

March 2, 1937.

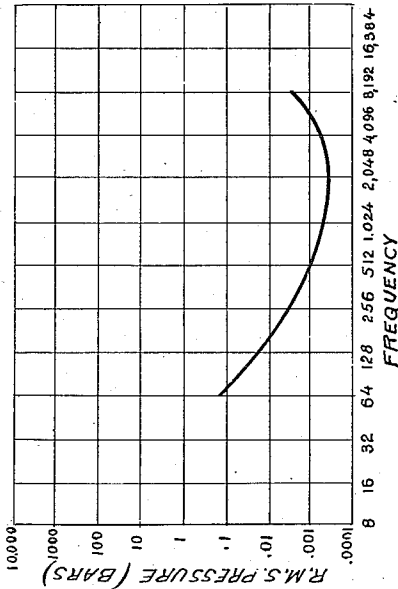
N. P. CASE

2,072,708

AMPLIFICATION CONTROL

Filed Aug. 4, 1934

3 Sheets-Sheet 1



March 2, 1937.

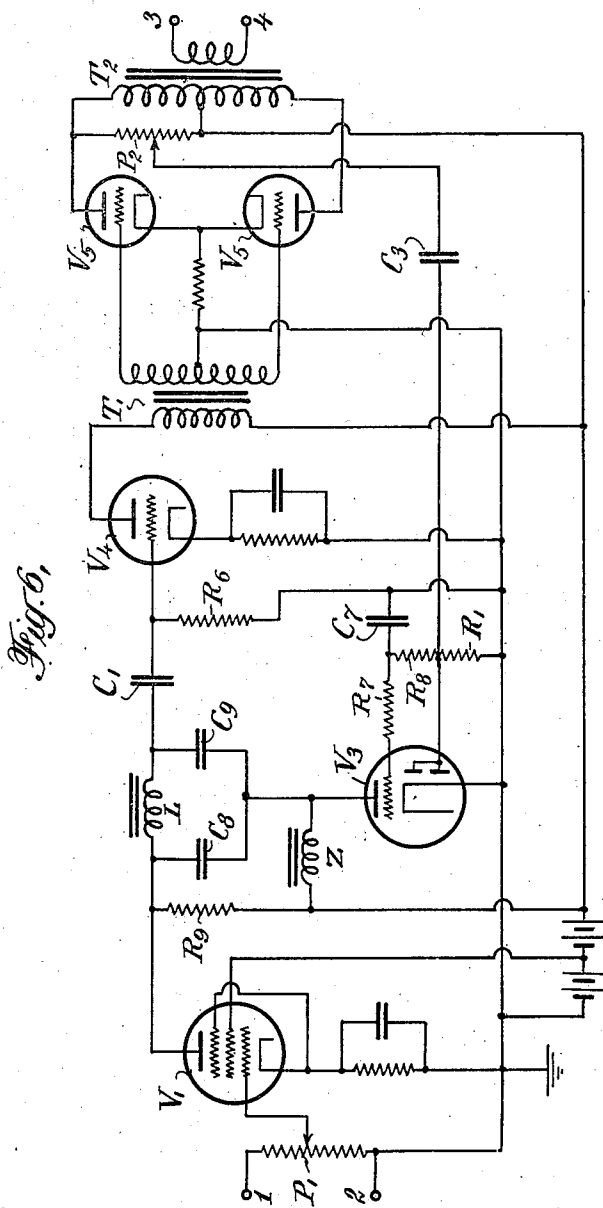
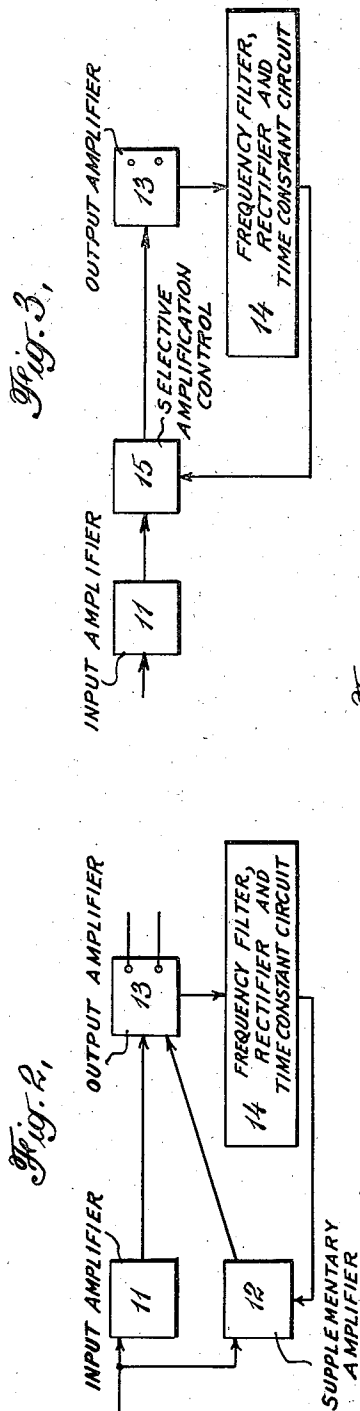
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AMPLIFICATION CONTROL

