Design and Construction of a Quality Stepped Attenuator.

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Following the recent successful upgrades to various resistors and capacitors in my WAD K5881 Mk II power amp and WAD Series II Modular Pre-Amp, I decided to turn my attention to the volume control. Although there is a quality Alps Blue supplied with the Series II kit, a friend of mind achieved significant improvement by replacing the Alps Blue in his KLPP1 pre-amp with a stepped attenuator.

An off-the-shelf stepped attenuator costs around £150 for a stereo version. However, spurred on by Richard White's article on budget stepped attenuator design (Hi-Fi World Supplement: December 1998), I felt that it would be possible to build an attenuator comparable in quality to a commercially available unit, but at a somewhat lower cost.

The first step along the track was to locate a supplier of a suitable switch. Although 12-way switches are readily available, the 24-way switch necessary for a quality unit was somewhat harder to find. After an extensive search, I found one UK based supplier who could provide a 23-way, 2 pole, make-before-break (or 'shorting') rotary wafer switch with end stop for just over £55. This constitutes the bulk of the cost as decent quality metal film resistors cost 7p +VAT from Maplin, so the cost of the finished unit will still be less than half the cost of a commercial product.

The next stage was to calculate the value of the resistors for each step. In Mr. White's original article, he stated that the attenuation for a given pair of resistors comprising the potential divider (Figure 1) could be calculated from:

$$A = -20 \times Log\left(\frac{Ry}{Rx + Ry}\right)$$

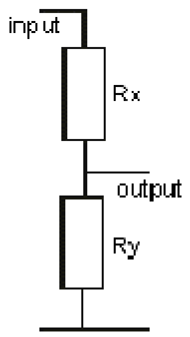

Figure 1. The Potential Divider

where Rx + Ry is the total value of the equivalent potentiometer, Ry is the sum of all the resistors in the chain to give the attenuation at a given point and Rx is the remainder of the resistor chain. What we actually want to calculate is the value of each individual resistor in the chain to give us the range of attenuations required. Rearranging the above equation, we get:

$$Ry = Rt \times 10^{\left(\frac{-A}{20}\right)}$$

where Rt is the total value of the attenuator (Rx + Ry) and A is the attenuation in dB required at a given step. For the Series II pre-amp, a total value Rt of 100KΩ is required. You, of course, may require a different value to suit your amplifier. At this point, I decided that it would be worth writing a simple program to allow the calculation of each resistor for a given value of Rt, number of steps and required attenuation at each step. I did this in Javascript so it could be published on the Web and it can be found on my Web site at http://homepages.tcp.co.uk/~nroberts/atten.html.

To use the program, change the ‘total value of attenuator’, ‘number of steps’ and ‘attenuation required for each step’ to the required values, then click the ‘Calculate Resistor Values’ button. The program suggests some default values for a 24-step, 100KΩ attenuator. Obviously, you will have to select the nearest ‘preferred value’ for each step. The exact value is not critical, but if you wish to see the exact attenuation you will get for a given Ry, there is another calculation area at the bottom of the screen that does this. If you are particularly fussy (like me!) you can use this to re-calculate the attenuation for each step using preferred values and build up the entire table with preferred values and the exact attenuation at each step. Incidentally, you can save the Web page locally and run it from your hard disk so you don’t need to be on-line while you are experimenting with the program.

For my 23-way switch, I calculated the approximate attenuation and resistor values shown in the following table:

Step	Attenuation (dB)	Resistor (W)
1	∞	0
2	75	18
3	69	18
4	63	36
5	58	56
6	53	100
7	48	180
8	43	300
9	39	430
10	35	620
11	31	1K1
12	27	1K6
13	23	2K4
14	20	3K3
15	17	3K9
16	14	5K1
17	12	5K6
18	10	6K2
19	8	8K2
20	6	11K
21	4	13K
22	2	16K
23	0	20K
	Total value:	**99.2K**W

It is a good idea to check before wiring up the switch that you don’t need to drill any additional holes in the front panel. In my case, I had to drill a hole to accommodate the locating pin to the side of the spindle as this was in a different position from that in the Alps Blue. It is easier to do any mechanical adjustments before wiring up the resistors.

