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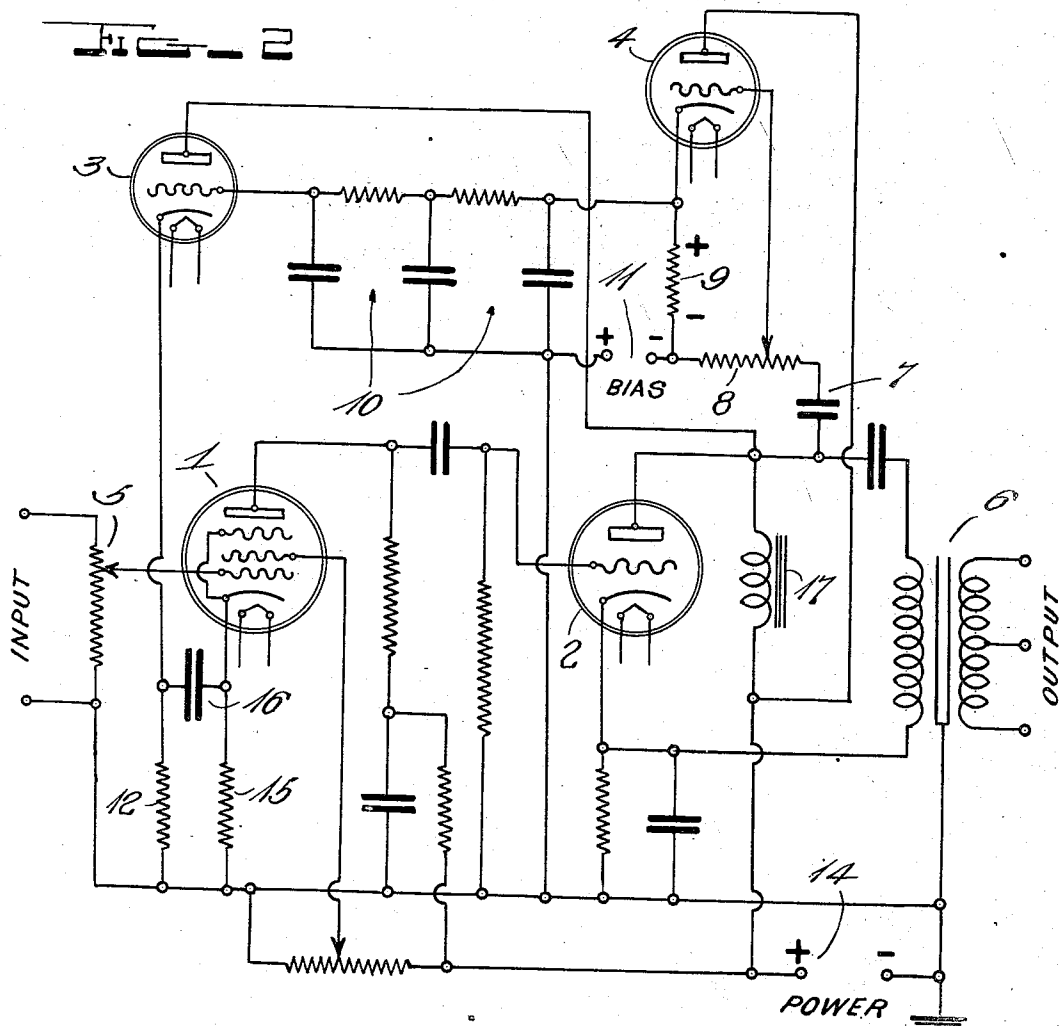
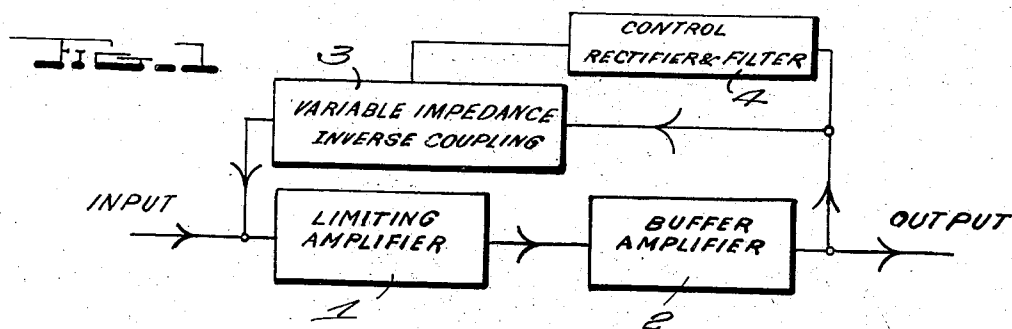
C. C. VAN COTT

