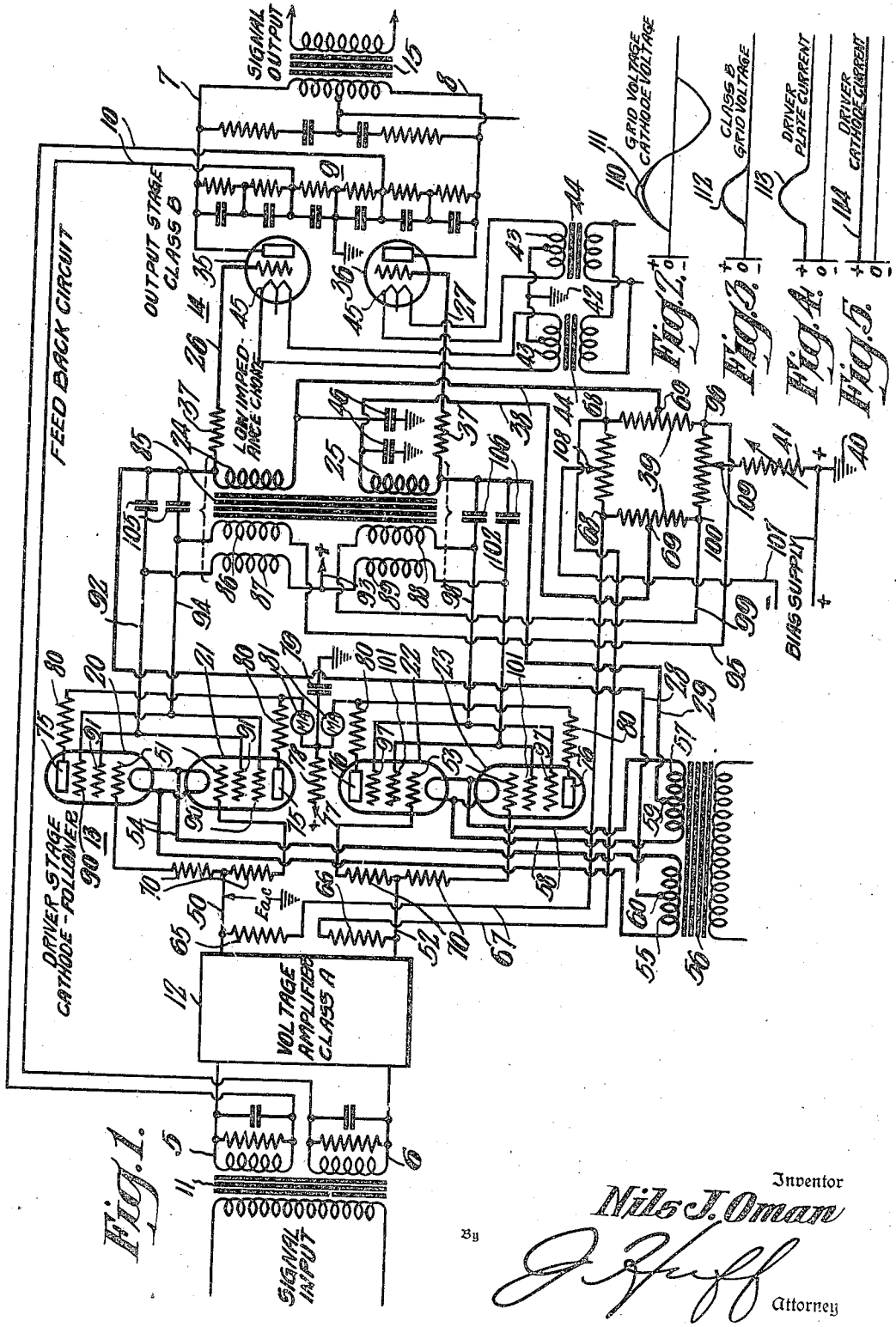
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AUDIO FREQUENCY AMPLIFIER

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AUDIO FREQUENCY AMPLIFIER

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This invention relates to audio frequency amplifiers, and has for its primary object, to provide an improved high efficiency amplifier of the character referred to, providing overall inverse feedback with minimum phase shift, in a wide frequency range.

