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A3

Stereo Stepped Attenuator

USER GUIDE

05/03/2011

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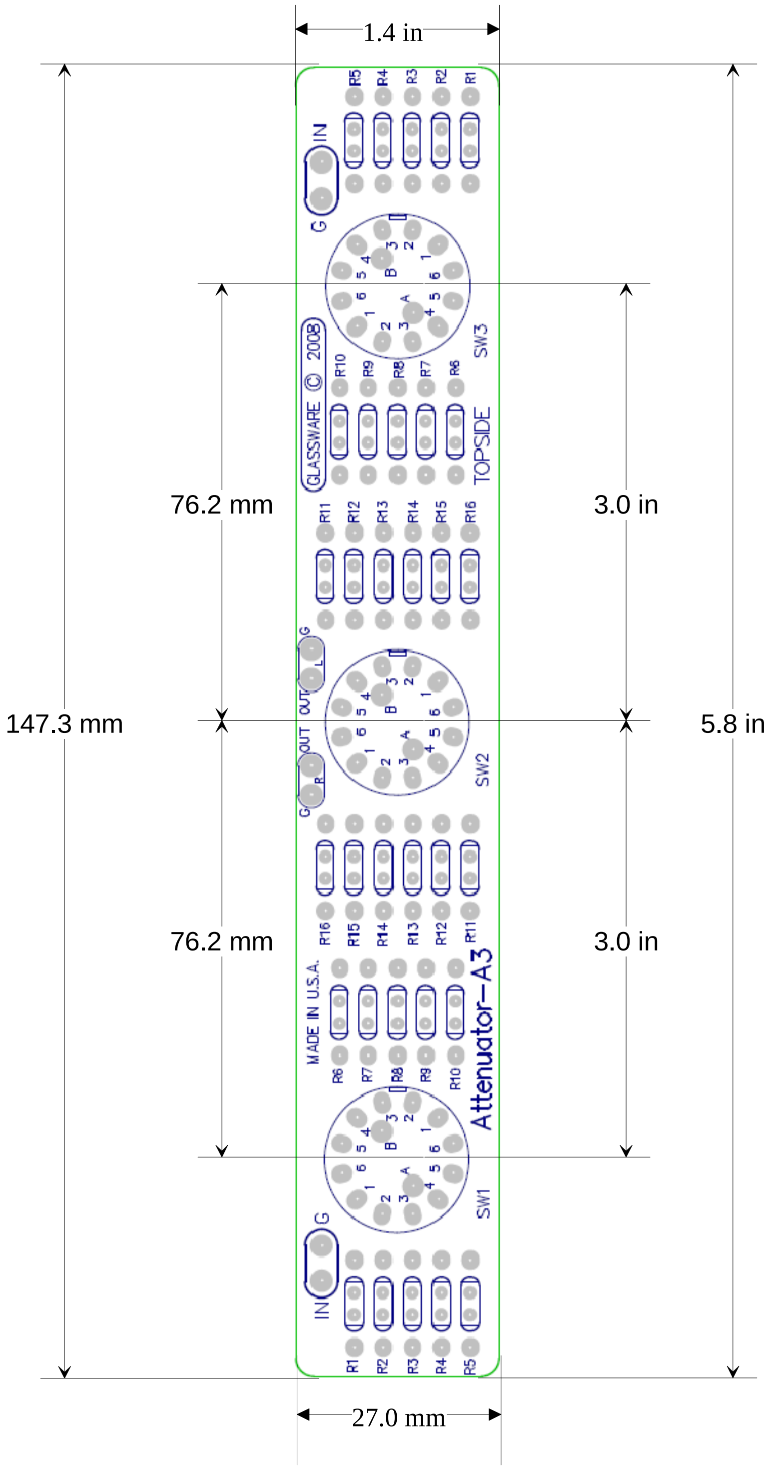


GlassWare Audio Design

Why Use A Stepped Attenuator?

