X-Altra Moving Coil/Moving Magnet RIAA EQ Preamplifier (Part 2)

MM Preamp, System Gain Amplifier, Filter, PSU, and Measurements

In the second part of this article, the author details the Moving Magnet EQ stage, system gain amplifier and filters, along with the system's power supply unit for the X-Altra design. The article concludes with some measurements of the X-Altra preamplifier.

By
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For the second half of this article, we will begin with the Moving Magnet (MM) EQ amplifier design (**Figure 1**). The junction field effect transistor (JFET) plus op-amp topology used in the X-Altra MM preamp stage borrows heavily from Denis Colin's excellent LP797 design published in *audioXpress* in 2007 but in this implementation, all active EQ is applied around the first stage rather than Colin's active/passive split EQ architecture.

The key gain element is U21, a dual ultra-low noise N-channel JET from Linear Systems, the LSK389B featuring 0.9nV/√Hz typical (1.9nV/√Hz maximum) input noise voltage. By paralleling the two devices, the equivalent input noise of the JFETs is reduced by 1/√2 to 0.63nV/√Hz typical. In the LP797, the JFET source resistor was set to 10Ω, which contributed just 410 pV/√Hz noise (57nV RMS over the audio band). In an all active EQ arrangement such as the X-Altra, if the gain resistor is set much below 100Ω (191nV RMS wideband noise contribution), the feedback equalization components quickly become large and unwieldy. At least 1% tolerance capacitors will be required for acceptable EQ accuracy, which are expensive at high values such as 0.47µF or 0.1µF. These are likely to be wound film types, so they will be large and prone to noise pickup. With the gain resistor set to 110 Ω, the EQ capacitors are readily available in 1% tolerance NPO/COG surface mount device (SMD) types and they are inexpensive.

By using a JFET front end in this MM amplifier, the current noise × R_{SOURCE} term discussed in Part I (*audioXpress*, February 2021) is effectively removed (Part 1, Figure 2) and results in a >3dB SNR improvement using the standard cartridge compared to a NE5534A op-amp.

The MM signal is fed from the source selection switch U25. R79 and R81 in conjunction with U22 DIP switch (left moving magnet load or LMML) enable the cartridge loading resistance to be set to either 26kΩ, 31kΩ, 35kΩ, or 47kΩ allowing the high-frequency response to be tailored to minimize response peaking due to the interaction of cable capacitance and cartridge inductance, and separately, tip mechanical resonance.

Note, to use this feature successfully, you will ideally need a test record and an oscilloscope. Failing this, the best solution is to simply set the loading by ear for the best sound. R80 provides a 47kΩ cartridge load (U22 switches open) and the bias for the JFET input pair. R74 and R75 at 110Ω combined resistance sets the self-bias JFET Id at nominally 1.5mA per device, 3mA in total, though Ids vs. Vgs spreads will mean this figure can vary by as much as 30% to 40%.

The output signal is developed across R82 (1kΩ) and the drain coupled to the input of one half of U26, an LM4562, via a 2.2µF film capacitor C90. The LM4562 provides the bulk of the open-loop gain and drives the EQ feedback network R71-R73 and C83-C85. R76 and C86 along with R77 and C87 provide loop compensation. The output secondary post filter (R58 and C63) -3dB bandwidth is set to 220kHz and provides just enough correction at 20kHz to pull the simulated EQ conformance to within ±0.15dB over the audio band.

To arrive at the specific values, I used the formulas from Stanley Lipshitz's 1979 "On RIAA Equalization Networks" paper in a spreadsheet and then optimized the secondary post filter in LTspice to ensure accurate conformance. R73 (220Ω) in the feedback network is also determined during the LTspice optimization and helps to flatten any residual RIAA conformance deviation in the mid band.

As with the MC front end preamplifier discussed in Part 1 of the article, the MM front end stage power supply rejection ratio (PSRR) is essentially zero. To remedy this, the other half of U26 is used to implement a very low noise 10V regulator, the reference input on pin 3 being derived from the resistor divider chain used in the MC voltage regulator circuit (Part 1, Figure 5). R78 and C88 provide further noise filtering prior to feeding the front end JFET drain load resistor R82, where the regulators simulated noise output is 50pV/√Hz (1kHz) or about 7nV RMS over the audio band.

