

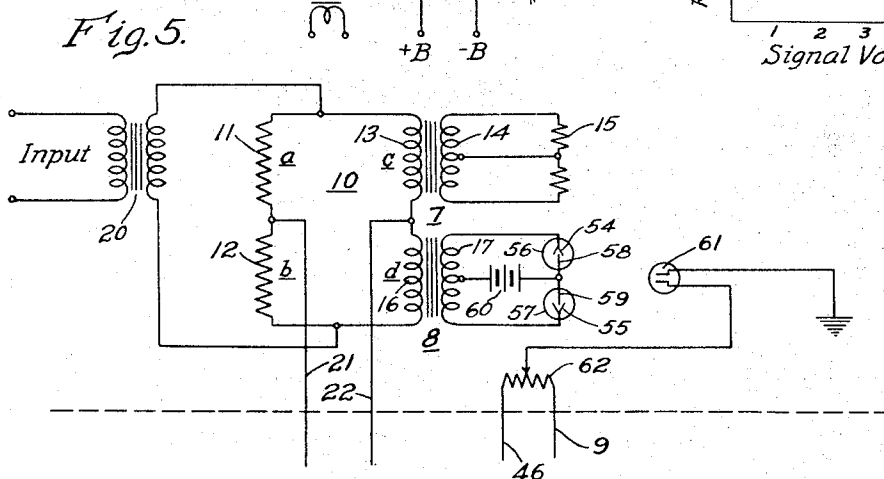
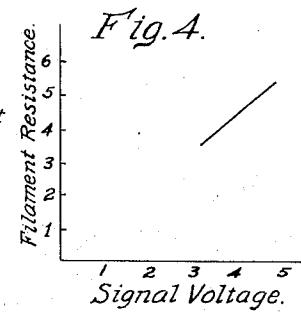
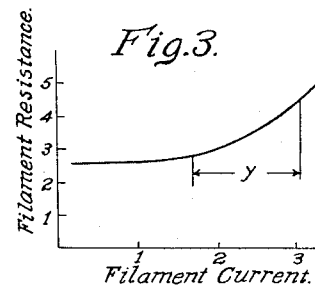
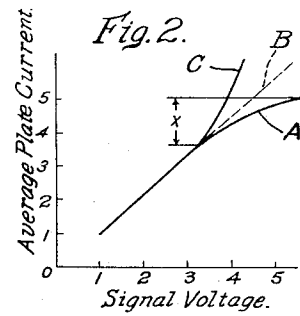
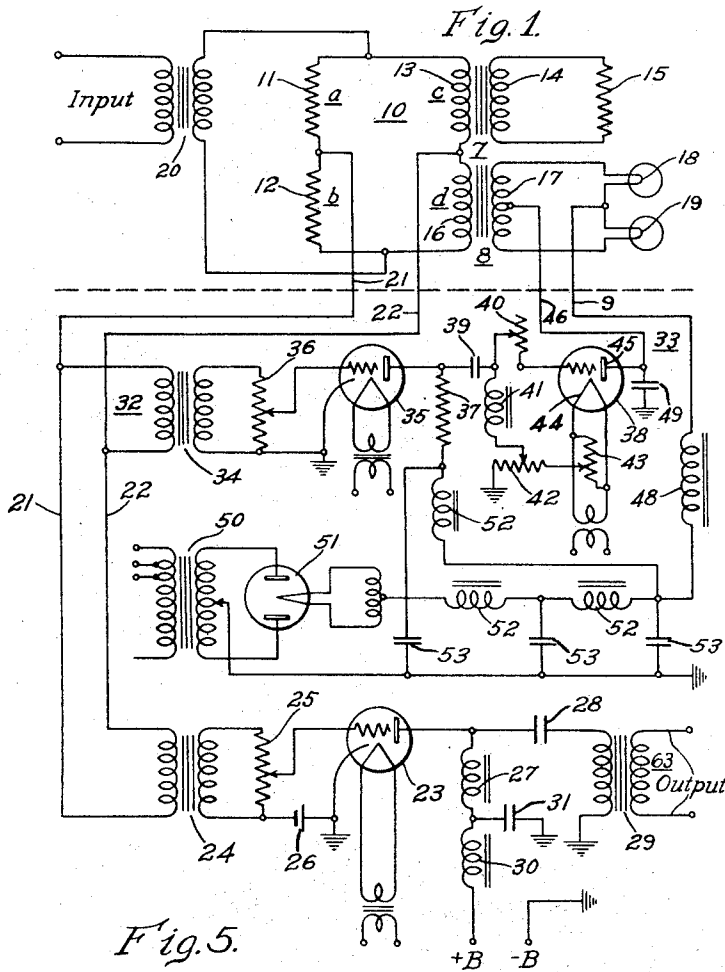
Dec. 26, 1933.

