Constant-Resistance Dividing Networks

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A presentation of the design parameters for dividing networks which use two coils of equal inductance with two identical capacitors.

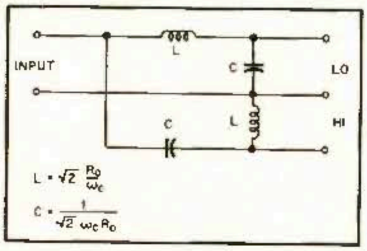

Fig. 1. Schematic of parallel configuration of constant-resistance dividing network.

There are two principal types of dividing networks in extensive use—the constant-resistance network and the "*m*" derived half section network, and the first type has several minor practical advantages over the second. These are: (1) It requires about 15 per cent less inductance in the low-pass section, and hence, for a given wire size the insertion loss is about 7½ per cent less. (2) It requires about 15 per cent less capacitance than the second. (3) When feeding from a zero impedance source each section of the first type is down 3 db, while for the second type each section is down 4 db, thus the second type results in a one decibel dip at crossover. (4) The input impedance of the first type is exactly equal to the characteristic impedance of the filter and contains no reactive component, providing the network is terminated in pure resistances. The last two points are of more academic than practical significance.

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The design procedure for the constant-resistance network is really quite simple.

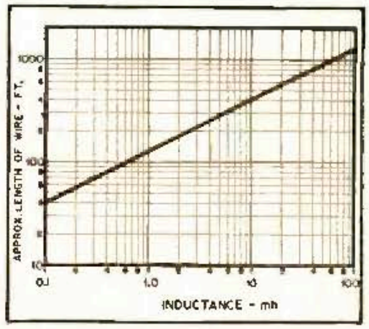

Fig. 3. Chart showing length of wire for given inductance. Example: If the required inductance is 5 mh, approximately 290 feet of wire will be needed for the coil.

The values of inductance and capacitance are read from the chart, *Fig.* 2, once the characteristic impedance of the filter and cross-over frequency have been selected. Next, the wire size is chosen from the following considerations: (1) If the wire size is too small, the insertion loss of the low-pass section will be excessive, and (2) if too large a wire size is chosen, the inductances become inconveniently bulky. A satisfactory compromise may be made by choosing a wire size which will result in a coil resistance equal to 10 per cent of the characteristic impedance of the filter. This produces about one decibel loss through the low-pass section and is undetectable on complex signals. The approximate length of wire needed may be obtained from *Fig.* 3, and the wire size may be selected from *Fig.* 4.

Next the coil is wound to approximate size using the length of wire already determined, and then turns are either removed or added as required to provide the exact inductance. If an impedance bridge is not available, the scheme shown in *Fig.* 5 may be used. When the inductance is of the correct value, the voltmeter indicates the null to occur at the crossover frequency. If the null is below the crossover frequency, the inductance is too high and turns must be removed; if above, the inductance is too low and turns must be added. This method has the advantage, over the impedance bridge method, that it automatically compensates for error in the capacitance. Thus, it is not necessary to have precision capacitors, but they should be of either

