MAKING FIXED RESISTIVE ATTENUATORS

INTRODUCTION

It seems nothing is ever easy. However simple they might appear, making fixed resistive attenuators (I'll call them pads in this article) requires doing some math if you want them to come out right. Sure, you could simply hook some resistors up and see what you get, but that is not audio engineering. The reasons for doing the math are simple: to make both the pad and the equipment you are using with the pad work properly. You will see why you should do the proper engineering when you read the notes below. Excessive noise, excessive loading, potential pad failure, and incorrect results will be avoided.

INSTRUCTIONS

To calculate resistive pads for typical pro audio equipment, follow the formulas in Figure 1 to find the values you need. It is fairly easy as long as you know how to do basic math formulas. If you are rusty, remember to calculate things inside parentheses first [e.g. (R1 + R2)]. Use the answer you get to continue the calculation. There are also step-by-step instructions for doing the log/dB calculations on your calculator.

As rough checks for your calculations:

If:	**Approx. attenuation =**
R1 = 10 x R2	-20 dB
R1 = 5 x R2	-15 dB
R1 = 2 x R2	-10 dB
R1 = R2	-6dB

BALANCED VS. UNBALANCED PADS

If the output equipment or input equipment is unbalanced, use an unbalanced pad. If both are balanced, then use a balanced pad.

IMPORTANT NOTES (and here is where the real engineering comes in)

Avoiding Incorrect Results:
Always measure the resistors you will use with an Ohmmeter. Do not accept the nominal values of resistors as accurate. This is especially true for R2. With high amounts of attenuation, variations in R2 will have a more significant effect on the attenuation.

Avoiding Incorrect Results:
For certain pieces of equipment you may find when selecting the "R values" that it is not possible to find values that are within the criteria given. This means that you will not have a "constant" voltage circuit. The consequence is some additional attenuation will take place either from loading down the output (RS) or loading down the output of the pad with input (RL). In this case go for the latter and use an R2 that is greater than (>) RL/10. You must then figure the total resistance of R2 and RL in parallel:

$$\textbf{Total R} = \frac{(R2 \times RL)}{(R2 + RL)}$$

Use this "Total R" as R2 in the equations. It will work just fine.

If you swap out the equipment fed by a pad where R2 > RL/10, then you must either use one with about the same RL (input impedance) or redo the pad to get the same attenuation.

Always maintain R1 + R2 > 10 x RS. The reason for this is to ensure that the resulting circuit allows the driving equipment to operate as the constant voltage device it was designed to be. Loading it down with less than 10 times the output impedance means possible distortion, overheating, or other undesirable consequences.

You Do Not Have the Resistor You Need (Also Avoids Incorrect Results):
You can make up odd resistor values by putting two or more in parallel or series. ***Always*** measure your combination with an Ohmmeter. Do not accept the nominal values of resistors as accurate.

To calculate what you need for two parallel resistors use this formula. R1 is a known resistor, RT is the total resistance you want to get, and R2 is the resistor you need to put in parallel with R1 to get RT:

$$\textbf{R2} = \frac{(R1 \times RT)}{(RT - R1)}$$

If putting resistors in series, the total resistance is found by simply adding resistor values together. So if you have a 1000 Ohms and you need 1100 Ohms put a 100 Ohm in series with the 1000 Ohms: 1000 + 100 = 1100.

Avoiding Noise:
Low tolerance (1% or better) resistors for the R1s are a must to use in balanced pads to help maintain the CMRR (Common Mode Rejection Ratio) of the input stage in the receiving equipment. In addition, if you have a good Ohmmeter, you should try matching up the two series R1 resistors as close as you can from a batch with the same nominal value.

Where To Install The Pad (Also Avoids Noise):
You should ***always*** put pads at the ***receiving*** end of the cable so that the cable "sees" the low output impedance (RS) over its length rather than the higher R2. Also the signal level will be higher in the cable. These things will help prevent noise intrusion.

Normally, you can usually squeeze a resistive pad inside an XLR connector. Just be sure to label the cable accordingly. For 1/4" plugs you can also put it inside the sleeve, though it is usually a fussy job. You can also hard-wire it into the cable near the receiving end or build it into a small utility box with the pad inside and appropriate connectors and / or pigtails with connectors on them. Be sure to connect the cable shield to the box.

Avoiding Pad Failures:
When pad attenuates a signal where does the excess signal you are getting rid of go? If you do not know I will tell you. If you do know I will tell you anyway. The resistors in the pad dissipate the excess signal as heat. So you need to find out just how much heat (in watts) the resistors in the pad must dissipate. If you don't, your resistors may overheat and either change value or burn up and stop working. Neither situation is a good thing for a pad.

You can safely use a 1/4 watt resistor for R1 for equipment that can put out +24 dBv / 24 dBm or less (about 12 volts in either case) ***and*** if R1 is 1,000 Ohms or higher (= two 500 Ohm resistors for a balanced pad). If R1 is less than 1,000 Ohms or your equipment can put out more than +24 dBv then you should calculate the wattage R1 needs to be. Use this worst-case formula where "V" is the maximum output of the equipment driving the pad. The formula is worst-case because it assumes a short circuit across the output of the pad. If all you have is a + dB number for the output specification, then you must covert it to volts. An article in the Live-Audio Study Hall about audio calculations (http://www.live-audio.com/studyhall/dB_calculations.pdf) will tell you how. Note: $V^2 = V \times V$.

$$\textbf{Watts} = \frac{V^2}{R1}$$

Now double this number and that's the wattage you should use for R1 = twice the expected worst-case condition. It is best to be conservative. In the case of balanced pads where the resistors values are 1/2 R1, the wattage you calculate is what you should use. This is because each resistor will only dissipate 1/2 the wattage. For the 1,000 Ohm R1 and a 12 volt (+24 dBv) output capability criteria, the wattage works out to be 0.14 watts. Double it and you need a 1/4 watt resistor for an unbalanced pad or two 1/8 watt resistors for a balanced pad.

