# Measuring the X-Altra MC/MM RIAA EQ Preamplifier Signal Chain Thermal Noise Floor

The X-Altra preamp MC input spot noise floor is specified at < 250pV/√Hz at 1 kHz. The following notes show how the thermal noise floor was measured using a QuantAssylum QA401 to confirm the simulated and calculated results. Figure 1 shows the relevant signal chain stages and associated gains.

Since the input to the MC head amp responds to current, any input generator resistance noise voltage must be converted to a noise current. To verify the equivalent *referred to input* thermal noise voltage, the calculated noise current at the MC head amp input is then translated to a voltage at the output of the MC head amp ($V_{noisemc}$) and then amplified by the MM EQ amp by a fixed gain of 63x. By comparing the calculated output noise $V_{noiseout}$ with the measured noise at the preamplifier output using the QA401, the input noise floor of the MC head amp + MM EQ amplifier chain can be verified.

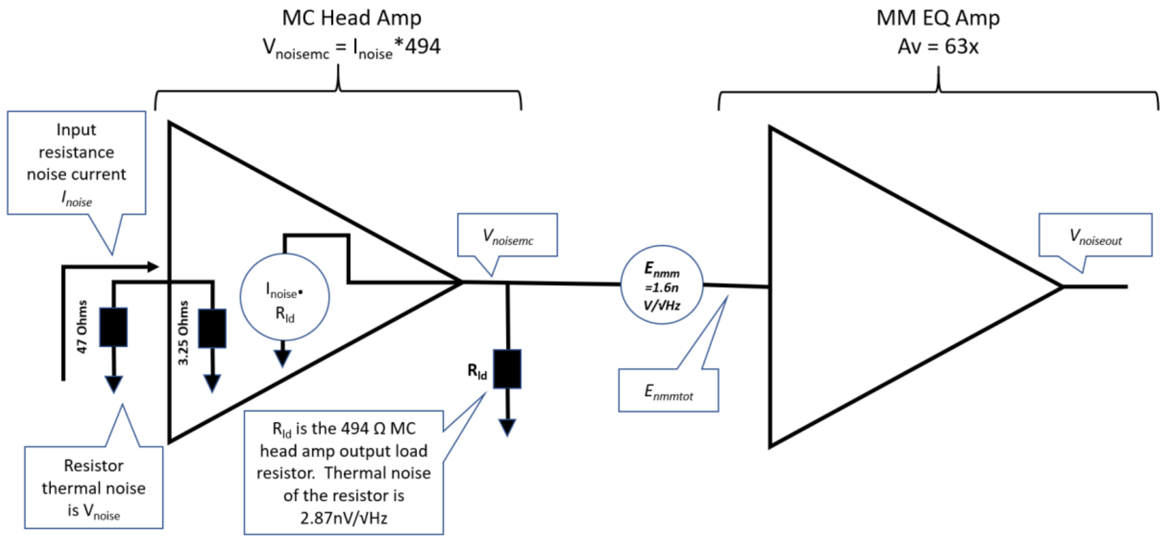


*Figure 1 - X-Altra MC/MM Signal Chain for the Noise Measurements*

In all the measurements discussed here, the QA 401 was set to Fs = 192 kHz, 1.46 Hz FFT resolution with 50 averages and 'rt√Hz' mode selected (this is in the dBV menu tab). This latter setting normalizes noise readings to a 1Hz bandwidth so that the spot noise can be directly read off the monitor.

To ensure a robust result, two measurements were done at the extremes of the MC head amp input resistance range, the first with the input shorted to ground with a 47 Ω resistor, and the second with the input shorted directly to ground. The X-Altra system gain in all measurements was set to 0 dB.

In both measurements, the 1 kHz spot noise ($V_{noiseout}$ in Fig. 1) was obtained by visual inspection of the QA 401 display.

