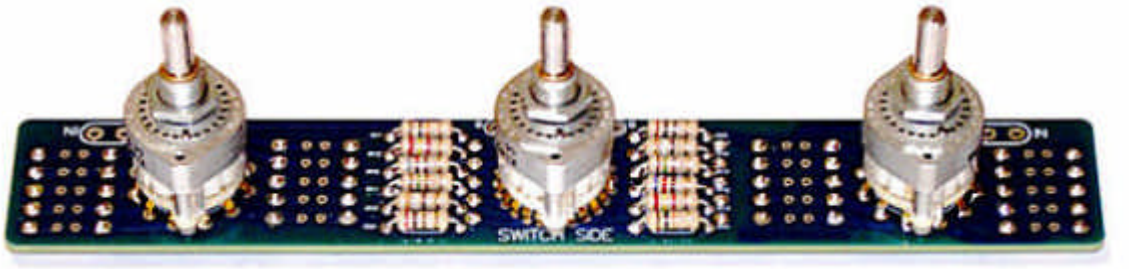
TCJ

Stepped Attenuator

USER GUIDE

02/16/2008

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.

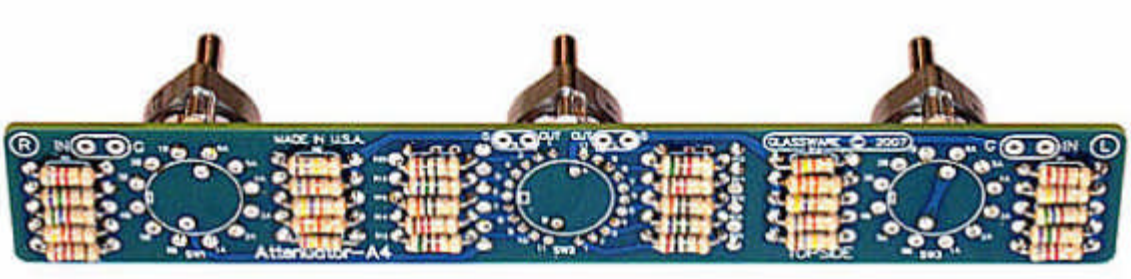
The TCJ Stepped Attenuator Kit

The kit includes user guide and three high-quality, Swiss-made, gold-heavy (3µm), precisely-designed and exquisitely-made, Elma rotary switches (two 2-Pol/6-Pos and one 2-Pol/11-Pos), and one USA-made extra-thick, high-quality PCB, with 2oz copper and solder mask and silkscreen. The kits are sold without resistors, so you, the purchaser, can use your favorite. But 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/

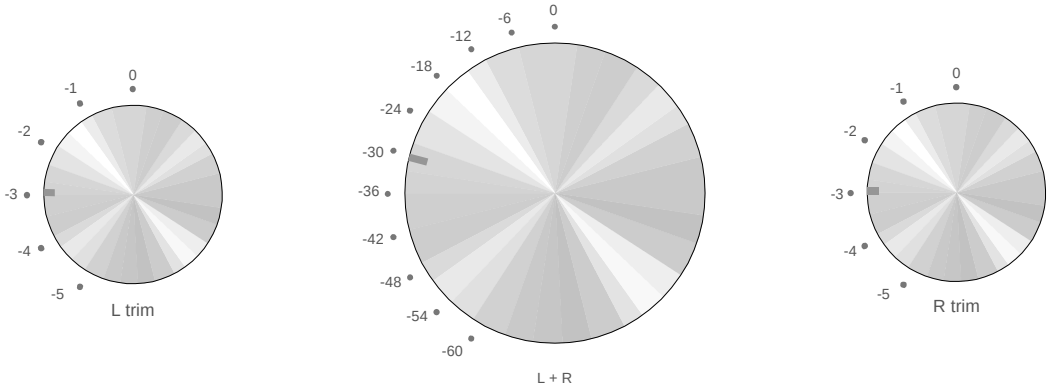
The PCB is 1.4 inches (36mm) tall and 9 inches (228mm) long and will fit within a 1U rack-mount enclosure. Each resistor position holds a redundant set of pads, so that either radial resistors, such as bulk-foil resistors, and axial resistors can be used. The spacing between switches is 3 inches (76.2mm) and the switches themselves hold the attenuator assembly to the front panel.