The stepped attenuator is an attempt to overcome the liabilities of the conventional potentiometer-based volume control. Even the best potentiometer compromises the quality of the signal that flows through it. The thin film of resistive paint and metal scraper that make up the average potentiometer seem to damage the signal almost as much as they attenuate it. Furthermore, finding a stereo potentiometer that follows a logarithmic taper and that can track from one channel to the other is tough. With the stepped attenuator, on the other hand, high-quality fixed resistors replace the thin resistive track and, likewise, high quality switch contacts replace the metal scraper. Because tight-tolerance resistors are readily available, there is no problem in following the logarithmic taper accurately and consistently.

A3 Stereo Stepped Attenuator

The kit includes three shorting rotary switches (2-pol/6-pos) and one USA-made extra-thick (0.94"), high-quality PCB, with 2oz copper traces and two side solder mask and silkscreen. The kits are sold without resistors, so you, the purchaser, can use your favorite. In addition, packs of all the needed resistors are also for sale, in both metal-film and carbon-film, at the GlassWare Yahoo Store:

http://glass-ware.stores.yahoo.net/

The A3 PCB is 1.4 inches (36mm) tall and 9 inch (147mm) long and will fit within a 1U rack-mount enclosure. Each resistor position on the PCB holds a redundant set of pads, so that either radial resistors, such as bulk-foil resistors, and axial resistors can be used. The spacing between switches is 3 inches (76.2mm) and the switches themselves hold the attenuator assembly to the front panel. The A3 stereo attenuator presents a constant load resistance to the signal source and can be optimized for either active or passive line stage use.

This cleverly designed stepped attenuator exploits both the series-attenuator and the ladder-attenuator stepped-attenuator configurations to yield the best compromise between flexibility, performance, and cost. The A3 attenuator uses three rotary switches and 32 resistors to yield a total of 36 positions of attenuation in -1dB or -2dB and -6dB or -12dB decrements. Had the attenuator been entirely of a series design, the attenuator would require 36-position rotary switch and 72 resistors; a purely ladder design, a two-deck, 2-pol, 66-position rotary switch and 140 resistors. In contrast, the A3 attenuator, from 0 to -5dB steps of attenuation, is solely a ladder attenuator, with no more than two resistors in the signal path; thereafter, the attenuator uses both a ladder and series configurations, with never more than 7 resistors in the signal path.

Passive Line Stages and the A3 Stepped Attenuator

Passive line-stages are popular, which proves that extra signal gain isn't always required. Yet passive line stages often prove inadequate, proving incapable of driving high-capacitance cables or low-input impedances. The culprit is often found to be too high an attenuator input resistance. The 100k that worked well with an active line stage amplifier, chokes a passive line stage, as the worst-case output resistance is grimly-high 25k. Additionally, even when the interconnect is short and of the low-capacitance type, the power amplifier's input impedance can be so low as to throw the pass line stage's attenuation scheme off track. For example, a 100k attenuator working into an amplifier with an input impedance of 22k does not work as advertised, because the amplifier's low input resistance will drag down the 100k attenuator, throwing al the calibrated steps off; for example, the -2dB position will actually equal -6dB.

The solution is to use an attenuator with a lower at input resistance. A good compromise resistance is 20k, which is good for sonic presentation, as the worst-case output impedance is at -6dB of attenuation. At this position, the 20k input resistance presents just 5k of output impedance to capacitance-laden interconnect or 47k input impedance. If the power amplifier's input impedance is much lower than 47k, say 10k or, even 2k, as is encountered with certain Zen amplifier configurations, then 20k will be too high a value; in fact, it is doubtful that any passive line stage setup will work well.

