

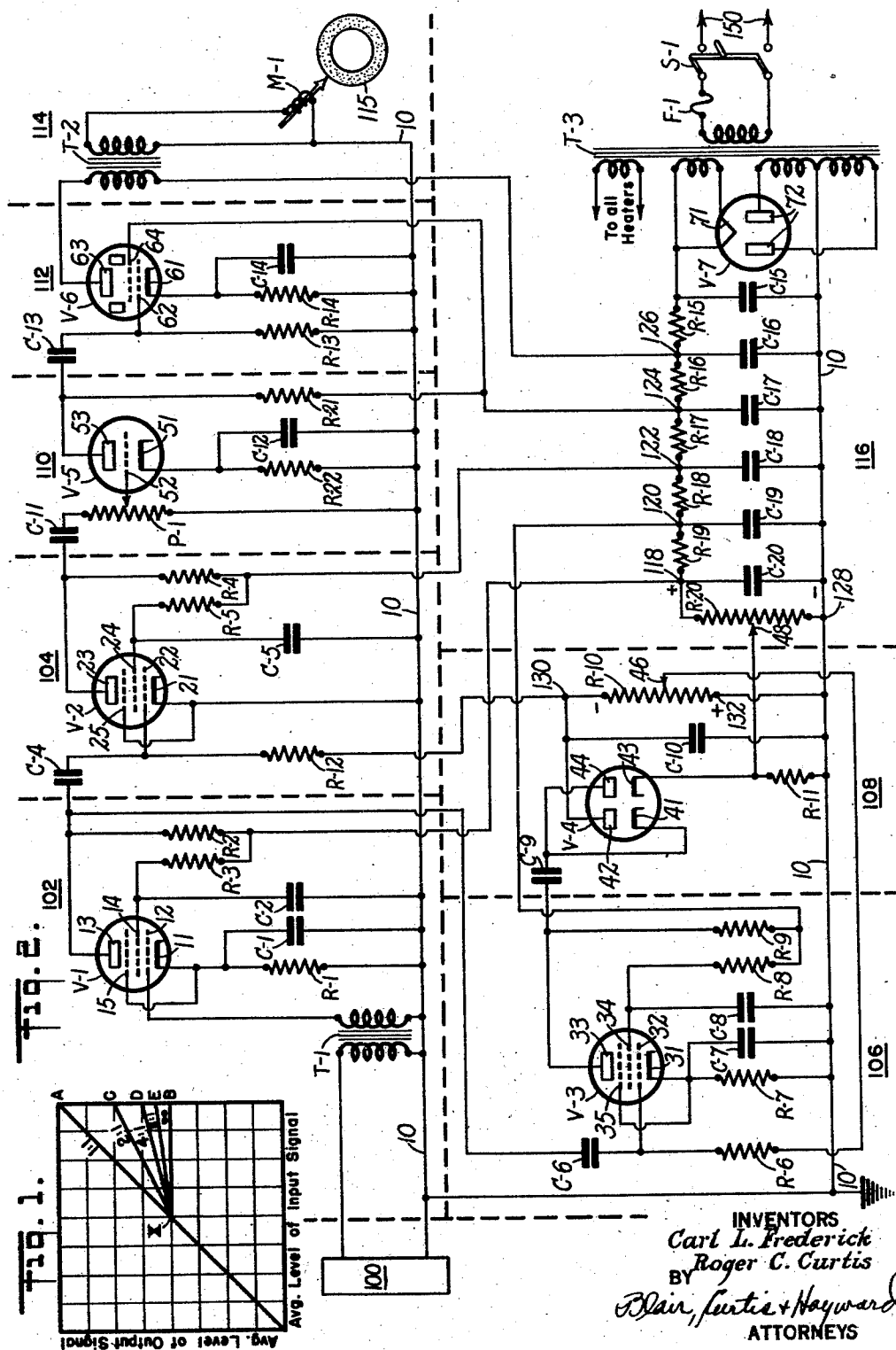
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ELECTRONIC AMPLIFIER CONTROL SYSTEM

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ELECTRONIC AMPLIFIER CONTROL
SYSTEM

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This invention relates to electronic tube amplifier control systems for use in sound recording equipment and, more particularly, to arrangements in such amplifiers for automatically controlling the output volume in accordance with some function of the volume of the signal being amplified.