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3 Sheets-Sheet 2



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AMPLIFICATION CONTROL

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3 Sheets-Sheet 3

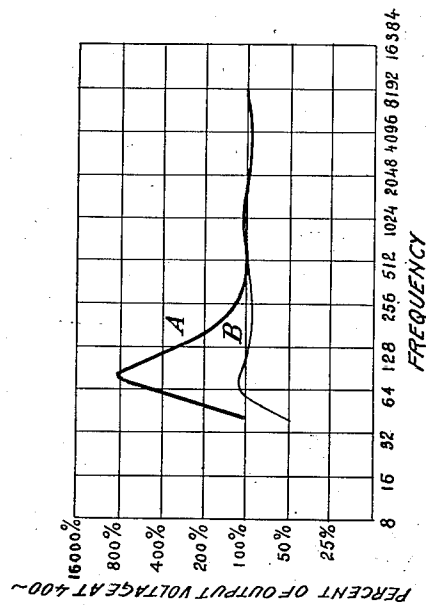
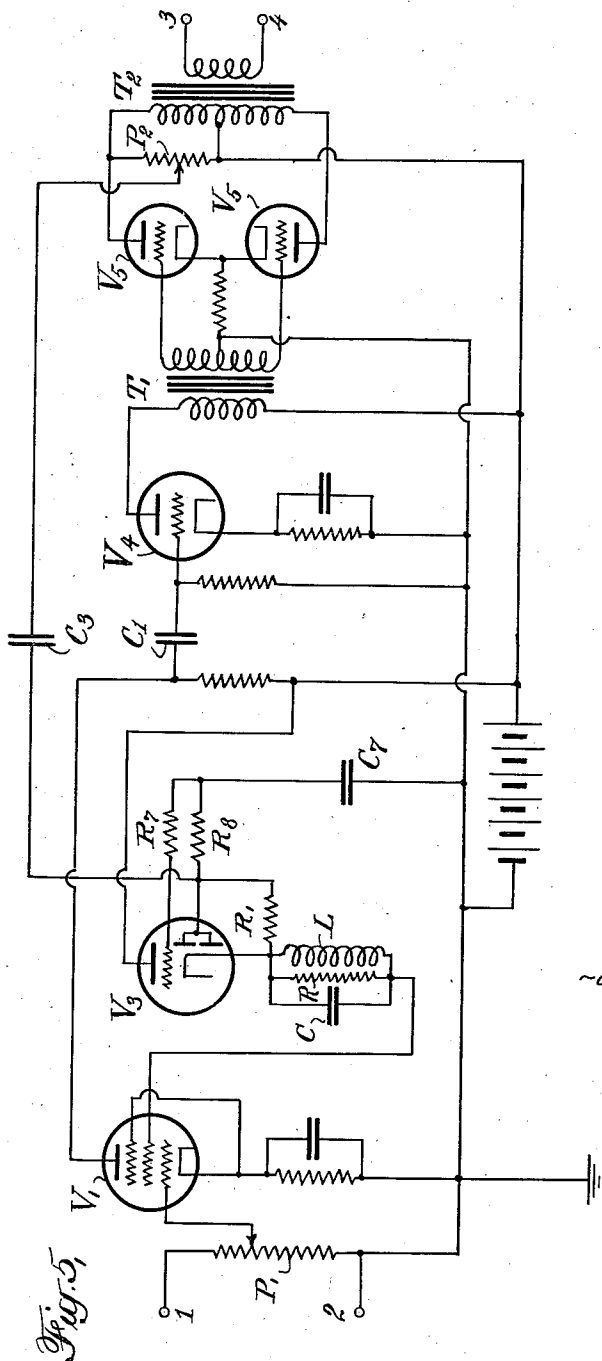


Fig. 7.

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AMPLIFICATION CONTROL

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18 Claims. (Cl. 179—171)

This invention relates to amplifier systems and more particularly to means for automatically varying the relative amplification of voltages at different frequencies within the frequency band in a desired manner and as a function of the signal level at a selected point in the system.

