Feb. 24, 1970 L. W. ERATH 3,497,621

AUDIO REPRODUCTION SYSTEM WITH LOW FREQUENCY COMPENSATION

Filed June 19, 1967

Fig. 1

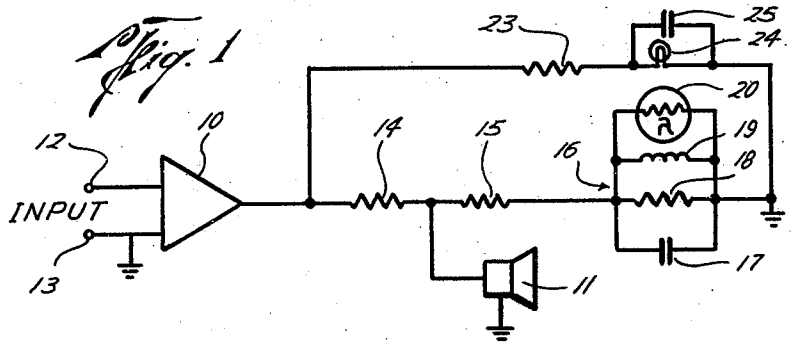


Fig. 2

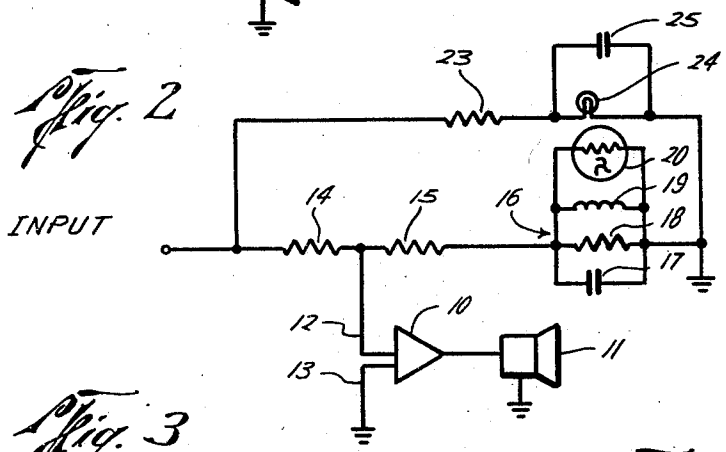


Fig. 3

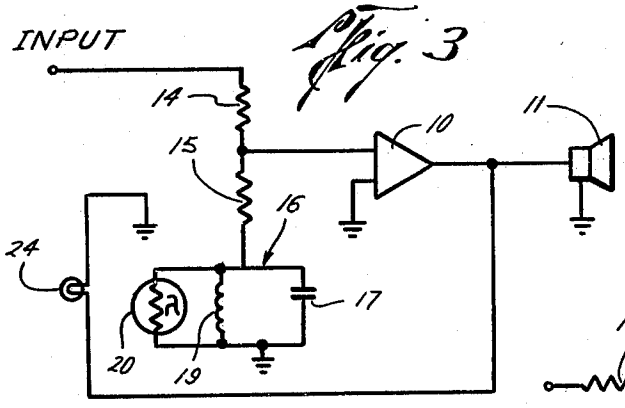


Fig. 4

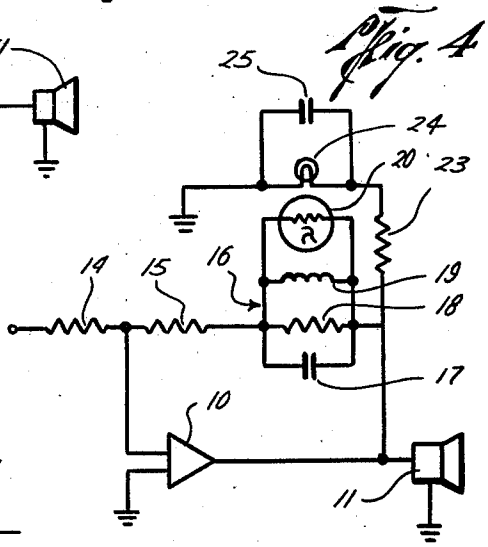
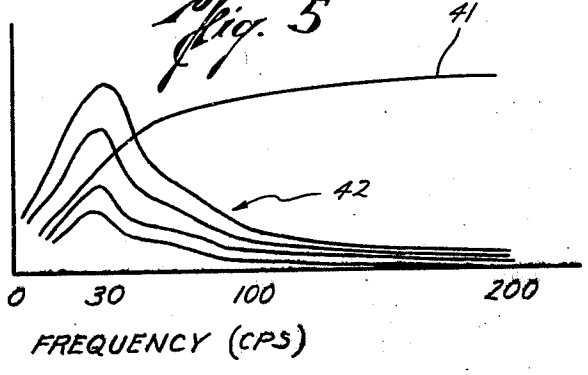


