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ELECTROSTATIC SPEAKER CIRCUIT

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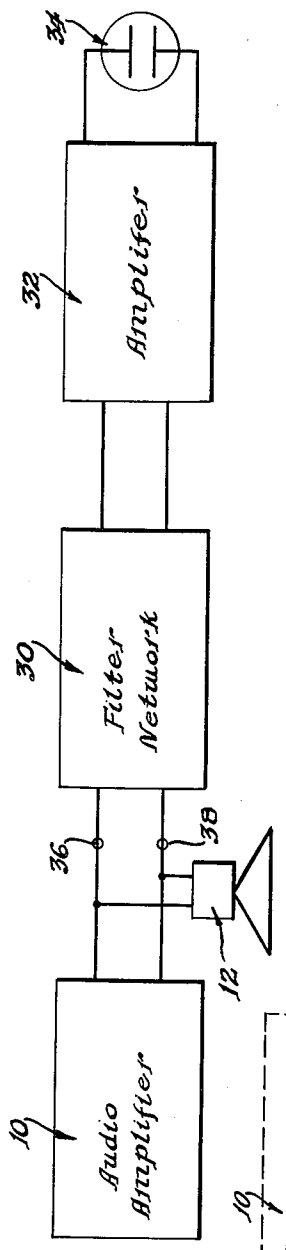


Fig. 1

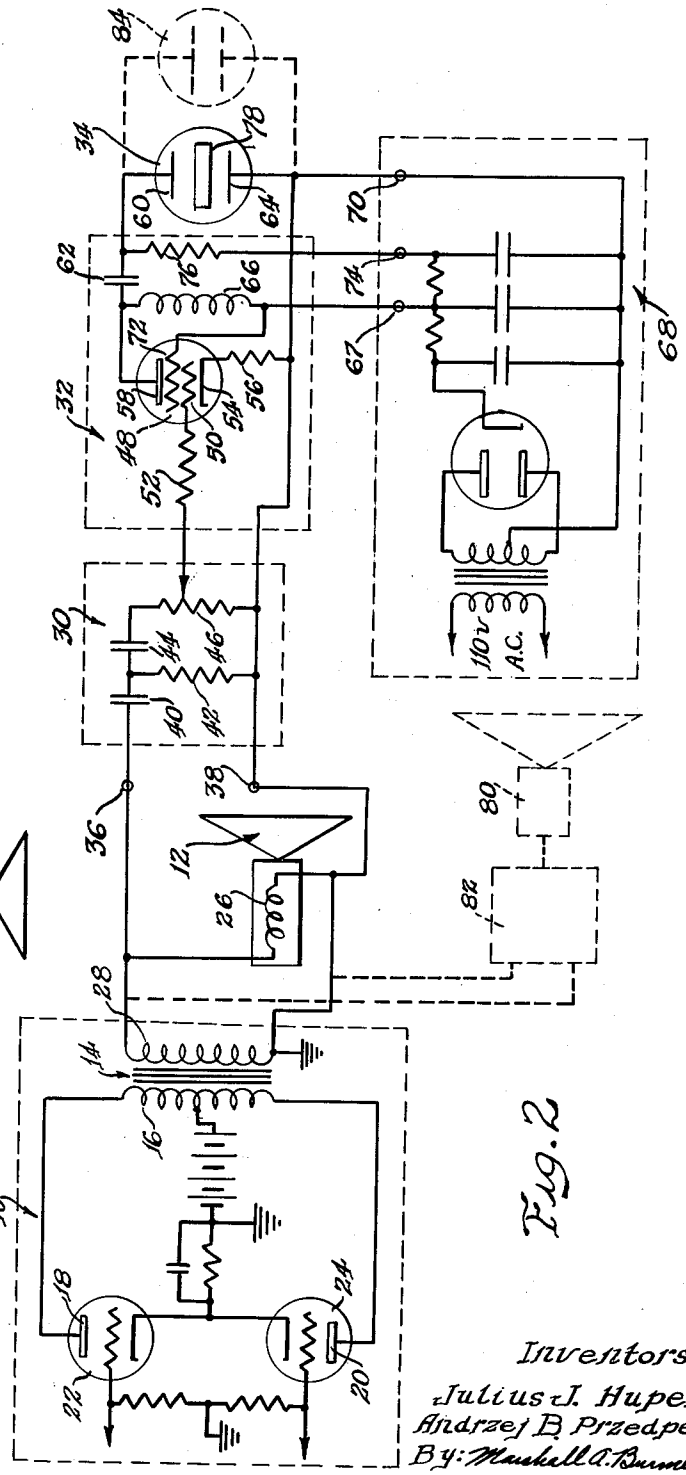


Fig. 2

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ELECTROSTATIC SPEAKER CIRCUIT

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The present invention relates to sound reproducing devices, and specifically to such devices utilizing separate loud speakers for high and low frequency audio signals.

