Notes from a phono preamp thread.

https://www.diyaudio.com/community/threads/phono-preamp-riaa-eq-using-iir-digital-filters.353387/post-7066767

I've been doing software RIAA realtime EQ with biquads for a while now. I also played with ffmpeg's built in RIAA EQ and have measured quite a few carts and stylii with multiple test records and EQ methods. Here are some things I learned along the way, hoping that someone might find something useful in my ramblings.

- A simple linear NE5532 gain stage is very useful, with this you can use any type of line level input DSP, I have used the Shure/Wondom ADAU1701 and Linux PCs before but with this anything that can do the EQ will work
- Many biquads and other solutions are not accurate above 15kHz - you won't be able to decode JVC quadrophonic discs unless you get this right
  - For this you want to go with the biquads from Scott's Linear Audio article - available here v10 sw appendix a tables and use at least a 96kHz sample rate
- Loading matters and is often not that straight forward - 47kOhm is not always great or even good. I have had success with 75k (Audio Technica) and no extra loading (Ortofon OMP). Some loadings might seem like they sound pleasing at first but then you measure and discover that they degrade frequency response overall
- Test records are worth their weight in gold. You'll need a few of them for cross referencing
- Capacitance is the enemy. Use low capacitance, well insulated wire and keep them very short
- Test records can help you find the correct loading and will help you correct for frequency response errors with a channel independant multiband EQ. This is very worthwhile with otherwise good MM carts.
- Getting both channels to sound identical helps a lot and tonality really improves if you straighten out the response by a few dB here and there
- You can have fun with crosstalk cancellation and reduce crosstalk by more than 10dB@1kHz with relatively low effort (plus a suitable test record)
- ffmpeg has a really good declicking algo included. It sure beats my Marantz SX72 by a lot. It can be used in realtime playback situations to great effect. Otherwise unlistenable records become very enjoyable again. Transients suffer, but not as much as I'd have expected.

Things I'd like to do as soon as I find the time and space:

- Implement this whole shebang in Henrik's excellent CamillaDSP - I still have to figure out how I can run filters on input channels instead of output channels
- Try my luck at decoding the DBX and CX encoded records I have purely with software. People have managed to decode DBX I and II in software, DBX Disc is just a version of DBX II with a low pass added somewhere. To me it seems quite cool to listen to DBX records with 90dB SNR, decoded purely in software. I tried my luck at this once but got stuck building the filter chain.
- Expand my research on crosstalk cancellation. I achieved spectacular results on Audio Technica carts where crosstalk dropped by more than 10dB but I have yet to replicate this with a Technics P33 cart. It probably needs a few samples of delay added and it will probably be fine but I have yet to test this hypothesis
- Record some needle drops of well produced albums and compare the aggregate frequency spectrum to that of the CD version. This way I might be able to deduce a frequency deviation between LP and CD. This could be compared to the measured frequency response obtained from my test records. Maybe, just maybe, we

could use specific, known-good albums available on CD and LP as a sort of "poor man's test disc", at least to look at frequency response errors...

I really hope I can pick up this hobby in a year or so. At the moment, other things need to come first. In the mean time I'll gladly contribute what I know to this thread.

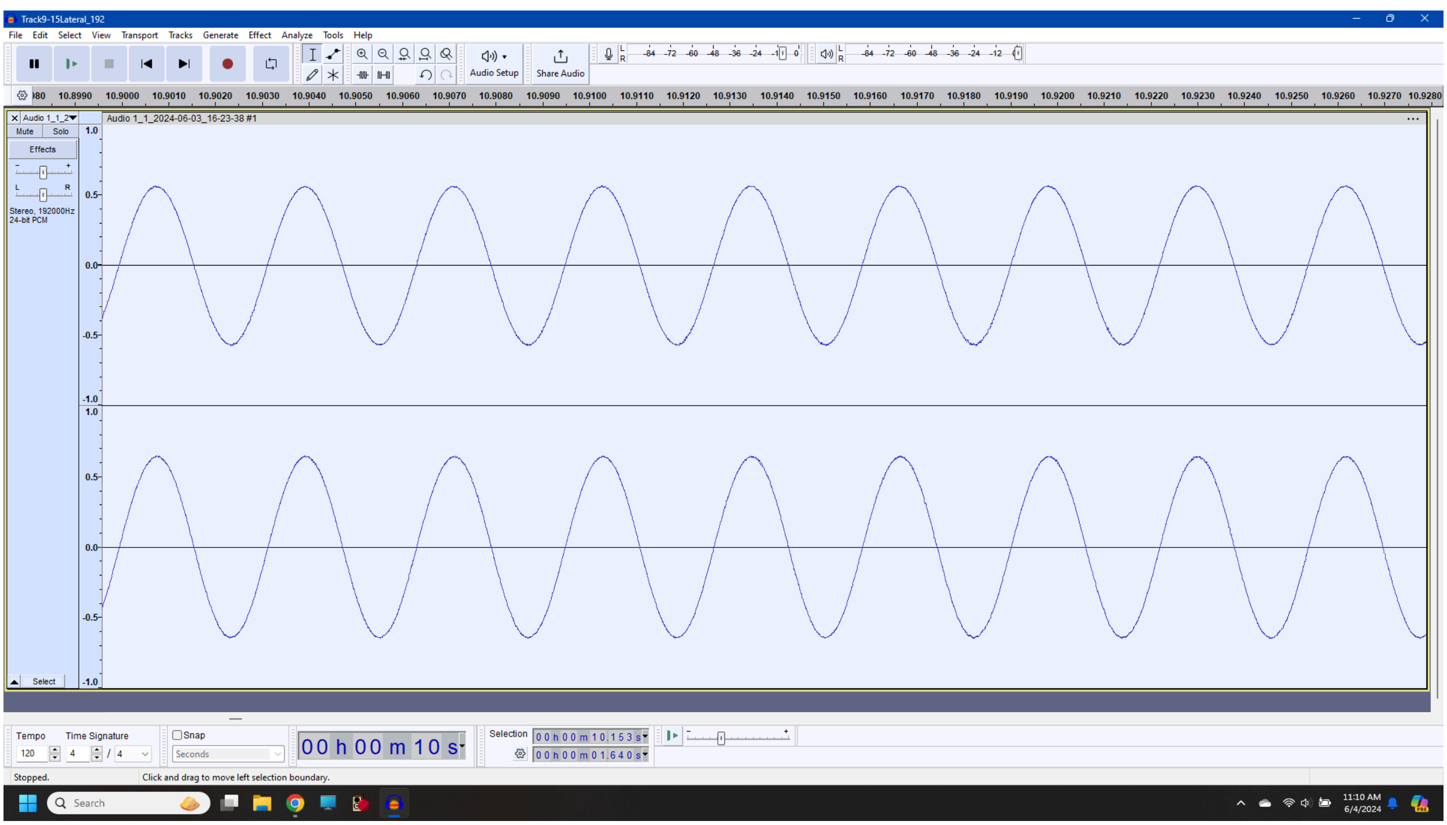
Reactions:
DRONE7

Measured Performance

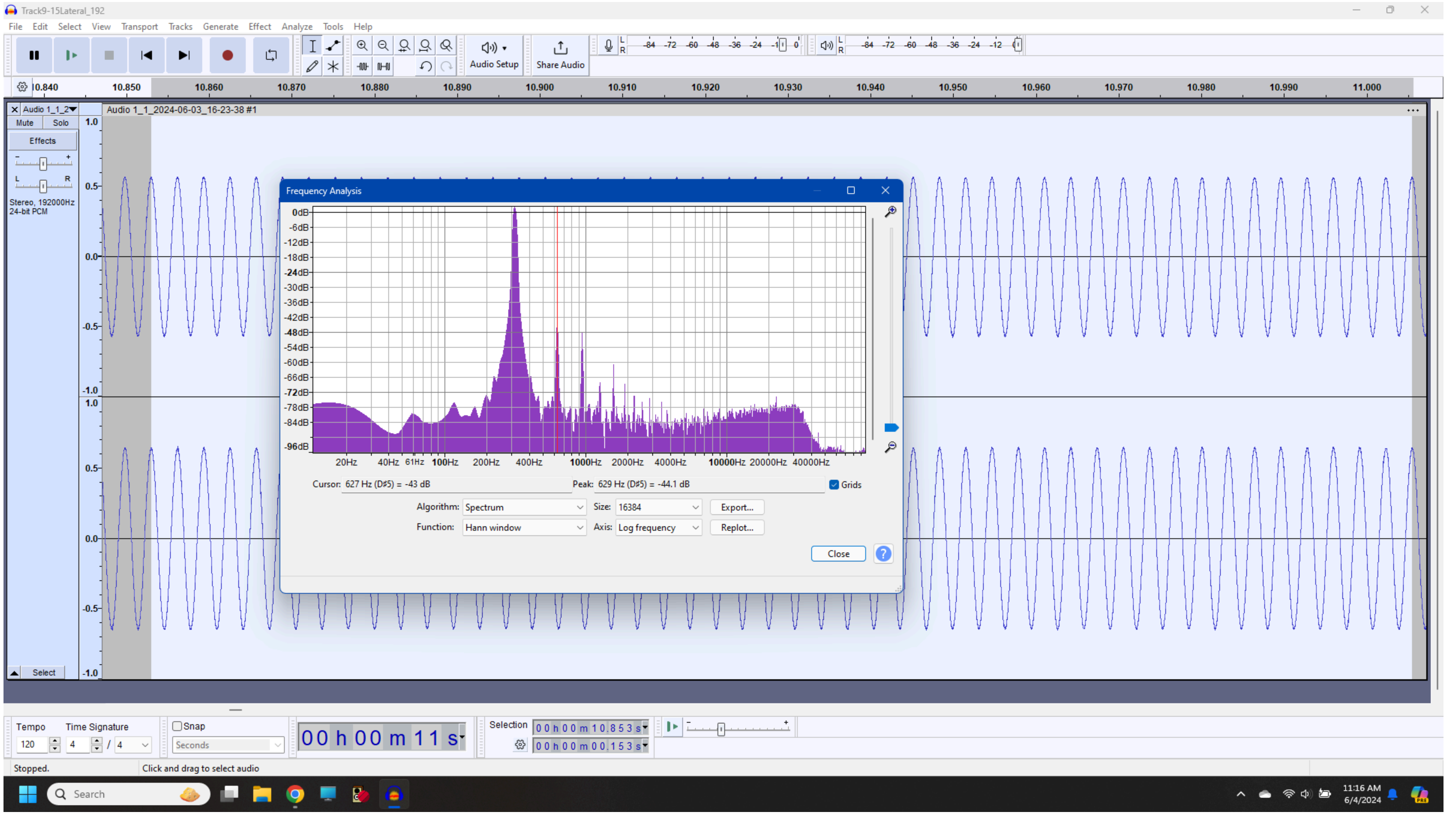
Configuration 2:

Flat Balanced preamp LT1037, 9V batteries,
MOTU M4, inputs 3/4
Series V cartridge, vivid line stylus,
Technics SL-Q5 after adjustments on 6/3/24
Silicone Platter Mat

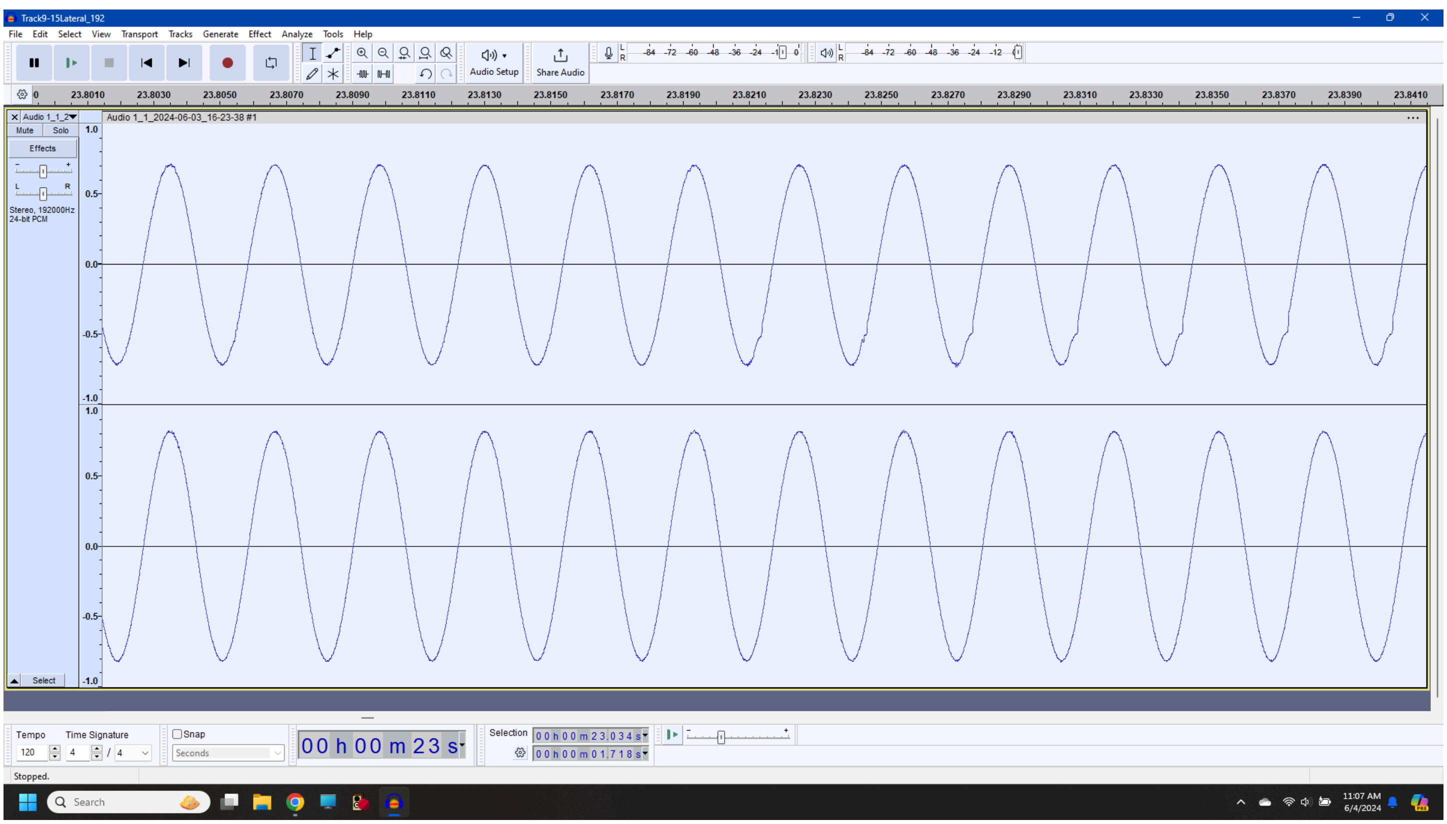
The tone arm angle was adjusted counter clockwise after these tests by half a turn.



