July 22, 1969 C. P. BONER 3,457,370

IMPEDANCE CORRECTING NETWORKS

Filed Dec. 30, 1965

FIG. 2.

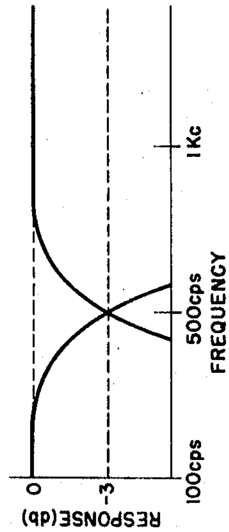


FIG. 4.

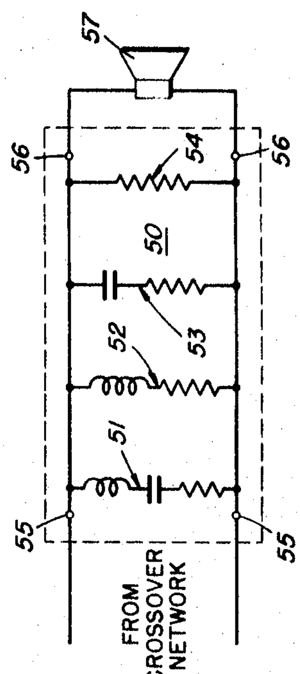


FIG. 1.

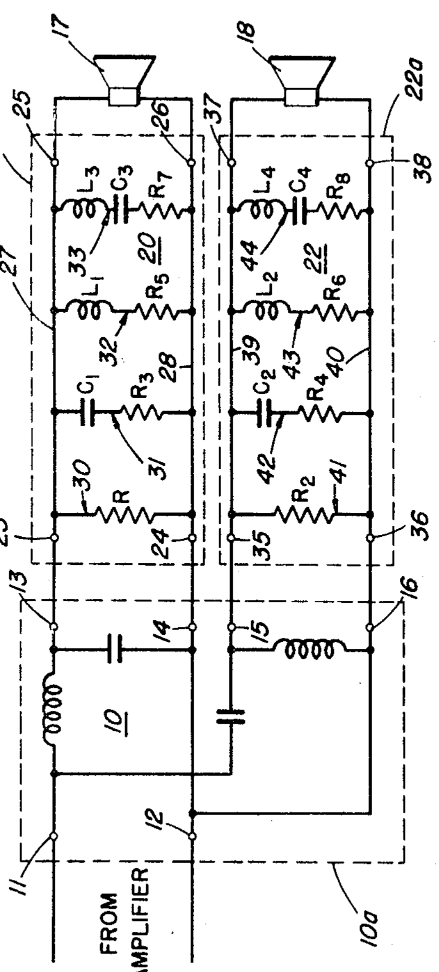
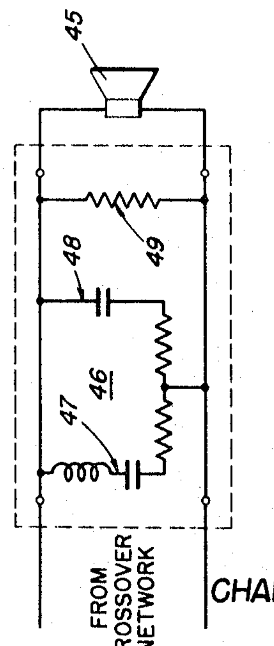


FIG. 3.



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IMPEDANCE CORRECTING NETWORKS

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U.S. Cl. 179—1 1 Claim

ABSTRACT OF THE DISCLOSURE

In a sound reenforcing system, impedence correcting networks for connection between a plurality of loud-speakers and a crossover network, whereby the loudspeakers and said correcting networks will properly load the crossover network so that its performance will be the same as if it were loaded at its design impedance.

This invention relates generally to impedance matching networks. More particularly it relates to impedance correcting networks for properly coupling a plurality of loudspeakers, or drivers therefor, to a crossover network.

It is common practice to divide the sound spectrum delivered by loudspeakers into two or more bands, with each band being reproduced by one or more loudspeakers capable of functioning most effectively in that band. Conventionally the spectrum is divided electrically before power is delivered to the loudspeakers by a crossover network.

The electrical performance of such crossover networks, terminated in their respective load impedances, is a function of such impedances. For example, if a crossover network using loudspeaker loading on its output terminals is designed for a crossover frequency of 500 cycles per second and for a terminating impedance of 16 ohms, its crossover properties may be such that the power delivered to a bass loudspeaker at 500 cycles per second is 3 decibels below that delivered to the 16 ohm load at 500 cycles per second. Similarly, the power delivered by the crossover network to a high frequency loudspeaker at 500 cycles per second may be 3 decibles below that delivered to the 16 ohm load at 500 cycles per second. In this ideal case the sum of the electrical powers delivered to the two 16 ohm loads at the 500 cycle per second crossover frequency is the same as that delivered to the low frequency load well below the crossover frequency, and to the high frequency load well above the crossover frequency. Also, the crossover network produces a 180° phase shift between the high and low frequency loudspeakers.

