

June 30, 1959

J. M. MANLEY ET AL

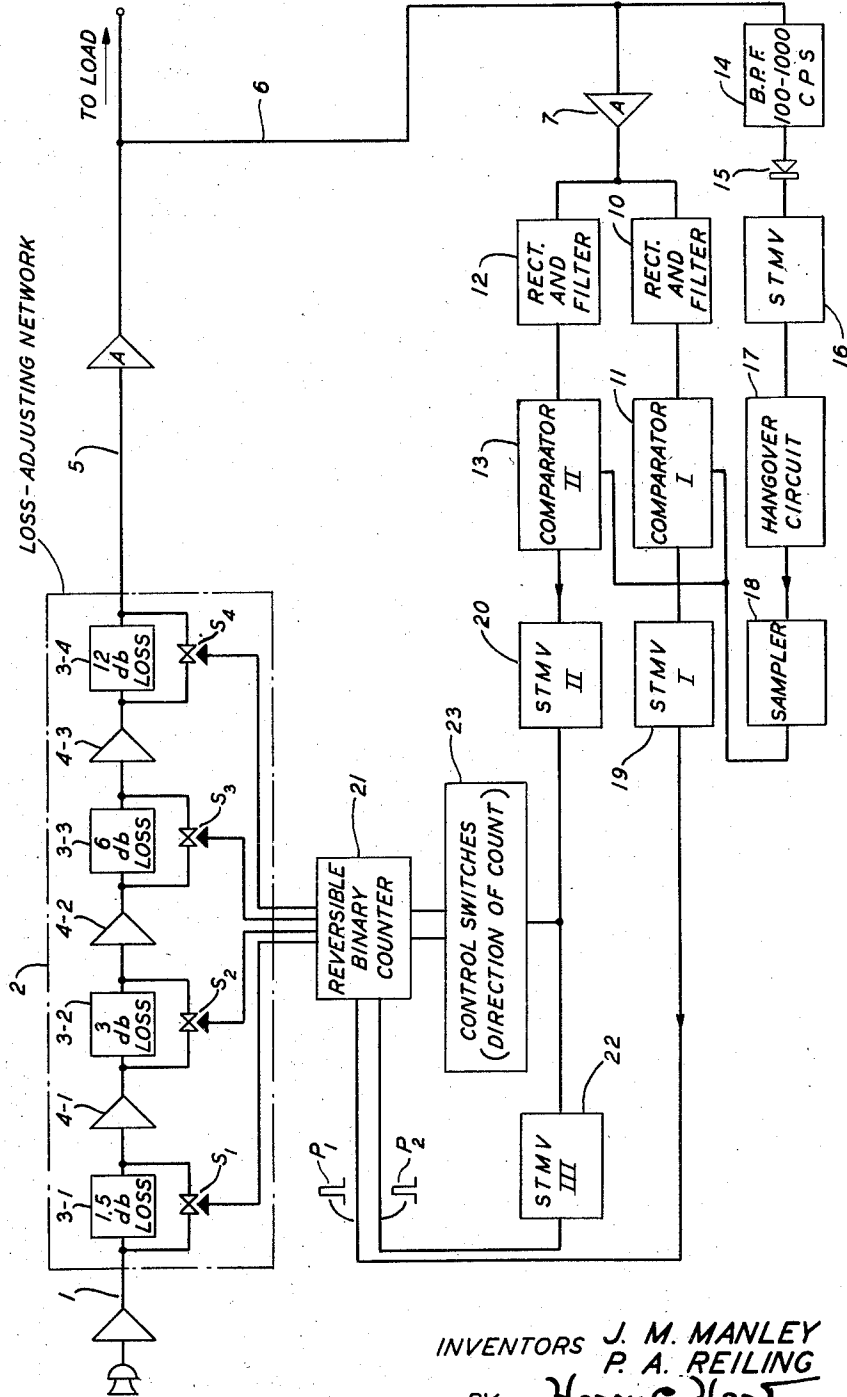
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VOICE-OPERATED GAIN ADJUSTING DEVICE

Filed Nov. 2, 1955

5 Sheets-Sheet 1

FIG. 1



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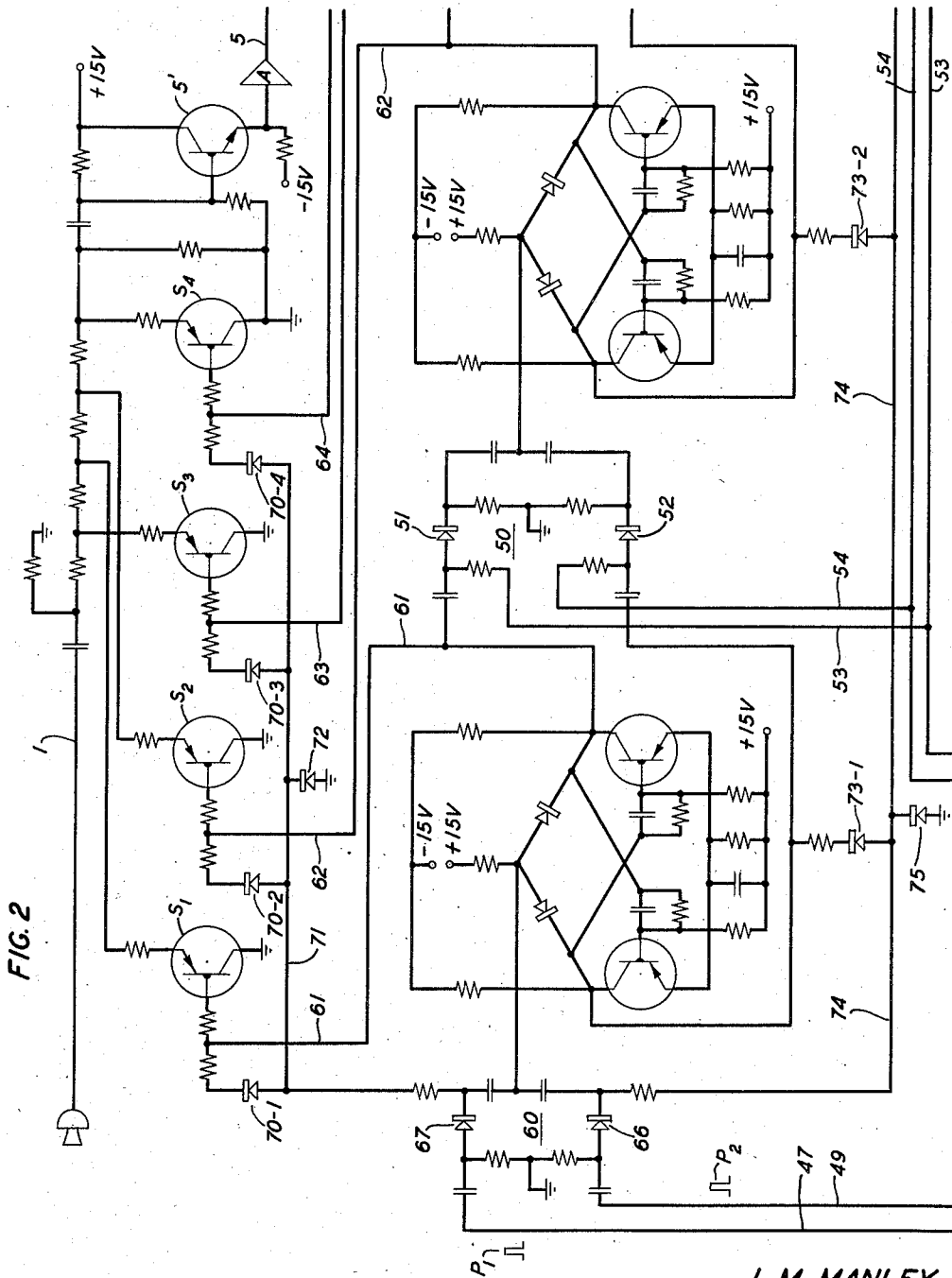
J. M. MANLEY ET AL

