A 12- or 24-step attenuator

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Adding construction examples ...

Content of this page

1. Introduction

- 1.1 Why use an attenuator
- 1.2 What's the problem

2. Design

- 2.1 Architecture overview
  - Principle of the voltage divider
  - Series attenuator
  - Series with shunt
  - Ladder attenuator
  - Shunt attenuator
- 2.2 A 12-step series attenuator
- 2.3 Series attenuator with ground resistor
- 2.4 Inverted amplifiers

3. Construction

- 3.1 What switch to use
- 3.2 What resistors to use

4. Examples (my examples)

- 4.1 type s12bn: Series attenuator with ground resistor
- 4.2 type s12mn: Series attenuator, shorting for non-inverted amps

- 4.3 type s12bi: Series attenurator for inverted amps with ground resistor (non-shorting)
- 4.3 type l12bn: 12-step ladder attenuator
- 4.4 type s24mn: 24-step series attenuator

5. Calculations with the Spreadsheet

- 5.1 Why a spreadsheet program
- 5.2 Excel spreadsheet supported functions
- 5.3 How the program works
- 5.4 Spreadsheet FAQ

6. References and Links

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1. Introduction

When building my own gainclone I decided to make a 12-step attenuator based on a rotary switch and some resistors just like the original gaincard amp.

Most people (including myself) think that a stepped attenuator gives better sound quality than a quality pot.

1.1 Why use an Attenuator

Why change your pot to a 12- or 24-step attenuator, or build your new amp with an attenuator instead of a potentiometer? Is it worth the trouble to change, and how much will you win?

Well, your mileage may vary, but in general the log pot used in many amplifiers could (over years) suffer from the following problems:

- Channel tracking might differ from 10% to up to 20%, with descrete resistor values it is possible (especially when measuring and matching before use) to get both channels within 1 a 2% over the full range.
- Cracking and popping due to wear of the carbon/cermet resistor elements.
- With dual-mono setup it is nearly impossible to get both channels in the same position (same gain).

I use an ALPS blue pot in my UL40-s2 amp, and I'm very satisfied. However, after the warranty period is over I might try an upgrade with just 12 resistors. Listening to the gainclones I've built with these switches its safe to say that this is a very good way to control your amp. Especially if both channels have their own volume control, it gives a reference for putting both channels in exactly the same position, something that's nearly impossible to do with a regular pot.

There are standard 12-step switches available from your local electronics store, and these are most likely mass production pieces that will do perfectly. However, there are also 24-step pieces available but sold new these are far more expensive. A cheaper alternative is to look for used switches in army-junk shops.

The photo on the right shows the Lorlin switch of just € 1.50 or so with 12 resistors that makes up the 12-step switch for Geenkloon (and Cyclone). The (big) shielded microphone cable connects ground and signal in, the thin silver/PTFE wire outputs the attenuated signal to the amplifier stage.

In the remainder of this page, I will describe the construction for a 12-step switch but the principle if the same for 24-step switches as well, it just requires a little more resistors and soldering.

1.2 What's the problem?

Like most other builders I knew how a 12- or 24-step attenuator should be constructed, but I needed to calculate the right resistor values for each step based on the desired input impedance, the number of steps and the desired maximum attenuation. The input impedance is often specified by the project you're working on, in my case I was working on the Gainclone with an input impedance around 20 kOhms.

The number of steps results from available switches, the amount of money you want to throw at it and your ears. I discovered that I can easily live with a 12-step attenuator, but of-course a 24-step (another standard value) would do much nicer. However, it is very important to define the first steps really well as they determine the critical low volume levels (candle light music etc.) and should be such that the sound level does not disturb conversations etc.

The maximum attenuation in dB will be 60 or better. For a 12-step project make it at least 48dB, but for a 24-step switch you might want to use a value of 60 dB or better.

The most simple way to make a 12-step attenuator with logarithmic volume control is of-course to make sure that every step of the attenuator has the same value in dB (which results by definition in a logarithmic gain). However, I found especially that with 12-step controls it's much better to tune the steps to your own favorite sound levels. In my case I might want the first steps to be fine, a mid section with more coarse steps and the last three steps to have steps that are three times as steep.

