

Feb. 22, 1944.

H. L. BARNEY

2,342,238

VARIABLE ATTENUATION CIRCUIT

Filed Dec. 31, 1941

2 Sheets-Sheet 1

FIG. 1

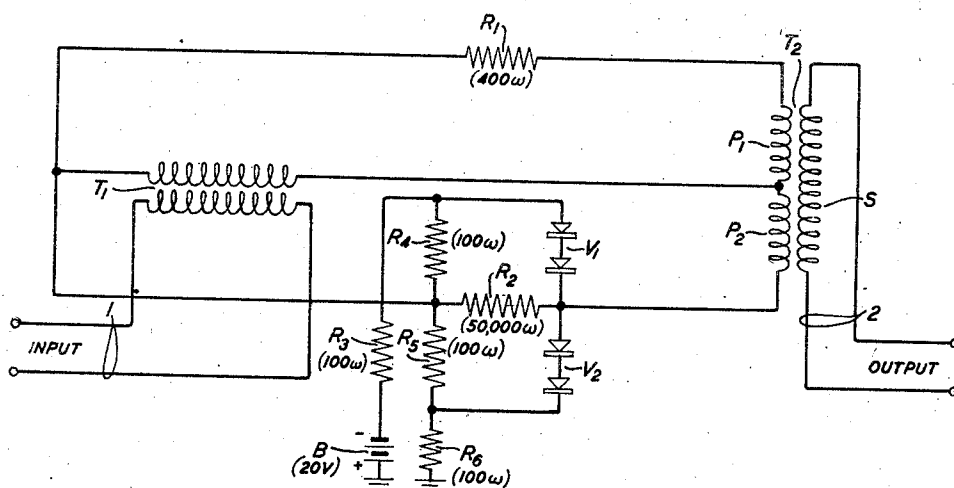


FIG. 2

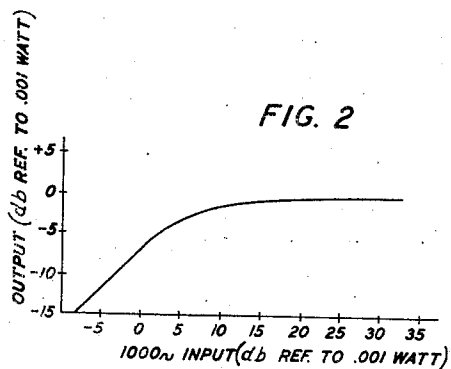


FIG. 3

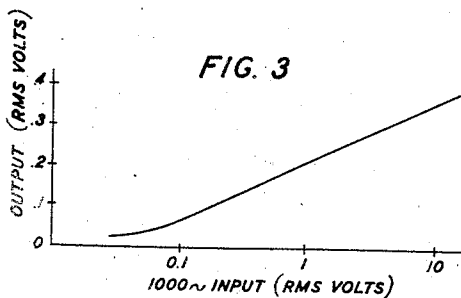
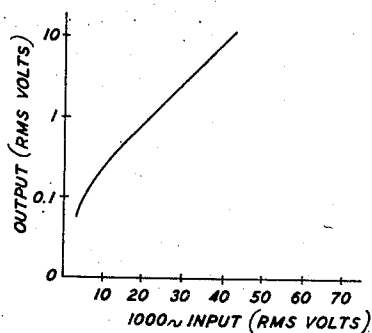


