A Stereo Tone-Control Unit

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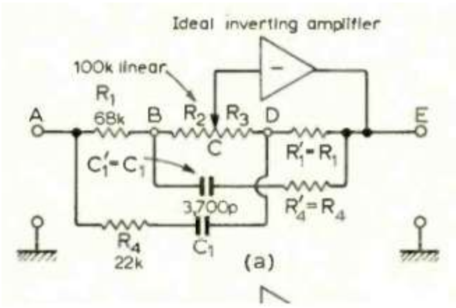
July 2025

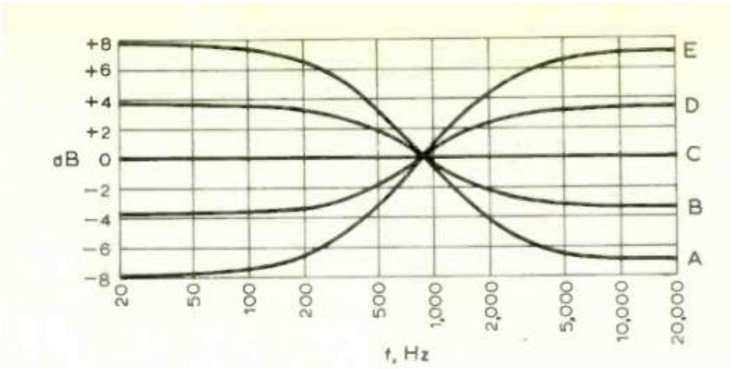
The "Tilt" Control.

In 1970 Ambler [1] proposed a single-potentiometer tone-control circuit for altering the balance between bass and treble frequencies. It was suggested that this circuit could complement the usual Baxandall bass and treble control, such that the latter could then be used exclusively for compensating for loudspeaker deficiencies, while Ambler's "tone-balance" control would be used for correcting the perceived tonal balance of inadequate recordings, or simply for adjusting to user preference.

On the face of it, this idea has merit. I will elaborate upon why most Baxandall tone controls that I have come across have served lousily for correcting for loudspeaker deficiencies at little further on. For now, I will just concentrate on the deficiencies of Ambler's original tone-balance control.

Here is Ambler's circuit from 1970, along with its frequency response characteristic:





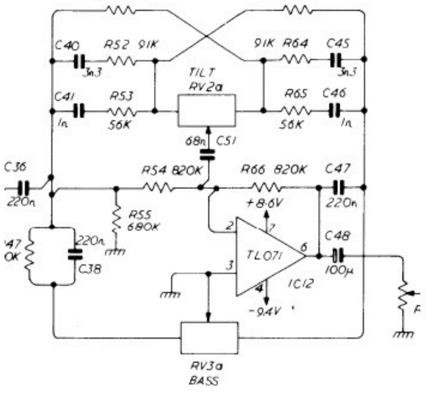
The frequency response is flat when the wiper of the potentiometer is centred. Deviation from this position progressively results in the bass frequencies being boosted while the treble frequencies are cut or vice versa.

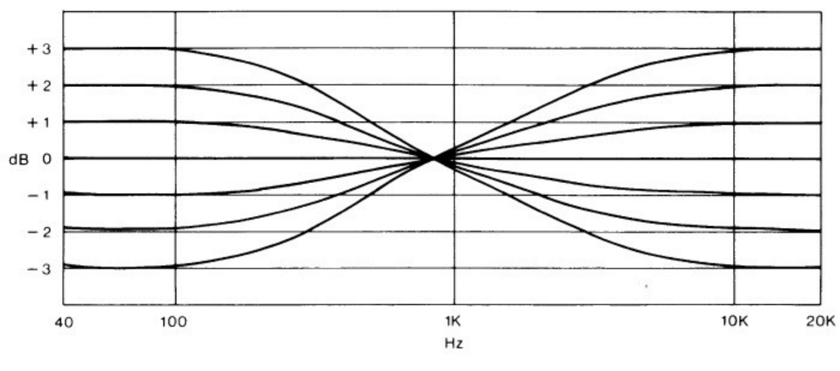
While this type of tone control circuit and variants thereof never gained a terribly great degree of popularity, one well-known exception and adopter of the concept was the manufacturer of domestic hi-fi equipment named Quad. Quad incorporated this type of control into at least a few of their pre-amplifier designs and rechristened it a tonal "tilt" control.

In my personal evaluation of Ambler's original circuit, subjective disappointment is rooted in the fact that the control intrudes far from subtly. Rather than gently and progressively tilting the amplitude response from one end of the frequency spectrum to the other, we essentially get a shelved response to almost the whole of the bass and treble regions with an abrupt transition in the midrange - the conceptual "tilt" is heavily confined to the middle of the frequency spectrum.

An idealised, alternative control response based on the concept of "tilt," could be a straight line on the logarithmic graph starting at 20Hz at a certain amplitude and ending at 20kHz at an equal but opposite amplitude. This line would necessarily intersect and thus pivot on a 0dB gain point located at the geometric mean on the horizontal frequency axis - this being approximately 632Hz: $\sqrt{(20Hz * 20kHz)}$.

Here is how Quad implemented the tonal tilt control in the model 34 pre-amplifier:



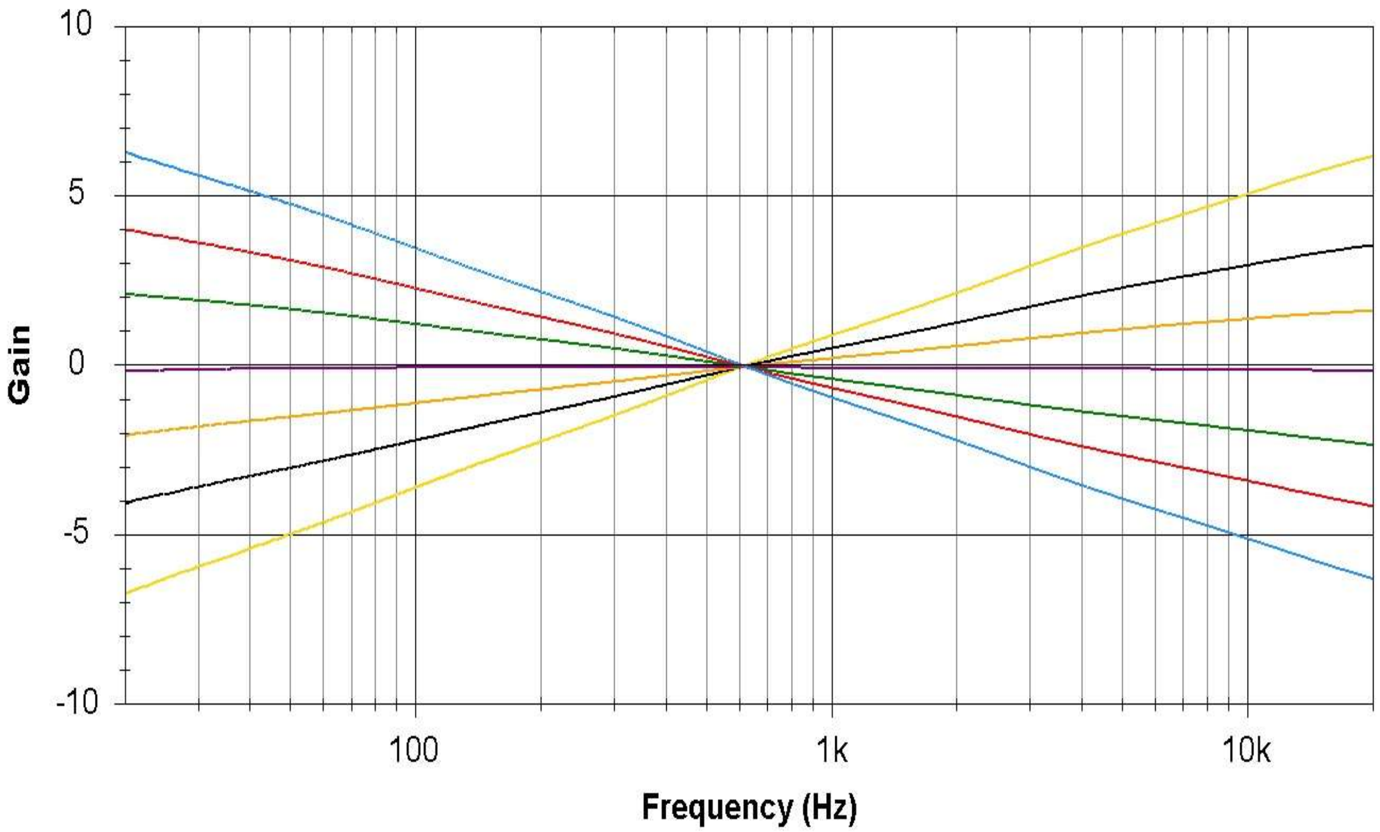


In this implementation the tilt control is combined with a bass cut/boost control. For this exposition I have no further interest in the bass section, but what I found immediately apparent is that the designer was obviously thinking along the same lines as I was to some degree, with regards to the conceptually ideal frequency response characteristic just detailed.

