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TONE INTERRUPTER FOR AUDIOMETERS

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My present invention relates to improvements in audiometers which are devices, instruments, apparatus or systems used in conjunction with suitable audio frequency reproducers of the air conduction type or bone conduction type to test the hearing characteristics of the human ear. Such audiometers customarily employ two sources of signal energy (one of which is in the nature of a suitable variable frequency signal generator and the other of which is in the nature of a microphone), a suitable audio frequency amplifier intermediate the said signal energy sources and the electrical output of the audiometer, and means for selectively connecting the two signal sources independently to the input of the amplifier.

In an audiometer, it is necessary to provide some means for periodically interrupting the test tone signal produced by the signal generator, and it is also highly desirable to provide means for similarly interrupting the speech signal delivered by the microphone when the latter is in use. Heretofore, the usual procedure for interrupting tone producing signal energy from the variable frequency signal generator has been to render the generator inoperative. Since signal generators used in audiometers are generally of the vacuum tube oscillator variety, the usual procedure has been to manipulate one way or another to stop oscillation of the oscillator tube, and this has been most frequently accomplished by interrupting the plate circuit of the oscillator tube, or by introducing into the grid circuit of a signal generating oscillator tube a D. C. voltage for the purpose of reducing the mutual conductance of the tube to a point where it will not oscillate.

These prior art tone interrupters of the kind which operate directly on the signal generator or oscillator tube thereof have several inherent disadvantages, two of which are as follows, to wit:

(A) They will not interrupt the microphone speech circuit, as is desirable in some types of malingering tests, due to the fact that the microphone and signal generator each comprise a complete and separate source of signal energy; and

(B) In audiometers of the so-called 2-channel type, which employ two separate and distinct signal channels, one for use with air conduction reproducers and the other for use in bone conduction reproducers, and wherein both said channels are driven from a common tone-producing signal generator or oscillator, it is obviously impossible to selectively interrupt the signal energy in one of the channels without also interrupting the signal energy in the other of

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the channels. Because of this fact, it has been necessary, in order to achieve selective independent interruption of signal energy in the air conduction and bone conduction channels of 2-channel audiometers, by direct operation on the signal generator, to employ two signal generators, one for the air conduction channel and the other for the bone conduction channel. However, this practice has been found objectional for several reasons, including the inherent difficulty of obtaining and maintaining perfect frequency balance between the two signal generators, particularly when these are of the vacuum tube oscillator type.

One of the primary objects of my invention is to overcome objection A, above, by the provision of an improved tone signal interrupting means or system, whereby the signal energy to the electrical output of an audiometer, from any one of a plurality of signal energy sources, such as the speech microphone and a signal tone producing generator, may be selectively and independently interrupted.

Another primary object of my invention is to overcome objection B, above, by provision of an improved tone signal interrupting means or system, whereby the signal energy in either of the two channels of the 2-channel audiometer, of the kind employing a single signal generator feeding the two channels, may be selectively and independently interrupted.

Another important object of the invention is the provision of an improved signal interrupter, of the general character described, wherein the fade-in and fade-out time is variable by variations in values of component elements of the system.

A further object of the invention is the provision of an improved signal energy interrupting system or means for audiometers having, in addition to the advantages above noted, the inherent ability to completely eliminate signal energy at the output when the tone interrupting system or means is operative.

A still further object of the invention is a provision of an improved signal energy interrupting system or means of the class described, whereby the signal is faded in and faded out without generation of extraneous clicking or other noise.

The above and other important objects and advantages of the invention will be made apparent from the following specification, claims and appended drawings.

Referring to the drawings, the single view is a schematic electrical diagram of a 2-channel

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audiometer incorporating a preferred embodiment of my invention.

In the drawing, two separate and distinct sources of signal energy are illustrated, one being in the nature of a variable frequency signal generator 1, and the other being in the nature of a speech microphone 2. The variable frequency signal generator 1 may be of any suitable type, but will usually be, and for the purpose hereof may be assumed to be, of a type employing a vacuum tube oscillator.