The TCJ 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 attenuator exploits both the series-attenuator and the ladder-attenuator configurations to yield the best compromise between flexibility, performance, and cost. The attenuator uses three rotary switches and 42 resistors to yield a total of 66 positions of attenuation in -1dB decrements. Had the attenuator been entirely of a series design, the attenuator would require a two-deck, 66-position rotary switch and 132 resistors; a purely ladder design, a four-deck, 66-position rotary switch and 260 resistors. In contrast, the TCJ attenuator, from 0 to -5dB steps of attenuation, is solely a ladder attenuator, with only the two flanking switches in play and with no more than two resistors in the signal path; thereafter, the attenuator uses both a ladder and series configurations, with never more than 12 resistors in the signal path.



Implicit Balance Control

The TCJ attenuator holds its own balance control of sorts. The center rotary switch controls the volume for both channels at the same time, and offers 11 coarse -6dB decrements; the flanking knobs offer 6 fine -1dB decrements for each channel, creating a volume control and balance control in one easy-to-use stepped attenuator. In other words, all three switches should be used to set the desired sound level. Far too many imagine that the flanking ladder stepped attenuators are only to be used when the source material is out of balance. Use all the rotary switches to set the volume, just as you would use both the coarse and fine focus adjusters on a microscope.



The best way to use the TCJ attenuator is to set the flanking ladder attenuators to their mid positions and then adjust the center series attenuator until the sound is almost at the right volume, then move the flanking switches up and down until the perfect sound level is achieved.

Passive Line Stages and the TCJ 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 found in using 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 the capacitance-laden interconnect or 47k amplifier 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 and the TCJ Stepped Attenuator

The TCJ attenuator works handsomely in a line stage amplifier. The only decision to be made 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 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/Capacitance/Resistance, 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.

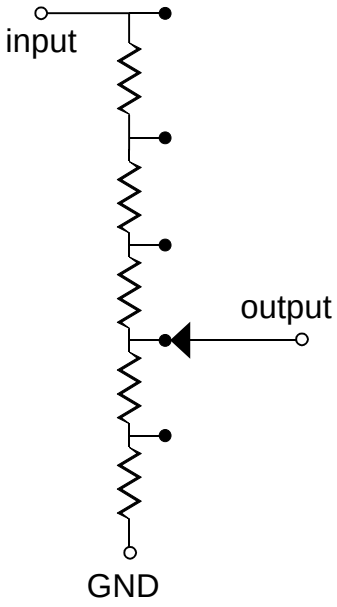
Below is a table of absolute resistor values for the TCJ attenuator that range from 600-ohms to 500k. you will not be able to buy a 614625-ohm resistor, nor are you expected to; instead, find the closest available value. On the next page are two tables showing the E24 and E96 closest values. On the other hand, many resistor companies use a blend of the E24 and E96 value, so if you are using 1% resistors, you may find a closer match to the values shown below. Additionally, 0.1% resistor follow the E192 value group, which offers many closer choices, although do not be surprised if the resistor vendor does not stock the full array of resistor values.

	Total Input Resistance										
	600	**5k**	**10k**	**20k**	**25k**	**50k**	**75k**	**100k**	**200k**	**250k**	**500k**
R1	65	544	1088	2175	2719	5438	8156	10875	21750	27188	54375
R2	123	1028	2057	4113	5141	10283	15424	20565	41130	51413	102825
R3	175	1460	2921	5841	7301	14603	21904	29205	58410	73013	146025
R4	221	1845	3691	7381	9226	18453	27679	36905	73810	92263	184525
R5	263	2188	4377	8753	10941	21883	32824	43765	87530	109413	218825
R6	4917	40975	81950	163900	204875	409750	614625	819500	1639000	2048750	4097500
R7	2317	19310	38620	77240	96550	193100	289650	386200	772400	965500	1931000
R8	1454	12120	24240	48480	60600	121200	181800	242400	484800	606000	1212000
R9	1026	8548	17095	34190	42738	85475	128213	170950	341900	427375	854750
R10	771	6425	12850	25700	32125	64250	96375	128500	257000	321250	642500
R11	299	2494	4988	9976	12470	24940	37410	49880	99760	124700	249400
R12	150	1250	2500	5000	6250	12500	18750	25000	50000	62500	125000
R13	75.2	627	1253	2506	3133	6265	9398	12530	25060	31325	62650
R14	37.7	314	628	1256	1570	3140	4710	6280	12560	15700	31400
R15	18.9	157	315	630	787	1574	2361	3148	6295	7869	15738
R16	9.5	78.9	158	316	394	789	1183	1578	3155	3944	7888
R17	4.7	39.5	79.1	158	198	395	593	791	1581	1976	3953
R18	2.4	19.8	39.6	79.2	99.1	198.1	297.2	396.2	792.4	990.5	1981.0
R19	1.2	9.9	19.9	39.7	49.7	99.3	149.0	198.6	397.2	496.5	993.0
R20	0.6	5.0	10.0	19.9	24.9	49.8	74.7	99.6	199.1	248.9	497.8
R21	0.6	5.0	10.0	19.9	24.9	49.8	74.7	99.6	199.1	248.9	497.8