It has proven to be difficult to construct a loud speaker which is equally effective in reproducing sounds at a low frequency range, for example 40 cycles per second to 5,000 cycles per second, and at a high frequency range, for example 5,000 cycles per second to 20,000 cycles per second. For this reason, it has become common practice to employ two separate low impedance speakers, one for the reproduction of low frequency audio signals and the other for the reproduction of high frequency audio signals.

Electrostatic speakers, or condenser speakers, have been known for many years, but these speakers have not been extensively used. An electrostatic speaker, in general, employs two electrically conducting plates separated by a dielectric. A direct current potential is applied to the electrically conducting plates to stress the dielectric, and the dielectric is modulated by an audio signal applied to the plates of the loud speaker. One of the plates is free to vibrate and produces sound from the audio signal. Dynamic loud speakers, on the other hand, utilize a moving coil which is attached to the apex of a paper cone, and disposed in a magnetic field. The audio signal is applied to the movable coil, and the interaction of the field of the coil produced by an audio signal and the magnetic field result in vibrations applied to the paper cone. Dynamic speakers present a low impedance to the driving circuit, while electrostatic speakers present a high impedance.

The prior devices have connected an electrostatic speaker in parallel with a low impedance speaker connected to the output stage of an audio amplifier. In one such circuit, an electrostatic speaker is connected to the plate of the power amplifier in parallel with the primary winding of the step-down transformer for a dynamic speaker through a resistance-capacitance coupling network, the stressing potential for the electrostatic speaker being applied through the resistor which is connected to the condenser and speaker. With this construction, the gain of the power amplifier is reduced at higher frequencies as a result of the decreased impedance of the electrostatic speaker at higher frequencies. In addition, audio signals which are deficient in power distributed in the higher frequency ranges can not be corrected. This is a particular disadvantage if the electrostatic speaker is to be added to an already existing audio amplifier system using a low impedance dynamic speaker.

Another circuit used to couple an electrostatic speaker to the output stage of an amplifier which also drives a low impedance dynamic speaker coupled to the amplifier through a step-down transformer, is a step-up transformer, the primary of which is connected in parallel with the low impedance speaker. In such a device, low frequencies are apt to saturate the core of the step-up transformer, and thus cause non-linear distortion. This difficulty can be corrected by means of a filter network discriminating against low frequency signals inserted between the step-down and step-up transformers, but such a filter network is bulky and costly due to the fact that it must operate at a low impedance level. Further, the gain of the output stage of the amplifier will again be reduced at higher frequencies due to the decreasing impedance of the electrostatic speaker as the frequency is increased.

The inventors have found that electrostatic speakers

can be successfully used in combination with low impedance speakers if the impedance of the electrostatic speaker is isolated from the output stage of the audio amplifier, and low frequency audio signals are not permitted to be impressed upon the electrostatic speaker. It is, therefore, an object of the present invention to provide an electrical device which combines a low impedance loud speaker with an electrostatic speaker and which includes an impedance isolating amplifier between the electrostatic loud speaker and the low impedance loud speaker to eliminate any harmful effects of the electrostatic speaker on the operation of the power amplifier.

It is also the object of the present invention to provide a sound reproducing device which combines a low impedance loud speaker and an electrostatic speaker and includes a filter network discriminating against low frequency signals and an impedance isolating amplifier between the low impedance speaker and the electrostatic speaker.

It is a further object of the present invention to provide an electrical device with an electrostatic speaker which may be directly connected to the output of an audio power amplifier or directly connected across a low impedance speaker without effecting the operation of the audio amplifier.

These and other objects of the present invention will be more readily understood from a further reading of the present disclosure, particularly when viewed in light of the drawings, in which:

FIGURE 1 is a block diagram of a device constructed according to the teachings of the present invention; and

FIGURE 2 is a schematic electrical circuit diagram of the device illustrated in FIGURE 1.

In the figures, a conventional amplifier output stage **10** is shown connected to a conventional low impedance low frequency speaker **12** through a step-down transformer **14**. The step-down transformer **14** has a center tapped primary **16** which is connected to the plates **18** and **20** of a pair of vacuum tubes **22** and **24** connected in a push-pull amplifier circuit. The voice coil **26** of the electromagnetic speaker **12** is connected to the secondary **28** of the transformer **14**.