More particularly, this invention relates to an inverse feedback amplifier having a class B output stage, in which the grids of the amplifier tubes are driven into the positive range, and has for its further object to provide an improved driver amplifier for the class B output stage which provides low distortion and high efficiency in operation, together with low initial and operating cost.

An amplifier embodying the invention may be used as a low cost, high efficiency modulation amplifier for a high power transmitter, and such an amplifier is illustrated in the drawing, wherein

Figure 1 is a schematic circuit diagram, and Figures 2–5, inclusive, are graphs showing curves illustrating certain operating characteristics of the amplifier of Fig. 1.

Referring to the drawing, 5—6 are the two halves of a balanced input circuit for an audio frequency amplifier of the balanced or pushpull type and 7—8 are the corresponding portions of the output circuit of the amplifier which includes a voltage dividing network 9 in connection with a feedback circuit 10 extending therefrom to the input circuit 5—6. This circuit provides for a predetermined degree of overall inverse feedback between the output and input circuits of the amplifier.

An audio frequency or modulating signals applied to the input circuit 5—6 through a suitable coupling transformer 11 are amplified in a voltage amplifier 12, a driver amplifier 13, and an output amplifier 14, connected in cascade between the input circuit and the output circuit. The output circuit 7—8 is coupled to any suitable utilization means through a coupling transformer 15. The amplifier arrangement shown is particularly adapted for use as a modulator amplifier in a high power transmitter.

In providing for overall inverse feedback in a multi-stage amplifier, the problem of controlling phase shift and gain over a wide frequency band must be considered, to obtain stability with the high degree of feedback required to reduce noise and distortion. Furthermore, in the operation of a class B power output stage 14, the problem of supplying power to the grid circuit thereof must be met also without introducing undue phase shift and distortion.

In the operation of a transmitter over a long period of time often involving full time operation, the current consumption and tube cost must be maintained at a minimum. Therefore, a high degree of gain in the driver stage as well as an arrangement for supplying power to the output stage is necessary.

In accordance with the invention, pentode amplifier tubes 20, 21, 22 and 23 are used in the driver stage 13, preferably in parallel pushpull as shown, and coupled to the output stage 14 through output coupling choke coil windings 24 and 25, located in the grid circuits 26 and 27 of the output stage and in the cathode circuits 28 and 29 of the driver stage. The driver stage is of the cathode-follower type, and by this means is directly coupled to the output stage, for maximum efficiency in the transfer of energy to the output stage as will be seen hereinafter.

The output amplifier tubes 35 and 36 are connected in balanced relation with the output circuit 7—8 and with the input circuit 26—27, the latter comprising the coupling choke coils 24 and 25. Each of the output grid circuits includes a series current limiting resistor 37, and is connected through bias supply leads 38 with a bias potential supply network or bridge circuit 39 having a ground connection 40 through a resistor 41. The grid circuit and plate circuit of the output stage is returned to the cathodes through the ground connection 42 and the secondaries 43 of the filament supply transformers 44 which are connected with the cathodes or filaments 45. The network 39 is suitably bypassed for audio frequencies by bypass capacitors 46 in connection with the bias supply leads 38.

The driver stage 13 is arranged with the tubes 20 and 21 connected in parallel in one side of the pushpull circuit while the tubes 22 and 23 are similarly connected in the opposite side of the pushpull circuit. Thus one side 50 of the input circuit from the amplifier 12 is connected to the signal input grids 51 of the tubes 20 and 21 while the opposite side of the circuit 52 is connected with the input grids 53 of the tubes 22 and 23.