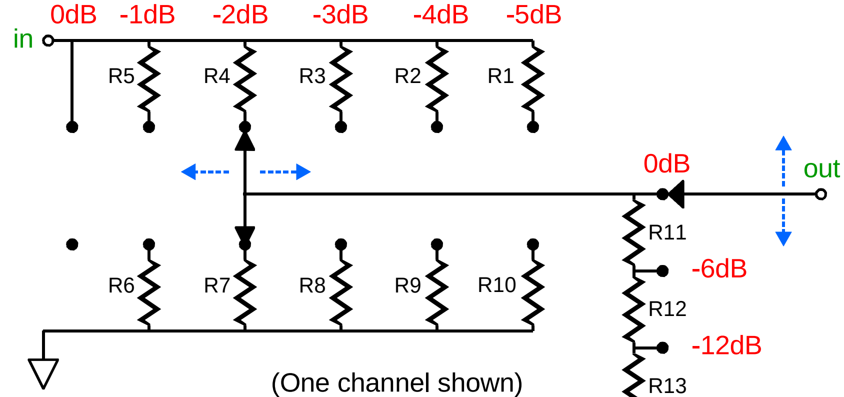
Active Line Stages & A3 Stereo Stepped Attenuator

This mono attenuator works handsomely in a dual-mono or stereo (two M1s will be needed) line stage amplifier. The only decision is which input resistance to use. In general, lower is better. A 50k-input resistance will present a worst-case 12.5k to the input of the line stage amplifier; thus, greatly sidestepping much of the baneful consequences of the Miller-effect capacitance. The downside is that some old tube gear (or poorly designed new tube gear) may balk at trying to drive the 50k input impedance of the attenuator. Most CD players and stand-alone DACs, however, can easily deliver a healthy 2V to 3V of output voltage into even a low-resistance 10k load, which helps to explain why passive line stages are so popular. On the other hand, if an old piece of tube gear expects to see a 250k or 500k load, then you better give it what it wants. For example, an old tube tuner that gave a low-frequency response down to 20Hz with a 500k load, will only go down to 500Hz with a 20k load. The formula is

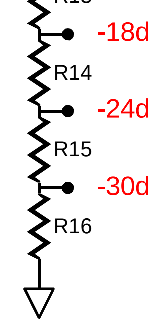
Low-Frequency Cutoff = 159155/C/R,

where the capacitance is in microfarads. For example, a 0.22µF coupling capacitor working into a 50k input resistance equals a -3dB frequency of 14.5Hz.

On pages 4 & 5 are tables of resistor values (both the E96 and E24 series of resistor values are listed) for the A3 attenuator that range from 600-ohms to 500k.



(One channel shown)



A3 Stereo Stepped Attenuator

What is a GlassWare A3 stereo stepped attenuator? The A3 stepped attenuator combines both series and ladder stepped attenuators into a single functional attenuator. The ladder attenuator's job is to provide six fine steps of attenuation, each step being -1dB; the series attenuator, eleven coarse steps of attenuation, each step being -6dB. The result is that 66 attenuation settings are possible. In other words, we can set the attenuation to any value from 0dB to -65dB in -1dB decrements. The genius of the design is that it only requires two inexpensive rotary switches, instead of one 66-position, insanely expensive rotary switch, assuming that a 66-position rotary switch is even made. In Addition, the GlassWare A3 stereo stepped attenuator only uses 21 resistors, not the 66 resistors that a series attenuator would require or the 130 resistors demanded by the ladder attenuator.

The ladder attenuator portion of the A3 takes account of its series attenuator's load impedance, so the A3 attenuator always presents a fixed load impedance to the signal source. The A3 attenuator's output impedance varies with the amount of attenuation, just as it does with a conventional volume control potentiometer.

Because the A3 stereo stepped attenuator holds a fine-decrement attenuator for each channel, the A3 stereo attenuator effectively creates a balance control, as each channel can be tweaked in 1dB or 2dB steps to restore balance. The best procedure is to leave the flanking fine volume controls set in the middle of its rotation; then adjust the coarse/stereo volume control to the closest appropriate volume setting, leaving the fine volume controls to make the fine adjustments.