FIG. 4



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FIG. 5

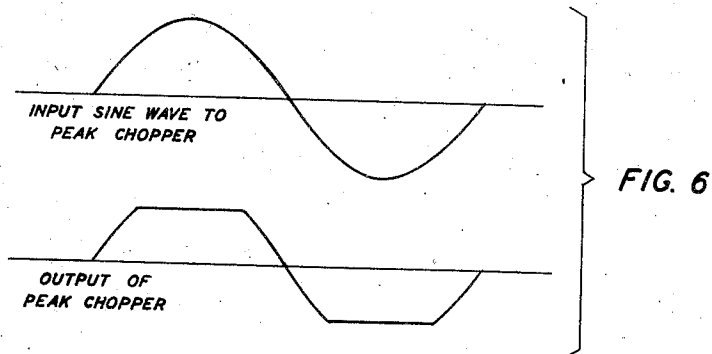
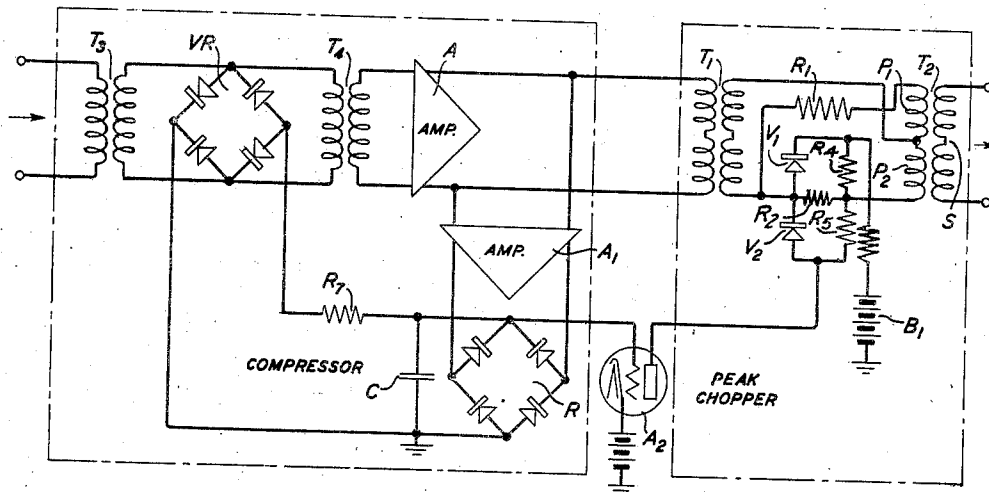
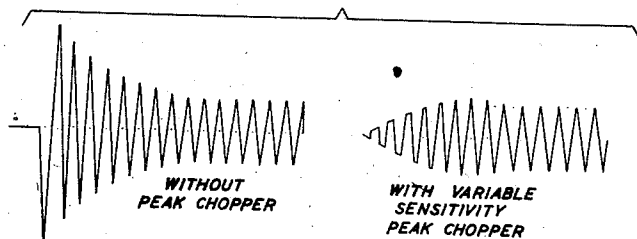


FIG. 7



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VARIABLE ATTENUATION CIRCUITS

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Application December 31, 1941, Serial No. 425,099

4 Claims. (Cl. 178-44)

The invention relates to variable attenuation networks and their applications to electrical signal wave control circuits.

Objects of the invention are to obtain various types of non-linear action, such as instantaneous compression and expansion, peak chopping, etc., on speech or other signal waves with relatively simple and economical apparatus and circuits.

These objects are attained in accordance with the invention by the use of non-linear impedance elements in combination with linear impedance elements in a particular arrangement in a Wheatstone bridge circuit, with the selection of suitable values for the impedance elements and the application of suitable direct current biasing voltages to the non-linear elements to provide the desired output-input characteristics.

A feature of the invention is the application of the circuit of the invention as a peak chopper with variable sensitivity for use with a variable gain device to prevent output amplitude "overshoots" tending to produce crosstalk, overloading or disturbing noise in the listener's receiver, when the variable gain device is subjected to sudden large increases in input.

The various objects and features of the invention will be better understood from the following complete description when read in conjunction with the accompanying drawings, in which:

Fig. 1 shows schematically a variable attenuation network embodying the invention;

Figs. 2 and 3 show curves illustrating two types of compressor output-input characteristics which may be obtained with the arrangement of Fig. 1;

Fig. 4 shows a curve illustrating a type of expander output-input characteristic which may be obtained with the arrangement of Fig. 1;

Fig. 5 shows schematically a circuit employing the variable attenuation network of Fig. 1 to provide a peak chopper of variable sensitivity; and

Figs. 6 and 7 show curves used to explain the operation of the circuit of Fig. 5.

As shown in Fig. 1, the variable attenuation circuit of the invention is in the form of a Wheatstone bridge. One arm of the bridge comprises a linear resistor R_1 ; a second adjacent arm includes a network comprising a series linear resistor R_2 and two branches in shunt therewith comprising linear resistor R_4 and copper-oxide varistor V_1 in series and the linear resistor R_3 and copper-oxide varistor V_2 in series, respectively, the two varistors V_1 and V_2 being equivalent and oppositely poled in that arm and biased by the voltage drop through the resistors R_4 and R_3 which are connected through resistances R_5 and R_6 to the battery B as shown; and the third and fourth arms of the bridge comprise respectively equal portions P_1 and P_2 of the primary winding of the output transformer T_2 . An in-

put circuit 1 is connected across one diagonal of the bridge between the point of connection of the first two bridge arms and the point of connection of the third and fourth arms, by input transformer T_1 . The output circuit 2 is effectively connected across the other diagonal of the bridge by connection to the secondary winding S of the output transformer T_2 , symmetrically inductively coupled to the two equal primary winding portions P_1 and P_2 of that transformer in adjacent arms of the bridge.

