LDO noise effects – part 1

July 1, 2023

KM5PO & KI5EMN

“Noise” is everywhere

- Noise is an unwanted disturbance in an electrical signal
- Noise generated by electronic devices varies greatly as it is produced by several different effects.
- In particular, noise is inherent in physics and central to thermodynamics. Any conductor with electrical resistance will generate thermal noise inherently. The final elimination of thermal noise in electronics can only be achieved cryogenically, and even then quantum noise would remain inherent.

"Noise" types

- Thermal generated by the random thermal motion of charge carriers (usually electrons), inside an electrical conductor, which happens regardless of any applied voltage
- Shot random statistical fluctuations of the electric current when the charge carriers (such as electrons) traverse a gap. If electrons flow across a barrier, then they have discrete arrival times
- Partition where current divides between two (or more) paths
- Flicker a signal or process with a frequency spectrum that falls off steadily into the higher frequencies
- Burst sudden step-like transitions between two or more discrete voltage or current levels
- Transit-time If the time taken by the electrons to travel from emitter to collector in a transistor becomes comparable to the period of the signal being amplified
- Coupled
  - can be coupled into a circuit from the external environment, by inductive coupling or capacitive coupling, or through an antenna..
  - Intermod/Crosstalk/Interference/Atmospheric/Industrial/Solar

Mitigation

1. Faraday cage – A Faraday cage enclosing a circuit can be used to isolate the circuit from external noise sources. *A Faraday cage cannot address noise sources that originate in the circuit itself or those carried in on its inputs, including the power supply.*
2. Capacitive coupling – Capacitive coupling allows an AC signal from one part of the circuit to be picked up in another part *through the interaction of electric fields.* Where coupling is unintended, the effects can be addressed through improved circuit layout and grounding.
3. Ground loops – When grounding a circuit, it is important to avoid ground loops. Ground loops occur when there is a voltage difference between two ground connections. A good way to fix this is to bring all the ground wires to the same potential in a ground bus.

Mitigation

1. Shielding cables – A shielded cable can be thought of as a Faraday cage for wiring and can protect the wires from unwanted noise in a sensitive circuit. The shield must be grounded to be effective. Grounding the shield at only one end can avoid a ground loop on the shield.
2. Twisted pair wiring – Twisting wires in a circuit will reduce electromagnetic noise. Twisting the wires decreases the loop size in which a magnetic field can run through to produce a current between the wires. Small loops may exist between wires twisted together, but the magnetic field going through these loops induces a current flowing in opposite directions in alternate loops on each wire and so there is no net noise current.
3. Notch filters – Notch filters or band-rejection filters are useful for eliminating a specific noise frequency. For example, power lines within a building run at 50 or 60 Hz line frequency. A sensitive circuit will pick up this frequency as noise. A notch filter tuned to the line frequency can remove the noise.

LDO PSRR vs other noise

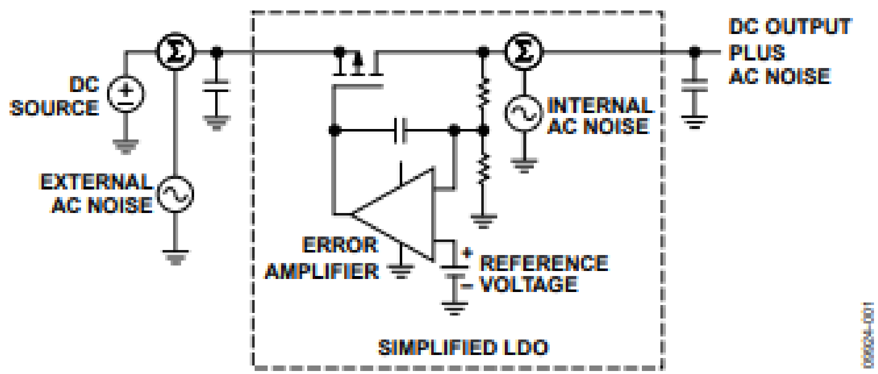
Power Supply Rejection Ratio (PSRR)

Is a measure of circuit's power supply rejection expressed as a ratio of output noise to noise at the power supply input – is a function of frequency/affected by the gain bandwidth of the EA/load current variation has impacts

PSRR = 20 log (Ripple input divided by Ripple output)

Other LDO noise

Noise generated by the transistors and resistors in the LDO's internal circuitry (thermal, flicker, shot) and by the external components



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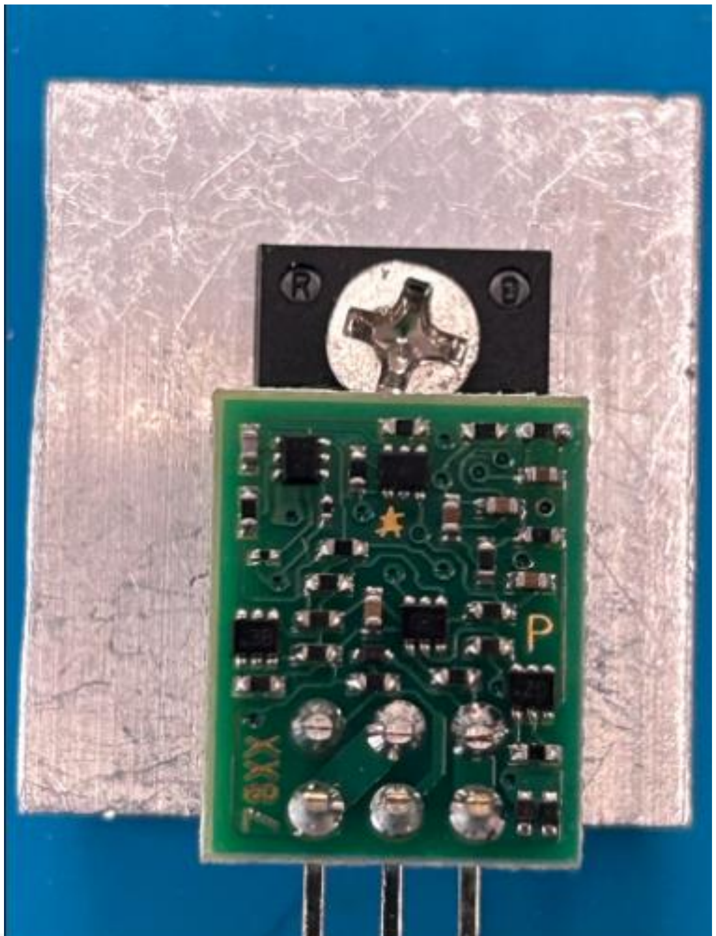
In the shop

Mats referred me to the Sparkos LDO



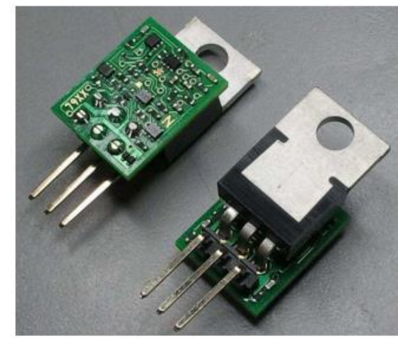
SS78XX / SS1117XX / SS79XX

SparkoS
LABS
SPARKOSLABS.COM

Discrete Voltage Regulator Family

Description :

The SS78XX / SS1117XX / SS79XX family of discrete voltage regulators are available in a TO-220 compatible package and are made to drop-in replace inferior monolithic voltage regulators. They are available in a wide output voltage range from +/- 3.3 to +/- 24 volts with over 1 amp of available output current.

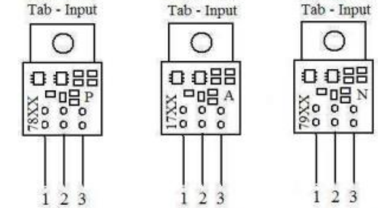


Features:

- **- 125dB input rejection**
- **3.2uV RMS Output Noise in a 20Khz Bandwidth @ 5 Vo**
- **2mV Load Regulation**
- **Output Current Of 1 Amp With Proper Heat Sinking**
- **Over Current Protection**
- **Output Decoupling Capacitor On - Board**
- **TO220 Compatible Package**
- **Stable With Ceramic And Low ESR Output Capacitors**
- **Available In Positive And Negative Fixed Outputs**
- **Available In 3 Different Industry Standard Pin-outs**
- **Fully Discrete Design Including The Error Amplifier**

Pin Assignments

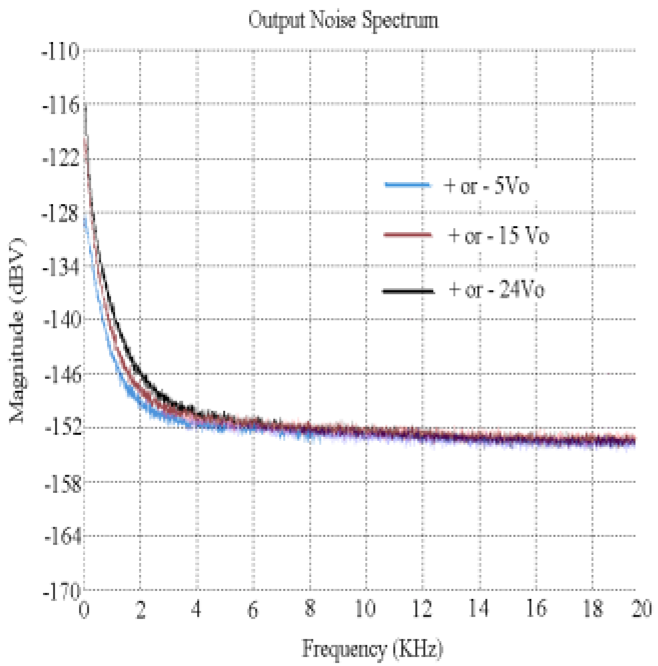
SS78XX Positive	SS1117-XX Positive	SS79XX Negative
Front View Tab - Input	Front View Tab - Input	Front View Tab - Input

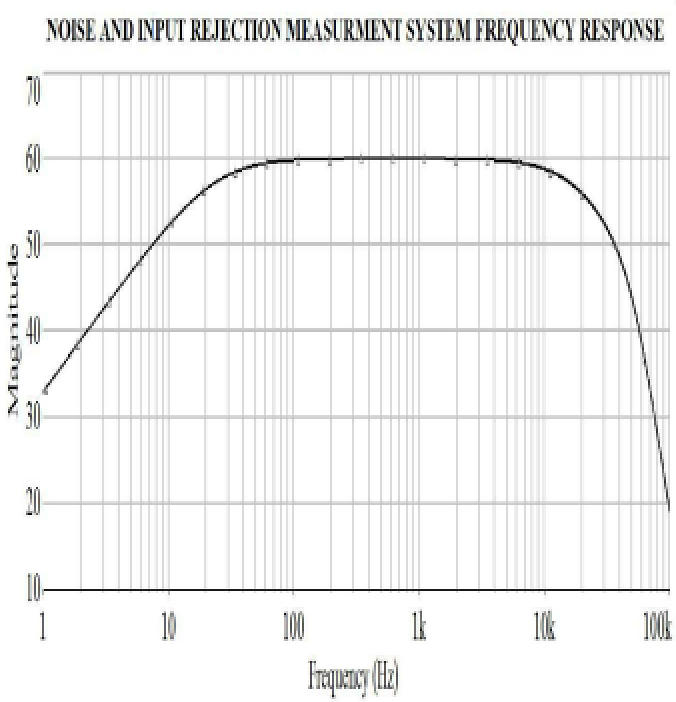


SS78XX Positive	SS1117-XX Positive	SS79XX Negative
1 - Input 2 - Ground 3 - Output	1 - Ground 2 - Output 3 - Input	1 - Ground 2 - Input 3 - Output
Compatible With LM78XX	Compatible With LM1117-XX	Compatible With LM79XX

