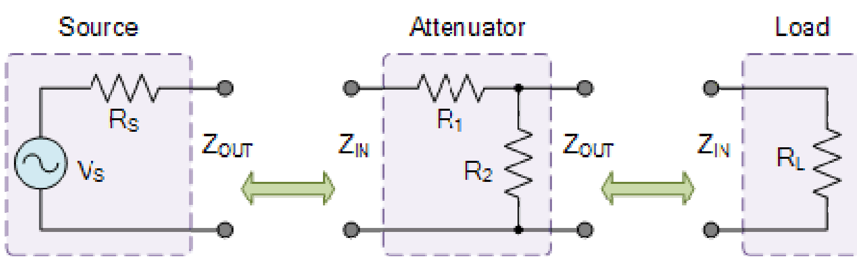
Passive Attenuator Basics

An Attenuator is a special type of electrical or electronic bidirectional circuit made up of entirely resistive elements. An attenuator is a two port resistive network designed to weaken or "attenuate" (hence their name) the power being supplied by a source to a level that is suitable for the connected load.

A *passive attenuator* reduces the amount of power being delivered to the connected load by either a single fixed amount, a variable amount or in a series of known switchable steps. Attenuators are generally used in radio, communication and transmission line applications to weaken a stronger signal.

The **Passive Attenuator** is a purely passive resistive network (hence no supply) which is used in a wide variety of electronic equipment for extending the dynamic range of measuring equipment by adjusting signal levels, to provide impedance matching of oscillators or amplifiers to reduce the effects of improper input/output terminations, or to simply provide isolation between different circuit stages depending upon their application as shown.

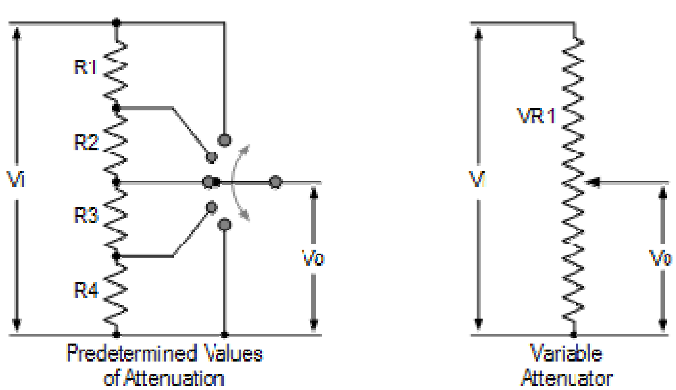
Attenuator Connection



Simple Attenuator Networks (also known as "pads") can be designed to produce a fixed degree of "attenuation" or to give a variable amount of attenuation in pre-determined steps. Standard fixed attenuator networks generally known as an "attenuator pad" are available in specific values from 0 dB to more than 100 dB. Variable and switched attenuators are basically adjustable resistor networks that show a calibrated increase in attenuation for each switched step, for example steps of -2dB or -6dB per switch position.

Then an **Attenuator** is a four terminal (two port) passive resistive network (active types are also available which use transistors and integrated circuits) designed to produce "distortionless" attenuation of the output electrical signal at all frequencies by an equal amount with no phase shift unlike a passive type RC filter network, and therefore to achieve this attenuators should be made up of pure non-inductive and not wirewound resistances, since reactive elements will give frequency discrimination.

Simple Passive Attenuator



Attenuators are the reverse of amplifiers in that they reduce gain with the resistive voltage divider circuit being a typical attenuator. The amount of attenuation in a given network is determined by the ratio of: Output/Input. For example, if the input voltage to a circuit is 1 volt (1V) and the output voltage is 1 milli-volt (1mV) then the amount of attenuation is 1mV/1V which is equal to 0.001 or a reduction of 1,000th.

However, using voltage, current or even power ratios to determine or express the amount of attenuation that a resistive attenuator network may have, called the **attenuation factor**, can be confusing, so for the passive attenuator its degree of attenuation is normally expressed using a logarithmic scale which is given in *decibels* (**dB**) making it easier to deal with such small numbers.

Degrees of Attenuation

An attenuators performance is expressed by the number of decibels the input signal has decreased per frequency decade (or octave). The *decibel*, abbreviated to “dB”, is generally defined as the logarithm or “log” measure of the voltage, current or power ratio and represents one tenth 1/10th of a Bel (B). In other words it takes 10 decibels to make one Bel. Then by definition, the ratio between an input signal (Vin) and an output signal (Vout) is given in decibels as:

Decibel Attenuation

$$dB_v = 20\log_{10}\frac{Vout}{Vin} \quad (dB)$$

Note that the decibel (**dB**) is a logarithmic ratio and therefore has no units. So a value of -140dB represents an attenuation of 1:10,000,000 units or a ratio of 10 million to 1!.