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2. Designing an Attenuator

In the following sections it is described how to design your own attenuator, and how to do the math for calculating the resistor values etc.

2.1 Architecture

Things to take into account when building your own volume control with a stepped attenuator are :

- What is the design of the next stage of the amp we're feeding the attenuator output into: Non-Inverted or Inverted?
- What is the output impedance of the CD-player, tuner or phono amp feeding into the attenuator?
- What is input impedance we want to create for the input of our amp?
- How many steps do you need?
- What are the steps in dB we want for Volume control: linear or a particular curve based on our preferred volume levels?
- What type of switch do we have: Make-before-break (=shorting) of break-before-make (non Shorting)?
- Is there a ground resistor from the input pin of the amp to ground (mostly used to give the amp a DC reference point), then we should take this resistor into account as it is a parallel resistor between wiper and ground and influences both impedance and gain (inverted amp).

Basic Principle

There are several ways to build a volume control for an amplifier, although all methods described below are based on a variation of the voltage divider. The basic circuit looks like this:

Figure 2.1: Voltage Divider

And the "gain" of a voltage divider is defined by the following formula.

Formula 1a: Basic principle of Voltage Divider

For the input voltage, according to Ohms law the following is true:

$$V_{inp} = i * R_{total} = i * (R_a + R_b)$$

$$V_{out} = i * R_b$$

The gain of the attenuator switch for non inverted topology is defined as:

$$A = \frac{V_{out}}{V_{inp}} = \frac{R_b}{R_a + R_b}$$

The gain in dB is therefore:

$$A_{dB} = 20 * \log\left(\frac{R_b}{R_a + r_b}\right)$$

And as we know the formulas for calculating the gain we can also work in the reverse direction and calculate resistor values for a given gain of the attenuator (which will mostly be negative e.g. -60 dB)

Formula 1b: Choosing Resistors in a Voltage Divider

For a given input impedance R_i of a voltage divider, what would be the resistor values for R_a and R_b that would make up a gain of X dB?

The gain is defined as follows: $A = 10^{(X/20)}$

And we know that this gain is defined as $\frac{V_{out}}{V_{inp}} = \frac{R_b}{R_a + R_b}$

As said above, the total impedance is chosen, and is equal to $R_i = R_a + R_b$

Therefore:

$$R_b = R_i * 10^{(X/20)}$$

$$R_a = R_i - R_b$$

These two formulas are the basis of all attenuators described on this page.

Series Attenuator

The series type consists of a chain of resistors connected between signal source and ground forming a constant input impedance. The wiper takes position between any adjacent pair of resistors and forms a classic voltage divider with all resistors from that position to the signal and all resistors from that position to ground. For the series attenuator you need a 12- or 24-step switch with only one deck.

Figure 2.2: Series attenuator

The series attenuator has a big advantage: Only a simple switch with one deck of 12 positions is necessary, and only 12 resistors per channel are used. The simple construction makes it less prone to failure. The disadvantage is that at most positions of the switch there are more than one resistors in the path to the signal source and also more than 1 resistor to ground. At the lowest listening levels there are 10 or 11 resistors in the signal path.

Series attenuator with ground resistor

A common variation of the series attenuator is the attenuator with shunt resistor (signal to ground). The reason for such a shunt resistor is normally to provide a defined impedance to ground to the amp input. Common reasons for presence of such a resistor are:

- There is an audio capacitor between the line input (with it's attenuator) and the input of the Opamp to protect the amplifier from DC offsets. The resistor provides a DC ground reference for the Opamp input.
- The attenuator is of the break-before-make type and therefore between switch positions there is a moment where the ground reference is not present. A permanent resistor between the wiper and ground will provide such an impedance at all time.
- The amp is used as a power-amp only and in order to protect the speakers when disconnecting the pre-amp the resistor provides a reference to ground.

Figure 2.3: Voltage Divider with ground resistor

The figure at the right explains the principle: Rg is used to provide an impedance to ground and influences the

attenuator (Ra and Rb for a certain position). When designing an attenuator for such environment it is good to remember that the effective input impedance of the amplifier at the signal input terminals will vary over the range of the attenuator.

