July 4, 1944. K. B. AUSTIN 2,352,931

FREQUENCY RESPONSE CONTROL CIRCUIT

Filed July 1, 1941

Fig. 1.

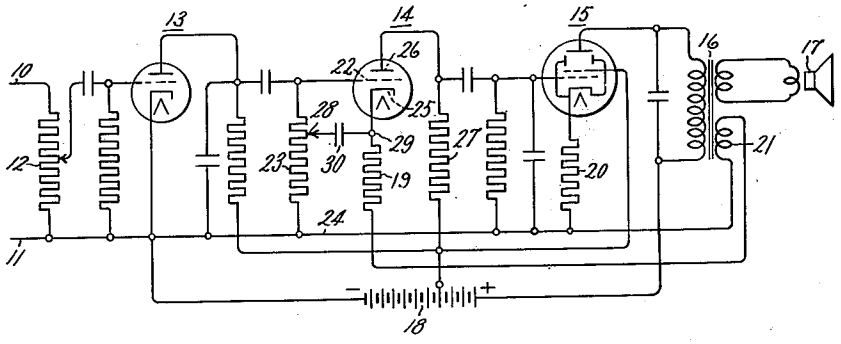


Fig. 2.

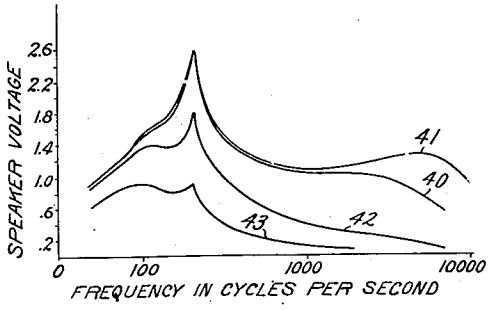
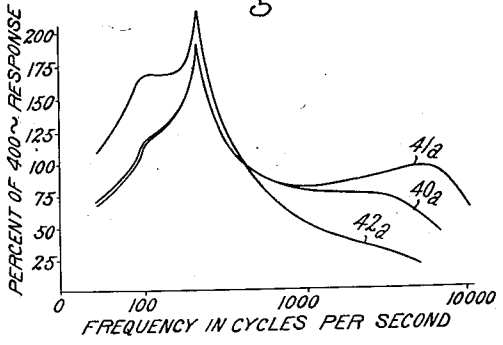


Fig. 3.



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Patented July 4, 1944 2,352,931

UNITED STATES PATENT OFFICE

2,352,931

FREQUENCY RESPONSE CONTROL CIRCUIT

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Application July 1, 1941, Serial No. 400,631

11 Claims. (Cl. 179—171)

My invention relates to apparatus for controlling the frequency response characteristics of an amplifying system and, while it is not limited thereto, it is particularly applicable to a manual tone control for the audio frequency circuits of a radio receiver.

It is an object of my invention to provide an improved control circuit having manual adjusting means which may be actuated to vary the frequency response characteristics of a signal amplifier in a predetermined manner.

Another object of my invention is to provide an improved tone control circuit, in conjunction with an audio frequency amplifier, by means of which the relative amplification of the higher and lower audio frequencies may be varied or adjusted in a predetermined manner.

It is often the practice to employ degenerative, or negative, feedback in low frequency signal amplifiers, such as audio frequency amplifiers. As is well-known, degenerative feedback tends to flatten the frequency response characteristics of the system. It is a specific object of my invention to provide an improved control circuit, in conjunction with such an amplifier, whereby the frequency response characteristics of the amplifier coupling circuits and also the relative degeneration at different signal frequencies may be varied simultaneously through movement of a manual control member having only a single movable contact.

Still another object of my invention is to provide a manual tone control for a radio receiver by means of which the "bass" response or the "treble" response may be varied at will in order to suit the individual preference of the listener, or to provide increased intelligibility in the reception of weak signals accompanied by "noise," or for other purposes.

It is also an object of my invention to provide a manual tone control which is economical and readily adapted to existing radio receiver circuits and which permits manual adjustment of the audio frequency response in a manner which is particularly suited to the requirements of commercial entertainment receivers.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in which Fig. 1 is a circuit diagram of an audio frequency amplifying and sound reproducing system embodying my invention and which may for example comprise the final stages of a radio receiver; and Figs. 2 and 3 are graphs illustrating the manner in which the frequency response characteristics of a particular experimental amplifier, of the general form shown in Fig. 1, could be controlled in accordance with my invention.