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VOICE-OPERATED GAIN ADJUSTING DEVICE

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5 Sheets-Sheet 2



INVENTORS J. M. MANLEY
P. A. REILING
BY *Harry C. Hart*
ATTORNEY

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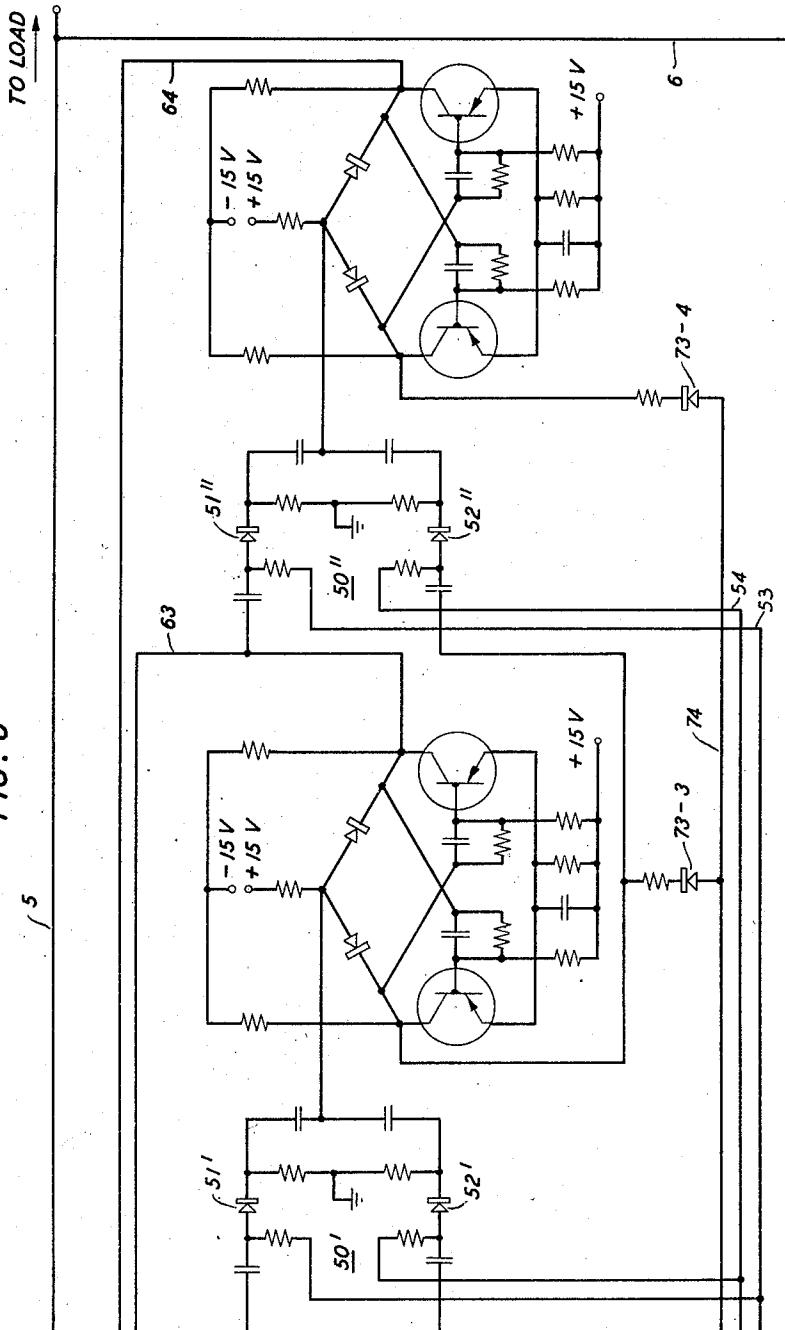
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5 Sheets-Sheet 3

