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AMPLIFIER CIRCUIT

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Fig. 1.

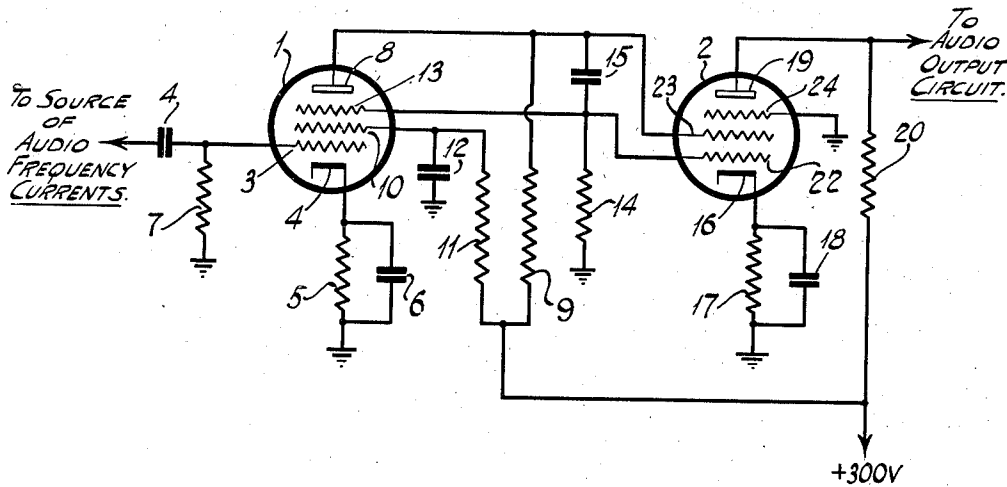
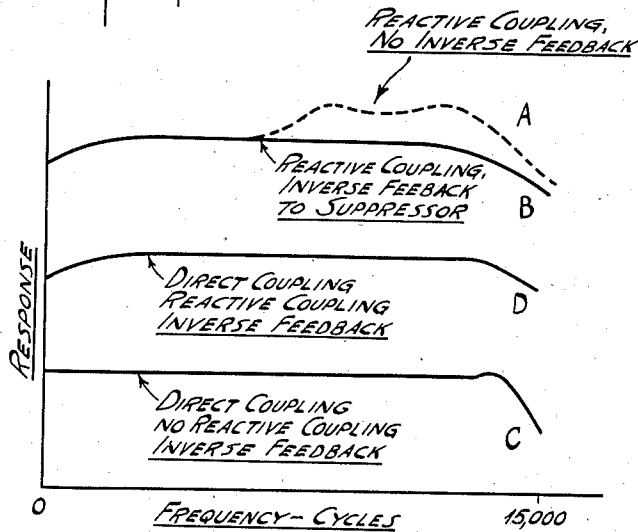


Fig. 2.



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AMPLIFIER CIRCUIT

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My present invention relates to audio frequency amplifier circuits, and more particularly to a novel and improved type of direct coupled amplifier circuit utilizing degenerative feedback.

One of the main objects of my present invention is to provide a method of degenerative feedback in an audio frequency amplifier, wherein there is utilized a minimum of circuit elements and there is secured faithful amplification of audio frequency voltages.

Another important object of this invention is to provide an audio frequency amplifier which has at least two direct coupled stages, and the amplifier having superior amplitude versus frequency and phase versus frequency characteristics.

Another important object of my invention is to improve the low frequency response of an audio frequency amplifier by employing a novel method of direct coupling between at least two stages of the amplifier, and additionally providing an improvement of response at all frequencies, especially the higher audio frequencies, by a novel method of applying degenerative feedback in the first of the coupled stages.

A more specific object of my invention is to provide an amplifier which comprises at least two cascaded stages employing direct coupling, there being utilized both the control and screen grids of the tube of the second stage as control elements; and a suppressor element of the tube of the first stage being employed as the electrode to which degenerative audio frequency voltage is applied.

