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AUDIO AMPLIFIER CIRCUIT

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Fig. 1.

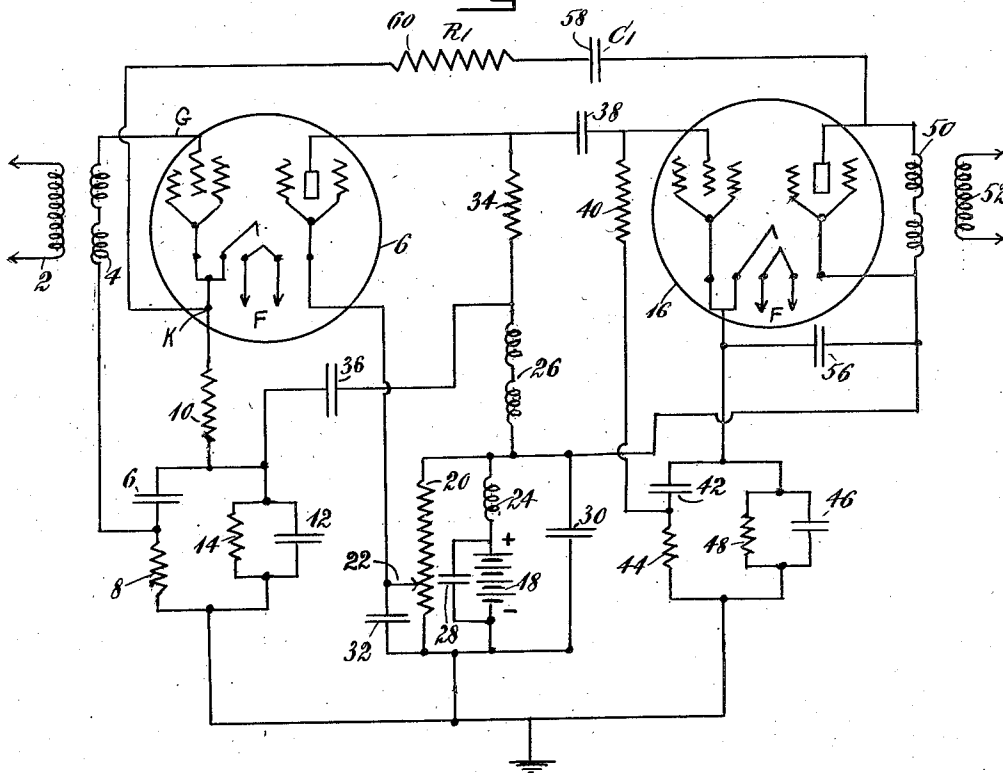
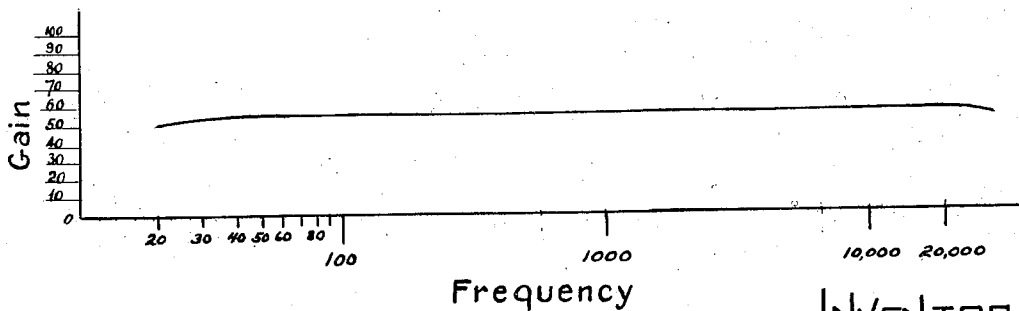


Fig. 2.



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AUDIO AMPLIFIER CIRCUIT

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4 Claims. (Cl. 179—171)

This invention relates to electrical thermionic amplifiers and especially to such amplifiers as operate the so-called audio frequencies, namely frequencies from 20 to 20,000 cycles per second. Amplifiers of this type are intended to give high fidelity or high quality amplification of speech, music or other sound effects.

The primary object of my invention is to provide an amplifier which will amplify with equal amplitude signals of all frequencies within the range of audibility. Another object of my invention is to accomplish this amplification with as simple a circuit as possible consistent with the desired degree of fidelity of reproduction.