Fig. 5



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AUDIO REPRODUCTION SYSTEM WITH LOW FREQUENCY COMPENSATION

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U.S. Cl. 179—1 8 Claims

ABSTRACT OF THE DISCLOSURE

A sound reproduction system including compensation means for improving the low frequency response of the system. The compensation means in the form of a voltage divider having at least two serially connected parts, one part being connected to receive an uncompensated signal. The other part includes a parallel resonant circuit. A compensated signal is derived from the common terminal of the serially connected parts. A light sensitive resistor in the parallel resonant circuit prevents the speaker from being overdriven by loud, low frequency notes. Alternatively, the parallel resonant circuit forms part of a compensated negative feedback loop for an audio amplifier. The degenerative feedback decreases at lower frequencies, thus increasing the gain of the amplifier. The light sensitive resistor in the circuit increases the feedback and decreases the amplifier gain in response to large, low frequency signals.

Background of the invention

This invention relates to audio reproduction systems and, more specifically, to means for compensating for the low frequency response of a speaker in such a system.

The quality of an audio reproduction system depends on how well the frequency response characteristics of the system correspond to the frequency response characteristics of the human ear, which extends from about 16 cycles per second to 20,000 cycles per second. However, the frequency response of most speakers used in such systems falls off substantially at lower frequencies. For example, the response may drop on the order of 30 decibels from 100 c.p.s. to 30 c.p.s.

Circuits have been designed to compensate for the drop in frequency response of a speaker at the lower frequencies. The main drawback of these circuits, though, is that the speaker is overdriven by loud, low frequency notes, which results in the speaker producing undesirable, harsh noise.

Accordingly, an object of this invention is an improved sound reproduction system.

Another object of the invention is means for improving the low frequency response of the speaker in an audio reproduction system.

Still another object of the invention is means operable with an audio amplifier for providing to a speaker a signal compensated in response to both the amplitude and frequency of an audio signal.

Summary of the invention

Briefly, the low frequency compensation means of this invention includes a voltage divider circuit having at least first and second serially connected parts. The first part is connected to receive an uncompensated audio signal, and the compensated signal is taken from the common terminal between the first and second parts. The second part comprises a low frequency parallel resonant circuit which includes a light sensitive resistor, the resistance of which varies inversely with the brightness of an impinging light. A light source is optically coupled with the light sensitive resistance, the brightness of the light source varying with the amplitude of the uncompensated signal. Alternatively, the light source may be connected in the circuit so that the brightness varies with the amplitude of the compensated signal. A high frequency filter may be provided to bypass higher frequency voltages around the light source. The voltage divider circuit may be suitably connected in the audio reproduction system to provide a compensated signal to the audio amplifier or a compensated signal to the speaker. Also, the parallel resonant circuit may form part of a compensated negative feedback loop for the audio amplifier. The degenerative feedback decreases at lower frequencies, thus increasing the gain of the amplifier. The light sensitive resistor in the circuit increases the feedback and decreases the amplifier gain in response to large, low frequency signals.

The invention will be more readily understood from the following description and appended claims when read in conjunction with the drawing.

Brief description of the drawing

FIGURE 1 is a schematic diagram of one embodiment of the invention wherein the compensated signal taken from the compensation means is applied directly to the speaker;

FIGURE 2 is a schematic diagram of an embodiment of the invention wherein the compensated signal taken from the compensation means is applied directly to the audio amplifier;

FIGURE 3 is a schematic diagram of another embodiment of the invention wherein the compensation signal taken from the compensation means is applied directly to the audio amplifier;

FIGURE 4 is a schematic diagram of still another embodiment of the invention wherein compensated negative feedback is provided for the audio amplifier, and

FIGURE 5 is the frequency response of a speaker and a family of impedance curves plotted against the same frequency axis.

Like elements have the same reference numerals in FIGURES 1–4.