In the shop

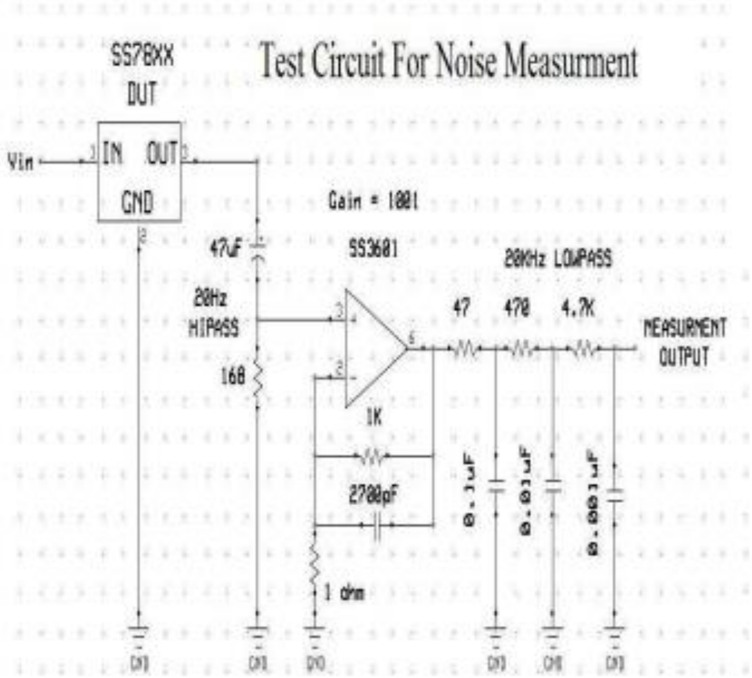
In the datasheet





In the shop

In the datasheet



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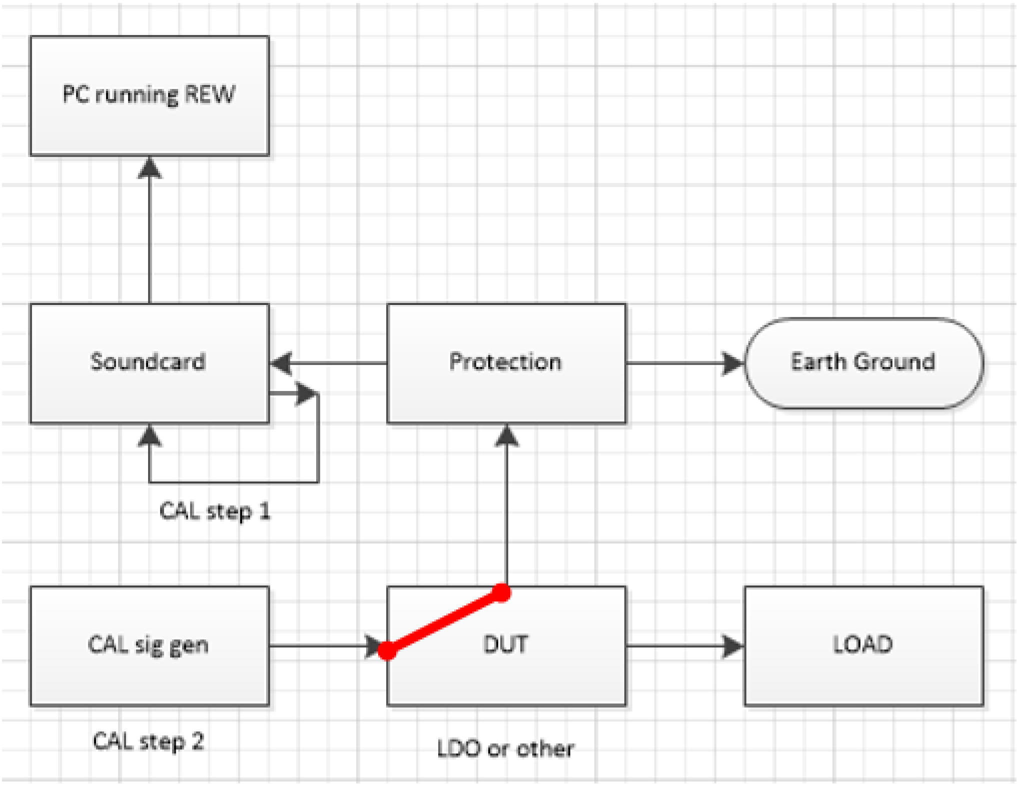
Noise measuring setup



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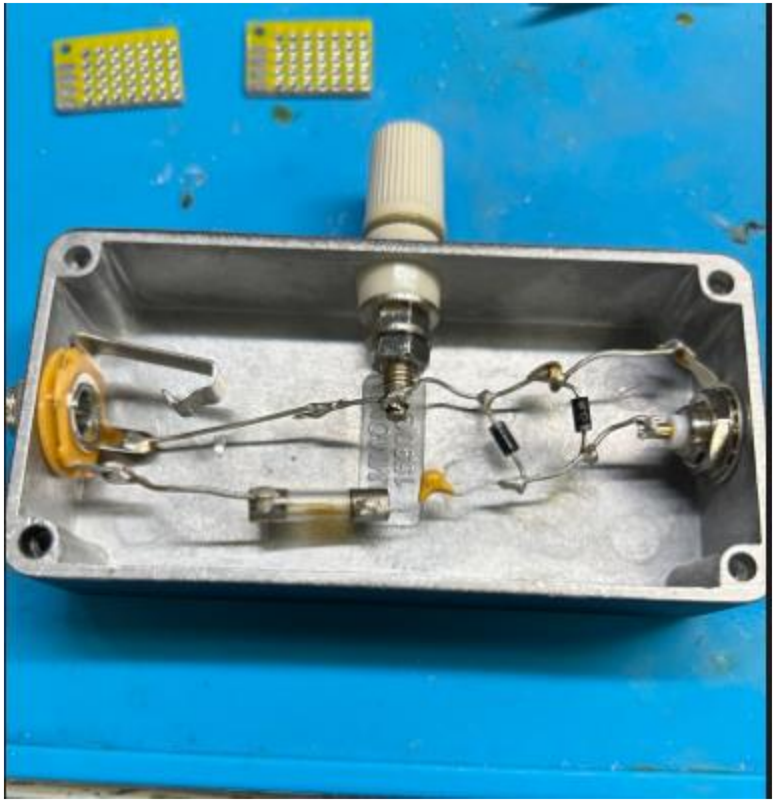
Protection for soundcard



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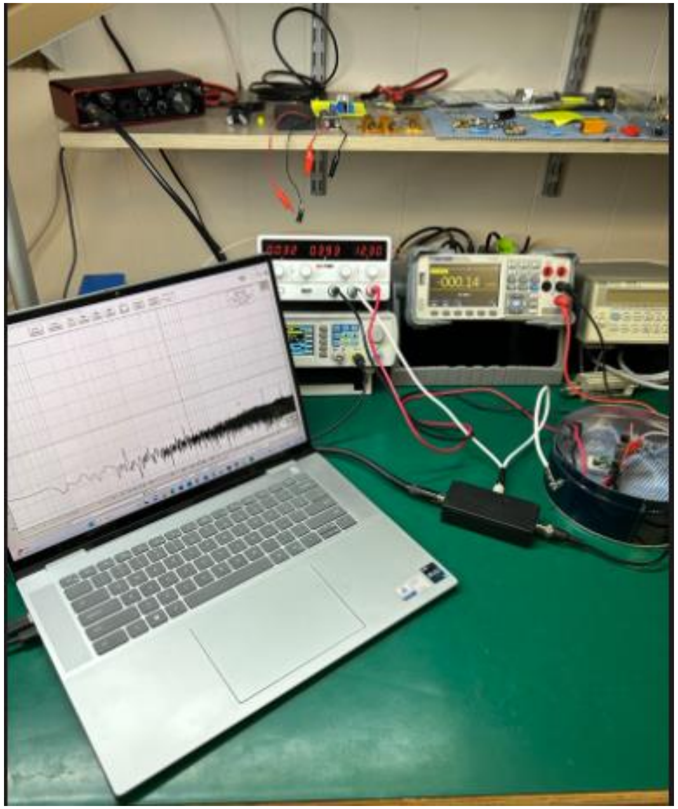
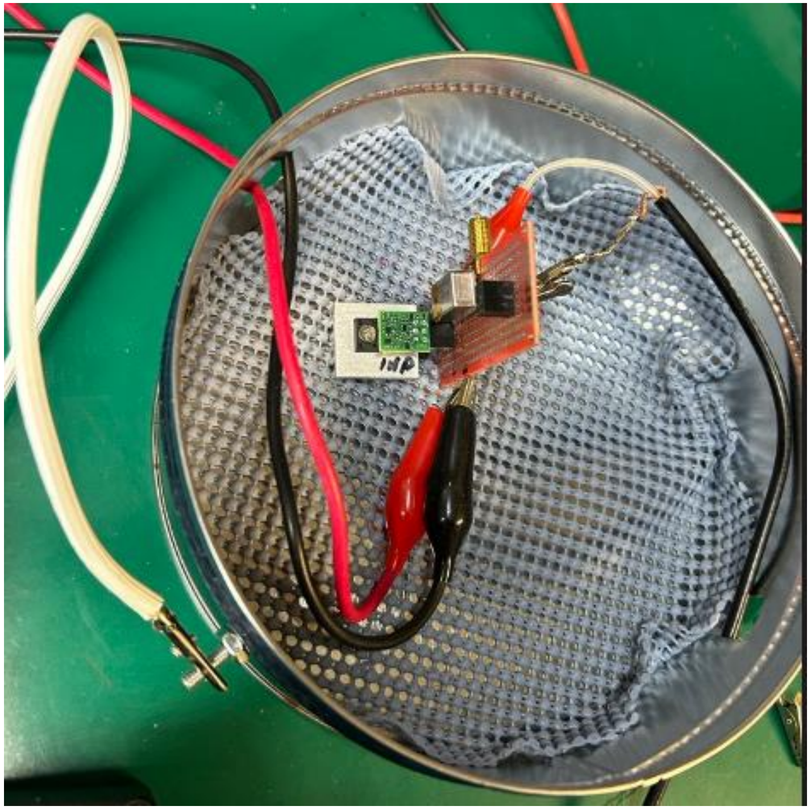
Ready to measure