The natural tendency of thermionic amplifiers of ordinary construction is to amplify disproportionately certain frequencies with respect to certain other frequencies, with the result that sound output is not a faithful reproduction of the sound input. In many cases, it is the higher frequencies that are amplified disproportionately. In order to compensate for this disproportionate amplification of the higher range of frequencies, it has been found possible through suitable circuits to feed back in various ways a portion of the output of the last stage of amplification or of some intermediate stage to the grid circuit of the first amplifying tube.

This return voltage is applied to the grid circuit of the first tube in such a way that it will modify the output of the first tube and consequently the output of the succeeding stage at the higher frequencies without decreasing the output of the lower frequencies. In this way the amplification of all frequencies may be held substantially proportionate so that faithful reproduction is obtained.

My invention is particularly concerned, therefore, with providing a circuit in which the means of feed back provides such control of the grid circuit voltage of the first tube that the output of the amplifier will give a flat gain curve.

Previous methods of accomplishing this result have taken several forms as, for instance, the use of an odd number of stages greater than one, thus returning to the grid of the first tube a voltage 180° out of phase with the grid voltage of this tube. Another method of prior art is to use push pull amplification in the second stage and thus obtain the necessary phase reversal with two stages, but this method involves the use of three tubes or an ordinary vacuum tube and a tube with two sets of elements therein.

By my invention, however, it is contemplated to compensate for the variations in amplifica-

tions which would naturally be obtained at the higher and lower frequencies by returning a portion of the output current of the second tube through a feed back circuit consisting of a condenser of suitable capacity and resistance of suitable value to the cathode circuit of the first tube.

By my circuit a current flows through the control grid circuit network of the first tube in such a manner as to oppose the voltage produced in this circuit by the secondary coil of the input transformer. By suitable selection of the various electrical constants of the circuit, it is possible to secure a degenerative action in the circuit which varies automatically with the frequency and prevents any tendency for the gain of the amplifier to change regardless of the frequency. As stated above, this circuit is designed to hold the gain curve flat throughout the entire range of audible frequency as this gives the most desirable reproduction.

With the constants that I have determined as being suitable, a flat gain curve is accomplished, but I have also found that by varying certain of the constants, it is possible to modify the response of the circuit through certain particular bands of frequency, if such modification is desired.

Fig. 1 of the drawing shows the circuit.

Fig. 2 gives graphically the results of the invention in the form of the gain curve produced by the amplifier.

Referring now to Fig. 1, it will be seen that my amplifier circuit includes two pentode vacuum tubes connected in cascade by means of a resistance coupling with the addition to the conventional form shown of the feed back circuit comprising the resistance R_1 and the condenser C_1 in series, which circuit provides a path from the plate of the second tube to the cathode and suppressor grid of the first tube.

Let us consider the action of the circuit shown in Fig. 1 without including, for the moment, the feed back circuit through R_1 and C_1 . The potential of point G when a constant current is flowing in the control grid circuit of the first tube in the direction of the arrow is lower than the potential at point K. When no current flows in the primary winding of the input transformer, the potential of the grid is the same as the potential of the point K. Let us assume a signaling wave flowing in the primary of the transformer inducing a current in the secondary in such a manner as to increase the potential of the grid. For instance, if with no signal grid po-

tential is minus 3 volts, a signal might increase it to minus 1 volt. There will be a resulting increase in the audio frequency plate current of the tube which change will be amplified by the second tube to increase still further the audio frequency plate current in the second tube. This increased current results in an increased output current from the second tube, and for any given frequency, the ratio of output current to input current will be a constant value depending on the electrical constants of the circuit provided, of course, that the tube is being worked on the straight portion of its characteristic curve.

This ratio of output current to input current is the amplification of the circuit and it is customary to designate the logarithm of this ratio as the gain of the amplifier. In decibel units, the gain may be expressed as

$$20 \log_{10} \frac{I_2}{I_1}$$

In terms of the ratio of voltage amplification the gain in decibels may be expressed as

$$20 \log_{10} \frac{E_2}{E_1}$$

This statement holds when the load resistance equals the input resistance.

Without some means of feed back the ordinary amplifier will show a varying gain with varying frequency because the space charge current in the plate circuit flows through that portion of the grid circuit which is connected to the cathode. At lower frequencies, the by-passing condensers in the grid return circuit offer a higher impedance path to low frequency currents than they do to high frequency currents, and at higher frequencies the losses in the transformers increase with frequency.

This impedance effect results in an increasing degenerative action as the frequency becomes lower because it reduces the effective change in potential in the grid circuit which causes the operation of the tube, while at higher frequencies the degenerative action is less, but above a certain limit the losses in the transformers increase and the gain decreases.

