

SOAREX GROUP

Lock In Amplifier (QRRS Beacon)

(Qrp Really Really Slow)

Dave VE3OOI

March 2024

AGENDA

1. Background

- ✓ Why am I doing this to myself?

2. Fundamentals:

- ✓ Correlation/Convolution
- ✓ Lock In Amplifier

3. Design

4. Results

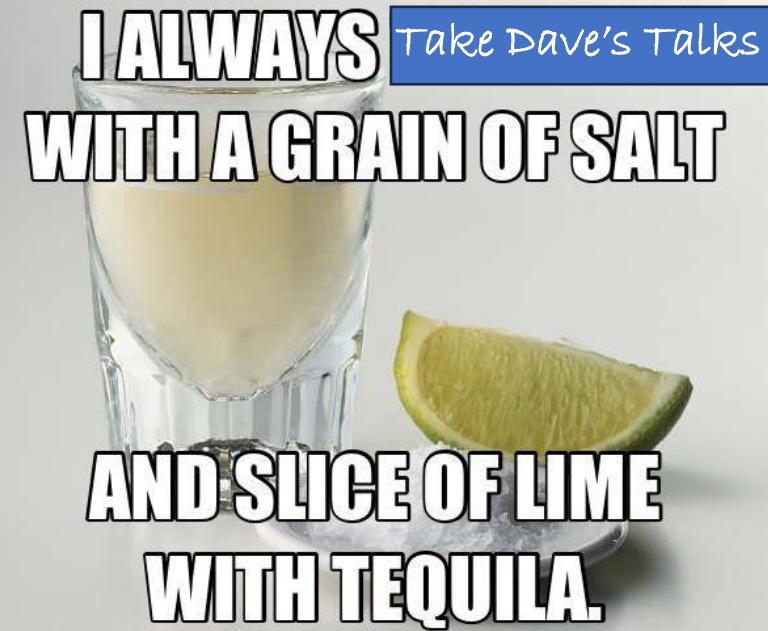
Danger Will Robinson...



Quote Charlie Morris, ZL2CTM:

This NOT a tutorial.

It's a log of my journey. Right or wrong.