The cathodes of the tubes 20 and 21 are connected through common cathode supply leads 54 with one filament supply secondary 55 of a transformer 56 which supplies alternating current to the filaments of the tubes. A similar secondary 57 on the transformer 56 is connected through supply leads 58 with the filaments of the

tubes 22 and 23. The cathode leads 26 and 29 are connected, respectively with centered taps 59 and 60 on the transformer secondaries 57 and 55 so that a circuit may be traced from the filaments of the tubes 20 and 21 through the leads 54 and the filament heater winding 55 to the center tap 60 and the lead 28, thence through the choke coil 24 and one of the leads 38, through one-half of the network 39 and the common resistor 41 to ground 40.

The grid circuits of the tubes of the driver amplifier 13 are returned to the bias supply network 39 through grid resistors 65 and 66 and supply leads 67 at suitable negative terminals 68 on the network 39, these terminals being more negative than the cathode connection points indicated at 69. It will also be noted that suitable suppressor resistors 70 are included in the grid circuits of the driver or cathode follower stage 13.

The plate circuits of the driver stage 13 are held free of signal voltages, and for this reason the anodes 75 of the parallel connected tubes 20 and 21 and the anodes 76 of the parallel connected tubes 22 and 23 are connected directly with a positive anode supply lead 77 through filters each comprising a series resistor 78 and bypass capacitor 79. Oscillation suppressor resistors 80 are also included in the individual plate connections as indicated. Also, in a transmitter modulator amplifier, suitable milliammeters for reading the anode current are included in each branch of the plate circuit as indicated at 81.

Each of the coupling choke coils 24 and 25 is provided with an iron core which may be a core common to both coils as indicated at 85. Associated also with each choke coil are a pair of windings coupled thereto, the windings associated with the choke coil 24 being indicated at 86 and 87 while those associated with the choke coil 25 are indicated at 88 and 89. These coils are provided with the same number of turns as the choke coils and are connected with the screen and suppressor grids of the driver amplifier stage to cause the suppressor and screen grids to vary in response to signals in the same manner as the cathodes thereby permitting full pentode operation of the driver tubes.

In the present example, the choke coil 24 is in the cathode circuit of the tubes 20 and 21 and the winding 86 associated therewith, is connected in circuit with the parallel connected suppressor grids 90, while the winding 87 is connected in circuit with the parallel connected screen grids 91 of these tubes. The screen grid circuit 92 through the winding 87 is connected with a positive supply lead 93, while the suppressor grid connection 94 is completed through a lead 95 and a negative terminal 96 on the bias supply network 39.

In a similar manner, the suppressor grids 97 of the tubes 22 and 23 are connected through a lead 98 and the choke coil winding 88 with a bias supply lead 99 and a corresponding terminal 100 on the network 39.

The screen grids 101 are connected in parallel with a screen grid lead 102, which is, in turn, connected through the winding 89 to the supply lead 93. With this arrangement one winding, that is, the main winding of the choke coil or cathode coupling impedance, on each side of the balanced circuit, supplies bias and signal to the output tubes 35 and 36. A second winding supplies D. C. screen current and the A. C. component of the signal to the screens, while the third winding supplies the D. C. suppressor grid current and the A. C. component of the signal to the suppressor grids.

As each winding of the choke coil has the same number of turns, full pentode driver operation is permitted in conjunction with a cathode follower coupling circuit by utilizing the auxiliary windings on the cathode chokes to introduce voltages into the suppressor and screen grid leads of the cathode follower tubes, thereby to obtain fixed potentials between the cathode and the suppressor and screen grids.

In order to eliminate undesirable effects of leakage reactance between the windings of the choke coils, coupling capacitors 105 and 106 are connected between points of equal A. C. or signal potential on the choke coils, in this case between the grid ends of the windings.

The application of the cathode follower principle is useful where the overall feedback, in an amplifier of the character shown, is relatively heavy and is used to reduce distortion and noise and at the same time to supply sufficient energy to the output stage to operate it as a class B amplifier, driven into the region of heavy grid current.