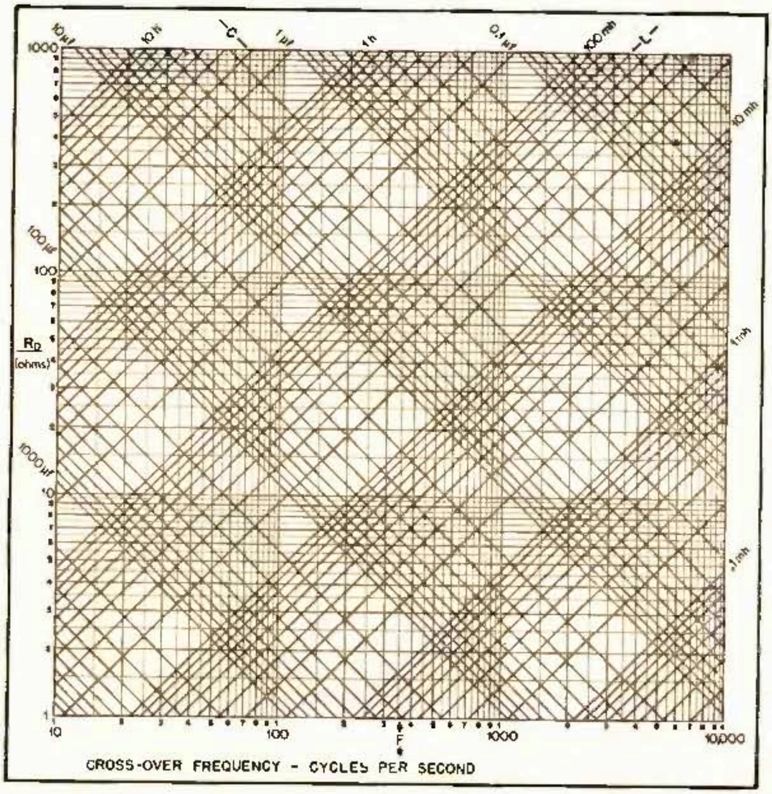

Fig. 2. Chart for determining constants for network. Example: Suppose the characteristic impedance is 11.5 ohms and the desired crossover frequency is 500 cps, then the inductance should be 5.0 mf and the capacitance should be 20 µf.

the oil or paper type and should be non-inductive.

Design of Network

The following example may clarify the procedure of producing a dividing network. Suppose it is desired to design a crossover network for a 16-ohm two-way speaker system. One might select 1,000 cps as the crossover frequency and 16 ohms as the characteristic impedance. *Figure* 2 indicates that the inductance should be 3.5 mh and the capacitance should be 7.0 µf. Referring to *Fig.* 3, it is seen that a coil having an inductance of 3.5 mh will require about 240 feet of wire. *Figure* 4 indicates that the resistance of the coil will be about 1.6 ohms if #18 wire is used. Since it is easier to remove turns from the coil than to add more to it, about 275 feet of wire is measured out and wound into a coil. The process is then repeated, since two such coils are required. Two 7.0 µf capacitors are connected in the circuit of *Fig.* 5, using a 15-ohm resistor for R_b. Suppose it is found that the null occurs at 800 cps; then turns are removed until the null occurs at 1,000 cps. The coil is taped and checked again in the circuit of *Fig.* 5 to be sure that the tape has not pressed the wires closer together and thus increased the inductance. Next the coils and capacitors are mounted and wired, completing the network.

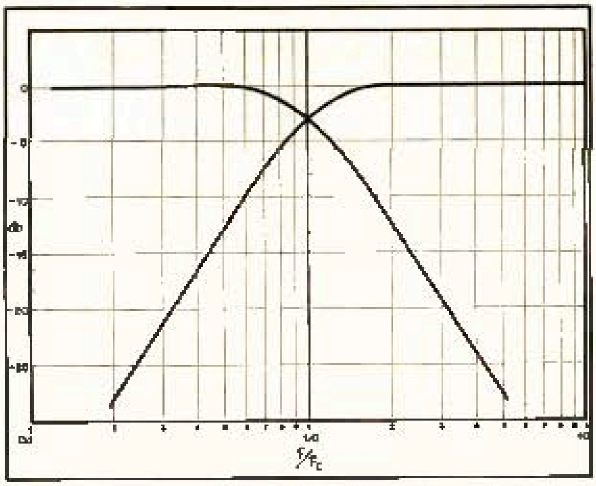

Fig. 6. Frequency response of constant resistance network.