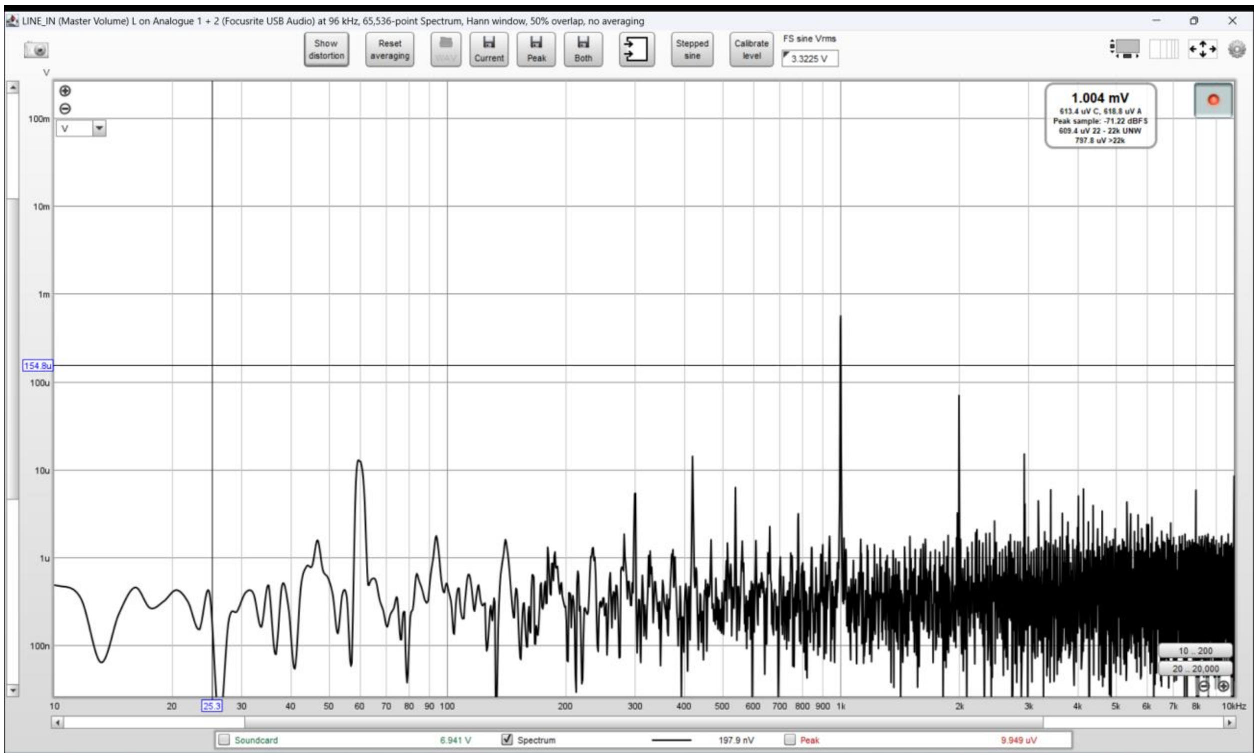




Noise measures

Calibrated system – laptop powered 6-10-23

Measurement of 1 Khz at .001v (1 mV) in the tin can



Noise measures

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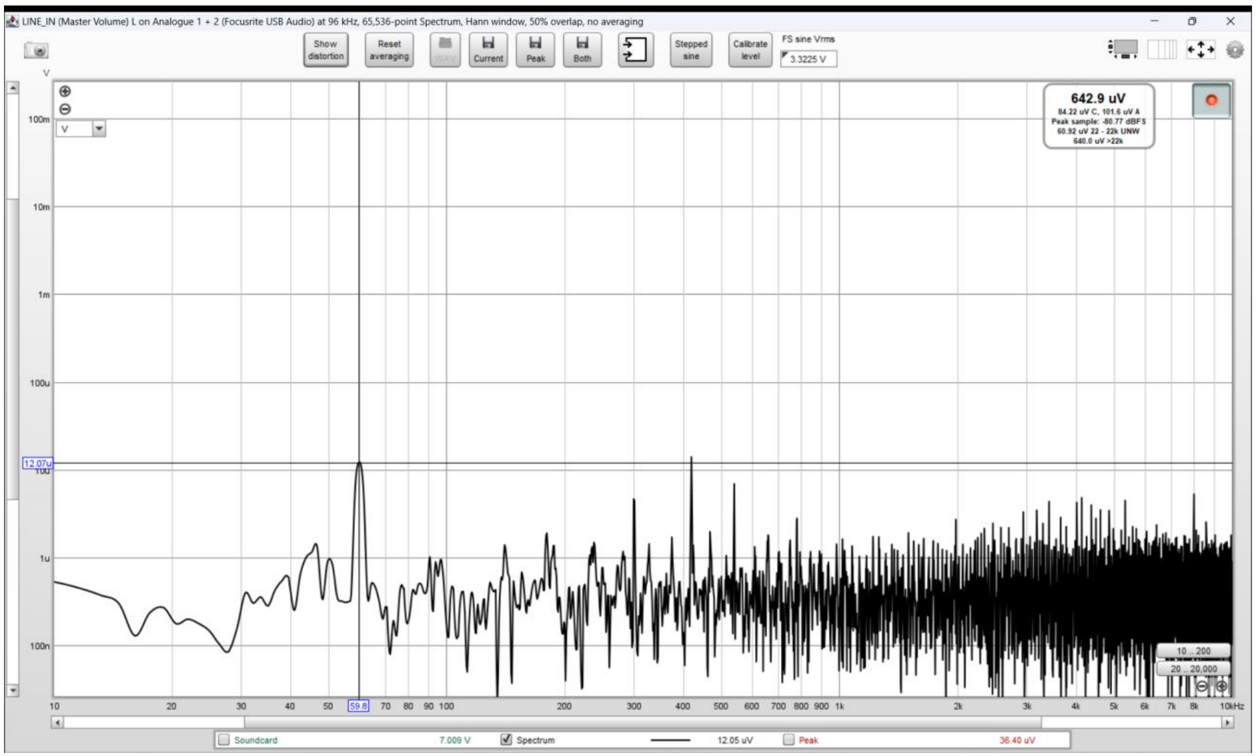
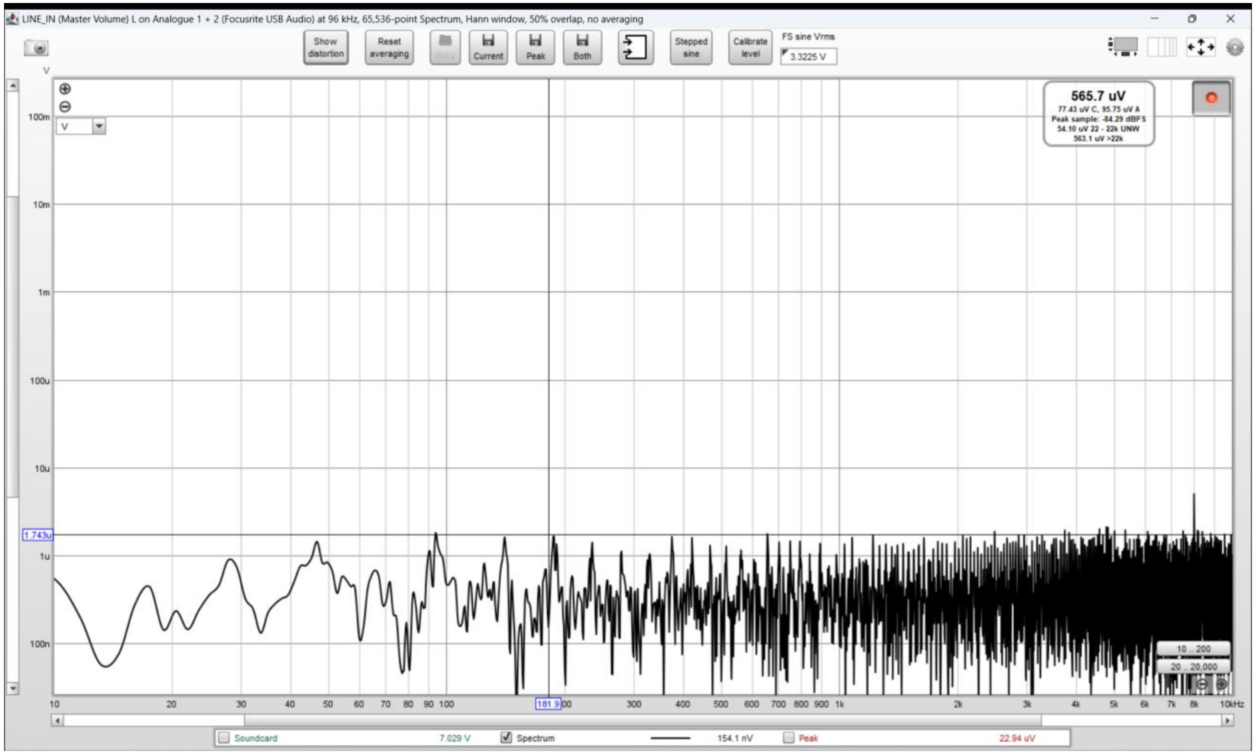
Calibrated system – laptop powered 6-10-23
Measurement of 51 ohm resistor in the tin can
12 uV of ripple at 60 hz



Noise measures

Calibrated system – laptop on battery 6-10-23
Measurement of 51 ohm resistor in the tin can
Peak of 1.74 uV < 20 KHz ~280 nV average noise < 20 Khz



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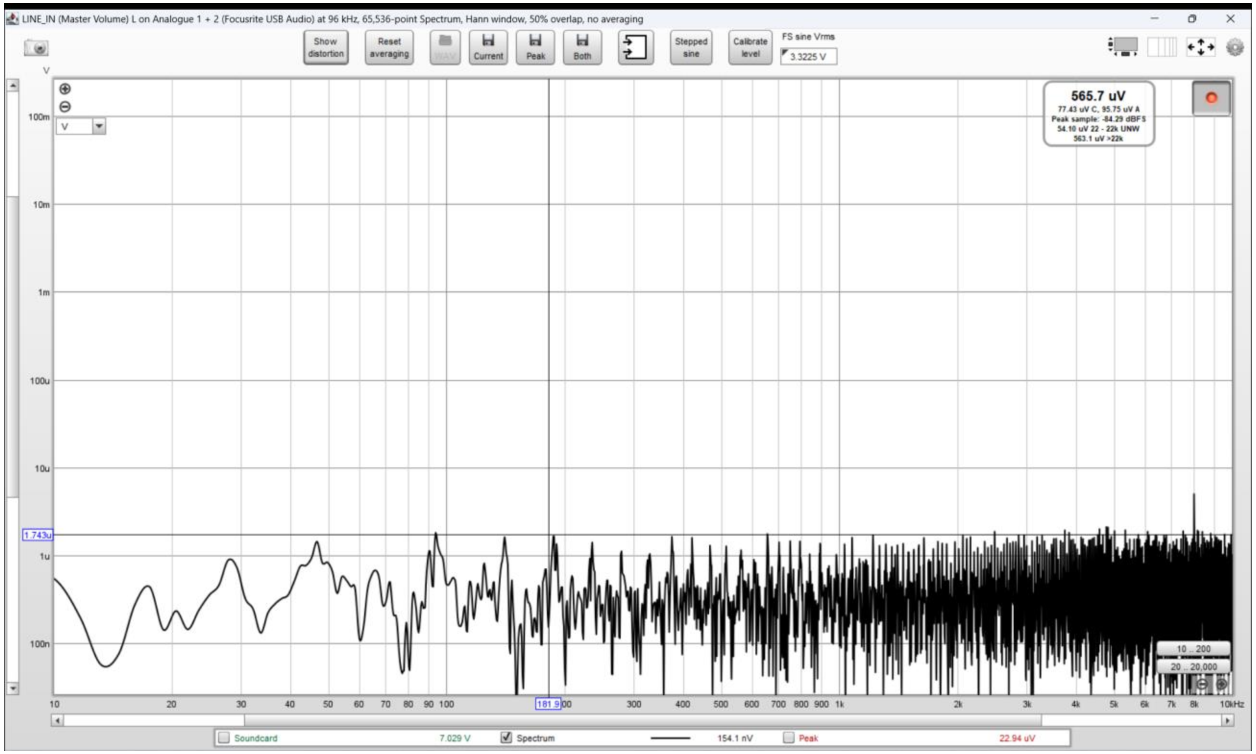

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Noise measures

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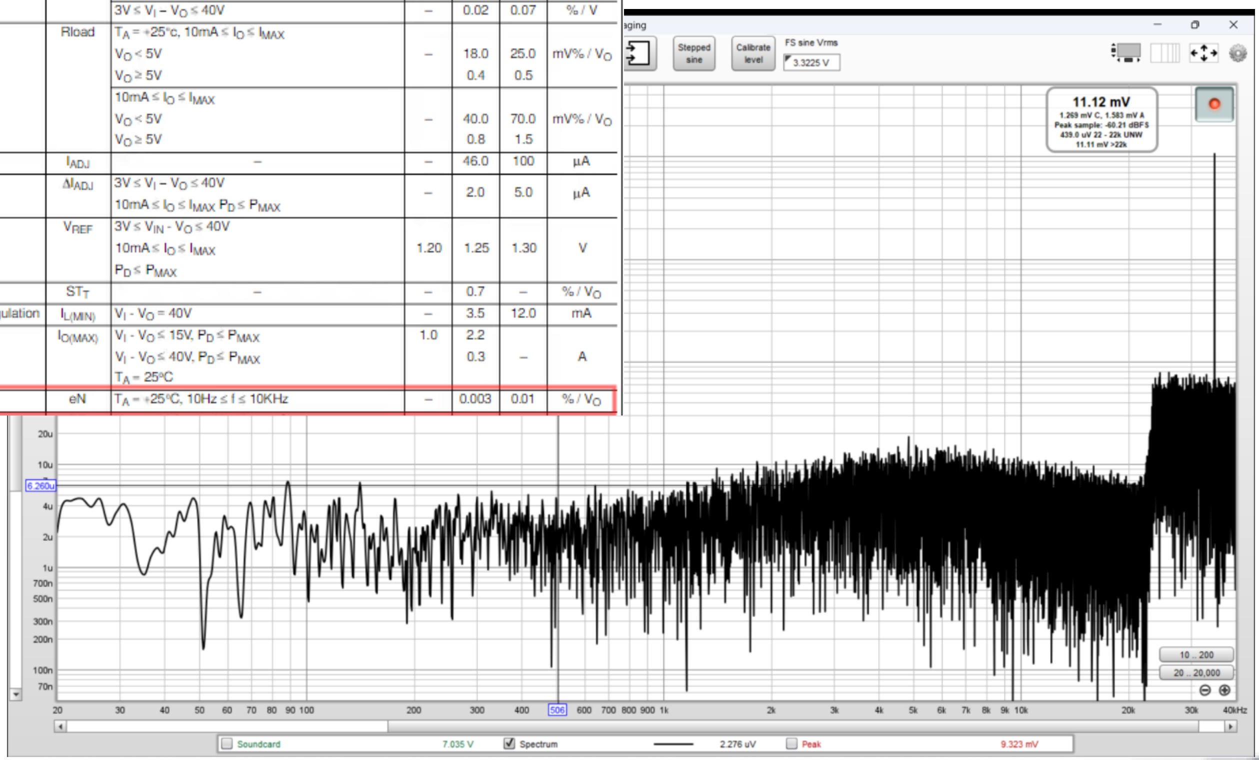
LM317 number 1 breadboarded circuit (12 vDC in – 5 vDC out – 51 ohm load - 75 mA draw) ~ 5-7 uV peaks below 2 khz, broad peak of 15 uV on 5 KHz, 10 mV spike at 35 Khz

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Line Regulation (Note 2)	Rline	T_A = +25°C 3V ≤ V_I – V_O ≤ 40V	—	0.01	0.04	% / V
		3V ≤ V_I – V_O ≤ 40V	–	0.02	0.07	% / V
Load Regulation (Note 2)	Rload	T_A = +25°c, 10mA ≤ I_O ≤ I_{MAX} V_O < 5V V_O ≥ 5V	–	18.0 0.4	25.0 0.5	mV% / V_O
		10mA ≤ I_O ≤ I_{MAX} V_O < 5V V_O ≥ 5V	–	40.0 0.8	70.0 1.5	mV% / V_O
Adjustable Pin Current	I_{ADJ}	–	–	46.0	100	µA
Adjustable Pin Current Change	ΔI_{ADJ}	3V ≤ V_I – V_O ≤ 40V 10mA ≤ I_O ≤ I_{MAX} P_D ≤ P_{MAX}	–	2.0	5.0	µA
Reference Voltage	V_{REF}	3V ≤ V_{IN} - V_O ≤ 40V 10mA ≤ I_O ≤ I_{MAX} P_D ≤ P_{MAX}	1.20	1.25	1.30	V
Temperature Stability	ST_T	–	–	0.7	–	% / V_O
Minimum Load Current to Maintain Regulation	$I_{L(MIN)}$	V_I - V_O = 40V	–	3.5	12.0	mA
Maximum Output Current	$I_{O(MAX)}$	V_I - V_O ≤ 15V, P_D ≤ P_{MAX} V_I - V_O ≤ 40V, P_D ≤ P_{MAX} T_A = 25°C	1.0	2.2 0.3	–	A
RMS Noise,% of V_{OUT}	eN	T_A = +25°C, 10Hz ≤ f ≤ 10KHz	–	0.003	0.01	% / V_O