One side of the output of the signal generator 1 is connected to ground by a lead 3 and the other side of the output of signal generator 1 is connected by a lead 4 to a contact 5 of a selector switch 6. Similarly, one side of the output of the microphone 2 is connected to ground by a lead 7 and the other side is connected by a lead 8 to a contact 9 of selector switch 6. The selector arm or movable contact of switch 6 is indicated by 10 and is connected to the air conduction signal energy channel by a lead 11 and to the bone conduction signal energy channel by a lead 12. The air conduction signal energy channel, as shown, comprises a suitable signal energy balancing controller 13 for modifying the characteristic power output curve of the signal generator to meet test requirements in connection with an air conduction reproducer, a power amplifier 14, and a power output transformer 15. The bone conduction signal energy channel, as shown, comprises a suitable signal energy balancing controller 16 for modifying the characteristic power output curve of the signal generator to test requirements in connection with a bone conduction reproducer, a power amplifier 17, and an output transformer 18. The signal energy balancing controllers 13 and 16 may be in the nature of the usual variable attenuators conventionally used for the purpose. The power amplifiers 14 and 17, as shown, and preferably, are each of the 2-stage variety afforded by a twin triode vacuum tube amplifier. The input section of the twin triode amplifier tube 14 comprises element 19, a cathode element 20, a cathode heater 21, and a control grid 22. The output section of amplifier 14 comprises a plate element 23, a cathode element 24, a cathode heater 25, and a control grid element 26. The input section of the twin triode amplifier 17 comprises a plate element 27, a cathode element 28, a control grid element 29, and a cathode heater 30. The output section of the amplifier 17 comprises a plate element 31, a cathode element 32, a control grid element 33, and a cathode heater 34.

The signal output energy from the signal energy balancing controller 13 of the air conduction signal channel is connected to the control grid 22 of the input section of amplifier 14 by a lead 35 having interposed therein a condenser 36. The output of the signal energy balancing controller 16 of the bone conduction signal channel is connected to the control grid 29 of the input section of amplifier 17 by a lead 37 having interposed therein a condenser 38. The cathodes 20 and 24 of amplifier 14 and the cathodes 28 and 32 of amplifier 17 are each connected to ground through a self-biasing resistor 39 and by-pass condenser 40. The plate 19 of the input section of amplifier 14 is connected to the positive side of a suitable source of high voltage D. C., such as a battery B, through a lead 41 having interposed therein a load resistor 42. The plate 27 of the input section of amplifier 17 is similarly connected to the positive side of battery B by a lead 43 having interposed therein a load resistor 44 and part

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of lead 41. The plate 23 of the output section of amplifier 14 is connected to the positive side of battery B by a lead 45 and the primary winding 46 of coupling transformer 15. The plate 31 of the output section of amplifier 17 is connected to the positive side of battery B by a lead 47, the primary winding 48 of coupling transformer 18, a lead 49, part of lead 43 and part of lead 41. One end of the secondary winding 50 of output transformer 15 is grounded at 51, and the corresponding end of secondary winding 52 of transformer 18 is grounded at 52'. The secondary winding 50 of transformer 15 of the air conduction signal channel is adapted to be connected and may be assumed to be connected to a suitable output power attenuator and air conduction reproducer. Similarly, the opposite ends of the secondary winding 52 of coupling transformer 18 are adapted to be and may be assumed to be connected to a suitable output power attenuator and bone conduction reproducer. The plate 19 of the input section of amplifier 14 is connected to the control grid 26 of the output section of the amplifier 14 through a lead 53, having interposed therein a coupling condenser 54. Similarly, the plate 27 of the input section of amplifier 17 is coupled to the control grid 33 of the output section of amplifier 17 by a lead 54' and coupling condenser 55. The amplifiers 14 and 17 may properly be referred to as cascade amplifiers, since the input and output sections thereof are cascade coupled.