Still other objects of my invention are to improve generally the response of audio frequency amplifiers, and more especially to provide a two stage audio frequency amplifier which is not only capable of providing faithful amplification but is economically constructed and assembled.

The novel features which I believe to be characteristic of my invention are set forth with 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 a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a circuit diagram of an amplifier embodying the invention.

Fig. 2 illustrates certain response characteristics of the amplifier circuit.

Referring now to Fig. 1, there are shown at

least two stages of amplification employing separate electron discharge devices 1 and 2. These devices are, more specifically, tubes of the pentode type. While not limited to the specific tube types, the circuit may employ 6SJ7 tubes. The source of alternating current input voltage is not shown, since it may be any desired source whose alternating voltage is to be amplified. For example, it may be audio frequency wave energy applied to the input grid 3 of tube 1 through the audio frequency coupling condenser 4 from the detector output load impedance of a radio receiver, the electrical pickup of a phonograph, a public address microphone, or the like. In general, modulation voltage in any form of radio receiver or transmitting equipment may be amplified in a highly satisfactory manner by the circuit of my invention.

The tube 1 has its cathode 4 connected to ground through the usual grid biasing resistor 5 shunted by the audio frequency bypass condenser 6. The resistor 7 returns grid 3 to the grounded end of biasing resistor 5. The plate or anode 8 is connected to a point of positive potential, for example about +300 volts, through output load resistor 9. The screen electrode or grid 10 is connected to the +300 volt point through voltage reduction resistor 11. The condenser 12 bypasses all alternating voltage components from the screen lead. The suppressor electrode 13 is connected to ground through the resistor 14. Condenser 15, functioning as a voltage feedback element, couples anode 8 to suppressor electrode 13.

The following tube 2 similarly has a biasing resistor 17 in its cathode circuit, the audio bypass condenser 18 shunting the resistor. The plate 19 is connected to the plate potential source through the output load resistor 20, and the amplified voltage developed thereacross may then be transmitted to a following audio output circuit (not shown). The control grid 22 is connected directly to the junction of condenser 15 and resistor 14. The latter acts as voltage return path for grid 22. The amplified audio voltage across resistor 9 is applied through condenser 15 to grid 22. The screen electrode 23 is directly coupled to the plate end of resistor 9. Hence, the plate 8 and screen 23 are at a common positive direct current potential. Suppressor grid 24 is connected to ground. It will be seen that both the control and screen grids 22 and 23 respectively function as input electrodes for the tube 2.

In general, improvement of the low audio frequency response is accomplished by using the nor-

mal precautions necessary with conventional methods of coupling, in addition to the novel method of direct coupling between stages. Improvement of response at all frequencies, especially the higher audio frequencies, is secured by applying degenerative feedback in the first stage. Considering the method of direct coupling between anode 8 and screen 23, the resistor 9 is chosen to give a voltage drop so that both the anode 8 and screen 23 are within the proper voltage operating limits.

Three effects result from the present method of feeding the plate of the first stage and the screen of the second through a common impedance. First, direct coupling between stages is secured, since variations in the plate current of tube 1 cause variations in the screen voltage of tube 2 whereby the plate current of tube 2 is caused to vary. In this connection it can be shown that these variations in the plate current of tube 2 are in phase with the variations caused by the amplified voltage fed to the grid 22 through the coupling condenser 15. Secondly, the direct coupling causes tube 1 to be degenerative, since an increase in the plate current of tube 1 causes a decrease in the voltage of screen grid 23. Due to the drop in voltage of screen 23 the screen current decreases thereby tending to cancel the rise of current through resistor 9 caused by the plate current of tube 1. This degenerative action is also present when the plate current of tube 1 is decreasing. Thirdly, the direct coupling causes tube 2 to be degenerative for two reasons. Since the screen voltage for screen grid 23 is supplied through an impedance 9 and is not bypassed to cathode, screen degeneration occurs due to fluctuation in screen voltage. Further, when the current through resistor 9 is increasing due to an increase in the plate current of tube 1 the grid 22 is driven in a negative direction. The screen current of tube 2 will, therefore, decrease thus partially nullifying the effect of the increase of current through resistor 9 caused by an increase in plate current of tube 1. This action is entirely separate from the action described above. This degenerative action in conjunction with the direct coupling between plate and screen greatly reduces amplitude, frequency and phase distortion.