In accordance with the general principles of this invention, signal voltage is applied to the input of an amplifier system which includes one portion designed to amplify voltages within a substantially broad band of frequencies and another portion designed to amplify voltages within a narrow frequency band which may be within or adjacent to the wide band of frequencies. A portion of the amplified signal voltage is rectified and applied to the control element of a vacuum tube which alters the transmission properties of that portion of the amplifier designed to amplify within the narrow frequency band, thus automatically varying the output—vs.—frequency characteristic of the amplifier system as a whole, depending upon the strength of signal voltage at a given point thereof.

For illustration, this invention will be described in detail as applied to an audio-frequency amplifying system, such as might be employed in a radio broadcast receiver or in a phonograph, although the same general principles may be applied to a system adapted to amplify radio-frequency currents or combined radio- and audio-frequency currents. By means of the invention an audio-frequency amplifier may be so arranged as to increase the ratio of low-frequency voltages to voltages of higher frequency in the output, whenever the output voltage level is reduced below a designated value.

It is a well-known characteristic of the human ear that it becomes relatively insensitive to sounds of very low frequency when the sound intensity falls to a low level. The effect of this characteristic, in relation to music, is as follows:

When a musical program, as from a radio broadcasting station, is being reproduced at an acoustic level nearly the same as that at the microphone, the reproduction should sound most natural if the output—vs.—frequency characteristic of the electro-acoustic system is flat, i. e., if all the component frequencies are present in the reproduction in the same relative amplitude as in the original rendition.

Due to the small size of the average room in which a radio receiver or phonograph is operated, it is not normally desirable to have the reproduced sound as loud as the original. However, when the volume level is reduced to a satisfac-

torily low value without altering the relative amplitudes of the various frequency components, it is found that, because of the above-mentioned characteristic of the ear, the music sounds "thin", as though there were a serious deficiency in the reproduction of the low frequencies or bass notes. Therefore, in order to produce the psychological effect of true tone balance at low acoustic levels, it is necessary to introduce frequency discrimination in the amplifier so that the actual low frequency response is much greater than that for high frequencies.

An object of the present invention is, therefore, to provide a new and improved sound reproducing system in which the output volume may be reduced to any audible level without an apparent loss or diminution of the low frequencies.

Attempts have been made to achieve the desired result by connecting appropriate circuit elements so that the output—vs.—frequency characteristic of the amplifier system varies in shape according to the setting of the manual audio-frequency volume level control. While this method results in an appreciable improvement over the performance of an uncompensated amplifier, it is not entirely satisfactory, since the actual output of the amplifier varies over a wide range with a fixed setting of the volume control device, because of the normal variation of musical amplitude between pianissimo and fortissimo, or for other reasons.

It is, therefore, an additional object of this invention to augment the low-frequency response of an amplifier system relative to the response at high frequencies whenever the output level is low, regardless of whether the level is low because of a low input level or because the volume level control device is set at a low value.

In one form which this invention may take, the audio-frequency voltages are amplified by an audio-frequency amplifier system including a supplementary low-frequency amplifier. This supplementary amplifier contains a frequency-selective network so that it amplifies only the low-frequency voltages, which it is desired to reinforce at low levels. A portion of the output of the audio-frequency amplifier is rectified and filtered. The time constant of the filter circuit is chosen so that the action of the circuit is fast enough to follow the normal amplitude variations of music, and slow enough so that it produces no noticeable action during the duration of a single musical note. The resulting direct-current voltage is utilized to control the gain of the supple-

mentary amplifier in such a manner that whenever the output voltage of the amplifier is large, the degree of amplification or gain of the supplementary amplifier will be reduced and the audio-frequency voltages will be amplified only in the main amplifier. Whenever the output voltage decreases to a sufficiently low level, the supplementary amplifier will operate to amplify the low audio frequencies disproportionately.

The action of the supplementary amplifier is controlled by the integrated values of the various audio-frequency voltages that are present in the output circuit, although it is not necessary, and is often not desirable, to integrate uniformly over the entire audio-frequency band. It is usually preferable to give the higher frequency components relatively greater weight in controlling the gain of the supplementary amplifier. The output volume of the reproducer or loud speaker may be controlled by the usual manual volume control arrangement provided in the input of the special amplifier constructed in accordance with this invention. In a radio receiver, the usual automatic radio-frequency amplification control and manual volume control may be provided, operative upon the signals before they are supplied to the amplifier system constituting the present invention.

An alternative arrangement incorporating this invention may be provided wherein the amplification characteristic of an amplifier stage is caused to be selective in favor of the frequencies which it is desired to accentuate whenever the output voltage of the amplifier is low.

Another alternative arrangement incorporating the present invention may be provided wherein a portion of the voltages of medium and high audio frequency is bypassed and thus prevented from reaching the final amplifier, whenever the total output voltage is low. In this arrangement, whenever the output voltage falls to a sufficiently low level, for any reason whatever, the low-frequency voltages are consequently disproportionately amplified.