Audio frequency signals from any suitable source, not shown, are impressed upon the terminals 10 and 11 of a volume control potentiometer 12. In a superhetrodyne radio broadcast receiver this potentiometer may be coupled to the output of the second detector. The signals are amplified in a three-stage signal amplifier, comprising a first audio frequency amplifier 13, a second audio frequency amplifier 14, and the final power amplifier 15. The output of the power amplifier 15 is supplied through an audio output transformer 16 to a suitable translating device, represented conventionally by the loud speaker 17. As illustrated, the stages 13, 14 and 15 are resistance-coupled together in the usual manner. Suitable operating potentials are supplied from the common power supply source, represented conventionally by a battery 18.

In the circuits of Fig. 1 the second audio frequency amplifier 14 and the final power amplifier 15 have unbypassed resistors 19 and 20, respectively, common in their grid and anode circuits. As is well understood in the art, the purpose of these resistors is to provide a certain amount of degenerative, or negative, feedback between the anode and grid circuits of the respective amplifiers. This not only tends to flatten the frequency response characteristics of the system, but also provides proper operating grid bias potentials for the amplifiers.

The common cathode return circuit of the amplifier 14 also includes a tertiary winding 21 on the output coupling transformer 16. This winding 21 is connected in the proper polarity to provide further degenerative feedback at signal frequencies to the grid of the amplifier 14. Thus, the grid circuit of this amplifier may be traced from its control grid 22 through the grid resistor 23, the negative power supply bus 24, the coil 21 and the degeneration resistor 19 to the cathode 25. The anode circuit for the amplifier 14 may also be traced from its anode 26 through the output coupling resistor 27, a portion of the power supply source 18, the negative power supply bus 24, the coil 21 and the degeneration resistor 19 to the cathode 25.

In order to provide manual control of the frequency response characteristics of the system of

Fig. 1, the grid resistor **23** is provided with an adjustable tap connection **28** which is connected to a point **29** upon the common cathode circuit, located between the cathode **25** and the degeneration resistor **19**, through an alternating current path including a tone control capacitor **30**. The grid resistor **23** is preferably in the form of a potentiometer and the adjustable tap **28** is preferably a sliding contact which may be adjusted to any point on the resistor **23** between the end connected to grid **22** and the opposite end connected to the negative power supply bus **24**.

If the capacitor **30** is properly proportioned with respect to the resistor **23** and the feedback elements **19** and **21**, the relative response of the system to high and low audio frequencies can be varied over a considerable range in a desired manner by adjustment of the tap **28**. The adjustment and operation of my invention will be better understood by reference to the curves of Figs. 2 and 3. These curves were prepared from test data taken on an experimental audio amplifying system essentially of the form shown in Fig. 1. While it will be appreciated that my invention is not limited thereto, the more important circuit constants for this particular amplifier are given in order to assist in understanding the physical significance of these curves. Thus, in this particular system the amplifier **13** was the triode section of a Type 6SQ7 tube, the amplifier **14** was a Type 6J5 tube, and the power amplifier **15** was a Type 25L6G beam power amplifier tube. The constants of some of the other circuit elements were as follows:

Resistor **19**	ohms	3300
Resistor **23**	megohm	1
Capacitor **30**	mfd	.01

Other circuit elements were conventional.

The abscissae of the curves of Fig. 2 correspond to frequencies in cycles per second over the audio range, and the ordinates correspond to voltages at the speaker **17**. The sharp peak in each of these curves in the vicinity of 200 cycles per second, as well as in the curves of Fig. 3, was due to the mechanical characteristics of the particular loud speaker used for the tests.

The curve **40** represents the response characterics of the system with the capacitor **30** entirely disconnected, and is included for purposes of comparison. When the capacitor **30** was connected in the circuit, with the sliding contact **28** at the lower end of the resistor **23**, the curve **41** was secured. It will be observed that this curve is essentially of the same form as curve **40** except that the response at higher frequencies is increased, giving an increased "treble" effect. The reason for this is as follows: In this position of the tone control, the capacitor **30** is in shunt to the degeneration path comprising the resistor **19** and the feedback coil **21** in series. Since the capacitor **30** was selected so as to have a relatively low impedance only at the higher audio frequencies (.01 mfd. in this case), these higher frequencies were largely bypassed around the resistors **19** and coil **21**. Consequently, less degeneration occurred at the higher audio frequencies, as is seen from curve **41**. The result was thereby to increase the gain at this end of the signal band.

With the slider **28** at the grid end of resistor **23** the curve **42** was secured. It will be observed that under these conditions the response at higher audio frequencies is decreased with respect to the response at the lower audio frequencies, giving an increased "bass" effect. The reason for this becomes evident when it is noted that the capacitor **30**, the resistor **19**, and the coil **21** in series now constitute a shunt load across the grid resistor **23**. Therefore, at the higher audio frequencies the impedance of the grid circuit of amplifier **14** is decreased. As will be apparent to those skilled in the art, this in turn causes the shunt load upon the amplifier **13** to increase with frequency.

