AUDIO COMBINING NETWORKS

by Charles D. Sears, Chief Engineer, WIAN, Indianapolis, Indiana—Properly designed combining and dividing networks provide optimum signal with minimum losses and distortion.

An item seldom included in impedance matching charts is the combining, or dividing, network. Typical networks of this type are shown in Fig. 1 (unbalanced) and Fig. 2 (balanced). Where all terminal impedances are equal, usually 500 or 600 ohms in professional audio applications, any terminal can be used as an input or output.

An example of a combining network is the mixing circuit of an audio console. A dividing network of this type occurs after a program amplifier with circuits going to output line, monitor amplifier, and tape-recorder input. These networks also occur in audio patch bays when "mult" circuits are employed.

It is not customary to consider these circuits as "pads," but insertion losses do occur, and it is possible to calculate matching elements so that these losses will be minimized and optimum signal transfer will occur. The number of lines which can be combined or divided is limited only by the amount of signal loss which the system can tolerate (either in signal amplification available, or undesirable noise or distortion which overamplification will produce).

In networks of this type it is necessary that all inputs and/or outputs be of matching impedances. If a circuit does not match the desired network impedance, it must be connected to the network through a matching transformer or resistive matching device.

Balanced or unbalanced systems can be used, but all elements of the network must be consistent.

To find the value of resistance required for each branch:

$$R = Z\left(\frac{n-2}{n}\right) \quad \text{(eq 1)}$$

Where

R = value of each resistor in ohms
Z = network impedance
n = total number of terminals

To find the loss of the network, from any terminal to any other terminal:

$$\text{Loss in db} = 20 \text{ Log } (n-1) \quad \text{(eq 2)}$$

Where

Log = Log to the base 10
n = total number of terminals

Fig. 1 is the basic unbalanced network. The isolation or matching resistor is inserted in the "hot" leg of each circuit. Normally the other leg is grounded. Fig. 2 shows the balanced configuration. In this network the branch resistance is divided equally between the circuit legs. Fig. 3 represents an unbalanced network with appropriate resistance values indicated, and Fig. 4 is the balanced network similarly represented. There are four terminals in each example (three branch terminals and one combined terminal). Therefore,

$$n = 4$$

and

$$Z = 600 \text{ ohms}$$

Branch resistances may be calculated by employing equation 1.

$$R = Z\left(\frac{n-2}{n}\right) = 600\left(\frac{4-2}{4}\right) = 300 \text{ ohms}$$

Use this value for each resistor in the unbalanced

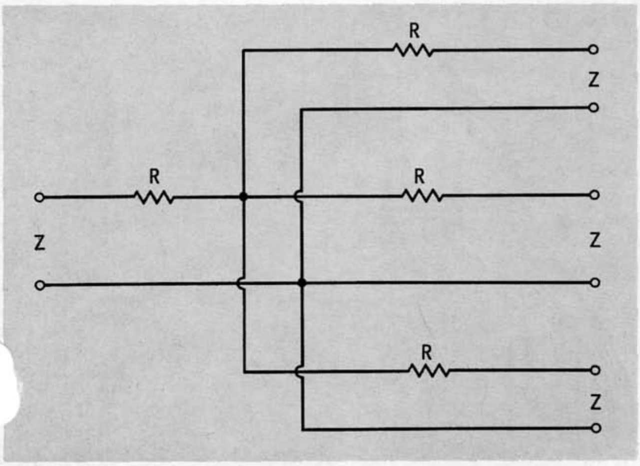

Fig. 1. Unbalanced combining network resistor placement.

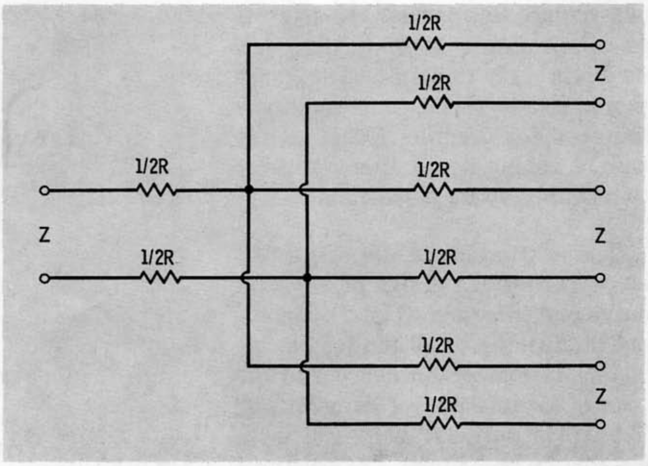

Fig. 2. Balanced configuration divides branch resistances.

Table 1. Resistances for splitting and combining networks.

Terminal Impedance	Number of Terminals — Unbalanced Networks 3	4	5	6	Balanced Networks 3	4	5	6
600Ω	200Ω	300Ω	360Ω	400Ω	100Ω	150Ω	180Ω	200Ω
200Ω	66.6Ω	100Ω	120Ω	133Ω	33.3Ω	50Ω	60Ω	67Ω
50Ω	16.6Ω	25Ω	30Ω	33.3Ω	8.3Ω	12.5Ω	15Ω	17Ω
Loss in db	6 db	9.5 db	12 db	14 db	6db	9.5 db	12 db	14 db

network (Fig. 3). For the balanced configuration (Fig. 4), divide the branch resistance by two. Each resistor will be

$$R = \frac{300}{2} = 150 \text{ ohms}$$

To find insertion loss in the networks, use equation 2. The loss is the same for both the unbalanced and the balanced networks, and for any network impedance value, and will appear at each terminal. For the example shown

$$n = 4$$

$$\text{Loss in db} = 20 \text{ Log } (n - 1) = 20 \text{ Log } (4 - 1) = 9.54 \text{ db}$$

Table 1 has been calculated for typical professional audio values of network impedances such as microphones (50 and 200 ohms) and "high-level" sources such as tape recorders and cartridge machines (600 ohms). Losses are identical at any impedance and whether balanced or unbalanced. Values of resistance are specific values to be used in appropriate networks.

