June 18, 1940. F. M. DAVIS 2,204,726

LIMITING AMPLIFIER CONTROL MEANS

Filed Oct. 20, 1938 2 Sheets-Sheet 1

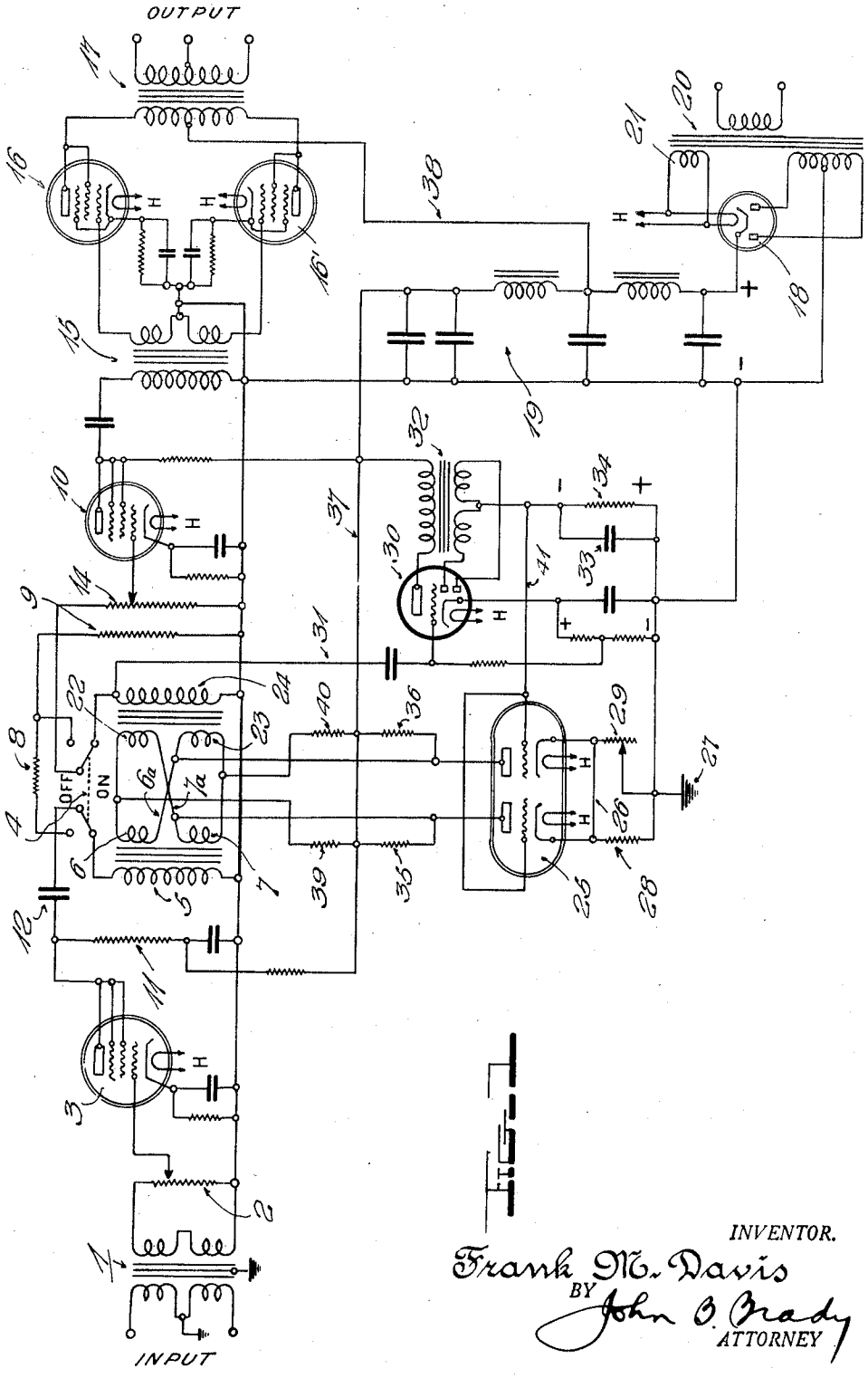


FIG. 1

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FIG. 2

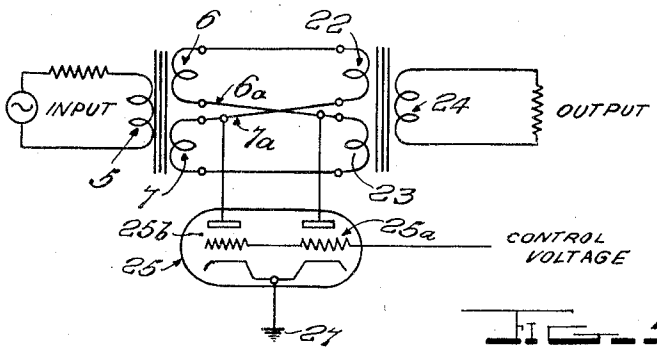


FIG. 3

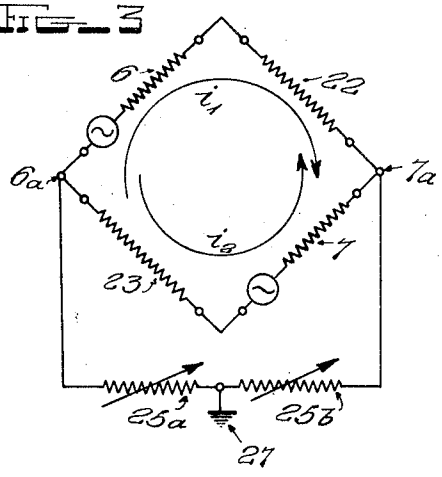


FIG. 4

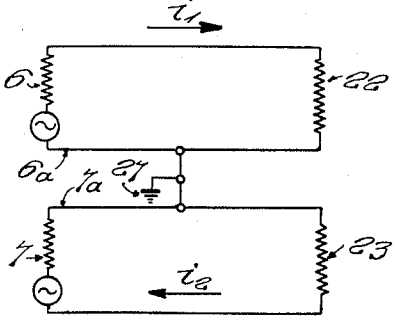


FIG. 5

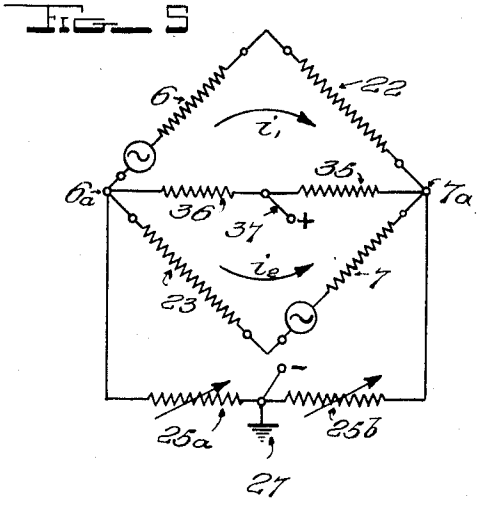
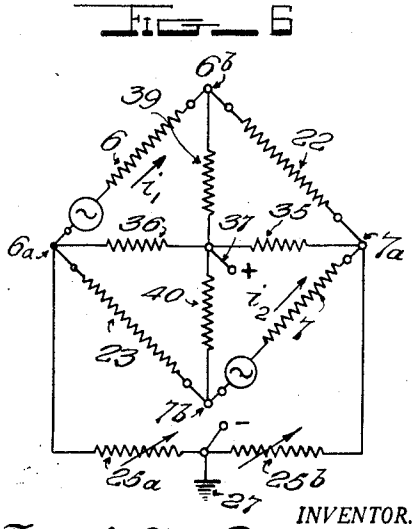


FIG. 6



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UNITED STATES PATENT OFFICE

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LIMITING AMPLIFIER CONTROL MEANS

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Application October 20, 1938, Serial No. 236,117

10 Claims. (Cl. 178—44)

My invention relates broadly to amplification systems and more particularly to limiting circuits for the controlled transmission of electrical energy.

This application treats of the further development and adaptation of the transmission control system shown and described in my copending application Serial No. 199,319, filed March 31, 1938, of which this application is a continuation-in-part.

One of the objects of my invention is to provide an improved transmission control system for use as a limiting circuit in an electrical amplification system.

Another object of my invention is to provide a balanced control means for a limiting circuit in an amplification system for reducing distortion and instability in the transmission of electrical signal energy.

A further object of my invention is to provide a balanced, dual electron tube control circuit in a transmission control system with means for supplying operating potentials to the electrodes in balanced relation so as not to affect the operation of the control circuit over its entire inherent range.

Still another object of my invention is to provide a transmission control circuit for producing substantially full range control of electrical signal transmission with balanced control means for preserving clarity and uniformity in the transmission.

A still further object of my invention is to provide an improved form of electron tube control means in a limiting circuit for the automatic control of electrical signal energy in accordance with the amplitude characteristics of the energy.