H. I. METZ

1,940,874

AUTOMATIC VOLUME CONTROL

Filed Feb. 9, 1932



WITNESSES:

C. J. Keller.
F. M. Harris

INVENTOR
Henry I. Metz.
BY *F. W. Lyle.*
ATTORNEY

UNITED STATES PATENT OFFICE

1,940,874

AUTOMATIC VOLUME CONTROL

Henry I. Metz, Chicopee Falls, Mass., assignor to
Westinghouse Electric & Manufacturing Com-
pany, a corporation of Pennsylvania

Application February 9, 1932. Serial No. 591,814

4 Claims. (Cl. 178—44)

My invention relates to volume control appa-
ratus and particularly to apparatus designed to
compress the wide range of volume levels encoun-
tered in music and speech before they are im-
pressed upon a radio transmitter or upon record-
ing apparatus.

The range in volume levels for speech and
music is so great that it is undesirable to impress
energy having the same variation in amplitude
directly upon radio transmitter or recording ap-
paratus. If the volume is too great, the appa-
ratus is overloaded and distortion results. If the
volume is too low, the signals will be transmitted
inefficiently by a radio transmitter; also, the
"noise to signal" ratio will be too great.

Formerly, the volume has been controlled man-
ually by an operator located in the control room
of the broadcast or recording studio.

It is an object of my invention to effect volume
control of the above-mentioned type by means
of apparatus which automatically controls the
volume.

It is a further object of my invention to so
automatically control the volume that the rela-
tive effects of soft and loud signals will be un-
changed.

It is a still further object of my invention to
provide apparatus for preventing more than 100%
modulation.

It is a still further object of my invention to
provide apparatus of the above-mentioned type
which is comparatively inexpensive and compact
in design.

In practicing my invention, I impress the speech
or music upon the input circuit of an unbalanced
Wheatstone bridge having resistance arms, the
amplitude of the current in the output circuit
of the bridge depending upon the amount the
bridge is unbalanced. The degree of unbalance
is controlled by means of a variable resistor in
one arm of the bridge, the value of the resistor
being determined by the amplitude of the signal
current in the output circuit.

In one modification of my invention, the vari-
able resistor is heated by current having a value
proportional to the output current of the bridge,
the resistor being of material such as tungsten
so that its resistance increases with an increase
in temperature.

In another modification of my invention, de-
signed to prevent more than 100% modulation,
the variable resistor comprises a pair of photo-
electric cells. The resistance of the cells is de-
termined by a beam of light, the intensity of
which varies in accordance with the output cur-
rent of the bridge.

Other features and advantages of my invention
will appear from the following description taken
in connection with the accompanying drawing,
in which:

Figure 1 is a circuit diagram of a volume con-
trol system constructed in accordance with my
invention,

Fig. 2 is a curve showing a characteristic of
a class B amplifier employed in my system.

Fig. 3 is a curve showing the temperature-re-
sistance characteristic of the variable resistor in
the bridge arm,

Fig. 4 is a curve showing how the two above-
mentioned characteristics may be combined to
produce a straight-line curve, and

Fig. 5 is a circuit diagram illustrating a modifi-
cation of my invention.

Referring to Fig. 1, the apparatus comprises a
Wheatstone bridge 10 having four resistance
arms, *a*, *b*, *c* and *d*. In the left-hand arms *a*
and *b*, the resistance units 11 and 12 are con-
nected directly into the circuit. In the right-
hand arms *c* and *d*, the resistance is connected
into the bridge through transformers 7 and 8.

The arm *c* comprises the transformer primary
13 connected directly into the bridge circuit. Its
secondary winding 14 has a resistance unit 15
connected across it.

The arm *d* comprises the transformer primary
16 connected directly into the bridge. The sec-
ondary 17 of the transformer 8 is connected to
two resistance units 18 and 19 connected in se-
ries. The resistance units 18 and 19 may be the
filaments of UX 199 vacuum tubes. The trans-
formers 7 and 8 preferably have cores of an iron-
nickel alloy, such as Hipernik.

