June 2, 1936. D. E. FOSTER 2,043,161

TONE CONTROL SYSTEM FOR ELECTRICAL SOUND REPRODUCTION

Filed June 20, 1933

FIG. 1

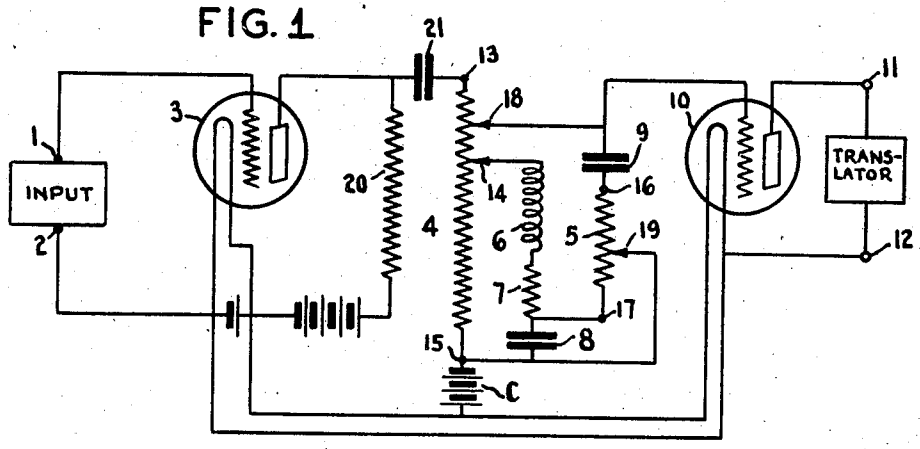


FIG. 2

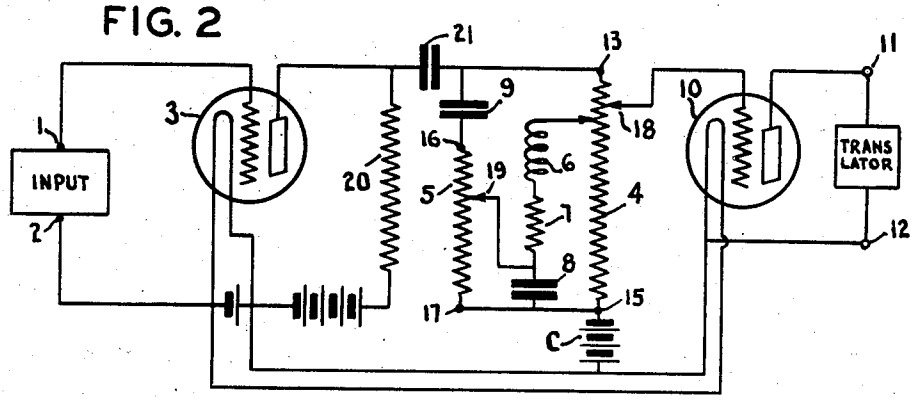


FIG. 3

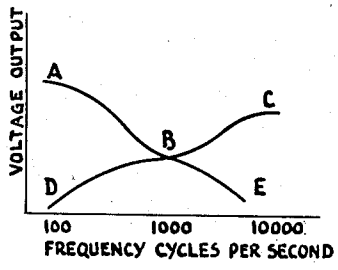
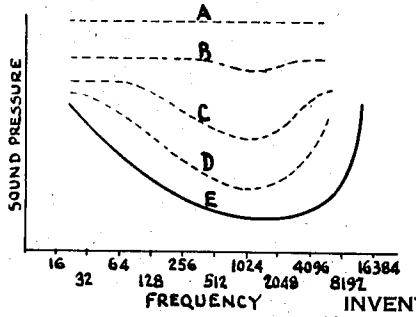


FIG. 4



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TONE CONTROL SYSTEM FOR ELECTRICAL SOUND REPRODUCTION

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5 Claims. (Cl. 179—1)

This invention relates to an arrangement whereby the tone quality or audible response characteristic of audio frequency amplifying apparatus, such as employed in radio receivers and other forms of sound reproducing apparatus, is selected, compensated or controlled as desired under all operating conditions.