FIG. 7

FIG. 2	FIG. 3
FIG. 5	FIG. 4

FIG. 3



INVENTORS
J. M. MANLEY
P. A. REILING
BY *Harry C. Hart*

ATTORNEY

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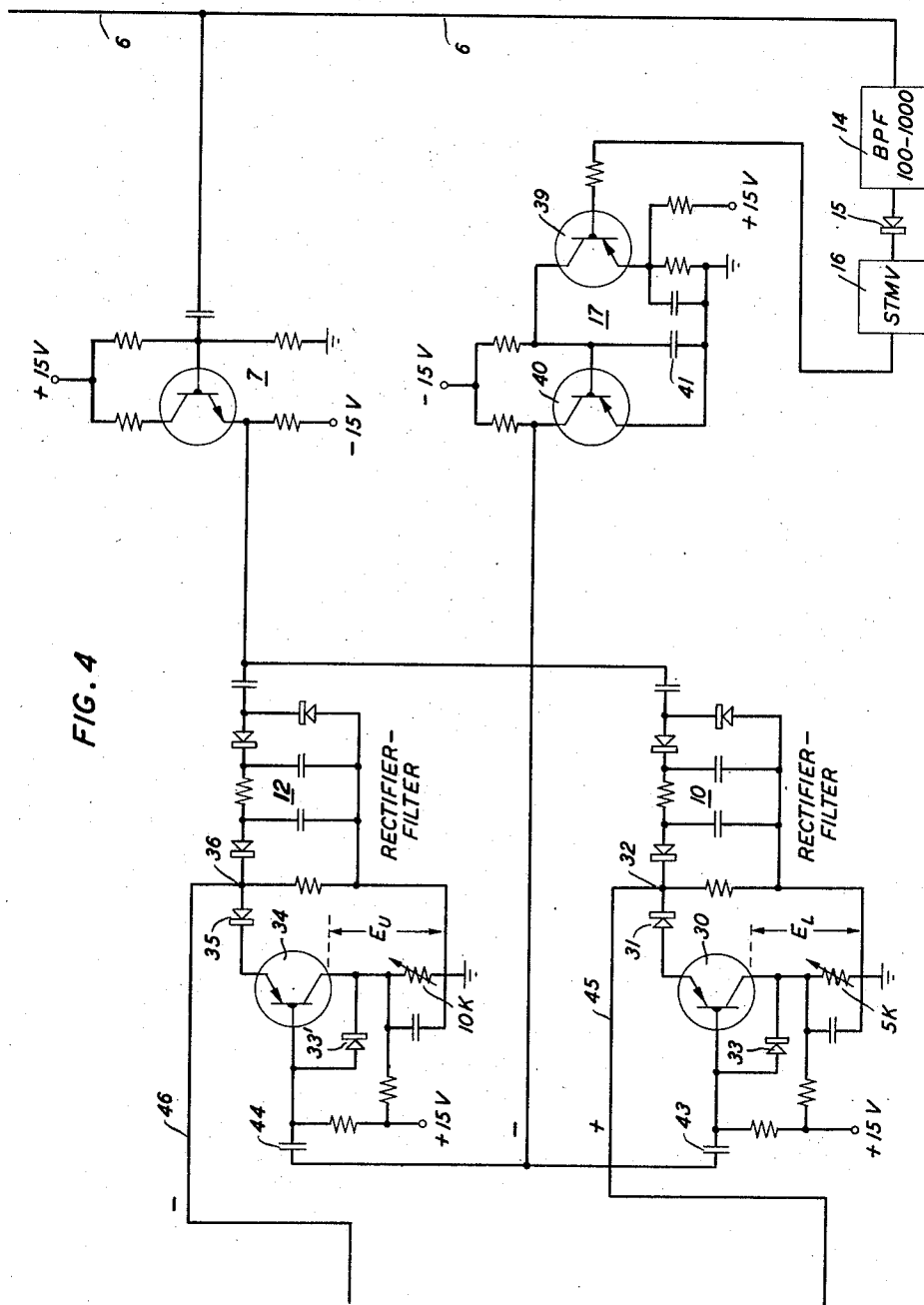
J. M. MANLEY ET AL

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VOICE-OPERATED GAIN ADJUSTING DEVICE

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5 Sheets-Sheet 4



INVENTORS J. M. MANLEY
P. A. REILING
BY Harry C. Hart
ATTORNEY

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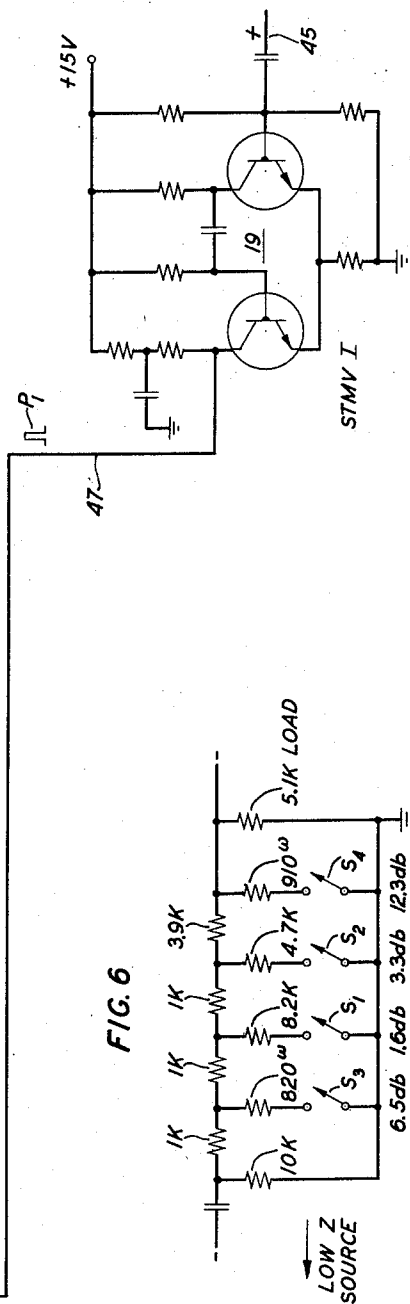
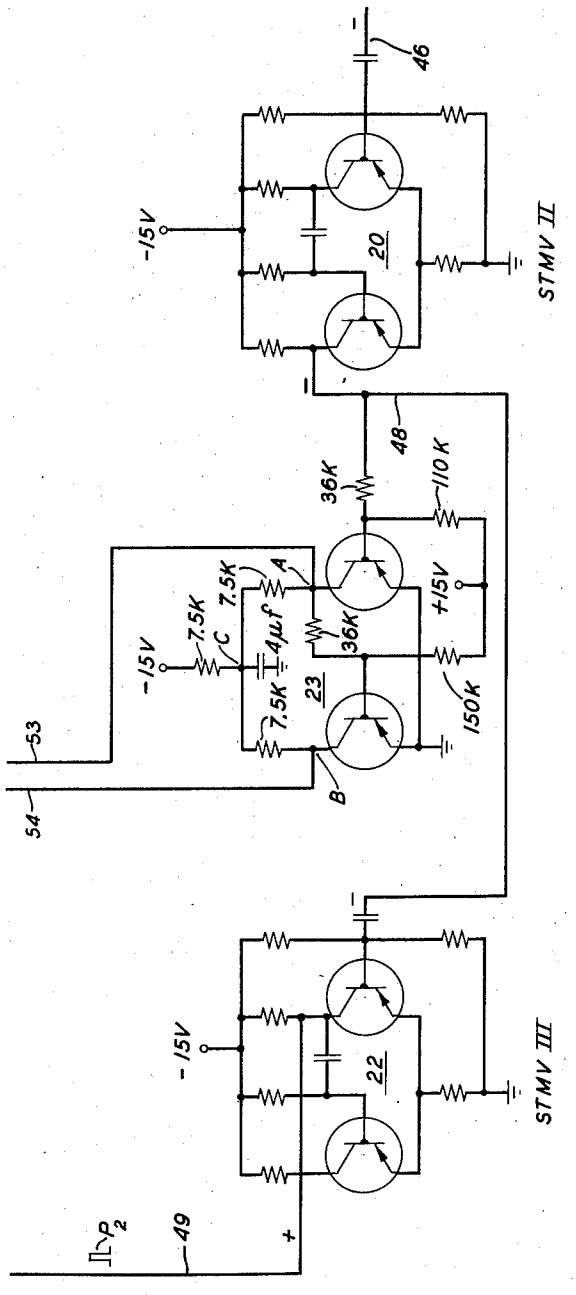
J. M. MANLEY ET AL

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VOICE-OPERATED GAIN ADJUSTING DEVICE

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5. Sheets-Sheet 5



INVENTORS J. M. MANLEY
P. A. REILING
BY Harry C. Hart

ATTORNEY

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2,892,891

VOICE-OPERATED GAIN ADJUSTING DEVICE

Jack M. Manley and Paul A. Reiling, Summit, N.J., assignors to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Application November 2, 1955, Serial No. 544,405

14 Claims. (Cl. 179—15.5)

This invention relates to transmission control, and particularly to the maintenance of speech signals at a uniform level in certain apparatus parts of a telephone system despite wide variation in the strength of such signals as they reach such apparatus parts.