-2dB Fine & -12dB Coarse Decrements

	Total Input Resistance E96 1% Values								
	600	10k	20k	25k	50k	75k	100k	250k	500k
R1	412	6.81k	13.7k	16.9k	34k	51.1k	68.1k	169k	340k
R2	360	6.04k	12k	15k	30.1k	45.3k	60.4k	150k	301k
R3	300	4.99k	10k	12.4k	24.9k	37.4k	49.9k	124k	249k
R4	220	3.65k	7.32k	9.31k	18.7k	27.4k	36.5k	93.1k	187k
R5	124	2.05k	4.12k	5.11k	10.2k	15.4k	20.5k	51.1k	1M
R6	2.32k	39k	78.7k	97.6k	192k	287k	390k	976k	2.2M
R7	1.02k	16.9k	34k	43k	84.5k	127k	169k	430k	845k
R8	604	10k	20k	24.9k	49.9k	75k	100k	249k	499k
R9	402	6.65k	13.3k	16.5k	33k	49.9k	66.5k	165k	330k
R10	280	4.64k	9.31k	11.5k	23.2k	34.8k	46.4k	115k	232k
R11	453	7.5k	15k	18.7k	37.4k	56.2k	75k	187k	374k
R12	113	1.87k	3.74k	4.7k	9.53k	14k	18.7k	47k	95.3k
R13	28	470	953	1.18k	2.37k	3.57k	4.7k	11.8k	23.7k
R14	7.1*	120	237	294	590	887	1.2k	2.94k	5.9k
R15	1.8*	30	59	75	150	226	300	750	1.5k
R16	0.6*	10	20	24.9	49.9	75	100	249	499

* Resistor value falls below E96 bottom limit

	Total Input Resistance E24 5% Values								
	600	10k	20k	25k	50k	75k	100k	250k	500k
R1	390	6.8k	13k	18k	33k	51k	68k	180k	330k
R2	360	6.2k	12k	15k	30k	47k	62k	150k	300k
R3	300	5.1k	10k	13k	24k	39k	51k	130k	240k
R4	220	3.6k	7.5k	9.1k	18k	27k	36k	91k	180k
R5	120	2k	3.9k	5.1k	10k	15k	20k	51k	100k
R6	2.3k	39k	75k	100k	200k	300k	390k	1M	2M
R7	1k	18k	33k	43k	82k	130k	180k	430k	820k
R8	620	10k	20k	24k	51k	75k	100k	240k	510k
R9	390	6.8k	13k	16k	33k	51k	68k	160k	330k
R10	270	4.7k	9.1k	11k	24k	36k	47k	110k	240k
R11	430	7.5k	15k	18k	36k	56k	75k	180k	360k
R12	110	1.8k	3.9k	4.7k	9.1k	15k	18k	47k	91k
R13	27.0	470	940	1.1k	2.4k	3.6k	4.7k	11k	24k
R14	6.8	120	240	300	560	910	1.2k	3k	5.6k
R15	1.8	30	62	75	150	220	300	750	1.5k
R16	0.5	10	20	24	51	75	100	240	510

Wiring the A3 Stereo Attenuator

The A3 stereo attenuator, unlike a stereo potentiometer, holds eight wire terminal pads: four input and output pads and four ground connection pads. The four ground connections can both prevent and, unfortunately, create ground-loops, when twisted pairs of signal wiring are used, depending on how the rest of the circuit is wired. Ideally, the input signal selector switch will choose between grounds as well as “hot” inputs. In other words, the each input’s ground would be treated as a “hot” input of sorts and at no time would all the grounds connections from different input sources tie together.