With a system of the character shown, the bias supply means for the class B amplifier stage may be a resistor network 39, to which bleeder current is supplied from any suitable source through the supply leads indicated at 107. This bias supply may also have relatively poor regulation because the grid current on the positive peaks is supplied from the plate circuit of the driver stage, which is maintained free of signal voltage, in accordance with the present invention. Considering one-half of the balanced driver and output stage, a sine wave of signal voltage *Eac*, for example, may be impressed on the input grids 51 of the tubes 20 and 21 from the voltage amplifier 12 through the circuit 50, as indicated, and also as indicated by the curve 110 in Fig. 2. The signal or A. C. voltage on the cathodes of the tubes 20 and 21 at the cathode end of the choke coil 24 and hence on the input grid circuit 26 of the power output tube 35, is indicated by the curve 111 of Fig. 2. This voltage is the resultant of the *Eac* on the grids of the tubes 20 and 21 and the grid current of the tube 35. If the class B tube 35 did not draw any grid current these two curves of voltage would be substantially alike.

It is evident that over a portion of the positive half cycle of the input signal, the voltage on the cathodes of the tubes 20 and 21 do not exactly follow the voltage on the grids. This distortion occurs when the tube 35 draws grid current which is indicated by the curve 112 of Fig. 2 in proper phase relation to the curves of Fig. 2.

The curve 113 of Fig. 4 indicates a plate current pulse from the plate circuit of the tubes 20 and 21 added to the normal D. C. plate current and corresponding to the grid current of the tube 35. The departure between the grid and cathode voltages of the tubes 20 and 21 will be such as is required to cause the plate current of these tubes to duplicate the grid current of the class B output tube 35. As there is a relatively high alternating current impedance represented by the output tube grid circuits in shunt with the low impedance choke coil 24 in the cathode circuit of the tubes 20 and 21, the cathode current will remain substantially constant at the zero signal value over the entire cycle of operation, as indicated by the curve 114 of Fig. 5. Thus the grid current for the power output

stage is supplied entirely from the plate circuit of the driver stage, which is free from signal voltage. The driver tubes may be of low power rating, of small size and low cost because of efficient class B operation of these tubes. Also as there is no loading resistor means required for the class B grid circuits to obtain low distortion, the maximum utilization of the driver power with a high degree of efficiency is attained. Furthermore, no driver coupling transformer is required. The latter is ordinarily of relatively large size and high cost as is well known, whereas in the present system a small low cost choke coil is used which carries only the zero signal plate current of the relatively low power driver tubes.

The input or grid impedance of the cathode follower tubes in the driver stage is high because the cathode and screen A. C. or signal potentials are substantially the same as the A. C. or signal grid potentials. Hence, these tubes are not driven positive and the preceding amplifier 12 may operate as indicated as a simple class A amplifier with a relatively high gain and output impedance without reducing the high frequency response.

It will also be noted that the impedance from the cathodes of the driver stage to ground will be low because of the degenerative effect of the cathode follower connection. Hence stray circuit and tube capacities across this low impedance have little effect on the frequency response of the amplifier except at extremely high frequencies.

It will be noted that the contacts 108 and 109 on the bias supply network may be moved in opposite directions to vary the balance in the biasing of the various grid electrodes and likewise the resistance in the network at 61 may be varied to move all of the grids in the same direction.

I claim as my invention:

1. In an audio frequency inverse feedback amplifier, the combination of a class B output stage, means for driving said output stage to grid current including a cathode follower driver stage coupled thereto and including pentode amplifier tubes having cathode, screen grid, and suppressor grid electrodes, an overall audio frequency inverse feedback circuit for said amplifier including said driver stage thereby to minimize phase shift in the feedback loop of the amplifier, and means in said driver stage for applying substantially equal signal voltages to the cathodes, screen and suppressor grid electrodes for full pentode operation of said stage.