The need, in telephony, for such transmission level control is well known, and many automatic devices have been proposed to meet it. Any such device controls the gain or loss in a speech signal path in response to a speech signal in some part of the system. It is therefore commonly designated a voice-operated gain adjusting device, and has come to be known as a vogad. In general, a vogad utilizes vacuum tubes as its active elements, and these are required to be operative through a range of amplitudes which is as wide as that of the incoming voice signal.

Situations may arise in practice wherein, because of their fragility, large space requirements and large power consumption, vacuum tubes are ruled out of consideration. In such a situation it is natural to attempt the substitution of transistors for the tubes. But the range of signal amplitudes through which the operation of a transistor is tolerably linear is much less wide than the amplitude range of the control signals which it is required to handle. For this reason vogad has heretofore successfully employed transistors as its active elements.

Accordingly, the principal object of the invention is to control the transmission level in a speech path through the agency of a vogad of which the active elements are transistors.

The invention is based upon the realization that, while the range of linear operation of a transistor is narrow, its switching characteristics are excellent. A modern junction transistor, in particular, may readily be switched from a condition in which the resistance of its emitter-to-collector path is very low; i.e., 5 ohms or less, to a condition in which its resistance is very high; i.e., several megohms. The change in condition is effected by the application of a control signal of a few volts to a proper point, e.g., to the base electrode of the transistor. These characteristics, and transistor switches which utilize them, are disclosed in an application of P. A. Reiling, Serial No. 410,924, filed February 17, 1954. The invention turns these excellent switching characteristics of the transistor to account in the following fashion:

A variable attenuation network or loss pad, having a number of control points; e.g., lateral taps, is interposed in tandem in the speech signal path. The energy of the voice signal emerging from this network is continuously compared with an upper threshold value and with a lower threshold value. If it exceeds the upper threshold value a gain reduction signal is derived; if it lies below the lower threshold value a gain increase signal is derived; while if it falls between the two thresholds the situation is allowed to remain as it was. To take full advantage of the transistor characteristics, each gain increase signal is a pulse of standard amplitude generated

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by a single trip multivibrator, and such pulses recur not at any preassigned rate, but at the conclusion of each voiced sound interval. The same is true of the gain reduction signal. This ensures that the apparatus shall not readjust speech path gain during the progress of a voiced sound, and so alter the quality of the reproduced voice. Furthermore, it readjusts the gain on the basis of average voice levels only.

Again to take fullest advantage of the transistor characteristics, a transistor switch is connected to each of the control points of the variable attenuation network, and these switches act to insert the several sections of this network in the speech path, or to remove them, as required to adjust the energy level of the speech signal. For operation of such switches on a sequential basis, a large number of steps would be required for smoothness of gain change. In accordance with the invention this difficulty is avoided by proportioning the sections of the variable attenuation network to introduce loss on a logarithmic basis; i.e., each section introduces twice as much loss as the prior section. With four such sections 2⁴ or 16 different values of loss are obtainable, each with a different permutation of the conduction conditions of the transistor switches connected to the control points of the network.

As a means for converting the train of gain increase pulses or gain reduction pulses into the corresponding permutations of switch conduction conditions, the invention employs a binary counter. Inasmuch as the space and power requirements which hold for the apparatus generally hold in particular for the counter, the counter employs transistors as its active elements. Because it must respond by counting in one direction to a train of gain increase pulses and by counting in the opposite direction to a train of gain reduction pulses, the counter is of the reversible variety and provision is made to reverse its direction of operation as called for. Provision is also made to prevent recycling of the counter after a full count from either end of its range to the other.

To avoid undesired gain increase under the influence of a weak unvoiced sound, thereby resetting the gain in the voice signal path inordinately high for the most probable ensuing voiced sound, provision is made to disable the control apparatus for such unvoiced sounds.

It is an important feature of the present apparatus that, when voiced sounds momentarily cease, it acts to hold the gain of the speech signal path at its latest voiced sound value; i.e., at that value which has the greatest probability of being the correct one for the next voiced sound to arrive.

The invention will be fully apprehended from the following detailed description of a preferred illustrative embodiment thereof, taken in connection with the appended drawings, in which:

Fig. 1 is a block schematic diagram illustrating the principles of the invention;

Figs. 2-5 together show circuit details of a system embodying the invention;

Fig. 6 is a schematic circuit diagram showing a variable attenuation network; and

Fig. 7 is a key figure showing the arrangement of Figs. 2-5.

Referring now to the drawings, Fig. 1 shows a portion of a speech signal path 1 whose energy is to be maintained at a uniform level. To this end a variable attenuation network or loss adjusting network 2 is interposed in tandem in the path. It may comprise a group of switched pads 3 between each two of which there is interposed a buffer or fixed pad 4. Each of the switched pads 3 is indicated as being inserted by actuation of

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one of a plurality of switches S_1, S_2, S_3, S_4 which opens that switch. Removal of the actuating signal from the control terminal of the switch allows it to close and so removes the corresponding loss pad from the voice path. It is the function of the control apparatus shown in the lower portion of the figure to operate these switches as required.

The signal energy which appears at the output conductor 5 of this variable attenuation network 2 is amplified as by a buffer for application to a load. It is also applied by way of a conductor 6 to a buffer 7 whose output terminal is connected in parallel to two paths. The lower path comprises a rectifier and filter 10 which derives a substantially steady voltage proportional to the voice signal energy. This is applied to a first comparator 11 to generate a signal when, and only when, this derived voltage falls below a preassigned lower threshold value E_L . In the upper path the rectifier filter combination 12 may be the same as that in the lower path. It acts to derive a substantially steady voltage which is equal in magnitude to that of the lower path, but which is electrically isolated therefrom. This is likewise applied to a comparator 13 which generates an outgoing signal when, and only when, the derived voltage exceeds a preassigned upper threshold E_U .