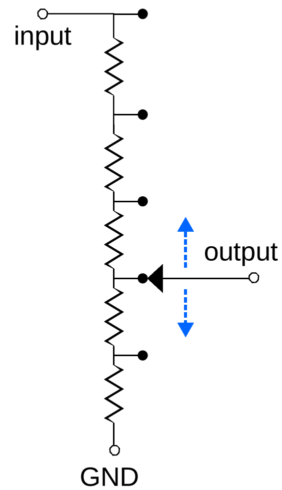
-1dB Fine & -6dB Coarse Decrements

	Total Input Resistance E96 1% Values								
	600	10k	20k	25k	50k	75k	100k	250k	500k
R1	261	4.42k	8.66k	11k	22.1k	33.2k	44.2k	110k	221k
R2	221	3.65k	7.32k	9.31k	18.7k	27.4k	36.5k	93.1k	187k
R3	174	2.94k	5.9k	7.32k	14.7k	22.1k	29.4k	73.2k	147k
R4	124	2.05k	4.12k	5.11k	10.2k	15.4k	20.5k	51.1k	102.k
R5	64.9	1.07k	2.15k	2.7k	5.49k	8.2k	10.7k	27k	54.9k
R6	4.99k	82.k	165k	205k	412k	619k	825k	2.2M	412k
R7	2.32k	38.3k	80.6k	97.6k	191k	287k	383k	976k	2.2M
R8	1.47k	24.3k	48.7k	60.4k	121k	182k	243k	604k	1M
R9	1.02k	16.9k	34k	42.2k	84.5k	12.7k	169k	422k	845k
R10	768	12.7k	24.9k	32.4k	64.9k	95.3k	127k	324k	649k
R11	294	4.99k	10k	12.4k	24.9k	37.4k	49.9k	124k	249k
R12	150	2.49k	4.99k	6.19k	12.4k	18.7k	24.9k	61.9k	124k
R13	75	1.24k	2.49k	3.16k	6.34k	9.31k	12.4k	31.6k	63.4k
R14	37.4	634	1.24k	1.58k	3.16k	47.5k	6.34k	15.8k	31.6k
R15	18.2	316	620	787	1.58k	2.37k	3.16k	7.87k	15.8k
R16	18.2	316	620	787	1.58k	2.37k	3.16k	7.87k	15.8k

	Total Input Resistance E24 5% Values								
	600	10k	20k	25k	50k	75k	100k	250k	500k
R1	270	4.3k	8.2k	11k	22k	33k	43k	110k	220k
R2	220	3.6k	7.5k	9.1k	18k	27k	36k	91k	180k
R3	180	3k	5.6k	7.5k	15k	22k	30k	75k	150k
R4	120	2k	4.3k	5.1k	10k	15k	20k	51k	100k
R5	68	1k	2.2k	2.7k	5.6k	8.2k	10k	27k	56k
R6	5.1k	82k	180k	200k	390k	620k	820k	2M	3.9M
R7	2.4k	39k	82k	100k	200k	300k	390k	1M	2M
R8	1.5k	24k	47k	62k	120k	180k	240k	620k	1.2M
R9	1k	18k	33k	43k	82k	130k	180k	430k	820k
R10	750	13k	24k	33k	62k	100k	130k	330k	620k
R11	300	5.1k	10k	13k	24k	36k	51k	130k	240k
R12	150	2.4k	5.1k	6.2k	12k	18k	24k	62k	120k
R13	75	1.3k	2.4k	3k	6.2k	9.1k	13k	30k	62k
R14	39	620	1.2k	1.5k	3k	4.7k	6.2k	15k	30k
R15	20	300	620	750	1.5k	2.4k	3k	7.5k	15k
R16	20	300	620	750	1.5k	2.4k	3k	7.5k	15k

On the other hand, if the all the input signal RCA input jacks are grounded and if the selector switch only switches between signal hots, then the better route is to only attach ground one connection per channel on the A3 PCB to the central ground point of the line-stage amplifier. (A grounded shield or a twisted pair of wires can still be used to relay the selector switch's output signal to the A3 PCB, just ground the shield at the attenuator’s input and float the other end at the selector switch (the same holds true for a twisted pair of output signal wires to the line-stage amplifier).

What is a Series Attenuator?

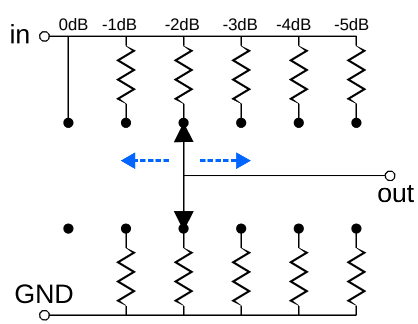


The closest analogy to the series attenuator is a normal audio-tapper potentiometer used as a volume control in 99.99% of audio gear. It consists of a rotary switch that holds many differently-valued resistors placed in series, creating a long chain of resistors, with each resistor connection attached to a switch contact. The rotary switch's moving contact then selects between resistor connections, thus providing a selectable amount of fixed signal attenuation. The chain of many fixed resistors wired in series defines the total input resistance of the attenuator. This is simple enough, but not without some problems. Where the conventional potentiometer has only three solder joints, these stepped attenuators have as many solder joints as there are steps (+1).