For a 47 + 3.25 Ω total resistance, the calculated Johnson noise $V_{noise}$ is 914pV/√Hz which we convert to an equivalent input noise current as follows

$I_{noise}$ $= V_{noise}/(Rcart+Rin)$

where Rcart is the cartridge resistance and Rin the input resistance of the head amp (and ultimately determines the noise floor). In this case, we are using a Rcart value of 47 Ωs for convenience

$I_{noise}$ $= 914\ pV/\sqrt{Hz}/(47+3.25)$

$I_{noise}$ = 18.2 pA/√Hz

This is the noise current being injected into the MC head amplifier input by the total source resistance, including the noise of the amplifier input resistance (3.25 Ωs).

The noise voltage appearing at the MC head amp output is then

$V_{noisemc}$ $=I_{noise}*R_{ld}$ where $R_{ld}$ is the gain setting load 494 Ωs

$=18.2\ pA/\sqrt{Hz}*494$

$=9\ nV/\sqrt{Hz}$

The 1 kHz spot noise for only the MM EQ amplifier is 1.6nV/√Hz, to which we have to add the thermal noise of the output load resistors of the MC head amp at 494 Ωs (2.87nV/√Hz) so the total noise at the input to the MM EQ amplifier is

$$E_{nmmtot} = \sqrt{(9nV^2+1.6nV^2+2.87nV^2)} = 9.58nV/\sqrt{Hz}$$

which calculates to an output of 603.6nV/√Hz or -124.4 dBV. Note that since the input current noise of the MM EQ amplifier is extremely low (< 1 pA/√Hz), it has been ignored in these calculations.

To confirm the noise, a 47 Ohm SMD thin film resistor was soldered across the right channel of the MC head amp input. The complete signal chain noise 1 kHz spot noise trace reading was then determined visually at -124 dBV which is 631nV/√Hz

The simulated figure is close to the measured noise floor, showing a difference of only 0.4dBV and verifying that the thermal noise floor of the MC head amplifier is in the region of 3.25 Ωs, or 232pV/√Hz.

The comparative voltage gain of the complete signal chain with 50.25 Ω source resistance is 619x or 55.8 dB.

For the second test, the input to the MC amplifier is shorted, leaving just the input resistance of 3.25 Ω into the front end of the signal path.

$I_{noise}$ $= V_{noise}/Rin$

The noise voltage for a 3.25 Ω resistance is 232 pV/rt Hz

We can now calculate the input noise current

$I_{noise}$ $= 232\ pV/rt\ Hz/3.25\ \Omega s$

$= 71\ pV/rt\ Hz$

The noise voltage appearing at the head amp output is

$V_{noisemc}$ $= I_{noise} * R_{ld}$ where $R_{ld}$ is the gain setting load 494 Ωs

$= 71\ pV/\sqrt{Hz} * 494$

$= 35\ nV/\sqrt{Hz}$

As before, we RMS sum the MC head amp noise, the 494 load resistor thermal noise and the MM input amplifier input referred thermal noise

$$E_{nmmtot} = \sqrt{(35nV^2 + 2.87nV^2 + 1.6nV^2)}$$

$$= 35.15nV/\sqrt{Hz}$$

which translates to a MM EQ amp output of 2.2uV or -113 dBV.

The comparative voltage gain of the signal chain with the input to the MC head amp shorted to ground is 9576x or 79.6 dB.

The measured spot noise on the QA401 was -112dBV which is 2.51uV, a difference of 1 dB compared to the calculated value, again confirming the MC head amp input thermal noise is in the region of 3.25 Ωs

Given the uncertainties of c. 1 dB in the QA401 visual noise reading due to display 'grass', and the input resistance range of the MC head amplifier due to normal component spreads, this is a good result from the measurement perspective and therefore confirms the simulations, measurements and theory are closely in agreement in both exercises.

By measuring the spot noise at 1kHz where the MM EQ amplifier gain is flat rather than the total integrated noise over the audio band, the complication of having to deal with noise shaping caused by RIAA equalization is avoided. Working with the total integrated noise would have required that the audio band be split into a number of sections, the noise contribution for each band calculated, and the results then RMS summed. You can read about this technique in 'AN-104: Noise Specs Confusing?' available the TI website.