In the circuit of Fig. 1, when alternating current signals are applied from input circuit 1 through input transformer T_1 , current flows through the primary winding P_1 of output transformer and resistance R_1 , and through the other primary winding P_2 of that transformer and the network comprising resistances R_4 and R_3 and the biased copper-oxide varistors V_1 and V_2 , shunted by resistance R_2 . The output-input characteristic of the circuit is dependent on the balance obtained between resistor R_1 on one side and the network of resistors and varistors on the other side of the circuit. At very low signal inputs, the impedance balanced against R_1 is essentially only that of R_2 . Thus if R_2 is larger than R_1 , the loss through the circuit is a minimum. Resistor R_2 is used in this circuit to give a small improvement in the sharpness with which the output-input curve breaks at the point where compressing starts. At higher signal inputs the impedances of the varistors V_1 and V_2 are decreased due to the applied higher amplitude currents and the balance with R_1 improves, thus increasing the attenuation between input circuit 1 and the output circuit 2 of the system. The amplitude at which output compressing starts is determined by the bias on the varistors V_1 and V_2 , the impedance ratios of the transformers T_1 and T_2 , and the magnitudes of R_4 and R_3 . Varying the value of R_1 changes the shape of the characteristic in the non-linear range. If the resistance value of R_1 is smaller, the output of the system rises more at higher inputs, and if it is larger, the output decreases with increasing input, and then rises again with phase reversed as the input is further increased.

With the constants of the impedance elements of the circuit as shown in Fig. 1 when measured between 600-ohm circuits, an output-input characteristic like given in Fig. 2 is obtained, which is that of an instantaneous compressor of very high compressing ratio or "peak chopper." It will be noted that this peak chopper is extremely simple; uses no vacuum tubes or gas-filled tubes; does not have a time lag due to ionization or de-ionization time such as is present in gas tube limiters; and gives a sharp break in the output-input characteristic at the limiting point. The

effect of the peak chopping action on a sine wave is illustrated in Fig. 6.

If the biasing potential is removed from the varistors V_1 and V_2 in the circuit of Fig. 1, and the value of resistance R_1 is made about 200 ohms, a compressing characteristic of the logarithmic type may be secured. Fig. 3 shows the output-input characteristic of such an arrangement. As shown, over about a 45-decibel range of inputs from .09 to 15 volts, the output voltage is proportional to the logarithm of the input voltage.

The circuit of Fig. 1 may readily be made into an instantaneous expander by changing R_1 from a low to a high resistance so that a good balance is obtained at low signal input. In that case, at high inputs the impedance of the varistors V_1 and V_2 decreases, unbalancing the arrangement and causing the signals to be transmitted from circuit 1 to circuit 2 with less attenuation.

By removing the direct current bias on the varistors V_1 and V_2 and using for the input transformer T_1 and the output transformer T_2 , transformers which provide a low impedance level at the varistors, the output-input characteristic may be made to approximate an anti-logarithmic expander, that is, one in which the logarithm of the output voltage is proportional to the input voltage, as shown in Fig. 4.

In addition to the characteristics described above obtainable with the circuit of Fig. 1, a number of others combining compressing and expanding actions may be produced by adjustments of R_1 and R_2 and the bias used on the varistors. An application of such circuits would be for shaping the control versus input amplitude characteristics of control circuits for voice-operated switching devices.

When variable gain devices such as vogads (volume-operated gain adjusting devices), compressors and volume limiters are subjected to sudden large increases in input, the finite length of the time interval required by the devices to make a gain reduction results in a momentary "overshoot" of the output amplitude. Though this overshoot may last only a few thousandths of a second, it may be objectionable because of overloading or crosstalk it produces, or because of the "click" or "pop" it causes in the listener's receiver which follows the output of the variable gain device. Fig. 5 shows a peak chopper of the type illustrated in Fig. 1 combined with a volume range compressor of known type to provide a peak chopper of variable sensitivity to prevent such momentary overshoots and thus their objectionable effects.