Thus, we have swapped a little conductive paint for a lot of lead-tin. In addition, if one of the resistors is sonically poor sounding it will always make itself heard as all the resistors see all of the signal current, since they are all in series. (Remember the childhood game of passing a secret from one child to another until the secret returns to the author in a completely unrecognizable form.) In other words, the series attenuator works best when it doesn't hold too many steps. How many is too many? As with all things analog, there is no specific answer, yet we can absolutely know that each additional step will add some miniscule sonic degradation to the signal.

What is a Ladder Attenuator?

Perhaps you have seen the small fixed attenuator plugs that hold one male RCA plug and one female RCA jack and two fixed resistors inside a small barrel; these fixed attenuators are useful when bi-ampping and one of the amplifiers offers too much voltage gain. Now, imagine an array of these fixed attenuators and some means of selectively swapping the right one in place. In other words, the ladder improves upon the series attenuator by setting up an array of many two-resistor voltage dividers and the means to switch to the desired pair.



Now we are back to just three solder joints and just two resistors in the signal path—but at the cost of twice the switch contacts and twice the resistors used. This is the no-compromise approach to stepped attenuator design. The downside to this attenuator topology is that twice as many resistors (-2) and switch poles are needed. In other words, a comparable series attenuator will cost roughly half as much as the equivalent ladder attenuator.

Assembly

The attenuator's resistors can be mounted either side (or on both sides) of the A3 PCB; the rotary switches mount only on the side marked "Switch Side." Each resistor finds its own white silk-screened oval placeholder on both side of the PCB. Before soldering, be sure to clean both sides the PCB with 90% to 99% isopropyl alcohol. In addition, do not use dull-looking solder; solder should shine. If it doesn't, first clean away the outer oxidation with some steel wool or a copper scouring pad. If the resistor leads look in the least gray, clean away the oxidation with either steel wool or a wire sniper's sharp edges. Admittedly, with new resistors and a fresh PCB such metal dulling is rare, but if the parts have sat in your closet for a year or two, then expect a good amount of oxidation to have developed.

First, solder all the resistors in place, and then solder the switches. Be consistent in orienting the resistors; keep all the tolerance bands on the resistor's body at the right side as you face the resistor straight on. This will pay dividends later, if you have soldered a few resistor in the wrong locations. Solder the resistors in sequence; for example, R1, R2, R3, R4, R5…Because the board is double sided, traces and pads on each side, it is easier to solder the resistors from their top side. (The board can then be flipped over and each resistor can be soldered again from the other side without fear of the resistor slipping out of position.) Try placing the PCB between two blocks of wood or two books tall enough to let the resistors fall into place. If fat resistors are used, they can be placed on both sides of the PCB. For example, all even numbered resistors on the switch side and all odd numbered resistors on the PCB's top side. Clip the resistor's leads before soldering the next in sequence, as the tight array of resistors make it difficult to trim the leads away when all the resistors are soldered place.

Before soldering in the switches, be sure that the resistors all in their correct location. Because the PCB is so overbuilt, it is extremely difficult to remove an incorrectly placed resistor (and it is almost impossible to remove a rotary switch). Think twice, solder once. The goal is to solder the rotary switches in place with the switch's shaft being perfectly perpendicular to the PCB. Try using a large spool of thread or wire on end, so the shaft can rest inside the hole. Then push the PCB firmly against the switch's PC pins; solder only two opposing pins in place. Then review the geometry. If the switch is not seated perfectly, corrections can be easily made, whereas if all the pins are soldered place, it will be almost impossible to set thing straight. So, solder twice, evaluate, solder again.