It is an object of this invention to provide apparatus of the class described which will permit selective control of the tone quality or tone characteristics of the receiver by varying the energy distribution as to frequency over the audible spectrum without changes in apparent volume.

It is a further object of this invention to provide a system of the class described which will operate to preserve a predetermined or previously selected tone quality or tone balance, regardless of changes in energy level in the audio amplifier and regardless of the non-linear response characteristic of the ear when the volume of sound delivered by the loud speaker changes.

It is still a further object of this invention to provide a system of the class described in which the operator may control or select the particular tone quality or tone balance most satisfactory for particular reproducing conditions, and in which that tone quality so selected is preserved even though large variations in volume be introduced.

It is still a further object of my invention to provide a system of the class described in which variations in the proportion of energy in the low, middle and higher register tones may be made to suit the particular conditions of reproduction, and further, to provide apparatus by which such variations may be introduced either manually to provide different tone balance as and when desired, or automatically, to compensate for differences in sensitivity of the ear to various frequencies, in order to maintain a predetermined or selected tone quality, independently of changes in volume.

Still other objects and advantages of my invention will be apparent from the specification.

The features of novelty which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, will best be understood by reference to the specification and accompanying drawing, in which

Fig. 1 is a circuit diagram of a two-stage amplifier in accordance with one embodiment of my invention;

Fig. 2 is a circuit diagram of similar apparatus in accordance with another embodiment of my invention; and

Figs. 3 and 4 are charts illustrating the performance characteristics of apparatus in accordance with my invention.

It is known that the apparent loudness or audibility of sounds is a complex function of the frequency or pitch of the sound, as well as on the amplitude of the vibration since the ear is not equally responsive to all frequencies nor is it linearly responsive to the intensity of the sound. The human ear is most sensitive or responsive to sounds of frequencies in the vicinity of 1,000 to 2,000 cycles per second and less responsive to sounds of lower or higher frequencies, and to produce a given sensory effect of loudness on the ear more energy is required at lower or higher frequencies than for the middle frequency range of 1,000 to 2,000 cycles per second.

For the purpose of this discussion, low notes as herein referred to may be considered as tones or notes with a frequency of less than 400 cycles per second, high notes or tones those with a frequency higher than 3,500 cycles per second, and the middle register or medium tones or notes those with a frequency between 400 and 3,500 cycles per second.

At high energy levels, i. e., loud signals from the loud speaker, the ear will hear high notes and low notes as well as the middle register. However, as the volume of sound is diminished, the ear first fails to respond to the extremely high and extremely low notes, and as the volume is progressively reduced, the frequency range of the sounds which are heard progressively diminishes, more and more of the low notes and of the high notes becoming inaudible, until at extremely low volume only the middle register remains audible. Thus, the listener notices an apparent change in tone balance or quality with variations in volume of sound output, and this is true even with the most faithful amplifying and loud speaking systems. This will be clear by a consideration of the solid line curve E of Fig. 4, representing the "threshold of audibility", i. e., sound pressure required to attain audibility as ordinates, plotted against frequency.

Furthermore, when the audio frequency portion of the amplifier employs iron cored devices, the inductance of the iron cored devices is affected by the magnitude of the audio frequency voltage impressed across the terminals of the devices, because of the change in the so-called "incremental permeability" of the iron. In general, the inductance is greater with larger impressed voltage, and since high inductance is conducive to greater amplification of low fre-

quency, the output of the sound reproducer may be affected with respect to the relative energy distribution of the low and middle frequency tones by the setting of the volume control.

Thus it will be seen that at least two causes enter into changes of tone quality or tonal balance with volume, the first being the non-uniform frequency response of the human ear, and the second, the change of inductance of iron cored devices with changes in energy level in the amplifier.

In the reproduction of speech, for example, it is frequently desirable to have a greater proportion of the total sound energy output distributed on the higher frequencies than is the case, for instance, in the reproduction of music, in which it is desirable to favor somewhat the lower frequencies. It is also in many cases desirable to maintain a selected tone balance constant, under conditions where considerable changes in volume are occurring.