In the present construction, a filter network **30**, amplifier **32** and electrostatic speaker **34** are constructed as a single assembly, and the filter network **30** is connected across the voice coil **26** of the speaker **12** through terminals **36** and **38**, although it will be understood that the present invention may be practicing constructing the output stage **20** and low impedance speaker **12** in a single assembly with the filter network **30** amplifier **32** and electrostatic speaker **34**.

The filter network **30** must be designed to attenuate frequencies below 5,000 cycles per second, and to reflect an impedance to the output circuit of the amplifier **10** at least equal to the output impedance of the amplifier. In practice, the output impedance of amplifier **10** is in the vicinity of 5,000 ohms, and transformer **14** matches this impedance with the impedance of the speaker **12** which is usually in the vicinity of 10 ohms. Hence the impedance reflected in the output circuit of the amplifier is approximately 500 times that of the filter network. However, since it is desirable that the filter network **30** has no appreciable effect on the operation of the output stage **10** and speaker **12**, the minimum impedance of the filter network **30** should be much larger than that of the speaker **12**. The applicants find that a minimum impedance for the filter network **30** of approximately 10,000 ohms is optimum and that this impedane should not be lower than 5,000 ohms. The filter network utilizes two low-frequency attenuating resistance-capacitance networks connected in cascade. The first resistance-capacitance network has a condenser **40** and a resistor **42** con-

nected in series across the terminals 36 and 38, and the next resistance-capacitance network has a condenser 44 connected to the junction of condenser 40 and resistor 42 and a variable tapped resistor 46 connected to condenser 44 and terminal 38.

In the particular construction described in this disclosure, condenser 40 has a capacity of 3,000 micromicrofarads, resistor 42 is 10,000 ohms, condenser 44 is 300 micromicrofarads and resistor 46 is 100,000 ohms. With this construction, the filter 30 attenuates 5,000 cycles per second approximately 6 decibel, 2500 cycles per second 14 decibel, and 1250 cycles per second 24 decibel. If the output of the output stage 10 is deficient in high frequency components, condenser 44 may be made smaller. The attenuation of the filter 30 when condenser 44 has a capacity of 60 micromicrofarads is approximately 19 decibel at 5,000 cycles per second.

The amplifier 32 employs a vacuum tube 48 which has a control grid 50 connected to the tap of resistor 46 through resistor 52. Vacuum tube 48 also has a cathode 54 which is connected to terminal 38 through a cathode resistor 56. The plate 58 of vacuum tube 48 is connected to one of the electrical conducting plates 60 of the electrostatic speaker 34 through a coupling condenser 62. The other plate 64 of the electrostatic speaker 34 is connected to terminal 38. A choke 66 is also connected to the plate 68 of vacuum tube 48, and the other end of the choke 66 is connected to the positive terminal 67 of a source of direct current power 68. The negative terminal 70 of the source of power 68 is connected to terminal 38. Vacuum tube 48 has a screen grid 72 which is also connected to the terminal 67 of the source of power.

A positive potential is applied across the plates 60 and 64 of the electrostatic speaker 34. The source of power 68 has a terminal 74 of higher positive potential than terminal 67 which is connected through resistors 76 to plate 60, thus placing the dielectric, illustrated at 78, of the electrostatic speaker 34 under strain.

In order to provide optimum gain in the desired frequency range from the amplifier 32, the choke 66 is constructed to resonate with the capacity of the electrostatic speaker 34 at a frequency between 10 and 20 kilocycles, this frequency range being in the upper portion of the frequency response of the electrostatic speaker. Resistor 76 shunts the resonant circuit to flatten the resonant characteristics of the choke 66 and electrostatic speaker 34. It is thus to be noted that resistor 76 performs a dual function of shaping the resonance curve of the resonant circuit and connecting the direct current potential to the electrostatic speaker 34 to stress the dielectric 78 of the electrostatic speaker 34.

In the particular construction described, the choke 66 has an inductance of 75 millihenries, the condenser 62 a capacity of 0.1 microfarad and the resistor 76 a resistance of 50,000 ohms. In this construction the vacuum tube 48 is a type EL 84, and the voltages applied at terminals 66 and 74 are respectively 250 and 275 volts.

Two or more electrostatic speakers can be employed in a device constructed according to the present invention. There is considerable value in employing more than one electrostatic speaker, since the frequency response of an electrostatic speaker is in the high frequency range. At high audio frequencies the sound waves from a speaker are directional, so a pair of speakers operating in this frequency range can be utilized to alleviate the uni-directional effect of speakers operating in the high frequency ranges. For this reason, a second electrostatic speaker 84 is shown in dotted lines in FIGURE 2. The second electrostatic speaker 84 is connected in parallel with the electrostatic speaker 34.