Wiring up the switch (Figure 2) is quite a fiddly affair, but it is worth taking the time to do it neatly. Make sure you have the following available before starting:

- Two sets of all the resistors (one for each channel) appropriately labelled and laid out in order (those coloured bands start to look all the same after a while!);
- Soldering iron, cutters and pliers;
- A couple of spare hours;
- A large gin and tonic!

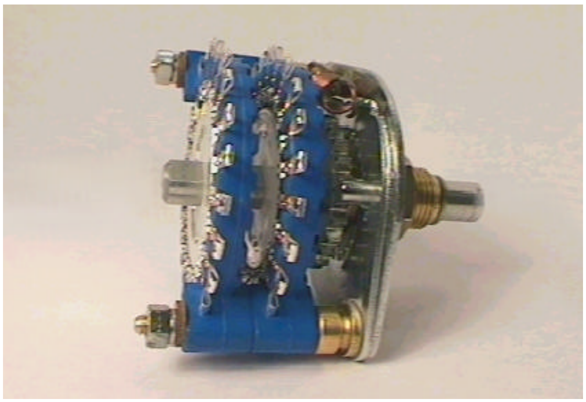

Figure 2. The switch

Remember that the switch is, in all probability, somewhat larger that the potentiometer it is replacing so it is worth getting the resistors to lie as flat as possible. When you have finished, you will have an assembly similar to that shown in Figure 3.

Before fitting the unit permanently in place, I wired up a temporary arrangement with the attenuator feeding into the existing volume control via one of the inputs. I was then able to switch between the attenuator and the volume control by turning the attenuator to maximum and using the volume control, and vice versa. As it turned out, this was very worthwhile as I discovered that my first step was too loud for a minimum setting. I originally had the first step at 60dB attenuation, but this was not enough for my preference. Incidentally, my loudspeakers (Chris Rogers' PRO9-TL transmission lines) are not very sensitive so the effect would have been worse with more sensitive speakers. After some experimenting, I decided on 75dB and so returned to my program to re-calculate all the other resistor values for a new range of attenuations shown in the above table. This necessitated replacement of about half of the resistors. My solder-sucker came in very handy at this point! All that then remained was to install the attenuator permanently in my amplifier.

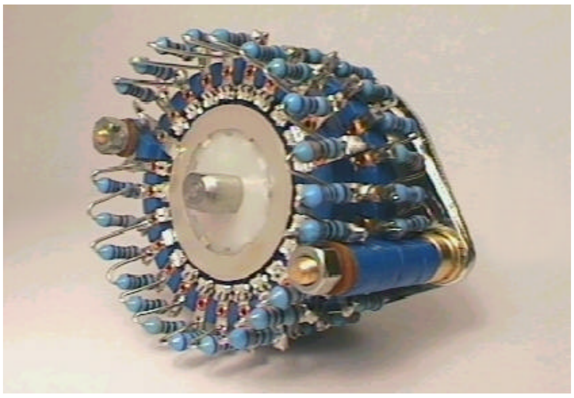

Figure 3. The finished unit

Well, was it worth it? Well, yes, definitely. The sound was noticeably more detailed and the sound sources more accurately placed between (and indeed, behind) the speakers. If anything, the sound was slightly brighter than with the Alps Blue. This was not surprising as metal film resistors typically have a bright sound. There was certainly greater clarity to the sound with individual instruments within an orchestra being more clearly identifiable.

Finally, it is worth mentioning that, apart from saving money and the satisfaction of having built an attenuator yourself, another advantage of the do-it-yourself approach is that it allows for experimentation. Not only can you change the attenuation of any step to suit personal preferences, but also use different qualities of resistors in the chain, although I haven't experimented with that yet. Maybe I can add a list of Shinkoh resistors to my next year's Christmas present list!

A 23-way, 2 pole, shorting switch (part number OPZ51201-2) can be obtained from:

Blore Edwards Limited,
Pontcynon Trading Estate,
Abercynon,
Mid Glamorgan,
South Wales. CF45 4EP
Tel: 01443 742202