	Total Input Resistance E24 5% Values										
	600	**5k**	**10k**	**20k**	**25k**	**50k**	**75k**	**100k**	**200k**	**250k**	**500k**
R1	68	560	1k	2.2k	2.7k	5.6k	8.2k	10k	22k	27k	56k
R2	120	1k	2k	4.3k	5.1k	10k	15k	20k	43k	51k	100k
R3	180	1.5k	3k	5.6k	7.5k	15k	22k	30k	56k	75k	150k
R4	220	1.8k	3.6k	7.5k	9.1k	18k	27k	36k	75k	91k	180k
R5	270	2.2k	4.3k	8.2k	11k	22k	33k	43k	82k	110k	220k
R6	5.1k	39k	82k	180k	200k	390k	620k	820k	1.8M	2M	3.9M
R7	2.4k	20k	39k	82k	100k	200k	300k	390k	820k	1M	2M
R8	1.5k	12k	24k	47k	62k	120k	180k	240k	470k	620k	1.2M
R9	1k	8.2k	18k	33k	43k	82k	130k	180k	330k	430k	820k
R10	750	6.2k	13k	24k	33k	62k	100k	130k	240k	330k	620k
R11	300	2.4k	5.1k	10k	13k	24k	36k	51k	100k	130k	240k
R12	150	1.2k	2.4k	5.1k	6.2k	12k	18k	24k	51k	62k	120k
R13	75	620	1.3k	2.4k	3k	6.2k	9.1k	13k	24k	30k	62k
R14	39	300	620	1.2k	1.5k	3k	4.7k	6.2k	12k	15k	30k
R15	20.0	150	300	620	750	1.5k	2.4k	3k	6.2k	7.5k	15k
R16	10.0	75	150	300	390	750	1.2k	1.5k	3k	3.9k	7.5k
R17	4.7	39	75	150	200	390	620	750	1.5k	2k	3.9k
R18	2.2	20	39	75	100	200	300	390	750	1k	2k
R19	1.2	10	20	39	51	100	150	200	390	510	1k
R20	0.5	5.1	10	20	27	51	75	100	200	270	510
R21	0.5	4.7	10	20	24	47	75	100	200	240	470

	Total Input Resistance E96 1% Values										
	600	**5k**	**10k**	**20k**	**25k**	**50k**	**75k**	**100k**	**200k**	**250k**	**500k**
R1	64.90	549	1.07k	2.15k	2.7k	5.49k	8.2k	10.7k	21.5k	27k	54.9k
R2	124.00	1.02k	2.05k	4.12k	5.11k	10.2k	15.4k	20.5k	41.2k	51.1k	102.k
R3	174.00	1.47k	2.94k	5.9k	7.32k	14.7k	22.1k	29.4k	59k	73.2k	147k
R4	221.00	1.87k	3.65k	7.32k	9.31k	18.7k	27.4k	36.5k	73.2k	93.1k	187k
R5	261.00	2.21k	4.42k	8.66k	11k	22.1k	33.2k	44.2k	86.6k	110k	221k
R6	4.99k	41.2k	82.k	165k	205k	412k	619k	825k	1.5M	2.2M	412k
R7	2.32k	19.1k	38.3k	80.6k	97.6k	191k	287k	383k	806k	976k	2.2M
R8	1.47k	12.1k	24.3k	48.7k	60.4k	121k	182k	243k	487k	604k	1M
R9	1.02k	8.45k	16.9k	34k	42.2k	84.5k	12.7k	169k	340k	422k	845k
R10	768.00	6.49k	12.7k	24.9k	32.4k	64.9k	95.3k	127k	249k	324k	649k
R11	294.00	2.49k	4.99k	10k	12.4k	24.9k	37.4k	49.9k	100k	124k	249k
R12	150.00	1.24k	2.49k	4.99k	6.19k	12.4k	18.7k	24.9k	49.9k	61.9k	124k
R13	75.00	634	1.24k	2.49k	3.16k	6.34k	9.31k	12.4k	24.9k	31.6k	63.4k
R14	37.40	316	634	1.24k	1.58k	3.16k	47.5k	6.34k	12.4k	15.8k	31.6k
R15	18.20	158	316	620	787	1.58k	2.37k	3.16k	6.2k	7.87k	15.8k
R16	10.00	78.7	158	309	392	787	1.18k	1.58k	3.09k	3.92k	7.87k
R17	4.7*	39.2	78.7	150	196	392	590	787	1.5k	1.96k	3.92k
R18	2.4*	20	39.2	75	100	200	294	392	750	1k	2k
R19	1.2*	10	20	39	49.9	100	150	200	390	499	1k
R20	0.6*	5*	10	20	24.9	49.9	75	100	200	249	499
R21	0.6*	5*	10	20	24.9	49.9	75	100	200	249	499

What is a Series Attenuator?