Resistor 76 is selected within a range of values between 10,000 and 470,000 ohms to produce the most desirable curve of frequency to sound amplitude from the speakers.

The present invention is equally applicable to devices which use a plurality of low impedance loud speakers as well as a single loud speaker 12 illustrated in FIGURE 2. For this reason, FIGURE 2 illustrates in dotted lines a second speaker 80 connected through a cross over network 82 to the secondary 28 of transformer 14, the frequency of the cross over network being selected in the conventional manner to restrict operation of speaker 80 to one portion of the useful frequency range of speakers 80 and 12, speaker 12 being used for the other portion of the frequency range.

With the two electrostatic speakers 34 and 84 connected in parallel, they present a total capacity of approximately 5,000 micromicrofarads to the output circuit of amplifier 32. Since choke 66 has an inductance of 75 millihenries, the resonant frequency of the choke 66 and electrostatic speakers 34 and 84 is approximately 10,000 cycles per second.

Many modifications and embodiments of the present invention may be derived from this disclosure. It is therefore intended that the scope of the present invention be not limited to the foregoing disclosure, but rather only by the appended claims.

What is claimed as our invention:

1. An electrical device comprising, in combination, a low impedance speaker, an electrostatic speaker and isolation means including an amplifier having an input circuit directly connected to the low impedance speaker reflecting an impedance to the low impedance speaker at least equal to the impedance of the speaker, said input circuit including a filter attenuating frequencies below 5,000 cycles per second and an output circuit connected to the electrostatic speaker including a resonant circuit with a frequency of resonance between 10 and 20 kilocycles.

2. An electrical device comprising the elements of claim 1 wherein the input circuit comprises a filter having a pair of cascaded low frequency attenuating resistance capacitance networks.

3. An electrical device comprising the elements of claim 1 wherein the isolation means includes a choke connected in parallel with the electrostatic speaker.

4. An electrical device comprising, in combination, a first amplifier having an output circuit, a low impedance speaker directly connected to the output of the first amplifier, a second amplifier having a vacuum tube with a plate, control grid and current return electrode, said second amplifier having a high impedance input circuit connected between the control grid and the return electrode of the vacuum tube directly connected to the output circuit of the first amplifier, and an output circuit connected between the plate and return electrode of the vacuum tube including a choke, an electrostatic speaker connected in parallel with the choke, and resonating at a frequency between 10 and 20 kilocycles, and a resistor connected in parallel with the choke to lower the Q of the resonant circuit.

5. An electrical device comprising an amplifier having a vacuum tube with a grid, plate, and return electrode, a filter attenuating frequencies below 5,000 cycles per second connected between the grid and return electrode of said vacuum tube including a pair of resistance-capacitance low frequency attenuating networks connected in cascade, a source of direct current power, a pair of electrostatic speakers connected to the plate of the vacuum tube through a coupling condenser and to the negative terminal of the direct current power source, a resistor having a resistance of from 10,000 ohms to 470,000 ohms connected to the positive terminal of the power source and to the junction between the condenser and the electrostatic speaker, and a choke with an inductance of 75 millihenries connected to the plate of the vacuum tube and the positive terminal of the power source.

6. An electrical device comprising a source of audio signals having an output stage, a low impedance speaker connected to the output stage of said source, and a device comprising the elements of claim 5, the filter net-

work being connected in parallel with the low impedance speaker.

7. An electrical device comprising the elements of claim 4 wherein a filter is connected in cascade with the input of the amplifier including a pair of serially connected condensers connected to the control grid of the vacuum tube of the amplifier, a resistor connected between the junction of the condensers and the return electrode, said pair of condensers and resistor attenuating frequencies less than 5000 cycles per second.

8. An electrical device comprising, in combination, an amplifier having a vacuum tube with a grid, plate, and return electrode, a filter attenuating frequencies below 5,000 cycles per second connected between the grid and return electrodes of said vacuum tube, a source of direct current power, an electrostatic speaker connected to the plate of the vacuum tube through a coupling condenser and to the negative terminal of the direct current power source, a resistor having a resistance from 10,000 ohms to 470,000 ohms connected to the positive terminal of the power source and to the junction between the condenser and the electrostatic speaker, and a choke connected to the plate of the vacuum tube and to the positive terminal of the power source, the electrostatic speaker and choke forming a parallel resonant circuit with a frequency of resonance between 10 and 20 kilocycles.

9. An electrical device comprising a source of audio signals having an output stage, a low impedance speaker connected to the output stage of said source, and a device comprising the elements of claim 8, the filter being coupled in parallel with the low impedance speaker.

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