REFERENCES



Mark Schnittker
217 subscribers

How a lock in amplifier works

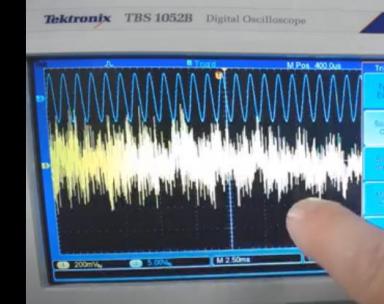
By Mark Schnittker

How a Lock in amplifier works

https://youtu.be/R0KN3ktpvUs?si=WBJhwNj8dEBUY_qF



Mark Schnittker
217 subscribers



Measuring signals buried in noise with an Oscilloscope

https://youtu.be/vv-xkNa1Z9s?si=TdN_vxI23mrKcUL



Dallin Durfee
577 subscribers

Lock-In Detection

Dallin S. Durfee
Physics 245
December 2018

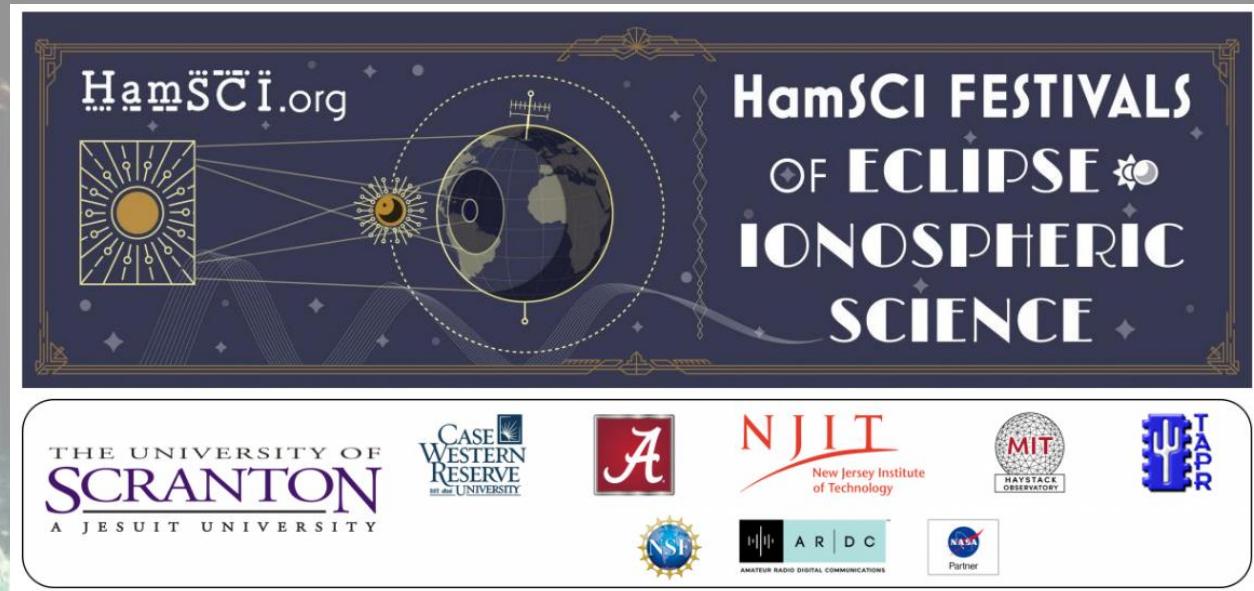
(c) Dallin S. Durfee

Lock In Detection

<https://youtu.be/Yqs-4TKGjjQ?si=ktAOdHCBNoIpUxaz>

2024 Eclipse

- ✓ HAMSCI will be collecting propagation information (WSPR, RBN, GRAPE, etc.)



- ✓ Excellent opportunity to do some experimentation

2024 Eclipse: What to do?

- ✓ Total Eclipse is (max) 2 to 3 minutes duration. Entire duration is 2:20ish
 - ✓ For where I am, probably several seconds for totality
 - ✓ “Nighttime” for less than a minute!
 - ✓ Sunset and Sunrise over a 2.5ish hour period. Much shorter where I will be.
- ✓ Setup and run WSPR (Tx, Rx or Both)
 - ✗ Transmits on even minutes and take 2 minutes to complete
- ✓ Reverse Beacon Network (RBN) (Tx only)
 - ✗ This is a spotting network – not propagation. Use for contacts
 - ✗ Does not identify every transmission. Spots reported several minutes apart
 - ✗ Total Eclipse is probably less than a minute duration. Entire duration is maybe and hours or two (for me)
- ✓ Decide to build my OWN propagation beacon & mode
 - ✓ Looked at QRSS (Slow CW) but seems to be more visual decoding and slow.
 - ✓ Needed mechanism to detect transmission.
 - ✓ Decided to send CW with a constant carrier (e.g., antenna tuning) over 15 to 20 seconds. Carrier is much easier to detect Short enough not to piss anyone off.