Connected in parallel with the input terminal of the buffer 7 is a band-pass filter 14 which is proportioned to pass a band of frequencies in the range 100-1000 cycles per second; i.e., the frequency range of principal energy of voiced sounds. This filter is connected to a rectifier 15 which derives a current substantially proportional to the voiced sound energy. This is applied to a single trip multivibrator 16 which may be of any well-known construction and is proportioned to deliver an output signal of standard magnitude when the signal applied to it from the rectifier 15 exceeds a preassigned threshold. By proportioning the elements of the single trip multivibrator 16 in well-known fashion its standard amplitude output signal occurs when, and only when, the voice signal at the output conductor 5 of the network 2 contains voiced sound components of significant amplitude, and endures without change as long as the voiced sound endures.

The output of the single trip multivibrator 16 is applied to an initial rise delay circuit or "start hangover" circuit 17. This is proportioned to introduce a delay; e.g., of the order of one hundred milliseconds, in the rise of the output signal of the single trip multivibrator 16. It is included in order to desensitize the apparatus to sharp, brief sound pulses which are generally of a spurious origin, for example, noises due to an accidental striking of a microphone by a subscriber.

The output of the hangover circuit 17 is applied to a sampler 18 which delivers a sampling pulse at the trailing edge of the output pulse of the single trip multivibrator 16; i.e., at the termination of each voiced sound interval. This sampling pulse is delivered as a secondary control signal to the lower threshold comparator 11 and to the upper threshold comparator 13 together, and it acts to enable these comparators 11, 13 at the conclusion of each voiced sound interval and at no other time.

The sampler 18 furnishes identical pulses to the two comparators 11 and 13. For the sake of economy it is shown in Fig. 1 as a single unit. Evidently it could be replaced by two like but electrically separate samplers, one applying pulses only to the comparator 11 and the other only to the comparator 13. At the price of reduced apparatus economy this alternative offers the advantage of eliminating all possible coupling between one comparator and the other.

Accordingly, any one of the following three conditions may occur at the conclusion of a voiced sound interval:

(a) The energy level in the speech path 1 lies below the lower threshold E_L , in which case the comparator 11 delivers a tripping signal to a single trip multivibrator 19;

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(b) The energy level in the speech path may exceed the upper threshold E_U , in which case the comparator 13 delivers a tripping signal to a single trip multivibrator 20;

(c) The energy level in the speech path may fall between the two thresholds E_L, E_U , in which case no tripping signal is delivered either to the single trip multivibrator 19 or to the single trip multivibrator 20.

It will be noted that no tripping signals are delivered, whatever the magnitude of the speech signal, during the progress of a sound, voiced or unvoiced, and that such tripping signals are delivered only at the conclusion of each voiced sound interval.

The tripping signal output of the comparator 11, if it exists, acts to trip the single trip multivibrator 19 which then delivers a standard amplitude gain increase pulse p_1 to an input point of a binary counter 21. Similarly, the output of the comparator 13 acts to trip the single trip multivibrator 20. The time constant of the single trip multivibrator 20 is longer than that of single trip multivibrator 19. Its output trips a single trip multivibrator 22 which delivers a standard amplitude gain reduction pulse p_2 to an input point of the binary counter 21. The constants and parameters of the single trip multivibrator 22 may be like those of the single trip multivibrator 19 so that the gain reduction pulse p_2 is similar in form to the gain increase pulse p_1 , i.e., it has the same magnitude and the same duration.

The output signal of the single trip multivibrator 20 also actuates switches 23 which control the direction or sense in which the conduction conditions of the counter 21 advance in response to its input pulses. By proportioning the elements of these switches in the fashion to be described the normal count of the binary counter is "upward;" i.e., from the binary representation of zero, 0000, in which all of its output terminals are deenergized and the switches S_1, S_2, S_3 and S_4 are all unactuated and therefore closed, to the binary representation of the upper limit of the count, in this case 15 in which its condition is represented by 1111; i.e., all its output points are energized and all four of the switches S_1, S_2, S_3 and S_4 are actuated and therefore open. Counting in the opposite or downward direction results when the direction control switches 23 are shifted to their actuated conditions by the output of the single trip multivibrator 20. In order that a downward counting pulse p_2 from the single trip multivibrator 22 shall be applied to the counter 21 only while it is conditioned to count downward, the elements of the single trip multivibrator 20 are proportioned to give it a time constant which is substantially longer than that of the single trip multivibrator 22.

Figs. 2-5, taken together in the order shown in Fig. 7, show the details of an actual working circuit which carries out the operations indicated in Fig. 1. Referring first to Fig. 2, the upper part of this figure shows a variable attenuation network or loss pad which is considerably simplified as compared with that of Fig. 1 by the omission of the buffers 4. This simplification is achieved at the price of insignificant reduction in precision of operation which is quite unnoticeable in practice, and by the selection of the magnitudes of the various resistance elements of the pad and the arrangement of the switches S_1, S_2, S_3 and S_4 out of the normal order as shown in Fig. 6, wherein actuation of each switch closes it and inserts the corresponding loss in the voice path. A complete pad with all the precision which it provides, as shown in Fig. 1 may, of course, be employed if preferred, in which case the switches S_1, S_2, S_3 and S_4 may be arranged in order of increasing loss as in Fig. 1.

The output of the variable attenuation network of Fig. 2 is applied to a transistor amplifier 5' connected as an emitter follower to secure a desired impedance match. The signal appearing across the emitter-resistor is brought to a desired level for use in the remainder of the system by an amplifier. The control signal, which acts to readjust the variable attenuation network 2 is derived from

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the output terminal of the amplifier and delivered to the control apparatus, shown in Figs. 4 and 5, over the conductors 5 and 6.

Referring now to Fig. 4, speech signals which have traversed the variable attenuation network are applied through a buffer 7 which may again be a transistor amplifier of the grounded emitter configuration to a first rectifier-filter 10 and a second rectifier-filter 12 in parallel. These filters may be alike in construction. Several of the respective elements of the circuits 10 and 12 are rectifiers in order that the filter output may in each case have a definite polarity. Capacitance and resistance values are preferably chosen to provide time constants of the order of a few seconds for currents flowing in the reverse senses of the rectifier elements. This enables the charge built up at the output terminal of each of these filters to hold its value without significant decay, over an interval of a second or less, falling between adjacent bursts of voiced sound.

To the output point 32 of the lower filter 10 a transistor sampling switch 30 is connected by way of a rectifier 31 poled for forward conduction toward the output point 32. This switch 30 is normally biased in the nonconducting condition as by a 15 volt source, a varistor 33, and resistors connected as shown. It may be driven into the conducting condition by application of a negative pulse to its base electrode.

The output point of the upper filter 12 is similarly connected by way of a transistor sampling switch 34 similarly biased Off, and by a diode rectifier 35 which, however, is connected for forward conduction away from the filter output point 36. This transistor switch may likewise be driven On; i.e., into the conducting condition, by application of a negative pulse to its base electrode.