As a means for selectively interrupting the test signal energy in the air conduction signal channel of the audiometer, I provide an improved control system or means which, in its preferred embodiment illustrated, comprises as major components a normally open interrupter switch 56, an electronic amplifier in the nature of a triode vacuum tube 57, a source of high voltage D. C. B2, rectifiers 58 and 59, and a suitable source of A. C., such as a transformer 60. The amplifier 57 comprises a plate element 61, a cathode element 62, a cathode heater 63, and a control grid element 64. The heater 63 of amplifier 57 is energized from the secondary winding 55 of transformer 60 to which it is connected by leads 66 and 67. The primary winding 68 of transformer 60 is energized from a suitable high voltage source, such as an A. C. power line 69. The plate circuit for amplifier 57 comprises battery B2, a load resistor 70 from the positive side of battery B2 to plate 61 through lead 71, cathode 62 and a self-biasing resistor 72 connected between cathode 62 and the negative side of battery B2 through a grounded lead 73. The plate circuit of amplifier tube 57 is connected to the output section control grid 26 of amplifier 14 by a lead 74 having interposed therein a coupling condenser 75, the rectifier 58, filter resistor 76, a lead 77, a filter resistor 78, a lead 79, and a grid bias resistor 80. The positive side of the rectifier 58 faces the plate 61 and the negative side thereof faces the control grid 26 of amplifier 14. In the preferred arrangement illustrated, the coupling circuit between the plate 61 of amplifier 57 and the grid 26 of amplifier 14 is of the voltage doubling variety and further comprises the rectifier 58 having its negative side connected to the positive side of rectifier 58 by a lead 81, and its positive side connected to grounded lead 73. In the arrangement illustrated, a filter resistor 82 and filter condenser 83 are connected between lead 77 and grounded lead 73, and a filter condenser 84 is connected between lead 79 and ground lead 73 by a lead 85. The control grid 64 of amplifier 57 is connected to ground by

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a grid bias resistor 86. For the purpose hereof, the control grid 64 of amplifier 57 may be excited from any suitable source of signal energy, including the secondary winding 65 of the cathode heater energizing transformer 60. As illustrated herein, the transformer secondary winding 65 is connected across the grid bias resistor 86 by ground connections from one end of winding 65 to the grounded end of resistor 86 and by a lead 87 to the other end of resistor 86 and grid 64, and which lead has interposed therein the normally open interrupter switch 56.

As a means for selectively interrupting the signal energy in the bone conduction signal channel of the audiometer, I provide an improved control system or means substantially identical to that described in connection with the air conduction signal channel and which, in the preferred embodiment hereof herein illustrated, comprises as major components a normally open interrupter switch 88, a triode electronic amplifier tube 89, a high voltage source of D. C. in the nature of a battery B1, a relatively low voltage source of A. C., in the nature of a transformer 90, and rectifiers 91 and 92. The primary winding 93 of the transformer 90 may be energized from any suitable source of A. C., such as the high voltage A. C. supply line 99. The amplifier 89 comprises a plate element 94, a cathode element 95, cathode heater 96 and a control grid element 97. The cathode heater or filament 96 is connected across the transformer secondary winding 98 by leads 99 and 100. The control grid 97 may be excited from any suitable source of signal energy, which may expediently be, and is shown as being, the secondary winding 98 of transformer 90. For connecting the secondary winding 98 across the grid bias resistor 101, I provide a lead 102 from one side of secondary winding 98 to grid 97 and the ungrounded end of resistor 101, and having interposed therein the normally open interrupter switch 88. The other end of secondary winding 98 is connected to ground through a grounded lead 103. The negative side of battery B1 is connected to ground through lead 103. The plate circuit for amplifier 89 comprises a load resistor 104 from the positive end of battery B1 to plate 94 through a lead 105, cathode 95, and a self-biasing resistor 106 from cathode to ground and B1. A plate circuit of amplifier 89 is connected to the control grid 33 of the output section of audiometer amplifier 17 by the lead 105, coupling condenser 108, a lead 107, rectifier 91, filter resistor 109, a lead 110, filter resistor 111, a lead 112, and a grid bias resistor 113. The adjacent ends of resistors 109 and 111 are connected to ground lead 103 by a filter resistor 114 and filter condenser 115, and the other end of resistor 111 is connected to ground through a filter condenser 116. In the preferred arrangement illustrated, the positive side of rectifier 91 is connected to ground through the voltage doubling rectifier 92.

Operation

When it is desired to utilize the signal generator 1 as a source of test signal energy, the switch arm 18 of selector switch 6 is moved into engagement with contact 5 of switch 6, and when it is desired to utilize the speech microphone 2 as a source of test signal energy, the selector arm 10 of selector switch 6 is moved into engagement with contact 9 of said switch.