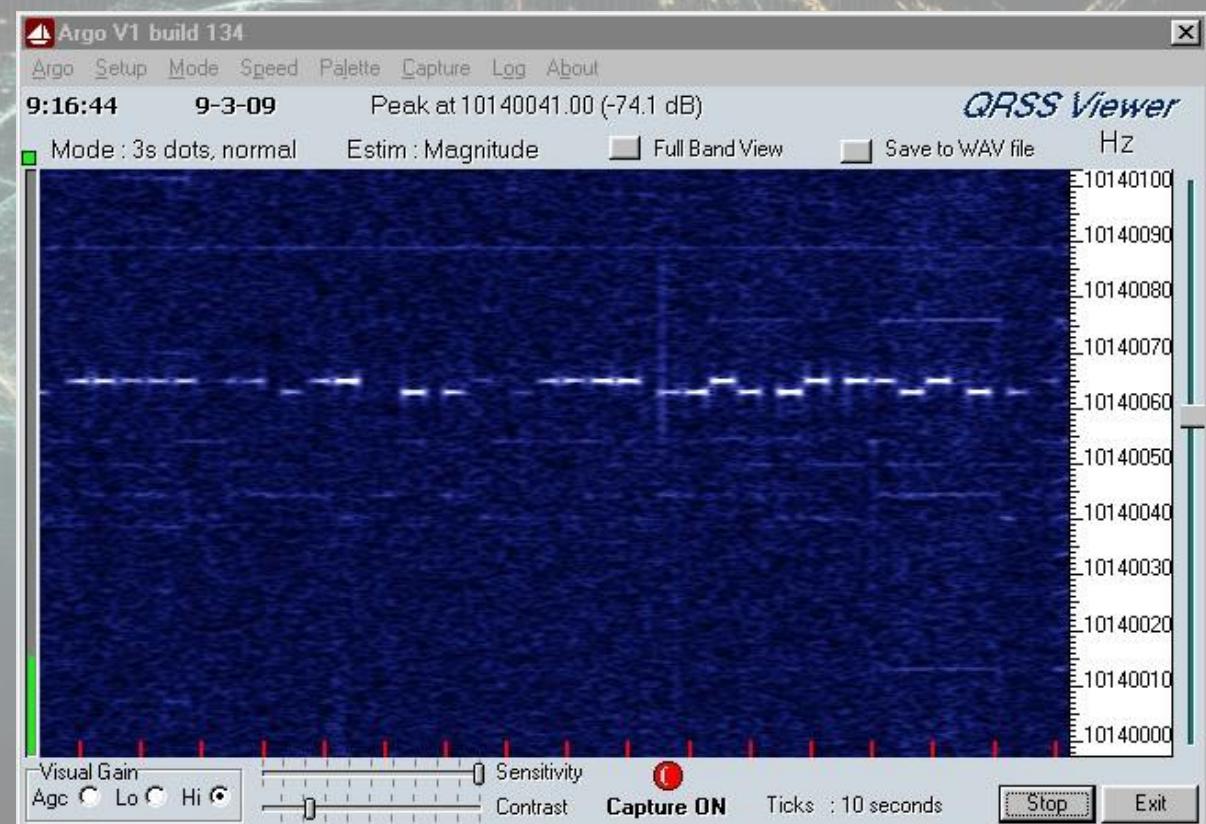
QRS, QRSS & QRRS

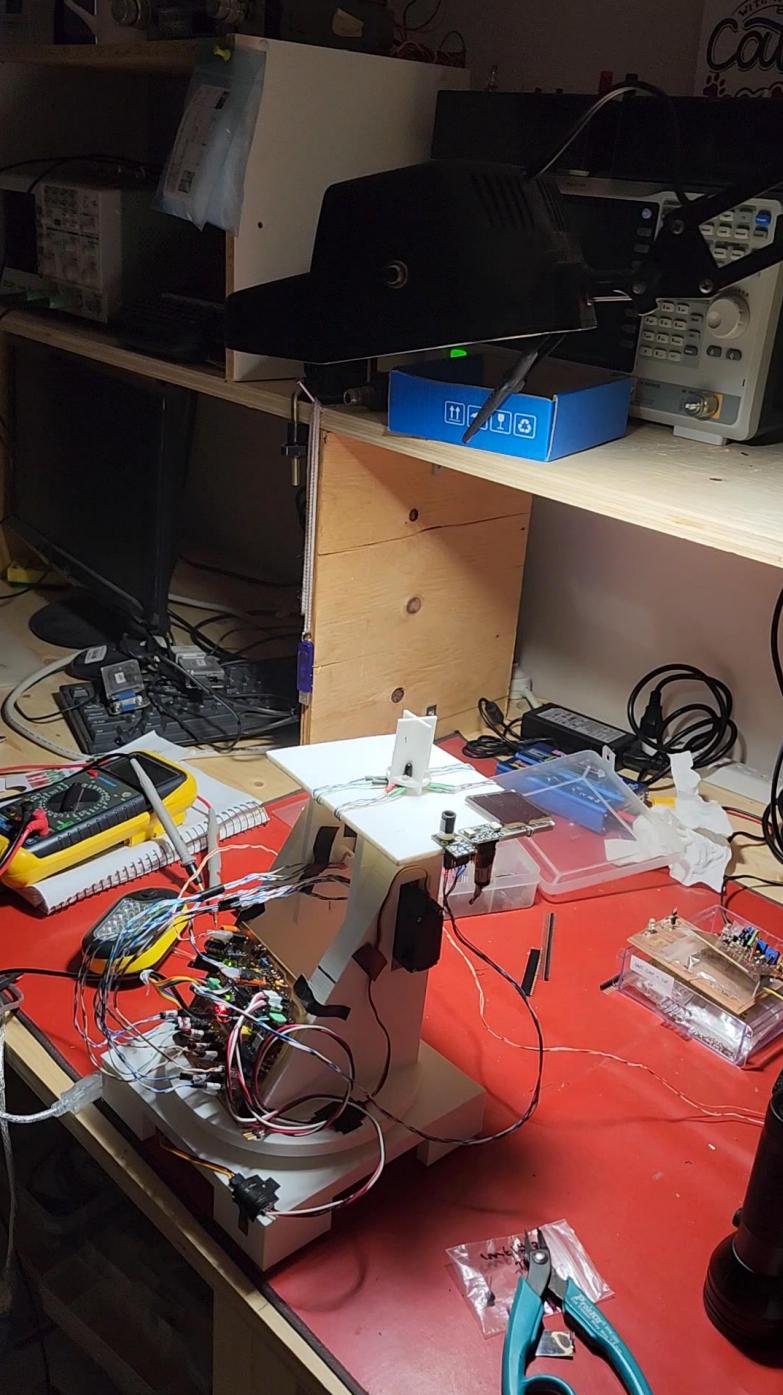
QRSS is an experimental radio mode that uses frequency-shift-keyed (FSK) continuous wave (CW) Morse code to transmit messages that can be decoded visually by inspecting the radio frequency spectrogram. The name "QRSS" is a derivation of the Q code "QRS", a phrase Morse code operators send to indicate the transmitter needs to slow down. The extra "S" means slow way, way down, and at the typical speed of 6 second dots and 18 second dashes most QRSS operators have just enough time to send their call sign once every ten minutes (as required by federal law). These slow Morse code messages can be decoded by visual inspection of spectrograms created by computer software processing the received audio. A QRSS grabber is a radio/computer setup configured to upload the latest radio spectrogram to the internet every 10 minutes. QRSS Plus is an automatically-updating list of active QRSS grabbers around the world, allowing the QRSS community to see QRSS transmitters being detected all over the world.