Another object of my invention is to provide balanced electron tube control means including grid electrodes supplied with control potential, in a limiting circuit for regulating the amplitude of signal energy in a transmission system.

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

Figure 1 is a schematic diagram of a limiting amplifier embodying a transmission control system in accordance with my invention; and Figs. 2–6 are theoretical schematic and equivalent diagrams explanatory of the improved transmission control system embodied in the diagram of Fig. 1.

In previous circuits for the control of signal energy in transmission, as by the system of my application Serial No. 199,319, above referred to, where a single triode electron tube is utilized for control purposes, alternating current harmonic components in the rectified controlling wave are reintroduced into the signal channel by virtue of the amplification of the control tube, which results in distortion and instability at high degrees of control. This feedback or reintroduction of signal is not necessary in the functioning of the system and may advantageously be prevented in accordance with my invention herein disclosed.

Referring to Fig. 1 in detail, the amplifier circuit shown comprises an input transformer 1 connected through an input regulating resistance 2 to the control grid-cathode circuit of an amplifying tube 3. The output of the tube 3 is shown connected through one section of switch 4 to the primary 5 of a transformer having separate secondaries 6 and 7 constituting part of the limiting circuit of the amplifier. Switch 4 is an on-off switch which in the "on" positions shown connects the limiting circuit in the system and in the alternative "off" positions connects the output of tube 3 to the compensating resistors 8 and 9. The succeeding amplifier tube 10 is resistance coupled with the output of tube 3 by resistor 11 connected with the anode of tube 3, coupling condenser 12 and resistor 14 which has a tap connection to the grid of tube 10 for selecting the output level of the amplifier. The output of the amplifying tube 10 is coupled by transformer 15 to the push-pull output tubes 16, 16', which supply the output transformer 17. The power supply for the amplifier is obtained through rectifier tube 18 and filter 19 from the transformer 20 connected with an alternating current source; heater elements in the several tubes are supplied from terminals H of the secondary 21 of transformer 20.

The limiting circuit between tubes 3 and 10 is similar to that disclosed in my copending application Serial No. 199,319, supra, and includes separate primary windings 22, 23, of a transformer having a secondary winding 24 which is connected in shunt with resistor 14. The secondary windings 6 and 7 and primary windings 22 and 23 are connected in a closed loop circuit in alternate relation and with the currents from the two secondary windings 6 and 7 in opposition. The connections from the adjacent terminals 6a and 7a of the secondaries 6 and 7 are normally crossed to connect with primaries 23 and 22, respectively, and when connected together divide the closed loop circuit into two portions in each of which the current from one of the secondaries supplies the opposite primary winding, resulting in full transmission of the signal energy through the system. Control of the degree of connection by the amount of resistance between the terminals 6a, 7a, results in regulation of the energy transfer through the system.

In Fig. 1, and in equivalent form in Fig. 2, I have shown as control means a dual triode electron tube device 25, separate anodes of which are

connected with the terminals 6a, 7a, so that the internal resistances between the respective anodes and cathodes may serve as the variable resistance between the terminals. The circuit is completed by connecting together the separate cathodes of the dual triode assembly shown, as at 26, and this connection is grounded at 27 through adjustment resistors 28 and 29 which serve to determine the limit of transmission of the limiting circuit with the control grids at zero potential. The control grids of the dual triode assembly are likewise connected together and are supplied with negative control potential, for increasing the internal resistances to the respective anodes in the dual triode 25, from an amplifier-rectifier device 30.

The amplifier portion of the tube 30 is a triode including a grid energized by a connection 31 from the secondary 24 in the output of the limiting circuit, and an anode which connects with the primary of a transformer 32 and supplies signal energy to a split secondary winding. The rectifier portion of the tube 30 is a dual diode with anodes connected with opposite terminals of the secondary winding of transformer 32 for full wave rectification of the signal energy. The rectifier circuit includes a by-pass condenser 33 and a load resistor 34, the potential drop across which is applied to the control grids of the dual triode 25 by lead 41, for varying the resistance effective between terminals 6a, 7a, in accordance with the amplitude of the signal in the output of the limiting circuit.

Such alternating current components as may appear across resistor 34 and become effective on the grids of tube 25, are nevertheless prevented from reentering the transmission system by virtue of the balanced control resistances provided by tube 25, the cathode midpoint or junction of which is substantially at ground potential. There can be no alternating current potential between the separate anodes of the control tube 25 and hence no such potential will be transferred through tube 25 back into the transmission system. Furthermore, the control tube 25 provides substantially symmetrical circuits from the secondaries 6 and 7 to ground 27, which is of advantage in maintaining balance at high frequencies.