In sound recording systems to be used to make sound records from a wide variety of sources, such as telephone conversations, conferences, office dictation, radio, and the like, in which the initial sounds have a wide range of average input signal levels, e. g. from -120 db. to +10 db., and a wide range of volume variations at such average levels, e. g. 60 to 70 db., it is necessary to amplify all signals, regardless of their diverse initial levels, to the particular average level necessary to operate the recorder element, e. g. 10 to 20 db., and to reduce the range of volume variation in the amplified signals to a sufficiently narrow range so that the recorder element will not "blast" or "overcut," e. g. a range of 25 to 30 db. In the past it has been customary to attempt to achieve these results by the use of automatic volume control circuits, commonly abbreviated "A. V. C. circuits." These circuits have been of two general types: the "forward-acting" type and the "backward-acting" type. The first is a circuit in which a portion of the input signal is amplified by a separate amplifier, rectified, and fed in a negative sense as an operating grid bias to the control grid of one of the amplifier tubes of the variable-gain, e. g. remote-cut-off, type so as to control the gain of the amplifier system in accordance with the volume of the input signal. In the "backward-acting" type, a portion of the output signal is rectified and fed back as an operating grid bias to the control grid of one of the amplifier tubes to control the amplification factor of the amplifier system in a similar manner. The first, or "forward-acting" type, system is relatively simple to design and operate, its operating characteristic tending to be degenerative, but it is subject to the disadvantage that the amplifier output level is maintained practically constant regardless of input level so that, if its speed of response is sufficiently fast to be of practical use, it completely robs the amplified signal of what might be called "volume level perspective," i. e. a relative difference in volume level between loud and soft passages in the amplified signal, producing a substantially mono-level output, which usually is highly undesirable. The curve of such an operating characteristic is shown at B in Figure 1. The sec-

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ond, or "backward-acting" type of automatic volume control is of the "compression" variety. It causes the amplifier to operate as a non-linear amplifier in which the range of volume change at its input is reduced in accordance with some predetermined ratio at its output. For example, assuming the amplifier to have a 2 to 1 compression ratio, if the input signal varies through a range of 40 db., the output signal will only vary through a range of 20 db. The curve of such an operating characteristic is shown at C in Figure 1. Such a system has the advantage of maintaining "volume level perspective" while still reducing the volume range of the signal to be recorded to the volume range which can be handled by the recorder element. However, it has the disadvantage that its operating characteristic tends to be regenerative so that it is subject to "motor-boating" even when carefully designed unless it is provided with circuits having long time-constants, a design feature which renders it useless for many practical applications.

In accordance with the present invention, compression of the amplified signal to a desired limited volume range throughout a wide range of input signal levels is accomplished with a "forward-acting" type of A. V. C. circuit by the provision of a novel control arrangement. A portion of the input signal potential is amplified, rectified to provide a D. C. potential and then is applied as an A. V. C. operating bias on one of the amplifier tubes, all in the usual manner. However, at the same time, a portion of this A. V. C. D. C. potential is fed back to control the amplification factor of the tube amplifying the portion of the input signal which is fed to the A. V. C. circuit. This novel arrangement permits effective A. V. C. operation throughout a very wide range of input signal levels and also preserves "volume level perspective" in the amplified output signal.

Accordingly, it is an object of the present invention to provide a novel "forward-acting" type A. V. C. system which incorporates the advantages but none of the disadvantages of the "backward-acting" type of A. V. C. system. It is a further object of the present invention to provide such an A. V. C. system in which the compression ratio may be varied throughout a wide range, and one which operates properly throughout a wide range of input signal levels without blocking or overloading of the A. V. C. circuit components. These and other apparent objects and advantages of this invention are obtained by the means described in the following specifica-

tion and may be more readily understood by reference to the accompanying drawings wherein:

Figure 1 shows typical operating characteristic curves of various types of automatic volume control systems including those of an amplifier system embodying the present invention; and

Figure 2 shows the schematic wiring diagram of an amplifier system embodying the present invention.

Curve A represents the operating characteristic, i. e. the relationship of the input volume level to output volume level, of a theoretically perfect amplifier not provided with any A. V. C. circuit, in which the output level varies directly with the input level. Curve B shows the operating characteristic curve of a typical amplifier equipped with the usual "forward-acting" type of A. V. C. circuit in which the output increases in direct proportion to the input level up to the point, point X in Figure 1, at which the A. V. C. circuit commences to function, after which the output is held at a substantially constant level regardless of further increase in the level of the input signal. Curve C is the operating characteristic curve of a typical amplifier equipped with the usual type of "backward-acting" A. V. C. circuit in which the output level increases directly with the input level up to the point X at which the A. V. C. circuit becomes effective and thereafter at a predetermined rate at some fixed ratio with respect to the rate of increase of the input signal, e. g. usually at a ratio of 2 to 1. In accordance with the present invention, an operating characteristic curve of the type illustrated by curve C can be achieved with a "forward-acting" A. V. C. circuit and the slope of the curve above the point X, usually called the "compression ratio" of the A. V. C. circuit, can be adjusted to suit the particular needs of the recording being made.