QRS	Low speed CW
QRSS	Very low speed CW

QRRS – does not exists.





2024 Eclipse: RFH (Request for Help)

- ✓ Tune to a WebSDR or your own Radio
- ✓ Run my python program to detect signals



How to detect a carrier?

✓ Fast Fourier Transform (DFT, FFT, Goertzel)

✓ <https://youtu.be/rzNZUtWf718?si=r8KAmnUoC78C7zbi>

✓ Correlation

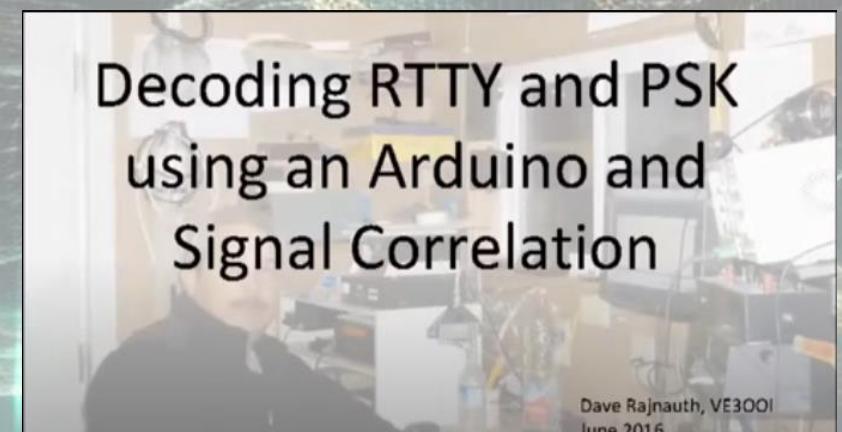
✓ Basis for signal processing. How much of a specific signal is present?