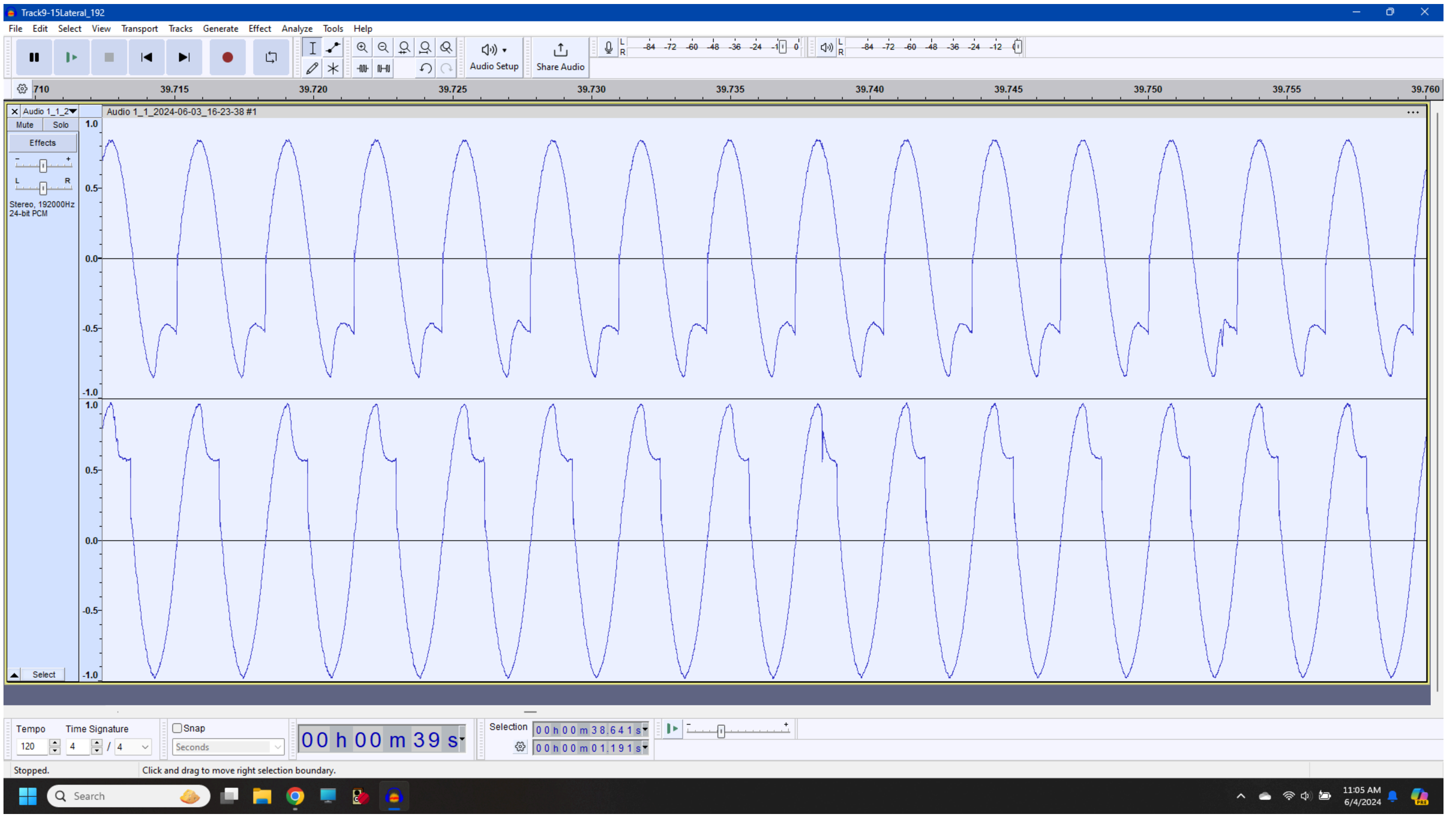
Track 9. Tracking ability, lateral 50 um peak. 315 Hz No visible mistracking distortion



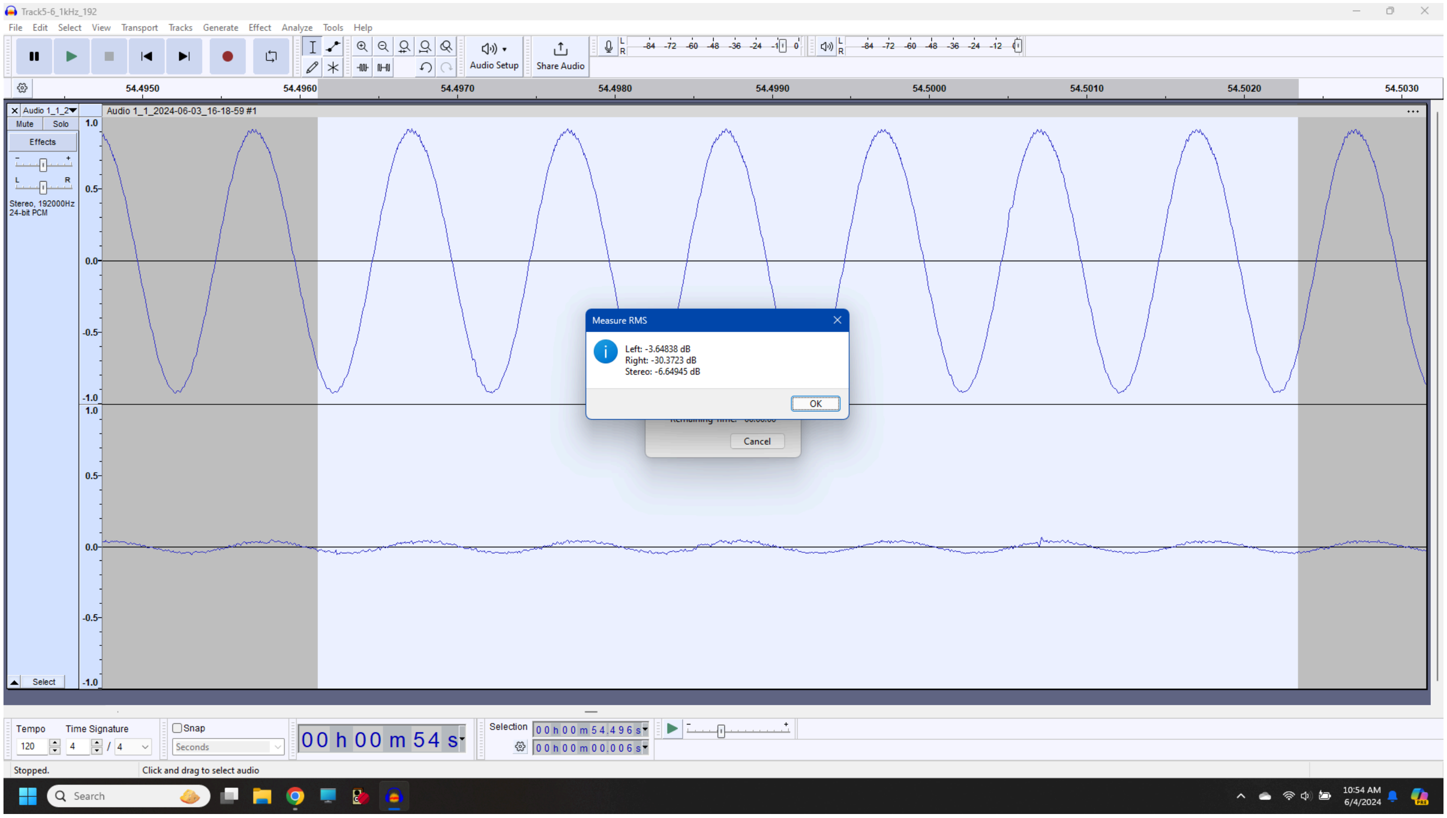
315 Hz 50 um peak waveform.   2nd Harmonic is -46 dB (fundamental is 1.6) or 0.5% distortion.



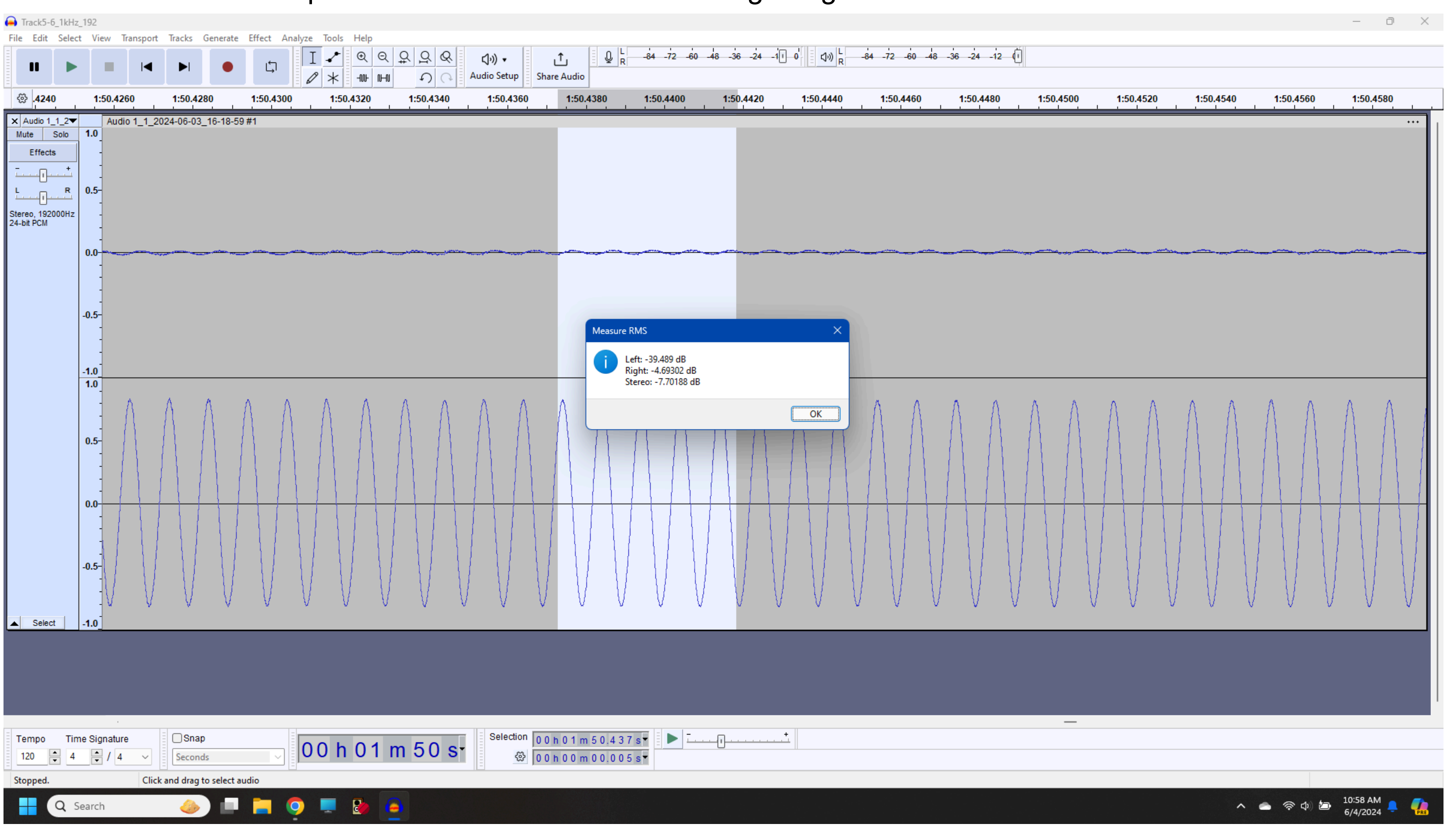
Track 10. 60 um peak,   L channel distortion is variable on lower peaks to the left



Track 11. 70 um peak. Massive distortion when tracing slope moving to the record center? Verify with a displacement graph. Try adjusting the tonearm setpoint towards the record center?



SL-Q5 Left channel separation 26.7 dB 6/4/24 tracking 1.5 gram



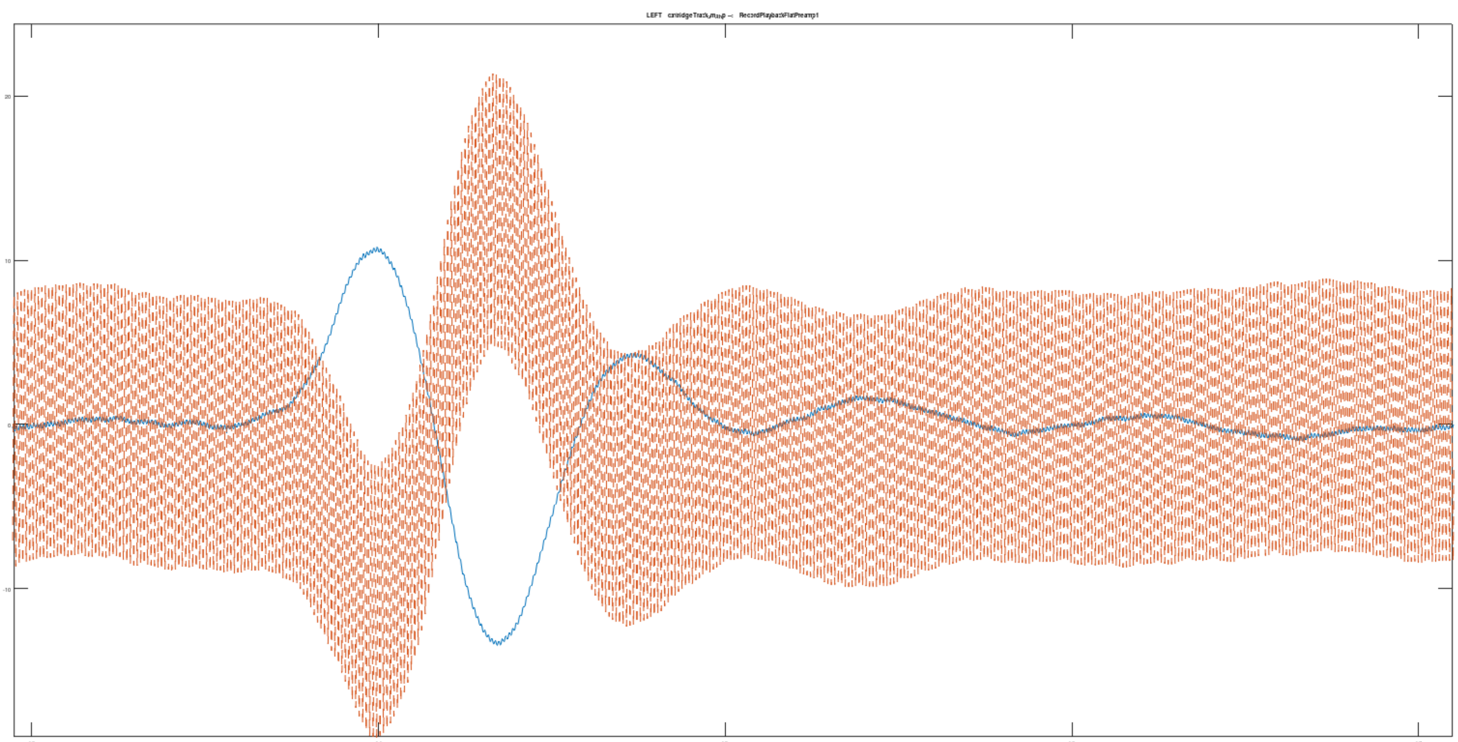
SL-Q5 Right Channel separation 34.8 dB

Derive L to R and R to L transfer function from sweeps. Use to digitally cancel crosstalk and improve channel separation in post processing.

FIR highpass rumble filter

Configuration 1:

Flat Balanced preamp LT1037, 9V batteries,
MOTU M4, inputs 3/4
Series V cartridge, vivid line stylus,
Technics SL-Q5 after adjustments on 5/30/24 Tracking 1.0 gram Gain 3.6V, Tone arm centered left
Silicone Platter Mat



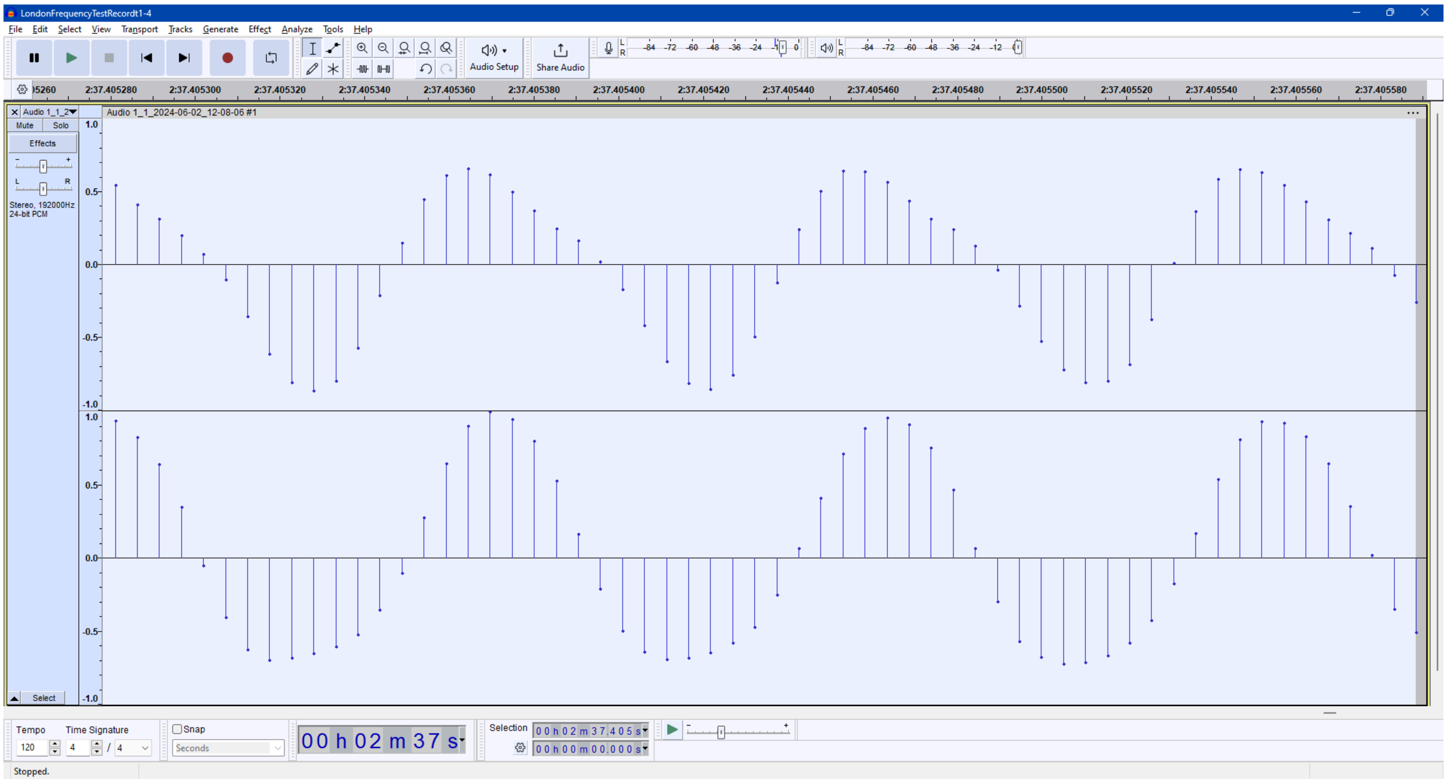
1 kHz 5 cm/s tone in R channel, dashed line. Displacement calculated by integrating the cartridge output and scaling to um. Waveform is about 10 Hz and poorly damped, corresponding to the tonearm-stylus resonance.

