over a wide frequency range extending to a low order of frequencies.

A further object is to provide means for rendering the optimum operating point of the pentode substantially independent of variations in supply voltages and/or variations in the constants of different pentodes of the same type.

A still further object is to provide a high gain amplifier in which a large amount of negative feedback may be applied and in which certain difficulties inherent in negative feedback arrangements of conventional multi-stage amplifiers are obviated.

Still another object is to provide a feedback stabilized amplified which is well adapted to utilize the negative feedback produced thereby to minimize the electrical loading of the input circuit of the amplifier on a high impedance source.

A still further object is to provide a circuit arrangement whereby electrical loading on the input circuit of an amplifier may be substantially eliminated.

An additional object is to provide new and improved means for increasing the effective value of an impedance.

Still other objects, features and advantages of the present invention are those which will become more clearly apparent as the description proceeds, reference being had to the accompanying drawings wherein:

Fig. 1 is a diagram of a preferred circuit arrangement for use with a conventional pentode whereby the gain of the pentode may be made to approach closely the amplification factor of the tube;

Fig. 2 is a diagram which illustrates the preferred manner in which electrical loading on the input circuit of an amplifier tube may be substantially eliminated;

Fig. 3 is a diagram which illustrates the preferred manner in which the basic circuits of Figs. 1 and 2 may be adapted for use as a highly

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stabilized feedback preamplifier for a high impedance source and in which the feedback is utilized to eliminate substantially electrical loading of the input circuit of the amplifier; and

Fig. 4 illustrates a suitable meter circuit which may be employed with the circuit of Fig. 3 to provide a vacuum tube meter.

Referring now to the drawings for a more complete understanding of the invention and more particularly to Fig. 1 thereof, the numeral 10 generally designates a conventional pentode which is connected as a voltage amplifier, the voltage to be amplified being applied to the control grid of tube 10 in the usual manner and the plate load impedance, in this case, being separated into two series connected impedances 11 and 12 through which the plate of tube 10 is fed from a suitable D. C. source B⁺, also in the usual manner.

A conventional tube 14, also conveniently fed from source B⁺, is connected in a cathode follower circuit to a cathode load impedance 15, the grid of tube 14 being connected preferably directly to the plate of tube 10 and the cathode of tube 14 being coupled to the junction of impedances 11 and 12 by means of a suitable coupling impedance 16 which is of relatively low value as compared to that of impedance 12. Coupling impedance 16 may be an electrolytic condenser for A. C. applications of the circuit, leakage currents having little effect on the overall operation thereof, and for D. C. applications of the circuit a suitable constant voltage source such, for example, as a battery may be employed. It will be appreciated that the use of an electrolytic condenser readily permits extension of the regions of flat frequency response to relative low values of frequency.

As is well known, the impedance looking into the cathode of a cathode follower is low. Therefore, the increment in cathode operating voltage due to leakage current from coupling means 16 flowing into the cathode of tube 14 will be inappreciable. Furthermore, owing to the degenerative effect of impedance 15, the voltage appearing at the grid of tube 14 due to the flow of the leakage current through impedance 12 will not materially affect the operating conditions of tube 14.

It is well known that the cathode signal voltage of a cathode follower tends to follow closely the grid signal voltage thereof such that a small voltage difference exists between the grid and cathode. By reason of the aforescribed coupling between tubes 10 and 14, this small volt-

age difference also appears across impedance 11. To the extent that the cathode signal voltage of tube 14 is made to follow the grid signal voltage thereof, the signal voltage across impedance 11 may be made small as compared with that appearing at the plate of tube 10. Accordingly, the effective value of impedance 11 as viewed from the plate of tube 10 is made many times greater than its actual value. For the reason that the ratio of the effective plate load impedance to the internal plate resistance of the tube gives a measure of the proportion of the tube amplification factor which may be realized as voltage gain of the tube, it will be apparent that, by a proper selection of circuit parameters, the effective load impedance may be increased, without exceeding the usual limitations of B^+ voltage, to such an extent that the gain realized may closely approach the amplification factor of the tube. For the reason that a pentode is characterized by high internal resistance and high amplification factor, a pentode is well adapted to provide a high order of gain in a single stage of amplification in the manner thus devised. For the foregoing purpose, it will be apparent that impedance 12 need be made only so large as not to impair materially the operation of tube 14 as a cathode follower.

The static voltages applied between the control grid and cathode, and between the screen grid and cathode, of pentode 10 may be obtained by any of the conventional methods. However, it has been found that the operation of this circuit is critically dependent upon the static screen grid voltage, and, therefore, means have been devised for causing the circuit to maintain conditions for optimum gain automatically. This is accomplished by feeding the screen grid through a suitable resistor 17 from the cathode of tube 14, provision being made for bypassing the signal voltage, which otherwise would appear at the screen grid, by means of a suitable condenser 18.