In Fig. 5 the compressor shown comprises the one-way amplifier A preceded by a vario-losser consisting of an input transformer T_3 , an output transformer T_4 and a copper-oxide rectifier bridge circuit VR having one diagonal connected in shunt to the circuit between the two transformers, and a backward-acting control circuit connected across the output of the amplifier A, including in order the one-way amplifier A_1 , the copper-oxide bridge rectifier R and the timing circuit comprising shunt condenser C and series resistance R_7 connected across the other diagonal of the copper-oxide rectifier bridge circuit of the vario-losser. The peak chopper comprises a variable attenuation network in the form of a Wheatstone bridge, like that of Fig. 1, including in one arm the resistance R_1 , in a second adjacent arm a resistance

R_2 shunted by a circuit comprising varistor V_1 and resistance R_4 in series, and by a circuit comprising varistor V_2 and resistance R_5 in series, the varistors V_1 and V_2 being oppositely poled in the latter arm; the third and fourth arms comprising equal primary windings P_1 and P_2 , respectively, of the output transformer T_2 , the secondary winding S of which is connected to output terminals; and an input transformer T_1 having a secondary winding connected across the input diagonal of the bridge circuit and a primary winding which is connected to the output of the amplifier A in the compressor.

The sensitivity of the peak chopper in the combination of Fig. 5 is controlled by the plate current of a three-electrode amplifying vacuum tube A_2 the anode-cathode circuit of which includes the resistors R_4 and R_5 of the variable attenuation network in series with the plate battery B_1 of that tube, which in turn depends on the voltage across the output terminals of the rectifier R of the compressor because of the connection of the control grid-cathode circuit of tube A_2 across those terminals. The greater the voltage produced across the output terminals of the rectifier R in the compressor control circuit the higher will be the just-operate point of the peak chopper, so that for a steady state high signal input to the compressor, the peak chopper will not be operated by the signals in the output of the compressor. However, on suddenly applied strong signals from the output of the compressor, the initial sensitivity of the peak chopper is sufficient to attenuate these output signals for the first few milliseconds until the control circuit rectifier R of the compressor charges up condenser C and thus causes a decrease of peak chopper sensitivity, along with a reduction of the signal amplitudes in the output of the compressor.

The operation of the combination of Fig. 5 is illustrated by the curves of Figs. 6 and 7. As in the case of the peak chopper circuit of Fig. 1, the effect of the peak chopper of Fig. 5 on a sine wave during the initial adjustment period of the compressor is as shown in Fig. 6.

Fig. 7 shows on the left an oscillogram of the output wave such as would be obtained by the use of a compressor only in the system of Fig. 5 when a strong tone is suddenly applied to the input. To the right in Fig. 7 is shown an oscillogram such as would be obtained by combining this compressor with the peak chopper in the invention shown in Fig. 5 to provide for the combination a variable sensitivity peak chopper. As shown in Fig. 7, an advantage of this system is that the peak chopper introduces no distortion on the steady state output, yet can limit the initial transient voltages to values lower than the steady state.

The scheme of Fig. 5 could be applied to other variable gain devices such as volume limiters and vogads by employing an auxiliary rectifier circuit connected across the output of such a device and arranged to decrease the sensitivity of the following peak chopper in a manner similar to that which has been described for the system of Fig. 5. With the latter circuit, the lag in charging the condenser from the rectifier, and the range of sensitivity of the peak chopper would be adjusted so as to introduce a minimum of distortion on speech which was not varying in volume at the vogad or volume limiter input. On application of a stronger signal which would require a large reduction of gain, the output amplitude

would be initially reduced by the peak chopper to less than the steady state value for a few milliseconds, thus minimizing the effect of overshoots in overloading the following line and in producing objectionable clicks.

The use of such a variable sensitivity peak chopper would result in an improvement in quality of transmission, as compared with a system in which the peak chopper is used with fixed sensitivity. Practically all speech sounds build up over a period of at least several vocal cycles. If a fixed sensitivity peak chopper is used, the first few vocal cycles at the output may have amplitudes as great as those in the middle part of the syllable, which would result in a very unnatural speech sound. With the variable sensitivity peak chopper, however, the initial few vocal cycles are attenuated to amplitudes more nearly approximating their relative importance in an unaltered syllable. This is done at the expense of introducing more distortion for these few vocal cycles, but the listener's ear would probably be less likely to discern this type of distortion than it would the greatly increased amplitudes permitted by the plain peak chopper or with no peak chopper at all.