Returning to the right-hand portion of Fig. 4, the control signal on the conductor 6 is applied to a band-pass filter 14 proportioned to pass the frequencies of principal energy of voiced sounds; i.e., 100-1000 cycles per second. Energy within this band passes the filter and is applied to a rectifier 15 which thus derives a unidirectional signal whose magnitude is proportional to the energy of the voiced sounds. This unidirectional signal is applied to a single trip multivibrator 16 which delivers a pulse of standard amplitude and of duration equal to that of the voiced sound interval. The output of the single trip multivibrator 16 is applied to the input point of an initial rise delay circuit 17, otherwise known as a hangover circuit. The latter comprises two transistors 39, 40, connected as shown. Of these, the transistor 39 is normally biased On by application of positive voltage, e.g., from a 15 volt source, to its emitter electrode. This positive voltage also appears across a storage condenser 41, through the low resistance path from collector to emitter of the transistor 39 and holds the base electrode of the transistor 40 at this positive voltage. Its emitter being connected to ground, the transistor 40 is biased Off, and its collector rests substantially at the potential of the negative 15 volt source.

Application of a signal to the base electrode of the transistor 39 from the single trip multivibrator 16, e.g., a signal of the order of 15 volts positive, turns the transistor 39 Off, whereupon the charge accumulated on the storage condenser 41 leaks away, allowing the base electrode of the transistor 40 to return toward the potential of the negative 15 volt source. After this leakage has progressed for a certain time, e.g., 100 milliseconds, dependent on the time constant of the circuit, the transistor 40 becomes conductive and remains so until the termination of the signal output of the single trip multivibrator 16. Upon termination of the single trip multivibrator output the original conditions are rapidly restored, since the charging path for the storage condenser 41 now includes the transistor 39 in its conductive condition. The output of the hangover circuit 17 is thus a signal which is normally minus 15 volts; which rises substantially to zero potential

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at an instant 100 milliseconds later than the commencement of the single trip multivibrator output pulse and falls again to minus 15 volts at the conclusion of the single trip multivibrator output pulse.

This signal is applied in parallel by way of condensers 43, 44 to the base electrodes of the transistor switches 30, 34. The combination of the condensers 43, 44 and resistors shown acts to differentiate the trailing edge of the signal to provide a sharp, negative sampling pulse. The latter drives both of the transistor switches, 30, 34 into their conducting conditions precisely at the termination of each voiced sound interval. By proper proportionment of the condensers 43, 44, in relation to all the resistances through which they are charged, the On condition of each of these switches may be made to endure for a time which is short compared with the length of the average unvoiced interval of speech, e.g., for about 2 milliseconds.

Thus the transistor switches 30 and 34, together with their differentiating circuits comprising input resistors and condensers 43, 44, serve to take samples of the outputs of the rectifier-filters 10 and 12 at their output terminals 32 and 36, respectively. These two switches thus together carry out the function indicated on Fig. 1 as being performed by the single sampler 18.

Establishment in the foregoing fashion on the On condition in these two transistor switches 30, 34 enables a comparison to be made between the potential developed at the filter output points 32, 36 and two preassigned threshold values. The first of these is a lower threshold designated E_L and the second is an upper threshold designated E_U . Their magnitudes may readily be adjusted by proportionment of the resistors in the biasing paths. Appropriate magnitudes are a lower threshold of 1.25 volts and an upper threshold of 3.0 volts.

The lower transistor switch 30 is connected by way of a rectifier 31 to the output point 32 of the lower filter 10 and the upper transistor switch 34 is connected by way of a rectifier 35 to the output point 36 of the upper filter 12. These two rectifiers 31, 35 are oppositely poled. With this arrangement, the output conductor 45 of the lower filter 10 carries a positive signal when, and only when, the potential at the filter output point 32, due to the speech signal, falls below the lower threshold E_L during the sampling interval. Similarly, the output conductor 46 of the upper filter 12 carries a negative signal when, and only when, the potential of its output point 36 exceeds the upper threshold E_U during the sampling interval. When the potentials of the filter output points lie between these two thresholds no signal appears on either output conductor 45 or 46.

The positive output signal on the lower conductor 45, when it appears, is equal to the difference between the rectified and filtered speech signal and the lower threshold value E_L . This is applied as a tripping signal to the single trip multivibrator 19, which may comprise two transistors coupled together in well-known fashion. As indicated by the outward-pointing arrowheads on their emitter electrodes, they are P-type transistors. The combination responds by delivery of a positive gain increase output pulse p_1 of standard magnitude and duration on the conductor 47.

Similarly, when the rectified and filtered counterpart of the voice signal exceeds the upper threshold E_U the output conductor 46 carries a negative signal whose magnitude is equal to the difference. This is applied to the single trip multivibrator 20 which may comprise two transistors coupled together in well-known fashion to deliver an intermediate pulse of negative polarity, standard magnitude and standard duration on a conductor 48. As indicated by the inward-pointing arrowheads on their emitter electrodes, they are N-type transistors. For a reason to appear shortly, the duration of this pulse is preferably two or three times the duration of the pulse p_1 .

This intermediate pulse is applied by way of a con-

ductor 48 to the single trip multivibrator 22, which again may comprise two transistors coupled together in well-known fashion to provide an output gain reduction pulse p_2 of standard magnitude and duration on a conductor 49. The constants of the single trip multivibrator 22 may advantageously be chosen to equalize the magnitude and duration of the gain reduction pulse p_2 with the gain increase pulse p_1 .

The intermediate output pulse from the single trip multivibrator 22 is applied to direction control switches 23 which may comprise two N-type transistors coupled together in the fashion shown. With the values of the circuit constants indicated, the left-hand transistor is normally biased On. This holds the point B substantially at ground potential and the point C at minus 7.5 volts. This in turn biases the right-hand transistor Off so that the point A adopts the potential of the point C, namely, minus 7.5 volts. When the single trip multivibrator 20 delivers its negative pulse, this pulse turns the right-hand transistor On, bringing its collector, and with it the point A, to ground potential. Through the action of the cross-coupling path and the positive 15 volt source, this acts to turn the left-hand transistor Off, whereupon the point B falls to minus 7.5 volts.