Referring now more particularly to Fig. 1, the electrical oscillations representing the sounds to be amplified, and which may be, for example, the output of the detector of a radio receiver, or the output of an electro-mechanical or electro-optical phonograph pick-up, are impressed on the input terminals 1 and 2 of a suitable vacuum tube amplifier 3 and amplified in the well-known manner by the tube 3 and delivered to the second vacuum tube amplifier 10 through a medium of resistance 20, coupling condenser 21, and resistor 4. The output of the tube 10 is obtained from output terminals 11 and 12, and impressed on any suitable translating device such as a loud speaker, but other translating devices may be used, such as an electro-mechanical or electro-optical recorder.

While I have shown the tubes 3 and 10 as being of the conventional three-electrode type well known in the art, it will be understood that such showing is merely by way of example, and that other types of tubes may be utilized, such, for example, as the screen grid, pentode, or other forms of tubes, and that the cathode may be indirectly heated, if desired, either by direct or alternating current.

Also, in certain instances, for purposes of simplicity, I have omitted showing batteries or other sources of potential which, in practice, will be utilized to provide the proper operating potentials or current for the various electrodes of the tubes, since such are well-known to those skilled in the art and form per se no part of this invention.

The direct current plate circuit of tube 3 may be completed by connecting the upper terminal of resistor 20 to the plate of tube 3 and the lower terminal through any suitable source of operating potential to the cathode circuit.

The resistor 4 may be provided, having upper and lower terminals 13 and 15 respectively, and may be provided with an intermediate tap at point 14 to which there may be connected a series circuit comprising inductance 6, resistor 7, and capacity 8. The lower terminal 15 of resistor 4 may be connected to a suitable source of potential, diagrammatically indicated at C, the other terminal of which is connected to the cathode circuit, thus serving to impart the proper operating bias to the grid of tube 10.

The lower terminal of condenser 8 may be connected to terminal 15 and also to a slider 19 or variable point on resistor 5, the lower terminal 17 of which is connected to the common point of resistor 7 and capacity 8, and the upper point 16 of which is connected through condenser 9 to the control grid of tube 10.

The control grid of this tube may be connected to slider 18 on resistor 4. Plate current may be supplied to the tube 10 by any suitable means not shown which may, for example, be the battery or other source of potential furnishing plate current to tube 3.

The position of the contact 18 on resistor 4 serves, as will be understood, to control the volume of the output delivered to output terminals 11 and 12.

When the slider 18 is moved to point 13 the maximum output will be delivered and when it is moved to point 15 minimum output will be delivered.

When the arm 18 is in the maximum volume position 13 the resistance included between points 13 and 15 may be made relatively high so that the series resonant circuit, consisting of inductance 6, resistance 7, and capacity 8, has little effect on the audio frequency response of the system.

When the movable arm of the tone control resistor 5 is moved to the point 17 on resistor 5, the capacity 8 is short-circuited and the tone control has little effect on the audio frequency response characteristic. However, when arm 19 is in the position designated as 16, the resistor 5 and condenser 8 are short-circuited and the impedance between the grid and cathode of the tube 10 consists merely of condenser 9. Since the impedance of a capacity varies inversely with frequency, the output of the tube 10 under such conditions is characterized by a decrease in output voltage with increasing audio frequency. As the arm 18 is moved away from tap 13 and toward tap 15, to decrease the volume, the effect of the resonance circuit 6, 7, 8 increases and the proportion of the audio frequency voltage developed across resistor 4, which is applied to the grid of vacuum tube 10, decreases, causing a decrease in output on all frequencies.

However, since the voltage drop through a series resonant circuit is a minimum for frequencies nearest the resonant frequency of the circuit, the voltage impressed on tube 10 will be a minimum for the frequency to which the circuit is tuned. Thus, the nearer slider 18 is brought to point 14, progressively decreasing the volume, the greater becomes the attenuation introduced by circuit 6, 7, 8 until when slider 18 reaches point 14, no part of the IR drop between points 13 and 14 is impressed on tube 10.

If the values of coil 6 and condenser 8 are chosen so that the circuit resonates at a middle register frequency, as slider 18 approaches point 14, the volume decreases, but at the same time the middle register volume decreases to a greater extent than low and high register tones, tending to maintain the tone balance constant, as indicated by curves A, B, C and D of Fig. 4, showing the effect in sound pressure output, of moving slider 18 downward, and it will be seen that the effect is to make the sound pressure output tend to follow the threshold of audibility curve at low volumes, as indicated by curve A, B, C of Fig. 3.