Fig. 5 is a typical combining network of unbalanced configuration frequently encountered in audio mixers. Standard 600-ohm attenuators are used, and in each instance are followed by the combining-network resistor calculated from equation 1. In this example all inputs and the output are unbalanced. If it is necessary to feed this network into balanced inputs, an isolating transformer would follow R_4. Conversely, a balanced input would require an isolation transformer ahead of the corresponding unbalanced attenuator, or between a balanced attenuator and one of the combining resistors (R_1, R_2, or R_3). In the event one or more of the terminals were of a different impedance, insertion of an appropriate matching device would be required.

In all combining network design and application, it is customary and desirable that input levels match. Amplification or attenuation should take place ahead of the network resistances in the appropriate circuit. ▲

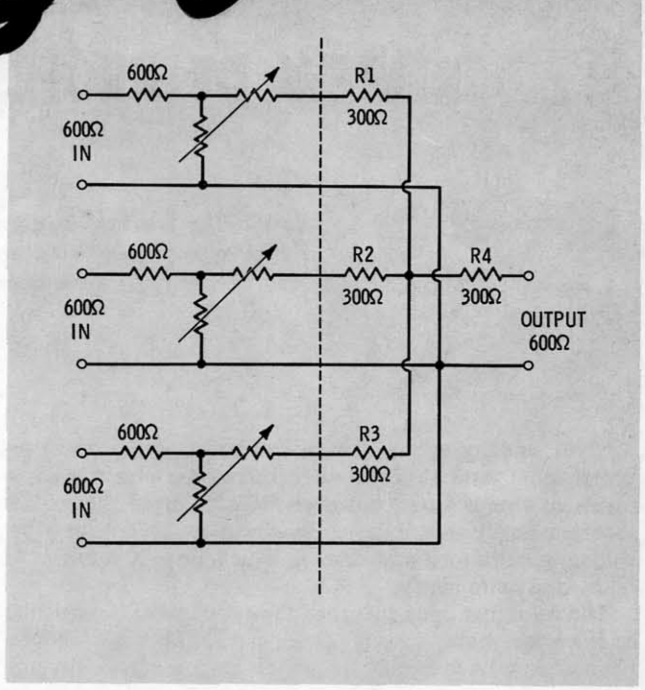

Fig. 5. Circuit of typical unbalanced audio mixer network.

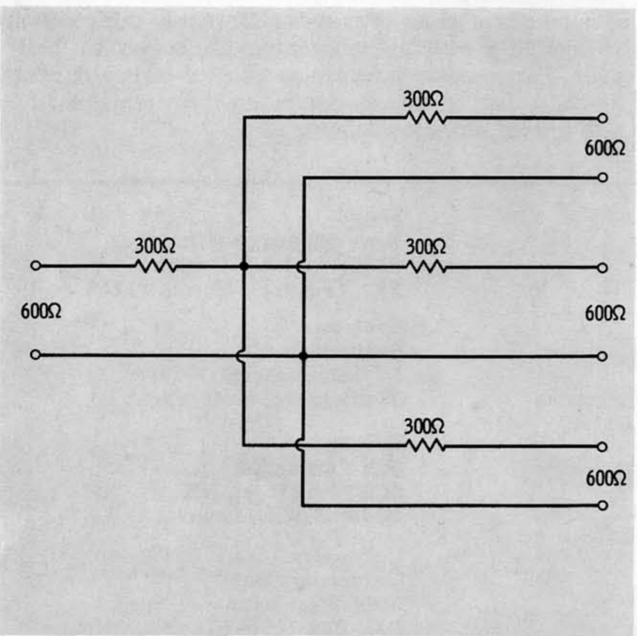

Fig. 3. Unbalanced network with resistance values given.

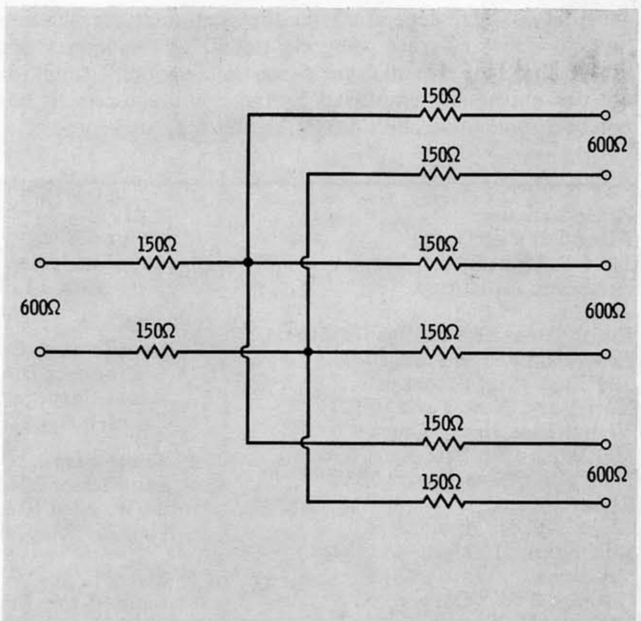

Fig. 4. Leg values in balanced system are ½ of branch R.