In either event, the signal energy from the connected source 1 or 2 will be conducted to the air conduction signal energy channel through lead

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11 and will be conducted to the bone conduction signal channel through lead 12. The signal energy thus conducted to the air conduction signal energy channel through lead 11 will be acted upon by the balancing controller or attenuator 13, which will vary the output power characteristic of the source at different frequencies in a manner desirable for use with an air conduction reproducer. The signal energy similarly conducted to the bone conduction signal energy channel through lead 12 will be similarly acted upon by the balancing controller or attenuator 16 in a manner which will modify the signal energy power at different frequencies, as is desirable for use in connection with a bone conduction reproducer. The air conduction signal energy channel will then be impressed upon control grid 22 of the input section of amplifier 14 through lead 35 and interposed coupling condenser 36; and the bone conduction signal energy channel will then be impressed upon control grid 29 of the input section of amplifier 17 through lead 37 and interposed coupling condenser 38.

Provided that the interrupter switches 56 and 88 are both open, as shown, the amplifiers 57 and 89 will be inoperative. Under these conditions, the input and output sections of signal channel amplifiers 14 and 17 will be grid biased to operate normally or on the linear portions of their characteristic plate current curves. The signal voltage thus impressed on control grid 22 of the input section of amplifier 14 will be reflected in and amplified in the plate circuit of the input section of amplifier 14, which latter comprises source of potential B, lead 41, load resistor 42, cathode 20 and grid bias resistor 39. Similarly, the signal voltage thus impressed on control grid 29 of the input section of amplifier 17 will be reflected in and amplified in the plate circuit of the input section of amplifier 17, and which latter comprises the source of potential B, part of lead 41, lead 43, load resistor 44, cathode 28 and grid bias resistor 39. The amplified signal voltage in the plate circuit of the input section of amplifier 14 is impressed upon the control grid 26 of the output section of amplifier 14 through lead 53 and interposed coupling condenser 54; and the amplified signal voltage in the plate circuit of the input section of amplifier 17 is similarly impressed upon the control grid 33 of the output section of amplifier 17 through the lead 54' and interposed coupling condenser 55. The amplified signal voltage thus impressed upon the control grid 26 of the output section of amplifier 14 is reflected in and amplified in the plate circuit of the output section of amplifier 14, which latter comprises the primary winding 46 of coupling transformer 15; and the amplified signal voltage thus impressed on the output section control grid 33 of amplifier 17 is reflected in and amplified in the plate circuit of the output section of amplifier 17, which comprises a primary winding 48 of coupling transformer 18. Hence, the output signal energy for use with an air conduction reproducer will be induced in the secondary winding 50 of transformer 15 and output signal energy for use with a bone conduction reproducer will be induced in the secondary winding 52 of coupling transformer 18.

If it now be desired to selectively and independently interrupt the output signal energy in the air conduction signal channel comprising amplifier 14, the normally open interrupter switch 56 will be closed. When this is done, the A. C. voltage in the secondary winding 65 of

transformer 60 will be applied across grid bias resistor 86 and impressed upon control grid 64 of amplifier 57, to excite the latter. The A. C. voltage thus impressed upon the control grid 64 of amplifier 57 will be reflected in and amplified in the plate circuit of amplifier 57 comprising load resistor 70 and lead 71. The amplified signal voltage in the plate circuit of amplifier 57 will be rectified and increased in value in the voltage doubler circuit comprising coupling condenser 75, rectifiers 58 and 59, and filter condensers 83 and 84, and will be applied to the control grids 22 and 26 of amplifier 14 as a negative D. C. grid bias potential of sufficient value to bias the plate circuits of the input and output sections of amplifier 14 to cut off. In this respect, it will be noted that negative D. C. biasing potential is applied, as indicated, to grid 26 of amplifier 14 through the lead 79 and the grid bias resistor 80, and that the said negative D. C. control potential is applied to control grid 22 of amplifier 14 through part of said lead 79, a lead 79' and a grid bias resistor 80'.