Attention is now invited to the accompanying drawings in which:

Fig. 1 is a diagram showing the threshold sound pressures of the average human ear for various audio frequencies;

Figs. 2 and 3 are schematic diagrams of amplifier systems constructed in accordance with this invention;

Fig. 4 is a circuit diagram of an audio-frequency amplifier system constructed in accordance with a preferred embodiment of the present invention;

Fig. 5 is a circuit diagram of an audio-frequency amplifier constructed in accordance with a modification of the present invention;

Fig. 6 is a circuit diagram of another modification of the present invention; and

Fig. 7 is a diagram showing the percentage relationships, for high and low output, voltage levels, between the various frequencies in the audio-frequency output of an amplifier constructed in accordance with this invention.

Referring first to Fig. 1, the ordinates represent the sound pressure and the abscissas represent audio frequencies. The curve, which was taken from "Speech and Hearing" by Fletcher, gives the minimum audible value of the sound pressure for various audio frequencies. It can be seen from this figure that the average ear is most sensitive to frequencies lying between 1000 and 4000 cycles and that the sound pressure necessary for audi-

bility at a frequency between 64 and 128 cycles is many times that necessary for audibility at 1000 cycles.

Fig. 2 shows a schematic diagram of an amplifier system constructed in accordance with a preferred embodiment of this invention. In this figure the signal to be amplified is supplied to the input amplifier 11 and the supplementary amplifier 12. The outputs of both the amplifiers 11 and 12 are supplied to the output amplifier 13 by which the signals are further amplified. A portion of the output of the output amplifier is supplied to the frequency filter, rectifier, and time constant circuit indicated at 14. Here the voltages of the various frequencies are integrated, the higher frequencies usually being favored over the lower, and rectified to produce a controlling bias for the supplementary amplifier 12. The circuit of 14 includes a time constant circuit in order that instantaneous variations of the output level will not affect the supplementary amplifier. The operation of this system will be described hereinafter in connection with the description of Fig. 4.

Fig. 3 is a schematic diagram of an alternative arrangement of an amplifier system embodying this invention. In this figure the signal is supplied to the input amplifier 11. The signal is then passed to the selective amplification control 15 and thence to the output amplifier 13. A portion of the output of the amplifier 13 is supplied to the frequency filter, rectifier and time constant circuit 14. Here the voltages of various frequencies are integrated, usually favoring the higher frequencies over the lower, and rectified to produce a controlling bias for the selective amplification control 15. The circuit of 14 includes a time constant circuit in order that instantaneous variations of the output level will not affect the selective amplification control. The operation of this system will be described hereinafter in connection with the description of Fig. 6.

Fig. 4 shows an amplifier circuit constructed in accordance with the invention. In this figure, the input terminals 1—2 are connected across a voltage divider P_1 , the variable tap of which serves to impress a desired portion of the input voltage across the input of the amplifier tube V_1 . The input signal is amplified in tube V_1 and is supplied through the usual network including the coupling condenser C_1 to the grid of the tube V_2 . The signal is further amplified in the amplifier tube V_2 and impressed through an appropriate network including the coupling condenser C_2 to the input of the amplifier tube V_4 . Here the signal is further amplified and impressed through the transformer T_1 upon the inputs of the push-pull connected vacuum tubes V_5, V_6 . The output of the push-pull connected amplifier is connected to the primary of output transformer T_2 . Across one-half of the primary of the output transformer T_2 is connected a voltage divider P_2 by means of the variable contact of which a desired portion of the output voltage is supplied through the coupling condenser C_3 to the diode plates of the tube V_3 . A diode resistor R_1 is connected between the diode plates and the cathode of the tube V_3 .

A circuit including resistor R_2 , condenser C_4 and condenser C_5 is connected between the plate of the tube V_1 and the cathode thereof. A connection between the condensers C_4 and C_5 is made to the input grid of the supplementary amplifier tube V_2 by which low-frequency signals are impressed upon the tube V_2 in a manner

hereinafter more fully described. The rectified voltage developed across the resistor R_1 and the normal voltage across the cathode resistor R_3 of the tube V_2 determine the bias voltage of the vacuum tube V_3 in a manner which will be described more fully hereinafter. The low-frequency voltages are amplified in the tube V_3 and supplied through an appropriate network including the condenser C_6 to the grid of the amplifier tube V_4 in which they are amplified together with the signal voltages supplied to the grid of tube V_4 through condenser C_2 .

Appropriate resistors, condensers and voltage supply sources are provided as indicated. Any appropriate voltage supply may be provided, although batteries have been shown for convenience.