Referring to Figure 2, the schematic wiring diagram of an electronic tube amplifier incorporating an A. V. C. circuit embodying the present invention is shown. This recording amplifier includes a source of signal to be recorded, generally indicated by the enclosed area 100, such as a microphone, telephone, radio or the like; a pre-amplifier stage, generally indicated at 102, and including an input transformer T-1 and a pentode amplifier tube V-1; an A. V. C. controlled amplifier stage, generally indicated at 104, including a variable-mu pentode tube V-2; an A. V. C. circuit comprising, an A. V. C. potential amplifying stage, generally indicated at 106, including a variable-mu pentode tube V-3, and an A. V. C. potential rectifier circuit generally indicated at 108, including a double diode rectifier tube V-4; a driver stage, generally indicated at 110, including a triode amplifier tube V-5; a power amplifier stage, generally indicated at 112, including a beam power pentode tube V-6; an output circuit, generally indicated at 114, including an output transformer T-2 and a recorder element M-1; and a power supply circuit, generally indicated at 116, including a full-wave rectifier tube V-7 and a power transformer T-3, for supplying operating potentials to all of these amplifier portions.

The signal to be recorded from the signal source 100 is impressed through the input transformer T-1 to the grid 12 of the pre-amplifier pentode V-1 of the pre-amplifier stage 102. This pre-amplifier pentode V-1 is provided with the customary cathode bias resistor R-1 with its bypass condenser C-1 connected to a common ground

circuit 10, and its suppressor grid 15 is connected to its cathode 11 in the usual manner. Its plate 13 is connected through a plate load resistor R-2 and its screen grid 14 through a series resistor R-3 to a suitable positive high voltage terminal 118 in the power supply 116, the screen grid 14 also being bypassed to ground by a bypass condenser C-2. The amplified signal appearing across the plate resistor R-2 is applied through a coupling condenser C-4 to the control grid 22 of the remote-cut-off screen grid pentode tube V-2 in the amplifier A. V. C. stage 104 where it is amplified in the normal manner so that the amplified signal appears across its plate load resistor R-4, which is connected to a positive high voltage terminal 122 in the power supply 116. The suppressor grid 25 of the pentode V-2 is connected to the cathode 21 in the usual manner, the cathode 21 in turn being connected to the common ground circuit 10. The pentode V-2 is also provided with a screen grid series resistor R-5 and bypass condenser C-5.

The amplified signal from the pre-amplifier stage 102 is also fed to the A. V. C. potential amplifying stage 106 through a coupling condenser C-6 to the control grid 32 of the pentode tube V-3 where it is amplified before being rectified by the A. V. C. rectifier circuit 108. This A. V. C. potential amplifying tube V-3 is provided with the usual grid return resistor R-6, cathode bias resistor R-7 with its bypass condenser C-7, and screen grid resistor R-8 with its bypass condenser C-8 and plate load resistor R-9 connected to a positive high voltage tap 120 in the power supply 116. Its suppressor grid 35 is connected to its cathode 31 in the usual manner. The amplified A. V. C. potential which appears across the plate resistor R-9 of amplifier tube V-3 is applied through a coupling condenser C-9 to the A. V. C. rectifier tube V-4. This rectifier tube V-4 is a double diode connected in a voltage-doubler arrangement as shown in the diagram, so that the rectified A. V. C. pulsating D. C. potential appears across resistor R-10 shunted by a condenser C-10. Briefly, this voltage doubler rectifier arrangement operates as follows: During the portion of the cycle of the signal impressed on the grid 32 of A. V. C. potential amplifying tube V-3 when the grid is going negative, the current through this tube decreases, thus decreasing the voltage drop across plate resistor R-9 and increasing the positive potential above ground of plate 33 and the side of the coupling condenser C-9 connected thereto. This causes condenser C-9 to be charged through the cathode 43 and the anode 44 of one of the diodes of rectifier tube V-4 to a voltage equal to the peak value of this voltage change. During the next half cycle of the signal voltage, when the grid 32 of tube V-3 goes positive, the current through tube V-3 increases, thus increasing the voltage drop across the plate resistor R-9 and thereby decreasing the potential above ground of the plate 33 of tube V-3 and, thus, of the plate of condenser C-9 connected to this resistor. This, in turn, causes condenser C-9 to discharge through cathode 41 and anode 42 of the other diode of rectifier tube V-4 and condenser C-10, thereby causing condenser C-10 to be charged to a voltage substantially equal to the voltage change across the plate resistor R-9 of tube V-3 during one complete cycle of the signal voltage. This discharge of condenser C-9 prepares it for the next negative half cycle of the signal voltage and, at the same time, pro-