First adjustment of the tonearm center after gain set to 3.6 volts. Tonearm was off center to the left resulting in a large disturbance when the carriage moved. Tracking force 1.0 grams caused mistracing of signals.

SL-5Q possible modifications

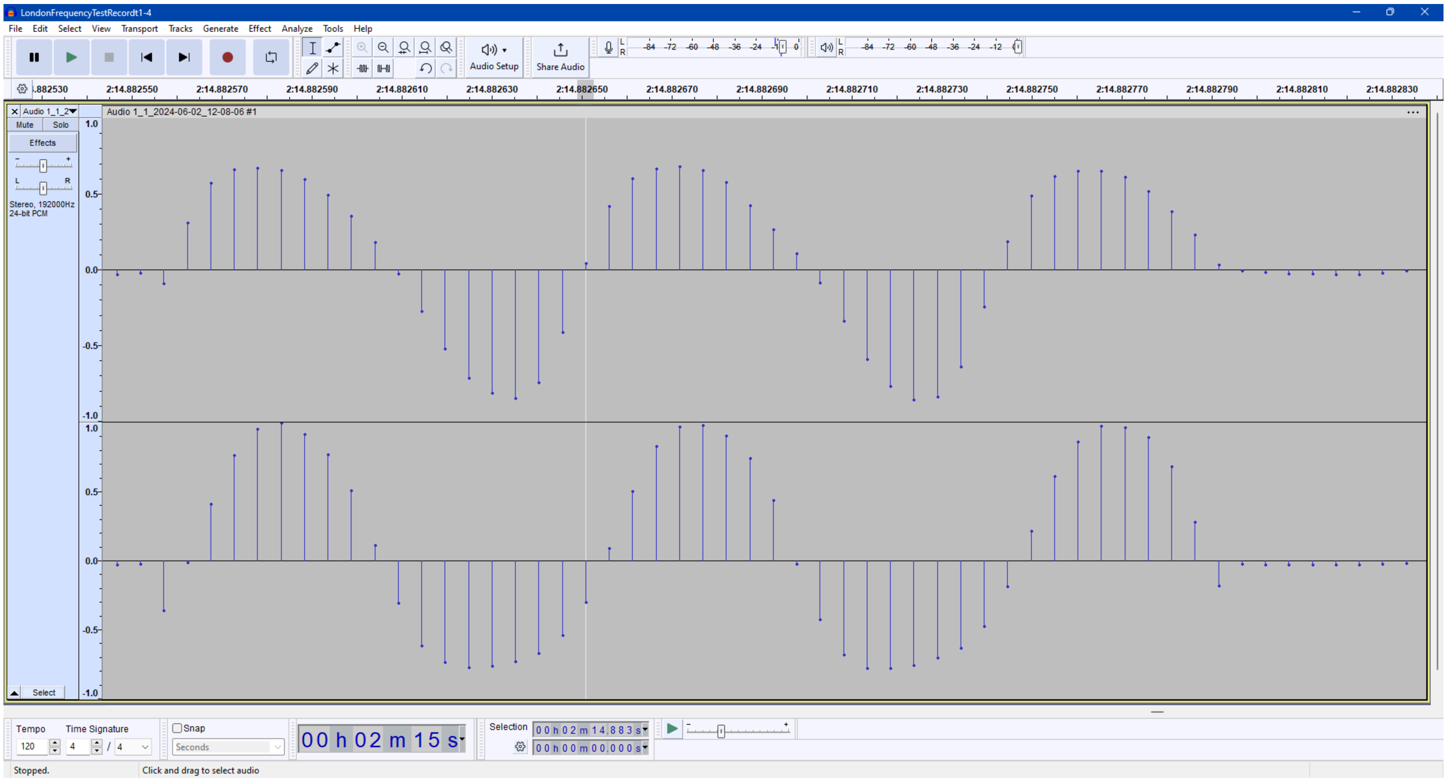
1. These pulses appear about every second. Add an FIR highpass filter at 25 Hz to reduce this.
2. Couple the drive string to tonearm with a spring and use thicker grease on carriage bushing for damping?

3. Trim the optical shade at an angle to reduce the signal for vertical tonearm motion.
4. Move the sensor to the horizontal gimbal to isolate it from vertical motion.



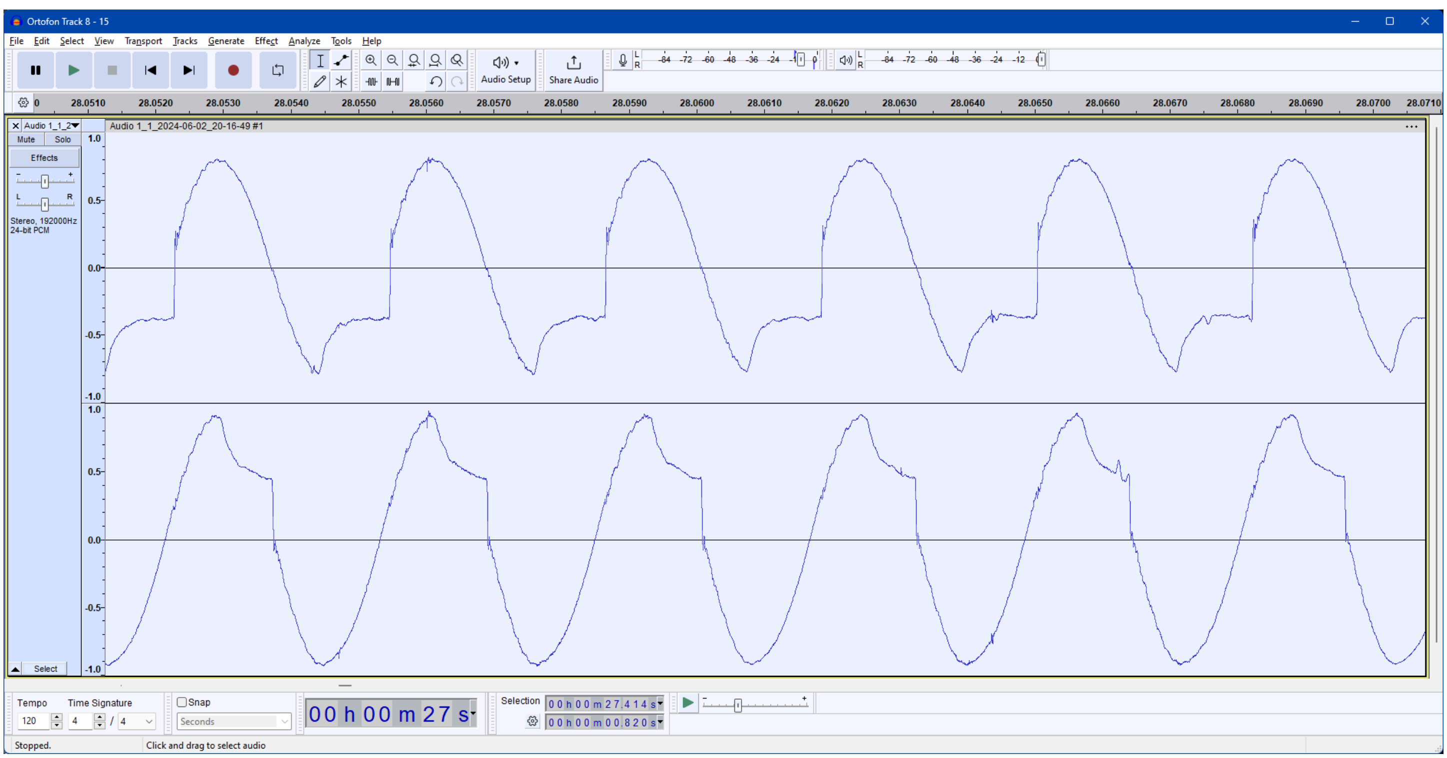
Near the end of Track 5, 11 kHz London Microgroove Frequency Test Record on loan from Rene’

Right channel is about one sample ahead of the left channel here.
Tracking force 1.0 grams



Near the beginning of Track 5, 11 kHz London Microgroove Frequency Test Record on loan from Rene’

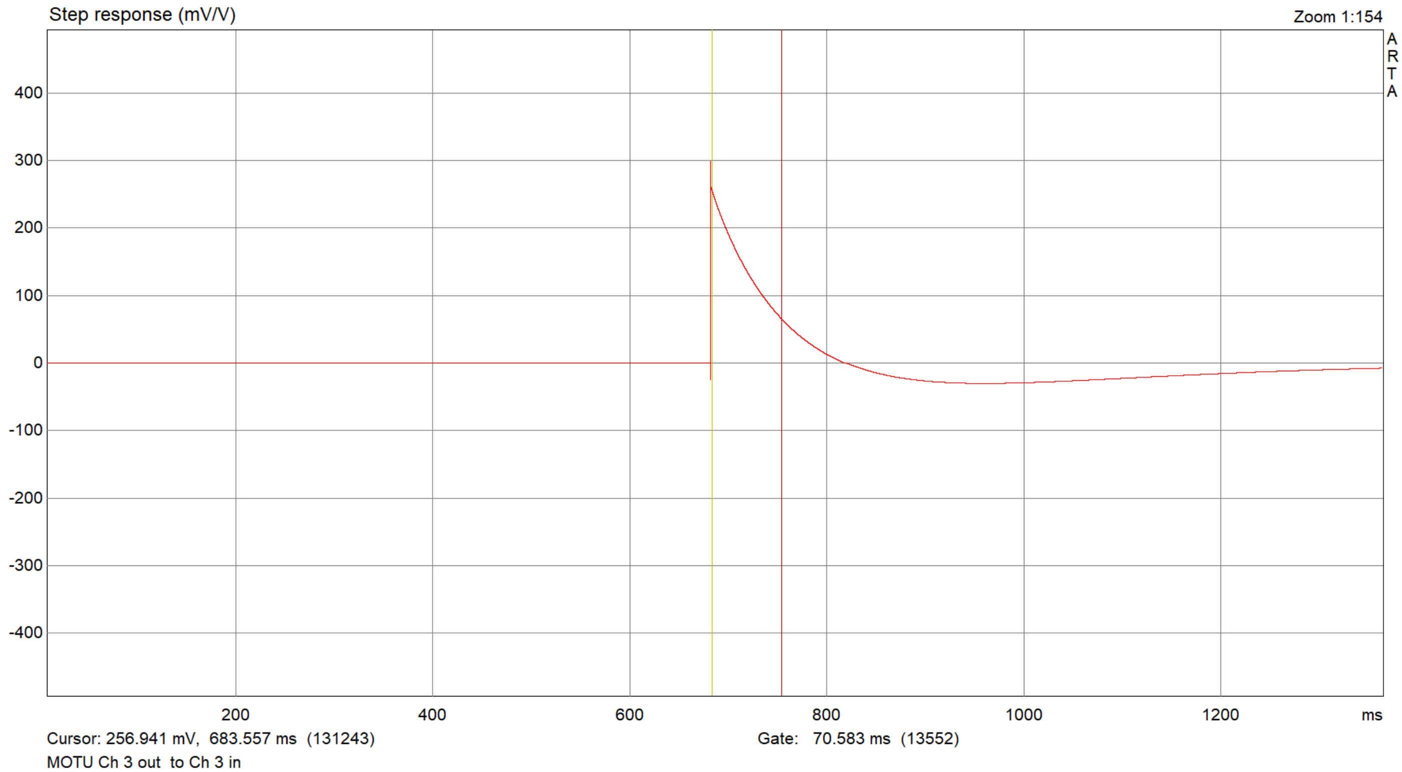
Right channel is about one sample behind the left channel. Tracking force 1.0 grams



Ortofon Track 9, Tracking ability, lateral, 50 um peak. SL-5Q, Series V VL stylus
Tracking force 1.0 grams

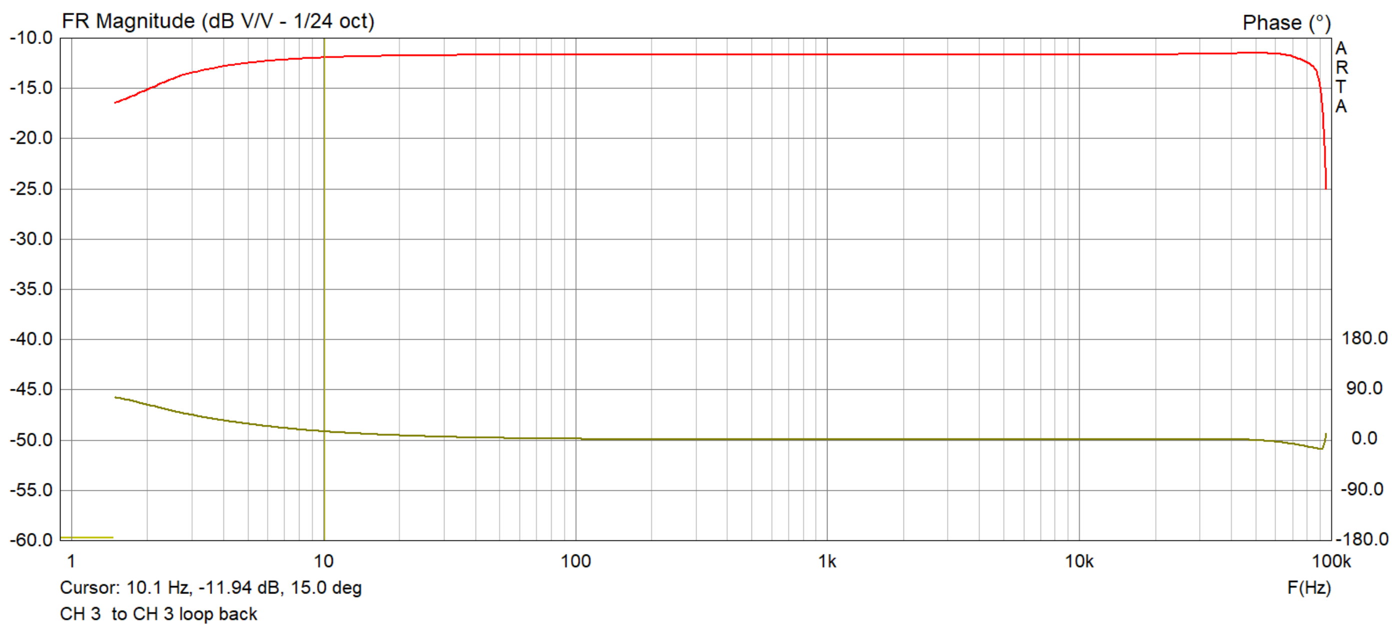
MOTU CH 3 & 4 Inputs

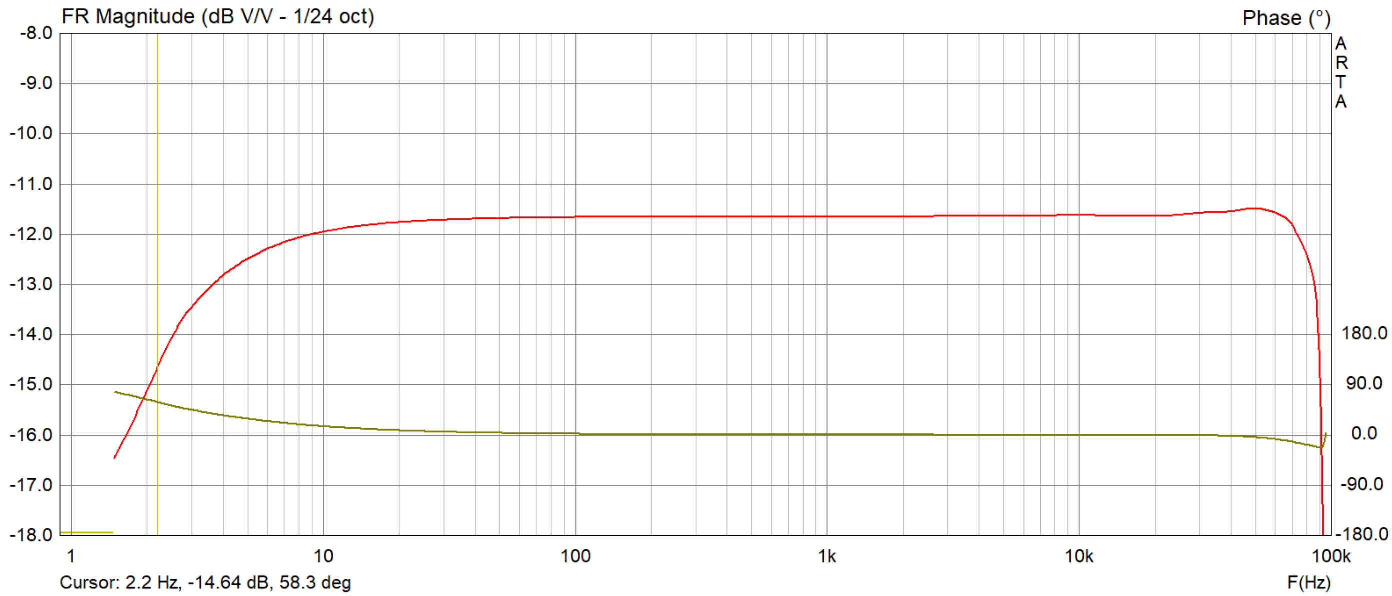
Balanced TRS loop back cable



0.368 *   256.9 = 94.5   56.1 ms Time constant, overshoot implies 2nd order?