.003 % of 5v=15 uV

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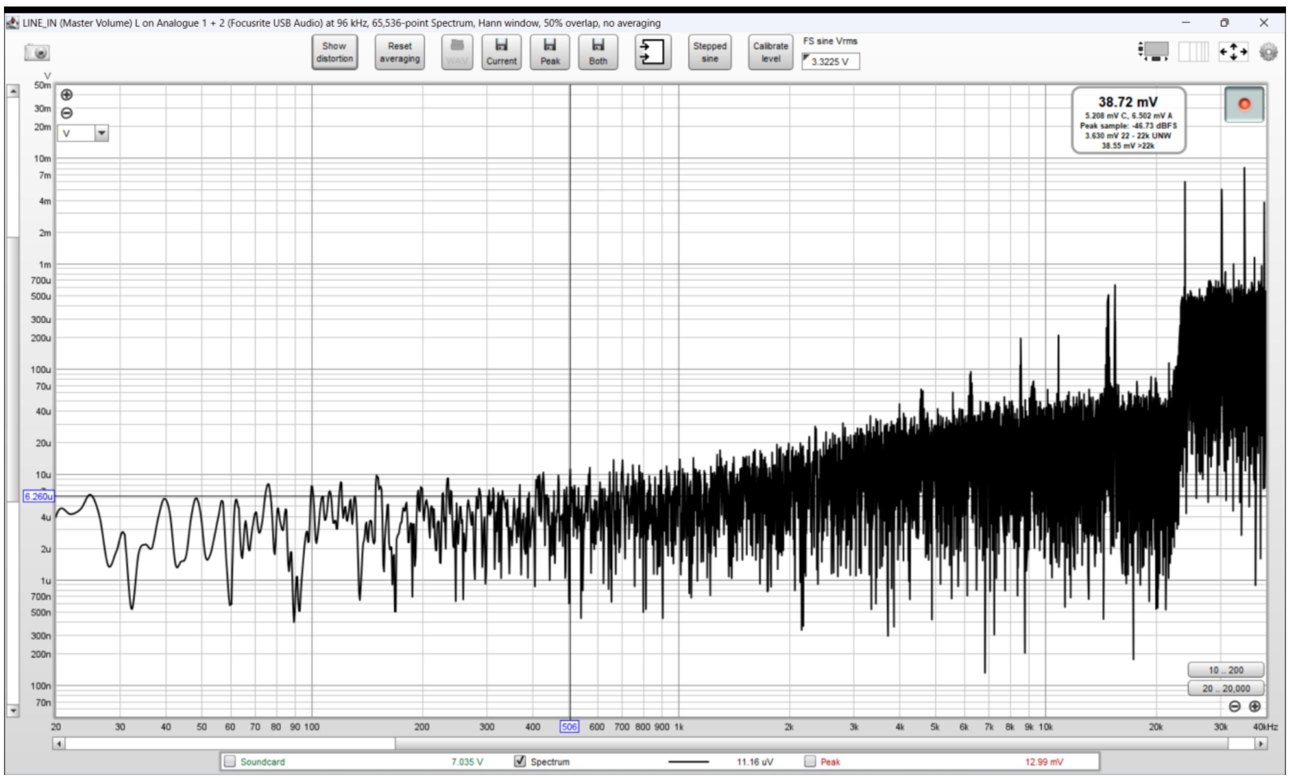
MH-MINI-360 (12 vDC in – 5 vDC out – 51 ohm load) ~6 to 10 uV peaks <500 Hz, rising noise of 10 to 40 uV at 20 KHz, peak of ~ 1 mV at 12 KHz



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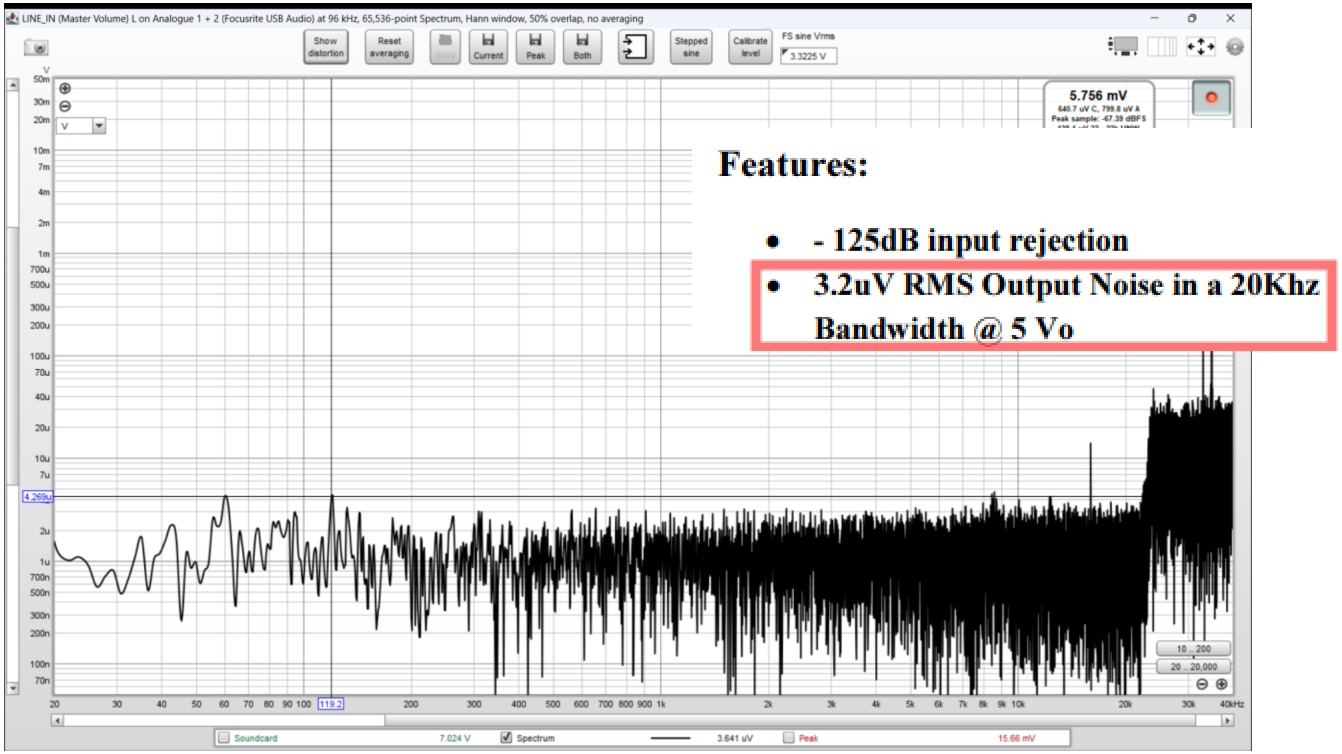
Noise measures

Sparkos lab SS7805 (12 vDC in – 5 vDC out – 51 ohm load - 120 mA draw) ~ 4 uV peak at 120 hz otherwise < 3 uV from 50 hz to 20 khz and 5 mV spike at 35 khz



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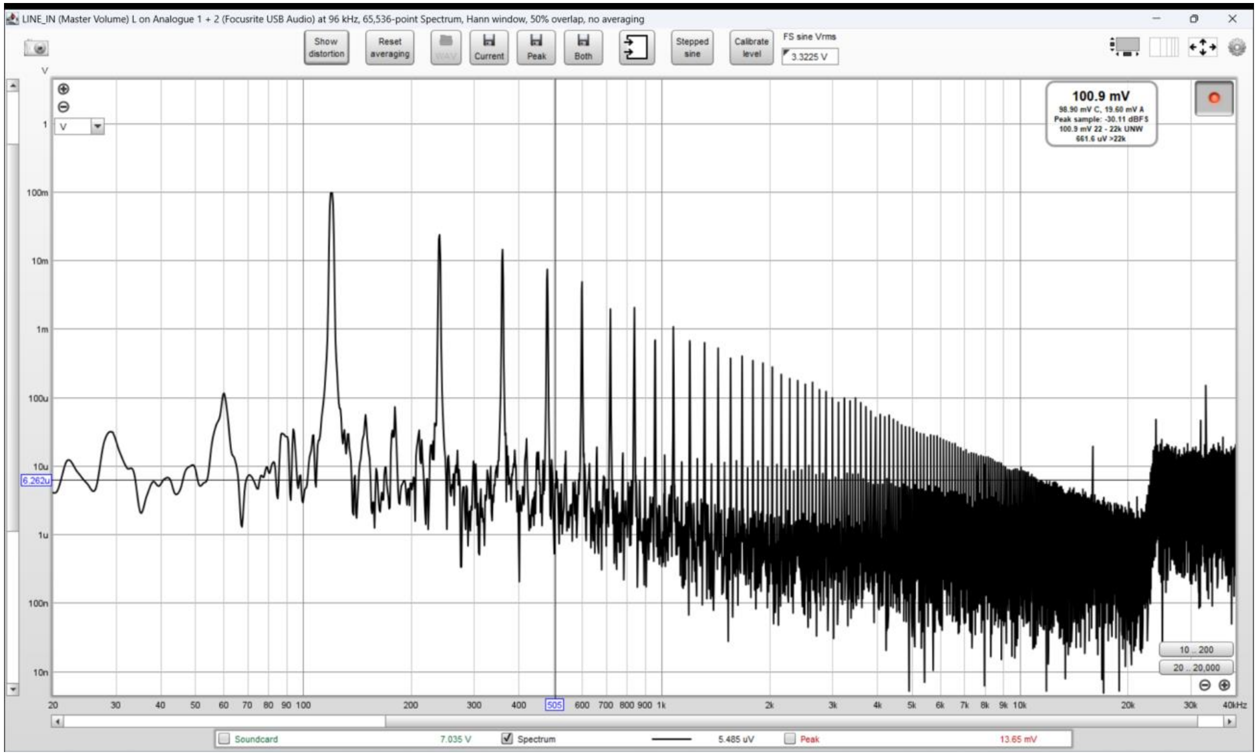
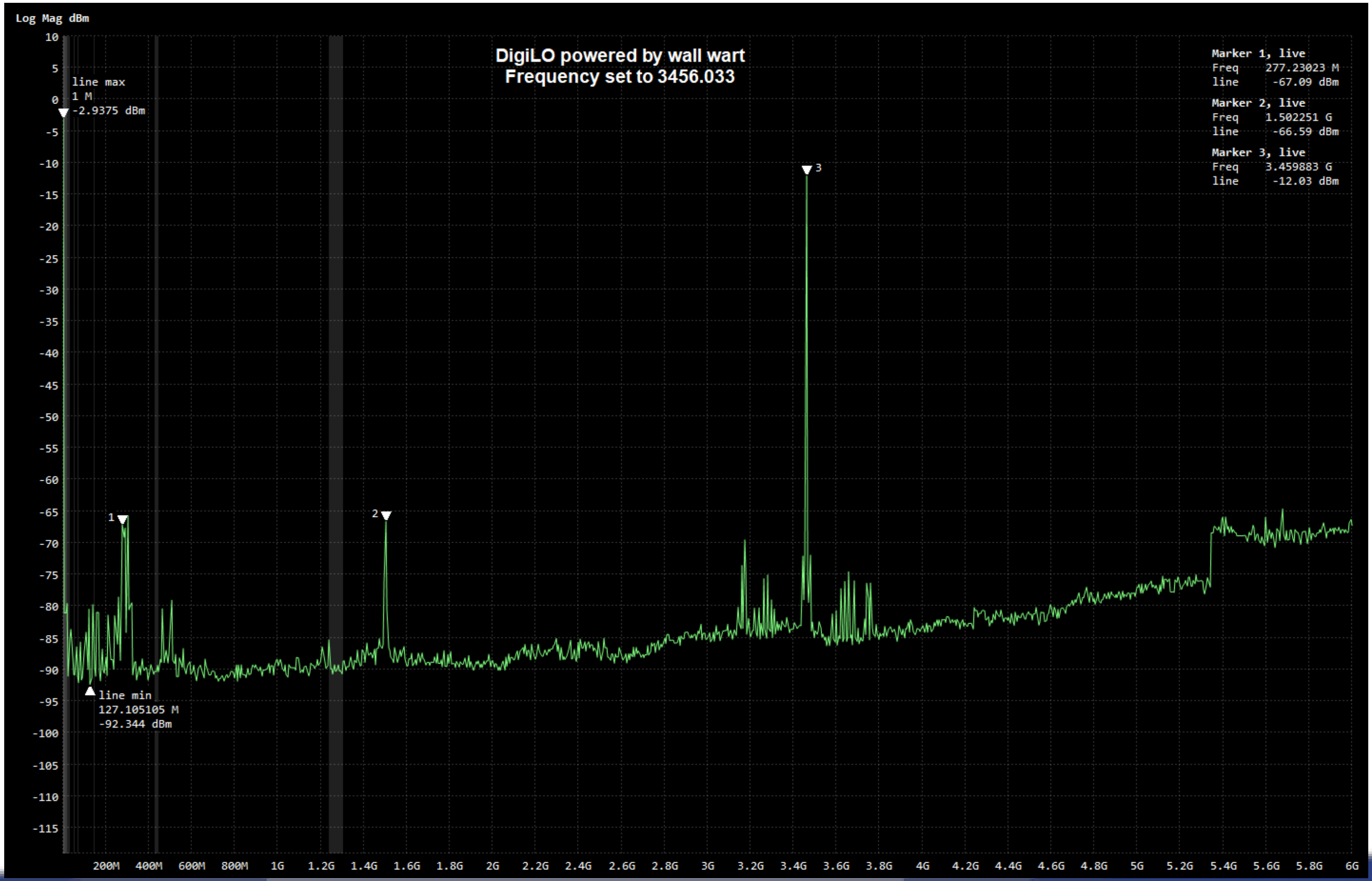
DigiLO wal wart power supply 100 mV ripple at 120 hz