Returning to Figs. 2 and 3, the lower portions of these figures show a reversible binary counter of four stages. Each stage comprises a bistable combination of two transistors, the base of each being cross-coupled to the collector of the other in well-known fashion. Energy is applied to the two collectors of each stage by way of routing diodes which serve their usual purposes. This input energy is derived by way of a two-sided circuit which precedes each stage. Thus, for example, between the first stage and the second the collector of the right-hand transistor of the first stage is connected to the input point of the second stage by way of the upper half of the two-sided circuit 50, while the left-hand collector of the first stage is connected to the same input point of the second stage by way of the lower half of the two-sided circuit 50. Evidently, one side or the other of each of these two-sided circuits may be enabled or disabled by application of potentials to the diodes 51, 52 to drive them into their conducting conditions or their non-conducting conditions as required. Thus when a positive potential is applied to the diode 52 and a negative potential is applied to the diode 51 the upper half of the two-sided circuit 50 is disabled and energy is transferred to the second stage of the binary counter from the left-hand collector of the first stage but not from its right-hand collector. This is the condition for upward counting from stage 1 to stage 2. With reversal of potentials on the diodes 51, 52, the reverse downward counting condition is obtained. These conditions are controlled in the present system by connection of the diodes 51, 52 to the points A and B of the control switches 23 described above by way of conductors 53 and 54. The other two-sided interstage circuits are similar in construction and function, the corresponding diodes all being connected together and to the points A and B by way of the conductors 53, 54.

Assume now that the speech signal traversing the variable attenuation network is of too low a level and that, at the termination of each voiced interval a gain increase input pulse p_1 has been derived in the fashion described above by the apparatus of Figs. 4 and 5. Under these conditions comparison of the rectified voice signal with the upper threshold E_T will have resulted in no gain reduction pulses p_2 . Hence, the aperiodic train of gain increase pulses p_1 is applied by way of the upper half of the first two-sided circuit 60 to the first stage of the counter and each such pulse causes the first counter stage to reverse its condition. Because the count reverse switches are in their forward count condition, the lower diodes 52, 52', 52'' are at ground potential, while the

upper diodes 51, 51', 51'' are biased negatively. Hence, each time the left-hand collector of the first stage of the counter goes positive it applies a pulse to the second stage to reverse its conduction condition. Similarly, each time the left-hand collector of the second stage goes positive it applies a pulse to the third stage to reverse its conduction condition, and so on.

The right-hand collectors of the several counter stages are connected by way of conductors 61, 62, 63, 64 to the base electrodes of several transistor switches S_1, S_2, S_3, S_4 . The collector of each such transistor switch is connected to ground, while its emitter is connected to one of the control points or taps of the variable attenuation network 2. Actual values of the resistors which make up this network are shown in Fig. 6. With these values when, for example, the right-hand collector of the first counter stage goes negative it establishes a path from a point of the voice path 1 and through resistance of 10,200 ohms, in shunt with a fixed 10,000 ohm resistor, to ground. With the circuit constants shown this makes for the introduction of a loss of 1.6 decibels in the speech signal path 1. Similarly, negative output voltage from the right-hand collector of each stage establishes a path to ground through one of the transistor switches from a specified point of the speech transmission path. The conduction conditions of these four switches may be combined in 24 or 16 different ways, giving 16 different values for the loss introduced in the speech transmission path. These various loss values are indicated in the following tabulation, for each combination of switches closed, for a network of the configuration shown in Fig. 6 interposed between a low impedance source and a load of a high impedance, e.g., 5100 ohms.

Switches closed:	Loss, db
None	0
S_1	1.6
S_2	3.3
S_2, S_1	4.7
S_3	6.5
S_3, S_1	7.8
S_3, S_2	9.4
S_3, S_2, S_1	10.5
S_4	12.3
S_4, S_1	13.8
S_4, S_2	15.2
S_4, S_2, S_1	16.4
S_4, S_3	18.2
S_4, S_3, S_1	19.4
S_4, S_3, S_2	20.7
S_4, S_3, S_2, S_1	21.8

From the foregoing it will be readily understood that, when the speech signal exceeds the upper threshold an aperiodic train of gain control pulses p_2 is generated and applied by way of the conductor 49 and the upper portion of the first two-sided circuit to the input point of the first stage. At the same time, the diodes 51, 51', 51'' are driven to minus 7.5 volts, while the diodes 52, 52', 52'' are returned to ground potential. Hence, energy is transferred to the input point of each stage from the right-hand collector of the prior stage. The fact that this reverse count condition holds only for the duration of one of the intermediate control pulses derived from the single trip multivibrator 22 is of no importance because, by the time the transfer networks 50 have returned to their normal conditions, the gain reduction pulse p_2 has come, has done its work and has gone.

In place of the four-stage binary counter shown, which controls 16 different values of insertion loss, a five-stage counter may, of course, be employed giving 32 values, a six-stage counter giving 64 values, and so on. It has been found in practice that a four-stage binary counter giving 16 values is sufficient for telephone purposes in a large majority of practical cases.

Whatever the number of different loss values deemed

to be required, and whatever the corresponding number of stages to be included in the counter, an occasional situation may arise in which a train of input pulses p_1 or p_2 may include one pulse too many. For example with the four-stage counter, starting from zero, occasion may arise in which it receives a sequence of 17 or more gain increase pulses. Of these, the first 16 operate to advance the counter throughout its full range and to remove all the loss from the speech transmission path. If provision were not made to prevent it, the 17th such pulse would return the counter to its starting condition and reinsert all the loss in the speech transmission path. To prevent this and its opposite, and so to ensure that the counter shall not respond to a number of pulses in excess of that for which it is designed, the present system includes a stopping circuit for each end of the counting range. To this end, the right-hand collectors of all the counter stages are connected by way of varistors 70-1, 70-2, and so forth to a common conductor 71 which is in turn connected by way of another varistor 72 to ground. Similarly, the left-hand collectors of all the counter stages are connected by way of varistors 73-1, 73-2, and so forth to a common conductor 74 which is in turn connected by way of another varistor 75 to ground. The varistors 70, 72, 73, 75 may be rectifiers poled in each case in such a fashion that the circuit traced from one of the collectors of one of the counter stages passes in the reverse direction first through its individual rectifier, then through the common rectifier. This circuit operates in the following fashion:

Under the condition in which the counter output is represented by 1111, and therefore all the switches S_1 , S_2 , S_3 and S_4 are closed, the left-hand collectors of the counter stages all adopt positive potentials of 6 volts determined in well-known fashion by selection of potential sources and resistances. The varistors 73-1, 73-2, 73-3 and 73-4 are then biased in their nonconducting conditions. They are effectively connected in parallel and the parallel combination of these four varistors is in series with the common varistor 75 and ground. Thus, four-fifths of this 6 volt bias appears across the common varistor 75. This voltage is applied by way of the common conductor 74 to the lower half of the first two-sided circuit 60 and so acts to bias the lower diode 66 in its reverse condition, thus to block the application of any further gain reduction pulse p_2 to the first counter stage. However, when any one or more of the left-hand counter stage collectors stands at minus 2 volts instead of at plus 6 volts, as is the case when the left-hand transistor of the stage is Off, the corresponding varistor 73-1, 73-2, 73-3 or 73-4 is biased in its forward direction. This reduces the potential of the common conductor 74, drawing the common varistor 75 into its forward condition and effectively placing ground potential on the diode 66 of the lower half of the two-sided circuit 60, thus to admit a gain reduction pulse.