In the circuit constituting my invention, the constants are so selected that the desired gain will be obtained at substantially the lower limit of audible frequency and the values for the feed back path through C_1 and R_1 are so selected that they will cause sufficient current to flow through them which may be introduced into the grid return network, and as a result of this additional current flowing into the grid network, a voltage will be set up which will oppose in varying degree the input voltage and tend to hold the entire amplifier stable.

Briefly, then, the feed back effect is lowest at low frequencies when the degenerative effect of the low frequency currents in the plate return circuit is highest, and increases as the by-passing condensers handle more and more of the plate return current. At the higher frequencies, the feed back path offers less impedance to the path of the feed back current, so the degenerative action of the feed back circuit is greater.

The feed back effect is limited more and more at the higher frequencies, however, by the value of the resistance R_1 so that the feed back curve flattens out as the frequency increases. By proper selection of C_1 and R_1 the desired flatness of the gain curve can be obtained. Also by proper proportioning of the grid return network,

varying proportions of the plate current can be made to return through the network to vary the degenerative effect according to any desired curve.

The results obtained with an amplifier connected as described herein have been attainable formerly only with three or more tubes or with much more apparatus than is required in the present invention.

A particular form of the amplifier as constructed and found to produce the results claimed for the invention is described as follows:

The input, which may be derived from any audio frequency source which it is desired to amplify, is connected to the primary 2 of the input transformer, which for best results should be shielded.

One terminal of the secondary 4 of the input transformer is connected to the control grid of the first stage vacuum tube 6 which may be a pentode tube such as the RCA #57 tube or any similar tube. The other terminal of the secondary 4 is connected to the grid return network at a point between the condenser 6 and resistance 3.

The suppressor grid and cathode of the first tube 6 are connected together and connected to a resistance 10 for which a suitable value may be 300 ohms, which in turn is connected into the first stage network consisting of condensers 6 and 12 and resistances 3 and 14. The constants and function of the network will be described later.

The filaments of both the first stage tube 6 and the second stage tube 16 serve merely as heaters for the cathodes and may be supplied from any suitable power source. For convenience the filament power supply is not shown on the diagram.

The plate supply of both tubes consists of a source of direct current 18 which may be a battery or any source of direct current without excessive ripple voltage. The potential of the direct current source should be approximately 220 volts. A drop wire, bleeder resistor, or potentiometer 20 is connected across the power supply and a tap 22 taken off to supply the proper voltage for the screen grid of tube 6. For the Type 57 tube this voltage should be about 30 volts.

Direct current source 18 also supplies plate voltage for both tubes and is filtered by means of the choke coils 24 and 26 and condensers 28, 30, 32.

The plate load of the first tube consists of the resistance 34 a suitable value for which is about 125,000 ohms. Condenser 36 of fairly large capacity, about 4 mf., provides a by-pass for the audio-frequency component of plate current around the D. C. power supply circuit, returning it to the cathode through the resistance 10.

The second stage vacuum tube 16 may be a pentode tube such as the RCA type 59 or any tube having similar characteristics. The second stage is connected to the first stage through the condenser 38 which has a value of about 0.4 mf. and is connected between the plate of the first tube and the control grid of the second tube. Resistance 40 is connected from the control grid of the second tube to the grid return network of the second tube, between condenser 42 and resistance 44.

The suppressor grid and cathode of the second tube are connected together and connected to the grid network consisting of condensers 42 and 46 75

and resistances 44 and 48. This network and its function will be described later.

The plate of the second tube is connected to one terminal of the output transformer primary coil 50, whose secondary 52 may connect to the loud speaker or other translating device. For best results a shielded transformer should be used, to prevent cross-talk and undesired feed-back.

The other terminal of the output transformer primary 50 connects to the positive terminal of the plate voltage direct current source 16 through choke 24. Condenser 56, a suitable value for which is 2 mf. is connected between the cathode and the terminal of the output transformer primary 50 not connected to the second tube plate, and furnishes a by-pass for the audio frequency component of the second tube plate current around the D. C. power supply.

The screen grid of the second tube is connected to the same terminal of the output transformer primary as condenser 56 in order to maintain it at a high positive potential with respect to the cathode.

The plate of the second tube 16 is connected to the cathode of the first tube 6 through condenser 58 or C_1 and resistance 60 or R_1 of values about 0.25 mf. and 250,000 ohms respectively.