While not a complete solution, the designer did get one step closer. You can see that this implementation makes use of an additional R-C time-constant in each symmetrical arm, having deviated frequency breakpoints, such as to flatten out and broaden the tilted amplitude response about the midband transition.

While Quad's implementation achieves only a modest improvement in this regard over that by Amber, it was immediately obvious to me that this concept could be expanded with an additional number of R-C time constants to deliver a much better piecewise approximation of an ideal, straight-line response.

How much better? Well, here is the actual measured response of my final circuit as presented in full further on in this document, which modifies the original circuit by Amber with the incorporation of five breakpoint frequencies per arm:



These measurements were done with my QuantAsylum QA403 audio analyser and the above graph was plotted with the companion control software. The circuit was essentially designed and empirically optimised with the help of my computer - I used LTspice to get here.

Op-amps U101A and U103A are signal-input buffers and the tilt control section makes use of op-amps U101B and 103B. At 20kHz the input impedance of the tilt-control network can dip to a worst-case value of approximately 1260 ohms. Worst-case drive requirements are always something to be cognizant of when designing these types of circuits as the input impedance can vary wildly with both frequency and control settings. Fortunately, modern audio op-amps (and even some not-so-modern ones) can quite happily drive low-impedance loads. The OPA1642 op-amp that I chose can easily drive a 600-ohm load.

I figured a dip down to ~1260 ohms was a good enough compromise between op-amp loading and the overall feedback network impedance - the latter impacts upon thermal noise generation.

Gain wise, I designed my tilt control for a maximum boost and cut of approximately 6dB. While this is much less than the 12dB or so that might be seen in a typical implementation of something like the Baxandall tone control circuit, 6dB is more than adequate in practice for a tilt control because the gain change at one end of the frequency spectrum is complemented by an equal and opposite amount of change at the other end of the spectrum. The tilt control of the venerable Quad 34 pre-amplifier, for comparison, only had a modest +/-3dB range of adjustment!

Given the modest amount of boost available from the tilt-control circuit in isolation, the input signal-level overload margin is high enough to permit the volume control attenuator to be placed after it rather than before it. This incurs a modest noise advantage. From a noise perspective, the best position for a volume control attenuator is directly at the input of the power amplifier - the potentiometer then not only attenuates the desired audio signal, but also the noise generated by all of the active and passive signal-processing circuitry preceding it. However, when a signal chain consists of a cascade of stages each contributing gain, some compromise is usually necessary to avoid running out of headroom with higher-level input signals.

The Baxandall Bass and Treble Control

The volume control potentiometer is followed by a unity-gain buffer stage and then a slightly unusual variation of the Baxandall bass and treble control. I can now elaborate upon my aforementioned gripe with how the Baxandall bass and treble control is typically implemented. Most pre-amplifiers or integrated power amplifiers incorporating a Baxandall tone control circuit, that I have owned or played with, simply perturb the midrange region too much. My gripe is predominately with the bass control, as it is in the bass region that many compact or bookshelf loudspeakers are lacking.

I have measured bass controls in domestic audio equipment with a turnover frequency approaching 1kHz. This is far too high - I have never owned a speaker intended for hi-fi use with a bass extension that lousy. I find such a bass control best set flat or switched out of circuit, if the facility is available. A bass control as described is not particularly useful for giving a balanced degree of compensation for the limited bass extension of a typical bookshelf hi-fi speaker. It would be best called a rumble/muffle effects control or something such, as this is what it really sounds like when the bass equalisation extends somewhat significantly and deleteriously into the midrange. Perhaps this is what most consumers demand - if a bass control knob cannot make music that is not naturally bass heavy and rumbly sound amply otherwise then it would probably be considered defective.

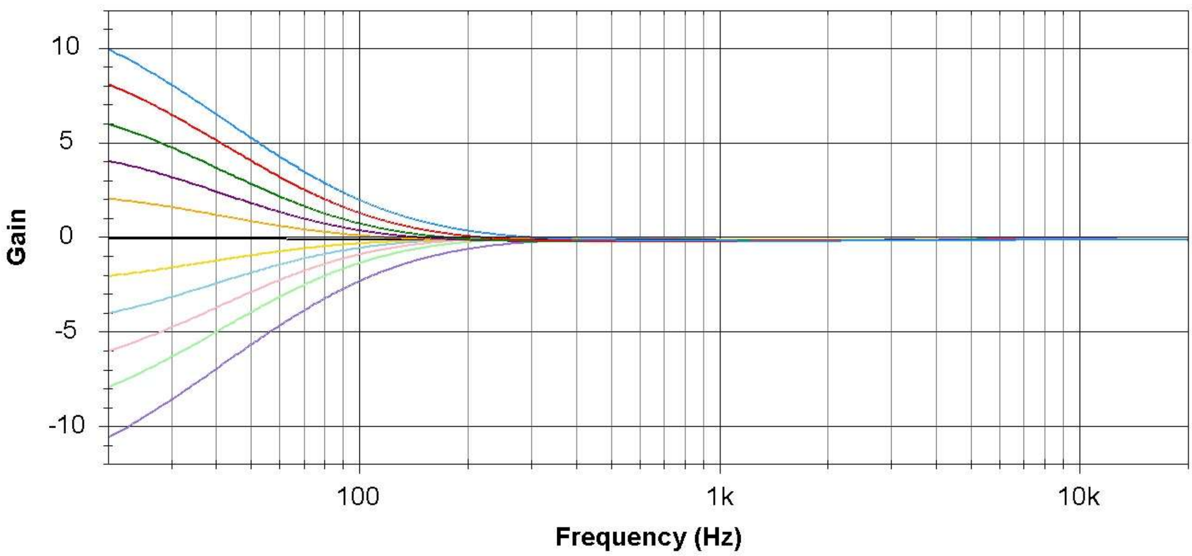
A sanely designed bass control can also be useful, when turned into the cut region, for compensating speakers where a non-ideal placement close to a wall or in the corners of a room, for practical reasons, results in a noticeable boost in bass frequencies due to reflections. Moving on from the bass knob, I have found the treble control to generally have limited usefulness for speaker correction as well. In the less common instance that a speaker sounds either a little too bright or, alternatively, a little too dull in the treble register, the treble control knob is generally of limited value because its influence begins at an excessively low frequency.

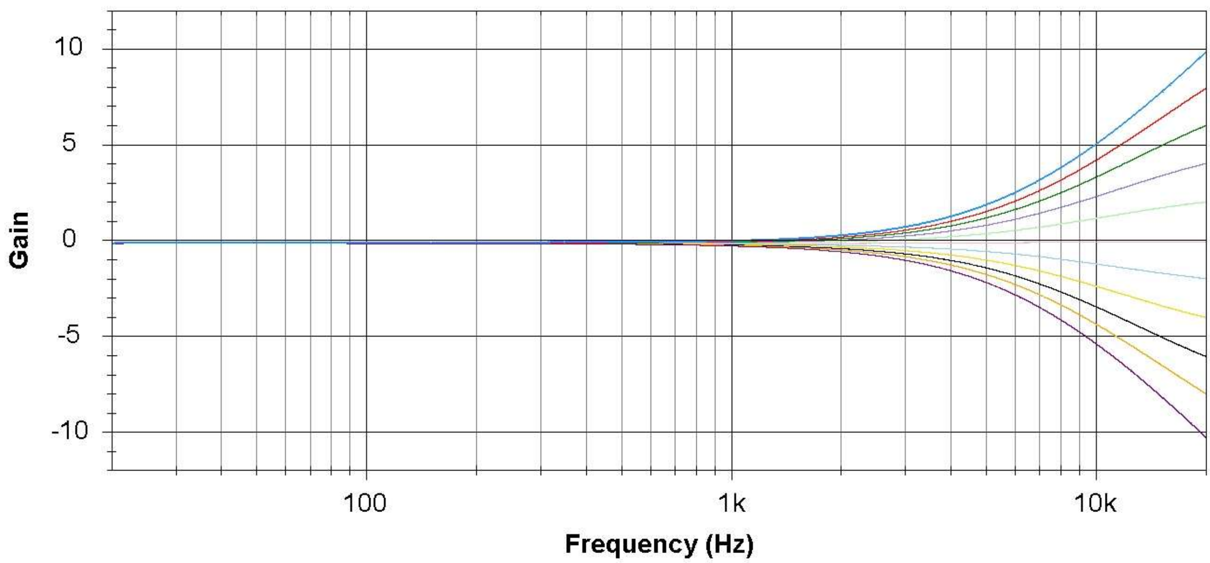
One instance of a well-implemented bass and treble control that I have come across was in stereo control unit made by Marantz. In this design the influence of the bass and treble control was adequately pushed aside, into to the bass and treble regions respectively, to make room for a band-pass “middle” boost/cut control. Ironically, the middle control itself is of little value for compensating for typical loudspeaker deficiencies.