To selectively and independently interrupt the signal energy in the bone conduction signal energy channel, the control grid 97 of amplifier 89 is excited with A. C. by closing interrupter switch 88. The A. C. voltage thus impressed upon control grid 97 of amplifier 89 is reflected in and amplified in the plate circuit of amplifier 89 comprising load resistor 104 and lead 105. The amplified signal voltage of the plate circuit of amplifier 89 is rectified and further amplified in the voltage doubler circuit comprising condenser 108 and rectifiers 91 and 92, is filtered by the filter network comprising filter resistors 109, 111, 114 and filter condensers 115 and 116, and is impressed upon the control grids 29 and 33 of amplifier 17 as a negative D. C. grid biasing and control potential of sufficient value to bias the input and output sections of amplifier 17 to plate current cut off. The rectified and filtered negative D. C. control potential is applied to grid 33 through lead 112 and grid bias resistor 113, and is applied to grid 29 through lead 112, a lead 112' and a grid bias resistor 113'.

From the above it will be evident that the invention provides highly efficient means or system for selectively and independently interrupting the signal energy in either of the two channels of a 2-channel audiometer of the kind wherein both channels are operated from a common source of signal energy. It will be further evident that my improved signal interrupting means or system serves equally well in connection with either of two sources of signal energy, such as the signal generator 1 and the speech microphone.

Important advantages arising from the use of 2-stage amplifiers, such as shown at 14 and 17, and the interruption of the signal through these amplifiers by simultaneous application of cut off control potential to the input and output sections of these amplifiers, are as follows, to wit:

(A) The magnitude of the signal from the source, if not altogether eliminated in the input section of the amplifier is, at least, so greatly reduced in value in the input section of the amplifier, that a D. C. biasing voltage of relatively low value is required to bias the output section of the amplifier to cut off and thereby positively keep any signal potential from feeding through the amplifier; and

(B) No objectionable distortion is generated between the time the tone interrupter switch is closed and the time that the signal energy and

the effected signal channel are completely cut off.

With the signal interrupting system or means of my invention, the signal channels are interrupted smoothly and silently without the production of any extraneous noise and the fade-in and fade-out time intervals may be controlled by varying values of component circuit elements, such for example as the condensers 75, 83, 84, 108, 115, 116, and resistors 76, 78, 82, 109, 111 and 114.

My invention has been thoroughly tested and found to be entirely adequate for the accomplishment of the objectives set forth; and, while I have shown a preferred embodiment of my invention, it will be understood that the same is capable of modification without departure from the spirit and scope of the invention as defined in the claims.

What I claim is:

1. In an audiometer, a normally operative first electronic signal amplifier having plate and cathode and control grid elements, a plate circuit for the first amplifier coupled to the electrical output of the audiometer, a source of test signal energy coupled to the control grid of the first amplifier to drive the same, and normally inoperative control means for biasing the first amplifier to plate current cut off to thereby interrupt the delivery of signal energy to the electrical output of the audiometer, said control means comprising a second electronic amplifier having plate and cathode and control grid elements, a normally open control grid driving circuit for the second amplifier, a manually operative interrupter switch controlling the grid driving circuit of the second amplifier, a plate circuit for the second amplifier, and a D. C. control circuit for the first amplifier comprising a rectifier coupled between the plate circuit of the second amplifier and an element of the first amplifier other than the plate thereof for applying a D. C. control potential to the first amplifier responsive to closing of the interrupter switch and resultant energization of the control grid driving circuit of the second amplifier, the polarity and value of the D. C. control potential thus applied to the said element of the first amplifier being such as to bias said first amplifier to cut off.

2. In an audiometer, a normally operative first electronic signal energy amplifier having plate and cathode and control grid elements, a plate circuit for said first amplifier coupled to the electrical output of the audiometer, a source of test signal energy coupled to the control grid element of the first amplifier to drive the same, and normally inoperative control means for biasing the first amplifier to plate current cut off to thereby interrupt delivery of signal energy to the electrical output of the audiometer, said control means comprising a second electronic amplifier having plate and cathode and control grid elements, a normally open control grid driving circuit for the second amplifier, a manually operative interrupter switch controlling the said grid driving circuit of the second amplifier, a plate circuit for the second amplifier, and a rectifier having its positive side coupled to the plate of the second amplifier and its negative side coupled to the control grid element of the first amplifier, whereby when the grid driving circuit of the second amplifier is closed a negative D. C. control potential will be applied to the control grid of the first amplifier as a grid bias, the value of the negative D. C. control potential thus ap-

plied to the control grid of the first amplifier being sufficient to bias said amplifier to plate current cut off.