Description of the preferred embodiments

Referring now to FIGURE 1, audio amplifier **10** is connected through input terminals **12** and **13** to a source of audio signals (not shown) such as, for example, a radio tuner, phonograph transducer cartridge or the like. The output of the audio amplifier is connected to resistor **14** which forms a first part of a voltage divider circuit. A second part of the voltage divider circuit includes resistor **15** and parallel resonant circuit **16** which are serially connected between resistor **14** and ground. The parallel resonant circuit includes a capacitor **17**, resistor **18**, inductor **19**, and a light sensitive resistor **20**, such as a cadmium sulfide photocell for example. Also connected to the output of the audio amplifier is a resistor **23** which is serially connected through a light source **24**-capacitor **25** parallel combination to ground. Resistor **23** and capacitor **25** function as a high frequency bypass filter. Light source **24** is optically coupled to light sensitive resistor **20**, the two elements preferably mounted within the same housing. The input to speaker **11** is connected to the common terminal of resistors **14** and **15**.

The compensation means comprising the described voltage divider circuit is designed to compensate for the drop in frequency response of the speaker at low frequencies, especially below 100 c.p.s. The input signal, S_I, to the

speaker is related to the output signal, S_O, of the audio amplifier as follows:

$$S_I = \frac{R15+Z16}{R14+R15+Z16} S_O$$

where

R14 is the resistance of resistor **14**
R15 is the resistance of resistor **15**
Z16 is the impedance of parallel resonant circuit **16**

For illustration, **R14** may be ten times as large as **R15**, **Z16** much larger than **R14** at the resonant frequency, and **Z16** much smaller than **R14** at frequencies substantially higher than the resonant frequency. Thus, at the resonant frequency of the parallel resonant circuit, 30 c.p.s. for example, the value of **Z16** is a maximum, and

$$S_I \approx \frac{Z16}{Z16} S_O$$

$$\approx S_O$$

and at higher frequencies, above 100 c.p.s. for example,

$$S_I \approx \frac{R15}{R14+R15} S_O$$

$$\approx \frac{1}{11} S_O$$

It is seen that S_I increases as a function of S_O at low frequencies thus compensating for the drop-off in frequency response of the speaker.

Light source **24** and light sensitive resistor **20** in the parallel resonant circuit cooperatively function to prevent the speaker from being overdriven in response to loud, low frequency notes from the audio source. When a large, low frequency signal is received by the audio amplifier, the increased signal output of the amplifier causes light source **24** to emit more light, which in turn decreases the resistance of light sensitive resistor **20** and the impedance of the parallel resonant circuit. The reduced impedance of the parallel resonant circuit, **Z16**, may then be negligible in comparison to the resistance **R14** of resistor **14**. In this case the value of the input signal to the speaker, S_I, will remain about one-eleventh ($\frac{1}{11}$) of the output signal of the amplifier, S_O.

FIGURE 5 illustrates the frequency relationship between the frequency response characteristics of the speaker and the impedance of the parallel resonant circuit, the curve **41** representing the response characteristics of the speaker and the family of curves **42** representing the impedance of the parallel resonant circuit at various levels of light intensity of the light source **24**. The speaker response curve **41** tends to be flat above 100 c.p.s., but drops off below 100 c.p.s. It is seen that the maximum impedance of the resonant circuit occurs at the resonant frequency, 30 c.p.s., and ranges from a large value when little or no light impinges on the light sensitive resistor to a negligibly small value as the impinging light increases.

The embodiment illustrated in FIGURE 2 provides the compensated signal to the input of audio amplifier **10**. In this embodiment, the uncompensated input signal from the audio source (not shown) is connected to resistor **14** of the voltage divider circuit which comprises serially connected resistor **14**, resistor **15** and parallel resonant circuit **16**. Light source **24** shunted by capacitor **25**, is serially connected with resistor **23** between the input terminal of resistor **14** and ground. Again, the light source is optically coupled to the light sensitive resistor **20** in the parallel resonant circuit. The compensated signal is taken from the common terminal of resistor **14** and resistor **15**, and the signal is applied to input terminal **12** of audio amplifier **10**. The output of the audio amplifier is connected directly to speaker **11**. Operation of the circuit is similar to the operation described above for the circuit of FIGURE 1.

FIGURE 3 is another embodiment of the invention wherein the voltage divider circuit provides a compensated signal input to the audio amplifier **10**, but the light source **24**, optically coupled to light sensitive resistor **20**, is connected to the output of the audio amplifier. In this embodiment, energy feedback is employed by the optically coupled light source and light sensitive resistor, whereas the embodiments in FIGURE 1 and FIGURE 2 do not utilize any feedback. It is also to be noted in FIGURE 3 that a high frequency bypass filter is not utilized in conjunction with light source **24**, nor is a fixed resistor included in the parallel resonant circuit **16**. The inclusion of these elements in the circuit is not essential, but depends upon particular design considerations.