In passive attenuator circuits, it is often convenient to assign the input value as the 0 dB reference point. This means that no matter what is the actual value of the input signal or voltage, is used as a reference with which to compare the output values of attenuation and is therefore assigned a 0 dB value. This means that any value of output signal voltage below this reference point will be expressed as a negative dB value, (**-dB**).

So for example an attenuation of -6dB indicates that the value is 6 dB below the 0 dB input reference. Likewise if the ratio of output/input is less than one (unity), for example 0.707, then this corresponds to 20 log(0.707) = -3dB. If the ratio of output/input = 0.5, then this corresponds to 20 log(0.5) = -6 dB, and so on, with standard electrical tables of attenuation available to save on the calculation.

Passive Attenuators Example No1

A passive attenuator circuit has an insertion loss of -32dB and an output voltage of 50mV. What will be the value of the input voltage.

$$dB_v = 20\log_{10}\frac{Vout}{Vin} \quad (dB)$$

$$-32 = 20\log_{10}\frac{Vout}{Vin}$$

$$\therefore \; -1.6 = \log_{10}\frac{Vout}{Vin}$$

The antilog ($\log^{-1}$) of -1.6 is given as:

$$\frac{Vout}{Vin} = 0.025$$

$$\therefore\ Vin = \frac{Vout}{0.025} = \frac{50mV}{0.025} = 2\,volts$$

Then if the output voltage produced with 32 decibels of attenuation, an input voltage of 2.0 volts is required.

Attenuator Loss Table

Vout/Vin	1	0.7071	0.5	0.25	0.125	0.0625	0.03125	0.01563	0.00781
Log Value	20log(1)	20log (0.7071)	20log (0.5)	20log (0.25)	20log (0.125)	20log (0.0625)	20log (0.03125)	20log (0.01563)	20log (0.00781)
in dB's	0	-3dB	-6dB	-12dB	-18dB	-24dB	-30dB	-36dB	-42dB

and so on, producing a table with as many decibel values as we require for our attenuator design.

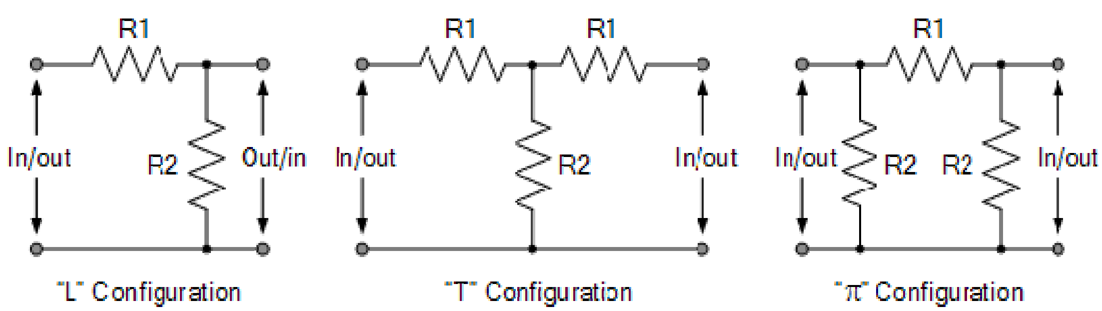
This decrease in voltage, current or power expressed in decibels by the insertion of the attenuator into an electrical circuit is known as *insertion loss* and minimum loss attenuator designs match circuits of unequal impedances with a minimum loss in the matching network.

Now that we know what a **passive attenuator** is how it can be used to reduce or "attenuate" the power or voltage level of a signal, while introducing little or no distortion and insertion loss, by an amount expressed in decibels, we can begin to look at the different attenuator circuit designs available.

Passive Attenuator Designs

There are many ways in which resistors can be arranged in attenuator circuits with the **Potential Divider Circuit** being the simplest type of passive attenuator circuit. The potential or voltage divider circuit is generally known as an "L-pad" attenuator because its circuit diagram resembles that of an inverted "L". But there are other common types of attenuator network as well such as the "T-pad" attenuator and the "Pi-pad" (π) attenuator depending upon how you connect together the resistive components. These three common attenuator types are shown below.

Attenuator Types



The above attenuator circuit designs can be arranged in either "balanced" or "unbalanced" form with the action of both types being identical. The balanced version of the "T-pad" attenuator is called the "H-pad" attenuator while the balanced version of the "π-pad" attenuator is called the "O-pad" attenuator. Bridged T-type attenuators are also available.