1 / .056 = 17.8 Hz




FR Magnitude (dB V/V - 1/24 oct)
Phase (°)
ARTA
-8.0
-9.0
-10.0
-11.0
-12.0
-13.0
-14.0
-15.0
-16.0
-17.0
-18.0
180.0
90.0
0.0
-90.0
-180.0
1
10
100
1k
10k
100k
Cursor: 2.2 Hz, -14.64 dB, 58.3 deg
F(Hz)

- 3dB at 2.2 Hz

Cutting Head feedback discussion

https://gearspace.com/board/mastering-forum/1246569-motional-feedback-disk-recording-system-design.html

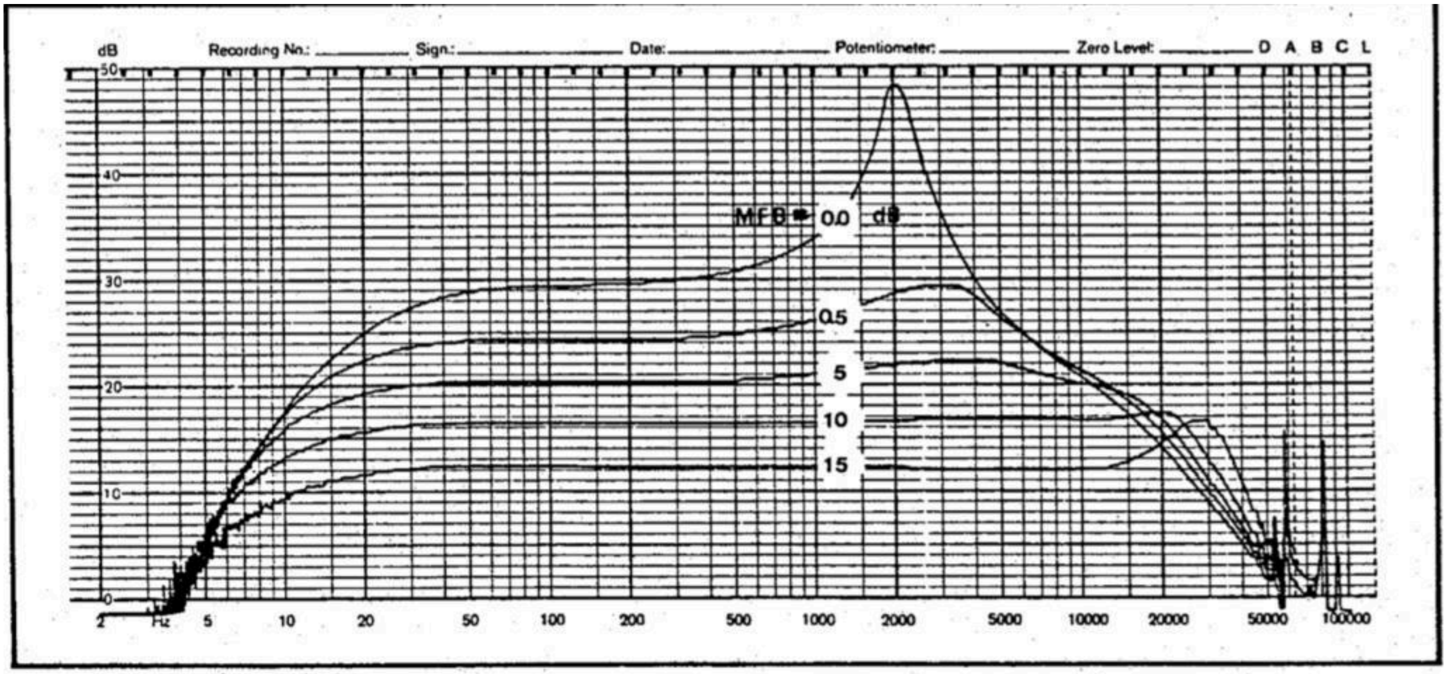
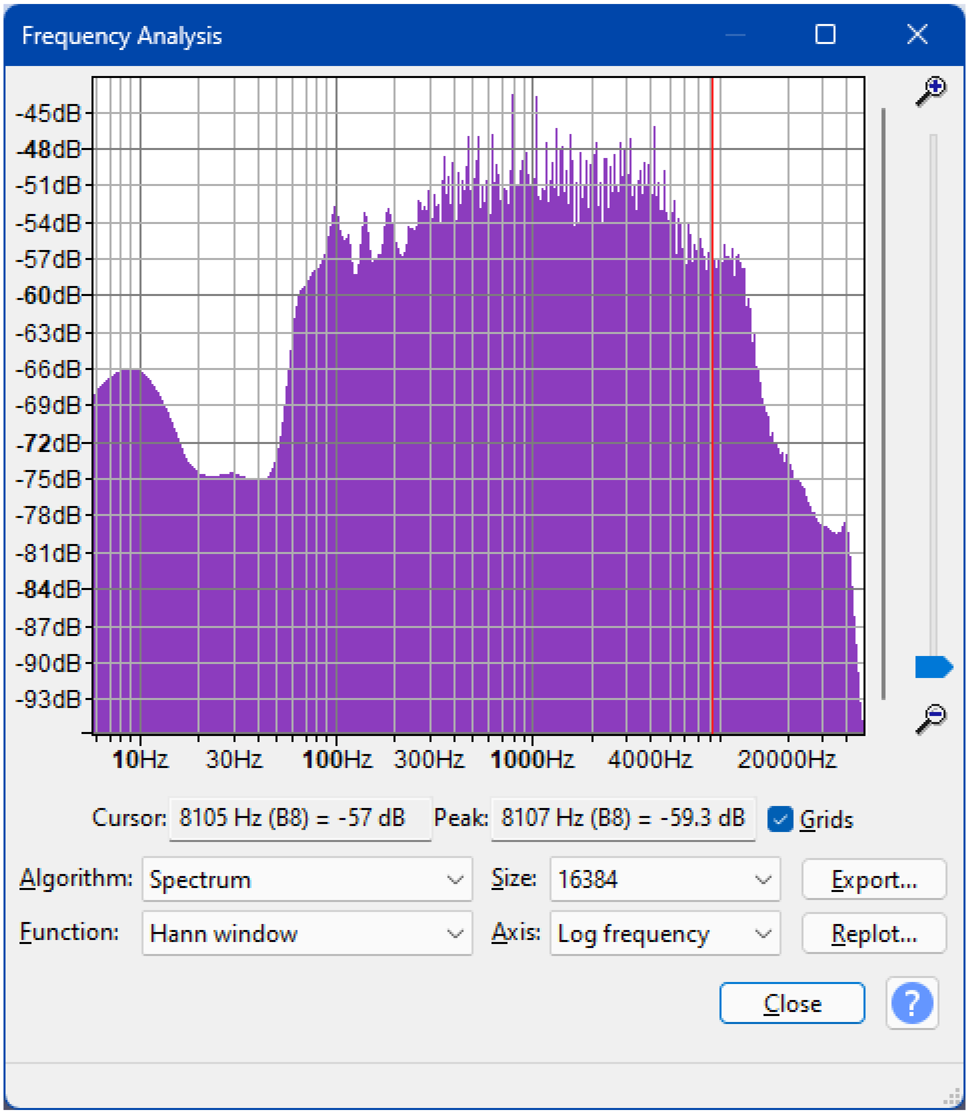


Fig. 1. Overall frequency response (4 Hz to 100 kHz) at different ratios of motional feed back (referred to 5 kHz), with Cutting Head DSS 731. **Measured at monitor output. Normal working condition: MFB = 10–12 dB.**

A new cutting head designed
https://agnewanalog.com/blog/lab-report-the-agnew-analog-stereophonic-cutter-head.html



Needle drop Maynard Fergason Ci Ci Side One Spectrum, Elliptical https://www.diyaudio.com/community/threads/digital-iir-inverse-riaa-filter-1khz-0-db-audacity-nyquist.393084/post-7198280

(Definitions of "Turnover" and "Tip" frequencies can be inferred from RIAA spec.)

Pre-RIAA Bass Tip/Bass Turnover/Treble Turnover combinations

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/ 150/ 3.4k Decca

/ 150/ 5.8k early Decca

/ 200/ flat Westrex

/ 200/ 5.8k Columbia 1925

40/ 200/ 6.36k American 1025, Victor 1925 (some)

50/ 250/ flat Blumlein, HMV

/ 250/ flat Columbia (Eng.), EMI 1931

40/ 250/ 6.36k London FFRR 1949, FFRR 78

/ 300/ 1.6k Columbia 1938

/ 300/ 2k FFRR 1951

50/ 353/ 3.18k BSI

/ 375/ 2.5k Decca 1934

/ 375/ 5.8k Decca FFRR 1949, EMI

/ 375/ 6.36k Decca FFRR 1949, EMI, Victor 1925 (some)

70/ 400/ flat early 78 (mid-'30s), US mid 30

/ 400/ 2.5k old AES, Decca 1934, Mercury

100/ 450/ 3k FFRR 1953
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/ 500/ flat early 78, Brunswick, Parlophone

100/ 500/ 1590 Columbia LP

/ 500/ 1590 early LP

/ 500/ 1.6k early LP, NAB, NARTB

70/ 500/ 2.5k EMI

/ 500/ 2.5k Capitol 1942, MGM, Victor 1947-1952

100/ 500/ 3k FFRR

50/ 500/ 3.18k CCIR

/ 500/ 3.18k London FFRR

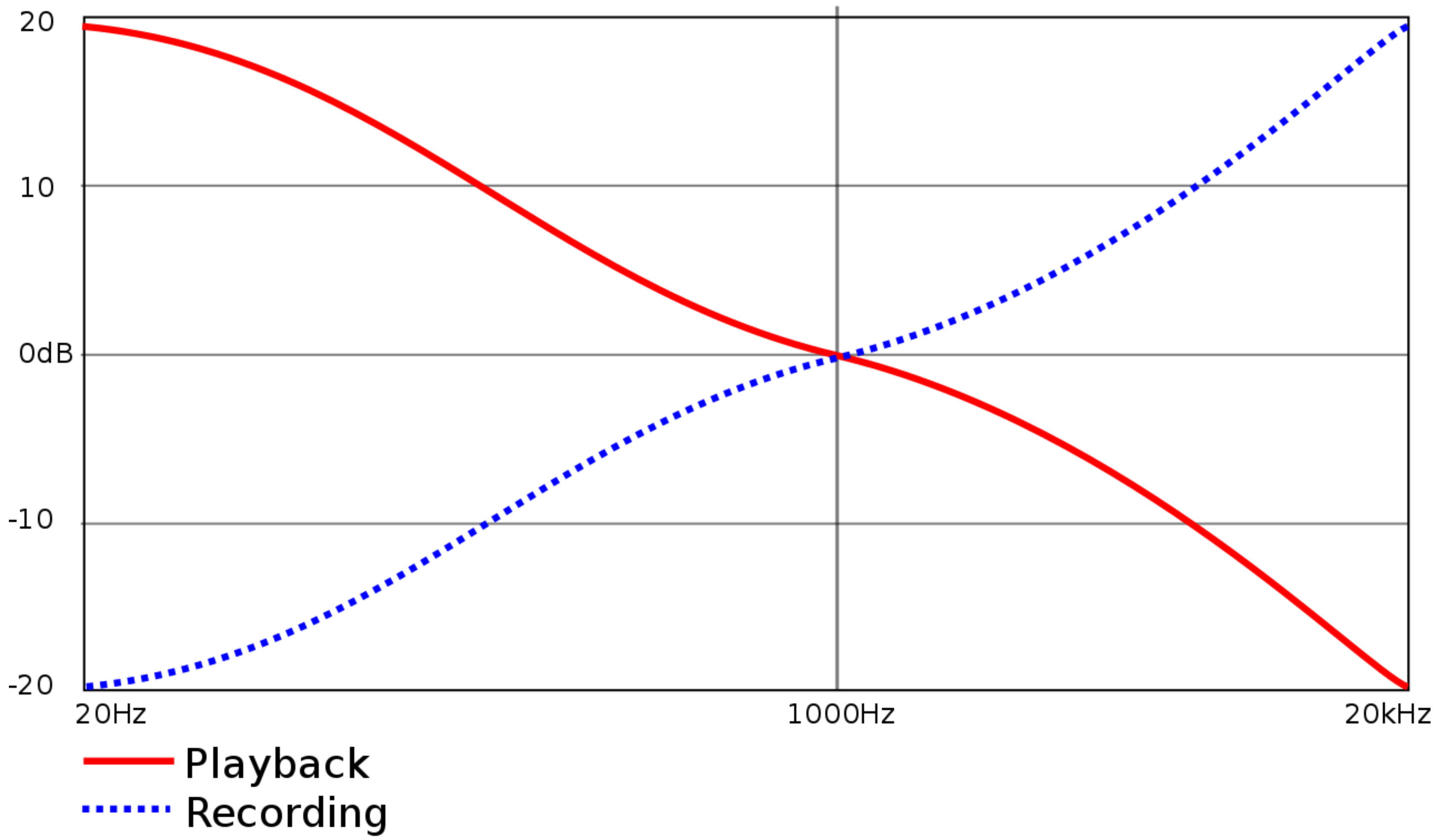
/ 500/ 3.4k Concert Hall until 1952, Oiseau-Lyre until 1954

/ 500/ 5.8k Victor 1938-1947

50.05/500.5/2.122k RIAA

/ 629/ flat "629"

/ 800/ 2.5k early RCA



https://en.wikipedia.org/wiki/RIAA_equalization

Equalization practice for electrical recordings dates to the beginning of the art. In 1926, Joseph P. Maxwell and Henry C. Harrison from Bell Telephone Laboratories disclosed that the recording pattern of the Western Electric "rubber line" magnetic disc cutter had a constant-velocity characteristic. This meant that as frequency increased in the treble, recording amplitude decreased. Conversely in the bass, as frequency decreased, recording amplitude increased. Therefore, attenuating the bass frequencies was necessary below about 250 Hz, the bass turnover point, in the amplified microphone signal fed to the recording head. Otherwise, bass modulation became excessive and overcutting took place, with the cutter getting into the next record groove. When played back electrically with a magnetic pickup having a smooth response in the bass region, a complementary boost in amplitude at the bass turnover point was necessary. G. H. Miller in 1934 reported that when complementary boost at the turnover point was used in radio broadcasts of records, the reproduction was more realistic and many of the musical instruments stood out in their true form.

The recorded audio signal is proportional to the acceleration or dynamic sound pressure.
RIAA pre-emphasis EQ (shallow differentiator) is applied, cutting the bass and raising the treble
The disc cutter acts as an integrator, boosting bass and cutting treble, so the displacement on the record is proportional to the velocity.
The phono cartridge acts as a differentiator, the output voltage being proportional to the stylus velocity.
RiAA de-emphasis (shallow integrator) EQ boosting bass and cutting treble.

The RIAA curve[edit]

RIAA equalization is a form of pre-emphasis on recording and de-emphasis on playback. A recording is made with the low frequencies reduced and the high frequencies boosted, and on playback, the opposite occurs. The net result is a flat frequency response, but with attenuation of high-frequency noise such as hiss and clicks that arise from the recording medium. Reducing the low frequencies also limits the excursions the cutter needs to make when cutting a groove. Groove width is thus reduced, allowing more grooves to fit into a given surface area, permitting longer recording times. This also reduces physical stresses on the stylus, which might otherwise cause distortion or groove damage during playback.

A potential drawback of the system is that rumble from the playback turntable's drive mechanism is amplified by the low-frequency boost that occurs on playback. Players must, therefore, be designed to limit rumble, more so than if RIAA equalization did not occur.