2,283,241

LIMITING AMPLIFIER

Filed Feb. 14, 1940

2 Sheets-Sheet 1



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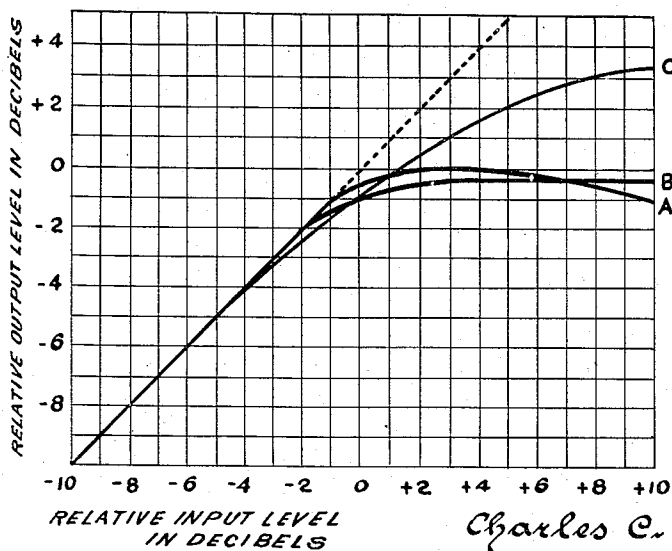
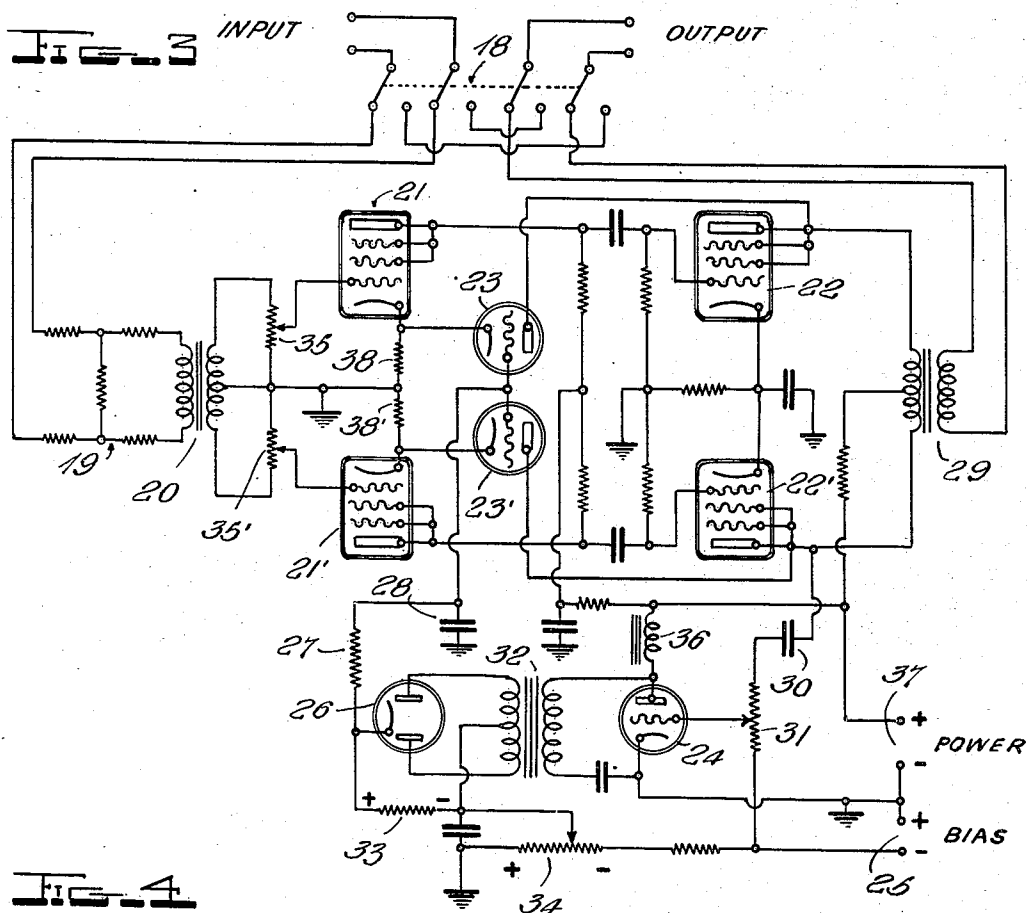
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2 Sheets-Sheet 2