In operation, the amplified signal voltage appearing at the plate of the tube V_1 , is applied to the grid of the tube V_2 through a network which does not discriminate amongst the various useful audio frequencies. The amplified signal voltage is also supplied to the control grid of the tube V_3 through the network R_2 , C_5 . The condenser C_4 is of high capacity and serves only to block off the high direct-current voltage from the grid of the tube V_3 . The grid of the tube V_3 is therefore excited by the voltage drop across the condenser C_5 . It is obvious that at high frequencies only a small percentage of the voltage appears across this condenser, while at very low frequencies most of the voltage is developed across it. The resistor R_2 is chosen to be of high enough resistance so that the condenser C_5 does not affect the input to the tube V_2 appreciably at high frequencies. Tube V_3 is a high gain amplifier tube, and the circuit constants are so chosen that with normal bias on the grid of the tube V_3 , the low frequencies which are amplified by V_3 are amplified to several times the extent to which the signals are amplified by the tube V_2 and its associated circuit elements. The signals which have been amplified by tubes V_2 and V_3 are combined and applied to the grid of the tube V_4 which feeds the push-pull output tubes V_5 in the usual manner. Usually a loud speaker is connected to the output terminals 3—4.

The signal voltage taken from the voltage divider P_2 is fed through the condenser C_3 to the diode detector embodied in the tube V_2 . The diode leak resistance R_1 must be high enough so that it produces a negligible loading effect upon the output circuit. The value of the condenser C_3 must be carefully chosen in relation to the resistance of R_1 . If this condenser is too small, the bass notes will be accentuated too much when the output level is high, providing the music being reproduced contains few treble notes. On the other hand, if this condenser is too large, the desired accentuation of the bass at low output levels cannot be achieved because the bass notes themselves will excite the diode circuit too much, on account of the relatively greater amplitude of the low frequencies in most music.

At high output levels, a large negative bias voltage is built up at the diode plates of the tube V_2 , and this voltage is transmitted through the filter network R_6 — C_7 — R_7 to the grid of the tube V_3 , sufficient to render the tube V_3 inoperative. Under these conditions the amplifier has a normal, flat frequency characteristic.

As the output voltage decreases, from any cause whatever, the negative voltage on the diode plates decreases until, at a certain output level, the tube V_3 commences to be operative. As al-

ready noted, the input circuit of the tube V_3 favors the lower frequencies with reference to the higher. The output circuit of the tube V_3 is also discriminatory against high frequencies to a certain extent; V_3 is a high impedance tube, which means that the voltage amplification obtained is approximately proportional to its plate circuit load impedance; for very low frequencies the plate circuit impedance is practically that of its plate resistor R_5 in parallel with the grid leak R of the tube V_4 ; for very high frequencies, the plate resistor R_4 of the tube V_2 is also effectively in parallel with the resistances R_5 and R_6 , and since R_4 is considerably lower in resistance, the gain through the tube V_3 for high frequencies is considerably lower than for low frequencies. Therefore when V_3 is operative, it serves to accentuate the bass notes relative to those of the middle and treble registers.

As the output voltage continues to decrease, the potential on the diode plates of tube V_2 approaches that of the cathode of V_2 , and under this condition, the tube V_3 operates with maximum gain. Therefore, for all outputs below a certain level, the bass receives the full accentuation of which the system is capable. The choice of the level at which to flatten out the gain curve and the choice of the particular frequency range to accentuate may be preselected by a variation of the circuit elements involved.

Although any appropriate amplifier tubes may be used, the following American type tubes are suitable:

V_1 ----- The triode section of a type 85 tube
 V_2 ----- A type 85
 V_3 ----- A type 77
 V_4 and V_5 --- type 42 tubes connected as triodes.

Although the resistors and condensers shown may have any appropriate characteristics, the following values are given for the purpose of illustration;

C_1 -----	μf -----	0.01
C_2 -----	μf -----	0.02
C_3 -----	μf -----	0.003
C_4 -----	μf -----	0.1
C_5 -----	μf -----	0.005
C_6 -----	μf -----	0.05
R_1 -----	ohms-----	500,000
R_2 -----	do-----	100,000
R_3 -----	do-----	4,000
R_4 -----	do-----	50,000
R_5 -----	do-----	160,000
R_6 -----	do-----	500,000
R_7 -----	megohms-----	0.5
R_8 -----	do-----	0.5
C_7 -----	μf -----	0.25

The alternative system of Fig. 5 includes an amplifier for amplifying the high and low frequency signals to a greater extent than the mid-die register signals whenever the output volume is reduced. In this circuit, where circuit elements having functions corresponding to those of similar elements in Fig. 4 are similarly designated, the input terminals 1—2 are connected across the voltage divider P_1 , the variable contact of which serves to impress any desired portion of the input voltage across the input of the tube V_1 . The output of the tube V_1 is connected through an appropriate network including the condenser C_1 to the control grid of the amplifier tube V_4 . The output of the tube V_4 is connected through the transformer T_1 to the inputs of the push-pull connected amplifier tubes V_5 , V_6 . The

output of the push-pull amplifier is connected to the primary of transformer T_2 , the secondary of which is connected to the output terminals 3-4 across which a loud speaker may be connected.