When, to the contrary, the counter output is represented by 0000 so that all of the switches S_1 , S_2 , S_3 and S_4 are opened, due to the application of positive potential to their base electrodes from the right-hand collectors of the several counter stages, such positive potentials; i.e., of 6 volts magnitude, act to bias the individual varistors 70-1, 70-2, 70-3 and 70-4 in the reverse direction. The parallel combination of these four varistors is connected in series with the common varistor 72, and four-fifths of this 6 volt potential appears across the latter varistor. This is applied by way of the common conductor 71 to bias the diode 67 in the upper half of the two-sided circuit 60 into its nonconducting condition, thus to block the application of any further gain increase pulse p_1 to the counter. When any one of the transistor switches S_1 , S_2 , S_3 or S_4 is, to the contrary, closed, this bias is removed in the fashion described above and the counter can then receive at least one additional gain increase pulse.

Various departures from the details of the illustrative embodiment shown will suggest themselves to those skilled in the art.

What is claimed is:

1. In a voice-operated automatic gain control system, the combination which comprises a variable attenuation network having an input terminal, an output terminal and a plurality of control points, a switch connected to each of said control points, said network comprising a plurality of impedance element sections interconnected in tandem and individually insertable between said input terminal and said output terminal by operation of corresponding ones of said switches, the magnitudes of said elements being so proportioned that the attenuations introduced into a signal traversing said network by the several sections are related as the integral powers of 2, a connection for applying a speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, a binary coding device having an input point and a plurality of output points and arranged to convert a control signal applied to its input point into a binary permutation code of electrical conditions on its several output points, means for applying said modified signal as a control signal to the input point of said coding device, and means for controlling said several switches in accordance with the electrical conditions at the several output points of said coding device.

2. Apparatus as defined in claim 1 wherein said coding device is a binary counter.

3. Apparatus as defined in claim 1 wherein said coding device is a reversible binary counter.

4. Apparatus as defined in claim 1 wherein said coding device comprises a tandem-coupled combination of bistable circuits.

5. In a voice-operated automatic gain control system, the combination which comprises a variable attenuation network having an input terminal, an output terminal and a plurality of control points, a switch connected to each of said control points, a connection for applying a speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, a binary coding device comprising a plurality of bistable transistor circuits connected together in tandem, said device having a plurality of output points and being arranged to convert a control signal into a binary permutation code of electrical conditions on said output points, means for applying said modified signal as a control signal to said coding device, and means for controlling each of said switches in accordance with the electrical condition at a single one of the output points of said coding device.

6. In a voice-operated automatic gain control system, the combination which comprises a variable attenuation network having an input terminal, an output terminal and a plurality of control points, a transistor of which one of the emitter and collector electrodes is connected to each of said control points and the other of said electrodes is connected to a point of fixed potential, a connection for applying a speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, a binary coding device having a plurality of output points and arranged to convert a control signal into a binary permutation code of electrical conditions on said output points, means for applying said modified signal as a control signal to said coding device, and means for applying to the base electrodes of the several transistors the electrical conditions appearing at the several output points of said coding device, respectively.

7. In a voice-operated automatic gain control system, the combination which comprises a variable attenuation network having an input terminal, an output terminal and a plurality of control points, a switch connected to each of said control points, a connection for applying a

speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, a binary coding device having a plurality of output points and arranged to convert a control signal into a binary permutation code of electrical conditions on said output points, means for applying said modified signal as a control signal to said coding device at instants coinciding, respectively, with the terminal instants of successive voiced sound intervals, and means for controlling each of said switches in accordance with the electrical condition at a single one of the output points of said coding device.

8. In a voice-operated automatic gain control system, the combination which comprises a variable attenuation network having an input terminal, an output terminal and a plurality of control points, a switch connected to each of said control points, a connection for applying a speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, a reversible binary counter having a plurality of output points and arranged to convert a control signal into a binary permutation code of electrical conditions on said output points, means for applying said modified signal as a control signal to said counter, thereby to actuate said counter to count in one direction up to and not beyond a preassigned number in response to control signals of one character and to count in the reverse direction down to and not beyond another preassigned number in response to control signals of a different character, and means for controlling each of said switches in accordance with the electrical condition at a single one of the output points of said counter.

9. In a voice-operated automatic gain control system the combination which comprises a variable attenuation network having an input terminal, an output terminal and a plurality of taps, a switch connected to each of said taps, connections for applying a speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, a binary counter having a plurality of output points and adapted to convert an applied sequence of input pulses into a permutation code of electrical conditions on said output points, means for deriving from said modified signal a first sequence of gain increase pulses for a modified signal lying below a first preassigned lower threshold and a second sequence of gain reduction pulses for a modified signal exceeding a preassigned upper threshold, means for applying pulses of said first sequence to said counter in a fashion to cause counting in one sense and pulses of said second sequence to cause counting in the opposite sense, and means for controlling each of said switches in accordance with the electrical condition at a single one of the output points of said binary counter.

10. In combination with apparatus as defined in claim

9, means for restricting the derivation of each pulse of said first and second sequences to instants coinciding, respectively, with the terminal instants of successive voiced sound intervals.

11. In a voice-operated automatic gain control system the combination which comprises a variable attenuation network having an input terminal, an output terminal, an attenuation variation terminal, a connection for applying a speech signal to said input terminal, means for deriving from said output terminal a signal modified by the attenuation interposed by said network, means including a rectifier and a filter for deriving from said modified signal a signal of preassigned polarity, means for storing said preassigned polarity signal, said storing means having a time constant which is greater than the normal interval between successive voiced intervals of speech sounds, a source of a reference signal of said polarity, means for intermittently connecting said reference signal source to said storage element, thereby to derive an auxiliary signal substantially proportional to the difference between said first preassigned polarity signal and said reference signal, and means for applying said auxiliary signal to the attenuation variation terminal of said network.

12. Apparatus as defined in claim 11 wherein said connecting means comprises the series combination of a varistor, the emitter terminal of a transistor and the collector terminal of a transistor, and means for applying actuating pulses to the base electrode of said transistor.

13. In a voice-operated automatic gain control system the combination which comprises a source of a speech signal, means including a rectifier and a filter for deriving from said speech signal a signal of preassigned polarity, means for storing said preassigned polarity signal, said storing means having a time constant which is greater than the normal interval between successive voiced intervals of speech sounds, a source of a reference signal of said polarity, and means for intermittently connecting said reference signal source to said storage element, thereby to derive an auxiliary signal substantially proportional to the difference between said first preassigned polarity signal and said reference signal.

14. Apparatus as defined in claim 13 wherein said connecting means comprises the series combination of a varistor, the emitter terminal of a transistor and the collector terminal of a transistor, and means for applying actuating pulses to the base electrode of said transistor.

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