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LIMITING AMPLIFIER

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6 Claims. (Cl. 179-171)

My invention relates broadly to gain control systems for electron tube amplifiers, and more particularly to a limiting amplifier employing varying impedance electron tubes and inverse feedback for automatic operation.

One of the objects of my invention is to provide an improved limiting amplifier of low distortion characteristics and substantially uniform response over the audio frequency range with standard component elements.

Another object of my invention is to provide a circuit arrangement for inverse feedback wherein the impedance of an electron tube or tubes is varied by control of grid potential in limiting the output of an audio frequency amplifier under input voltage peaks.

A further object of my invention is to provide a circuit arrangement for remote or automatic gain control in a limiting amplifier through inverse feedback.

Still another object of my invention is to provide a limiting amplifier wherein inverse feedback is effected through the impedance of an electron tube circuit arranged for compressing the output voltage wave on the occurrence of voltage peaks in the input.

A still further object of my invention is to provide a circuit arrangement for a limiting amplifier employing inverse feedback from the output of the amplifier through the impedance of an auxiliary electron tube circuit.

Other and further objects of my invention reside in the circuit arrangements hereinafter described, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram indicating the general arrangement of the portions of the system of my invention; Fig. 2 is a schematic diagram of one embodiment of my invention; Fig. 3 is a schematic diagram of a modified form of my invention for a push-pull amplifier circuit; and Fig. 4 is a graph showing performance characteristics of the system of my invention shown in Fig. 3.

The system of my invention affords a simplified arrangement for the control of inverse feedback in an electron tube amplifier for limiting the output voltage upon the occurrence of voltage peaks in the input. Within the normal range of operation, for input voltages below a predetermined level, the amplifier functions substantially without compression, but the limiting elements of the circuit of my invention function efficiently and effectively when the predetermined level is exceeded, to control the output voltage with a minimum of distortion and circuit readjustments so that an output wave of desired fidelity and regularity is delivered. Losses are minimized, and the assembly may be constructed compactly and light in weight for various useful adaptations, such as in aircraft and portable units.

In Fig. 1, the limiting amplifier is shown to

comprise a controlled amplifier stage 1, and a buffer amplifier stage 2 connected between the input and output lines. An inverse feedback coupling stage at 3 operates under the influence of a control at 4, supplied with a portion of the output energy, to supply feedback energy to the controlled stage 1 inversely as the output voltage varies above a predetermined level. Suitable delay provisions are made in a portion of the control circuit for proper regulation.

Referring specifically to the form of my invention shown in Fig. 2, the controlled amplifier at 1 is shown with a potentiometer 5 in the input circuit and resistance coupling of the output circuit to the buffer amplifier 2 in conventional manner, the output of amplifier 2 being delivered through transformer 6. A portion of the output voltage of amplifier 2 is applied through condenser 7 and potentiometer 8 to the grid of a self-biased rectifier 4, and the resulting unidirectional control current in the anode circuit of the tube 4 flows through resistor 9 connected with the cathode thereof. Coupling tube 3 has a grid circuit which includes a filter 10 connected with the resistor 9, a source of bias potential 11 and a resistor 12 which is a load resistor in the anode circuit of the tube 3. The bias source 11 is in circuit also with the cathode and grid of rectifier 4 and thus affects both electrodes equally; the source 11 is of the same relative polarity as the anode source of power 14 in respect to the rectifier 4.