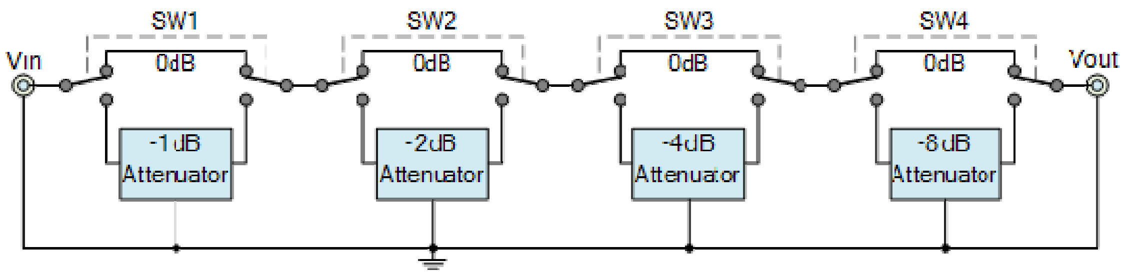
In an unbalanced attenuator, the resistive elements are connected to one side of the transmission line only while the other side is grounded to prevent leakage at higher frequencies. Generally the grounded side of the attenuator network has no resistive elements and is therefore called the "common line".

In a balanced attenuator configuration, the same number of resistive elements are connected equally to each side of the transmission line with the ground located at a center point created by the balanced parallel resistances. Generally, balanced and unbalanced attenuator networks can not be connected together as this results in half of the balanced network being shorted to ground through the unbalanced configuration.

Switched Attenuators

Instead of having just one attenuator to achieve the required degree of attenuation, individual**attenuator pads** can be connected or cascaded together to increase the amount of attenuation in given steps of attenuation. Multi-pole rotary switches, rocker switches or ganged push-button switches can also be used to connect or bypass individual fixed attenuator networks in any desired sequence from 1dB to 100dB or more, making it easy to design and construct switched attenuator networks, also known as a **step attenuator**. By switching in the appropriate attenuators, the attenuation can be increased or decreased in fixed steps as shown below.

Switched Attenuator



Here, there are four independent resistive attenuator networks cascaded together in a series ladder network with each attenuator having a value twice that of its predecessor, (1-2-4-8). Each attenuator network may be switched "in" or "out" of the signal path as required by the associated switch producing a step adjustment attenuator circuit that can be switched from 0dB to -15dB in 1dB steps.

Therefore, the total amount of attenuation provided by the circuit would be the sum of all four attenuators networks that are switched "IN". So for example an attenuation of -5dB would require switches SW1 and SW3 to be connected, and an attenuation of -12dB would require switches SW3and SW4 to be connected, and so on.

Attenuator Summary

- An attenuator is a four terminal device that reduces the amplitude or power of a signal without distorting the signal waveform, an attenuator introduces a certain amount of loss.
- The attenuator network is inserted between a source and a load circuit to reduce the source signal's magnitude by a known amount suitable for the load.
- Attenuators can be fixed, fully variable or variable in known steps of attenuation, -0.5dB, -1dB, -10dB, etc.
- An attenuator can be symmetrical or asymmetrical in form and either balanced or unbalanced.
- Fixed attenuators also known as a "pad" are used to "match" unequal impedances.

- An attenuator is effectively the opposite of an amplifier. An amplifier provides gain while an attenuator provides loss, or gain less than 1 (unity).
- Attenuators are usually passive devices made to from simple voltage divider networks. The switching between different resistances produces adjustable stepped attenuators and continuously adjustable ones using potentiometers.

To simplify the design of the attenuator, a "K" (for constant) value can be used. This "K" value is the ratio of the voltage, current or power corresponding to a given value of dB attenuation and is given as:

$$\text{"K"} = \text{antilog}\left(\frac{dB}{20}\right) = 10^{\frac{dB}{20}} \quad \text{for Voltage or Current}$$

$$\text{"K"} = \text{antilog}\left(\frac{dB}{10}\right) = 10^{\frac{dB}{10}} \quad \text{for Power}$$

We can produce a set of constant values called "K" values for different amounts of attenuation as given in the following table.

Attenuator Loss Table

dB	0.5	1.0	2.0	3.0	4.0	5.0	6.0	10.0	20.0
"K" value	1.0593	1.1220	1.2589	1.4125	1.5849	1.7783	1.9953	3.1623	10.000

and so on, producing a table with as many "**K**" values as we require.

Fixed value attenuators, called "attenuator pads" are used mainly in radio frequency (Rf) transmission lines to lower voltage, dissipate power, or to improve the impedance matching between various mismatched circuits.

Line-level attenuators in pre-amplifier or Audio Power Amplifiers can be as simple as a 0.5 watt potentiometer, or voltage divider L-pad designed to reduce the amplitude of an audio signal before it reaches the speaker, reducing the volume of the output.

In measuring signals, high power attenuator pads are used to lower the amplitude of the signal a known amount to enable measurements, or to protect the measuring device from high signal levels that might otherwise damage it.

In the next tutorial about **Attenuators**, we will look at the most basic type of resistive attenuator network commonly called a "L-type" or "L-pad" attenuator which can be made using just two resistive components. The "L-pad" attenuator circuit can also be used as a voltage or potential divider circuit.