From the foregoing, it should now be apparent that the aforescribed circuit is, in effect, a single stage amplifier for the reason that the output voltage actually appears at the plate of tube 10. However, in practice, it has been found desirable to take the output voltage from the cathode of tube 14, as indicated, in order to avoid loading the circuit in such a manner as to impair its operation for the purposes intended.

Moreover, it should now be evident that inasmuch as the gain achieved in the first stage of an amplifier determines, for a given overall amplifier gain, the precautions which must be taken to avoid ripple and surge voltages in the power supply for the amplifier, and the precautions which must be taken to prevent coupling through a common power supply between the first and subsequent stages of the amplifier, considerations of power supply filtering and regulation are relatively of little concern in the design of the circuit disclosed by reason of the high gain achieved in a single stage of amplification thereof.

Referring now to Fig. 2, the numeral 19 generally designates a conventional amplifier tube to the cathode of which a negative feedback signal, which may be derived in any conventional manner, is applied by way of a voltage divider network comprising impedances 21 and 22. The voltage signal to be amplified by the tube is applied to the control grid thereof from a high impedance signal source by way of an input circuit, here shown to be a conductor surrounded by a

length of electrostatic shield 23. This shield, if grounded in the usual manner, would electrically load the high impedance source by reason of the shunting capacitance between the conductor and the shield.

A grid leak comprising series connected resistors 24 and 25 is connected between the control grid of tube 19 and ground or point of fixed potential in accordance with the usual arrangement, which, in the absence of the corrective measures hereinafter to be described, imposes shunt resistive loading on the high impedance source.

It has been discovered that the foregoing capacitive and resistive loading effects on the high impedance source may be greatly reduced or entirely eliminated, as is desired, by reducing substantially to zero, or to a relatively small value as compared to the source voltage, the signal voltage appearing across the shunting load and effective in producing loading current therein. Thus, by this method, the loading current is reduced substantially to zero, thereby increasing the effective or apparent values of the loading impedances by many times their actual values. This is accomplished by coupling the loading impedances to a voltage source which is constrained to follow closely the signal voltage applied to the control grid rather than to ground or a point of fixed potential, as in the usual case.

As is well known, when a negative feedback signal is applied to the cathode of a tube, the signal voltage at the cathode is constrained to follow closely the signal voltage on the control grid of the tube. The greater the amount of feedback the smaller will be the difference between the grid and cathode signal voltages. This fact is utilized in the circuit of Fig. 2 to reduce the loading due to impedance 24 by coupling the impedance to the cathode of tube 19 by means of a suitable low impedance element, in this case shown to be a condenser 26. By reason of this coupling, the loading effect of impedance 24 is reduced in the ratio of the small grid to cathode signal voltage difference to the applied grid voltage.

The use of a feedback circuit of the type shown further permits, by proper selection of impedance 21, the selection of a point in the feedback circuit which provides a voltage equal to the applied grid signal voltage. This point also may be coupled by means of a suitable low impedance element, here shown to be a direct connection, to shield 23, this coupling serving to eliminate completely the capacitive loading due to the shield. Furthermore, by proper selection of impedance 21, point 27 may be caused to provide a voltage which is somewhat greater than the applied grid signal. This may be utilized to provide the effect of a small negative capacitance between the control grid and ground, which negative capacitance effect may be increased sufficiently to compensate for any residual capacitance in the input circuit which has not been eliminated by the means heretofore described. Similar results may be obtained by connecting the shield to the cathode and introducing a suitable additional capacitance between the grid and point 27, as shown in Fig. 3.

Referring now to Fig. 3 in which the basic principles set forth in connection with the circuits of Figs. 1 and 2 are applied to provide a highly stabilized preamplifier for a high impedance voltage source and in which similar parts are designated by like reference characters, the numeral 28 designates a high impedance source such, for example, as a piezo-electric crystal mi-

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crophone which may be used together with the negative feedback amplifier operating therefrom as a transducer adapted to give an accurate measure of sound pressure existing in the medium in which the microphone is placed.

The secondary winding of a transformer generally designated 29 is inserted in series with microphone 28 in the input circuit of tube 10 for applying a signal thereto which simulates the internal signal voltage generated within the crystal for the purpose of calibrating the transducer. Electrical loading due to the presence of transformer 29 in the input circuit is obviated generally in the manner set forth in connection with the description of Fig. 2 and as specifically set forth hereinafter.

Resistor 30, connected between the B⁺ supply and the cathode of tube 10 is employed as a suitable means of obtaining bias for the tube.

Negative feedback is applied to the cathode of tube 10 from the plate of tube 14 by way of a circuit or path which includes the primary winding of an output transformer generally designated 31 and a blocking condenser 32, a suitable impedance 33 being interposed between the plate of tube 14 and the B supply in order to cause substantially all of the signal current from tube 14 to flow through the feedback path. Impedance 33, for this purpose, is made as high as feasible, particularly as compared to the impedance of the feedback circuit.

The secondary winding of calibration transformer 29 is surrounded by an electrostatic shield 34 which is connected to the cathode of tube 10 in order to minimize the capacitive loading of the source, which loading otherwise would occur by reason of the stray capacitance of the winding. The remaining small amount of stray capacitance in the input circuit is compensated for by means of condenser 35 which is connected between the grid of tube 10 and point 27 in the feedback circuit, as suggested in connection with the description of Fig. 2.