An LTspice model used to investigate the phono amp's performance showed that the 1kHz input referred spot noise with the input shorted was just under 1.6nV/√ Hz, most of this attributable to the 110Ω source resistor. By way of contrast, Colin's LP797 input referred noise floor was under 1nV/√Hz. However, with the standard cartridge connected to the input, the simulated noise figure was 5.4nV/√Hz, just 0.2nV higher than the LP797 despite the 11x higher source resistor used on the X-Altra.

The overload margin, measured by driving the input at 1kHz to the onset of clipping at the output of the preamplifier (U15), is 189mV peak at 1kHz or, reference a 5mV input, 31.5dB with the system gain set to 0dB. Since this is an all-active feedback design, the 31.5dB figure holds over the whole audio band from < 20Hz through to > 50kHz. The DC offset at the output of U26 pin 7 is as much 70mV due to U26's bias current flowing through R76, necessitating DC blocking capacitor C62.

System Gain Amplifier and High-Pass Filter

The system gain amplifier is configured around U27, an OPA1641 JFET input op-amp. The gain may be adjusted to 0dB, 6dB and 9.5dB via DIP switch U16 left gain system (LSG). This stage provides additional signal chain gain flexibility in the case of lower output cartridges—both MC and MM. Note that in this position, and in U7, U17, and U18, a lower-cost NE5534A op-amp can be used, in which case a 33pF NPO/COG 0805 capacitor should be fitted (C95, C96 for the left channel and C5 and C6 for the right channel).

The system gain stage feeds into a conventional Sallen-Key high-pass filter constructed around U17. The 20Hz high-pass filter is permanently enabled, which is the case when J2 (45Hz high-pass filter) is closed and completely removes the problem of bass speaker "flap" due to record warp. When the switch, located on the rear panel, is opened, the turnover frequency moves up to 45Hz as the total filter capacitance (C64-C67 and C72 and C73) is reduced from 141nF to 47nF. Many older classical recordings (vinyl and their CD re-releases) suffer from an annoying "acoustic" rumble, which is particularly apparent if a sub bass is used. It has been suggested the cause is air conditioning and/or low-frequency air current noise being picked up by the sensitive microphones in large recording spaces. The 45Hz filter reduces this noise significantly without really affecting the music's bass "weight." With organ music, you might lose notes well below 45Hz, but if this is a concern, you can simply switch the filter out.

The output from the filter stage is routed through C61, a 22µF bipolar capacitor, R57 (47Ω) to U15, the preamplifier output connector. A 3.3nF capacitor provides additional radio frequency interference (RFI) noise protection.

About the Author

Andrew C. Russell worked for the first half his career in the electronics industry in product development, qualifications and marketing, During the second half of his career, Russell was in business management and business development in the semiconductor industry working for a global MNC, spending the last 10 years based in Japan, Taiwan, and China. He struck out on his own in 2015, founding Ovation High Fidelity and doing freelance audio design consulting and contracting with an emphasis on power amplifiers and preamplifiers. When not working in his lab, he can be found walking his dog or enjoying his vinyl collection.

System's Power Supply

The power supply (**Figure 2**) uses a 3.5VA 2× 18VAC secondary Nuvotem Talema PCB mount toroid (marketed in the US under the "Acme" and now "Amgis" brand names from Digi-Key). Figure 7 from Part 1 shows the MC performance with Rgen = 47Ω and despite the power supply unit (PSU) being co-located with the amplifier circuit, and the very high gains involved, mains noise measured at the preamp output remains below -90dBV. Each