✓ <https://youtu.be/OdIKsElgz64?si=hTpqqk6gCSKOlkU91>

✓ Lock In Amplifier



Decoding RTTY and PSK
using an Arduino and
Signal Correlation



Lock In Amplifier

Lock In Amplifier

✓ Used to detect weak periodic signals in noisy environments

✓ E.g., Garage door sensor in light

✓ <https://youtu.be/Yqs-4TKGjjQ?si=vawaVNgV88wfB1NM>

✗ Mainly hardware based

✗ Very little about software based

✓ <https://youtu.be/R0KN3ktpvUs?si=1xkTmoFZ9cXbp03m>



How a lock in amplifier works

By Mark Schnittker

Lock in detection

■ Used to

– Pull signals out of noise

– Measure phase shifts

– Measure derivatives of . . . Stuff

■ Multiple ways to think about it

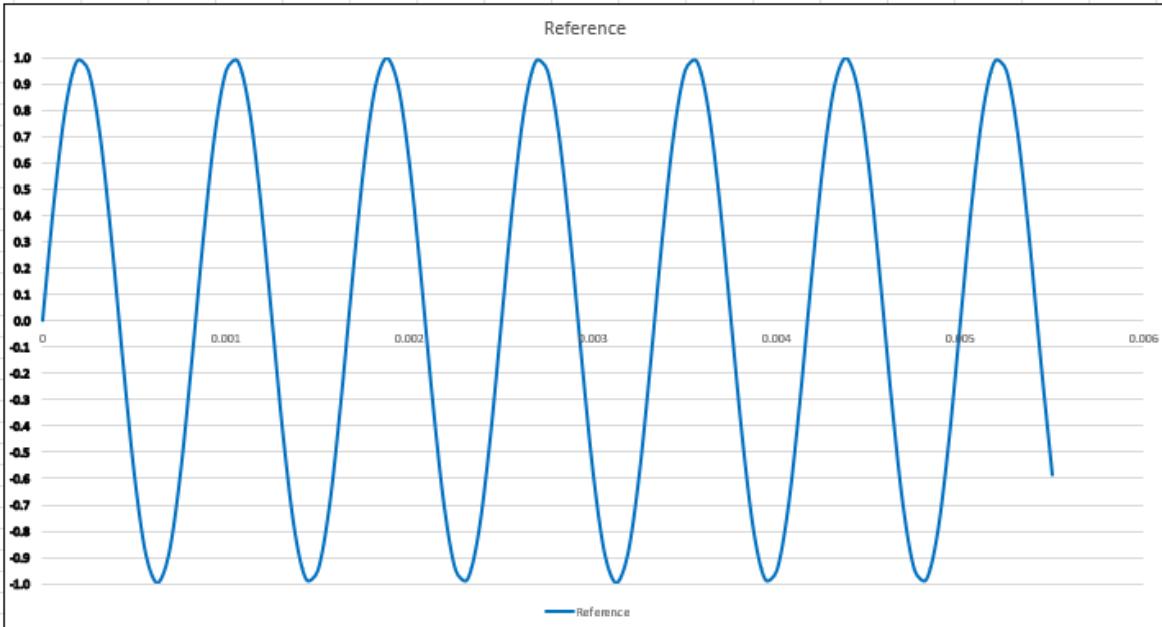
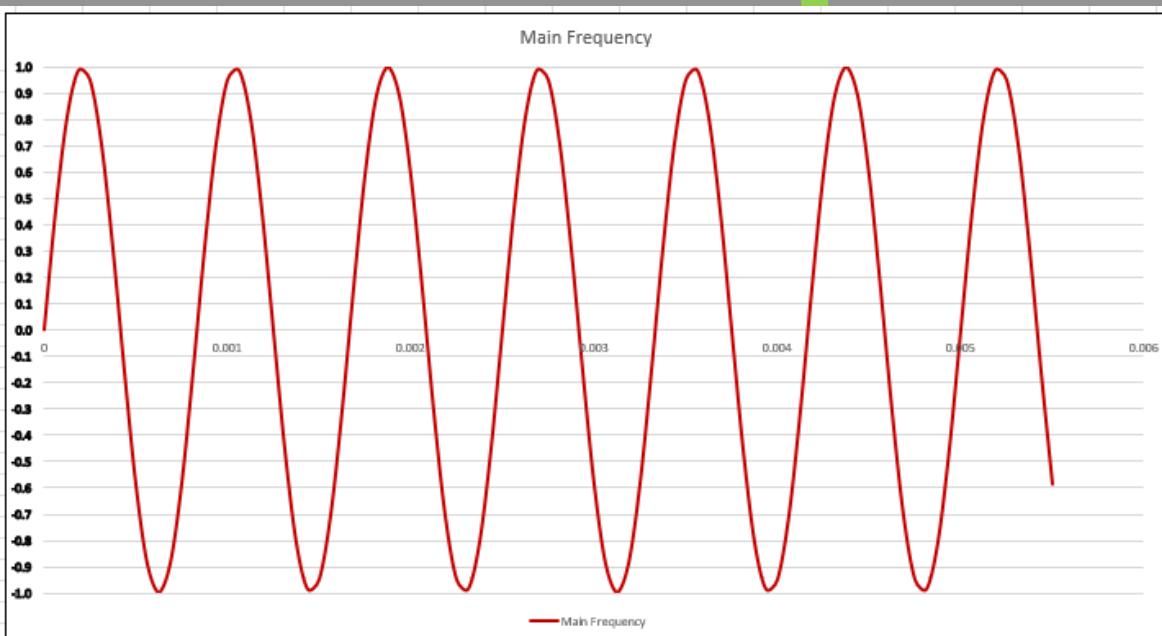
■ Involves modulating the signal you detect