Resistor 36 is connected across the primary winding of output transformer 31 to provide the proper output impedance as viewed from the primary winding. The impedance of the amplifier circuit itself, as viewed between points X—X in the feedback circuit with transformer 31 removed therefrom, is made to appear extremely high by reason of the large amount of negative current feedback achieved in the circuit.

The use of a large amount of negative feedback is permitted in the circuit of Fig. 3 without the tendency toward instability resulting from the greater degree of phase shift at the lower extreme of the range of flat frequency response which might occur if tubes 10 and 14 were connected as a conventional capacitance coupled two stage amplifier. This relative freedom from instability results from the specific manner in which tubes 10 and 14 are intercoupled to produce the gain achieved in a single stage of amplification, the gain of tube 10, by the association of tube 14 therewith in a cathode follower circuit, being as great as ten to one hundred times what it otherwise would be if operated alone.

In view of the foregoing, it will now be apparent that the circuit of Fig. 3 may be employed advantageously as a vacuum tube meter which is well adapted to give a true measure of substantially the average value of the input signal, output transformer 31, for this purpose, being replaced by the diode and meter circuit of Fig. 4. In this circuit, the two sections of a dual diode

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or rectifier 37 are connected in push-pull such that the negative feedback current is caused to flow alternately therethrough on successive half cycles of the current, the tube sections being arranged to operate into resistors 38 and 39 respectively as load impedances thereon. Diode 37, in effect, functions as a switch whereby predetermined portions of both negative and positive half cycles of the alternating current flowing in the feedback circuit are caused to flow through a D. C. meter 40 in the same direction therethrough, thus giving an indication of the average value of the input signal voltage. Since the feedback current produces an effectively high source impedance for the diode, effects of non-linearity in the diode operation are minimized.

From the foregoing, it should now be apparent that certain circuit arrangements have been provided which are well adapted to fulfill the aforesaid objects of the invention. Moreover, while the invention has been described in particularity with respect to these circuit arrangements, which give satisfactory results, it will be apparent to those skilled in the art that additional circuits applying the principles of the invention may be devised without departing from the spirit and scope of the invention defined by the appended claims.

The invention herein defined and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of any royalties thereon or therefor.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In a single stage amplifier of the character disclosed, in combination, a pentode, an operating circuit for the pentode including a plate load impedance therefor, a cathode follower, means coupling the grid and cathode of the cathode follower to opposite sides of the load impedance for causing the effective value thereof to be increased to many times its actual value, and means coupling the cathode of the cathode follower to the screen grid of the pentode for stabilizing the optimum D. C. operating point of the pentode.

2. In an amplifier for a voltage source and having an input circuit which includes shunt loading impedances, means for eliminating substantially the loading of said impedances on said source which comprises, in combination, an electronic tube, a negative feedback circuit connected to the cathode of said tube, and means for coupling said loading impedances to selected points in said negative feedback circuit including a point having greater than unity feedback ratio with respect to the grid of the tube whereby voltages may be provided which are adapted to eliminate substantially the voltages appearing across the loading impedances.

3. A negative feedback amplifier for a voltage source and having an input circuit which includes shunt loading impedances, the combination of an electronic tube having cathode and plate elements, a plate load impedance connected to said plate element of the tube, a cathode follower, coupling means between the grid and cathode of said cathode follower and said load impedance for multiplying its effective value in relation to its actual value, a feedback circuit connected to said cathode follower for developing a feedback voltage, and means for coupling said loading impedances to selected points in said feedback circuit whereby portions of said feedback voltage are

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applied to said shunt loading impedances in a manner to eliminate substantially the voltages appearing across the shunt loading impedances.

4. In a circuit including an amplifier tube and a cathode follower driven therefrom, the combination of an input circuit for said tube, means for electrostatically shielding a selected portion of said input circuit, a feedback circuit interconnecting said cathode follower and the cathode of said tube, and means for coupling said shield to the feedback circuit at a point of potential therein having greater than unity feedback ratio with respect to the grid of the tube whereby the effect of capacitive loading on said input circuit may be greatly reduced.

5. In a signal voltage amplifier of the character disclosed, a pentode, an operating circuit for the pentode including a first impedance connected to the plate thereof and a second resistive impedance connected to the opposite end of said first impedance, a cathode follower having substantially unity feedback ratio with respect to the grid thereof and having its grid connected directly to said plate of the tube, a circuit element having low impedance to the signal voltage for coupling the cathode of the cathode follower to the junction of said first and second impedances whereby the effective value of the first impedance is increased by many times its actual value and the gain of the pentode closely approaches the am-

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plification factor thereof, a resistive impedance element connecting said cathode to the screen grid of the pentode thereby to stabilize the D. C. operating point thereof, and a bypass element connected to said screen grid for preventing application of the signal voltage thereto.

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