Spectrum effects

DigiLO output spectrum



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Spectrum effects

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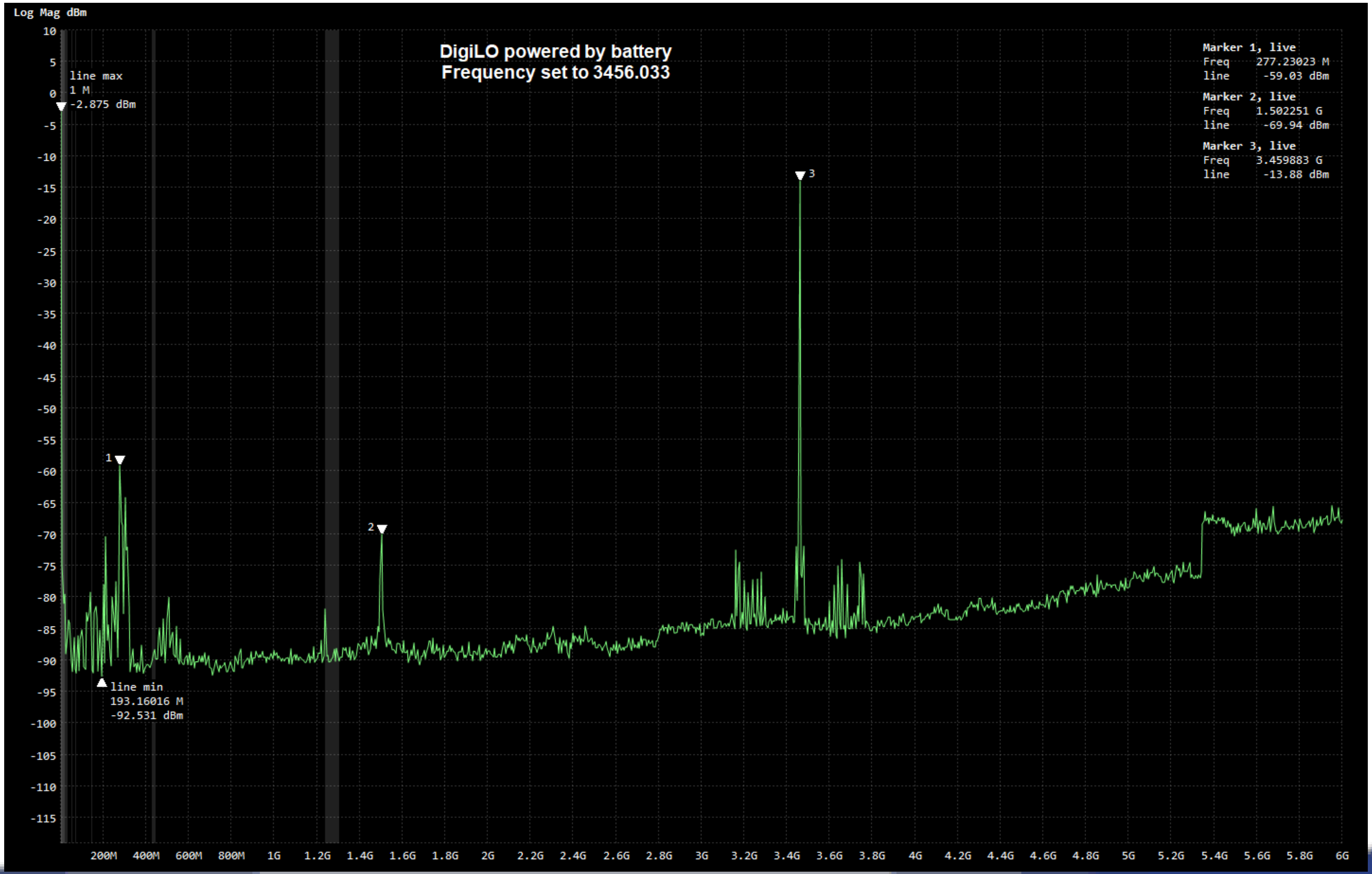
DigiLO output spectrum



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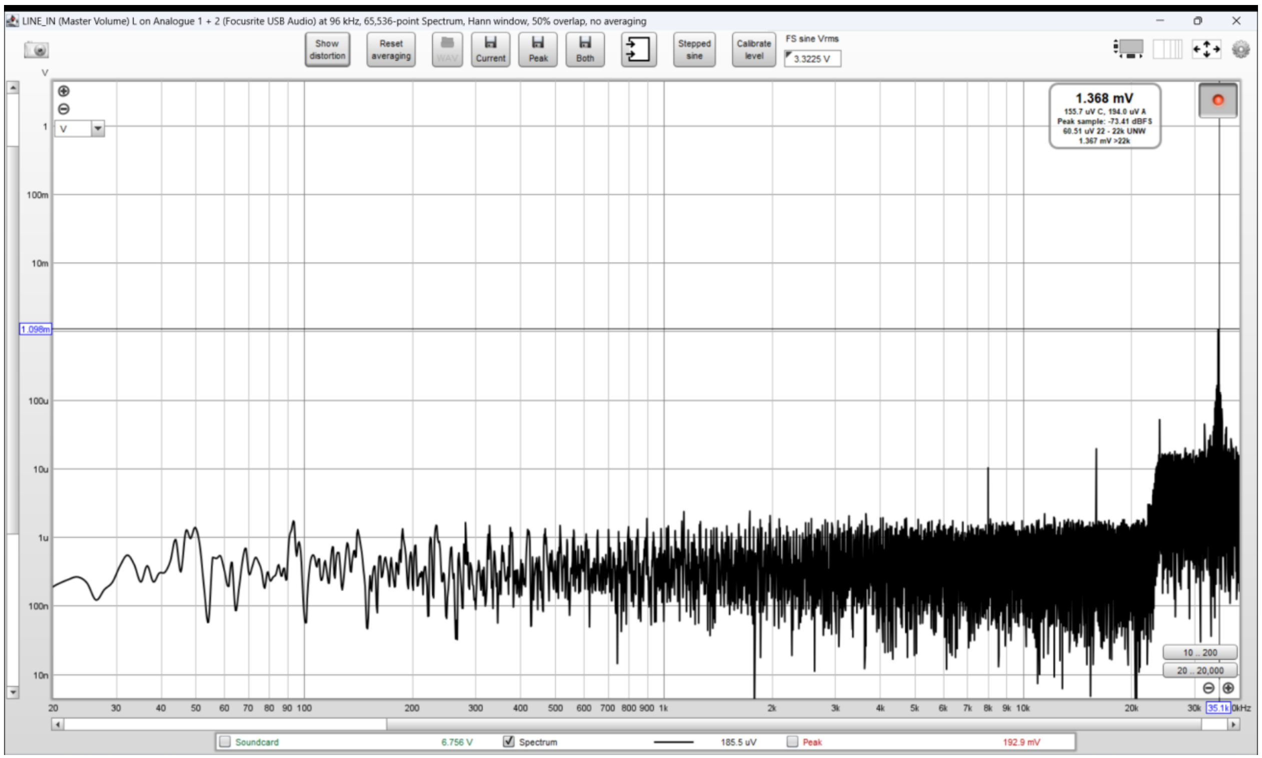
iPhone charger (120vAC in 5.0 vDC out) 1 mV spike at 35 KHz



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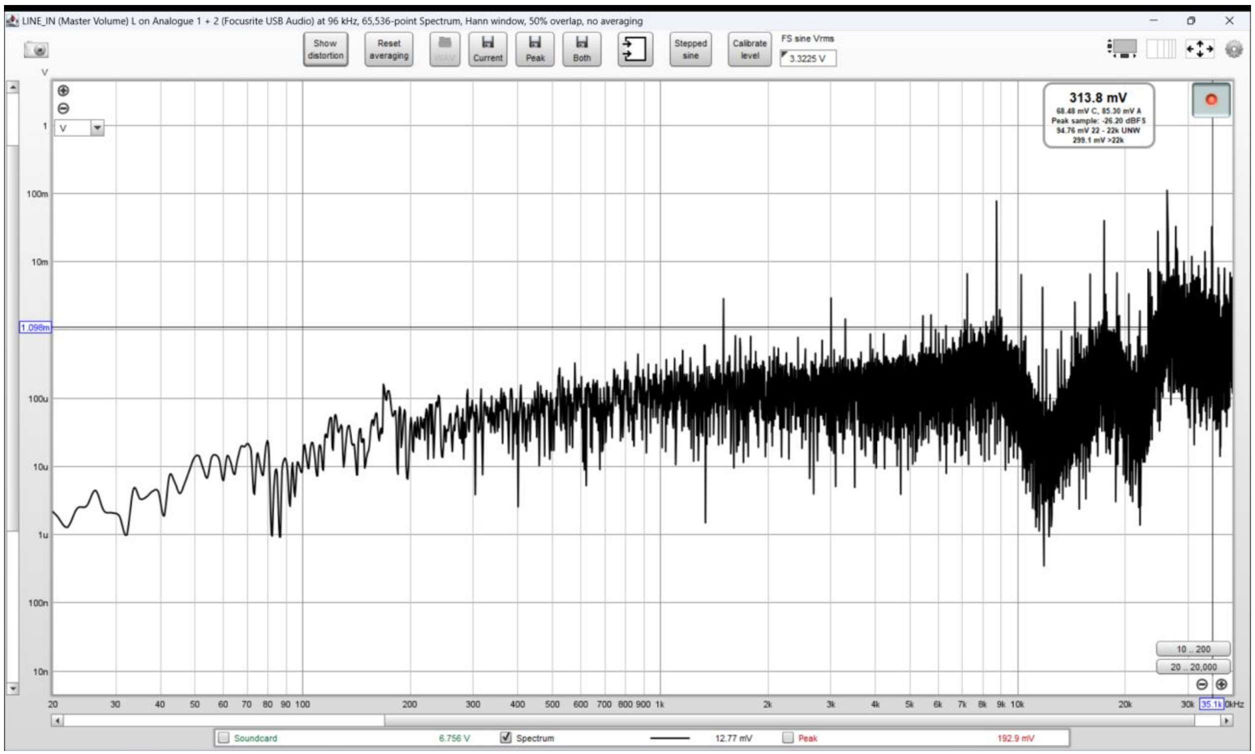
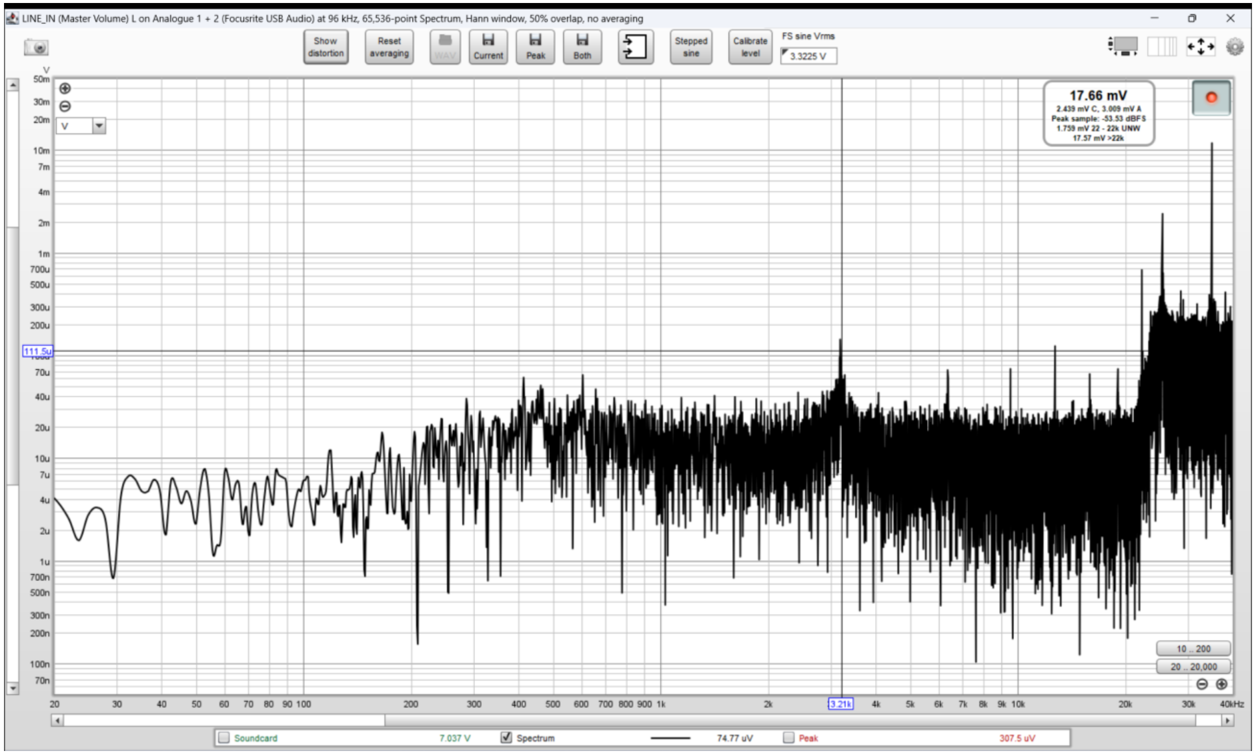
Noise measures

“Switcher power supply” (120vAC in 6.0 vDC out) I was using back in 2008 to drive a T/R relay for 1296 MHz



Noise measures

Buck converter XL4016E1 number 1 (12vDC in – 5.0vDC out – 100 ohm load – 50 mA draw) ~40 uV < 20 Khz, broad 100+ uV spike at 43.2 Khz, 11 mV spike at 35