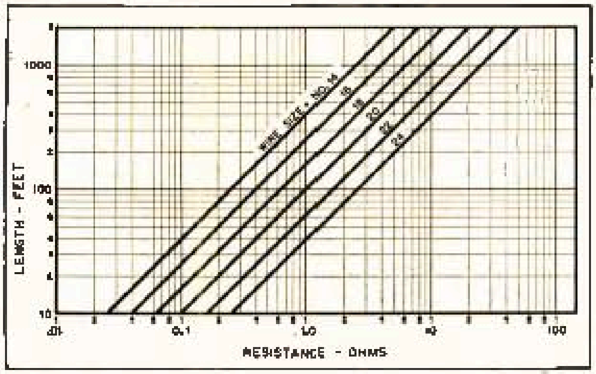

Fig. 4. Chart showing length of wire vs. resistance for various gauges. Example: A coil resistance which is 10 per cent of the characteristic impedance results in coils of practical size. Since the impedance is 11.5 ohms and the approximate length of wire is 290 ft., #18 wire should be used.

The expression for the transmission of the low-pass section is:

$$K = 20 \log \frac{\frac{f_c}{f}}{\sqrt{\left(\frac{f}{f_c} - \frac{f_c}{f}\right)^2 + 2}}$$

and the expression for the gain of the high-pass section is:

$$K = 20 \log \frac{\frac{f}{f_c}}{\sqrt{\left(\frac{f}{f_c} - \frac{f_c}{f}\right)^2 + 2}}.$$

These expressions are plotted in *Fig.* 6. It is evident that the slope of the curve in each stop band is 12 db per octave.

The effect of the coil resistance in the low-pass section is to provide almost uniform attenuation throughout the pass band but to have little effect in the stop band. The effect of the coil resistance in the high-pass filter is negligible in the pass band and also in the stop band down to the frequency for which the coil reactance becomes equal to the coil resistance. Below this frequency the slope becomes asymptotic to 6 db per octave. Thus, for the case in which the coil resistance is 10 per cent of the characteristic impedance of the filter, the high-pass section drops 12 db per octave from crossover down to 7 per cent of the crossover frequency, and from then on is asymptotic to 6 db per octave. Actually, this is hardly significant for a practical network since at 7 per cent of crossover the attenuation is already 46 db.

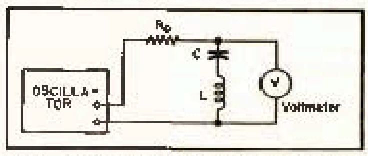

Fig. 5. Equipment set-up used to adjust inductance. Turns are added or removed to obtain a null indication on the voltmeter at the crossover frequency.

Is Your Ear Tin or Golden? Step Right Up and Get Your Answer

Announcement of the 1951 Audio Fair, scheduled for November 1, 2, and 3, in Manhattan's famous Hotel New Yorker, has already started the ingenuity of many exhibitors working at top speed.

Lafayette Radio, for example, has cooking a plan to give every visitor to its display a "Golden Ear" test to determine the frequency range of his hearing. According to Irving Frisch, Lafayette advertising manager, the idea is being developed in the form of a "Golden Ear" contest with prizes posted for the winners who prove their "ear superiority." To ensure absolute fairness in the contest, all measurements will be made with an Audiometer.

The feature is expected to create a high degree of interest among those sharp-eared high-fidelity enthusiasts who are constantly boasting about their superior sense of hearing. Each contestant will be given a token "Golden Ear" as evidence of his having participated in the contest.

This test should provide some enlightening comparisons between the hearing characteristics of persons with training in the field of audio, and those of the population as a whole.

Note: There is some question as to whether the Lafayette exhibit should be illuminated with red lights to minimize the visibility of red faces. Suggestions are in order.

Headache Saver

Many of the headaches usually associated with the solution of complex mathematical problems are eliminated by the latest "thinking machine" developed by Friden Calculating Machine Co., San Francisco, Calif.

Capable of extracting the square root of 10-digit numbers in nine seconds, without use of tables of any kind, the machine is entirely automatic—extracts square roots and automatically points off the correct decimal in the root through entry of the number and touch of but one key.

The machine is expected to ease greatly many of the mathematical aspects of engineering and electronic design in many industries.