

Calculating the attenuator

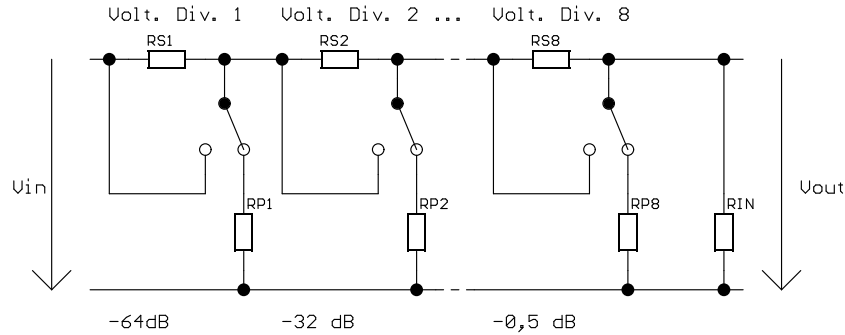


Figure 1: schematic

The trick is to have 8 voltage dividers weighted in db in powers of two. This assures a logarithmic character and fine resolution provided we can select or bypass each voltage divider individually.

If we look at the circuit as a pot connected as a variable voltage divider, R_{in} is the value of the pot.

Our problem is to ensure that each voltage divider sees a constant load on its right side, no matter how many of them are selected or bypassed. That way, they will not influence each other. In other words, each section must provide an input resistance equal to R_{in} while seeing the same R_{in} at its output. On the other hand, the ratio of R_{Sn} and R_{Pn} is determined by the attenuation of each individual section. If we put both conditions into equations, we should be able to calculate the beast.

Let us first define A as attenuation of the signal. If $A = 2$, the output will be half the voltage of the input:

$$A = \frac{U_{in}}{U_{out}} \quad (1)$$

To express this in dB:

$$A_{db} = 20 \log A \quad (2)$$

$$A = 10^{\frac{A_{db}}{20}} \quad (3)$$

For a simple, unloaded voltage divider, we remember this formula:

$$U_{out} = U_{in} \cdot \frac{R_{Pn}}{R_{Pn} + R_{Sn}} \quad (4)$$

Using A as defined before:

$$\frac{R_{Sn}}{R_{Pn}} = A - 1 \quad (5)$$

In our case, the voltage dividers are loaded by R_{in} which is in parallel to R_{Pn} . Taking this into account, we get:

$$\frac{R_{Sn}}{R_{Pn} \parallel R_{in}} = A - 1 \quad (6)$$

Expanded:

$$\frac{R_{Sn}}{\frac{R_{Pn}R_{in}}{R_{Pn}+R_{in}}} = A - 1 \quad (7)$$

Resolved to R_{Sn} :

$$R_{Sn} = \frac{R_{Pn}R_{in}}{R_{Pn} + R_{in}} (A - 1) \quad (8)$$

We will keep this in mind. Our second condition, stating that the input resistance of each section should equal R_{in} , can be met when:

$$R_{Pn} \parallel R_{in} + R_{Sn} = R_{in} \quad (9)$$

Expanded:

$$\frac{R_{Pn}R_{in}}{R_{Pn} + R_{in}} + R_{Sn} = R_{in} \quad (10)$$

After resolving to R_{Sn} :

$$R_{Sn} = R_{in} - \frac{R_{Pn}R_{in}}{R_{Pn} + R_{in}} \quad (11)$$

We now have two equations for R_{Sn} . Simply combining (8) and (11), we get:

$$R_{in} - \frac{R_{Pn}R_{in}}{R_{Pn} + R_{in}} = \frac{R_{Pn}R_{in}}{R_{Pn} + R_{in}} (A - 1) \quad (12)$$

This can be simplified to a simple formula for each R_{Pn} :

$$R_{Pn} = \frac{R_{in}}{A - 1} \quad (13)$$

We now insert (13) into (11) and simplify again to get a handy formula for each R_{Sn} :

$$R_{Sn} = \frac{R_{in}(A - 1)}{A} \quad (14)$$

We are now able to calculate the beast. All we need is R_{in} as input resistance of the attenuator and the attenuation of each section. Using (3), A can be determined for each voltage divider. Use positive values here, as we defined A_{db} as attenuation, not gain. The result will be inserted into (13) and (14) to calculate the resistor values.