Potential is supplied to the anodes of tube 25 through ballast resistors 35, 36, from the positive lead 37 from which the anodes of tubes 3, 10 and 30 are also energized. The anodes of tubes 16, 16', are supplied through a separate lead 38. Resistors 39, 40, connected between the limiting circuit and the positive lead 37 have balancing functions which will be further discussed in reference to Figs. 5 and 6.

The basic limiting circuit of my invention is essentially a bridge circuit in its equivalents, as shown in Figs. 3, 5 and 6. Each of the secondary windings 6 and 7 can, by Thevenin's theorem, be replaced by a generator in series with an impedance; and each of the primary windings 22, 23, can be replaced by an impedance equal to the impedance which the transformer reflects into its primary circuit. These substitutions are made and the circuit rearranged in the form of a bridge in Fig. 3. With a signal from the primary 5, Fig. 2, then at any instant the voltage induced in winding 6 is equal to and in phase with the voltage induced in winding 7, and the respective circulating currents i_1 and i_2 in the bridge loop 6, 23, 7, 22, Fig. 3, are opposite and balanced. This is the condition when the resistance provided in the tube 25, as represented by equivalent resistances 25a, 25b, Fig. 3, is infinite due to a high negative potential on the grids of tube 25, and is the condition where the transmission through the circuit is zero.

Considering then the condition where the equivalent resistances 25a, 25b, are very small, due to decrease of the negative grid bias on tube 25. This places substantially a short circuit between terminals 6a, 7a, and the equivalent circuit may be rearranged as shown in Fig. 4. The phase relations are such that the current i_1 in winding 22 produces flux additive to that produced by current i_2 in winding 23, so that an output voltage appears in the secondary 24, Fig. 2. In this case, the transmission through the circuit, neglecting the loss in the transformers, is unity. Because of the short circuit between terminals 6a, 7a, there is no intermingling of the currents i_1 and i_2, each being confined to a separate loop circuit, so that the mutually cancelling effect thereof is not produced. It will be understood that various intermediate values of resistance at 25a, 25b, between infinity and zero, will produce more or less mutual cancellation in the currents i_1 and i_2 and a correspondingly lesser or greater degree of transmission of signal energy through the circuit.

In Fig. 5 I have illustrated the equivalent bridge circuit of Fig. 3 with the ballast resistors 35, 36, in the potential supply lines added. It is evident that at values of resistances 25a, 25b, approaching infinity, the finite resistance across points 6a, 7a, presented by resistors 35, 36, will prevent a complete balancing of the currents i_1 and i_2 so that complete blocking of the transmission of energy through the circuit is not possible. To restore the balance and the full range of control, auxiliary resistors 39 and 40 are connected from the same potential line 37 to the alternate opposite points of the bridge, 6b, 7b, Fig. 6. The resistances 35, 36, 39, 40 are all of like value so that the balance is restored and control by means of the resistances 25a, 25b is again effective over the full range of variation.

A further advantage of the arrangement is that there are four resistors effectively in parallel with regard to direct current to each of the anodes of tube 25, allowing each resistor to be very high in value while still maintaining a sufficiently high direct current voltage for the anodes.

The arrangement shown in Fig. 1 is operative for automatic gain control by virtue of the connection 31 from the transmission circuit to the monitor tube 30. It will be understood that the control voltage for the grids of tube 25 can be provided by rheostat or voltage divider from a separate source for manual control, if such is desired, in lieu of the automatic control afforded by the voltage across resistor 34, Fig. 1. Fig. 2 broadly illustrates the adaptability of the device to any suitable control voltage, automatic or manual as may be preferred.

While I have illustrated my invention in a certain specific embodiment, I desire it understood that modifications may be made, and that no limitations upon my invention are intended except as may be imposed by the scope of the appended claims.

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

1. In a limiting amplifier, a transmission control system comprising a transformer coupling circuit having dual loop circuits interconnected in opposed relation for blocking the transfer of

energy, and means for altering the opposed relation of the loop circuits consisting of a dual triode electron tube device having separate anode electrodes connected with the respective loop circuits, and cathode electrodes in common, the internal anode-cathode resistances in said device being additive between said loop circuits and constituting the control factor for altering the opposed relation of the loop circuits, and means including grid electrodes in said electron tube device for varying the internal anode-cathode resistances in said device for controlling the transfer of energy in varying degree.