In FIGURE 4, the compensated signal is again taken from the common terminal of resistors **14** and **15** and applied to the input to amplifier **10**, but the parallel resonant circuit **16** forms part of a negative or degenerative feedback loop for the amplifier. Negative feedback will stabilize the frequency response of an amplifier but at the expense of amplifier gain. The impedance of the feedback loop in FIGURE 5 increases at lower frequencies due to the resonance of circuit **19**, thus the degenerative feedback is reduced and the amplifier gain increases. However, the cooperative action of the light source **24** and photosensitive resistor **20** decreases the feedback loop impedance in response to large, low frequency signals. Thus, the degenerative feedback is increased and the amplifier gain is reduced. Consequently, the speaker is not overdriven.

While the invention has been described with reference to preferred embodiments, this description is not to be construed in a limiting sense but for purpose of illustration only. Various modifications and adaptions may occur to those skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A low frequency signal compensation system for use with an audio amplifier and speaker in audio reproduction system, comprising:
- a voltage divider circuit having at least first and second serially connected parts, the compensated signal being taken from the common terminal thereof,
- means connecting said first part to receive the uncompensated signal,
- said second part comprising a low frequency parallel resonant circuit including a light sensitive resistor the resistance of which varying inversely with the brightness of impinging light, and
- a light source optically coupled with said light sensitive resistor, the brightness of said light source varying with the amplitude of the uncompensated signal.

2. A low frequency compensation system in accordance with claim **1** wherein said first part is a fixed resistor, said means connects said resistor to receive the uncompensated signal from the output of said audio amplifier, and second means connects the input to said speaker to said common terminal of said first and second parts of said voltage divider circuit.

3. A low frequency signal compensation system in accordance with claim **1** wherein said first part of said voltage divider circuit is a fixed resistor, said means connects said resistor to a source of audio signals, and second means connects the input to said audio amplifier to said common terminal of said first and second parts of said voltage divider circuit.

4. A low frequency signal compensation system for use with an audio amplifier and speaker of an audio reproduction system, comprising:
- a voltage divider circuit having at least first and second serially connected parts, the compensated signal being taken from the common terminal thereof,
- said first part comprising a fixed resistor connected to receive signals from a source of audio signals,

said second part comprising a low frequency parallel resonant circuit including a light sensitive resistor varying inversely with the brightness of impinging light,

means connecting said common terminal to the input of said audio amplifier, and

a light source connected to the output of said audio amplifier and optically coupled with said light sensitive resistor, the brightness of said light source varying with the amplitude of the output signal from said audio amplifier.

5. A low frequency compensated sound reproduction system comprising:

a source of audio signals,

an audio amplifier,

means connecting said source of audio signals to the input of said amplifier,

an audio speaker,

means connecting the output of said amplifier to said audio speaker,

feedback means connected between the output and the input of said amplifier,

said feedback means comprising a low frequency parallel resonant circuit including a light sensitive resistor the resistance of which varying inversely with the brightness of impinging light, and

a light source optically coupled with said light sensitive resistor, the brightness of said light source varying with the amplitude of the output signal from said audio amplifier.

6. The low frequency compensated sound reproduction system defined by claim 5 including a high frequency pass filter connected in parallel with said light source.

7. An audio amplifier circuit comprising:

an audio amplifier having an input terminal and an output terminal,

a negative feedback loop connected between said input and output terminals,

said negative feedback loop comprising a low frequency parallel resonant circuit including a light sensitive resistor the resistance of which varying inversely with the brightness of impinging light, and

a light source optically coupled with said light sensitive resistor, the brightness of said light source varying with the amplitude of the output signal of said audio amplifier.

8. A sound reproduction system complementary with the normal response characteristics of the human ear comprising:

a source of audio signals,

amplifier means for amplifying said audio signals,

low frequency compensation means operably connected with said amplifier means, said low frequency compensation means comprising a voltage divider circuit including first and second serially connected parts,

said first part including a fixed resistor connected to the output of said amplifier means,

said second part including a low frequency parallel resonant circuit having a light sensitive resistor therein, the resistance of said light sensitive resistor varying inversely with the brightness of impinging light,

a light source optically coupled with said light sensitive resistor, the brightness of said light source varying with the amplitude of the output signal from said audio amplifier, and

a speaker connected to receive low frequency compensated signals from said common terminal of said first and second parts of said low frequency compensation means.

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