RIAA playback equalization is not a simple low-pass filter. It defines transition points in three places: 75 μs, 318 μs and 3180 μs, which correspond to 2122 Hz, 500.5 Hz and 50.05 Hz.[2] Mathematically, the pre-emphasis transfer function is expressed as follows, where T_1=3180 μs, T_2=318 μs, T_3=75 μs:[3]

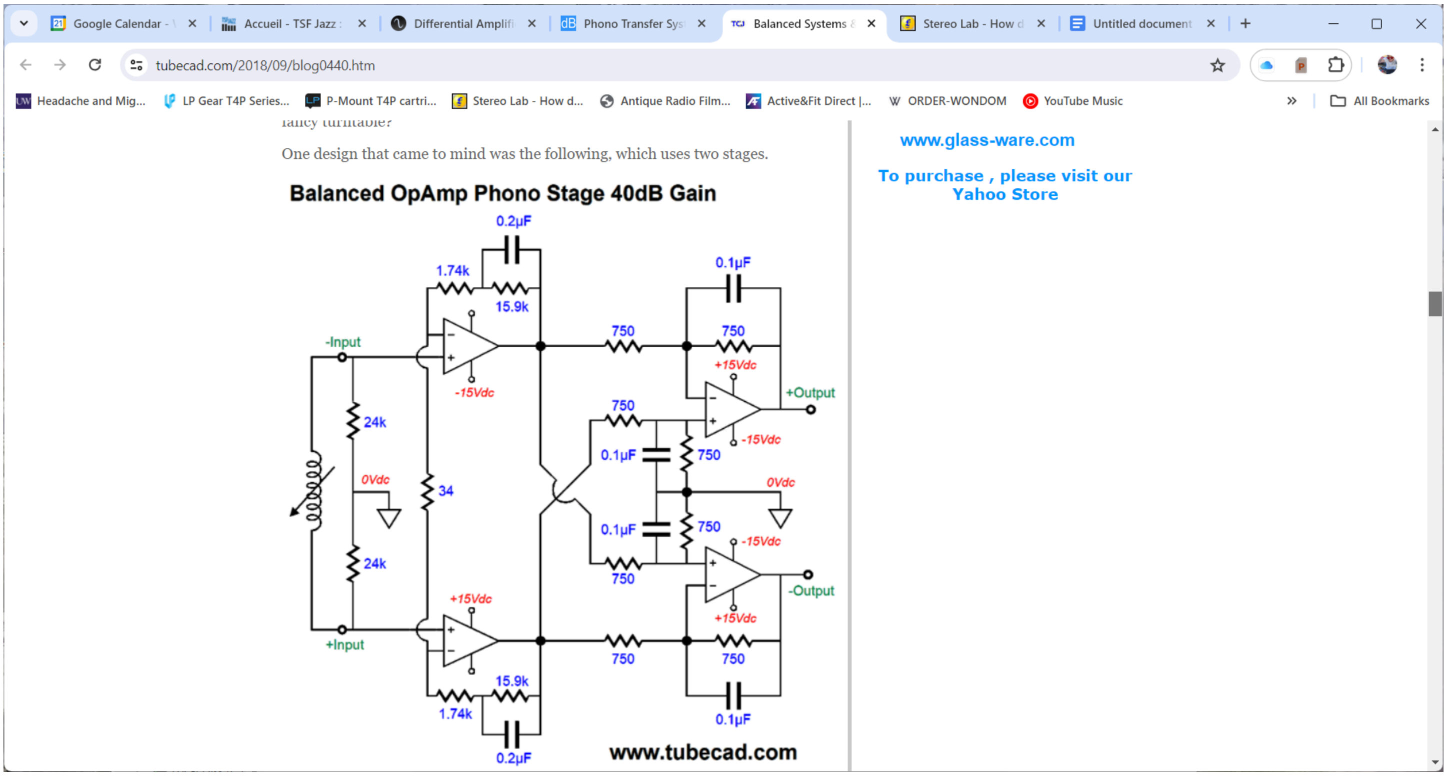
$f(s)=(sT1+1)\ (sT3+1) / (sT2+1)$ Pre-emphasis

https://www.diyaudio.com/community/threads/what-about-digital-riaa.268276/page-6

Develop and Build a Flat Response Preamp

https://www.electronics-tutorials.ws/opamp/opamp_5.html

https://www.tubecad.com/2018/09/blog0440.htm



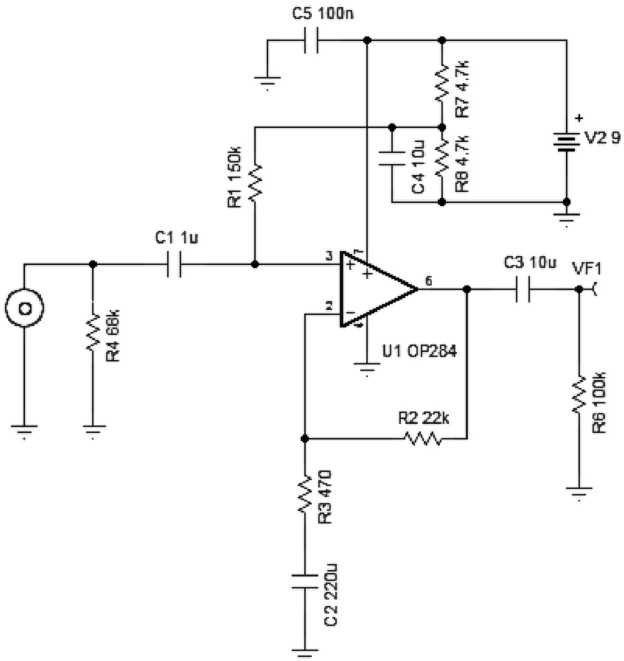
https://pspatialaudio.com/LP_performance.htm

Flat preamp

https://ka-electronics.com/shop/index.php?route=product/product&product_id=98

https://www.proaudiodesignforum.com/forum/php/viewtopic.php?f=7&t=753

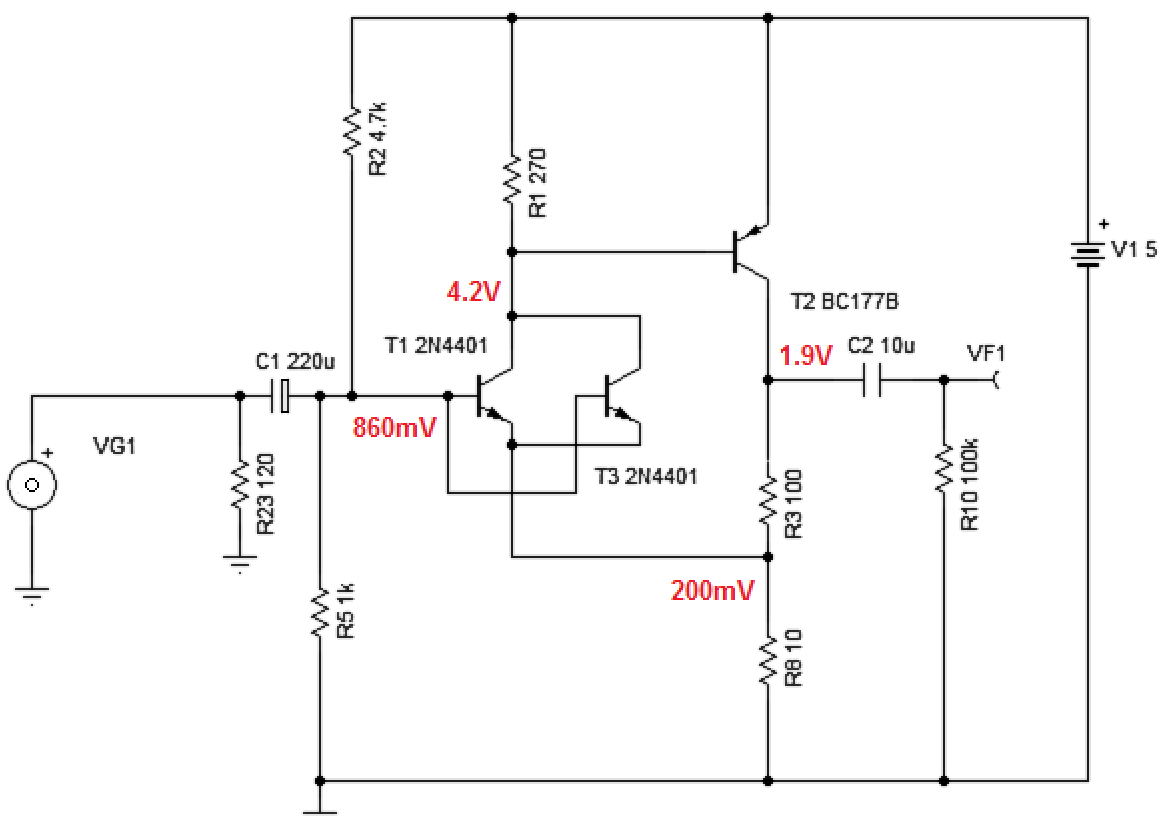
https://pspatialaudio.com/flatpreamp.htm#TML



Gain: x48 = 34dB
0.01% distortion on 50mV RMS signal at 1kHz
EIN: 750nV RMS with input shorted (76dB below nominal level)
EIN: 2.3uV RMS with MM cartridge (-67dB below nominal level)
F'resp: 0.1dB 20Hz to 20kHz (non inductive source)
Max input (before clipping): 64mV RMS (22dB above nominal level)

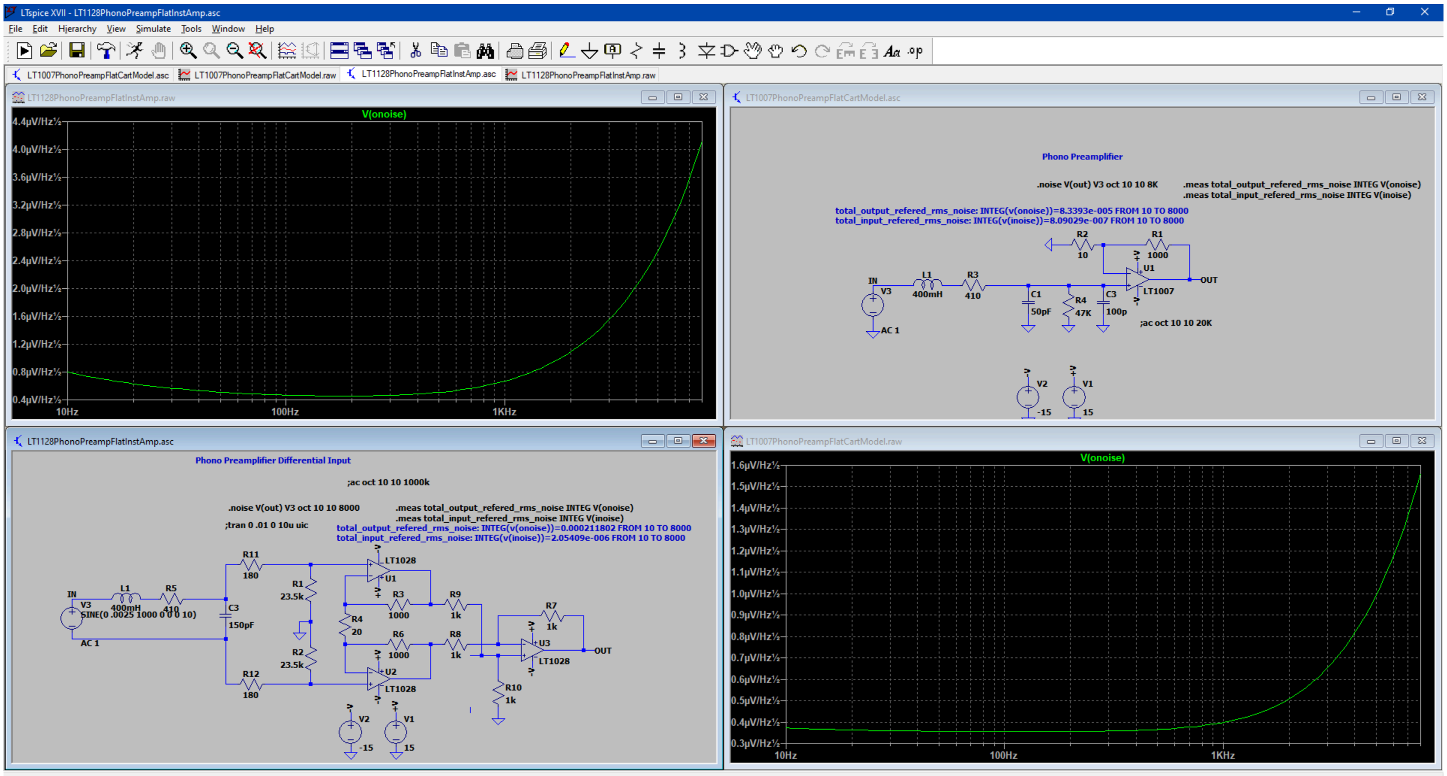
RAB Jan 2020

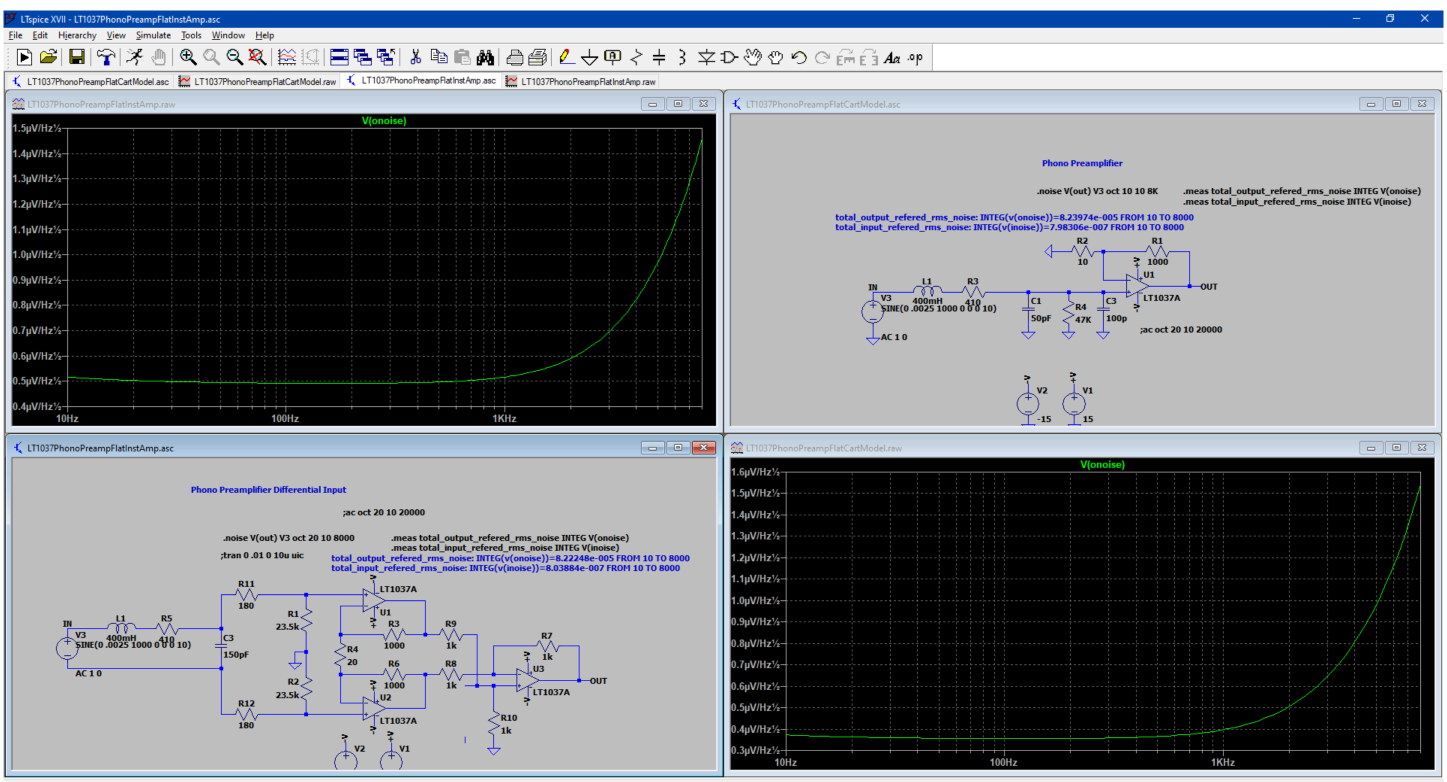
Moving magnet preamp



MC Preamp

total_output_refered_rms_noise: INTEG(v(onoise))=8.3393e-005 FROM 10 TO 8000
total_input_refered_rms_noise: INTEG(v(inoise))=8.09029e-007 FROM 10 TO 8000