duces across resistor R—10 the D. C. potential to be used as the A. V. C. control potential which is a function of the magnitude of the input signal. A part of this potential, determined by the position of a slider 46 on resistor R—10, is applied as a negative operating bias to the A. V. C. potential amplifying pentode V—3 by means of a connection from this slider 46 through the grid return resistor R—6 to the control grid 32 of tube V—3. With this novel arrangement of applying a portion of the A. V. C. D. C. potential back to the grid of the A. V. C. potential amplifying tube V—3, an A. V. C. effect is superimposed upon the original A. V. C. effect so as to greatly increase the signal range over which the A. V. C. circuit is effective. As will hereinafter be described, by suitably positioning the slider 46 on resistor R—10 to determine the portion of the A. V. C. D. C. potential fed back to tube V—3, the slope of the A. V. C. operating characteristic curve can be predetermined as desired. A bias resistor R—11 is connected in the circuit between the cathode 43 of rectifier tube V—4 and the common ground circuit 10 and the cathode end of this resistor R—11 is connected to a sliding contact 48 on a bleeder resistor R—20 connected across the output terminals 118 and 128 of the power supply 116. With the connection just indicated, a positive bias potential is applied to the cathode 43 of one diode of the A. V. C. rectifier tube V—4 to provide a bias which prevents the A. V. C. circuit from operating until the signal voltage exceeds a predetermined value, as will hereinafter be described in greater detail. The A. V. C. D. C. potential developed across resistor R—10 is applied through a connection from the negative end 130 of this resistor through a grid resistor R—12 to the control grid 22 of the amplifier A. V. C. tube V—2 to control the amplification factor of this tube and thus determine the extent of amplification of the signal in the amplifier system.

The volume-controlled amplified signal appearing across the plate resistor R—4 of the A. V. C. amplifier tube V—2 is applied through a coupling condenser C—11 and a recording level control potentiometer P—1 to the control grid 52 of the driver tube V—5. This amplifier tube V—5 is provided with the usual cathode bias resistor R—22 with its bypass condenser C—12 connected to the common ground circuit 10, and its plate 53 is connected through a plate load resistor R—21 to a suitable high voltage tap 124 in the power supply 116. The output of the driver stage 110 is applied to the power output amplifier stage 112 by connecting the plate 53 of the driver tube V—5 through a coupling condenser C—13 to the control grid 62 of the beam power pentode V—6. The control grid 62 of tube V—6 is also connected to the common ground circuit 10 through the usual grid resistor R—13 and its cathode 61 is connected to this ground circuit 10 through the customary cathode biasing resistor R—14 with its bypass condenser C—14. The circuit of the power amplifier stage 112 is of conventional design. The anode 63 of tube V—6 is connected to one side of the primary of the output transformer T—2, the other side of which is connected to a suitable high voltage tap 126 in the power supply 116. The screen grid 64 is connected to another tap 124 therein of slightly lower voltage. The secondary of the output transformer T—2 is connected to the recorder element M—1 and one side of this secondary is connected to the common ground circuit 10.

This recorder element M—1 may be of any suitable type, such as that shown in U. S. Patent No. 2,054,980 to M. J. Johnson for impressing the usual sound groove on a suitable recording medium, such, for example, as the wax cylinder 115 shown in the drawings.

The power supply 116 is of the conventional full-wave rectifier type. It includes a power supply transformer T—3 the primary of which is connected to an alternating current supply line 150 through a fuse F—1 and a double-pole single-throw "off-on" switch S—1, and a full-wave rectifier tube V—7 having a cathode 71 and two anodes 72 connected in the usual manner to the high voltage secondary of the transformer T—3 and to a filter system comprising a plurality of filtering resistors R—15, R—16, R—17, R—18, R—19, the bleeder resistor R—20, and filter condensers C—15, C—16, C—17, C—18, C—19 and C—20 connected in the usual manner. It provides D. C. operating potentials between the negative terminal 128 and a plurality of positive high voltage terminals 118, 120, 122, 124 and 126 connected to the various amplifier circuit portions as above-described.