As a result, care must be taken to select the right values for the resistors in the attenuator so that the impedance of the amplifier as seen by the source (Cdplayer etc) will not deviate too much from the desired values.

Ladder Attenuator

Figure 2 shows the setup of the ladder version. The rotary switch makes two connections at a time, connecting on one side to the signal in and to the other side to ground. The wipers are both connected to the signal out that is fed to the next amplifying stage. For the Ladder type you need a switch with two decks.

Figure 2b: ladder type

The ladder type of attenuator has a big advantage over the series version: Only one resistor is in the signal path and there is always one resistor to ground. The voltage divider always consists of two resistors Ra (to signal input) and Rb (to ground) and the wiper connects the two to the output of the attenuator.

The ladder attenuator therefore in fact contains 12- or 24- voltage regulators, which makes it the most elegant (and expensive) solution for volume control.

Resistor 12b may be omitted and replaced by a short to ground if the volume needs to be really 0 in the lowest position.

I updated the Excel spreadsheet, to include a ladder attenuator for both a 12- and 24-step switch.

Shunt Regulation

The shunt type is a mix of the ladder and the series version and offers in most of its range the advantages of both. The shunt type is not usable in all amplifier designs.

Figure 2c: Shunt attenuator

The advantages of the shunt regulator are in principle the same as for the ladder: Only two resistors (except in position 1) are in the signal path. The disadvantage of this design is that the input impedance is not flat but is a value of Ra + Rbx and thus changes with every value of x. For tube pre amps special care must be taken that the input impedance still is high enough for the tube pre amp.

In most cases resistor number 11 will be replaced with a hardware to ground so that there is no signal on the output in the lowest volume position. However, with a 12-step attenuator its a choice to use position 12 for very soft music and not completely shut off the amp.

2.2 Building a 12-Step Series Attenuator

Let's start with a 12-step attenuator for non-inverted designs such as my GeenKloon project. Such attenuator switch is based on the principle of voltage-divider: Eleven, Twelve (or twenty-four) resistors are connected in series, and the rotary switch positions between two resistors. The effective attenuation on pin "pos" of the voltage divider then can be computed as shown in formula 1a below. In this example I assume 11 resistors for a 12-step attenuator which means step 1 is full power and step 12 is 0 volume (wiper connected to ground). But it is equally possible to give step 12 a resistor value to ground which means that the volume then is low but never completely off.

Figure 1a is the schema for the attenuator I used for the GeenKloon (my non inverted version of the gainclone based on a LM3875 chip):

It is very advisable to observe the resistor values and solder them the right way (determine which is pin 1 and which is pin 12) because it's easy to build it the wrong way around which results in poor (hardly no) attenuation at all.

Formula 1.a

For the input voltage, according to Ohms law the following is true:

$$V_{inp} = i * R_{total} = i * \sum_{a=1}^{11} R_{attn}(a)$$

For the output voltage at the wiper of the switch the following formula is true with the wiper in position pos between 1 and 11

$$V_{out} = i * R_{pos} = i * \sum_{b=pos}^{11} R_{attn}(b)$$

The gain of the attenuator switch for non inverted topology is defined as:

$$Attn_{pos} = \frac{V_{out}}{V_{inp}} = \frac{\sum_{b=pos}^{11} R_{attn}(b)}{\sum_{a=1}^{11} R_{attn}(a)}$$

Well, the above formulas allow you to calculate the resulting dB attenuation on every position given that you know all resistor values already. And of-course this is where the problem is, since we would like to work the other way around: First determine the number of steps, the maximum attenuation in dB and the input impedance of the circuit and then calculate the corresponding resistor values.

Because this requires more than just a few calculations I wrote an Excel file that does just this and is easy to use. The following table contains example output from the spreadsheet for some typical impedance values.