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Spectrum effects

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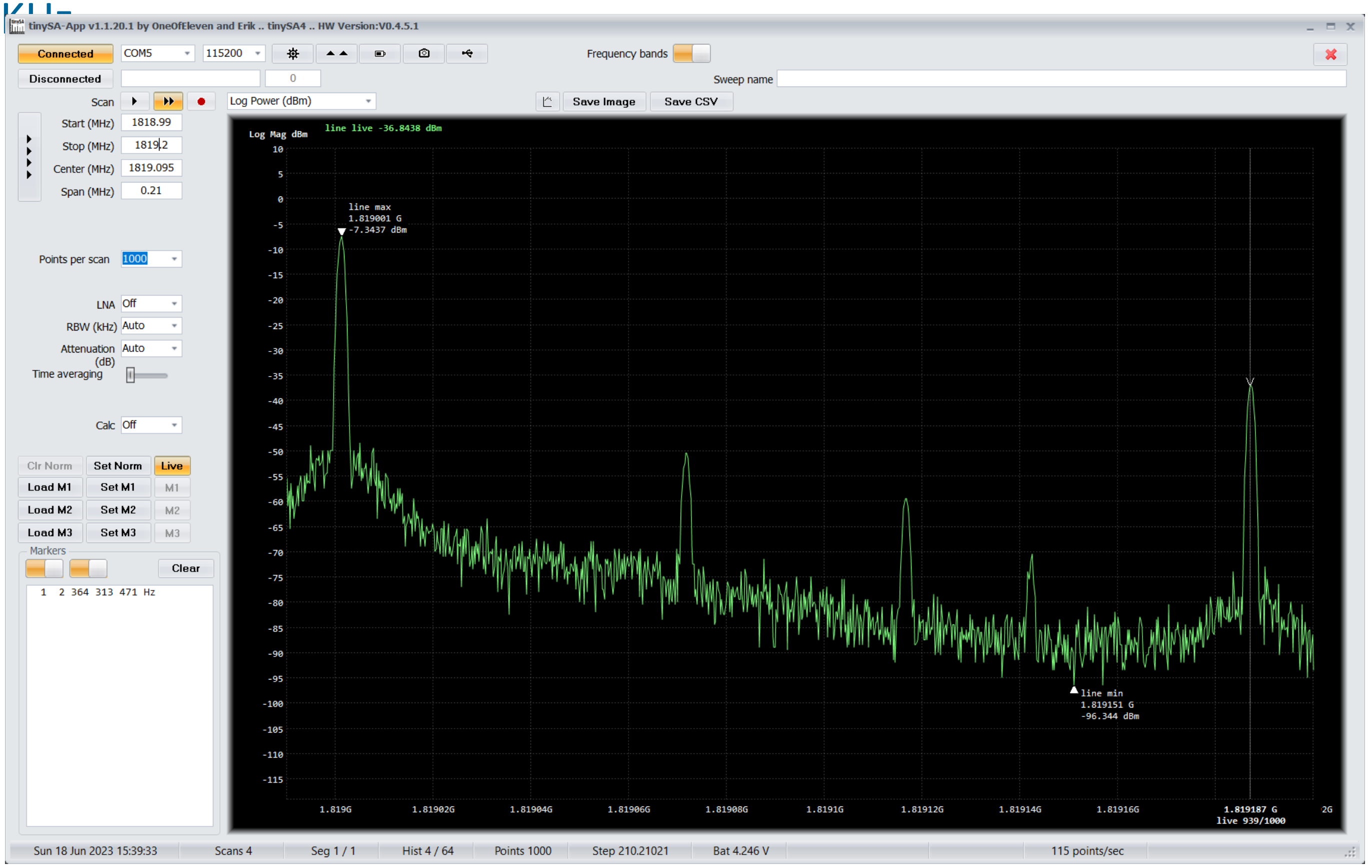
Wavelab 1819 MHz LO - McCoy 10 MHz OCXO (12 vDC) sharing PDU with 24 GHz system (uses XL4016 buck conv) – spur is -37 ~+184 KHz



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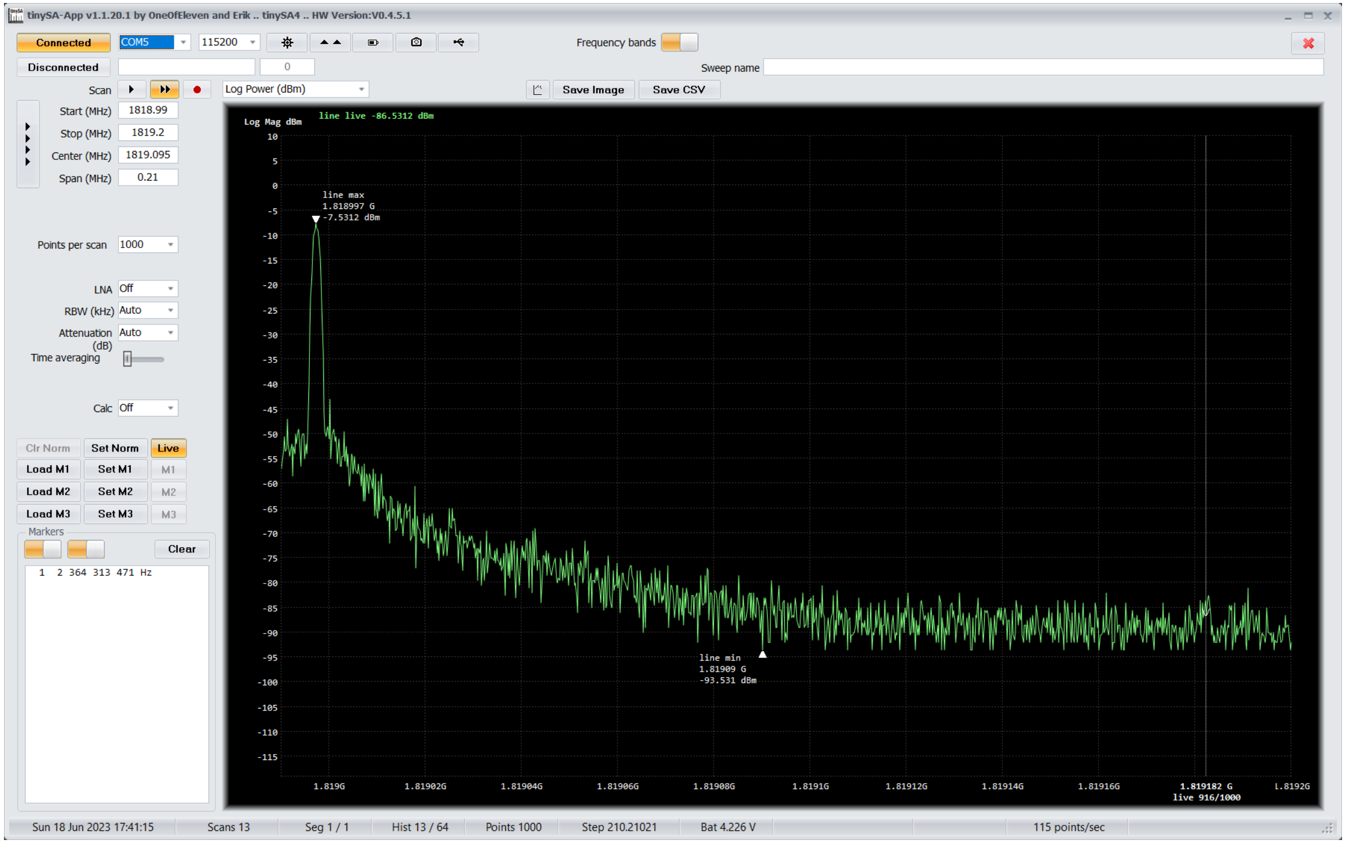
Spectrum effects

Wavelab 1819 MHz LO - 5v 10 MHz OCXO powered by Sparkos LDO sharing PDU with 24 GHz system (uses XL4016 buck conv) – spur is negligible



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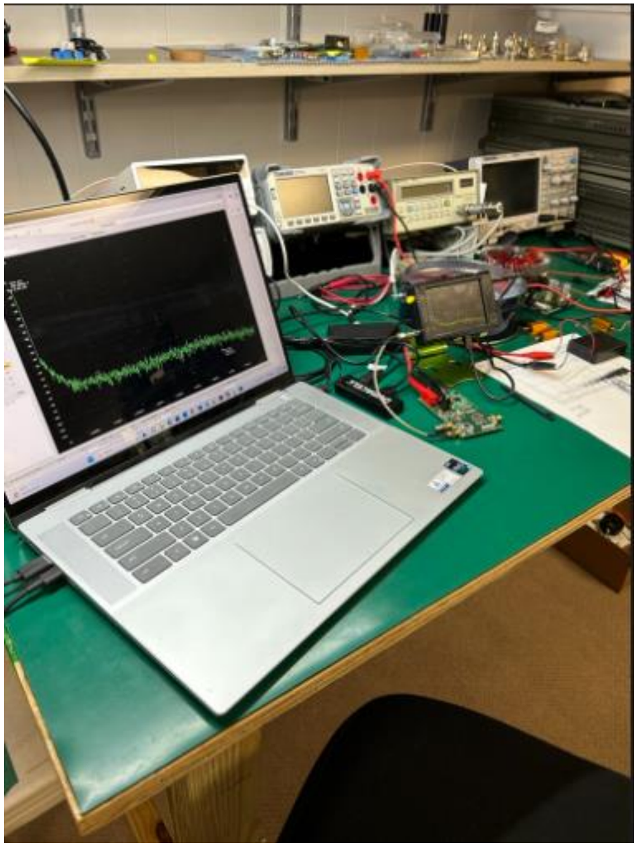
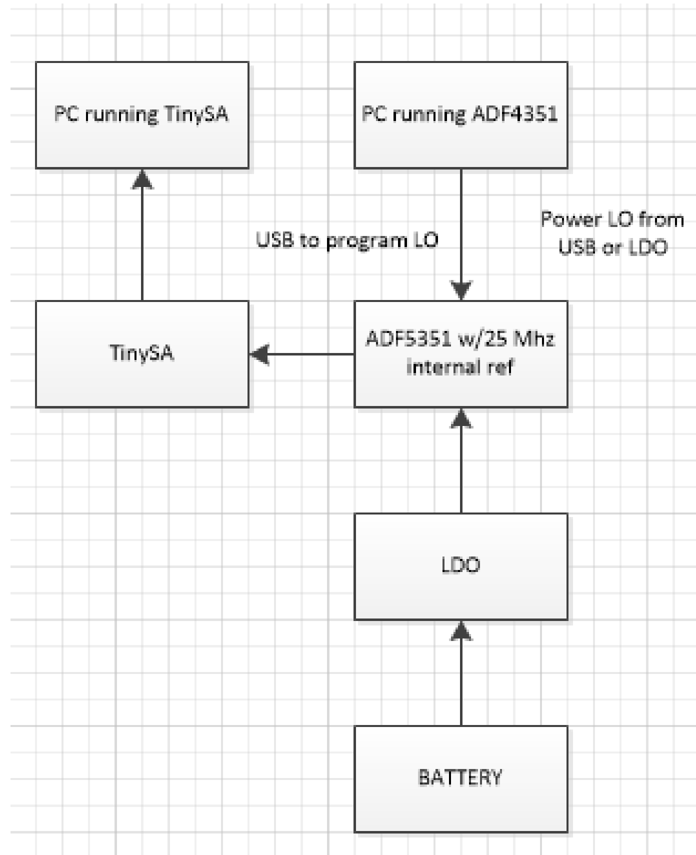
Focus testing





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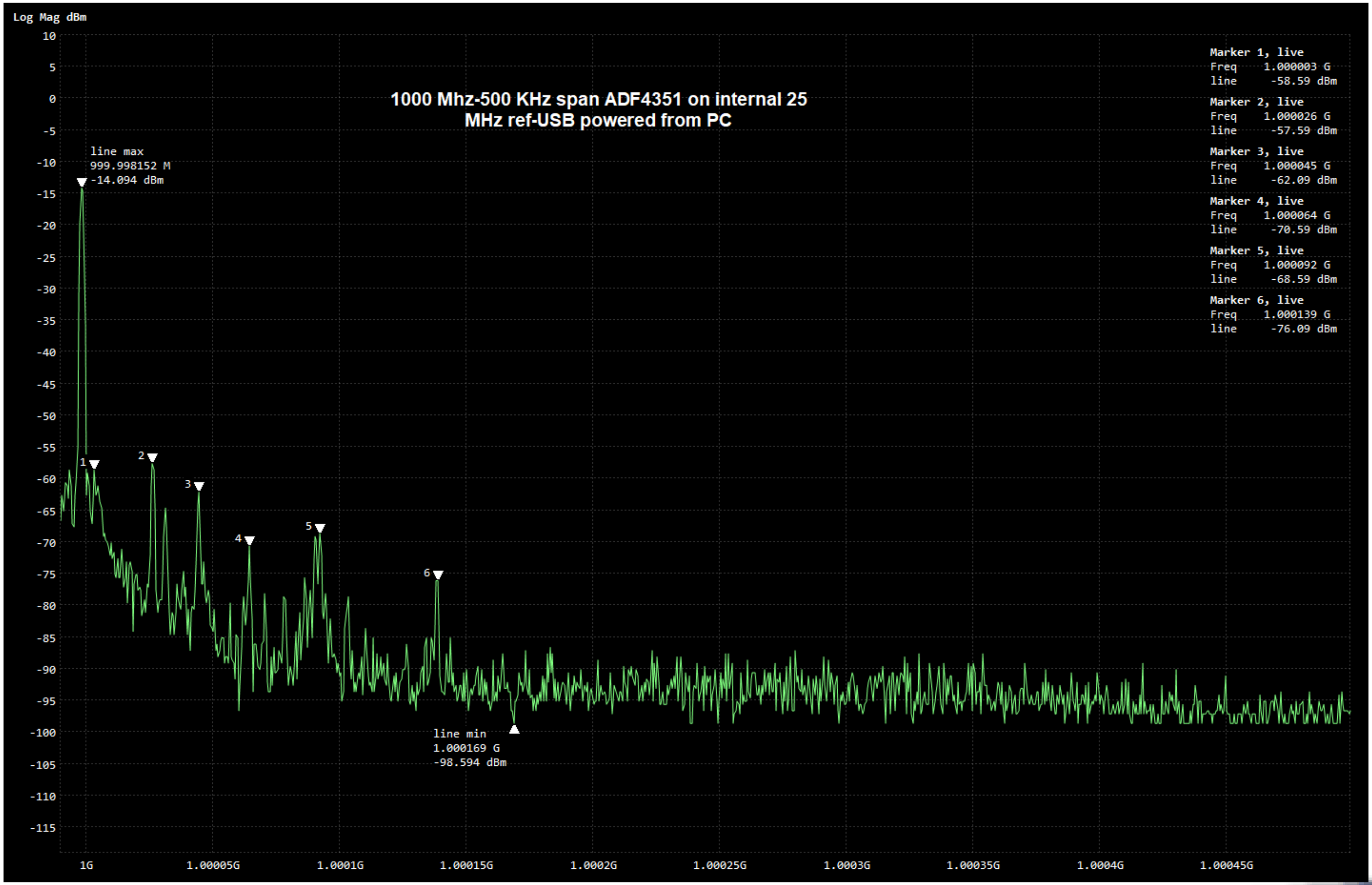