If now the arm 18 be allowed to remain at position 14 and the arm 19 moved to position 16, it will be seen that the voltage output decreases with frequency, and the tone balance will be changed to favor the lower tones as shown by curve A, B, C in Fig. 3.

If the arm 19 now be moved to position 17

substantially short-circuiting condenser 8, it will be noted that 6, 7, 8 is no longer a series resonant circuit, but is, in effect, reduced to inductance 6 and resistance 7. Maximum tone compensation will be secured when slider 18 is in the same position as point 14.

Under such conditions condenser 9 has little or no effect in varying the response characteristic, because the comparatively high resistance of the tone control resistance 5 is in series with it.

Inductance 6 has a characterstic of increasing impedance with frequency so that attenuation is less for higher frequencies than for lower frequencies, and the response curve will have a shape somewhat like D, B, C in Fig. 3.

Thus it will be seen that as the arm 19 is moved over its range, the relative proportion or energy distribution of the voltage output may be shifted within the audible spectrum at will.

By proper selection of the values of inductance 6, resistance 7, and capacity 8, the middle frequencies will be little affected by movement of arm 19, so that the audible effect produced is of relative variation of high and low note proportions with little or no effect on apparent audible volume.

Referring now more particularly to Fig. 2, in which the same reference characters designate the same parts, the tone control circuit, consisting of condenser 9 and resistor 5, is shown connected across the entire portion of resistor 4 instead of to arm 18, but the operation is substantially the same as that already described.

It will be understood that modifications and changes may be made without departing from the spirit and scope of my invention, as will be apparent to those skilled in the art.

I claim:

1. In an audio frequency electrical system, in combination, a source of electrical oscillations, a circuit through which said oscillations are passed, a portion of said circuit being shunted by a series resonant circuit tuned to a middle register frequency, volume control means for picking off a potential from the first mentioned circuit including the voltage drop through the portion of said first circuit which is shunted by said resonant circuit and the voltage drop through a selected additional portion of said first circuit, and means for selectively destroying the resonant character of said resonant circuit.

2. In an audio frequency electrical system, in combination, a source of electrical oscillations, a circuit through which said oscillations are passed, comprising an impedance, a series resonant circuit shunting a portion of said impedance, and tuned to a middle register frequency, means for selectively reducing the effect of the capacity and inductance in said resonant circuit to render either predominant, and a volume control for picking off from said impedance the potential between one terminal of said circuit and a desired point on said impedance.

3. In an audio frequency amplifying system, in combination, a pair of relays each having input and output circuit, an impedance connecting the output of one of said relays and having an adjustable portion thereof connected in the input circuit of the second relay, a series resonant circuit shunted around a portion of said impedance, a connection including a variable resistance in shunt to the capacity of said resonant circuit, and a connection from said variable resistance to the control circuit of said second relay, said last mentioned connection including capacity in series.

4. In an audio frequency electrical system, in combination, a source of electrical oscillations of sound frequency, a work circuit to be supplied with said oscillations, and a combined volume and tone control circuit interposed between said source and said work circuit, said control circuit comprising a first branch consisting of a resistance, a second branch shunted around a portion of said first branch and comprising a series resonance circuit tuned to a middle register frequency, and a third branch shunted across at least a portion of said first branch, a connection between said second and third branches for selectively and gradually destroying the resonance characteristic of said second branch, and means for utilizing a desired portion of the potential drop across said first branch.

5. In an audio frequency electrical system, in combination, a source of electrical oscillations of sound frequency, a work circuit to be supplied with said oscillations, and a combined volume and tone control circuit interposed between said source and said work circuit, said control circuit comprising a resistance path, a second path in shunt with a portion of said resistance path, the second path comprising inductance and capacity in series and being arranged to resonate at a middle register frequency, and a third path shunted around at least a portion of said resistance path, said third path comprising capacity and resistance in series, a variable connection between said third path and said second path for including a variable portion of the resistance in said third path in shunt with the capacity of said second path and a variable connection to said resistance path for utilizing the desired portion of the potential drop therein.

DUDLEY E. FOSTER.