If, for example, you have a loudspeaker that sounds a little too pronounced in the midrange, a little boost to both the bass and treble together will effectively depress the midrange. Oppositely, a little cut to both bass and treble together will effectively accentuate the midrange frequencies if necessary. This generally works much more effectively than the middle control with its excessively peaky/high-Q and generally ill-fitting bandpass response characteristic.

In my experience and therefore opinion, a Baxandall bass and treble control that is more usefully applicable to the role of partially compensating for typical loudspeaker deficiencies is one that is designed to have little influence in the 500Hz to 2kHz midrange region.

Here is the measured response of my circuit:





One thing that you might note, as the influence of control has been adequately pushed out to the bass and treble regions, is that the response curves to not have the usual amplitude shelving characteristic at the band extremities.

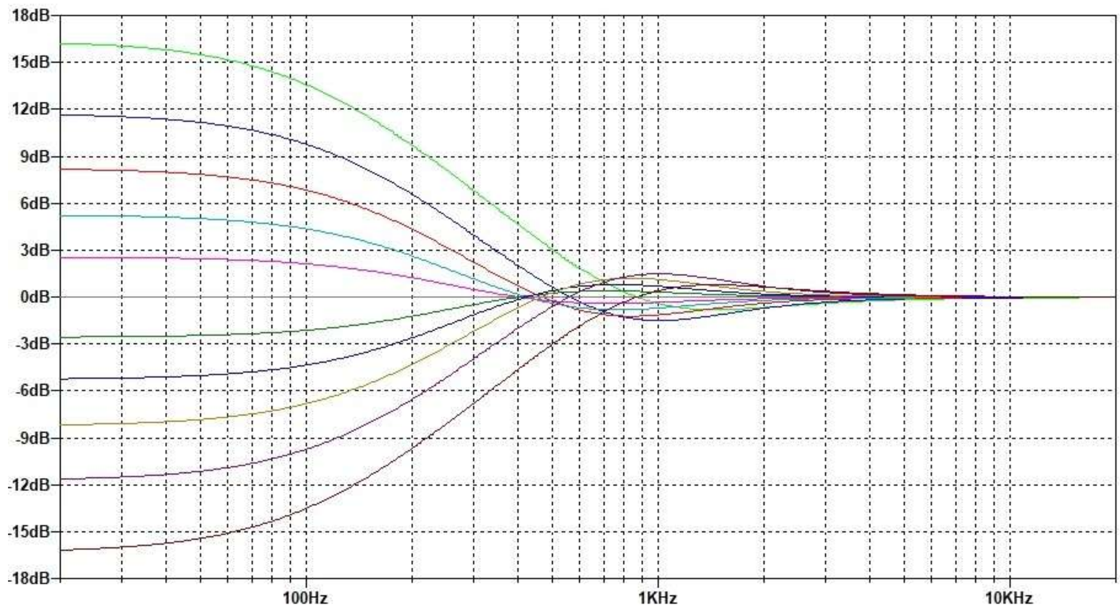
Bass characteristic improvement.

There are a number of practically standardised circuit variants in common use, derived from the design originally proposed by Baxandall. Both the bass and treble turn-over frequencies can be defined with either one or two capacitors. Of particular interest is the bass implementation, as the one-capacitor and the two-capacitor variants have distinctly different response characteristics.

As described by Self [2], the single-capacitor version has a fixed "breakpoint" frequency. The two-capacitor version, in contrast, has a breakpoint frequency that rises as the amount of boost or cut is increased. Self remarks that the two-capacitor version is much better for compensating loudspeaker deficiencies as it permits small levels of either boost or cut to be applied without effecting the whole of the bass region. This sound reasonable to me and I think that this would be particularly true in examples of the design which are implemented with an excessively high breakpoint frequency.

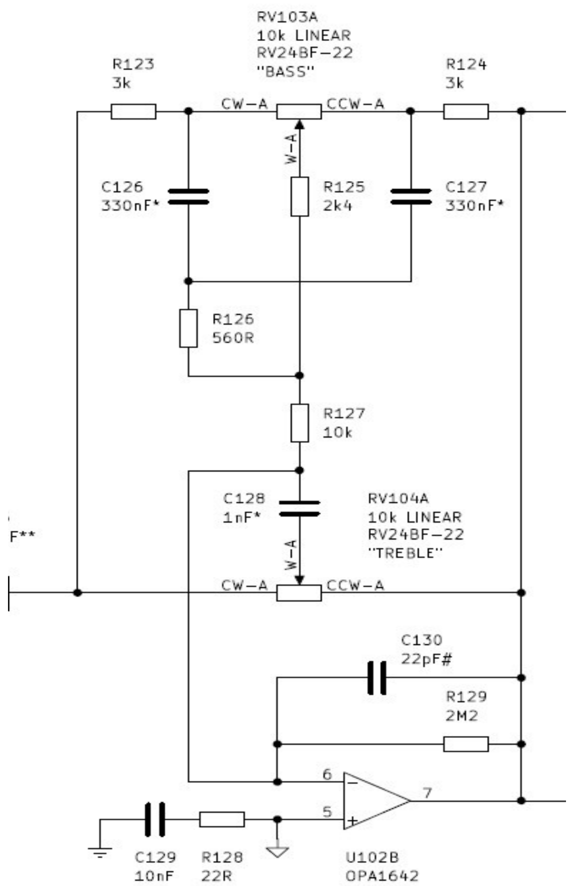
However, things are not entirely rosy, as there is an undesirable aspect to the frequency response characteristic of the standard two-capacitor version.

To illustrate, here is the simulated bass frequency response for a two-capacitor Baxandall control circuit as presented by Self [2] (which, incidentally, is designed with a breakpoint frequency much too high for my liking):



The response curves decay to 0dB gain with a significant degree of amplitude ripple beforehand. My implementation of the Baxandall tone-control circuit uses two capacitors to define the bass response turnover frequency, but if you look back to the previous page showing the measured response of my implementation, you will notice that this undesirable characteristic has been completely avoided.

How so? Well, my implementation complicates the design with two additional resistors – these being R125 and R126 in the schematic snippet here:



These two extra resistors give me the freedom to both achieve the desired breakpoint frequency with lower value capacitors and to decouple the capacitors from the network such that the damping can be tailored just enough to eliminate the ripple. Excessive dampening beyond this point progressively transitions to response characteristic to be very similar to that of the one-capacitor version – that being with a fixed breakpoint frequency. The component values were empirically optimised in SPICE, rather than with actual components plugged into breadboard, to preserve my sanity.

In conclusion

As detailed in the photos on the pages that follow, I have built this tone-control unit, with a companion mains-input power supply, into a safe, sturdy, and compact plastic equipment enclosure with the aid of a home-workshop fabricated sheet-steel sub-chassis.