As described above, the arrangement of Fig. 5 does not provide a definite limit point beyond which the output voltage may not rise. On steady state input, presumably the peak chopper described would not limit regardless of amplitude of the signal passing through the system. If it were desirable to have a given maximum amplitude not exceeded, the circuit of Fig. 5 could be modified by adjusting the resistances R_4 and R_5 so that when the vacuum tube A_2 is overloaded and the maximum amount of plate current through it was reached, the sensitivity of the peak chopper could not be reduced further. This would set the upper limit of amplitudes the system could put out, regardless of transient characteristics.

Various modifications of the circuits which have been illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art. It is understood that the values of the impedance elements in the circuits of the invention given above are for illustrative purposes only and should not be construed as limiting the invention.

What is claimed is:

1. A system for controlling the amplitude range of alternating current signals of varying amplitudes, comprising a Wheatstone bridge having a linear resistor in series with one arm, a network having three parallel branches in series with a second adjacent arm, two of said branches being equivalent each comprising a copper oxide varistor in series with a linear resistor with the two varistors oppositely poled with respect to said second arm, and the third branch comprising a relatively large series resistor, and equal impedances in the other two adjacent arms, an input circuit supplied with said signals, inductively coupled to one diagonal of said bridge and a signal output circuit effectively inductively coupled to the other bridge diagonal, the resistance values of the copper oxide varistors and the linear resistors in said bridge being proportioned so that it is balanced to provide a high loss between said input circuit and said output circuit for signal inputs of certain amplitudes and is unbalanced to provide a low loss between those circuits for input signals of other amplitudes.

2. A system for controlling the amplitude range

of alternating current signals of varying amplitudes including a Wheatstone bridge having a linear resistor in series with one arm, a network comprising two equivalent parallel branches in series with a second adjacent arm, each branch comprising a copper oxide varistor biased by a direct current voltage, in series with a linear resistor, the two varistors being oppositely poled in said second arm, and equal impedances in the other two adjacent arms, an input circuit supplied with said signals, inductively coupled to one diagonal of said bridge and a signal output circuit effectively inductively coupled to the other bridge diagonal, the values of the linear resistors and the copper oxide varistors in said bridge and of the biasing voltages applied to said varistors being proportioned so that the balance of the bridge varies with the amplitude of the input signals to provide an output-input characteristic which is that of an instantaneous compressor of very high compressing ratio, a large loss being produced between said input and output circuits for high amplitude signal inputs and a low loss therebetween for very low signal inputs.

3. The system of claim 2, in which said amplitude range controlling system includes an amplifier in said input circuit, a rectifier in circuit with said amplifier for rectifying a portion of the input signals, control means having an appreciable time constant, responsive to the rectified signals for varying the gain of said amplifier in accordance with variations in the signal level and an electron discharge device having an input circuit connected across the output of said rectifier, and an output circuit including said network in said second arm of said bridge so that the amount of bias on the copper oxide varistors in said network, and thus the sensitivity of said bridge, is a function of the amplitude of the output current of said electron discharge device, which in turn depends on the voltage in the output of said rectifier, the combination providing a signal peak chopper the sensitivity of which varies in such manner as to compensate for momentary overshoots in the amplitude of output signals when said amplifier is subjected to sudden large increases in signal input, due to the time interval required for the adjustment of gain of said amplifier.

4. The system of claim 2, including a volume-operated gain adjusting device comprising an amplifier, a variolossor in the input thereof, a rectifier for rectifying a portion of the signal output of said amplifier and control means having an appreciable time constant, responsive to the rectified signals to vary the loss value of said variolossor in accordance with the level of the signal output of said amplifier, connected in said input circuit in front of said bridge, and an electron discharge device having a control grid-cathode circuit and an anode-cathode circuit, said control grid-cathode circuit being connected across the output of said rectifier, said anode-cathode circuit including said network in said second arm of said bridge so that the biasing direct current voltage applied to the copper oxide varistors therein and thus the sensitivity of said bridge is controlled by the space current in said electron discharge device which in turn depends on the voltage across the output of rectifier, the combination providing a peak chopper whose sensitivity varies in such manner that it is greatest during the initial part of an applied signal and decreases thereafter.

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