The input circuit is connected across one diag-
onal of the bridge through a transformer 20. The
output circuit comprising conductors 21 and 22 is
connected across the other diagonal of the bridge.

The output of the bridge is amplified and trans-
mitted to a telephone line 63 or directly to a radio
transmitting station or to recording apparatus by
means of an amplifier tube 23 to which the con-
ductors 21 and 22 are connected.

The conductors 21 and 22 are connected to the
input circuit of the amplifier tube 23 through a
transformer 24 a volume control potentiometer 25
and a biasing battery 26. The output of the tube
23 is connected to the line 63 by means of a cou-
pling choke coil 27 a condenser 28 and a trans-
former 29. The choke coil 30 and condenser 31
comprise a portion of the usual filter apparatus.
The amplifier tube 23 is of the three-electrode
indirectly-heated cathode type.

The arm *d* of the bridge is normally given such
a low resistance value that the bridge is unbal-
anced to a large degree and a large proportion
of the input energy appears in the bridge output
circuit. If the increase in volume in the input
circuit were too great, the increase in volume in
the output circuit would also be too great if the
unbalance of the bridge remained unchanged. In
accordance with my invention, the bridge is caused

to become more nearly balanced as the volume of the input energy increases. Therefore, the increase in volume in the output circuit is less than it would be otherwise.

5 The control of the bridge balance is accomplished by means of an amplifier which has its input circuit 32 connected to the output circuit of the bridge and its output circuit 33 connected to the bridge arm *d*. The input of this amplifier is shown connected to the output circuit of the bridge through the transformer 34 which is connected to the bridge output conductors 21 and 22.

The secondary of the transformer 34 is connected to the grid and cathode of an amplifier tube 35 through a volume control potentiometer 36. The plate of the amplifier tube 35 is connected to a source of positive potential through a resistor 37 and to the input circuit of the amplifier tube 38 through a coupling condenser 39 and a variable resistor 40. The amplifier tube 38 is adjusted to operate as a class B amplifier.

A class B amplifier is defined as one which operates so that the power output is proportional to the square of the excitation voltage. This is accomplished by operating the amplifier tube with a negative grid bias such that the plate current is almost zero with no excitation. An excitation grid voltage is applied such that essentially half sine-waves of plate current are produced on the least negative half-cycle of the grid voltage. The grid usually swings positive on the excitation peaks.

The point between the coupling condenser 39 and the variable resistor 40 is connected through a choke coil 41 to a grid biasing resistor 42. The biasing resistor 42 is connected between ground and the mid-point on a resistor 43 connected across the filament 44.

The plate 45 of the amplifier tube 38 is connected to a source of positive potential through a circuit which may be traced from the plate 45 through the conductor 46 through both the upper half of the transformer winding 17 and the resistance unit 18 and the lower half of the transformer winding 17 and the resistance unit 19 and through the conductor 9 and the choke coil 48 to the positive terminal of the filter. A by-pass condenser 49 is connected between the plate 45 and ground.

50 The conductors 46 and 9 are connected to the mid-points of secondary 17 and resistors 18 and 19, respectively, for two reasons. One reason is that, by having the plate current of tube 38 flow through the winding 17 in opposite directions, saturation of the Hipernik core is avoided. The other reason is that undesirable interaction between the control or plate current of tube 38 and the audio signal in the bridge circuit is prevented.

60 The rectifier-filter unit for supplying plate potential is of conventional construction and comprises a transformer 50, a double wave rectifier tube 51 and a filter having series inductance coils 52 shunted by condensers 53.

65 It will be understood from the foregoing description that as the signal volume at the bridge input increases, the unbalance of the bridge is decreased by means of the increased heating current supplied by the amplifier tube 38. One reason for operating the tube 38 as a class B amplifier is that its average plate current increases with increases in grid excitation. The tube 38 may be looked upon as a form of amplifier.

70 Another reason for operating amplifier tube 38 class B is that the resistance of the resistors 18

and 19 changes with current passed therethrough in the manner shown in Fig. 3. It is desired that the resistance of resistors 18 and 19 change in a straight line relation with respect to the signal voltage across reactor 41 as shown in Fig. 4, to obtain a uniform change in volume with change in signal level. This operation is obtained by so adjusting the linearity compensator resistor 40 that the output current of tube 38 follows curve A of Fig. 2 where the plate current is plotted against the signal voltage across reactor 41.