A voltage divider P_2 is connected across one-half of the primary of the output transformer T_2 . The variable contact of voltage divider P_2 is connected through condenser C_3 to the diode plates of the tube V_3 . A resistor R_1 is connected between the cathode of the tube V_3 and the diode plates. The screen-grid of the tube V_1 is connected through a network comprising the parallel impedances L , R , and C to the cathode of the tube V_3 . Appropriate biasing resistors, coupling resistors and voltage supply sources are provided as indicated. Specific details of these elements are not essential to the operation of the invention. For instance, any appropriate voltage source may be provided.

In operation, whenever the voltage of the output at the terminals 3-4 is high, a high voltage is impressed upon the diode plates of the tube V_3 resulting in a considerable direct-current voltage being built up across the resistor R_1 . This causes the grid of tube V_3 to have a high negative bias so that this tube acts as a high resistance in the screen circuit of the tube V_1 . If the resistance of the tube V_3 is large compared with the anti-resonant impedance of the circuit $L-R-C$, then the amplifier will have a flat characteristic. For low level signals, the resistance of the tube V_3 is relatively small and therefore the gain-vs.-frequency characteristic curve of the tube V_1 will have a dip at the resonant frequency of $L-C$. The characteristics of $L-R-C$ are chosen to cause the combination to be broadly resonant at the middle register by means of which the amplification of the amplifier at middle register frequencies may be greatly reduced at low output volumes. The circuit $L-R-C$ may be replaced by a more complicated network to produce any desired shape of response curve.

Attention is now invited to Fig. 6, which is a circuit diagram of an arrangement related to the block diagram of Fig. 3. The signal voltage is applied to the input terminals 1 and 2, across which is connected a voltage divider P_1 . The portion of the input voltage appearing between terminal 2 and the variable tap on the voltage divider is applied to the control grid of the high gain amplifier tube V_1 . Neglecting consideration of the action of the filter circuit $L-C_8-C_9$ for the moment, it will be seen that amplified signal voltage appears across the coupling resistor R_6 and is transferred through the coupling condenser C_1 to the grid of the amplifier tube V_4 . After being further amplified by tube V_4 , the signal voltage is applied through the push-pull input transformer T_1 to the grids of the push-pull connected output amplifier tubes V_5 . After being further amplified by tubes V_5 the signal voltage is applied to the output transformer T_2 and thence to the output terminals 3 and 4.

Across one-half of the primary of transformer T_2 is shunted a voltage divider P_2 . The fraction of the amplified signal voltage which appears between the variable tap of P_2 and ground is applied through the coupling condenser C_3 to the diode plates of tube V_3 . Resistance R_1 serves as a load resistance for the diode circuit of V_3 . The rectified current flows through R_1 resulting in a pulsating direct-current voltage appearing across R_1 . The alternating current components

of this voltage are substantially removed by means of the filter circuit $R_7-C_7-R_8$ and the resulting direct-current voltage is applied as a bias voltage to the grid of tube V_3 . Tube V_3 acts as a variable resistance connected in the common ground lead of the low-pass filter network C_8-L-C_9 . Direct-current plate potential is supplied to V_3 through the impedance Z , which has a high impedance to all frequencies in the useful range and plays no part in the action of the device except to prevent signal currents from passing directly from the plate of tube V_3 to ground through the plate voltage source, in this case indicated by a battery for the sake of simplicity.

The action of the control circuit is as follows: When the signal level across the primary of T_2 is high, a relatively high negative bias voltage is applied to the grid of V_3 , which causes V_3 to have a very high resistance to signal currents. Consequently the filter circuit C_8-L-C_9 has a negligible effect on the transmission properties of the amplifier, since the input impedance of tube V_4 is high for all audio-frequencies. As the signal level at T_2 is reduced, however, less bias voltage is applied to the grid of V_3 , and when the bias voltage falls to a low value, the tube V_3 offers a relatively low resistance to currents of signal frequency. This condition permits the low-pass filter C_8-L-C_9 to become effective and therefore the transmission characteristic of the amplifier is altered so that low frequencies are amplified to a greater extent than high frequencies.

In each of the circuits shown, the resistors R_7 and R_8 and the condenser C_7 comprise a filter to prevent the alternating current components from reaching the grid of the control tube and to introduce a time constant to average the controlling voltage over a desired time interval. In the example given the time constant is $\frac{1}{2}$ second. This time constant is not critical, but should be small enough to enable the bias to follow the normal variations in loudness of a musical passage, and large enough so that no noticeable controlling action appears during the duration of a single normal musical note.