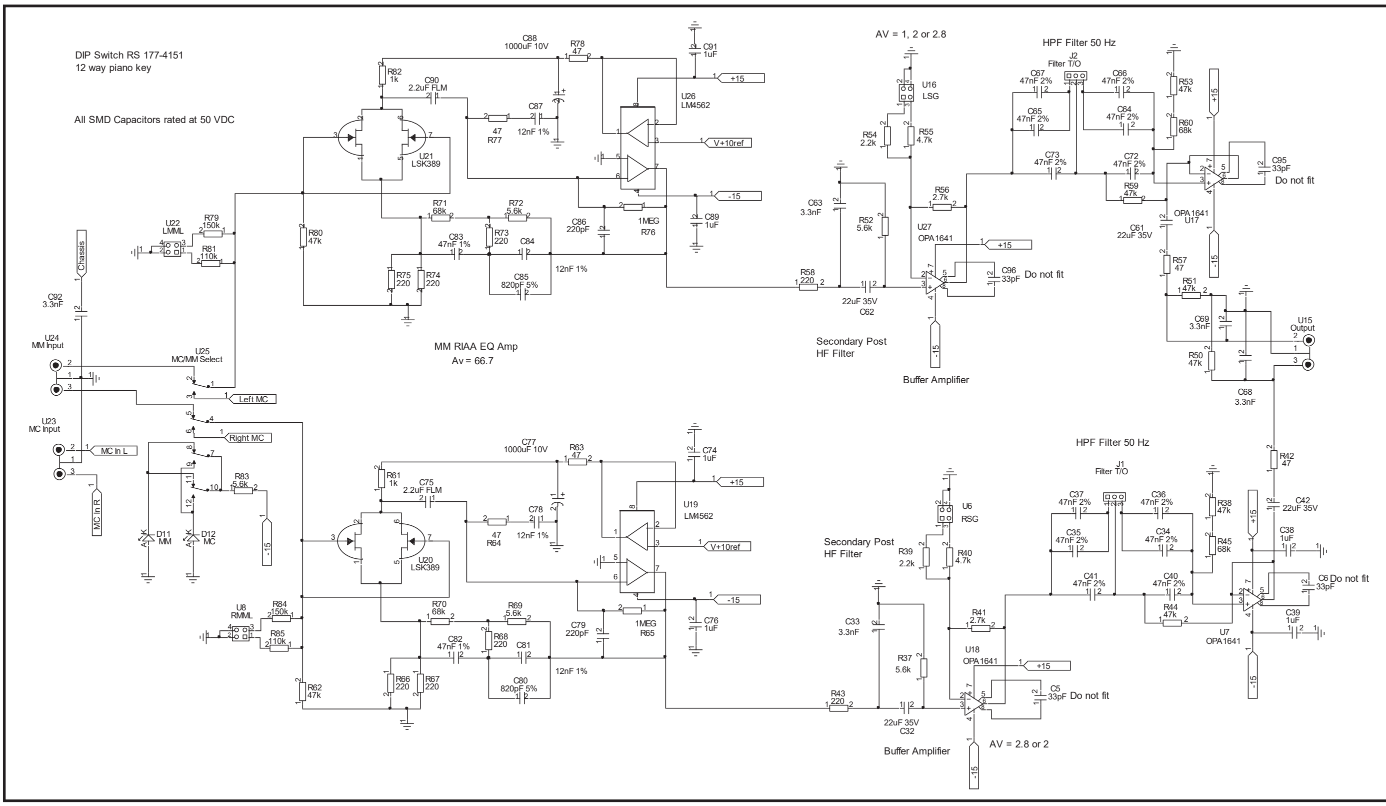

Figure 1: This schematic shows the design for the moving magnet phono amp, system gain amp, and the rumble filters.