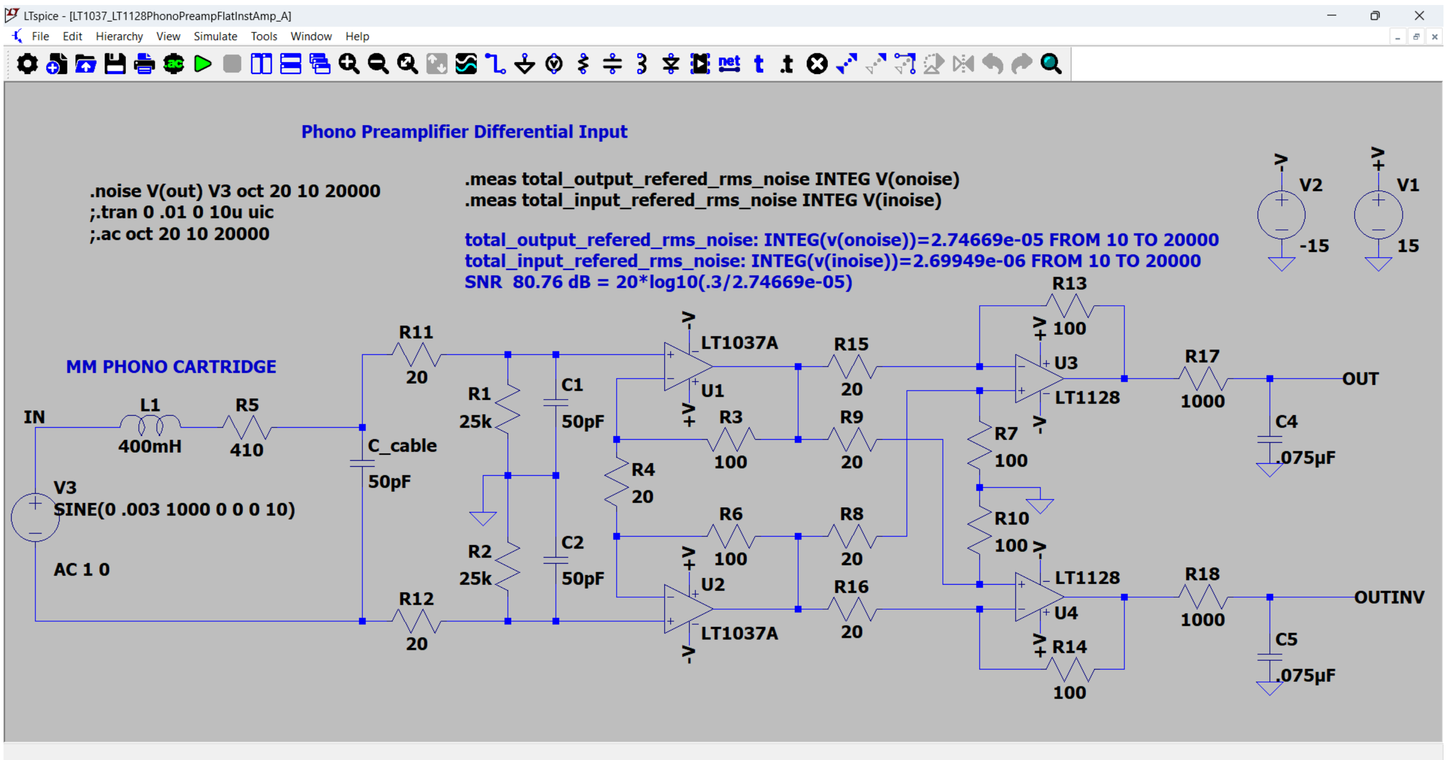


71.2 dB = 20 * log10(0.3 / 8.2e-5)

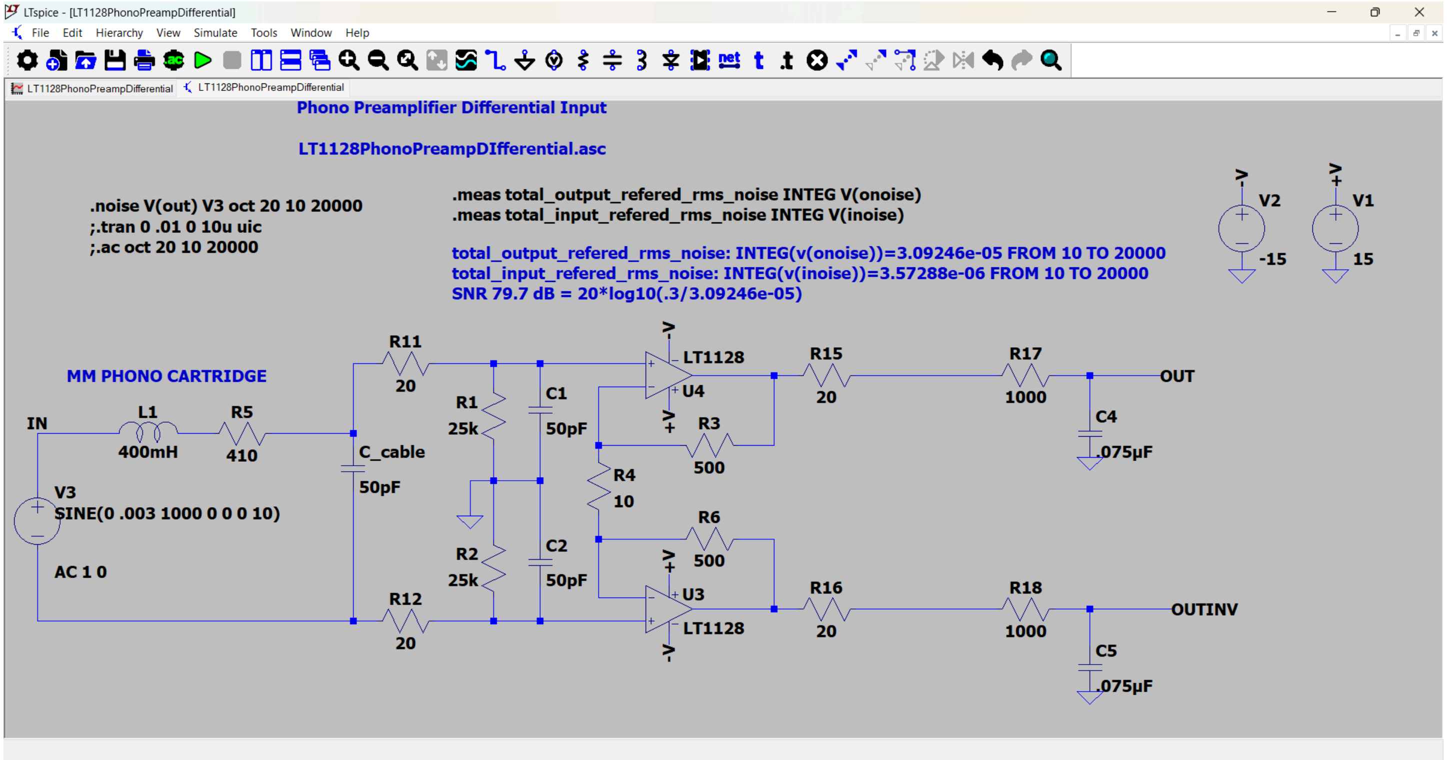
74.2 = 20*log10(0.3 / 5.87e-5)

Lowered the resistor values to 10 ohms
https://electronics.stackexchange.com/questions/423900/reason-for-small-valued-feedback-resistors-in-low-noise-op-amp

With 0.15 volt output the current is less than 1 mA

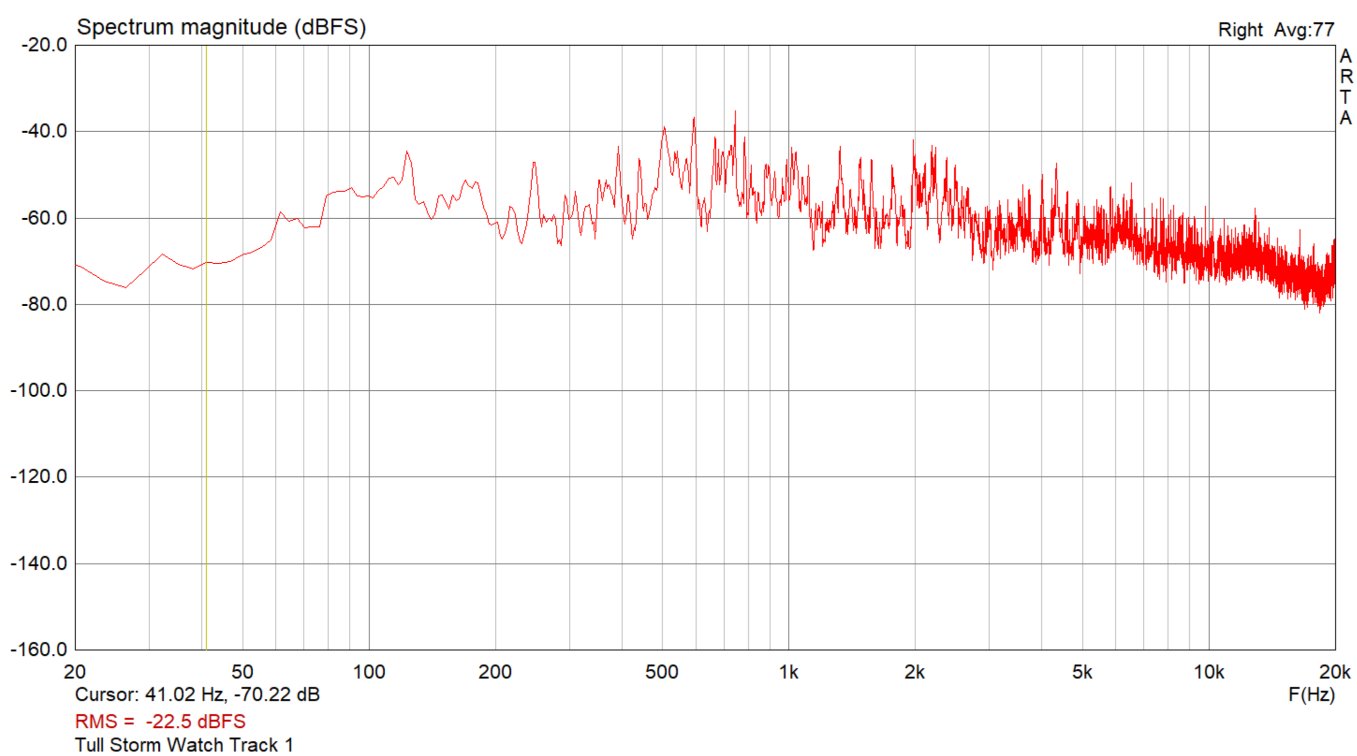


RC at output 75 uS lowpass filter of RIAA to give a more representative noise figure than the flat response.

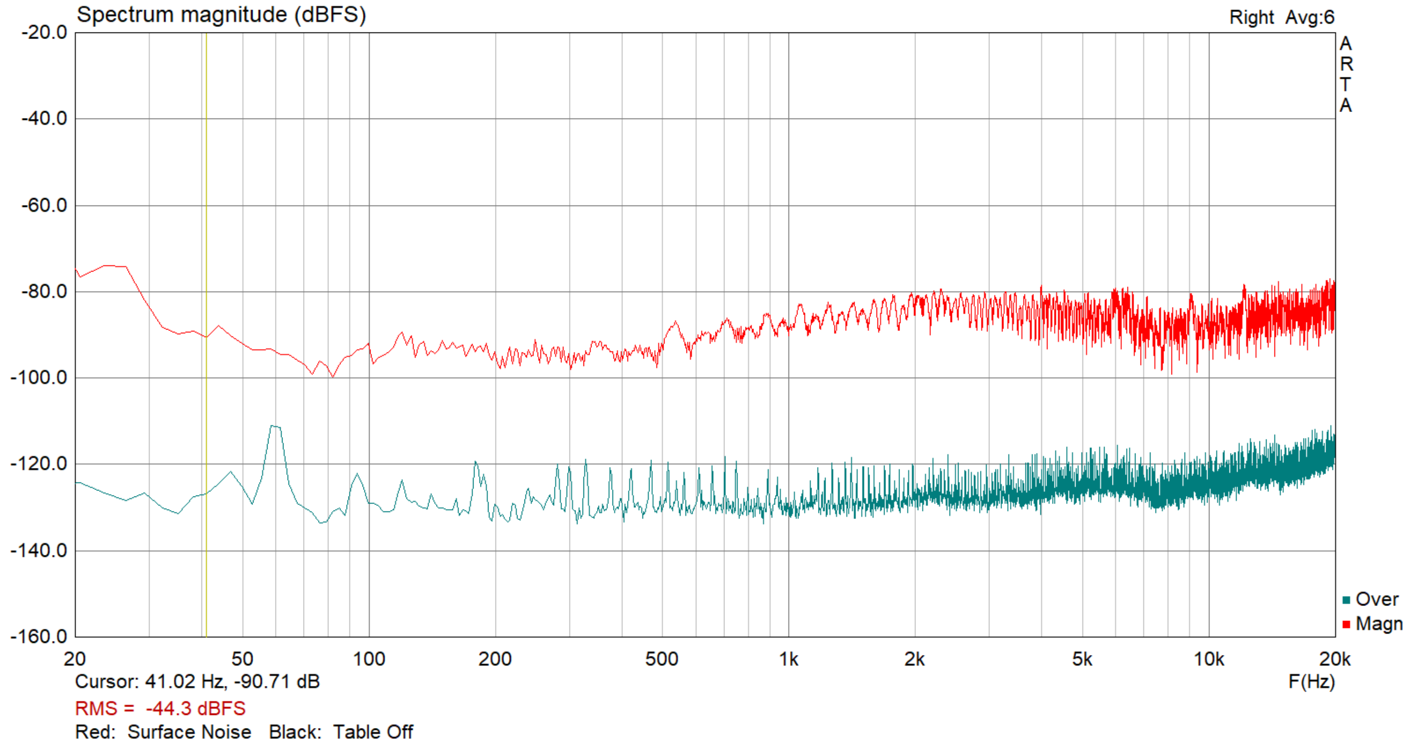


Proto 1 Assembled from parts I had around the house.

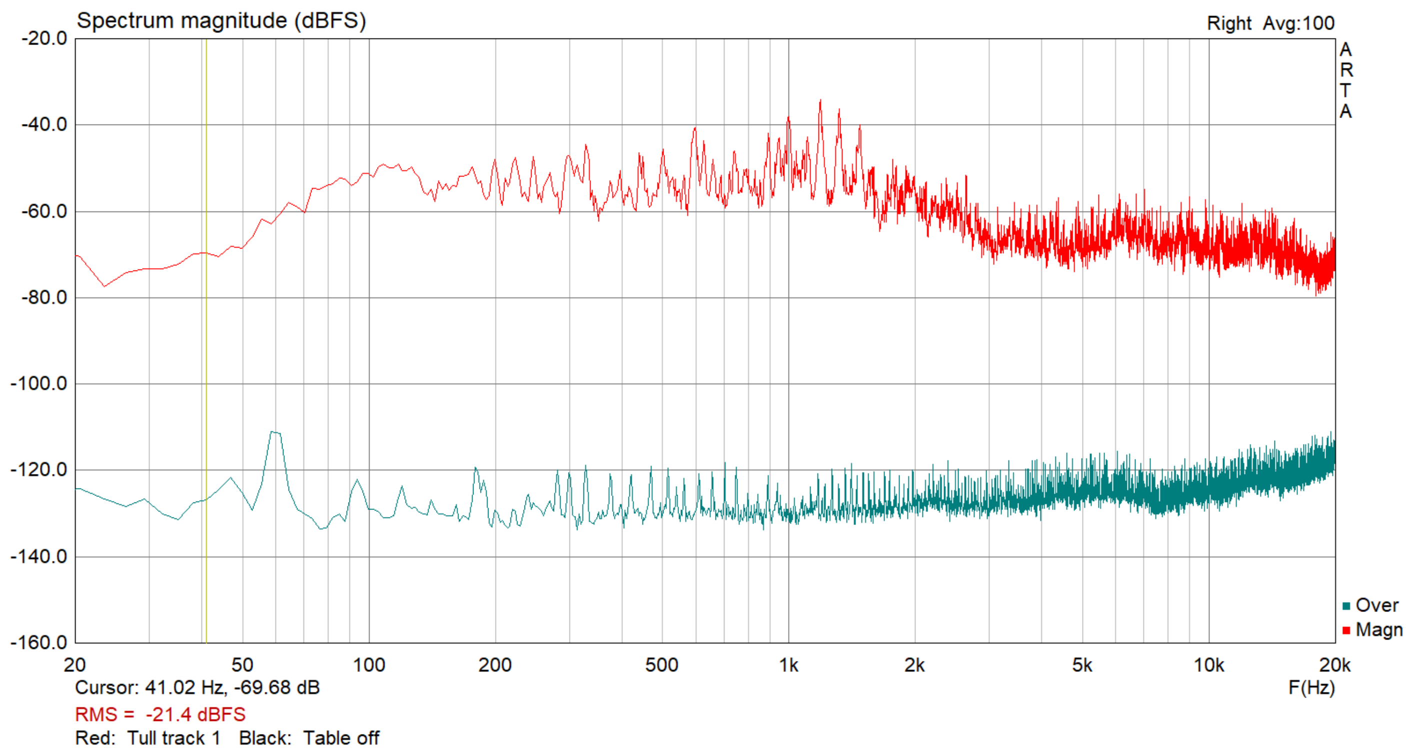
Configuration 0:
Turntable: Technics Q-350
Various preamps