If, however, a crossover network is designed for a certain terminating pair of load impedances and the loudspeakers providing the load do not have such impedances, then the performance of the network will be less than ideal and the power delivered to the high and low frequency loudspeakers will not follow the ideal curve, i.e., additional low frequency power will be delivered to the high frequency loudspeaker and additional high frequency power will be supplied to the low frequency loudspeaker, in a band of frequencies around the crossover frequency.

Moreover, the phase shift between the output of the crossover network and the high and low frequency loudspeakers will be distorted. If the variation of the loudspeaker impedance with frequency, in the vicinity of the crossover frequency, is sufficiently great, then an otherwise ideal crossover network will be improperly loaded and its output to the loudspeakers will depart substantially from that to be expected. Phase relationships will also vary rapidly with frequency throughout the crossover region.

Variations in phase with frequency will result in phase variations in the sound field produced by the loudspeakers. Inasmuch as feedback in a sound reinforcing system is known to be caused by the existence of a gain greater than unity and by a phase shift of $2n\pi=0$ in the room containing the sound system, where n is the standard notation in technical literature for any integer, the disruption of the normal and relatively smooth performance of a loudspeaker-loaded crossover network by variation in impedance of the loudspeakers with frequency would be accompanied by a number of feedback modes in the total system. The term "feedback mode" is a standard term in contemporary technical literature in acoustics and electroacoustics, e.g., Journal of the Acoustical Society of America and Journal of the Audio Engineering Society, to denote a frequency at which a sound system is self-oscillatory. It has been demonstrated experimentally that a sound system embodying a crossover network which drives both bass and treble loudspeakers exhibits severe feedback in the region around the crossover frequency. For example, in a number of systems having a 500 cycle per second crossover frequency, a number of feedback modes occur in the vicinity of crossover, i.e., more or less in the range 400 to 600 cycles. Although these feedback modes may be eliminated by the use of the process described in U.S. patent application Ser. No. 273,333, filed Apr. 16, 1963, now Patent No. 3,256,391, they are so numerous that considerable time and expense are required to remove them.

An important object of the present invention, therefore, is to provide means for causing a loudspeaker to present to a crossover network a constant impedance independent of frequency throughout the crossover region, whereby said loudspeaker and said means will properly load said crossover network so that its performance will be the same as if it were loaded at its design impedance.

Another object of the invention is to provide impedance correcting networks which may be readily interposed between a crossover network and a plurality of loud-speakers, and which will not require adjustment after proper installation has been effected.

Other objects of the invention will become apparent as the description thereof proceeds.

In the drawings:

FIG. 1 is a circuit schematic showing a pair of impedance correcting networks connected between a crossover network and a pair of loudspeaker devices;

FIG. 2 is a chart showing ideal crossover network performance;

FIG. 3 is a circuit schematic showing a modified impedance correcting network for connection between a crossover network and a high frequency loudspeaker; and

FIG. 4 is a circuit schematic of a modified impedance correcting network for connection between a crossover network and a low frequency loudspeaker.

Referring more particularly to the drawings, and first to FIG. 1 thereof, a conventional crossover network is shown at **10**. The network **10**, which is enclosed by broken line **10***a*, includes input terminals **11** and **12** for connection to an amplifier (not shown), low frequency output terminals **13** and **14**, and high frequency output terminals **15** and **16**. A low frequency, or bass, loudspeaker is shown schematically at **17** and a high frequency, or treble, loudspeaker at **18**.

To cause the low and high frequency loudspeakers **17** and **18** to present a constant impedance to the crossover network **10**, impedance correcting networks **20** and **22**, respectively, are employed. For clarity the networks **20** and **22** are enclosed by broken lines **20***a* and **22***a*, respectively.

The low frequency network **20** includes input terminals **23** and **24**, for connection to the terminals **13** and **14** of the crossover network, and output terminals **25** and **26** for connection to the terminals of the loading loudspeaker **17**. Parallel conductors **27** and **28** connect the terminals **23** and **25** and **24** and **26**, respectively. To match the impedance of the loudspeaker **17** to the low frequency crossover output, impedance elements **30**, **31**, **32**, and **33** are connected in parallel and to the conductors **27** and **28**. The element **30** consists of a resistor R which, in parallel with the impedances to the right of element **30** and the impedance of the loudspeaker, loads the low frequency network **10** to its design impedance, essentially independent of frequency throughout the crossover region. The element **31** comprises a capacitor C_1 and a resistor in series. The element **32** is an inductance L_1 and a resistor R_5 in series, and the element **33** is comprised of an inductance L_3, a capacitor C_3 and a resistor R_7 in series.