Fig. 7 illustrates the output-vs.-frequency characteristic of an amplifier constructed in accordance with the circuit arrangement of Fig. 4. The curves A and B represent, respectively, the output-vs.-frequency characteristic at various audio frequencies for low and high output levels, respectively. The ordinates represent the output voltage at the various frequencies with reference to the output at 400 cycles. It can be seen that with low output voltage the low frequencies between 64 and 128 cycles predominate by from about 300 to 800% relative to the frequencies of more than 500 cycles. Therefore as the volume of the output is reduced by any means whatever, the low-frequency amplification becomes relatively greater. Thus with this arrangement, the response at the low frequencies is maintained at a sufficiently high level to remain above the threshold value of the average ear in order that the low frequencies will not seem to fade out as the output level is reduced.

Whereas this invention has been described for the purpose of illustration with reference to the three specific examples given above, it is to be understood that any appropriate circuit in which the shape of the output-vs.-frequency characteristic curve is controlled by a voltage derived from the rectification of all or part of

the audio-frequency components of the signal being amplified may be used to accomplish the objects of this invention.

What I claim:

1. In a multi-stage vacuum tube amplifier system adapted to amplify signal voltages within a wide frequency band, a path including main amplifier means adapted to amplify voltages of all of the frequencies of said band and a second path connected in circuit with at least a portion of said first path and including supplementary amplifier means adapted to amplify voltages of only a portion of the frequencies within said band, means for combining the voltages so amplified, and means for automatically varying the amplifying properties of the supplementary amplifier means in accordance with the amplitude of signal voltages.

2. In a multi-stage vacuum tube amplifier system adapted to amplify signal voltages within a wide frequency band, a path including main amplifier means adapted to amplify voltages of all of the frequencies of said band and a second path connected in circuit with at least a portion of said first path and including supplementary amplifier means adapted to amplify voltages of only the lower frequencies within said band, means for combining the voltages so amplified, and means for automatically varying the amplifying properties of the supplementary amplifier means in accordance with the amplitude of signal voltages.

3. In a multi-stage vacuum tube amplifier system adapted to amplify signal voltages within a wide band of frequencies, a path including main amplifier means adapted to amplify voltages of all of the frequencies of said band, a second path connected in circuit with at least a portion of said first path and including supplementary amplifier means adapted to amplify only voltages within a narrow frequency range in said wide band of frequencies, a rectifier associated with said system to develop a direct-current potential from signal current supplied thereto, and connections for applying said direct-current potential to a control element of said supplementary amplifier means to control automatically the amplification of said supplementary amplifier means.

4. In an amplifier system, the method of audio-frequency amplification which includes automatically varying the relative amplification of voltages of different frequencies within the audio-frequency band in accordance with the variations of the audio-frequency voltage level at a given point in the amplifier, said voltage level being integrated with discrimination against a selected portion of the audio-frequency band, and averaged over a preselected interval of time.

5. In an amplifier system, the method of audio-frequency amplification which includes substantially uniformly amplifying voltages of all of the frequencies of a wide band, simultaneously supplementally amplifying the voltages of the lower frequencies of said band and automatically increasing said supplemental amplification of said low-frequency voltages as the integrated audio-frequency voltage level at a given point in the amplifier decreases.

6. In an amplifier system for amplifying simultaneously voltages representative of a broad band of audio-frequencies, said voltages being subject to variations in amplitude, an input circuit, an amplifier coupled to said input circuit,

an output circuit, means for integrating the voltage level at a given point in the amplifier system with discrimination against a portion of the audio-frequency band, means for averaging said integrated voltage level over a preselected interval of time, and means for automatically varying the relative amplification of voltages of different frequencies within the audio-frequency band in accordance with the variations of said integrated and averaged voltage level.

7. In an amplifier system for amplifying simultaneously voltages representative of a broad band of audio-frequencies, said voltages being subject to variations in amplitude, an input circuit, an amplifier coupled to said input circuit, an output circuit, means for integrating the voltage level at a given point in the amplifier with discrimination against a portion of the audio-frequency band, means for averaging said integrated voltage level over a preselected interval of time, and means for automatically increasing the ratio of the amplification of low-frequency voltages to the amplification of voltages of higher frequency as the said integrated and averaged voltage level decreases.

8. In an amplifier system for amplifying simultaneously voltages representative of a broad band of audio-frequencies, said voltages being subject to variations in amplitude, an input circuit, an amplifier coupled to said input circuit, a frequency-selective network incorporated in said system, a variable-resistance device controlling the action of said frequency-selective network, an output circuit, means for integrating the voltage level at a given point in the amplifier system with discrimination against a portion of the audio-frequency band, means for averaging said integrated voltage level over a preselected interval of time, and means for automatically varying the resistance of said variable-resistance device in accordance with the variation of said integrated and averaged voltage level.