Coupling tube 3 is constituted as a variable high impedance device connected between the output circuit of tube 2 and resistor 12. The bias potential for tube 3, from source 11, is such that current is blocked up to the point at which limiting is to begin, at which point the potential drop across resistor 9 is sufficient to apply a net potential to the grid of tube 3, through filter 10, to produce current in tube 3 and in resistor 12 which results in a voltage thereacross. Resistor 12 is connected with the control grid of amplifier 1, in shunt with the cathode bias resistor 15 through condenser 16, so that a feedback voltage opposite in polarity to the input signal voltage is applied to the control grid to limit the output voltage. The compression resulting from this operation is adequate to produce the desired output voltage, but the non-linearity, thus introduced does not materially distort the output wave. The condenser 16 and resistor 12 may be omitted if desired and the cathode connection from tube 3 made directly to the cathode terminus of resistor 15, with the same results. The filter 10 is designed with the desired delay characteristic for preventing undue fluctuation in the control effect.

As above noted, the point at which limiting will begin may be regulated by the bias potential on the grid of tube 3, obtained from the source 11. The amount of compression afforded is determined by the position of the tap connection to

the grid of tube 4 on the potentiometer 8. And the input potentiometer 5 controls the signal voltage applied to the limiting amplifier 1. The resistances and capacitances in the remainder of the circuit are conventional elements and of such character that an assembly embodying the limiting amplifier of my invention may be constructed compactly and light in weight. An audio frequency choke 17 is provided in the anode power supply connection to the buffer amplifier 2 and coupling tube 3, beyond the connection of rectifier 4 to the power supply 14.

The modified form of my invention illustrated in Fig. 3 employs a double rectification stage in order that a filter having a smaller time constant may be employed for more alert limiting action in the limiting amplifier. Double rectification results in a large proportion of direct current at the cathode of the control rectifier with only higher frequency distortion components to be filtered out, which components may be blocked by a smaller resistance-capacitance filter, causing the amplification to drop very fast on sudden large signals.

In Fig. 3, a limiter cut-out switch 18 permits the input line to be directly connected with the output, but in the position shown switch 18 connects the input through a resistance pad 19 to an input transformer 20. A push-pull limiting amplifier stage 21, 21', corresponding to the limiting amplifier 1, is energized from the input transformer 20 and resistance coupled with a push-pull buffer amplifier 22, 22', which corresponds to buffer amplifier 2, in conventional manner. The inverse coupling stage comprises electron tubes 23 and 23' associated respectively with the opposite portions of the push-pull limiting amplifier 21—22, 21'—22', similarly as the coupling stage 3 of Fig. 2 in respect to limiting amplifier 1—2. The rectifier and filter 4 of Fig. 2 is represented by a control amplifier tube 24 which, by virtue of a high negative grid bias from a source at 25, functions as a half-wave square law amplifier, or primary rectifier; in cooperation with tube 24 is a full wave secondary rectifier 26, the output of which is supplied through a filter, consisting of resistor 27 and condenser 28, to the grids of tubes 23, 23' in parallel.

The output of buffer amplifier 22, 22' is delivered through output transformer 29, but a portion of the output from one of the tubes 22' is applied through coupling condenser 30 to the grid of the control amplifier tube 24. Potentiometer 31 is provided in the coupling connection for regulating the amount of compression effected in the limiting amplifier 21, 21'. The rectified output of the square law half-wave amplifier 24 is applied through transformer 32, without filtration, to the full wave rectifier 26 and the resulting direct current in a load resistor 33 produces a voltage therein which is applied to the grids of tubes 23, 23', through the filter 27, 28. The potential on the grids of tubes 23, 23' comprises the control potential from resistor 33, and a bias potential derived from the source at 25 through a potentiometer 34 which is adjusted to a value at which a loss in gain is first noted, with zero potential difference on the resistor 33.