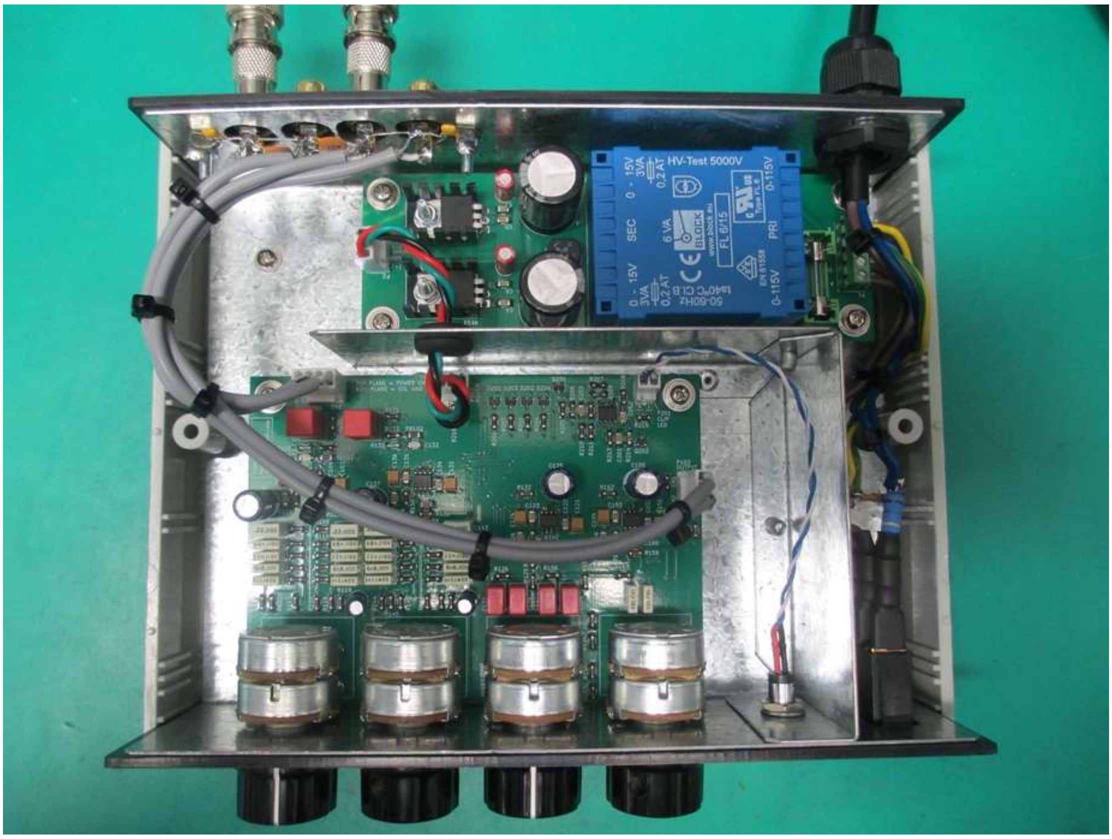
Some albums are subjectively mastered either a little too bass-heavy or a little too bright. I have found my improved implementation of the so-called tone-balance control, overall, to be satisfying effective at restoring the overall tonal balance of these recordings.

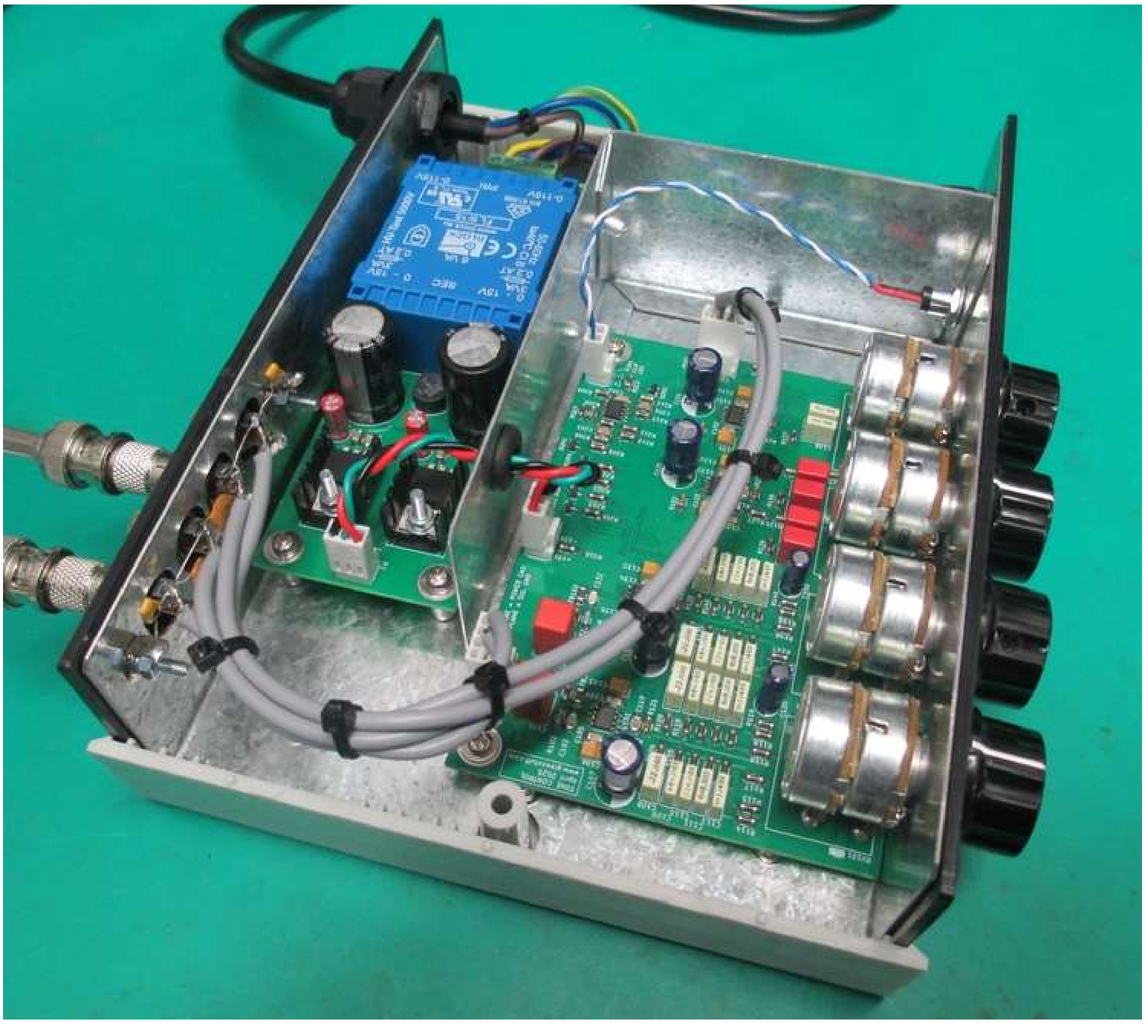
I currently have this unit plugged inline with the integrated amplifier used in my study. Despite the bass extension limitations of the bookshelf speakers in use, I have always kept the bass control knob of this integrated amplifier set to the flat position because it just sounds better that way - this is one of those integrated amplifiers where the bass control implementation fails miserably due to an excessively high breakpoint frequency. It’s basically a rumble effects knob for wienies into doof-doof music.

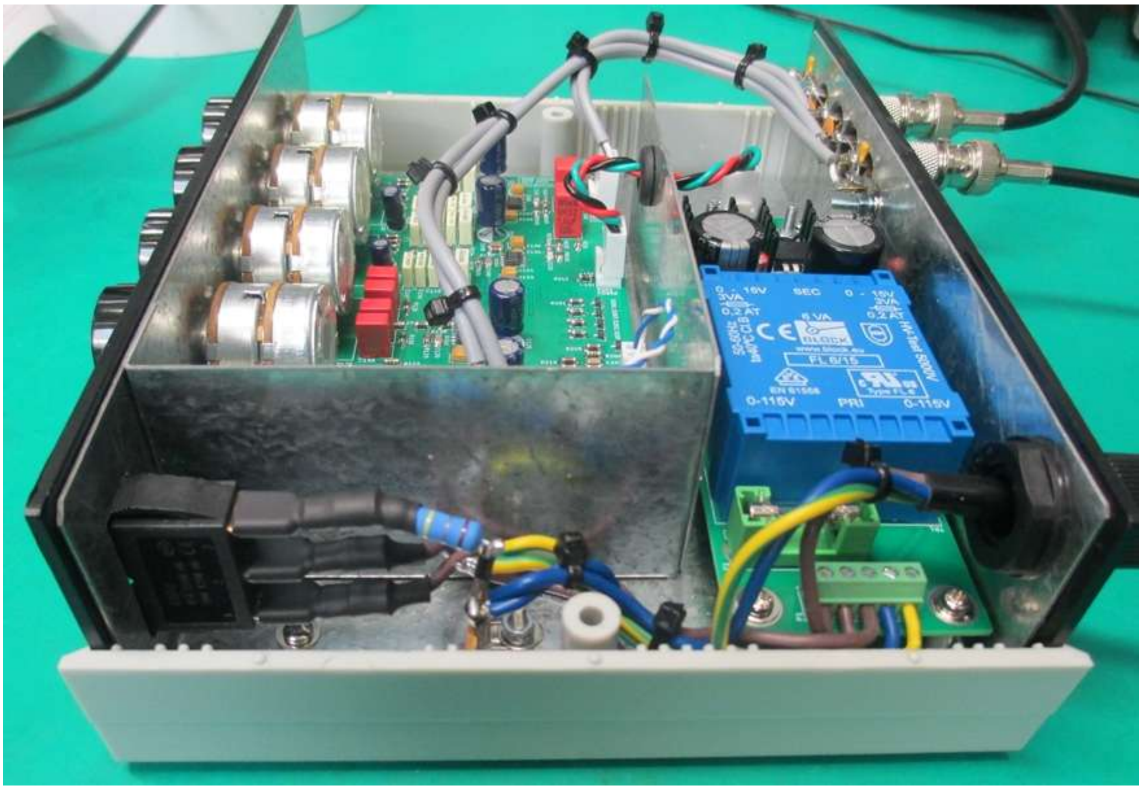
My refined Baxandall tone control is currently working quite effectively at extending the low-frequency response of these speakers. I think I will be keeping this unit plugged in for the foreseeable future. What else is there to say?