The resistor 40 is effective in changing the plate current-signal voltage curve of tube 38 for the reason that the grid draws current at the peak excitation voltages. With the resistance of resistor 40 set at zero, the plate current follows the curve C of Fig. 2. If its resistance is set at a low value the plate current follows the curve B. A still further increase in the resistance of resistor 40 results in the curve A having the proper shape to combine with the curve shown in Fig. 3 to give the straight line curve of Fig. 4.

It is evident from the above description that the linearity compensator resistor 40 determines how uniformly the volume control operates with changes in signal level. The adjustment of the potentiometer 36, on the other hand, determines the amount that the signal volume is compressed.

The modified circuit shown in Fig. 5 is the same as that shown in Fig. 1, except that the resistance units 18 and 19 have been replaced by photo-electric cells controlled by a neon lamp. The cathodes 54 and 55 of the photo-electric cells 56 and 57, respectively, are connected to the terminals of the transformer secondary winding 17, while the anodes 58 and 59 are connected together and connected to the mid-point of the transformer winding 17 through a battery 60. The resistance of the photo-electric cells 56 and 57 depends upon the intensity of the light emitted from a neon lamp 61. The neon lamp 61 is connected between ground and a point on a resistor 62 in the plate circuit of the vacuum tube 38.

If the current in the bridge output circuit increases, the current in the resistor 62 increases, and the voltage impressed across the neon lamp 61 increases so that the lamp emits a more intense light. This increase in light intensity decreases the resistance of the photo-electric cells 56 and 57 and the resistance of the bridge arm *d* is decreased to improve the balance of the bridge. It is to be understood that the bridge was unbalanced by making the resistance of the arm *d* too high.

In the case of the modification shown in Fig. 1, the bridge was unbalanced by making the resistance of the arm *d* too low so that the balance was improved by increasing the resistance of the resistors 18 and 19.

It will be understood that this apparatus does not give an output having constant volume. Such action is not desired as the relative effects of soft and loud music would be lost. The apparatus merely reduces the range in the change of volume levels.

In the apparatus shown in Fig. 1, there is a certain time delay in the volume control action since it takes the resistors 18 and 19 an appreciable time to heat up. This delay is desirable in certain cases to avoid distortion.

However, if it is desired to employ my invention for preventing more than 100% modulation in recording or transmitting equipment, any delay in the volume control action should be avoided.

ed and a circuit like that shown in Fig. 5 should be employed where the response of the photo-electric cells 56 and 57 to the change in light intensity is relatively instantaneous.

5 Various modifications may be made in my invention without departing from the spirit and scope thereof, and I desire, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and are set forth in the
10 appended claims.

I claim as my invention:

1. A volume control system comprising a Wheatstone bridge having input and output circuits, a transformer having primary and secondary windings, said primary winding being in one arm of said bridge, and said secondary winding having a resistance unit connected there-
15 across, and means for heating said resistance unit in accordance with the amplitude of the energy in said output circuit.

2. A volume control system comprising a Wheatstone bridge having input and output circuits, a transformer having primary and secondary windings, said primary winding being in one arm of said bridge, and said secondary winding having a resistance unit connected there-
25 across, and means for heating said resistance unit in accordance with the amplitude of the energy in said output circuit, said means including a vacuum tube output circuit having one output
30 terminal connected to the mid-point of said sec-

ondary winding and having the other output terminal connected to the mid-point of said resistance unit.

3. In a system of the volume control type, an amplifier having an input circuit responsive to changes in the volume level of the system, an impedance in the output circuit of said amplifier, the voltage drop across which is adapted to be used to compensate for changes in the volume level of the system, said impedance being non-linear over a portion of its impedance characteristic curve and means for compensating for this non-linearity to produce a linear voltage response across said impedance. 80 85

4. In a system of the volume control type, an amplifier having an input circuit responsive to changes in the volume level of the system, an impedance in the output circuit of said amplifier, the voltage drop across which is adapted to be used to compensate for changes in the volume level of the system, said impedance being non-linear over a portion of its impedance characteristic curve and means for compensating for this non-linearity to produce a linear voltage response across said impedance, said means comprising a resistor in the input circuit of said amplifier, said amplifier being adjusted to draw grid current on the peak voltages of the input signal energy. 90 95 100

HENRY I. METZ. 105

35 110
40 115
45 120
50 125
55 130
60 135
65 140
70 145
75 150