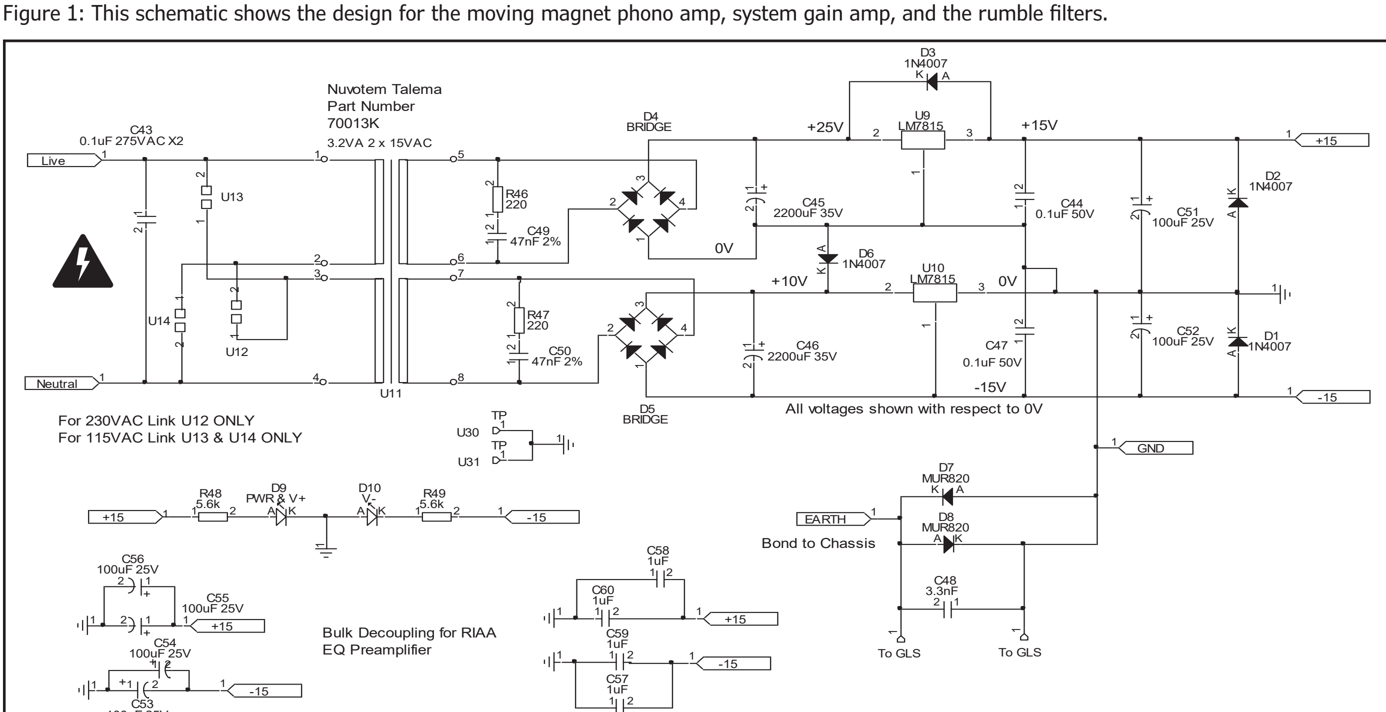

Figure 2: This is the schematic for the system's power supply unit and ground lifter.

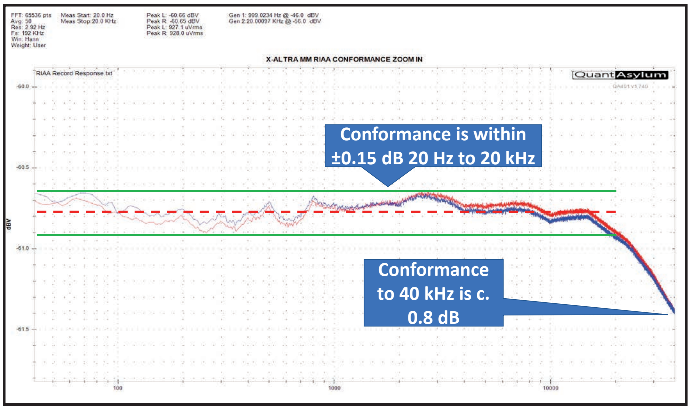

Figure 3: X-Altra RIAA's measured conformance 20Hz to 40kHz with the rumble filter switched out