The input to each of the tubes 21, 21', is controlled by a separate potentiometer 35, 35', respectively, adjusted for a degree of amplification to overcome the loss in the resistance pad 19 or, alternatively, to control the amplification when the pad 19 is not employed. Audio frequency

choke 36 is provided in the anode power supply connection from source 37 to control amplifier tube 24.

Similarly as in the arrangement of Fig. 2, the tubes in the coupling stage of the limiting amplifier are constituted as high impedance valves in circuit with the outputs of the respective buffer stages and resistors connected in the cathode circuits of the limiting stages. In Fig. 3, tube 23 is in circuit with resistor 38 and conducts feedback current from the output of tube 22 in accordance with the potential on the grid thereof resulting from operation of the control amplifier 24 and rectifier 26. Tube 23' is similarly related to limiting stage 21' through the cathode resistor 38'.

In brief, then, the operation of the limiting amplifier of my invention is as follows, referring to Fig. 3. Tubes 23, 23', are constituted as variable resistance elements for passing current from the output circuits of tubes 22, 22', through the input circuit resistances 38, 38', a limiting action in the amplifiers 21, 21', being effected by inverse feedback with increase of feedback current in the impedance tubes 23, 23'. The grids of tubes 23, 23' are normally maintained at high negative potential, adjusted by potentiometer 34, but the potential is varied by a rectified potential in positive polarity, at resistor 33, produced by rectification of alternating current derived in transformer 32 from half wave pulsations delivered from control amplifier 24. The tube 24 controls the amount of gain reduction that takes place at a given voltage level in accordance with the magnitude of the control potentials derived from the amplifier 22' and adjusted in potentiometer 31. Tube 24 delivers uni-directional current impulses at the selected signal level. Such current impulses produce alternating impulses in the secondary of transformer 32 which are then rectified and emerge with substantially little distortion as a direct current in the resistor 33. A positive potential from the resistor 33 applied to the grids of the tubes 23, 23', decreases the impedance thereof, thus increasing the feedback currents in resistors 38, 38'.

Fig. 4 shows three curves representing operating conditions achieved with the arrangement shown in Fig. 3. Curve A with little compression shows rapid limitation of the output voltage above a certain level; such a curve is useful in the operation of a broadcast transmitter as a safeguard against overmodulation when compression is not desired at normal operating level. Curve B allows a moderate degree of compression at normal level with limitation on peaks to prevent overmodulation. Curve C may be used for automatic level control for a voltage source, such as a speech channel, to hold the output constant for various speakers' voices and at differing microphone distances. Curve A is obtained with highest threshold bias voltage on the grid of tube 24, and curve C with the lowest. For curve A, potentiometer 31 is set for application of maximum signal voltage to tube 24, and potentiometer 34 at 80% maximum for applying a less negative potential on the grids of tubes 23 and 23'; for curve B, the controls are respectively 80% and 60% positions; and for curve C, both the controls 31 and 34 are at 50% positions.

With the circuit shown in Fig. 3, frequency response uniform with one decibel from 30 to 12,000 cycles is obtained with inexpensive standard circuit components due to the improvement in frequency response achieved by the limiting ac-

tion employed in my invention. This limiting action is effected by inverse feedback through electron tubes of varying impedance, as explained. The internal resistance of these tubes is a function of the bias potentials on their grid electrodes, and the variation of feedback current in the tubes corresponds to the change in resistance. The control voltage, having been derived after rectification of the signal voltage and filtered to remove harmonic and distortion components, is essentially a direct current voltage and thus does not affect the signal components in the limiting amplifier.

Double rectification is a valuable feature because the higher frequency of the distorted signal components and large proportion of direct current at the cathode of control rectifier 26 allows the use of a smaller RC filter causing the amplification to drop very fast on sudden large signals. The high bias on control tube 24 serves further to provide an action relay, forming a threshold so no reduction in the amplification of the system will occur until the signal reaches a certain predetermined value.

The half-wave characteristic of tube 24 is of further use if the device is used for transmitter modulation control. By phasing the positive excursion of the grid of control tube 24 to coincide with the negative modulation excursion of the transmitter, negative peak protection is afforded in the case of asymmetric signal waves with the greatest peak extending in a negative direction. If the direction of asymmetry extends in a positive direction the half-wave feature allows the level reduction to be determined by the minor side of the wave, giving a level increase equal to the ratio of peak asymmetric of the wave.

