Audio Pads and Attenuators

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In one of our previous articles on impedance we mentioned using pads and attenuators to match impedances and adjust levels between two pieces of audio equipment. We thought some additional exposition on the subject may be useful.

In the "good old days" of mostly 600 ohm circuits and matched impedances, it was not uncommon to have to do something to adjust the levels between two pieces of equipment while maintaining the proper impedance(s). This sounds easy enough until you look at it a bit closer. The problem becomes even more complicated when you have to match two pieces of equipment with unequal impedances. The math required to calculate the correct resistors for these pads is even more complicated, requiring either the use of hyperbolic trig functions or calculating current ratios through the pad.

Of course, the big need for this was mostly in the days BC (before calculators), when all you had to work with was paper, pencil, your brain, and a slide rule. If you don't know what a slide rule is, check with an "old-timer." He may still have his and be able to show it to you. A good engineer never went anywhere without one. Of course, the accuracy was limited in comparison to a calculator, but it didn't need batteries. To help with this problem, the major broadcast manufacturers of the time (RCA and Gates were the biggies) had large reference sections at the rear of their catalogs with some shortcuts for calculating pads. These shortcuts were tables for the most commonly used pads and special factors for calculating the odd ones.

There are a number of types of pads that are used, each one named for the shape of the components on the schematic. There are T, H, L, U, Pi, and O pads. The drawing on page 5, shows the schematic of each one. The top figures in each group are all unbalanced pads, while the bottom figures are all balanced. You will most commonly encounter the L, T, and H pads in real situations, but it helps to know a bit about the others as well.

If you look at the schematics on page 5, you will notice that the series elements of the balanced pads are all half the value of the series elements of the unbalanced pads. Z1 and Z2 are the impedance presented to the source device and the impedance presented to the load device, respectively. We will use these values in the calculations.

Think of a situation where you have an equalized phone line, but the level is too high for the amplifier you are using. The phone line requires a 600 ohm termination for the equalization to be correct, and the amplifier has a 600 ohm input impedance. In most cases you would connect the line to the amplifier and all would be well, but in this situation doing so would overdrive the input stage of the amplifier. If the source impedance were significantly lower, such as a solid state output, or the input impedance were higher you would have no problem, but you have 600 ohms for each. You have measured the level coming from the phone line and it is only about 4 dB hotter than what the amplifier can handle. The solution is a simple 4 dB, 600 ohm pad. Since the phone line is balanced, you will need to use a balanced pad, such as an O or H pad.

Although there are formulas to calculate the values of the individual pad resistors, another way is to look at a chart and apply some simple math. The chart on page 5, was taken from an old (1963) edition of the Allied Electronics Data Handbook, edited by Nelson M. Cooke. This was an 88 page booklet that sold for $.50 and contained all sorts of electronics information — well worth the investment, at the time. I am not aware of any similar book on the market today. If you ever find one at a flea market, grab it!

Just look up the dB loss in the left column of the chart, and then look across to the proper values to fill in the various simple formulas, shown beside each pad. Plug the numbers into the formulas and you have your answers.

Another use for pads is to match impedances where you don't have a proper transformer. You can match from a higher impedance to a lower one, or the other way around. However, you will have a certain amount of loss, depending on the ratio of the impedances being matched. This is called a minimum loss, or taper pad. For instance, a pad matching 600 ohms to 150 ohms would have 11.4 dB of loss. *(We'll cover these, and other types of special-purpose pads, in a future article . . . editor)*

Fortunately, you don't need these impedance matching pads very often today. With the low source impedances and high input impedances that you have in typical modern equipment, you can make much simpler pads. First determine the input impedance (Z) of the second device. Then find a convenient resistor that is about 1/10 the input impedance (Z), and make that your shut resistor (R1).

Calculate the voltage ratio, E2/E1 (E_R), or find the value from the table, representing a specific dB loss. Enter the value of R1 and the voltage ratio E_R into the formula, and you have your series resistor (R2). As long as the total of all the resistors is larger than the minimum load on your source, all is fine. This type of pad is shown in **Figure 1**, on page 5.

(continued on page 5)

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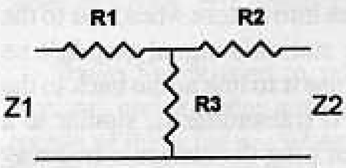
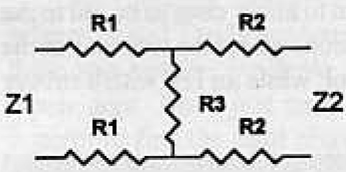
Pad Configurations and Formulas

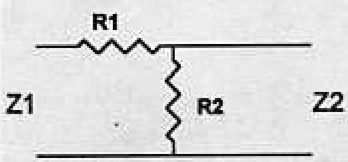
(Z1 = Z2 in all pads, and is the value for Z)