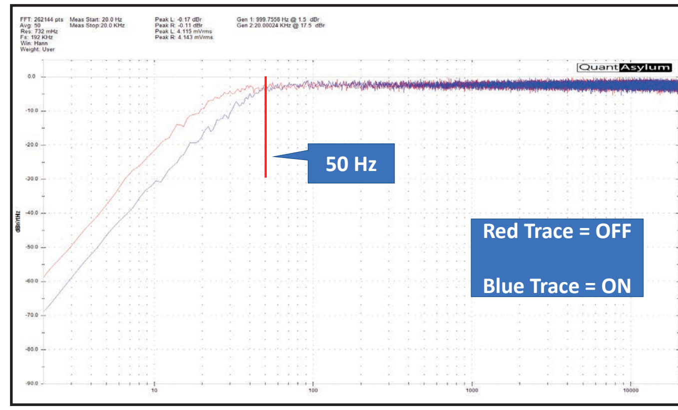

Figure 4: Acoustic rumble filter performance

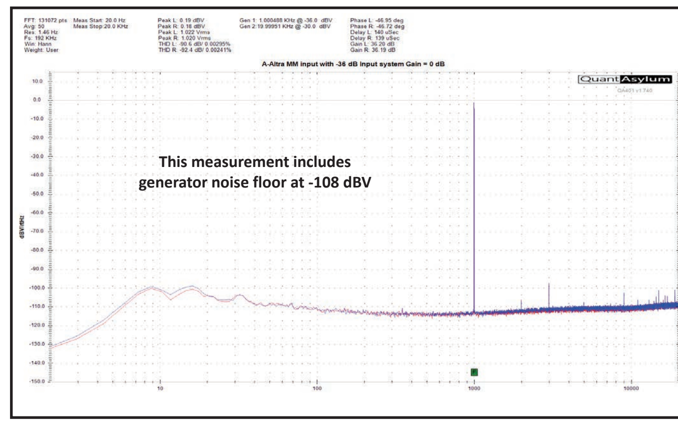

Figure 5: MM distortion at 15mV input (X scale 2Hz to 20KHz)

secondary is separately rectified and smoothed (D7, D8, and C49 and C50). A snubber consisting of a 220Ω and 47nF capacitor is used across each of the bridge rectifiers to minimize RFI caused by diodes switching as they come out of conduction.

The smoothed DC appearing across the filter capacitors is fed to standard TO220 LM7815 linear regulators (U15 and U16) after which the two single rail supplies are combined to provide a -15V, 0V, +15V output. Output decoupling is provided by C44, C47 and C51 and C52. D1 and D2 ensure during power up or down, the rails are clamped and any polarity inversion greater than 0.6V is avoided—if not, potential latch-up may occur (see Douglas Self's *Small Signal Amplifier Design* for a write-up on this). Additional decoupling and local reservoir capacitance is placed around the

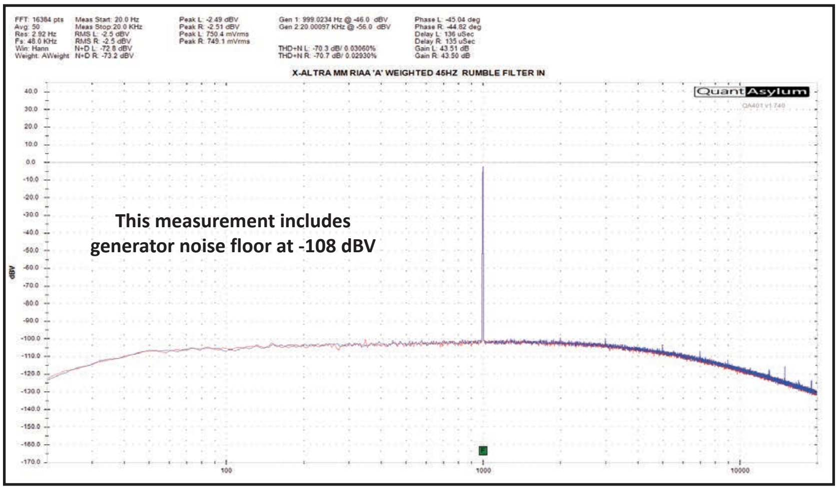

Figure 6: "A" weighted MM noise and distortion with acoustic rumble filter switched in

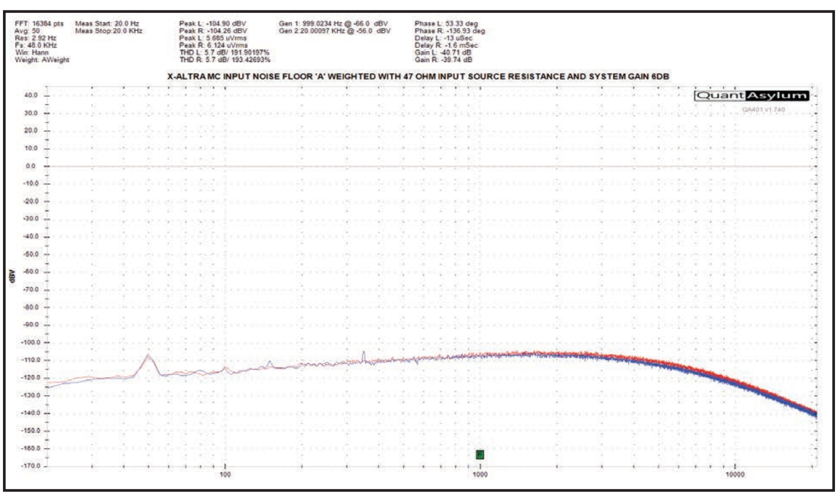

Figure 7: "A" weighted MC noise floor with 47Ω source resistance and acoustic rumble switched in