The negative side of the D. C. high voltage supply, the metal mounting base, all metal equipment covers, and the common connections of resistance 8, 14, 44, and 48 are connected to the ground.

The grid return networks are connected as follows:

In the first stage, the cathode and suppressor grid are connected together and connect to resistance 10, for which a suitable value is about 800 ohms; the other terminal of resistance 10 connects to an impedance consisting of resistance 14 and condenser 12 in parallel, the other end of which is grounded; and to an impedance consisting of condenser 6 and resistance 8 in series the other end of resistance 8 being grounded. As previously stated, the grid circuit return from input transformer secondary connects to the common terminals of condenser 6 and resistance 8. The by-passing condenser 36 instead of being connected directly to the cathode as is usually done in prior practice, connects to the cathode through resistance 10, which is thus common to the grid circuit and the plate circuit. In the second stage, the network consisting of condensers 42 and 46 and resistances 44 and 48 is similar to the first stage network except that the 800 ohm resistor 10 between the cathode and network proper is omitted. The second tube cathode is connected directly to the network, and the plate by-passing condenser 56 is connected directly to the cathode.

Suitable values for use in the networks have been found to be as follows:

Condensers	Resistances
	Ohms
6—1 microfarads.....	10-800
12—8 microfarads.....	8-60000
42—1 microfarads.....	14-2500
46—16 microfarads.....	44-10000
	48-400

The amplifier circuit operates in the following manner:

Alternating current of varying frequency and voltage flows in the primary 2 of the input trans-

former inducing a voltage of similar wave form in the secondary 4.

This voltage induced in the secondary, together with the difference in potential existing in the first stage grid network because of the cathode current flowing through the network, is impressed on the control grid of the first tube, causing a variation in the plate current of the first tube in accordance with the well-known action of the vacuum tube. This plate current flows through the resistance 34 and the voltage across 34, within the limits between which the tube has a linear characteristic, is a definite multiple of voltage impressed on the grid.

The current flowing through resistance 34 and from plate to cathode in the first tube 6 can return from the cathode through either of two paths; currents of the higher frequencies will flow in most part through condenser 36 which offers a low impedance to high frequencies; currents of the lower frequencies, however, tend to return through the grid return network, especially resistance 14. The lower frequency currents thus tend to set up an E. M. F. in the grid return circuit opposing the E. M. F. induced by the input and causing a degenerative action which is most pronounced at lower frequencies.

The output of the first tube 6 is transmitted to the second tube 16 by means of the condenser 38 which blocks direct current but impresses the alternating component of the voltage across resistance 34 on the control grid of the second tube. Resistance 40 furnishes a grid leak for the control grid of the second tube.

In accordance with the operation of the second vacuum tube 16 the plate current varies with the grid voltage to produce a varying current in output transformer primary 50 which should be a definite multiple of the input. There is, however, a degenerative effect in the second stage similar to that which occurs in the first stage, and the result of this degenerative effect is to produce a gain curve which tends to vary with frequency. This degenerative effect is compensated by the feed back.

In accordance with the well-known vacuum tube theory, each single stage of amplification shifts the phase 180°; consequently the output of the second tube is in phase with the input. A portion of the alternating component of the plate current of the second tube flows through the condenser 58 and resistance 60 to the cathode of the first tube. This current flows through resistance 10 in a direction tending to make the grid of the first tube more negative, hence tending to decrease the output of the first tube and consequently the output of the second tube. However, as the output of the second tube decreases, the feed back current also decreases. Hence it can be seen that the feed back current tends to stabilize the amplification at any given frequency.

The condenser 58 is selected with a rather small capacitance, about 0.25 mf., so that the feed back circuit offers relatively high impedance to low frequency currents when the inherent degenerative effect of the returning cathode current is greatest, and, as the frequency increases, the feed back path offers less and less impedance passing back more current to compensate for the fact that more cathode-plate current returns through condenser 36.

The resistance 60 is selected with a relatively high resistance, about 250,000 ohms, so that at higher frequencies, when the condenser 58 offers

very little impedance to the feed back current the resistance 60 limits the upper value of the feed back current so that its degenerative effect will not cause the gain curve to drop off at frequencies of 10,000 or thereabouts and above.

Having described my circuit and having mentioned the values that have been found suitable to produce a satisfactory result, I wish, however, it would be distinctly understood that I do not intend to limit myself thereby but only by the appended claims.