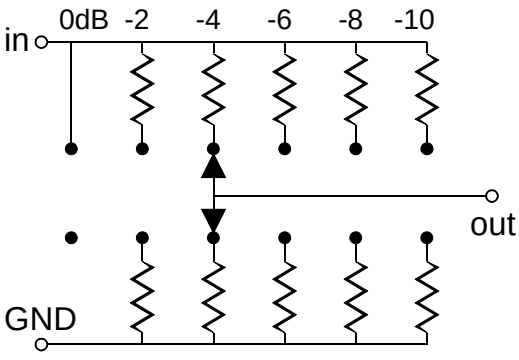
The closest analogy to the series attenuator is a normal audio-taper potentiometer used as a volume control in 99.9% of audio gear. A rotary switch holds many differently-valued resistors daisy-chained in series, with each connection attached to a switch contact. The rotary switch's moving contact then selects between resistor connections, thus providing a selectable amount of signal attenuation. The many fixed resistors wired in series define 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 attenuators have as many solder joints as there are steps.

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 a bunch of these fixed attenuators and some means of selectively swapping the right one in place. So 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 and switch poles are needed. In other words, a comparable series attenuator will cost half as much as the equivalent ladder attenuator.



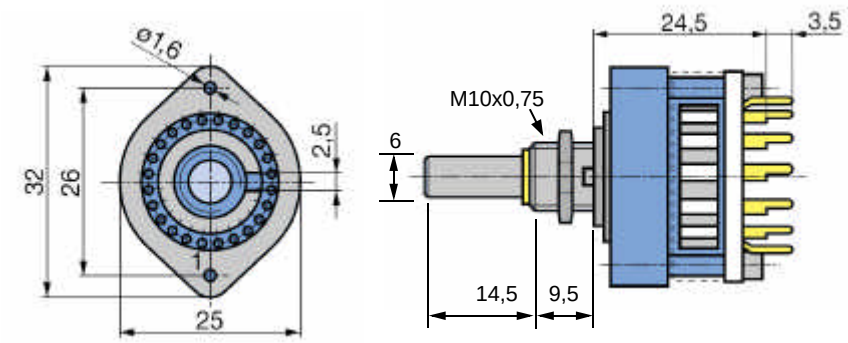
Assembly

The resistors mount on both sides of the PCB; the rotary switches mount only on the side marked "Switch Side." Each resistor finds its own white silkscreen place on 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 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 the a few resistor in the wrong locations. Place and solder the resistors in pairs, with the same resistor number being soldered into each channel for example, R1 & R1, R2 & R2, R3 & R3… 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.

With resistors R11 through R21, 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 24-pin 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.

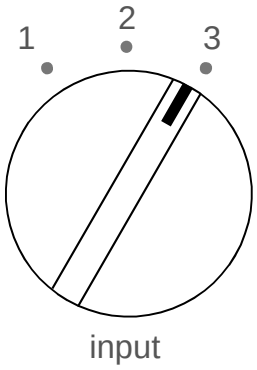


Switch dimensions in mm

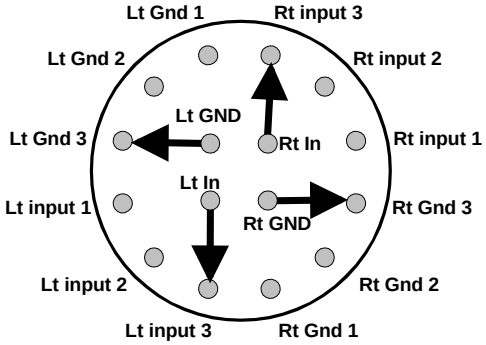
Wiring the TCJ Attenuator

The TCJ attenuator does not use a single ground for both channels; instead, each channel receives is own input and output ground connection. This helps prevent ground-loops when twisted pairs of signal wiring are used. This configuration may confuse those who are only familiar with stereo potentiometers that offer only five connections, not eight.

Ideally, the selector switch will choose between grounds as well as inputs. In other words, the each input's ground should be treated as a "hot" input of sorts and at no time should all the grounds ties from five different input sources tie together. This configuration is rare to point of nearly being nonexistent; nonetheless, it is the best way to wire an input selector switch, particularly when using dual-mono line stage amplifiers.