It will also be noted that the shunting effect of the capacitor **30**, when the tap **28** is at the grid end of resistor **23**, is limited by the impedance of the resistor **19** and the signal voltage appearing across the coil **21**. If the .01 mfd. capacitor **30** were connected directly from the grid **22** to the conductor **24** in this particular amplifier the attenuation at the higher frequencies in particular would be far too great. The type of response curve obtained by this connection is indicated at **43** in Fig. 2 for the purposes of comparison.

The curves **40***a*, **41***a*, and **42***a* of Fig. 3 correspond respectively to the curves **40**, **41** and **42** of Fig. 2 and the data for them were taken under the same conditions. The abscissae of these curves likewise correspond to audio frequencies in cycles per second but the ordinates in this figure are expressed in terms of "percent of 400 cycle response." Such curves give an approximate qualitative indication of the receiver response characteristics as they seem to the human ear. Therefore, these curves indicate how the tone quality of the receiver may be adjusted to produce a ratio of high frequencies to low frequencies most pleasing to the listener. Also, it is often desirable to cut down the high frequency response to provide greater intelligibility of weak signals partially masked by "noise." Curves **41***a* and **42***a* show that the apparent response characteristics may be varied over a wide range to accomplish this result.

It will be understood that the manner in which the frequency response varies with adjustment of the tap **28** may be predetermined by a proper selection of the various circuit constants so as to suit the design requirements of any particular receiver. It may be desirable in some cases to connect the right-hand terminal of the capacitor **30** to a point farther down on the common cathode connection **19, 21**. In such case it will be observed that the shunt loading effect upon the amplifier **13** is greater when the tap **28** is at the grid end of resistor **23** and that the reduction in degeneration at the higher frequencies is less when the tap **28** is at the opposite end. It may also be desirable in some cases to modify the bypassing effect of capacitor **30** by employing additional impedance in series with capacitor **30** between tap **28** and point **29**. Therefore, I wish it to be understood that where the term "point" is used in the appended claims in reference to the connections of the tone control capacitor, it may include intermediate points upon the grid and cathode impedance elements, as well as terminal points, unless otherwise qualified.

Summarizing, it will be seen that my invention provides an improved means for manually controlling the frequency response characteristics of a feedback amplifier operating over a band of signal frequencies. Only a single adjustable contact is needed to permit simultaneous adjustment of the interstage coupling characteristics and the feedback characteristics of the amplifier at different signal frequencies within the

pass band. Therefore, while I have shown a particular embodiment of my invention, it will be of course understood that I do not wish to be limited thereto since various modifications may be made. and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In a system for amplifying signals having frequencies extending over a predetermined frequency band, the combination of an amplifier for said signals having a control element and a cathode, an impedance element connected between said control element and a reference point, a circuit connection between said cathode and said point including a plurality of means for supplying feedback voltages to said grid at signal frequencies, and an alternating current connection from an adjustable point on said impedance element to a point on said circuit connection between said reference point and said amplifier, said connection including an impedance of such value that the frequency response characteristic of said amplifier is varied by movement of said adjustable point on said impedance element with substantially little change in the gain of said amplifier.

2. In a system for amplifying signals having frequencies extending over a predetermined frequency band, the combination of an amplifier for said signals having a control element and a cathode, an impedance element connected between said control element and a reference point, a circuit connection between said cathode and said point including a plurality of means for supplying feedback voltages to said grid at signal frequencies, a contact adjustable on said impedance element and a capacitance element connected from said contact to a point on said circuit connection between said feedback means and said amplifier, said capacitance being of such value that movement of said adjustable contact on said impedance element is effective to vary the frequency response characteristic of said amplifier with substantially little change in the gain of said amplifier.

3. In combination, a signal amplifier having grid and anode circuits, said grid circuit including a grid resistance of relatively high impedance, an adjustable contact slidable along said resistance, a circuit connection common to said circuits including a plurality of means for providing degenerative feedback therebetween at signal frequencies, and a capacitance having a relatively low impedance only at the higher signal frequencies connected from said contact to a point on said common circuit connection between said feed-back means and said amplifier, adjustment of said contact along said resistance being effective to vary the frequency response characteristic of said amplifier without substantial change in the gain thereof.

4. In a system for amplifying a band of signal frequencies, a signal amplifier having grid and anode circuits, said grid circuit including an element of relatively high impedance to signal frequencies, a circuit connection common to said circuits including a plurality of means for providing degenerative feedback therebetween at signal frequencies, a tap adjustable on said impedance element, and a capacitance connected from said tap to a point between said feedback means and said amplifier, the valve of said capacitance being so proportioned that, at higher signal frequencies in said band, the impedance of said grid circuit is decreased when said tap is at one end of said impedance element and the degeneration is decreased when said tap is at the opposite end, the response of said amplifier for lower signal frequencies being maintained substantially constant for all positions of said adjustable tap.