Attenuator	Attn dB	Resistor	10k	20k	50k	100k
Step 1 (lo)	-60	R1	10	20	51	100
Step 2	-54	R2	10	20	51	100
Step 3	-48	R3	20	40	100	200
Step 4	-42	R4	40	81	200	390
Step 5	-36	R5	81	160	390	820
Step 6	-30	R6	160	330	820	1,600
Step 7	-24	R7	300	620	1,600	3,000
Step 8	-18	R8	620	1,300	3,000	6,200
Step 9	-12	R9	1,300	2,400	6,200	13,000
Step 10	-8	R10	1,500	3,000	7,500	15,000
Step 11	-4	R11	2,400	4,700	12,000	24,000
Step 12 (hi)	0	R12	3,600	7,500	18,000	36,000
		TTL:	**10,041**	**20,171**	**49,912**	**100,410**

2.3 A series attenuator with ground resistor

Figure 2.3.1: Voltage Divider with ground resistor

As described above in the architecture overview there are amplifier designs where apart from the attenuator there will be another resistor parallel to ground. This resistor is normally connected between the amp input and ground. the capacitor is there to assure that there will be no DC offset voltage at the speaker output.

On the right the principle is found in a figure where I modelled the amplifier with a power opamp (as used in gainclones) and the attenuator with the Ra and Rb resistors in the ellipse. And for the sake of this exercise we assume that the value of the capacitor is such that the lowest frequencies in audio land are passed through this capacitor (for filter background the reader is referred to the RIAA/filter background pages). The ground resistor ***Rg*** can also be used to make a non-shorting switch more usable for an amp, in this case the capacitor may or may not be present. If the resistor is not present the resistor will probably be soldered directly on the attenuator between the wiper and ground.

on the attenuator between the wiper and ground.

Formula 2.3.1: Series Attenuator with ground resistor

We apply the voltage divider formula keeping in mind that the voltage divider in this case consists of the resistors from wiper to signal input R_a on one site and the sum of all resistors from wiper to ground R_b in parallel with the additional ground resistor R_g as found in the schematic above

Gain A_v is defined as: $A_v = \frac{R_b \| R_g}{R_a + R_b \| R_g}$

$R_b \| R_g = \frac{R_b * R_g}{R_b + R_g}$ and therefore $A_v = \frac{R_b R_g}{R_b R_g + R_a (R_b + R_g)}$

This is the moment to remember that $R_a + R_b = R_i$ where R_i is the desired input impedance of the attenuator. By substitution of $R_i - R_b$ for R_a we get:

$$A_v = \frac{R_b R_g}{-R_b^2 + R_i R_b + R_i R_g}$$

This equation can be rewritten to a classical form

$$-A_v R_b^2 + (A_v R_i - R_g) R_b + A_v R_i R_g = 0$$

and we can resolv R_b by:

$$R_b = \frac{-(\frac{R_g}{A_v} - R_i) + \sqrt{(\frac{R_g}{A_v} - R_i)^2 - 4 R_i R_g}}{2}$$

and R_a in turn can be solved by $R_i - R_b$

Put all these formulas in a spreadsheet and you're done

These formulas are used in the spreadsheet (found on the download page).

2.4 An Inverted Amplifier Design

For inverted designs we must use different resistors values for the same dB steps as in a non-inverted setup. The reason is as follows:

The gain of an inverted design is determined by the feedback resistor and the effective impedance found on the inverted input of the OpAmp. And here lies the source of the problem; The attenuator is in series with this resistor on the inverted input and therefore part of the gain loop as well. Moreover, the output Z of the source device (CD-player, preamp, phono pre) is also in series and plays a role in the gain calculation, especially when using tubes on the input.

Important is to recognize that the attenuator itself still behaves exactly in either setup, and that the effective attenuation measured between input and ouput of the attenuator is independent from the amp architecture chosen. However, in an inverted setup the total attenuation/amplification of the amp is influenced by the attenuator itself and therefore we deal with it in this chapter.

The following figure illustrates the issue described above. Clearly is shown how the input resistor Ri is in series with the effective impedance of the attenuator and the output impedance of the connected source equipment (CD-player or other preamp). The attenuator is modeled with Ra and Rb: On any given position of the wiper, Ra defines the sum of all resistance to signal and Rb the sum of all resistance to ground (R_a + R_b = constant).