3. In an audiometer, a normally operative first electronic signal amplifier having plate and cathode and control grid elements, a plate circuit for the first amplifier coupled to the electrical output of the audiometer, a source of test signal energy coupled to the control grid of the first amplifier to drive the same, and normally inoperative control means for biasing the first amplifier to plate current cut off to thereby interrupt the delivery of signal energy to the electrical output of the audiometer, said control means comprising a second electronic amplifier having plate and cathode and control grid elements, a normally open driving circuit for the control grid element of the second amplifier comprising a source of A. C. potential and a normally open signal energy interruption control switch, a plate circuit for the second amplifier, a first rectifier having its positive side connected to the plate of the second amplifier through the medium of a coupling condenser and its negative side connected to the control grid element of the first amplifier, and a second rectifier having its negative side connected to the positive side of the first rectifier and its positive side connected to the negative side of the plate circuit of the second amplifier, whereby when said signal interruption control switch is closed, amplified signal energy in the plate circuit of the second amplifier will be increased in value, rectified and applied as a negative D. C. grid bias potential to the control grid of the first amplifier, the value of the potential thus applied being sufficient to bias the first amplifier to plate current cut off.

4. In an audiometer, a normally operative first electronic signal amplifier having plate and cathode and control grid elements, a plate circuit for the first amplifier coupled to the electrical output of the audiometer, two sources of test signal energy, switch means for selectively and singularly coupling the two sources of signal energy to the control grid element of the first amplifier to drive the same, and a normally inoperative control system for biasing the first amplifier to plate current cut off to thereby interrupt delivery of signal energy to the electrical output of the audiometer, said control means comprising a second electronic amplifier having plate and cathode and control grid elements, a normally open control grid driving circuit for the second amplifier having interposed therein a normally open interrupter switch, a plate circuit for the second amplifier, a first rectifier having its negative side coupled to the control grid of the first amplifier, a condenser interposed between the positive side of said rectifier and the plate element of the second amplifier, and a second rectifier having its negative side coupled to the positive side of the first rectifier and its positive side connected to the negative side of the plate circuit of the second amplifier.

5. In an audiometer, a normally operative two-stage amplifier, each stage of which has plate and cathode and control grid elements, a source of test signal energy having its output coupled to the control grid of the first stage of said two-stage amplifier to drive the same, a plate circuit for the first stage of said two-stage amplifier, means coupling the plate circuit of the first stage

of said amplifier to the control grid element of the second stage of said amplifier to drive the same, a plate circuit for the second stage of the 2-stage amplifier coupled to the electrical output of the audiometer, means normally biasing the first and second stages of said amplifier to operate at normal plate current, and a normally inoperative signal energy interrupter for said audiometer comprising a second electronic amplifier, a normally open control grid driving circuit for the second amplifier having interposed therein a normally open interrupter switch, a plate circuit for the second amplifier and a rectifier having its positive side coupled to the plate of the second amplifier and its negative side coupled to the control grids of the first and second stages of the first-said amplifier to apply a negative D. C. grid biasing potential to the said grids of the first amplifier, the value of the D. C. biasing potential thus applied to the control grid elements of the first and second stages of the first amplifier being sufficient to completely eliminate the signal voltage in the plate circuit of the second stage of said amplifier.

6. In a multiple channel audiometer, a first signal channel comprising an electronic amplifier, a second signal channel comprising an electronic amplifier, a signal generator common to the two said channels, means for coupling the output of the signal generator to the control grid of each of said amplifiers to drive the same, a plate circuit for each said amplifier coupled to the electrical output of the signal channel of which said amplifier is a part, and a normally inoperative manually controlled signal interrupter system for each said signal channel, each said interrupter system comprising an electronic amplifier having plate and cathode and control grid elements, manually controlled circuit means for driving the control grid of each control system amplifier, each such means comprising a manually-operated interrupter switch, a plate circuit for each said control system amplifier and circuit means coupling the plate circuit of each said control system amplifier to an element of a different one of said signal channel amplifiers other than the plate element thereof, each last said circuit means comprising a rectifier for rectifying the current impressed upon the coupled element of the signal channel amplifier, the D. C. control potential thus applied to the coupled elements of the signal channel amplifiers being of proper polarity and sufficient value to reduce the amplification factor of that amplifier to a point where the signal energy will be eradicated in the output of that signal channel.

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