Focus testing

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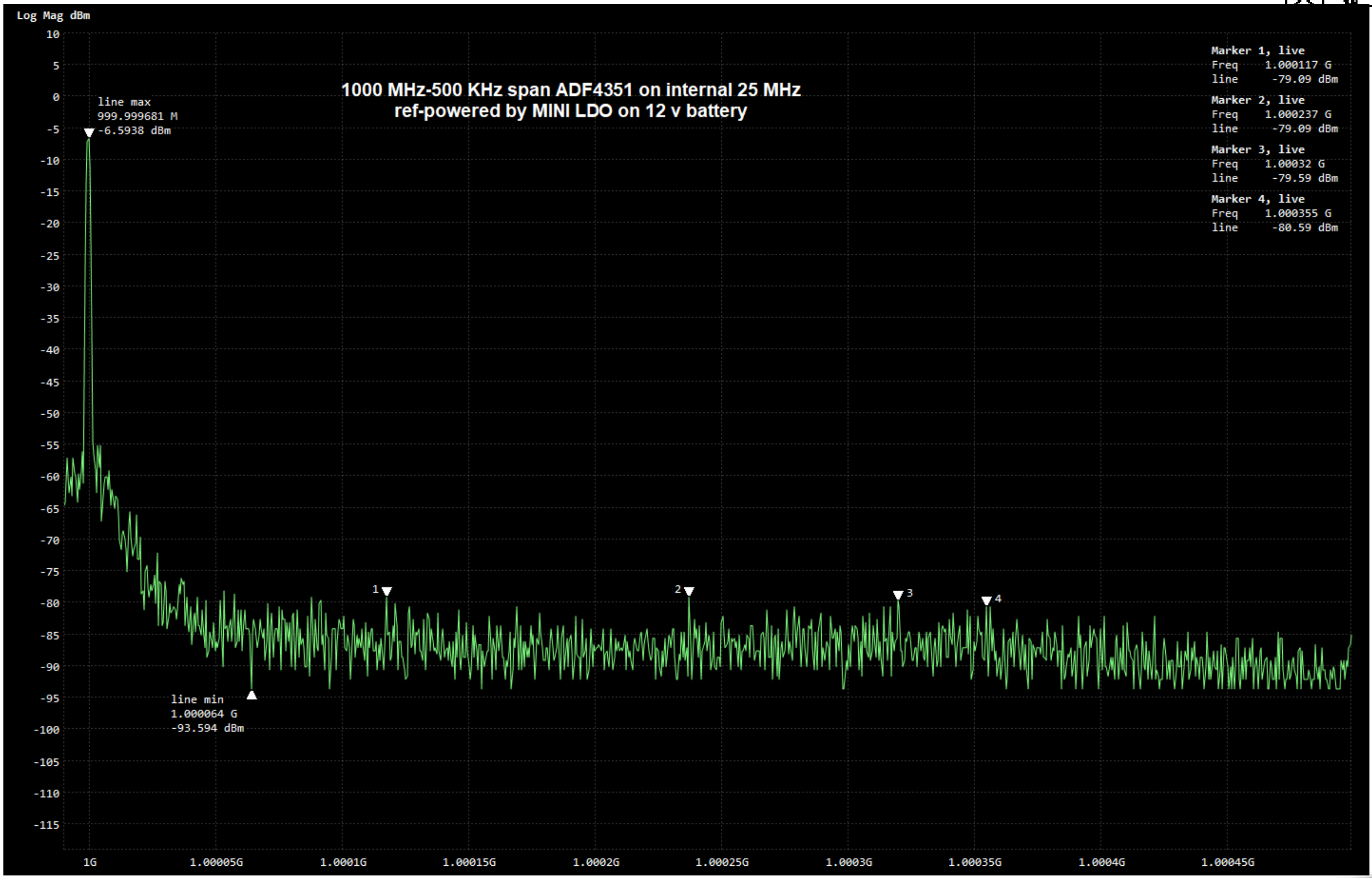

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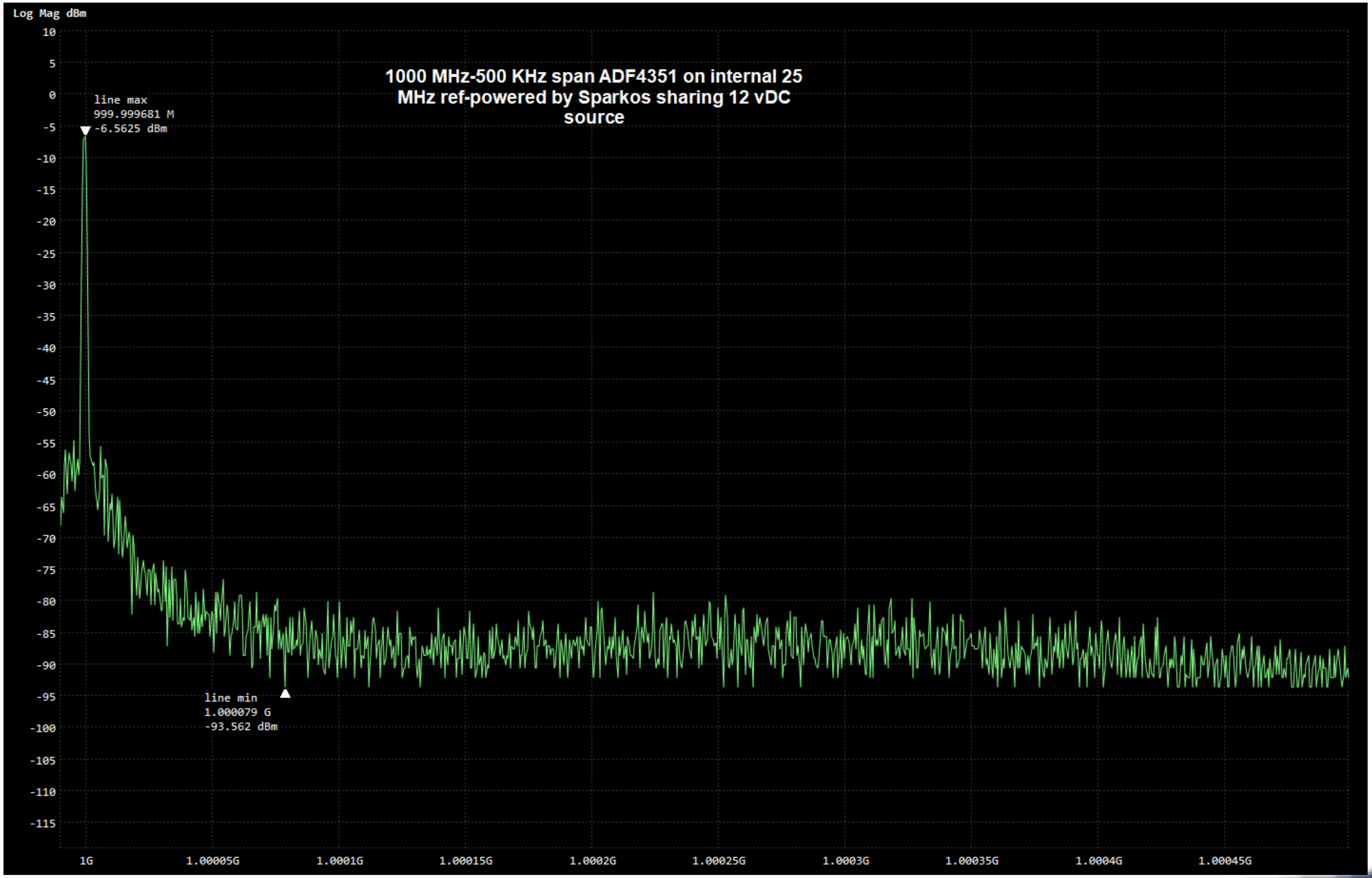

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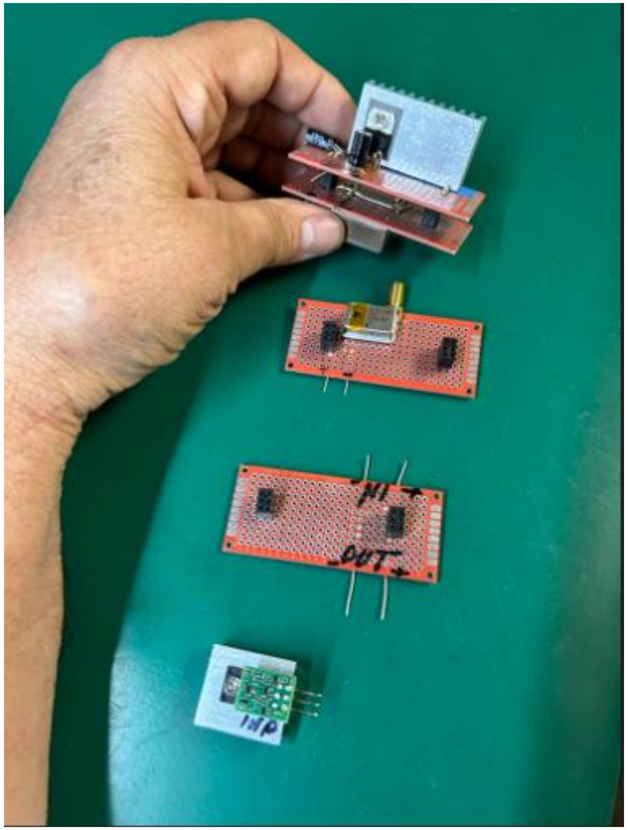

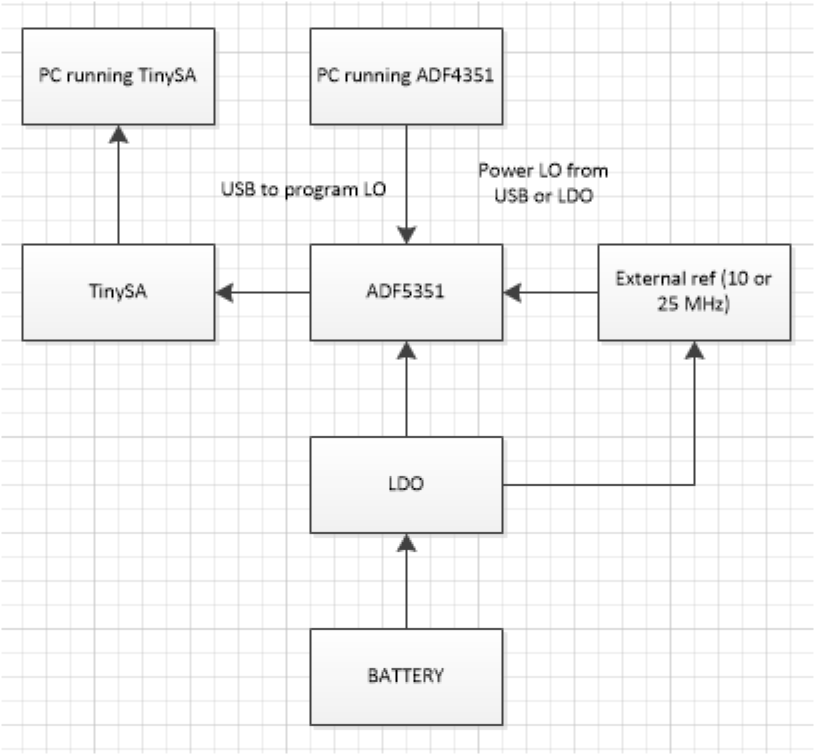

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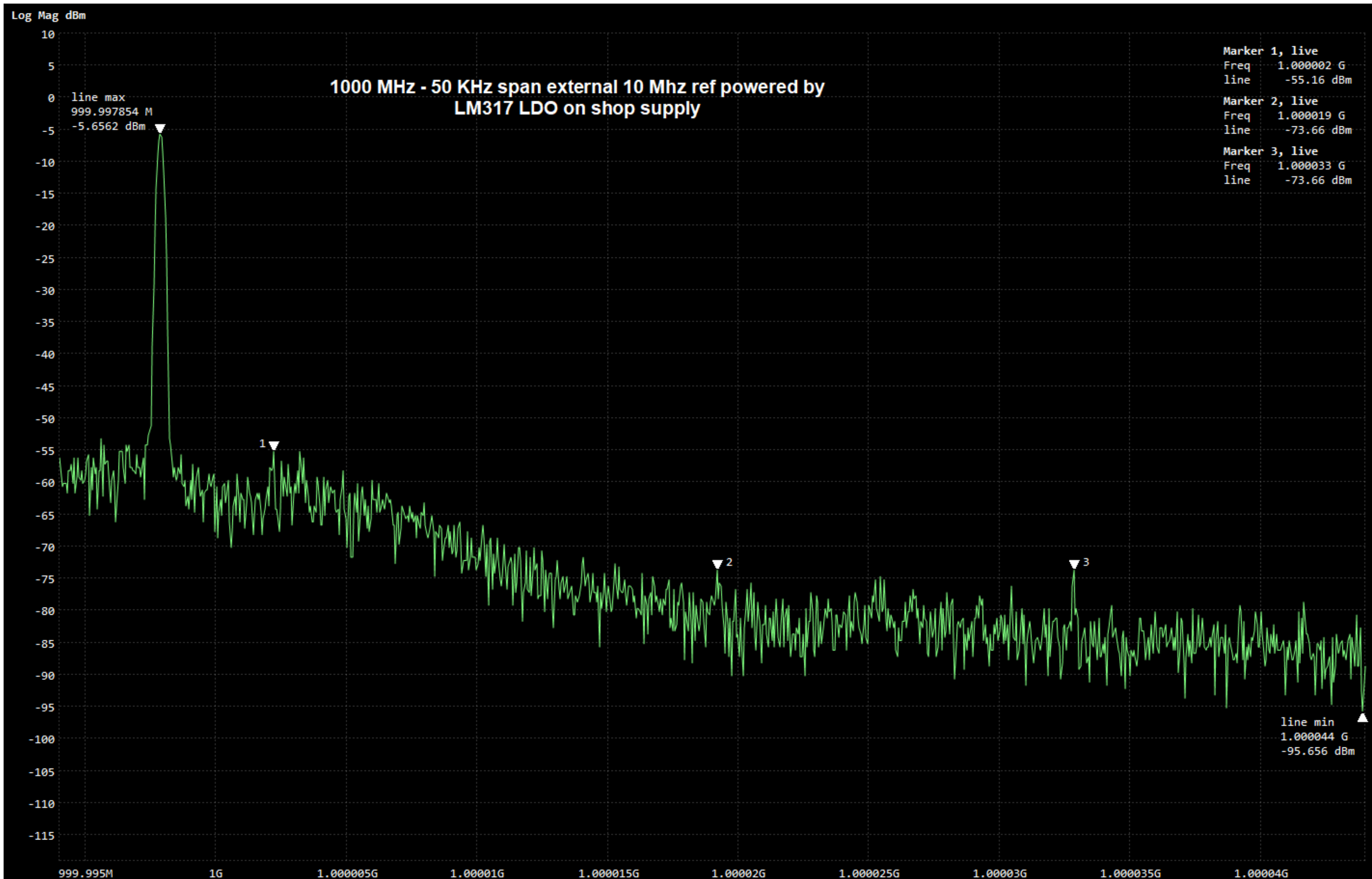
Focus testing – 50 KHz span