– Often done with a sine-wave modulation

– We'll start with a square wave

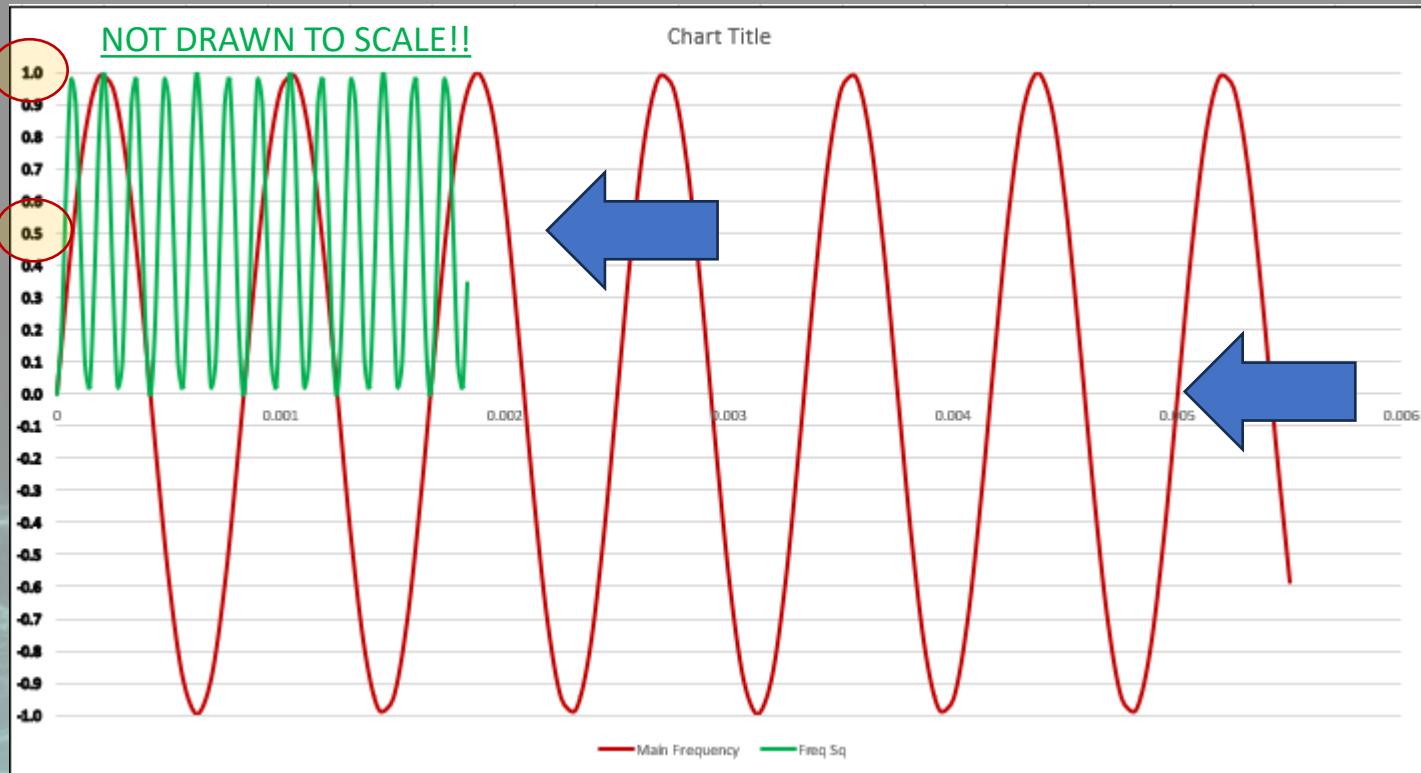
(c) Dallin S. Durfee

Lock In Amplifier: How it works?



- ✓ Red: Signal
- ✓ Blue: Reference
- ✓ How much of reference (Blue) is in sample (Red)
- ✓ Convolution: Multiply them together
- ✓ Basically, get the signal squared **2X Frequency WITH DC Offset**

Lock In Amplifier: How it works?

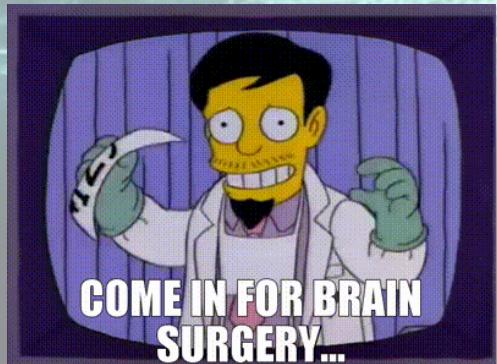


- ✓ Red: Signal
- ✓ Green Convolution
 - ✓ (i.e., Red x Blue): Signal Squared
 - ✓ Mixing both signals – get 2x Frequency
- ✓ Red – No DC Offset
- ✓ Green - **WITH DC Offset**
- ✓ DC offset is $\frac{1}{2}$ of Amplitude

Because of phase of Reference and Sample, you need to use quadrature. Convolution with Sine and Cosine