9. In an amplifier system for amplifying simultaneously voltages of varying amplitudes representative of a broad band of audio-frequencies, an input circuit, an amplifier, an output circuit, a supplementary amplifier system connected in parallel with at least a portion of said amplifier, a frequency-selective network incorporated in said supplementary amplifier system, means for integrating the voltage level at a point of said amplifier with discrimination against a portion of the audio-frequency band, means for averaging said integrated voltage level over a preselected interval of time, and means for varying the amplification of the supplementary amplifier in accordance with the variation of said integrated and averaged voltage level.

10. In an amplifier system for amplifying simultaneously voltages representative of a broad band of audio frequencies, said voltages being subject to variations in amplitude, an input circuit, an amplifier coupled to said input circuit, an output circuit, means for integrating the voltage level at a point of the amplifier, comprising a rectifier, a coupling between said point of said amplifier and said rectifier, said coupling including a frequency-selective network, and a load resistance for said rectifier across which a controlling voltage is developed; and means for averaging over a preselected time interval the integrated voltage developed across said rectifier load resistance, comprising a coupling circuit between the high-potential end of said load resistance and the point at which said controlling

voltage is applied, said coupling circuit including series resistance together with shunt capacitance, said resistance and said capacitance being so proportioned that the time constant of said coupling circuit is small enough to enable the controlling voltage to vary substantially as the amplitude envelope of a normal musical passage and large enough so that the controlling voltage will not vary substantially during a single musical note.

11. In an audio-frequency amplifier system including an input and an output, the method of audio-frequency amplification which includes substantially uniformly amplifying voltages representative of the entire audio-frequency band in one path, in a separate path amplifying voltages representative of the low-frequency portion of the band, and increasing said last mentioned amplification as the level of the voltage in said output is decreased.

12. In an amplifier system for amplifying voltages of varying amplitudes within a broad band of frequencies, an input amplifier, an output amplifier, a path coupling said input amplifier to said output amplifier, a separate path coupling said input amplifier to said output amplifier and including a supplementary amplifier, and a filter whereby only a predetermined part of the frequencies of said band are impressed upon said supplementary amplifier, and means for automatically controlling the amplification in said supplementary amplifier in accordance with the amplitude of the amplified voltage in the output of said output amplifier.

13. In an amplifier system for amplifying voltages covering a broad band of frequencies and subject to variation in voltage level, an input, an amplifier tube connected to said input, a supplementary amplifier, a coupling separately connecting said input and said supplementary amplifier, said coupling including means for discriminating against voltages of certain frequencies in said band of frequencies, individual output circuits coupled to said amplifiers, means for controlling the amplification of said supplementary amplifier in accordance with the amplitude of the signal voltages, and means introducing a time constant into the action of said amplification controlling means.

14. In an amplifier system for amplifying volt-

ages covering a broad band of frequencies and subject to variation in voltage level, an input circuit, an output circuit, two parallel amplifier circuits coupled between said input and output circuits, a network included in one of said amplifier circuits for discriminating against voltages of certain frequencies in said band of frequencies, and a coupling between the output circuit and said last-mentioned amplifier circuit for accentuating therein the amplification of voltages of other frequencies in said band of frequencies whenever the output signal voltage decreases.

15. In an amplifier system, the method of audio-frequency amplification which includes substantially uniformly amplifying the voltages of all frequencies within a wide band, in a separate path supplementally amplifying voltages of certain of said frequencies, and automatically varying the supplemental amplification according to the amplitude of the signal voltages.

16. An amplifier system for amplifying signal voltages within a wide frequency band, a main path designed substantially uniformly to pass the frequencies of said band, a separate path electrically connected in circuit with at least a portion of the main path and designed to pass only a portion of the frequencies of said band, and means for automatically controlling the passage of frequencies through said separate path according to the amplitude of said signal voltages.

17. In a multi-stage vacuum tube amplifier system, a path including amplifier means designed substantially uniformly to amplify signal voltages of all frequencies within a wide band, a separate path electrically connected in circuit with at least a part of the first said path, including amplifier means adapted to amplify voltages of frequencies within a narrow range included substantially in said wide band, and means for automatically varying the amplification of said second amplifier means according to the amplitude of said signal voltages.

18. In an amplifier system, the method of amplifying voltages of frequencies within a wide band, which includes simultaneously and automatically augmenting the amplification of low-frequency voltages as the amplitude of the signal decreases and maintaining the amplification of higher frequency voltages substantially constant.

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