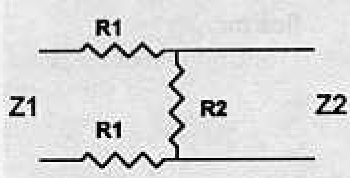
T pad
(unbalanced)
R1 = R2 = ZD
R3 = ZE



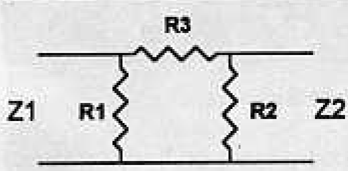
H pad
(balanced)
R1 = R2 = ½ZD
R3 = ZE



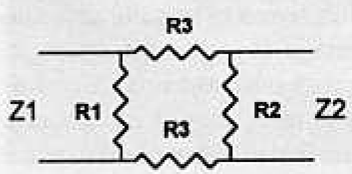
L pad
(unbalanced)
R1 = ZB
R2 = ZC



U pad
(balanced)
R1 = ½ZB
R2 = ZC

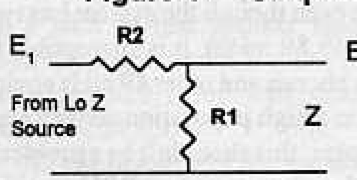


Pi pad
(unbalanced)
R1 = R2 = Z / D
R3 = Z / E

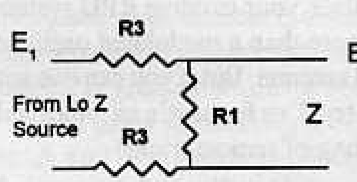


O pad
(balanced)
R1 = R2 = Z / D
R3 = ½(Z / E)

Figure 1 — Simplified Loss Pad



Unbalanced
R1 = 0.1Z
$R2 = (R1 / E_R) - R1$
$E_R = E_2 / E_1$



Balanced
R1 = 0.1Z
R3 = ½R2

Table for Attenuator Network Formulas

dB	Voltage Ratio E_R	B	C	D	E
0.1	.98855	.011447	86.360	.005756	86.857
0.2	.97724	.022763	42.931	.011512	43.426
0.3	.96605	.034046	28.456	.017268	28.947
0.4	.95499	.045008	21.219	.023022	21.707
0.5	.94406	.055939	16.876	.028774	17.362
0.6	.93325	.066745	13.982	.034525	14.428
0.7	.92257	.077429	11.915	.040274	12.395
0.8	.91201	.087989	10.365	.046019	10.842
0.9	.90157	.098429	9.1596	.051762	9.6337
1.0	.89125	.10875	8.1955	.057501	8.6667
2.0	.79433	.20567	3.8621	.11462	4.3048
3.0	.70795	.29205	2.4240	.17100	2.8385
4.0	.63096	.36904	1.7097	.22627	2.0966
5.0	.56234	.43766	1.2849	.28013	1.6448
6.0	.50119	.49881	1.0048	.33228	1.3386
7.0	.44668	.55332	.80728	.38247	1.1160
8.0	.39811	.60189	.66143	.43051	.94617
9.0	.35481	.64519	.54994	.47622	.81183
10.0	.31623	.68377	.46248	.51949	.70273
11.0	.28184	.71816	.39244	.56026	.61231
12.0	.25119	.74881	.33545	.59848	.53621
13.0	.22387	.77613	.28845	.63416	.47137
14.0	.19953	.80047	.24926	.66732	.41560
15.0	.17783	.82217	.21629	.69804	.36727
16.0	.15849	.84151	.18834	.72639	.32515
17.0	.14125	.85875	.16449	.75246	.28826
18.0	.12589	.87411	.14402	.77637	.25584
19.0	.11220	.88780	.12638	.79823	.22726
20.0	.100000	.90000	.111111	.81818	.20202
22.0	.079433	.92057	.086287	.85282	.15967
24.0	.063096	.93690	.067345	.88130	.12670
26.0	.050119	.94988	.052763	.90455	.10049
28.0	.039811	.96019	.041461	.92343	.079748
30.0	.031623	.96838	.032655	.93869	.063309
32.0	.025119	.97488	.025766	.95099	.050269
34.0	.019953	.98005	.020359	.96088	.039921
36.0	.015849	.98415	.016104	.96880	.031706
38.0	.012589	.98741	.012750	.97513	.025183
40.0	.010000	.99000	.010101	.98020	.020002
45.0	.0056234	.99438	.0056552	.98882	.011247
50.0	.0031623	.99684	.0031723	.99370	.0063246
55.0	.0017783	.99822	.0017815	.99645	.0035566
60.0	.0010000	.99900	.00100100	.99800	.0020000
65.0	.00056234	.99944	.00056266	.99888	.0011247
70.0	.00031623	.99968	.00031633	.99937	.0006325
75.0	.00017783	.99982	.00017786	.99964	.0003557
80.0	.00010000	.99990	.00010000	.99980	.0002000
90.0	.00003162	.99997	.00003162	.99994	.00006325