Zout V1

figure 2: Gain, defined by feedback over input impedance

In the schematic, I omitted other components such as the input cap, as these were not necessary for an understanding of the issue. The gain of the OpAmp is therefore determined as follows:

Formula 2

Calculating the gain of an inverted amp
According to the two AopAmp rules, the following formulas

$V_{+i}=0$, $V_{-i}=0$ And $i_1=-i_2$ the gain is $\frac{V_o}{V_i} = \frac{i_2 * R_f}{i_1 * R_i} = -\frac{R_f}{R_i}$, thus

$$V_o = -\frac{R_f}{R_i} * V_i$$

The resistance for a voltage devider of two resistors R_a and R_b is defined by: $\frac{R_b}{(R_a+R_b)}$

The effective resistance of two resistors in parallel $R_a \| R_b = \frac{R_a * R_b}{R_a+R_b}$

The above formulas also define the resulting voltage: V_i as a function of V_x:

$$\frac{V_i}{V_x} = \frac{(R_b \| R_i)}{(R_o+R_a+(R_b \| R_i))} = \frac{(R_b * R_i)}{(R_o+R_a)(R_b+R_i)+(R_b * R_i)} = \frac{R_b R_i}{R_o R_b + R_a R_b + R_o R_i + R_a R_i + R_b R_i}$$

With this last formula and the first formula we can now calculate the gain for the total circuit as found in figure 2

$$V_o = -\frac{R_f}{R_i} V_i = -\frac{R_f}{R_i} * \frac{R_b R_i}{R_o R_b + R_a R_b + R_o R_i + R_a R_i + R_b R_i} * V_x$$

With this formula it is also possible to make a spreadsheet for inverted topology that takes into account the attenuator and the gain setting of an inverted opamp.

Therefore the calculation method used for non-inverted designs does not work a 100% for non-inverted designs and that calculating the optimum gain requires even more compute power. Well, let's first see what role each component plays in the equations.

In order to make a rotary attenuator switch for inverted mode amplifiers, we need to find the resistor values for any given attenuation step between two switch positions. After all, it's nice to be able to calculate the attenuation for a given resistor setting, but rather we would like to work the other way around. For example: If I want a gain of -50dB on step 2, what resistor values for R_a and R_b do belong to that setting.

OK, based on this we can calculate the following formulas:

Formula 3

Calculating the resistor values for any given values for R_a and R_b

At position pos the value in dB is X, and the value for $R_a = \sum_{a=pos}^{11} R(a)$

and value for $R_b = \sum_{b=1}^{pos-1} R(b)$ according to figure 2

Then the gain value for a step in dB at position pos is calculated as follows: $A_{pos} = 10^{(gain_{dB}/20)}$

From formula 2 we know that: $V_i = A_{pos} = \frac{R_b * R_i}{(R_0 + R_a)(R_b + R_i) + (R_b R_i)}$

As A_{pos} is a constant just like R_o, R_i and $R_a = R_{total} - R_b$ we can solve R_b

$$A_{pos}(R_o R_b + R_a R_b + R_o R_i + R_a R_i + R_b R_i) - (R_b R_i) = 0$$

$$A_{pos}(R_o R_b + (R_{tot} - R_b) R_b + R_o R_i + (R_{tot} - R_b) R_i + R_b R_i) - (R_b R_i) = 0$$

$$R_b^2 - (R_{tot} + R_o - \frac{R_i}{A_{pos}}) R_b - (R_i R_o + R_{tot} R_i) = 0$$

And this is a clissical square root which we can solve easily

$$R_b = \frac{(R_{tot} + R_o - \frac{R_i}{A_{pos}}) \pm \sqrt{(R_{tot} + R_o - \frac{R_i}{A_{pos}})^2 + 4(R_i R_o + R_{tot} R_i)}}{2}$$

And since $R_a = R_{tot} - R_b$ we can build the resistor values for every position of the attenuator

Therefore I made some calculations with a spreadsheet. Lets assume an inverted design with a feedback resistor of 220k and a resistor R_i on the negative input of 10k. Taking just the two into account we have a gain of 22 times (26 dB). Now take into account the rotary attenuator switch (R_tot = 22kOhms) and lets see how apart from the attenuation itself(!) the effective impedance changes the gain of the amp.