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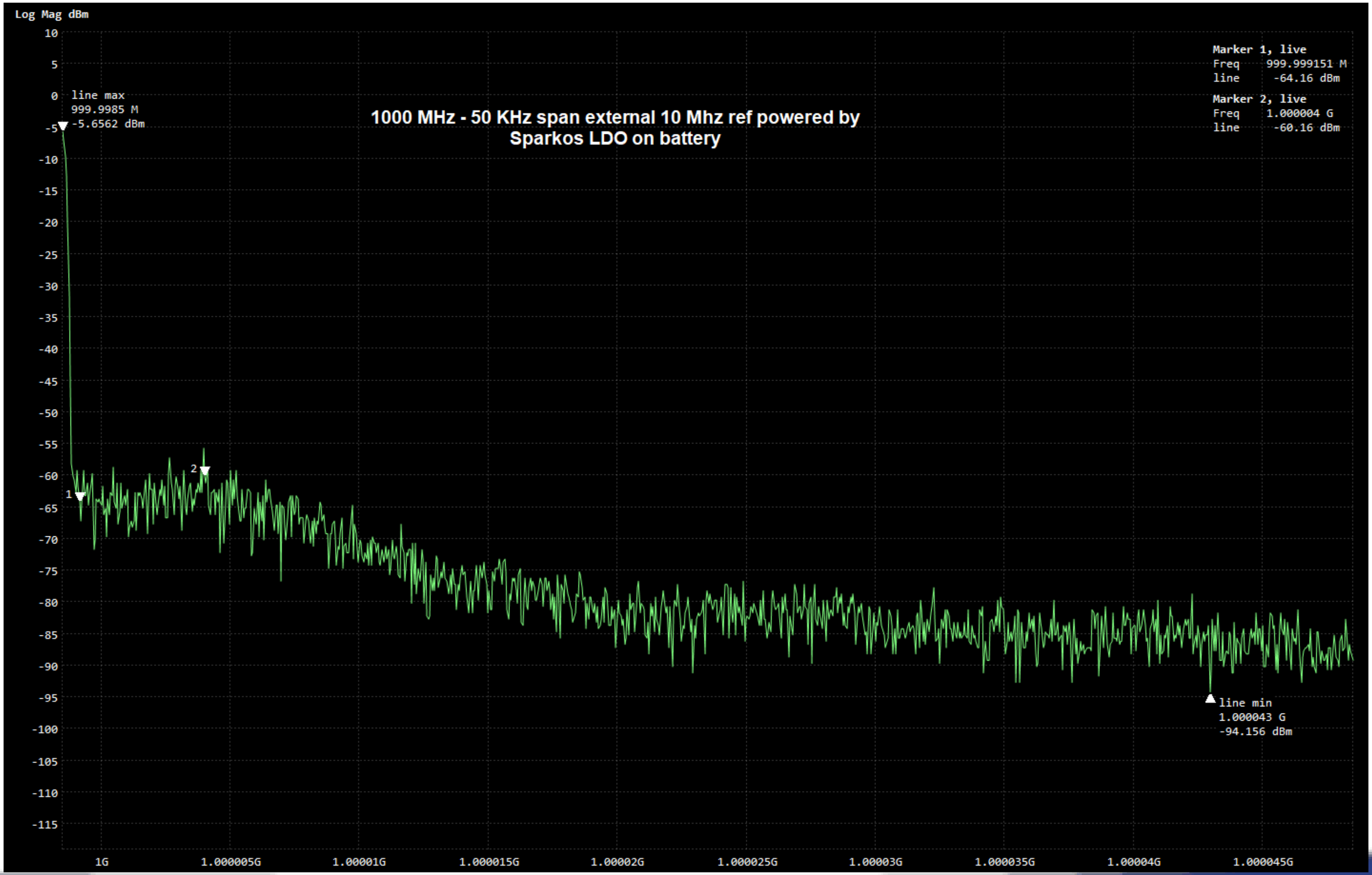
Focus testing



Focus testing

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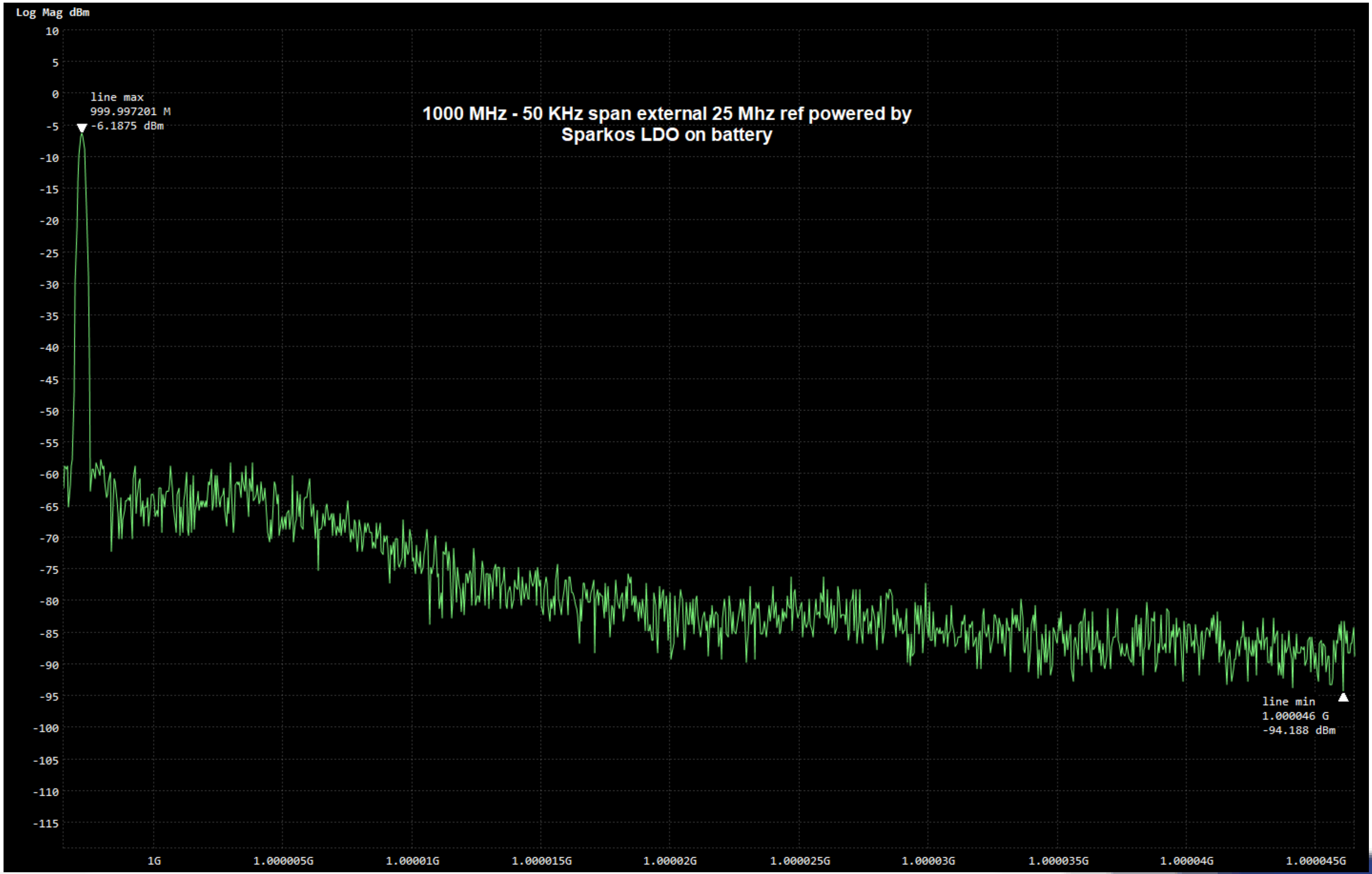

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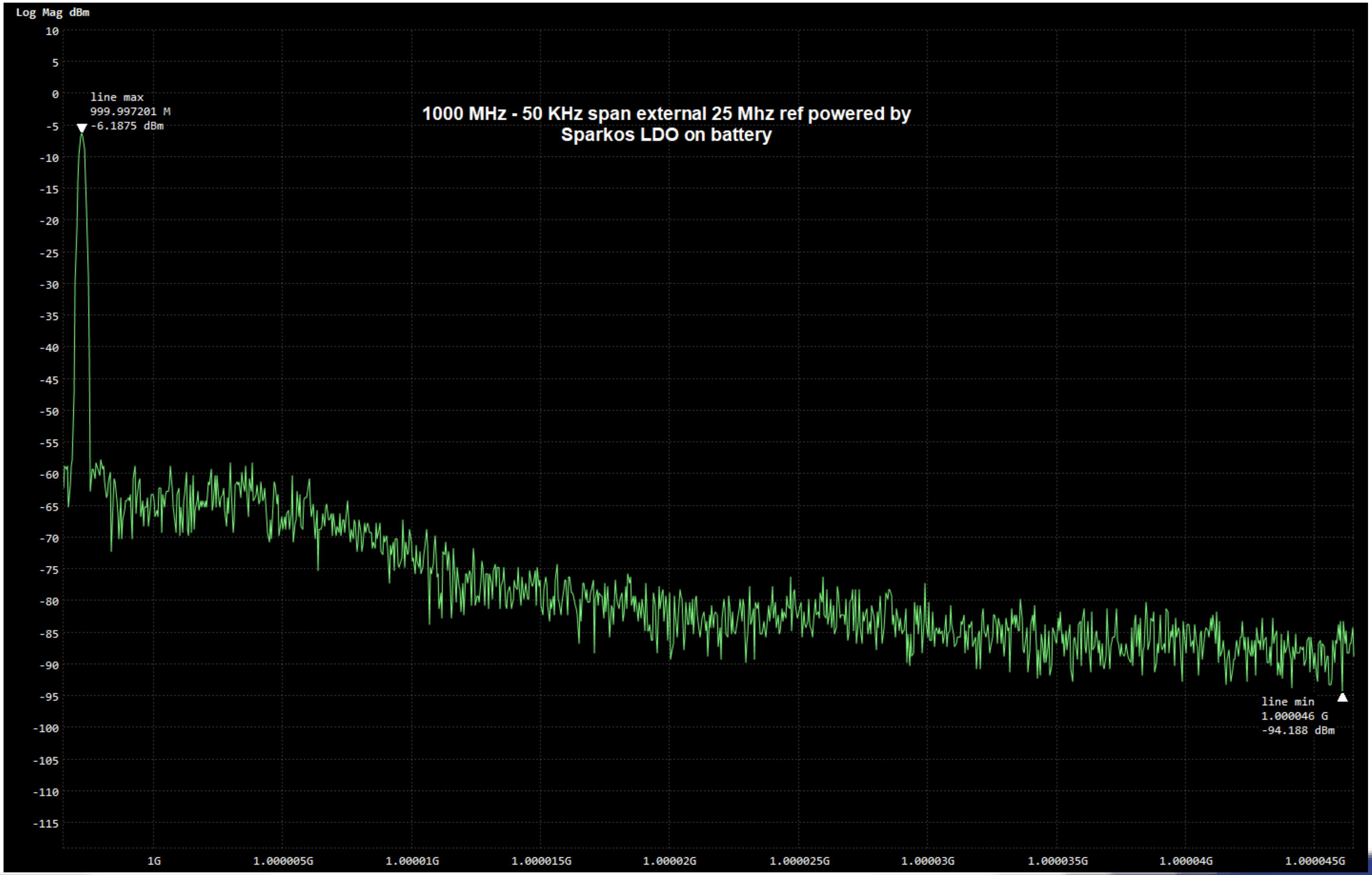
Focus testing



Next steps – to be continued

Spectral Noise density curve and a rising noise floor for RF apps

Effects on ADC or DAC. Sampling system causes high frequency noise to fold to lower frequencies due to aliasing

Reducing LDO noise-

- Understanding the datasheet
- Use best LDO you can afford
- Cascade multiple LDOs

Questions?