It will further be noted that the present circuit applies inverse voltage feedback from plate 8 to suppressor grid 13 by virtue of condenser 15. Two important advantages are secured because of this feature of my invention. In the first place, it minimizes the number of circuit elements required. Normally if inverse feedback is supplied to the control grid, at least one or two extra resistors are required and in some cases an extra condenser. However, by the present arrangement the coupling condenser 15 and grid resistor 14 of the stage 2 are used, and no extra elements are required. A second advantage resides in the fact that the output capacitance of tube 1 is reduced thereby improving high audio frequency response of that stage. This follows from the fact that the plate to suppressor capacity is usually the greater of the capacities due to the proximity of the plate and suppressor. When the suppressor is connected to the grid 22 of the following tube the output capacitance is considerably reduced.

In Fig. 2 I have graphically shown the advantages secured by the present invention. The curve A shows the normal response of a two stage amplifier employing reactive coupling and no inverse feedback. Curve B shows the amplifier re-

sponse when degenerative feedback to the suppressor grid of the first tube is employed. The effect of using both direct coupling and degenerative coupling is pictured by curve C. The overall response of the amplifier of Fig. 1, when using both direct and reactive coupling and inverse feedback, is depicted by curve D. These curves are purely pictorial, and are intended to represent only ideal conditions. By employing both direct and reactive coupling, in accordance with my invention, a compromise is reached which gives better low audio frequency response, less phase distortion and still a reasonable amount of gain without the use of very high voltage power supplies.

To summarize the operation of the present amplifier circuit there is first considered the inverse feedback action to the suppressor grid. As the signals are applied to grid 3 in a sense to increase the flow of current through the plate circuit of tube 1, the voltage at plate 8 decreases. That is, the plate end of resistor 9 becomes less positive. This drives the suppressor grid 13 in a negative direction due to the coupling action of condenser 15. As a result, the plate current is caused to decrease thereby causing degeneration. Should the applied signals cause the plate current to decrease, the effect will be to cause the suppressor grid to be less negative than its normal bias. Consequently the plate current decrease is less than it would otherwise be. While the normal negative bias on the suppressor causes a slight reduction in stage gain, the response is improved.

The signals causing an increase in plate current of tube 1 are additionally degenerated by the direct coupling from the plate 8 to screen 23. As the plate current of tube 1 increases it causes the plate voltage to decrease. The screen 23 being tied directly to plate 8 becomes less positive, and causes a decrease in plate current of tube 2. If the signals cause the plate current of tube 1 to decrease, then the plate current of tube 2 is caused to increase. The action of control grid 22 is cophasal with the action of screen grid 23. At the instant when the plate 8 of tube 1 has its potential shifted in a positive polarity sense, the screen grid 23 and control grid 22 of tube 2 have their respective potentials increase in a positive sense whereby they both cause an increase in plate current of tube 2. Should the plate voltage of tube 1 decrease, then the potential of control grid 22 and that of screen grid 23 move in a negative direction thereby causing the plate current of tube 2 to decrease.

As a specific illustration of constants that may be used in the circuit of Fig. 1 there are given the following magnitudes:

$R_{14}=R_7=2$ megohms
 $R_{11}=0.1$ megohm
 $R_{20}=R_8=680,000$ ohms
 $C_{15}=1800$ micro microfarads
 $C_{12}=2$ microfarads

While I have indicated and described a circuit 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 circuit organization shown and described, but that many modifications may be made without departing from the scope of my invention.