2. In a limiting amplifier as set forth in claim 1, a connection from said cathode electrodes to ground, and a common grid connection in the last said means, whereby said resistances may be varied in balanced relation with regard to the respective loop circuits.

3. In a limiting amplifier, a transmission control system comprising a bridge circuit having sources of signal energy of like phase and magnitude in opposite legs of said bridge circuit connected for producing currents in opposite directions, and output impedance elements in the alternate opposite legs; a control resistance connected between opposite points in said bridge circuit and variable substantially from infinite to zero resistance for dividing said bridge circuit into separate loop circuits, said control resistance having a middle connection to ground for maintaining a balance therein with respect to said bridge circuit; the currents from said sources being balanced in said output impedance elements with said control resistance infinite, and the current from each said source being confined to a separate output impedance with said control resistance zero.

4. In a limiting amplifier, a transmission control system comprising a bridge circuit having sources of signal energy of like phase and magnitude in opposite legs of said bridge circuit connected for producing currents in opposite directions, and output impedance elements in the alternate opposite legs; a control resistance connected between opposite points in said bridge circuit and comprising the internal anode-cathode resistances of a dual triode electron tube device, separate anode electrodes in said device being connected with said opposite points in said bridge circuit, and cathode electrodes in said device being in common, and means including grid electrodes in said device for varying said internal anode-cathode resistances for controlling the balance of said currents in said output impedances in verying degree and the transfer of energy in said amplifier accordingly.

5. In a limiting amplifier as set forth in claim 4, a connection to ground from said cathode electrodes at the middle point of said control resistance, and a common grid connection in the last said means, whereby said anode-cathode resistances may be varied in balanced relation with respect to said bridge circuit.

6. In a limiting amplifier as set forth in claim 4, in combination with said bridge circuit, means for supplying anode potential to said anode electrodes comprising a single source of potential and separate ballast resistors connected between said source and said anode electrodes, said resistors in series being disposed in shunt with said control resistance between said opposite points in said bridge circuit, and said source of potential being connected between the junction of said resistors and said cathode electrodes.

7. In a limiting amplifier as set forth in claim 4, in combination with said bridge circuit, means for supplying anode potential to said anode electrodes comprising a single source of potential and separate ballast resistors connected between said source and said anode electrodes, said resistors in series being disposed in shunt with said control resistance between said opposite points in said bridge circuit, and said source of potential being connected between the junction of said resistors and said cathode electrodes, and auxiliary ballast resistors connected between the junction of the aforesaid ballast resistors at said source of potential separately to the alternate opposite points in said bridge circuit, said auxiliary ballast resistors being effectively in parallel with the aforesaid ballast resistors with respect to direct current from said source of potential to said anode electrodes and operative to maintain a balance in said bridge circuit with respect to signal energy.

8. In a limiting amplifier, in combination, a transmission control system including a bridge circuit, and grid regulated electron tube control means connected with opposite points in said bridge circuit; automatic operating means including a rectifier energized by signal energy derived from said amplifier, a resistor connected in series with said rectifier having a potential difference thereacross substantially proportional to the magnitude of the signal energy in said amplifier, and means for impressing said potential difference as a grid voltage on said electron tube control means; and a source of anode potential for said electron tube control means connected therewith through the said opposite points in said bridge circuit, and means connected with said source and the alternate opposite points in said bridge circuit for balancing said bridge circuit with respect to signal energy, with said source of anode potential effective on said control means also through the last said means and said bridge circuit; said control means, said rectifier and said source of anode potential having a connection in common at ground potential.

9. In a limiting amplifier, in combination, a transmission control system including a bridge circuit, grid regulated electron tube control means connected with opposite points in said bridge circuit, a source of anode potential for said electron tube control means connected therewith through the said opposite points in said bridge circuit, and means connected with said source and the alternate opposite points in said bridge circuit for balancing said bridge circuit with respect to signal energy, with said source of anode potential effective on said control means also through the last said means and said bridge circuit.

10. In a limiting amplifier, in combination, a transmission control system including a bridge circuit, grid regulated electron tube control means connected with opposite points in said bridge circuit, a source of anode potential, ballast resistors separately connected between said source and said electron tube control means at said opposite points in said bridge circuit, and auxiliary ballast resistors separately connected between said source and the alternate opposite points in said bridge circuit for balancing said bridge circuit with respect to signal energy, with said source of anode potential effective on said control means through the first said and said auxiliary ballast resistors and through said bridge circuit.

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