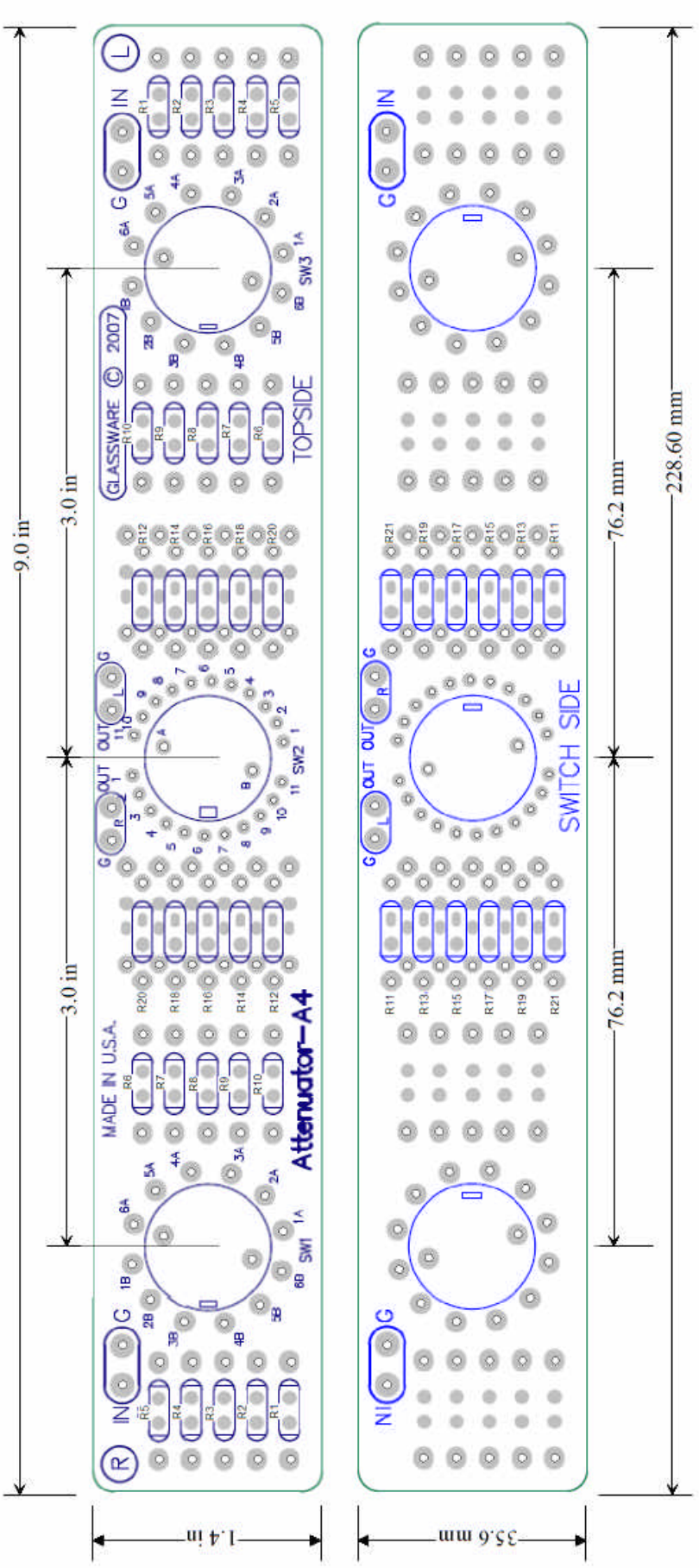
Switch Front



Switch Rear

On the other hand, if the all the RCA input jacks are grounded at the back panel and the selector switch only switches between signal hots, then the better route is to only attach ground connections to the outputs of the TCJ attenuator; a grounded shield or a twisted pair can still be used, just ground the shield leading to the attenuator's input at the attenuator's input and float the other end at the selector switch (the same holds true for a twisted pair).

When building a passive line stage, the best plan is to keep both the right and left channel grounds separate throughout. Use the selector switch arrangement shown above and use isolation washers on all the RCA jacks. Then ground the chassis to either the house's ground, via the wall socket's third prong, or to the two channel's ground through a two-resistor voltage divider made up of two 10-ohm to 1k resistors.


9.0 in
3.0 in
3.0 in
3.0 in
76.2 mm
76.2 mm
228.60 mm
1.4 in
35.6 mm
TOPSIDE
SWITCH SIDE
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Attenuator-A4
IN
OUT
SW1
SW2
SW3

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