What I claim is:

1. In an amplifier circuit, at least two electron discharge tubes, each tube being provided with at least a cathode, a control grid and an

output electrode, means directly connecting the output electrode of one of said tubes to an auxiliary cold electrode located in the second tube between its control grid and its output electrode, reactive means coupling the output electrode of the first tube to the control grid of the second tube, means establishing the output electrode of the first tube and said auxiliary electrode at a common positive voltage, means for applying a voltage to be amplified to the control grid of the first tube, and means for deriving from the output electrode of the second tube said voltage in amplified form.

2. In an amplifier circuit, at least two electron discharge tubes, each tube being provided with at least a cathode, a control grid and an output electrode, means directly connecting the output electrode of one of said tubes to an auxiliary cold electrode located in the second tube, reactive means coupling the output electrode of the first tube to the control grid of the second tube, means establishing the output electrode of the first tube and said auxiliary electrode at a common positive voltage, means for applying a signal voltage to be amplified to the control grid of the first tube, means for deriving from the output electrode of the second tube said signal voltage in amplified form, an auxiliary cold electrode located in the first tube between the control grid and output electrode, means for establishing the last named cold electrode at a normal negative potential, and means for reactively coupling the output electrode of the first tube and said negative cold electrode.

3. In an amplifier circuit, at least two electron discharge tubes, each tube being provided with at least a cathode, a control grid and an output electrode, means directly connecting the output electrode of one of said tubes to an auxiliary cold electrode located in the second tube between its control grid and its output electrode, reactive means coupling the output electrode of the first tube to the control grid of the second tube, means establishing the output electrode of the first tube and said auxiliary electrode at a common positive voltage, means for applying a voltage to be amplified to the control grid of the first tube, means for deriving from the output electrode of the second tube said voltage in amplified form, said first tube including a suppressor grid adjacent its output electrode, and means coupling the output electrode and suppressor grid of the first tube.

4. In an amplifier system of the type employing at least two electron discharge tubes in cascade, and each tube including at least one control element in addition to the usual input and

output electrodes; the improvement which includes means for impressing a signal voltage upon the input electrodes of the first tube, means for inversely feeding back amplified signal voltage from the output electrode of the first tube to its additional control element, means for directly coupling the output electrode of the first tube to the control element of the second tube, means for reactively coupling the input electrode of the second tube to the first tube output electrode, and means for deriving amplified signal voltage from the second tube.

5. In combination in an audio amplifier circuit, at least two tubes arranged in cascade, the first tube including a suppressor grid, the second tube including a screen grid, means for establishing the output electrode of the first tube and the screen grid of the second tube at a common positive direct current voltage, means providing inverse voltage feedback from the output electrode of the first tube to its suppressor grid, said means additionally coupling the first tube output electrode to the input electrode of the second tube, means for applying an audio frequency voltage to the input electrode of the first tube, and means for deriving an amplified audio signal voltage from the output electrode of the second tube.

6. In combination in an audio frequency amplifier circuit, at least two pentode tubes arranged in cascade, means for establishing the output electrode of the first tube and the screen grid of the second tube at a common positive direct current voltage, capacity means providing inverse audio voltage feedback from the output electrode of the first tube to its suppressor grid, said last means additionally coupling the first tube output electrode to the input electrode of the second tube, means for applying an audio frequency voltage to the input electrode of the first tube, and means for deriving an amplified audio voltage from the output electrode of the second tube.

7. A system for amplifying an alternating voltage comprising a pair of cascaded amplifiers each having input and output electrodes, means for applying said voltage to the first amplifier input electrodes for a first amplification of said voltage, means for applying the amplified voltage output of said first amplifier to the input electrodes of the second amplifier for a second amplification, said second amplifier including an auxiliary electrode, means for applying said amplified voltage output of said first amplifier to the auxiliary electrode of said second amplifier over a path auxiliary to the first path, and means providing a degenerative voltage feedback during said first amplification.

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