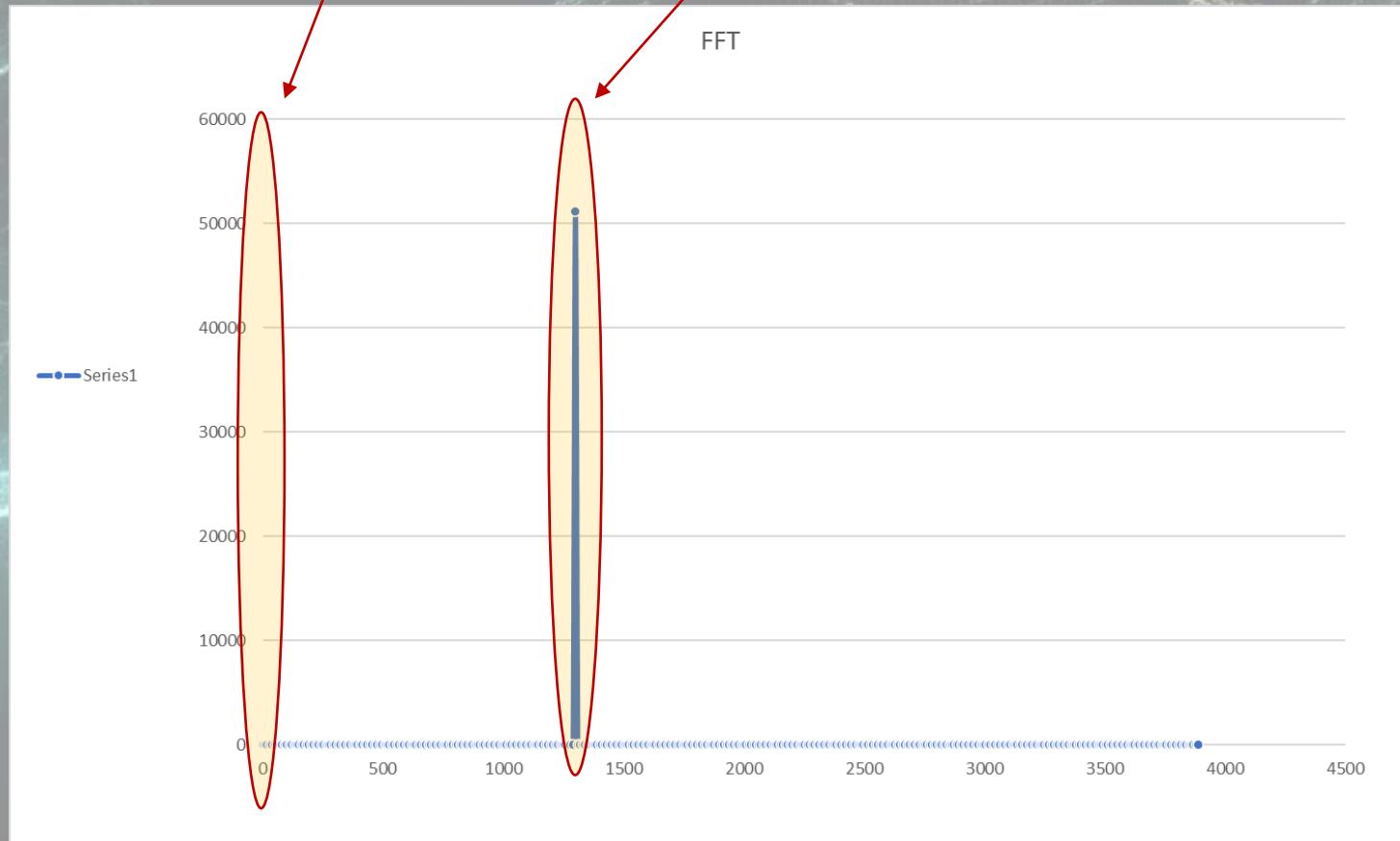


This won't hurt at all...