In the figure, we plotted the effective gain for a low-impedance source (e.g. CD-player) of 100 Ohms and a high-impedance source (tube preamp) of 2000 Ohms.

Finally, lets see how the ideal attenuation of just the switch changes in an inverted setup and what the resulting real steps in dB are when taking into account the variation in gain over the range of 12 positions. We do this by taking the gain (in dB) defined by the feedback loop above and add to it the dB attenuation by the 12-step switch.

The chart below shows how for any given attenuator with 12 steps gain in dB the required resistor values are highly dependent on the topology (inverted/non inverted) and the load on the input.

As shown above, if precision is your goal, the resistor values for inverted topologies differ significantly from the non inverted counterpart. The yellow line shows the behavior for non inverted designs, as a reference for how the same attenuator and the same resistor values in the feedback loop produce such different results in an inverted setup.

As to be expected, the gain of a non-inverted amp is dependent on the voltage divider made from R_a and R_b only and not dependent on the serial resistance of R_i and R_o. Therefore it's optimum values are far more linear than for the inverted setup as is shown by the yellow line in the chart above.

2.4b Alternative for Inverted amps

There is of-course several alternatives to the above solution. One would be to use a shunt design: One resistor permanently between input and ground. For the principle: Imagine in figure 2 above that the Rb side of the switch is not connected to ground.

Of course we need different values for the attenuator and therefore let's work out some formulas and maybe a new sheet entry in the spreadsheet.

<formula>

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3. Building Attenuators

Now that we know how to calculate resistor values for a voltage divider, it's time to think about construction of the attenuator itself, the best switch to use, wiring, resistors etc. Below some examples are given for concrete applications.

What switch to use

Series Types

For my own gainclone designs I used cheap Lorlin switches so far. These switches are available from Conrad (Internet) and in shops. The website of Lorlin specifies several types of switches such as 6*2 or 12*1, in both shorting and non-shorting versions, with lugs or pins etc. Unfortunately, the non shorting (break before make) is the most widely used switch and is used for sources and output selection etc. For these applications a shorting version is hardly used and therefore shorting versions are hard to get. As the Lorlin switch is a closed design, it requires no maintenance and is self-cleaning (the inside only).

I found an open shorting switch in the conrad catalog (it is not advertised to be shorting but is definately is a shorting switch) and this one is easily modified to be useful for our application. Standard the switch does not have a stop and can be turned more than 360 degrees. With a very small drill and a bolt it is possible to modify the switch such that it becomes usable for an attenuator.

Anyway, should you be looking for 24-step switches or out-of-the-box shorting switches that are zombie proof etc, then alternative switches are available as well from antique, angela, reichelt etc.

etc. then alternative switches are available as well from antique, angela, reichert etc.

Ladder Types

As shown on the right below there are some cheap alternatives for double deck switches, these will only cost a fraction of what a Dact switch will cost. These are of course 12-step switches and not the 24-step versions. However, for the average gainclone project this may just be good enough to work with.

As said, the Dact 24-step switches are amongst the best available. However, these switches are very expensive. Price differences between single of double deck switches is relatively low, so if you have room enough in your amp I would recommend to go for a double deck of 24 * 2 positions (sometimes incorrectly called stereo).

What Resistors to use

Metalfilm resistors do a better job here than carbon resistors is my experience. I have used Dale, Caddock and several types of metalfilm resistors. BC components (Philips) makes nice ones, but I do not hear much of a difference.

Then there is always the questionwhether carbon or metalfilm resistors provide the best sound in this application. As far as I'm concerned I would metalfilm resistors for an attenuator, but I like a clear and transparent sound. Carbon will make the sound slightly softer and if this is a design goal for you then by all means build your attenuator with carbon resistors. There is probably no good or bad only a matter of taste.

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4. Examples

This section contains examples of attenators. The code in the subheaders refer to the corresponding worksheet in the spreadsheet found on the download page.