2. In an audio frequency inverse feedback amplifier, the combination of a class B output stage, a cathode follower driver stage therefor comprising a pair of pentode amplifier tubes having a balanced output circuit, a cathode circuit choke coil in each half of said output circuit providing an input coupling impedance for said class B output stage for driving said output stage to grid current, auxiliary windings on each of said choke coils connected with suppressor and screen circuits for said pentode amplifier tubes to apply signal voltage thereto, a voltage amplifier coupled to said driver stage having an audio frequency signal input circuit, and means providing an overall audio frequency inverse feedback circuit between the output circuit of said first named amplifier stage and input circuit of said voltage amplifier stage thereby to include said cathode follower driver stage in the inverse feedback loop of the amplifier.

3. In an audio frequency inverse feedback amplifier, means for effecting a maximum degree of stabilized inverse feedback within the frequency range of the amplifier comprising, in combination, a class B audio frequency amplifier stage, an overall audio frequency inverse feedback circuit for said amplifier, and a cathode follower driver stage coupled to said class B output stage in the feedback loop of the amplifier, comprising a pentode tube having an input grid, a suppressor grid, a screen grid, an anode and a cathode, a low impedance choke coil in circuit with the cathode, a signal input connection for the class B stage on said choke coil, an auxiliary winding on said choke coil in circuit with the suppressor grid, a second auxiliary winding on said choke coil in circuit with the screen grid, said windings having substantially the same number of turns as the choke coil for applying substantially equal signal voltages to said grids and the cathode.

4. In an audio frequency inverse feedback amplifier, means for effecting a maximum degree of stabilized inverse feedback within the frequency range of the amplifier comprising, in combination, a class B audio frequency amplifier stage, an overall audio frequency inverse feedback circuit for said amplifier, and a cathode follower driver stage coupled to said class B output stage in the feedback loop of the amplifier, comprising a pentode tube having an input grid, a suppressor grid, a screen grid, an anode and a cathode, a low impedance choke coil in circuit with the cathode, a signal input connection for the class B stage on said choke coil, an auxiliary winding on said choke coil in circuit with the suppressor grid, a second auxiliary winding on said choke coil in circuit with the screen grid, said windings having substantially the same number of turns as the choke coil for applying substantially equal signal voltages to said grids and the cathode, and capacity means coupling substantially equal voltage points on said choke coil and windings.

5. In an audio frequency inverse feedback amplifier, means for effecting a maximum degree of stabilized inverse feedback within the frequency range of the amplifier comprising, in combination, a class B audio frequency amplifier stage, an overall audio frequency inverse feedback circuit for said amplifier, and a cathode follower driver stage coupled to said class B output stage in the feedback loop of the amplifier, comprising a pentode tube having an input grid, a suppressor grid, a screen grid, an anode and a cathode, a low impedance choke coil in circuit with the cathode, a signal input connection for the class B stage on said choke coil, an auxiliary winding on said choke coil in circuit with the suppressor grid, a second auxiliary winding on said choke coil in circuit with the screen grid, said windings having substantially the same number of turns as the choke coil for applying substantially equal signal voltages to said grids and the cathode, and means for maintaining said anode free of signal voltages and for supplying grid current pulses to the class B stage therefrom.

6. An inverse feedback amplifier having a class B output stage comprising amplifier tubes driven into the positive grid range of operation, an overall inverse feedback connection between the input and output ends of said amplifier, and a pentode driver stage for said class B output stage having a cathode follower coupling therewith comprising two low impedance cathode choke coils and windings thereon for applying signal

voltages to the screen and grid electrodes of the pentode driver stage.

7. An inverse feedback amplifier having a class B output stage comprising amplifier tubes driven into the positive grid range of operation, an overall inverse feedback connection between the input and output ends of said amplifier, and a pentode driver stage for said class B output stage having a cathode follower coupling therewith comprising two low impedance cathode choke coils and windings thereon for applying signal voltages to the screen and grid electrodes of the pentode driver stage, and controlling bias supply network in circuit with said windings and choke coils for supplying biasing potentials to said output and driver stage in predetermined relation.

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