Peak output level from MOTU Ch3 Input, Grado cartridge R channel only Playing Jethro Tull Storm Watch



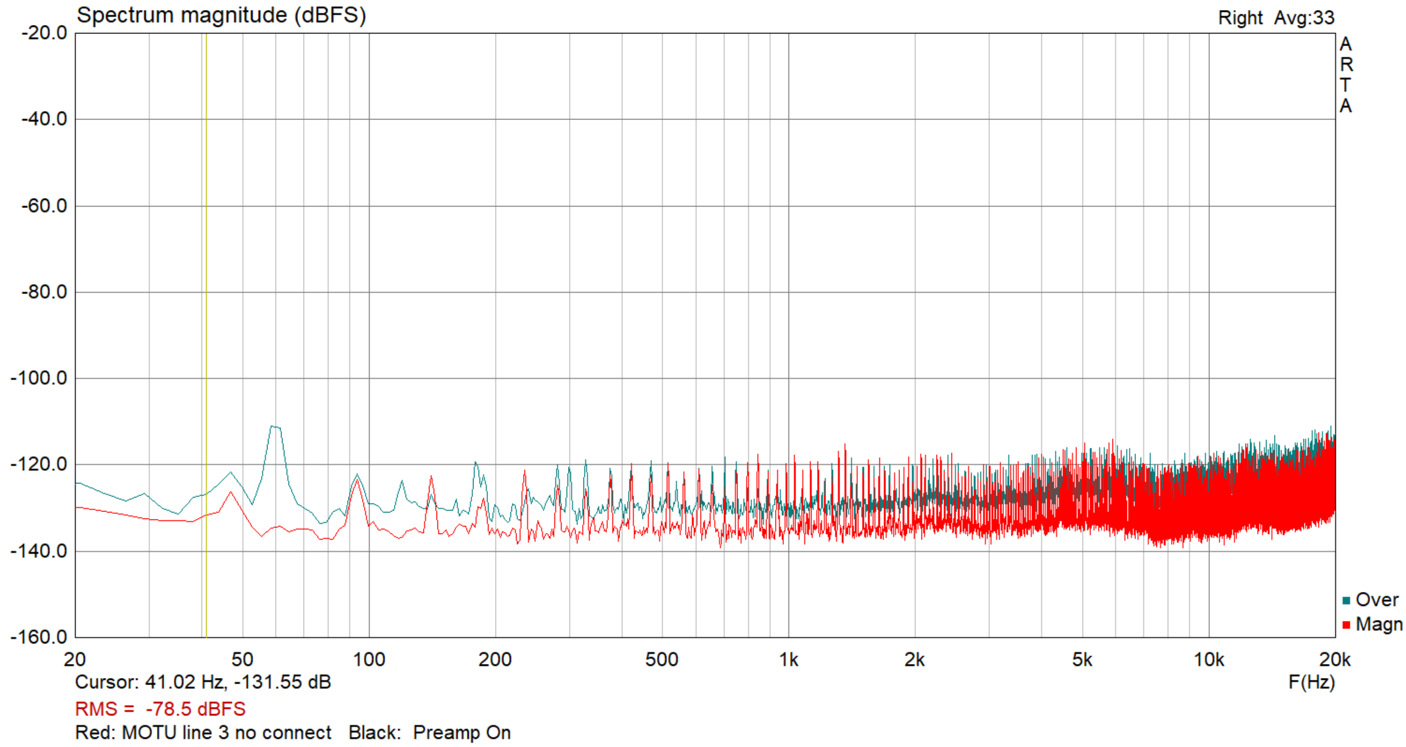
Red: Record surface noise. Black: Off the record.



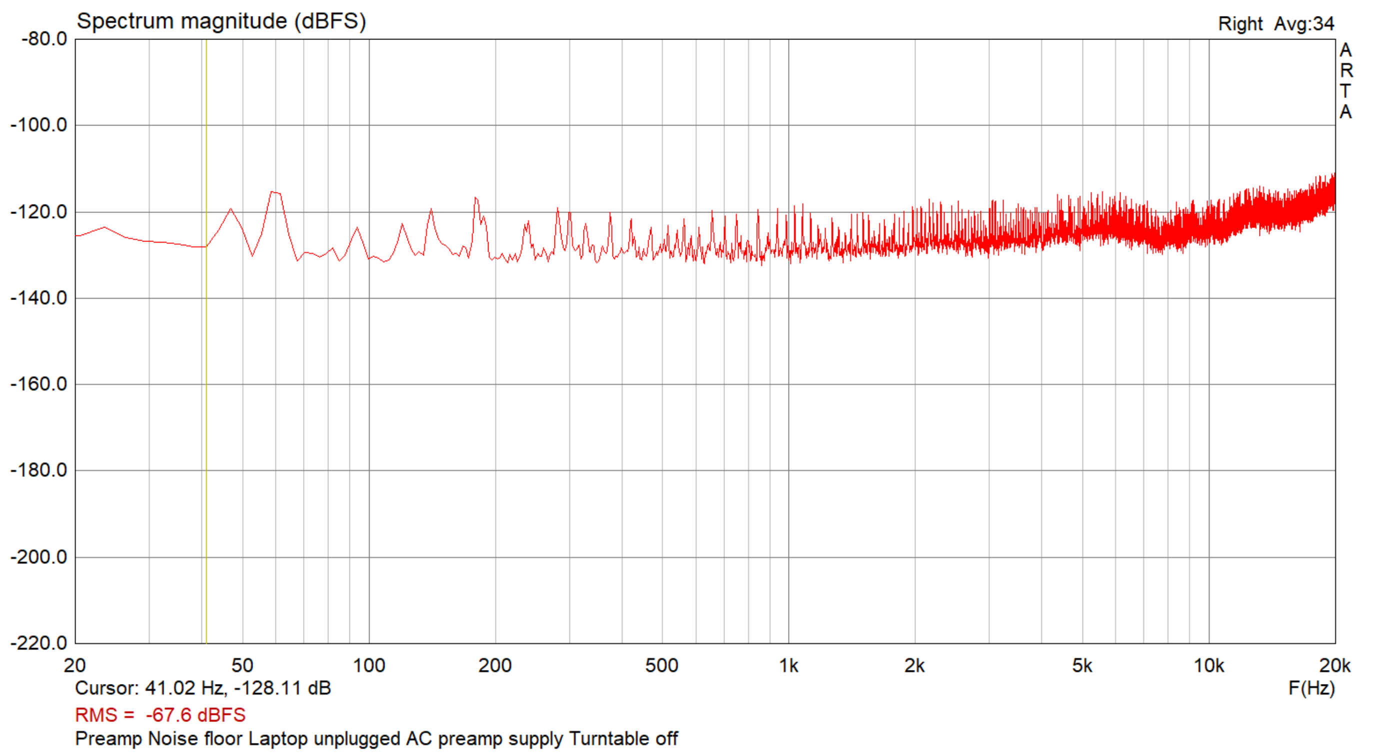
Red: Peak Signal Black: Noise floor, not playing a record

SNR 60 Hz = -35 dB Playback 1 kHz - -115 dB @ 60 Hz = 80 dB

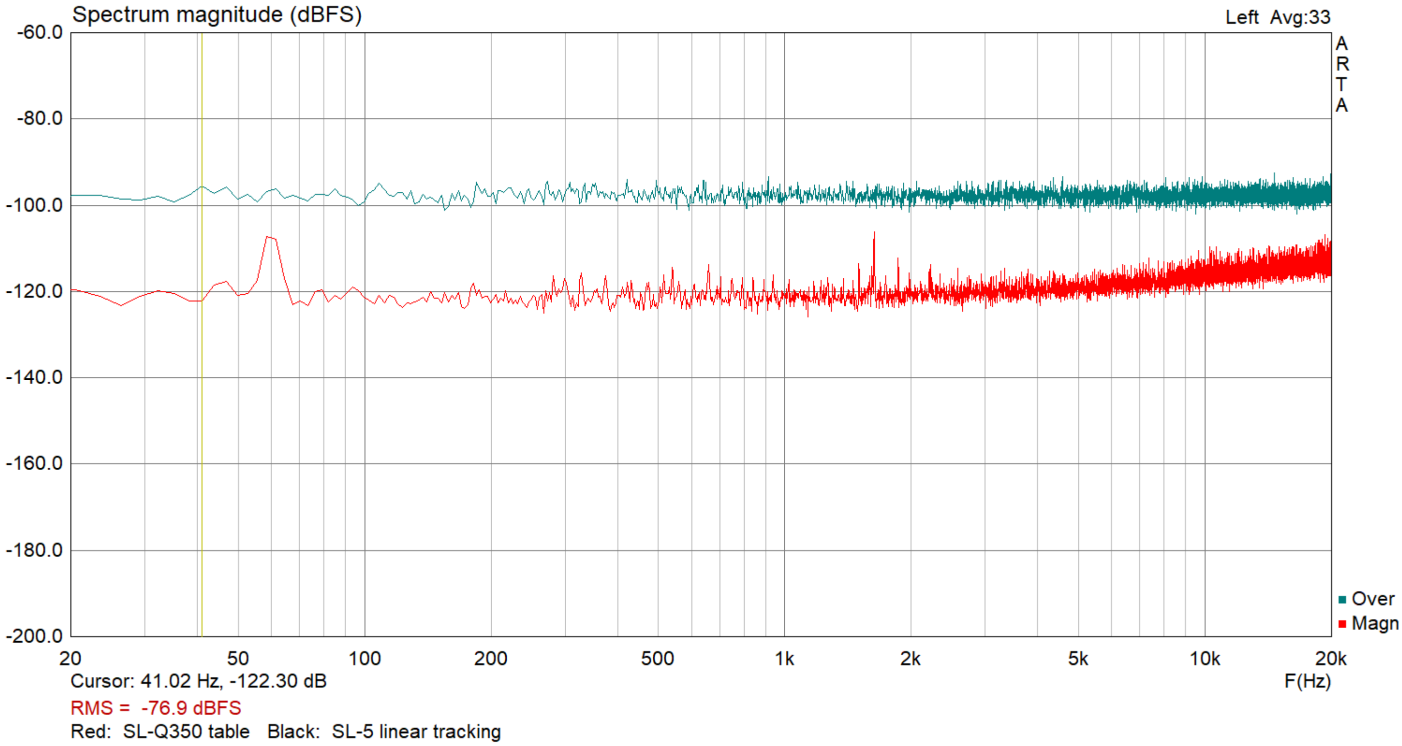
SNR 1 kHz = 115 - 35 dB Playback = 80 dB



First rev R feedback = 470 ohms, 22 kOhms

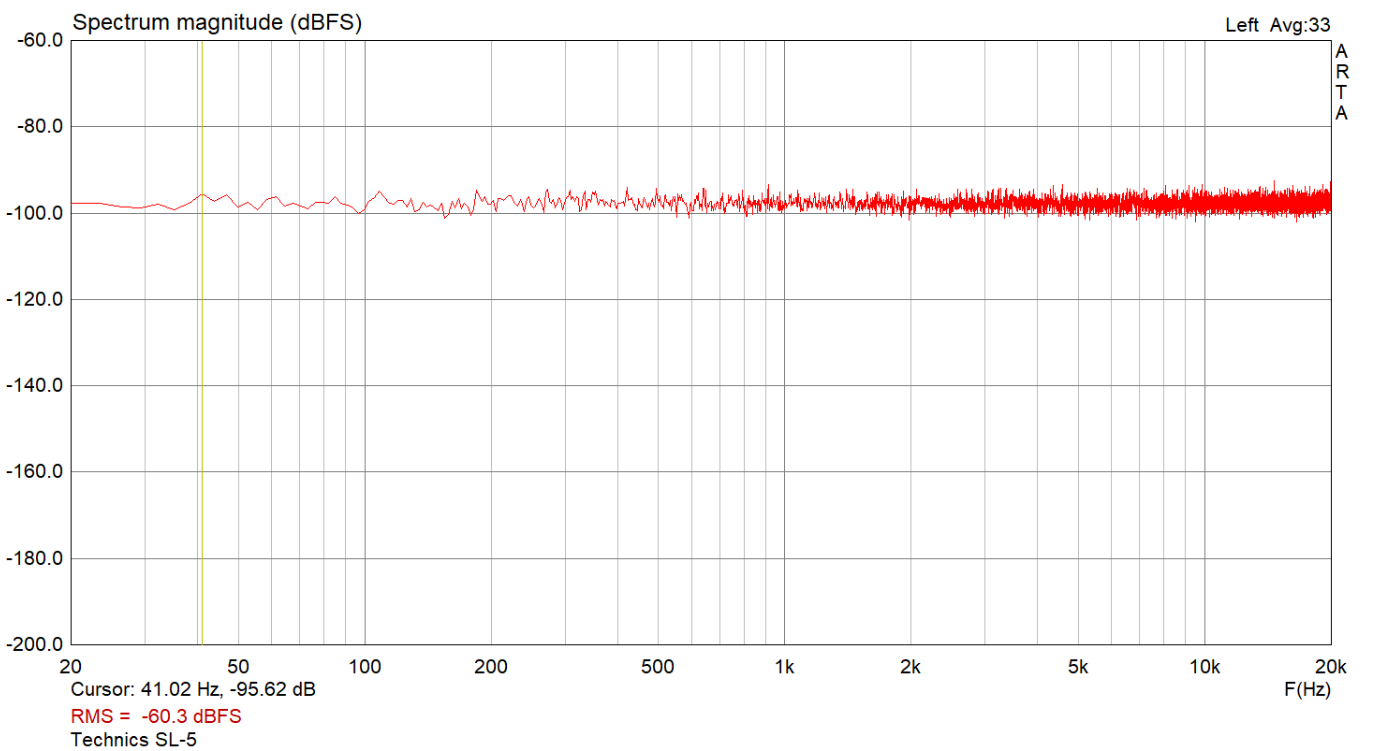


Updated: R = 500 ohm, 24 kOhms, Matched resistors 0.01%



Black:: Technics SL-5 Ortifon cartridge, Red: Technics: SL-Q350 w Audio Technica AT85EP eliptical

One turntable has 20 dB higher noise floor than the other ????? **Relay shorts SL-5 output.**



Technics Linear Tracking Turntables

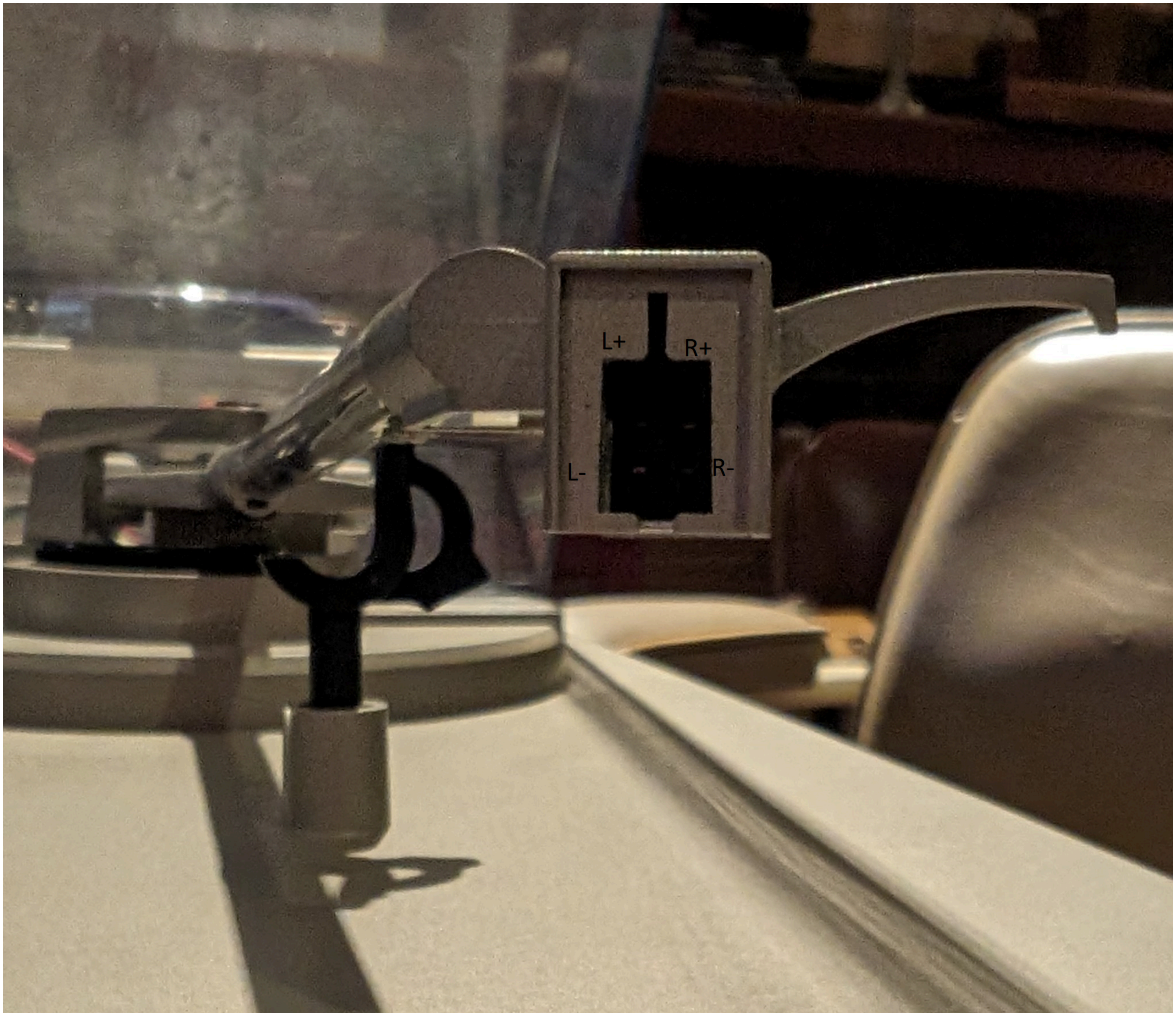
Technics Belted and
Direct Drive Linear Turntables