12-step series attenuator with shunt

Code	**s12bn**
Descr	**Series 12-step break-before-make non-inverted**
Project	**Geenkloon**

First, lets look at the 12-step switch made for GeenKloon. The first version made for Geenkloon was based on a switch which was non-shorting. This means that between two switch positions the wiper does not make contact with either contact. As a result, for a short moment there is not path from the wiper to either ground or signal in, and therefore the amplifier stage following the switch will see a non-defined impedance. Loud pops will result from your speakers and possibly cause damage.

Needless to say that these switches are not the first choice for building attenuators. But at the time I built Geenkloon I did not have an alternative and therefore I had to find a work-around.

The solution was simple: Connect a fixed resistor from the wiper to ground which will provide a defined impedance for the amp even between switch positions. And it's easy to live with the few drawbacks introduced by this design, the sound quality is very good.

Step	from pin	to pin	Resistors (1/4W,1%)	dB attn	dB step	Impedance
1 (low)	GND	1	wire	infinite	--	19,910
2	1	2	100	-45.98	--	19,910
3	2	3	270	-34.62	11.26	19,904
4	3	4	390	-28.37	6.11	19,885
5	4	5	750	-22.40	5.71	19,813
6	5	6	1,300	-17.01	5.02	19,592
7	6	7	1,100	-14.14	2.61	19,320
8	7	8	1,500	-11.32	2.55	18,842
9	8	9	2,000	-8.59	2.50	18,043
10	9	10	3,000	-5.63	2.85	16,566
11	0	11	3,900	-2.87	3.07	14,270
12 (hi)	11	12	5,600	0.00	4.33	10,451
			19,910		**45.98**	

Unfortunately I did not take the time to do calculations too carefully at the time, although in practise the attenuator works real well. That's the reason why I'll upgrade the geenKloon with an attenuator that is capable of playing less loud at lowest volume settings. Biggest problem being that due to the low value of the parallel resistor the impedance for high-volume setting drops significantly below the 20k. This makes the Geenkloon with this attenuator not really usable for tube sources.

Fortunately this can easily be corrected using another attenuator as described below, trying to get hold of the make-before-break (shorting) version of the Lorlin switch used for Geenkloon.

12-step series attenuator

Code	**s12mn**
Descr	**Series 12-step make-before-break non-inverted**
Impedance	**22k7 (over full range)**

Project Geenkloon upgrade

This attenator will be used as a modification to the first version of the Geenkloon switch. This is really a very cheap 12 position switch that needs a little modification as the switch does not have a stop. It is however a make-before-break (shorting) switch and thus it's worth a little work in order to get a really cheap fnished product.

I described the modifaction process in some detail below for the double deck switch of the same manufacturer. It is a simple process, drill a small hole through one of the little dimples in the top plate and use a little bolt and fix it in the hole. The bolt needs to stick at least 1.5 mm through the hole on the innner side in order to provide a "stop" for the rotary switch mechanism inside.

Now you can solder the little resistors (1% types of 0.25W, matched per pair) on the small terminals. By using a layout at the outside of the swicth it's possible to make a quite elegant attenuator that can stand some mechanical use without intentional shorting once in a while.

Step	from pin	to pin	Resistors	dB attn	dB step	Impedance
1 (low)	GND	1	47	-53.69	--	22,729
2	1	2	82	-44.92	8.77	22,729
3	2	3	150	-38.22	6.70	22,729
4	3	4	330	-31.44	6.78	22,729
5	4	5	470	-26.47	4.97	22,729
6	5	6	820	-21.56	4.91	22,729
7	6	7	1,430	-16.69	4.88	22,729
8	7	8	2,400	-11.97	4.72	22,729
9	8	9	2,200	-9.15	2.82	22,729
10	9	10	3,300	-6.12	3.02	22,729
11	0	11	4,700	-3.09	3.04	22,729
12 (hi)	11	12	6,800	0.00	3.09	22,729
			22,729		**54.00**	

And after surgery of Geenkloon, the finished attenuator section looks like this:

The only drawback I can think of of this switch is it's open construction. But on the other hand with a little cleaning or eve better, regular use of the Geenkloon I do not anticipate any cracking or so. After all, I use small boxes for the clone without openings so dust and dirt will stay out under normal circumstances.