In the amplifier system just described incorporating the novel "forward-acting" A. V. C. circuit embodying the present invention, it is possible to achieve the desirable operating characteristics shown by curve C in Figure 1 of a "backward-acting" A. V. C. arrangement, i. e., the retention of "volume level perspective," without the disadvantages inherent therein, and to set the slope of the A. V. C. operating characteristic curve at any value desired between that of the normal "backward-acting" A. V. C. arrangement shown by curve C, i. e. a compression ratio of approximately 2 to 1, and that of the normal "forward-acting" A. V. C. circuit illustrated by curve B in Figure 1, i. e. an infinite compression ratio. Such an adjustment of the compression ratio of the A. V. C. circuit is accomplished by adjustment of the slider 46 on the resistor R—10. If this slider is moved to the positive terminal 132 at the end of resistor R—10, none of the A. V. C. D. C. potential is fed back to the A. V. C. potential amplifying tube V—3, and thus the circuit operates as a normal "forward-acting" A. V. C. circuit providing an operating curve similar to curve B of Figure 1. If the slider 46 is moved to the other terminal 130 at the negative end of resistor R—10 so that the entire A. V. C. D. C. potential is fed back to the control grid 32 of A. V. C. potential amplifying tube V—3, as well as the control grid 22 of the A. V. C. amplifier tube V—2, then the operating characteristic curve of the amplifier system is that of the usual "back-acting" A. V. C. circuit corresponding to curve C of Figure 1 having an approximate 2 to 1 compression ratio. By positioning the slider 46 at some point intermediate terminals 130 and 132 of resistor R—10 intermediate compression ratios can be obtained as, for example, compression ratios of 4 to 1 or 8 to 1 as illustrated by curves D and E, respectively, of Figure 1. Additional flexibility in the control of the characteristics of the A. V. C. system embodying the present invention, is achieved by the provision of the slider 48 on the bleeder resistor R—20. As above described, the setting of this slider 48 determines the amount of fixed positive bias applied to the cathode 43 of the A. V. C. rectifier tube V—4, thus affecting the point on the operating curve at which the A. V. C. circuit goes into operation. In addition to per-

mitting control of the slope of the A. V. C. characteristic curve over wide limits, the novel A. V. C. circuit arrangement of the present invention makes possible an A. V. C. arrangement which operates over an exceptionally wide range of input signal levels, a feature which is of considerable importance in making satisfactory sound recordings from a wide variety of signal sources. In the usual A. V. C. circuit, when the A. V. C. potential amplifying tube, i. e. tube V—3, is operated with sufficiently high operating potentials to quickly charge the A. V. C. condenser C—10 and thus permit rapid operation of the A. V. C. circuit, an operating characteristic which is necessary in many sound recording systems, the A. V. C. potential amplifying tube V—3 tends to become saturated and block at high input signal levels if it is effective at low levels. On the other hand, if its circuit is adjusted so that it is operative on high input signal levels, it is ineffective when the input signal level is very low, thus limiting the input signal level range over which the A. V. C. circuit is effective. In accordance with the present invention, this disadvantage is overcome by the novel feature of feeding back a portion of the A. V. C. potential to the A. V. C. potential amplifying tube so that its range of effective operation is considerably extended.

As many embodiments may be made in the above invention and as many changes may be made in the embodiment above described, it is to be understood that all matters hereinbefore set forth or shown in the accompanying drawing is to be interpreted as illustrative only and not in a limiting sense.

We claim:

1. In an electronic tube amplifier system for sound recording, an A. V. C. compression circuit, comprising, in combination, first amplifier means including A. V. C. means responsive to a D. C. bias potential for controlling its gain, means for applying the signal to be amplified to the input circuit of said first amplifier means, means for connecting the output circuit of said first amplifier means to the output circuit of said amplifier system, second amplifier means including A. V. C. means responsive to a D. C. bias potential for controlling its gain, means for applying the input signal to the input circuit of said second amplifier means, means for converting the amplified signal output of said second amplifier means into a D. C. potential, means for applying said D. C. potential as an A. V. C. potential to control the amplification of said first amplifier means, and means for applying a predetermined portion of said D. C. potential as an A. V. C. potential to control the amplification of said second amplifier means.