It should be noted that the cathode resistance 15 of tube 1 in Fig. 2, and cathode resistances 38, 38', of tubes 21 and 21' in Fig. 3, can not be by-passed to ground through a large condenser, such as is shown in the cathode circuit of tube 2. The signal voltage fed back from the anode of tube 2, for example, through the anode-cathode resistance path of tube 3 must appear across the cathode resistance of tube 1. Any audio voltage thus introduced into the cathode circuit of tube 1 and appearing across resistance 15 is effectively impressed across the grid and cathode of tube 1 and is accordingly reintroduced into the input of the signal channel in the manner necessary for inverse feedback, whereas a by-pass condenser would conduct the audio currents around the resistance 15, Fig. 2.

While I have described my invention in certain preferred embodiments, I desire it understood that further modifications may be made within the scope of my invention, and that no limitations upon my invention are intended except as are imposed by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A limiting amplifier comprising a push-pull electron tube amplifier having a separate cathode resistor in each portion thereof, a buffer push-pull amplifier coupled with the output of said electron tube amplifier, a separate inverse feedback circuit connected with each said cathode resistor and including a variable impedance electron discharge device having a control electrode, a primary rectifier connected with the output of said buffer amplifier, a secondary rectifier, a transformer for coupling said primary and secondary rectifiers and energized by current pulsations from said primary rectifier, a resistor in

circuit with said secondary rectifier, and a circuit connected with both said control electrodes including said resistor and a source of bias potential connected in series, with the potential drop in said resistor in opposite polarity with respect to the voltage of said source, for varying the impedance of each said electron discharge device in accordance with the amplitude of the signal voltage above a predetermined level, for simultaneously regulating the feedback energy supplied to both portions of said push-pull amplifier through said impedances.

2. A limiting amplifier as set forth in claim 1 with said primary rectifier comprising a triode electron tube, a potentiometer in series with the output of said buffer amplifier with a portion of the voltage thereacross impressed between cathode and grid electrodes in said triode electron tube, and means for biasing said grid electrode, the potential on said grid electrode determining the magnitude of the resulting feedback in the limiting amplifier at a given signal voltage.

3. A limiting amplifier as set forth in claim 1 with filter means interposed in the circuit connected with both said control electrodes, said filter means being adapted to suppress high frequency distortion and harmonic components in the output of said secondary rectifier and interposing substantially no delay in the application of control components of potential to said control electrodes.

4. A limiting amplifier as set forth in claim 1 with a potentiometer connected with said source of bias potential for adjusting the magnitude of the bias potential applied to said control electrodes, for selectively determining the level at which limiting begins.

5. In a limiting amplifier, an electron tube amplifier including a cathode resistor, a variable impedance connected in circuit with said cathode resistor and the output of said amplifier for inverse feedback operation, a primary rectifier energized from the output of said electron tube amplifier, a secondary rectifier, a transformer for coupling said primary and secondary rectifiers and energized by current pulsations from said primary rectifier, a resistor in circuit with said secondary rectifier for producing a voltage proportional to the amplitude of the signal voltage above a predetermined level, and means energized by said voltage for varying said impedance for regulating the feedback energy supplied to said electron tube amplifier through said impedance.

6. In a limiting amplifier, an electron tube amplifier including a cathode resistor, an electron discharge device connected as a variable impedance in circuit with said cathode resistor and the output of said amplifier for inverse feedback operation, said variable impedance electron discharge device having a control electrode, a primary rectifier energized from the output of said electron tube amplifier, a secondary rectifier, a transformer for coupling said primary and secondary rectifiers and energized by current pulsations from said primary rectifier, a resistor in circuit with said secondary rectifier for producing a potential proportional to the amplitude of the signal voltage above a predetermined level, and means for applying said potential to said control electrode for varying the impedance of said electron discharge device and regulating the feedback energy supplied to said electron tube amplifier through said impedance.

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