12-step series for Inverted Amps

Code	**s12bi**
Descr	**Series 12-step break-before-make inverted**
Project	**Cyclone**

The Cyclone project is an inverted amplifier. And therefore, the switch is part of the feedback loop of the inverted amp and the impedance will influence the gain (as does the voltage divider also).

How to use a non-shorting (break before make) switch in your amp? What I did is add a parallel resistor from the wiper which connects to the chip input, to ground. That parallel resistor will make sure that between the positions of the attenuator the input of the amplifier is in a defined state. For a 20K input impedance, a value of 47k or 100k would be nice, for a 50k attenuator I would use a 100k resistor. In general, use a resistor value at least 2 times the desired input impedance.

Important with the table below is to know that i used a parallel resistor of 47k and assumed an output resistance of the source device on the signal input of 100 Ohms, an input resistor of 10k and a feedback resistor of 220k for the inverted amp.

Step	from pin	to pin	Resistors	dB attn	dB step	Impedance
1 (low)	GND	1	82	-49.35	5.94	23,724
2	1	2	82	-43.41	5.49	23,723
3	2	3	150	-37.92	5.92	23,722
4	3	4	330	-32.00	5.67	23,715
5	4	5	680	-26.33	4.73	23.688
6	5	6	1,200	-21.60	3.98	23.595
7	6	7	2,000	-17.62	2.83	23,327

8	7	8	2,400	-14.79	2.57	22.835
9	8	9	3,000	-12.23	2.57	21,994
10	9	10	3,900	-9.36	2.87	20,582
11	0	11	4,700	-5.71	3.65	18,487
12 (hi)	11	12	5,200	-0.14	5.57	15,766
					49.35	

As you can see, the resulting impedance as seen by the source device (CDplayer) is not constant but is between 15k8 and 23k7. But it stays above the 22k for most of it's range and in practise this is not a show-stopper.

Building a 12-step ladder Switch

Code	**l12bn**
Descr	**Ladder 12-step break-before-make non-inverted, or a make-before-break type with grounding resistor on the opamp input.**
Impedance	**50k Ohms**
Project	**tbd, would fit Gainclone and Cyclone**

For a ladder switch one needs a rotary switch with 2 decks. The wipers of both decks are connected with each other and with the input of the amp. For each of the 2 decks, the resistors are connected on 1 side with the switch contacts and are connected with each other and either ground or signal input on the other side.

The switch above and the one the right is a 12*2 switch. Although it's an open construction, which means cleaning once in a while in order to avoid corrosion or dirty contacts, it's build quality is excellent. And if you, like me, use the switch in an amp enclosure which is more or less air tight, corrosion will not play a large role anyway.

Figure e4: example ladder type with shunt

Only problem: Out of the box the switch does not have a stop (it's possible to turn it 360 degrees). But there is a work-around, and it's possible to fix the stop. Drill a small hole through one of the 12 marks/dimples in the top plate. Then us a little m1 bolt and screw it into place. Done. For just € 3.00 you made yourself a 2*12 switch that can be used to make a ladder attenuator.

see screw in top plate

Of course the switch can also be used to build a stereo version of a series attenuator, bit apart from the easy of use the technical construction is not different from the mono series attenuator described on this page and therefore not discussed further in this section.

However, in order to be protected even when the switch would degrade over time and would not be shorting in every position, I used a parallel resistor just in case. And unlike the series attenuator, for a ladder attenuator the parallel resistor does not cause the input impedance to vary over its range as long as you take its' value into account for every resistor pair on the ladder.

Look in the spreadsheet for examples of 50K attenuators (or any impedance value you choose yourself), the spreadsheet takes the optional parallel/shunt resistor into account and computes a ladder attenuator with 12 positions.

In this case I used a 100k parallel resistor which is effectively always in parallel with the resistor 2 in the table. Therefore, the voltage divider consists of the following resistors: Resistor 1 to signal in and the two Resistors 2 and the parallel resistor to ground.

Step	from pin	to pin	Resistor 1	Resistor 2	dB attn	dB step	Impedance
1 (low)	GND	1	49,900	47	-60.53	--	49,947