5. A frequency response control circuit for an amplifier of signals having frequencies extending over a predetermined frequency band comprising, in combination, a thermionic amplifying device having input and output circuits, said input circuit comprising an input impedance and a pair of degenerative feedback means in series, said means being responsive to amplified signal voltages developed in said output circuit, and a capacitor having one terminal connected to a point on said feedback means and the other terminal connected to a point variable along said impedance, said capacitor having a relatively low impedance only at the higher signal frequencies within said band whereby as said point is varied along said impedance the response of said amplifier for signals of higher frequencies is varied with substantially no perceptible change in the response of said amplifier for signals of lower frequencies.

6. A tone control for an amplifier of signals having frequencies extending over a predetermined frequency band comprising, in combination, a thermionic amplifying device having input and output circuits, said input circuit comprising an input impedance and a plurality of degenerative feedback means in series, said means being responsive to amplified signal voltages developed in said output circuit, a contact slidable along said input impedance, a capacitance connected from said contact to a point between said feedback means and said device, the value of said capacitance being so proportioned that, at higher frequencies within said band, the impedance of said input circuit is decreased when said contact is at one end of said impedance and the degeneration is decreased when said contact is at the opposite end, the response of said amplifier for lower frequencies in said band being maintained substantially constant for all positions of said contact.

7. A tone control for an audio frequency signal amplifying system comprising, in combination, a signal amplifier having a grid, a cathode, and an anode, a grid circuit comprising a grid resistor and a plurality of degenerative feedback means in series, said means also being included in the anode circuit and being responsive to amplifier signal currents, a tone control capacitor having one terminal thereof connected to a point between said cathode and said feedback means and the other terminal thereof connected to an adjustable contact upon said grid resistor, said capacitor having a relatively low impedance only at higher audio frequencies and being so proportioned with respect to said feedback means and said resistor that, at said higher audio frequencies, the impedance of said grid circuit is decreased when said contact is connected to the grid end of said resistor and the degeneration is decreased when said contact is connected to the opposite end, the response of said amplifier for lower signal frequencies being maintained substantially constant for all positions of said adjustable contact.

8. In a signal amplifying system comprising at least two cascaded electron discharge amplifiers, a grid circuit for the second amplifier serially

including a grid impedance of relatively high impedance to signal frequencies and means for supplying degenerative signal voltages to its grid, said means being connected to the cathode of said second amplifier and being responsive to amplified signal voltages developed in its output circuit, a capacitor of relatively low impedance to higher signal frequencies having one terminal thereof connected to a point between said cathode and said feedback means and the other terminal thereof connected to an adjustable tap on said grid impedance, said capacitor being so proportioned with respect to said feedback means and said impedance that, at said higher signal frequencies, the shunt load upon said first amplifier is increased when said tap is at the grid end of said impedance and said degenerative feedback voltages are decreased when said tap is at the opposite end.

9. In an audio frequency amplifying system comprising at least two cascaded thermionic amplifiers resistance-coupled together, a grid circuit for the second amplifier including a grid resistor of relatively high impedance, means common to the grid and anode circuits of said second amplifier for providing a degenerative feedback therebetween at audio frequencies, an adjustable contact slidable along said grid resistor, and a tone control capacitor connected between the cathode of said second amplifier and said contact, said capacitor having a relatively low impedance only at the higher audio frequencies, whereby the shunt load upon said first amplifier at said higher frequencies is increased when said contact is at the grid end of said resistor and the degenerative feedback at said higher frequencies is decreased when said contact is at the opposite end.

10. In combination, a pair of signal frequency amplifiers connected in cascade, each of said amplifiers having an input circuit and an output circuit, the output circuit of the first of said amplifiers being coupled to the input circuit of the other of said amplifiers, the input circuit of said first amplifier comprising two impedance elements in series, one of said elements also being included in the output circuit of said first amplifier and being adapted to have developed thereacross voltages derived from the output circuit of said other amplifier, and a capacitance connected from a point between said one element and said first amplifier to an adjustable tap on the other of said elements, said capacitance being of such value that as the position of said adjustable tap is varied the gain of said amplifiers for higher signal frequencies is varied with no perceptible change in the gain of said amplifiers for lower signal frequencies.

11. The combination, in a system for amplifying signals having frequencies extending over a predetermined frequency band, of a pair of amplifiers for said signals connected in cascade, input and output circuits for said pair of amplifiers, said input circuit comprising two impedance elements connected in series, one of said elements being coupled to said output circuit and being adapted to have developed thereacross voltages of said signal frequencies, and a control means comprising said elements and a capacitance, said capacitance being connected from a point between said one element and the first of said amplifiers to a variable point on the other of said elements, and said capacitance being of such value that as said point is varied on said element the frequency response characteristic of said amplifiers is changed with substantially little change in the gain of said amplifiers.

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