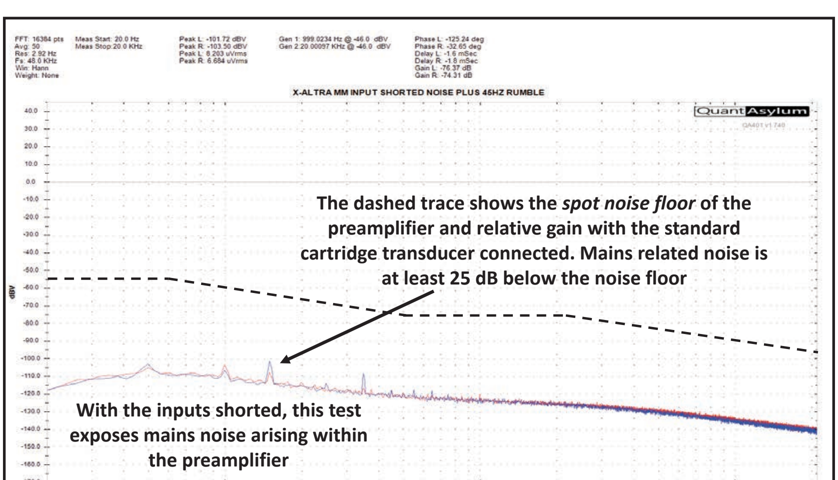

Figure 8: MM noise floor, input shorted, and acoustic rumble filter switched in, no weighting

PCB near the amplifiers, of which C53-C60 form part (the others are shown on the various amplifier section schematics). D3 and D6 clamp the reverse voltage across the LM7815 devices should the main filter capacitors discharge more quickly than the output filter capacitors.

A ground lifter consisting of two anti-parallel connected MUR820 200A peak surge capability diodes (D7 and D8) ensure that at audio frequencies the amplifier electronics float with respect to the housing and assume the ground potential of the preamplifier to which the X-Altra connects. At RF, C48 (3.3nF) effectively bonds the chassis to the power supply 0V, thus providing RFI screening through the metal housing. The ground lifter can be defeated by the "GL" switch located on the rear panel. C43, a 0.1µF 275 VAC "X" cap, is connected across the mains supply right next to the transformer and provides some filtering of any series mode line conducted noise, while U12, U13 and U14 allow the PSU to be configured for 115VAC or 230VAC mains input. For 230VAC operation, link U12 and leave U13 and U14 open, and for 115VAC operation leave U12 open, and link U13 and U14.

All of the PCB tracks around the rectifiers and reservoir capacitors are short and where possible all return paths are laid adjacent to each other on opposite sides of the PCB to minimize loop areas and thus any radiated noise.

Measurements

All the measurements (**Figures 3–8**) were taken with the QuantAsylum 401 Audio Analyzer, using the provided RIAA pre-emphasis curves. It is important to note, where applicable, that the input to the DUT is taken directly from the QA401 set at -46dBV for MM and -66dBV for MC and will include the DAC noise floor at -108dBV. In the noise floor measurements where the DUT input is shorted, no DAC noise is present, and the figures more accurately represent the preamplifier's noise floor.

Conclusion

The X-Altra RIAA EQ preamplifier's noise performance is achieved using input devices and circuit topologies best suited to the different requirements of MM and MC generator sources. On both inputs types, given the simplicity of the design, the thermal noise floor approaches state of the art, and particularly so in the case of the MC input preamplifier stage. On the MM input, noise performance is ultimately limited by the pickup cartridge L and R, but nevertheless, the SNR with the standard cartridge is > 3dB better than a NE5534A based circuit at >75 dB reference 5 mV, and just 0.2dB lower than Colin's LP797 from 2007

Project Files

To download additional material and files, visit audioxpress.com/page/audioXpress-Supplementary-Material.html

Resources

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despite an 11× difference in the gain setting resistor. On both MC and MM, overload margin is > 31dB ref 500µV and 5mV, respectively.

The compact PCB layout was facilitated by the extensive use of SMD components, allowing the PSU to be co-located with the amplifier in the same housing. The mains-related noise measured below -100dBV on MM inputs and -90dBV on MC inputs (both unweighted measurements).

For readers wishing to buld the X-Altra preamplifier, PCB sets can be ordered at http://hifisonix.com/x-altra-phono-eq-preamp.