If your equipment could put out +28 dBv, the wattage works out to be almost 0.4 watts the resistor would need to be able to dissipate. For a 500 Ohm R1 and +24 dBv it is 0.3 watts. In either case a 1/4 watt resistor would be too small. It would likely overheat if the equipment was at full output and there was a short circuit across the output of the pad. You could probably get away with it, but designing for worst-case is part of good engineering.

If R1 is 2,000 Ohms or higher, then 1/8 watt resistors can be used for a 12 volt (+24 dBv or dBm) output.

R2 Wattage (Also Avoids Pad Failures and Incorrect Results):
You can use a 1/4 watt resistor for R2 if it is 200 Ohms or higher and the driving

equipment can put out 12 volts (+24 dB) or less. If R2 is 400 Ohms or higher, you can use 1/8 watt resistors. To work out the wattage needed for R2, find V2 from the formula in Figure 1 and use this for V in the "Watts" formula. A small change in for R2 will significantly change the attenuation of the pad. So I have been doubly conservative in the R2 wattage requirements using 4 times the wattage that might be dissipated. Be very conservative in the wattage requirements for R2 to avoid any small changes in value that could occur with heating.

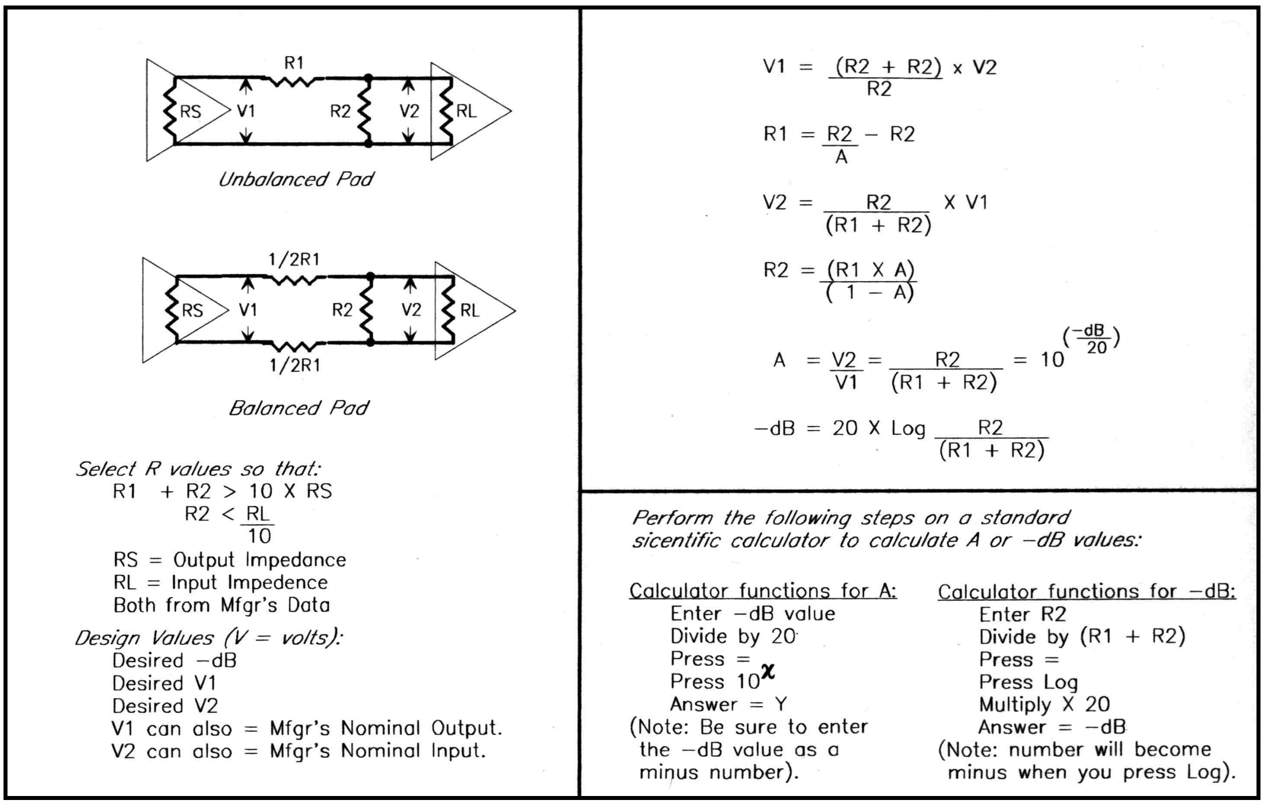

Figure 1

(Error in figure: the "Answer" in "Calculator functions for A" equals "A" not "Y")

SUMMARY

You should know now that making what would appear to be a simple device using 2 or 3 resistors is not that easy. It requires thoughtful engineering design to avoid a number of potential problems. So get out your calculator and Ohmmeter and get to work. You will have the satisfaction of knowing you did it the right way and that they will work properly and reliably.

Chuck McGregor 5 Mar 2000