The high frequency impedance correcting network **22** consists of input and output terminals **35**, **36** and **37**, **38**, respectively, connected by parallel conductors **39** and **40**. The terminals **35** and **36** are connected to the crossover high frequency output terminals **15** and **16**, whereas the terminals **37** and **38** are connected to the high frequency loudspeaker **18**. Adjustment of the impedance presented by the high frequency loudspeaker to the high frequency crossover output, so as to make the load impedance on the crossover high frequency output essentially independent of frequency throughout the crossover region, is effected by impedance elements **41**, **42**, **43**, and **44** which are connected in parallel and to the conductors **39** and **40**. As in the correcting network **20**, the elements **41**, **42**, **43**, and **44** consist, respectively, of a resistor (R_2), a resistor and capacitor in series (R_4C_2), an inductance and a resistor in series (L_2R_6), and an inductance, a capacitor and a resistor in series (L_4, C_4, R_8).

The values of the components of the elements of the networks **20** and **22** would, of course, depend upon the impedances to be matched. Moreover, their wattage ratings would vary, depending upon the power output of the amplifier connected to the crossover network **10**. More specifically, the values of the elements of the correcting networks **20** and **22** are so chosen that the loudspeakers **17** and **18** will present constant impedances to the terminals of the crossover network independent of frequency throughout the crossover region. Thus, the combination of the correcting networks and the loudspeakers will properly load the crossover network **10** so that its performance will be the same as if it were loaded at its design impedance.

If the crossover network exhibits the ideal characteristic at the crossover frequency, as shown in FIG. 2, with a resistive loading on its low and high frequency outputs of 12 ohms, then the correcting networks which are to be connected between the loudspeakers and said crossover network must be so designed that the impedance "seen" by the crossover network is 12 ohms resistive throughout the crossover region (for example, from 400 to 600 cycles per second for a 500 cycles per second crossover frequency). Examples of such impedance correcting networks are shown in FIGS. 3 and 4.

In the example shown in FIG. 3, a high frequency loudspeaker, such as an Altec-Lansing Model 288C, is shown at **45** and is connected to the output terminals of a correcting network **46** consisting of impedance elements **47**, **48**, and **49** connected in parallel and to the high frequency output terminals of a crossover network such as the network **10**, designed for 12 ohm loading. The values of the components of the elements **47**, **48**, and **49** are such that an impedance of approximately 12 ohms will be presented to the crossover network throughout the crossover region centering at 500 cycles per second, and the loudspeaker will thus properly load said network. To effect such proper loading in the example of FIG. 3, the element **47** utilizes a 5 mh. inductance, an 18 mf. capacitor and a 25 ohm resistor in series. The element **48** consists of a 1.1 mf. capacitor and a 20 ohm resistor in series, and the element **49** comprises a 50 ohm resistor.

In FIG. 4 there is shown a correcting network for causing a low frequency loudspeaker, such as an Altec-Lansing Model 515 bass loudspeaker, to present to the low frequency output terminals of the crossover network **10** an impedance of 12 ohms throughout the crossover frequency region. The correcting network of FIG. 4 is shown at **50** and comprises impedance elements **51**, **52**, **53** and **54** connected in parallel and across input and output terminals **55** and **56**, respectively. The low frequency loudspeaker is shown at **57** and is connected to the output terminals **56**. The input terminals **55** are connected to the low frequency output terminals of the crossover network **10**.

To provide proper 12 ohm matching between the loudspeaker **57** and the crossover network **10**, the impedance element **51** comprises a 78 mh. inductance, a 15 mf. capacitor, and a 50 ohm resistor in series; the element **52**, a 40 mh. inductance and a 25 ohm resistor in series; the element **53**, a 14 mf. capacitor and a 20 ohm resistor in series, and the element **54**, a 100 ohm resistor.

It will be understood from the foregoing that when the networks **46** and **50**, together with their respective loudspeakers **45** and **57**, are connected to their proper crossover network output terminals, the impedance "seen" at said crossover network will be 12 ohms throughout the crossover frequency region. Moreover, the irregularities in phase in the outputs of the two loudspeakers will be markedly reduced, with the result that the number of feedback modes in the room containing the loudspeakers as a part of a sound reinforcing system including amplifiers and microphone(s) will also be substantially reduced. The overall result of the use of the above described impedance correcting networks is a more satisfactory sound reinforcing system which may be equalized to control feedback modes at minimum cost.

What is claimed is:

1. In combination with a crossover network having a plurality of pairs of divergent frequency output terminals, and a plurality of loudspeakers having divergent frequency responses,

an impedance correcting network connected between each pair of crossover network output terminals and one of said loudspeakers,

each said impedance correcting network comprising a plurality of impedance element means for matching the impedances of the loudspeakers with the impedance of the crossover network in the crossover frequency region, whereby said loudspeakers will properly load the crossover network,

said impedance element means comprising a resistor paralleled by a capacitor series coupled to a second resistor paralleled by an inductor series coupled to a third resistor paralleled by a capacitor-inductor-resistor series combination.

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