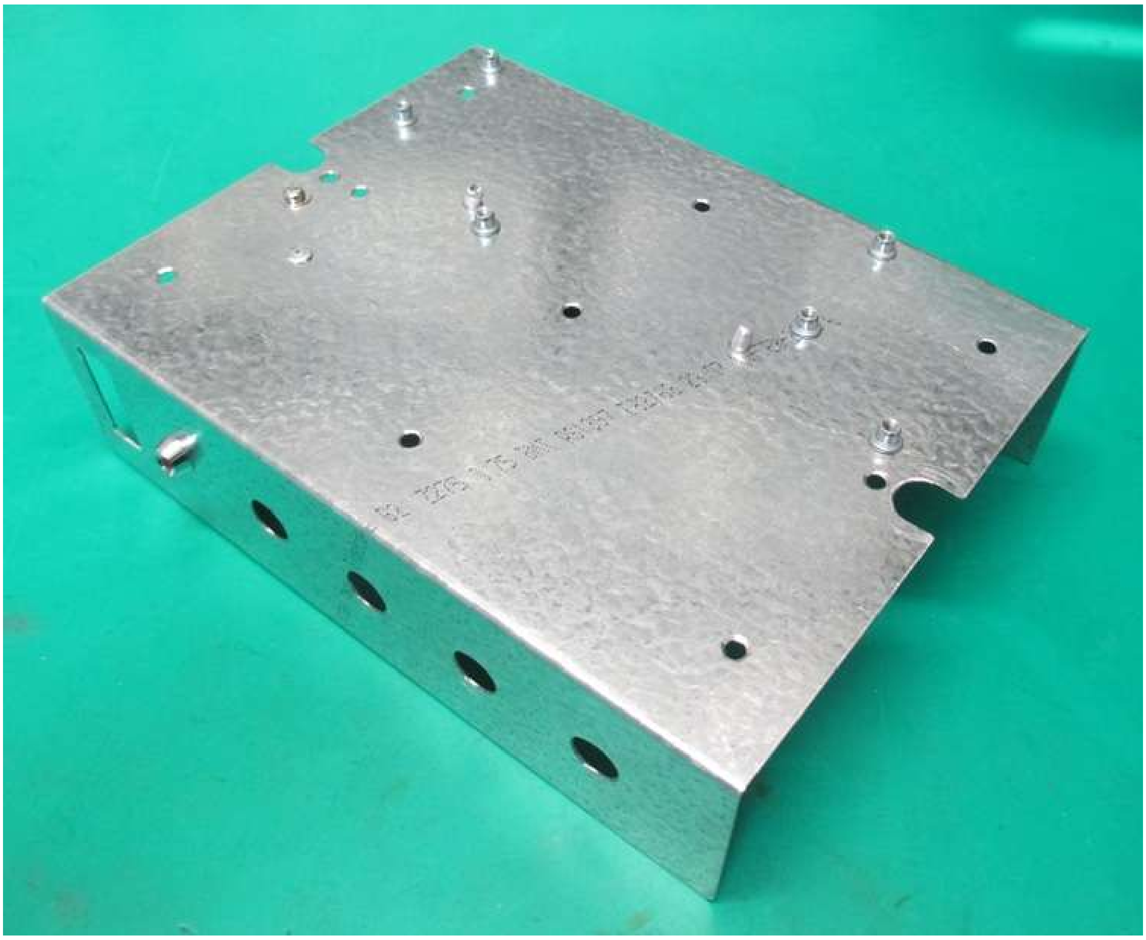
[1] R. Ambler, Tone-balance control, Wireless World March 1970

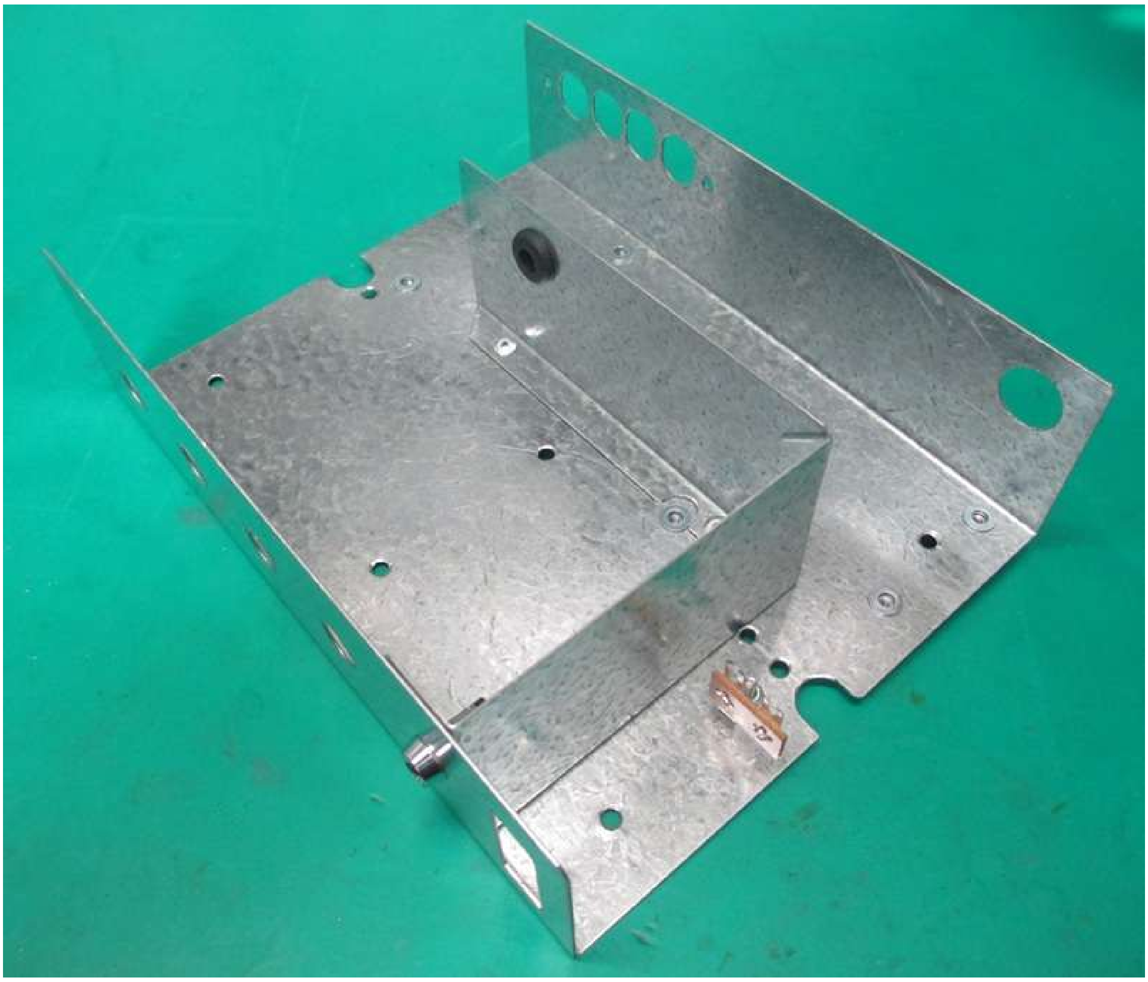
[2] D. Self, Chapter 10 – Tone control and equalizers, Small Signal Audio Design, 1st edition.