I claim:

1. A vacuum tube amplifier circuit comprising two stages of pentode vacuum tubes coupled in cascade with a feed back connection comprising a resistance and a capacitance connected in series between the plate of the second tube and the cathode of the first tube for the purpose of feeding back a portion of the output of the second tube to the first tube, networks comprising interconnected resistances and capacitances connecting the control grids with their corresponding cathodes, the network of the first tube being connected between the cathode of the first tube and the control grid of the first tube, and comprising a resistance one terminal of which is connected to the cathode and suppressor grid circuit of the said first tube, and the other terminal of said resistance connected to (a) one terminal of a condenser, the other terminal of which connects both to one terminal of the secondary winding of the input transformer and to one terminal of a second resistance, the other terminal of said second resistance being connected to a common ground, (b) one terminal of a path comprising a resistance and a capacitance in parallel, the other terminal of said parallel resistance and capacitance being connected to the common ground, (c) one terminal of a capacitance comprising one or more relatively large condensers in parallel, the other terminal of said condensers being connected to one terminal of the resistance forming the plate return circuit of the first tube.

2. A vacuum tube amplifier circuit comprising two stages of pentode vacuum tubes coupled in cascade with a feed back connection comprising a resistance and a capacitance connected in series between the plate of the second tube and the cathode of the first tube for the purpose of feeding back a portion of the output of the second tube to the first tube, networks comprising interconnected resistances and capacitances connecting the control grids with their corresponding cathodes, the network of the first tube being connected between the cathode of the first tube and the control grid of the first tube and comprising a resistance, one terminal of which is connected to the cathode and suppressor grid of the said first tube and the other terminal of said resistance connected (a) to the terminal of a condenser, the other terminal of which connects both to one terminal of the secondary winding of the input transformer and to one terminal of a second resistance, the other terminal of said second resistance being connected to a common ground, (b) one terminal of a path comprising a resistance and a capacitance in parallel, the other terminal of said parallel resistance and capacitance being connected to the common ground, (c) one terminal of a capacitance comprising one or more relatively large condensers in parallel, the other terminal of said condensers being connected to one terminal of the resistance forming the plate load of the first tube, the net-

work of the second tube being connected between the cathode of the second tube and the control grid of the second tube, said second network comprising a resistance and capacitance in parallel, one terminal of which is connected to the common ground and the other terminal of which is connected to (a) the cathode and suppressor grid of the first tube, (b) one terminal of a condenser, the other terminal of said condenser being connected to the screen grid of the second tube, (c) the terminal of another condenser, the other terminal of which is connected both to a path including a resistance to the control grid of the second tube and to a path to the common ground including another resistance.

3. A vacuum tube amplifier circuit comprising two stages of pentode vacuum tubes coupled in cascade with a feed-back connection comprising a resistance and a capacitance connected in series between the plate of the second tube and the cathode of the first tube for the purpose of feeding back a portion of the output of the second tube to the first tube, networks comprising interconnected resistances and capacitances connecting the control grids with their corresponding cathodes, the network of the second tube being connected between the cathode of the second tube and the control grid of the second tube, said network comprising a resistance and a capacitance in parallel, one terminal of which is connected to the common ground and the other terminal of which is connected to (a) the cathode and suppressor grid of the second tube, (b) one terminal of a condenser, the other terminal of said condenser being connected to the screen grid and plate return circuit of the second tube, (c) one terminal of another condenser, the other terminal of which is connected both to a path including a resistance to the control grid of the second tube and to a path to the common ground including another resistance.

4. A vacuum tube amplifier circuit comprising two stages of pentode vacuum tubes coupled in cascade with a feed back connection comprising a resistance and a capacitance connected in series between the plate of the second tube and the cathode of the first tube for the purpose of feeding back a portion of the output of the second tube to the first tube, networks comprising interconnected resistances and capacitances connecting the control grids with their corresponding cathodes, said networks providing a negative grid voltage on their respective control grids, said negative grid voltage being of sufficient magnitude and so varying with signal frequency as to hold the gain of the amplifier circuit substantially constant, one of said networks comprising a network connected between the cathode of the second tube and the control grid of the second tube, said network comprising a resistance and capacitance in parallel, one terminal of which is connected to the common ground and the other terminal of which is connected to (a) the cathode and suppressor grid of the second tube, (b) one terminal of a condenser, the other terminal of said condenser being connected to the screen grid and plate return circuit of the second tube, (c) one terminal of another condenser, the other terminal of which is connected both to a path including a resistance to the control grid of the second tube and to a path to the common ground including another resistance.

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