2. In an electronic tube amplifier system for sound recording, an A. V. C. compression circuit, comprising, in combination, first amplifier means including A. V. C. means responsive to a D. C. bias potential for controlling its gain, means for applying the signal to be amplified to the input circuit of said first amplifier means, means for connecting the output circuit of said first amplifier means to the output circuit of said amplifier system, second amplifier means including A. V. C. means responsive to a D. C. bias potential for controlling its gain, means for applying the input signal to the input circuit of said second amplifier means, means for converting the amplifier signal output of said second amplifier means into a D. C. potential, means for applying said D. C. potential as an A. V. C. potential to control the

amplification of said first amplifier means, means for applying a predetermined portion of said D. C. potential as an A. V. C. potential to control the amplification of said second amplifier means, and means for biasing said converter means to render it inoperative until the amplified signal output from said second amplifier means reaches a predetermined value.

3. An A. V. C. compression circuit for use in an electronic tube amplifier system, comprising, in combination, a first A. V. C. amplifier circuit including a first variable-mu pentode tube, a second A. V. C. amplifier circuit including a second variable-mu pentode tube, an input circuit for applying the signal to be amplified to the input of said first A. V. C. amplifier circuit and to the input of said second A. V. C. amplifier circuit, an output circuit for connecting the output circuit of said first amplifier circuit to the remainder of said amplifier system, rectifier means for changing the amplified signal output of said second amplifier circuit into a D. C. A. V. C. potential, means connecting the D. C. output of said rectifier means to the control grid circuit of said first pentode tube as an A. V. C. grid biasing potential, and voltage control means applying a predetermined portion of the D. C. output of said rectifier means to the control grid of said second pentode as an A. V. C. grid biasing potential to permit adjustment of the compression ratio of said A. V. C. circuit.

4. An A. V. C. compression circuit for use in an electronic tube amplifier system, comprising, in combination, a first A. V. C. amplifier circuit including a first variable-mu pentode tube, a second A. V. C. amplifier circuit including a second variable-mu pentode tube, an input circuit for applying the signal to be amplified to the input of said first A. V. C. amplifier circuit and to the input of said second A. V. C. amplifier circuit, an output circuit for connecting the output circuit of said first amplifier circuit to the remainder of said amplifier system, rectifier means for changing the amplified signal output of said second amplifier circuit into a D. V. A. V. C. potential, means connecting the D. C. output of said rectifier means to the control grid circuit of said first pentode tube as an A. V. C. grid biasing potential, voltage control means applying a predetermined portion of the D. C. output of said rectifier means to the control grid of said second pentode as an A. V. C. grid biasing potential to permit adjustment of the compression ratio of said A. V. C. circuit, and means for applying a positive D. C. bias to the cathode of said rectifier means to permit the amplified signal output of said amplifier circuits to reach a predetermined level before said A. V. C. circuit becomes effective.

5. In an electronic tube amplifier system, an automatic volume compression circuit, comprising, in combination, first amplifier means including means for controlling its gain in accordance with a bias potential, means applying the signal to be amplified to the input circuit of said first amplifier means, means connecting the output circuit of said first amplifier means to the output circuit of said amplifier system, second amplifier means including means for controlling its gain responsive to a bias potential, means applying the input signal to the input circuit of said second amplifier means, means applying a first predetermined portion of the amplified signal output of said second amplifier means to the gain control means of said first amplifier means, and means applying a second predetermined portion

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of the amplified signal output of said second amplifier means to the gain control means of said second amplifier means.

6. In an electronic tube amplifier system for sound recording, the method of automatically compressing the magnitude of the output signal in accordance with the magnitude of the input signal which comprises the steps of performing a first amplification operation on said input signal, performing a second and separate amplification operation on said input signal, producing a control potential in accordance with the magnitude of the amplified output signal of said second amplification operation, controlling the gain of said first amplification operation with said control potential, simultaneously controlling the gain of said second amplification operation with said control potential, and applying the amplified signal output of said first amplification operation to the output portion of said amplifier system.

7. In an electronic tube amplifier system for sound recording, the method of automatically compressing the magnitude of the output signal in accordance with the magnitude of the input signal which comprises the steps of performing

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a first amplification operation on said input signal, performing a second and separate amplification operation on said input signal, rectifying the output signal of said second amplification operation to produce a D. C. control potential, applying said D. C. control potential to control the gain of said first amplification operation, simultaneously applying a portion of said D. C. control potential to control the gain of said second amplification operation, and applying the amplified signal output of said first amplification operation to the output portion of said amplifier system.

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