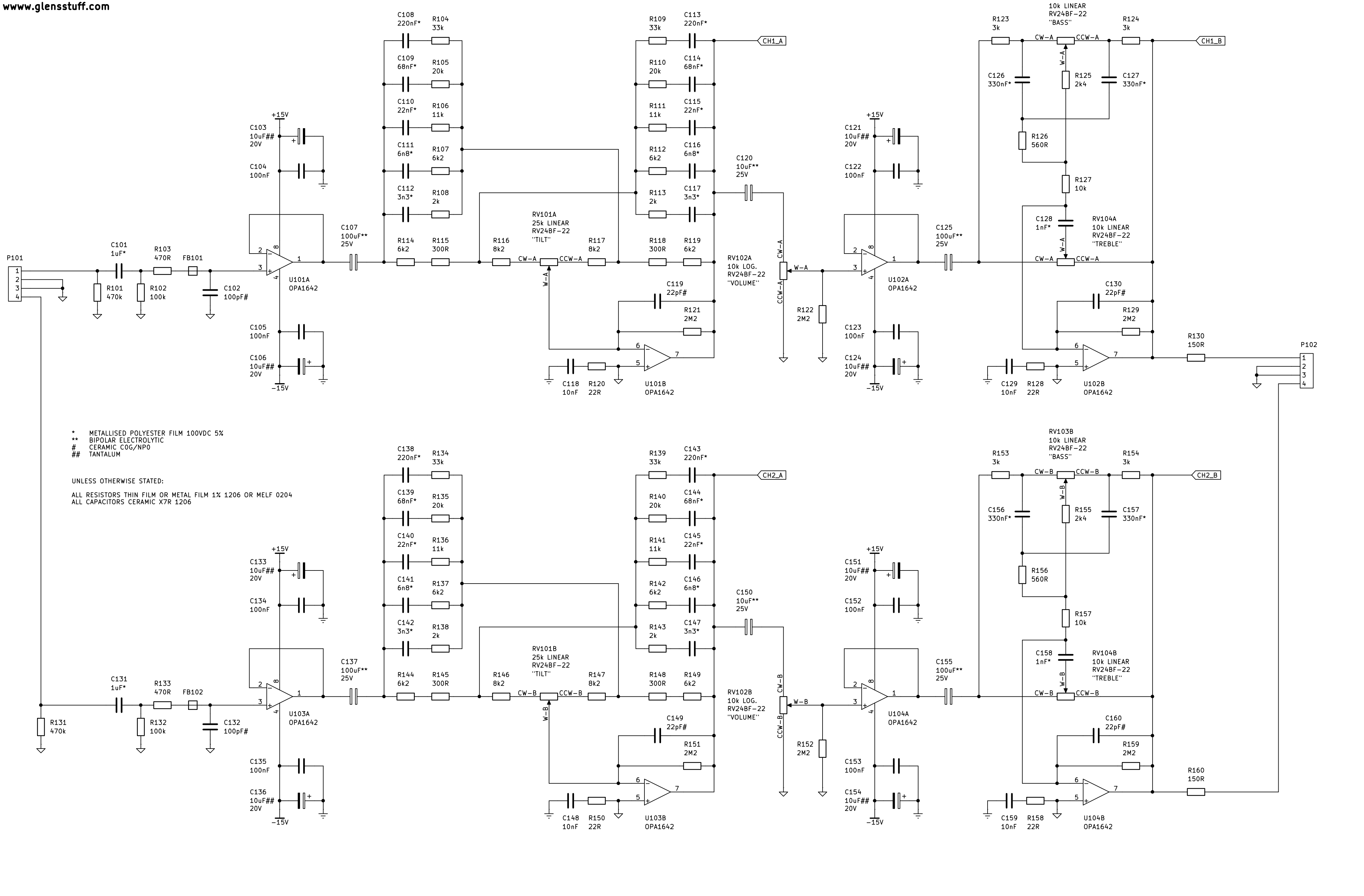

SEC
6 VA
FL 6/15
0-115V
PRI
0-115V





TILT, BASS AND TREBLE CONTROL

SIGNAL SECTION
www.glensstuff.com



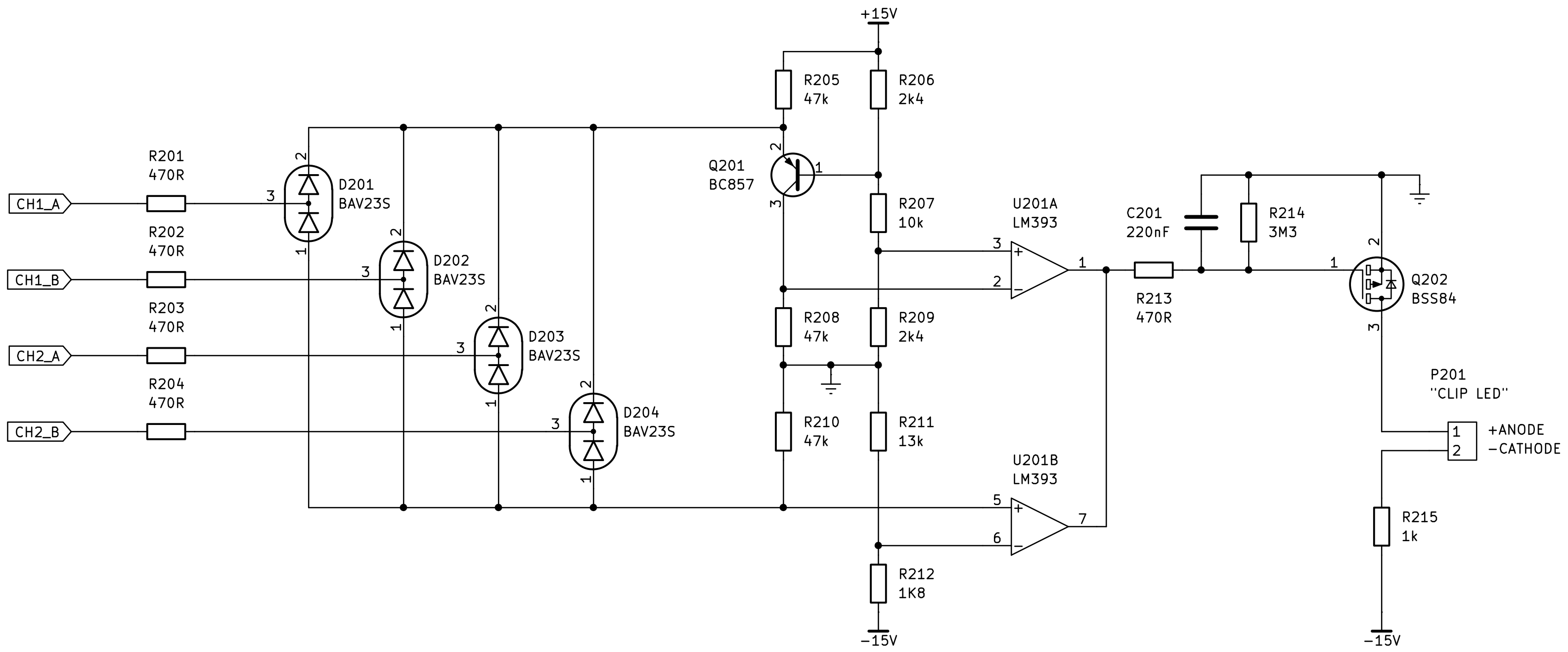
*	METALLISED POLYESTER FILM 100VDC 5%
**	BIPOLAR ELECTROLYTIC
#	CERAMIC C0G/NP0
##	TANTALUM

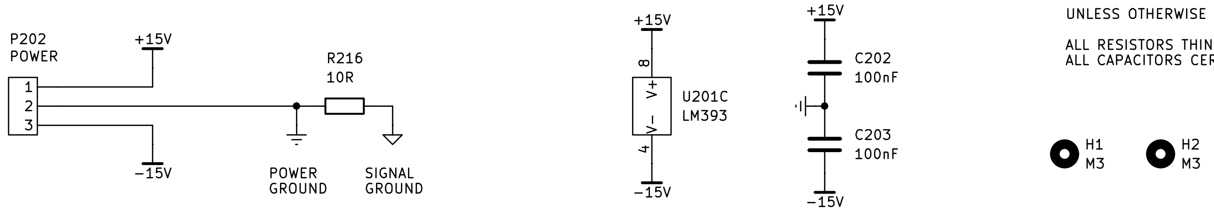
UNLESS OTHERWISE STATED:

ALL RESISTORS THIN FILM OR METAL FILM 1% 1206 OR MELF 0204
ALL CAPACITORS CERAMIC X7R 1206

TILT, BASS AND TREBLE CONTROL

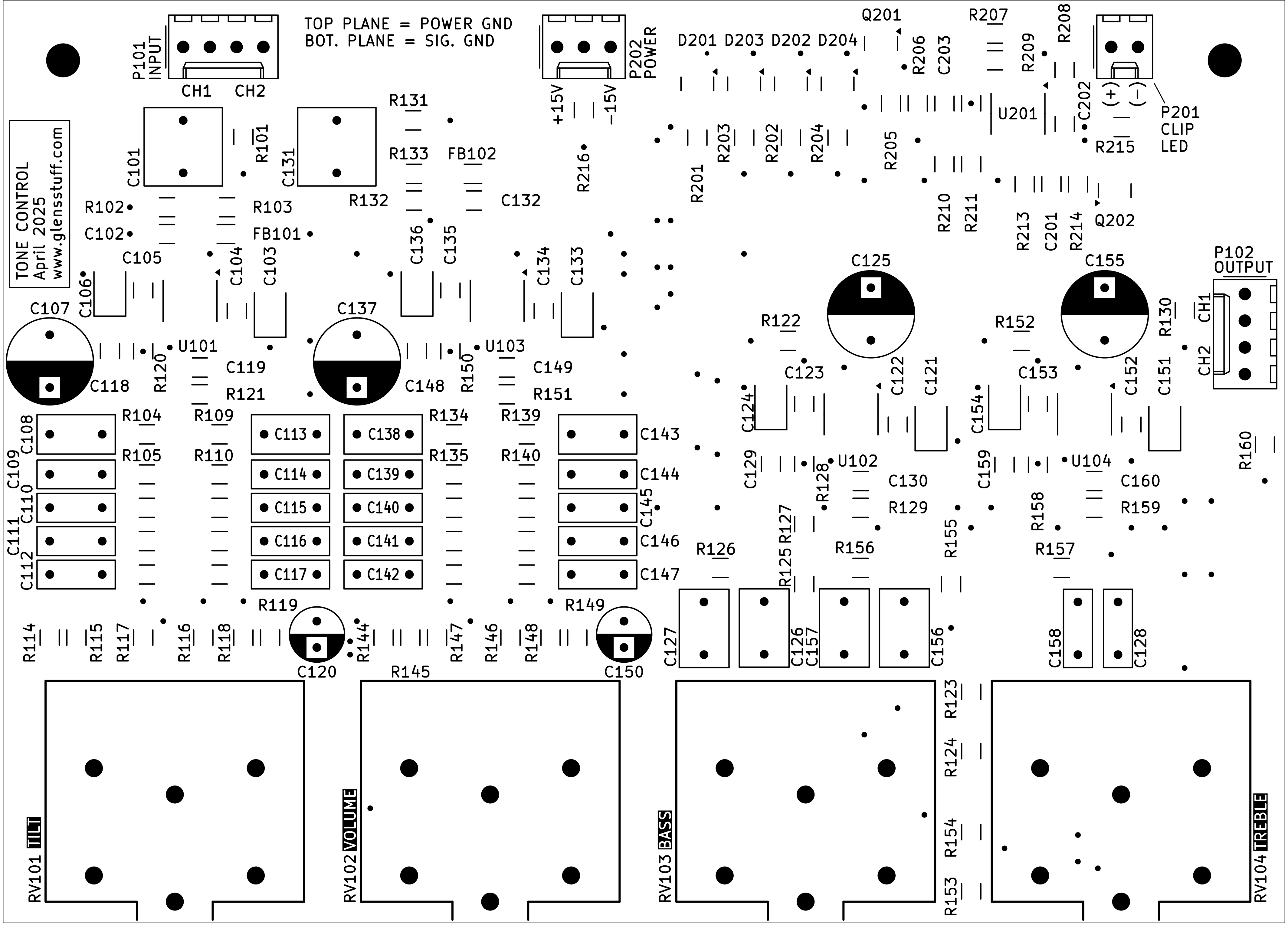
CLIPPING DETECTOR/INDICATOR
wwww.glensstuff.com



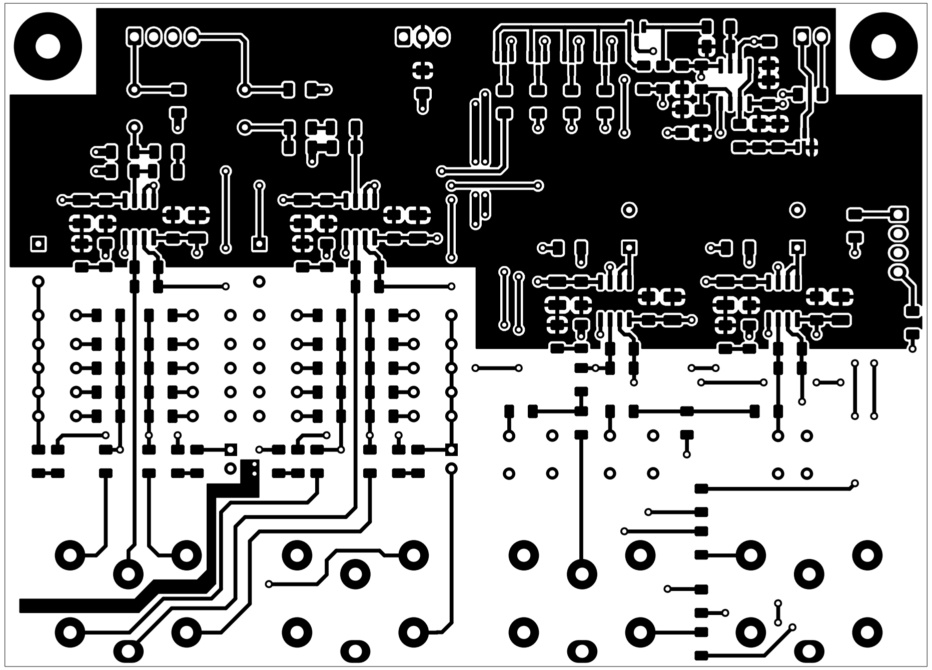


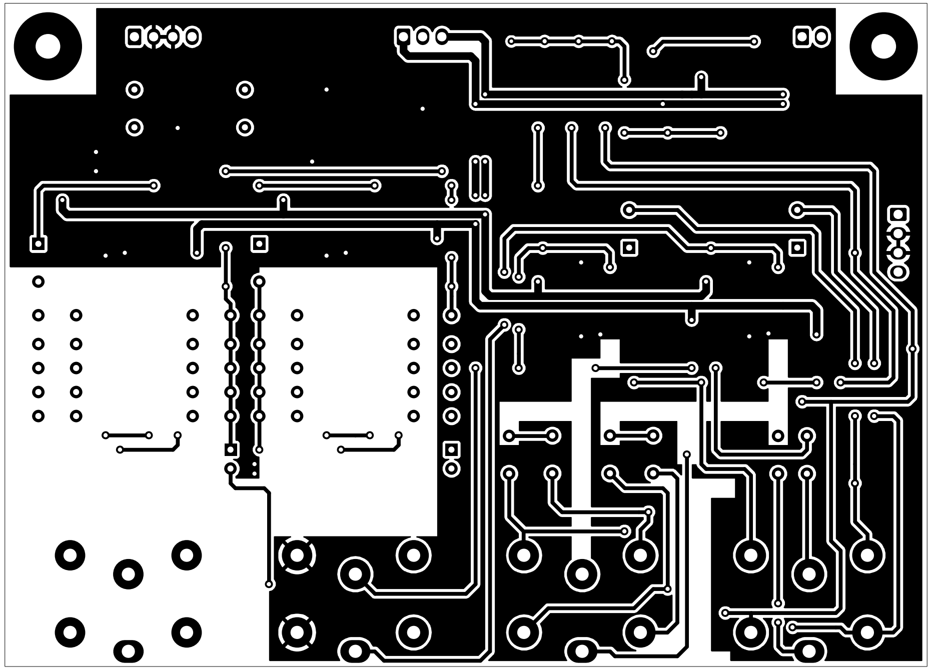
UNLESS OTHERWISE STATED:

ALL RESISTORS THIN FILM OR METAL FILM 1% 1206 OR MELF 0204
ALL CAPACITORS CERAMIC X7R 1206

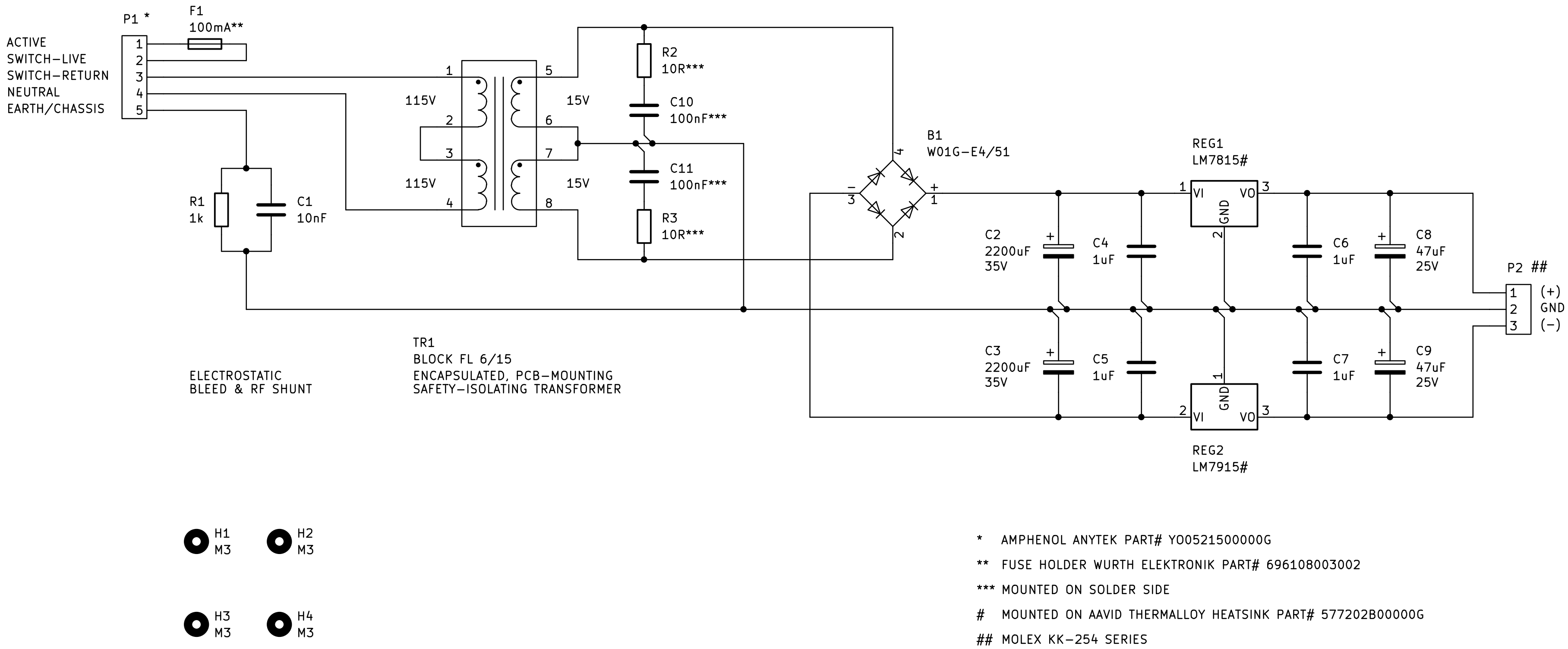


TOP PLANE = POWER GND
BOT. PLANE = SIG. GND
TONE CONTROL
April 2025
www.glensstuff.com
P101 INPUT
CH1 CH2
P202 POWER
+15V -15V
P201 CLIP LED
(+) (–)
P102 OUTPUT
CH1 CH2
Q201 Q202 U201
D201 D203 D202 D204
R201 R202 R203 R204 R205 R206 R207 R208 R209 R210 R211 R213 R214 R215 R216
C201 C202 C203
U101 U102 U103 U104
FB101 FB102
C101 C102 C103 C104 C105 C106 C107 C108 C109 C110 C111 C112
C113 C114 C115 C116 C117 C118 C119 C120 C121 C122 C123 C124 C125 C126 C127 C128 C129 C130
C131 C132 C133 C134 C135 C136 C137 C138 C139 C140 C141 C142 C143 C144 C145 C146 C147 C148 C149 C150
C151 C152 C153 C154 C155 C156 C157 C158 C159 C160
R101 R102 R103 R104 R105 R109 R110 R114 R115 R116 R117 R118 R119 R120 R121 R122 R123 R124 R125 R126 R127 R128 R129 R130
R131 R132 R133 R134 R135 R139 R140 R144 R145 R146 R147 R148 R149 R150 R151 R152 R153 R154 R155 R156 R157 R158 R159 R160
RV101 TILT
RV102 VOLUME
RV103 BASS
RV104 TREBLE





+/- 15V POWER SUPPLY



* AMPHENOL ANYTEK PART# YO05215000000G

** FUSE HOLDER WURTH ELEKTRONIK PART# 696108003002

*** MOUNTED ON SOLDER SIDE

\# MOUNTED ON AAVID THERMALLOY HEATSINK PART# 577202B00000G

\#\# MOLEX KK-254 SERIES

BOM for tone-control PCB.

Designator	Component type	Tolerance +/-%	Value	Part#	Manufacturer	Package	Description	Quantity
R101, R131	Resistor	1	470k			1206 or Melf 0204	Thin film / metal film	2
R102, R132	Resistor	1	100k			1206 or Melf 0204	Thin film / metal film	2
R103, R133, R201, R202, R203, R204, R213	Resistor	1	470R			1206 or Melf 0204	Thin film / metal film	7
R104, R109, R134, R139	Resistor	1	33k			1206 or Melf 0204	Thin film / metal film	4
R105, R110, R135, R140	Resistor	1	20k			1206 or Melf 0204	Thin film / metal film	4
R106, R111, R136, R141	Resistor	1	11k			1206 or Melf 0204	Thin film / metal film	4
R107, R112, R114, R119, R137, R142, R144, R149	Resistor	1	6k2			1206 or Melf 0204	Thin film / metal film	8
R108, R113, R138, R143	Resistor	1	2k			1206 or Melf 0204	Thin film / metal film	4
R115, R118, R145, R148	Resistor	1	300R			1206 or Melf 0204	Thin film / metal film	4
R116, R117, R146, R147	Resistor	1	8k2			1206 or Melf 0204	Thin film / metal film	4
R120, R128, R150, R158	Resistor	1	22R			1206 or Melf 0204	Thin film / metal film	4
R121, R122, R129, R151, R152, R159	Resistor	1	2M2			1206 or Melf 0204	Thin film / metal film	6
R123, R124, R153, R154	Resistor	1	3k			1206 or Melf 0204	Thin film / metal film	4
R125, R155, R206, R209	Resistor	1	2k4			1206 or Melf 0204	Thin film / metal film	4
R126, R156	Resistor	1	560R			1206 or Melf 0204	Thin film / metal film	2
R127, R157, R207	Resistor	1	10k			1206 or Melf 0204	Thin film / metal film	3
R130, R160	Resistor	1	150R			1206 or Melf 0204	Thin film / metal film	2
R205, R208, R210	Resistor	1	47k			1206 or Melf 0204	Thin film / metal film	3
R211	Resistor	1	13k			1206 or Melf 0204	Thin film / metal film	1
R212	Resistor	1	1K8			1206 or Melf 0204	Thin film / metal film	1
R214	Resistor	1	3M3			1206 or Melf 0204	Thin film / metal film	1
R215	Resistor	1	1k			1206 or Melf 0204	Thin film / metal film	1
R216	Resistor	1	10R			1206 or Melf 0204	Thin film / metal film	1
RV101	Potentiometer		25k	RV24BF-22	Taiwan Alpha	24mm	Dual gang, linear taper	1
RV102	Potentiometer		10k	RV24BF-22	Taiwan Alpha	24mm	Dual gang, logarithmic taper	1
RV103,RV104	Potentiometer		10k	RV24BF-22	Taiwan Alpha	24mm	Dual gang, linear taper	2
C101, C131	Capacitor	5	1uf, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	2
C108, C113, C138, C143	Capacitor	5	220nF, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	4
C109, C114, C139, C144	Capacitor	5	68nF, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	4
C110, C115, C140, C145	Capacitor	5	22nF, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	4
C111, C116, C141, C146	Capacitor	5	6n8, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	4
C112, C117, C142, C147	Capacitor	5	3n3, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	4
C126, C127, C156, C157	Capacitor	5	330nF, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	4
C128, C158	Capacitor	5	1nF, 100VDC			Through hole	Metallised polyester film, lead pitch 5mm	2
C107, C125, C137, C155	Capacitor		100uF			Through hole	Bipolar electrolytic. Diameter 8mm, Pitch 5mm	4
C120, C150	Capacitor		10uF			Through hole	Bipolar electrolytic. Diameter 5mm, Pitch 2.5mm	2
C103, C106, C121, C124, C133, C136, C151, C154	Capacitor		10uF, 20V			EIA-3528-12	Tantalum	8
C118, C129, C148, C159	Capacitor		10nF			1206	X7R chip ceramic	4
C104,C105,C122,C123,C134, C135,C152,C153,C202,C203	Capacitor		100nF			1206	X7R chip ceramic	10
C201	Capacitor		220nF			1206	X7R chip ceramic	1
C102, C132	Capacitor		100pF			1206	C0G/NP0 chip ceramic	2
C119, C130, C149, C160	Capacitor		22pF			1206	C0G/NP0 chip ceramic	2
U101, U102, U103, U104	Integrated circuit			OPA1642	Texas Instruments	SO-8	Audio op-amp.	4
U201	Integrated circuit			LM393	Various	SO-8	Dual comparator	1
D201,D202,D203,D204	Diode			BAV23S	Various	SOT-23	Dual small-signal diode	4
Q201	Bipolar transistor			BC857		SOT-23	PNP, general purpose transistor	1
Q202	MOSFET			BSS84		SOT-23	P-channel enhancement mode MOSFET	1
FB101, FB102	Ferrite bead			HZ1206D102R-10	Laird-Signal Integrity Products	1206	Ferrite bead, 1k@100MHz	2
P101, P102	Connector				Molex	Through hole	KK-254 vertical header, 4-way	2
P201	Connector				Molex	Through hole	KK-254 vertical header, 2-way	1
P202	Connector				Molex	Through hole	KK-254 vertical header, 3-way	1