Model	Year	Price	Footprint	Weight	Track Access	Track Indica	Owner's Man	Service Manu
SL-10	80-84	$620.00	C	H	M		Y	Y
SL-Q4	81	$470.00	FS					
SL-15	81	$875.00	C	H	DAB	FLED	Y	Y
SL-DL1	81-82	$360.00	FS	H	M		Y	N
SL-7	81-83	$400.00	C	H	M		Y	Y
SL-5	82-83	$200.00	C	L	M		Y	N
SL-DL5	82-83	$220.00	FS	L	M		Y	N
SL-6	82-83	$300.00	C	L	DAB	FLED	Y	N
SL-QL1	82-85	$470.00	FS	H	M		Y	N
SL-BL3 (B)	83	$180.00	FS	L	M		N	N
SL-V6	83	$260.00	C	L				
SL-V5	83-84	$220.00	C	L				
SL-QL15	83-84	$280.00	FS	L	DAB	FLED	N	N
SL-QL5	84	$190.00	FS	L	M		N	Y/S
SL-J1 (B)	84-85	$160.00	C	L	F/RDSB	N	Y	N
SL-J2	84-85	$200.00	C	L	F/RDSB	LED	Y	Y/S
SL-J3	84-85	$250.00	C	L				
SL-M3	84-88	$450.00	Traditional	H			N	Y
SL-L1	85	$160.00	FS	L	M		N	Y/S
SL-L2	85	$200.00	FS	L	F/RDSB	LED	Y	N
SL-L3	85	$230.00	FS	L	DAB	FLED	N	Y/S
SL-L92	86	$235.00		L				
SL-J110 (B)	86-87	$175.00	C	L				
SL-J33K	86-89	$220.00	C	L				
SL-L20K (B)	86-91	$189.00						
SL-Q6								

B = Belted
C = Compact
DAB = Direct Access Button
FLED = Flasning LED
FS = Full Size
H = Heavy
L = Light
Y / S = Yes w/ Supplements
F/R DSB = Forward / Reverse Direct Search Button

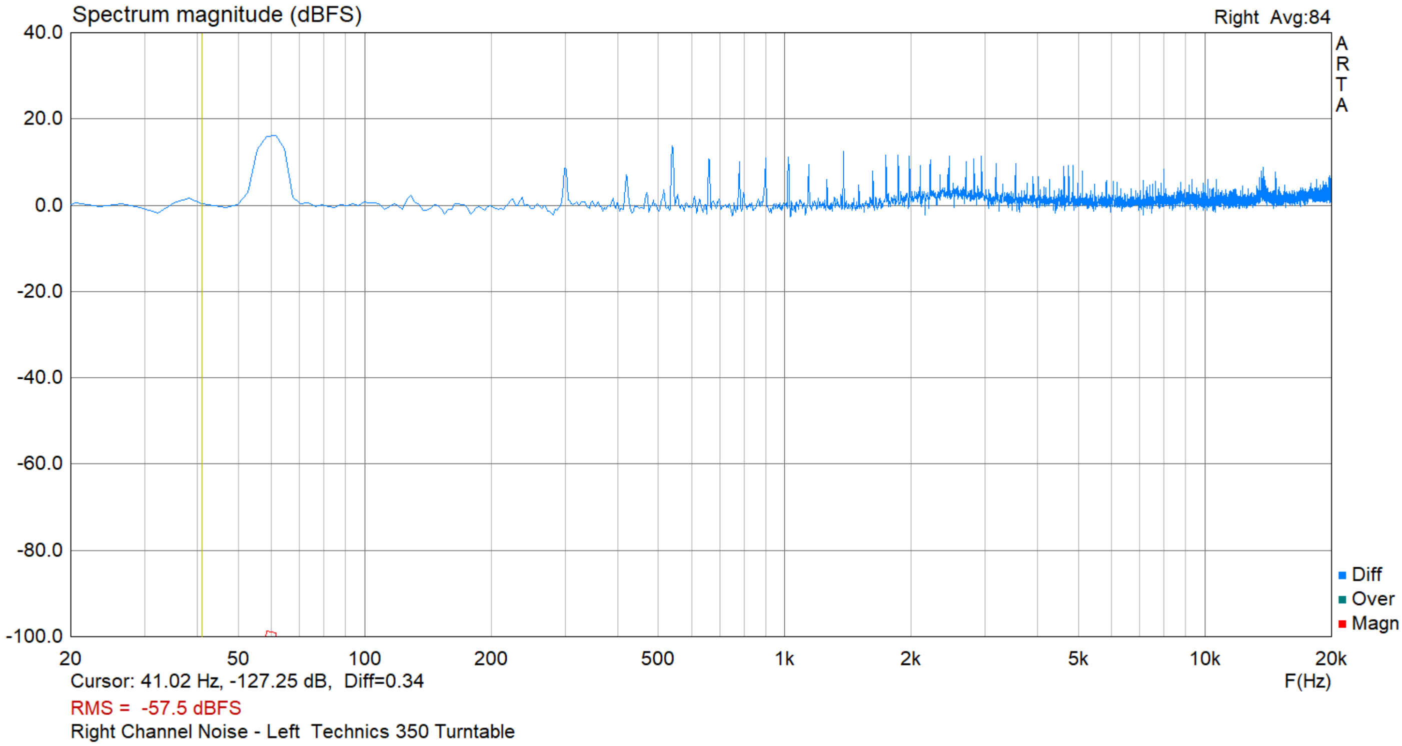
Q: Quartz Lock

Shopping for turntables.



Pin assignments for the P4T cartridge receptacle.

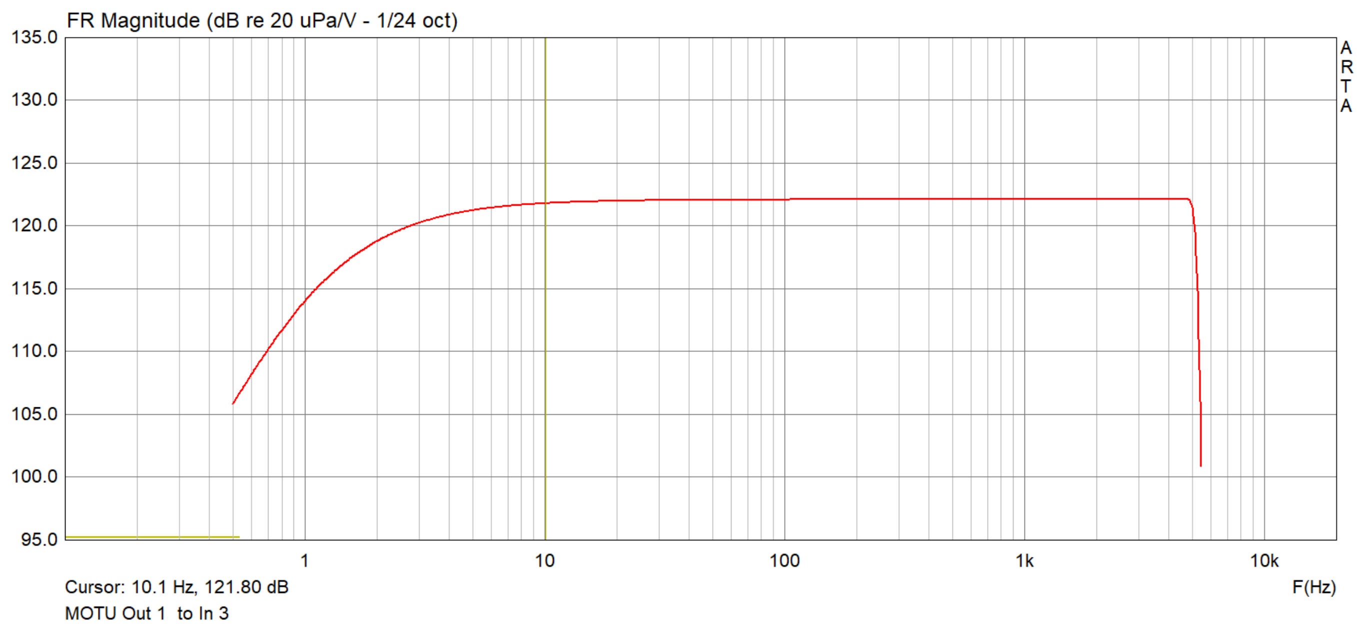
code is right signal = red, right ground = green, left signal = white, left ground = blue,

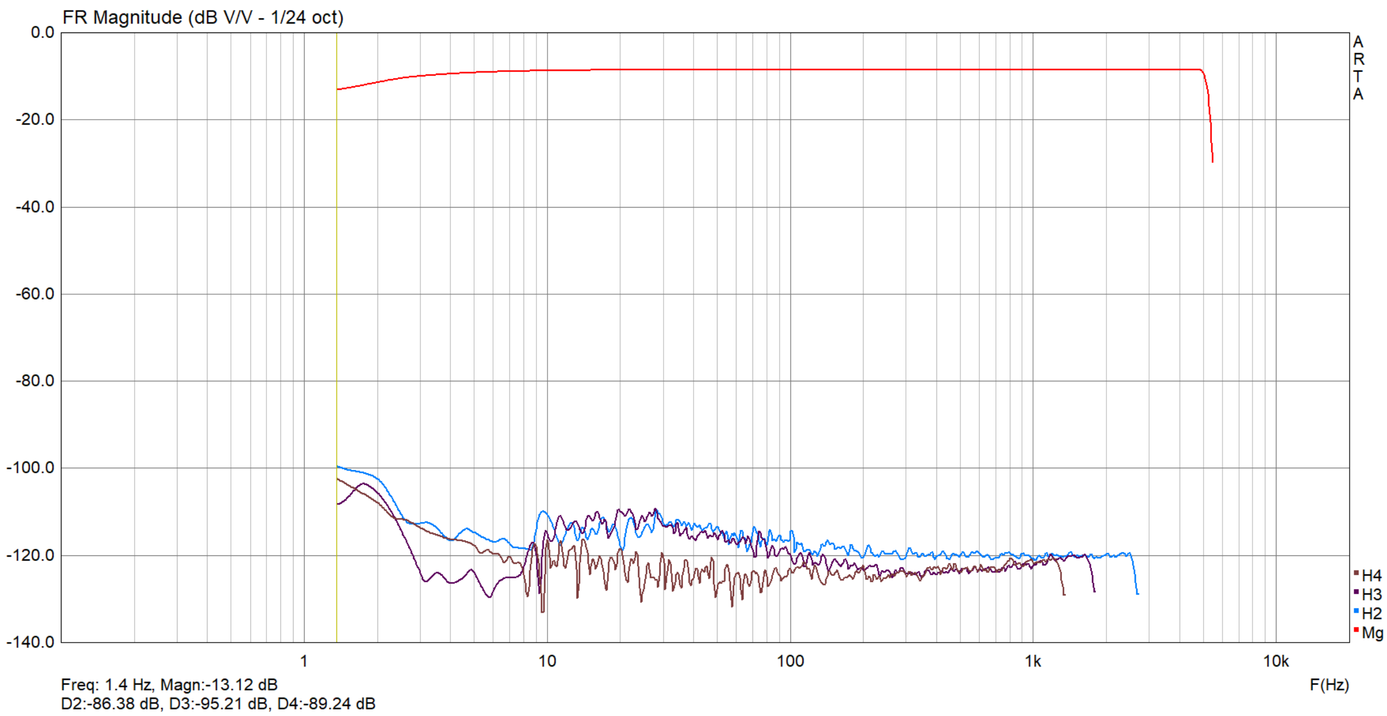


Right channel has 15 dB higher 50 Hz noise than the left channel. Table plugged in, power off. Laptop on battery. Time to rewire the tone arm!

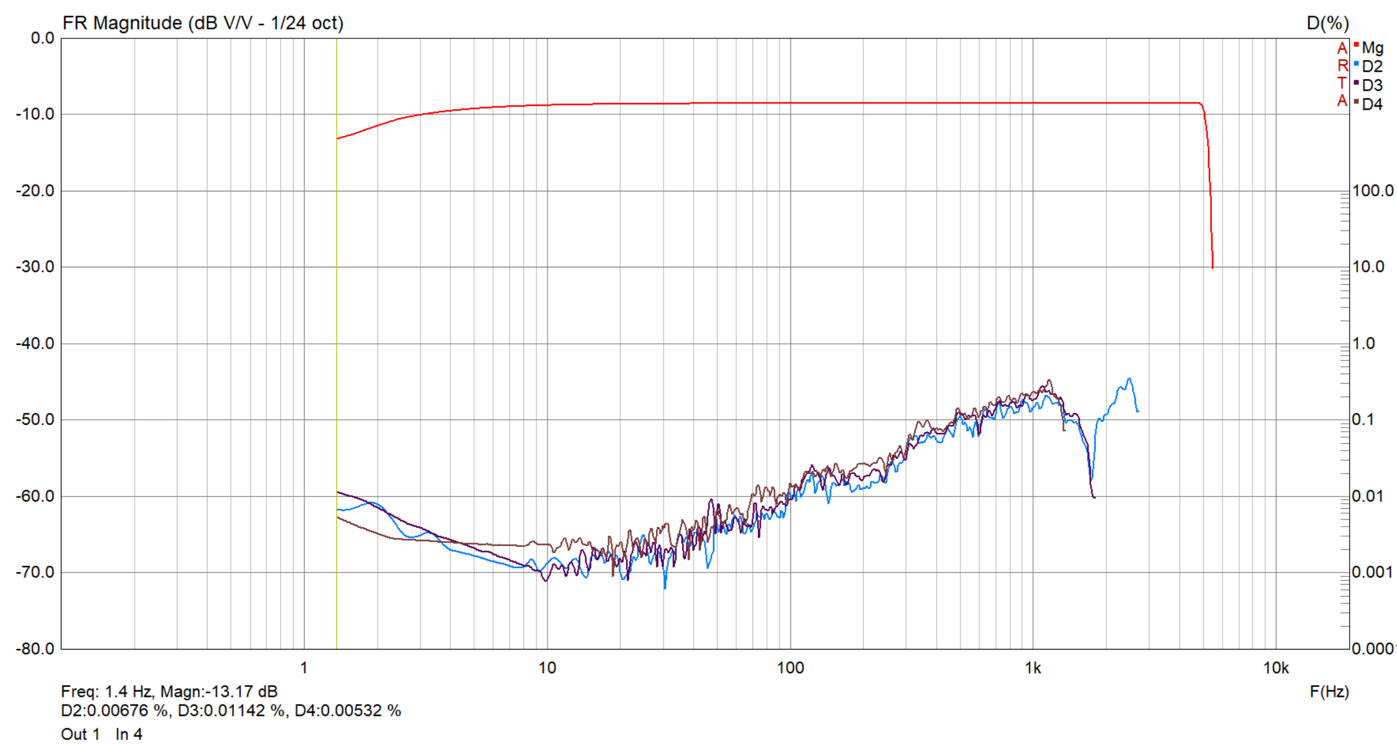
MOTU DC coupled output, AC coupled input

Input - 3 dB at 2.1 Hz





Out 3 to In 4



Monitor output 1 volume at 5 O-Clock. Use at 3 O-Clock to avoid distortion