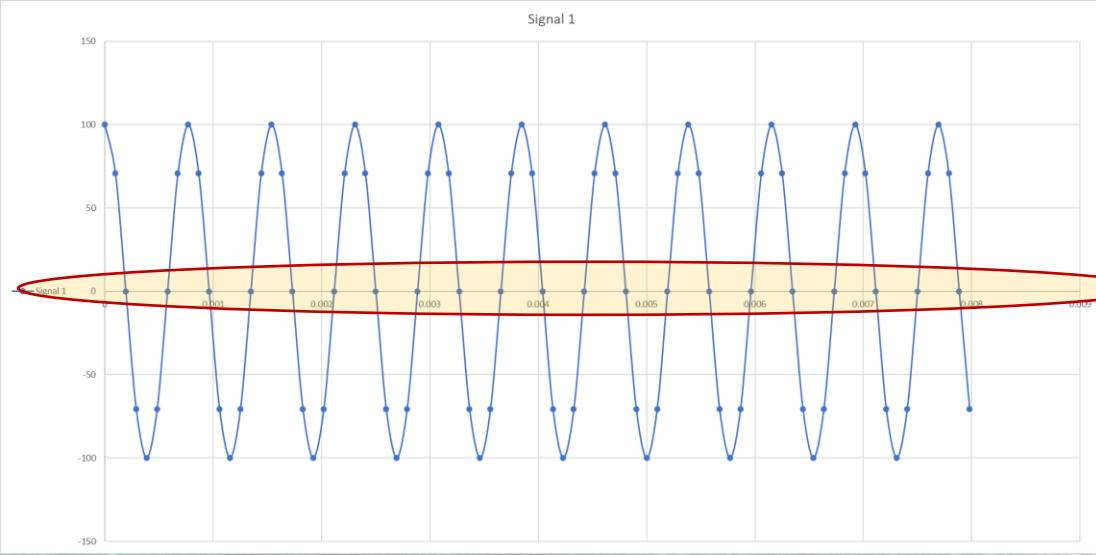


Frequency Spectrum

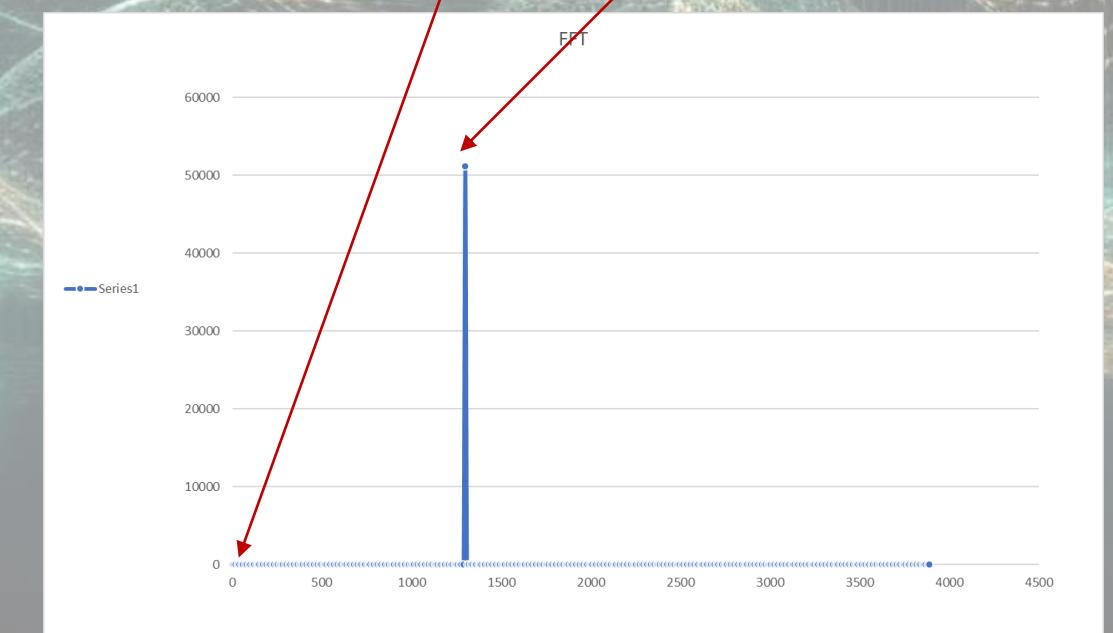
Single frequency
with no DC Offset



Frequency Spectrum



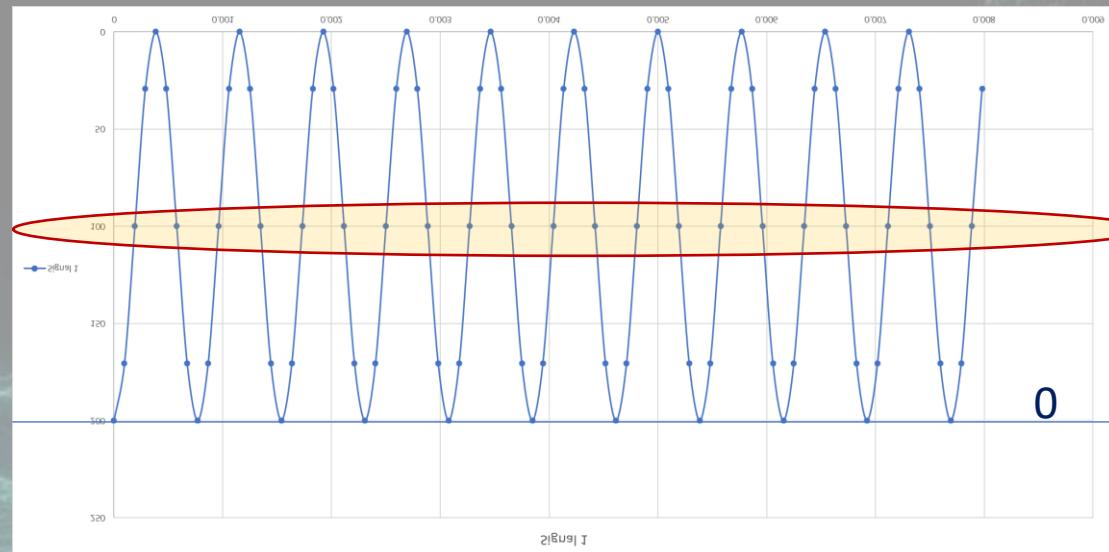
Bipolar. No DC Offset



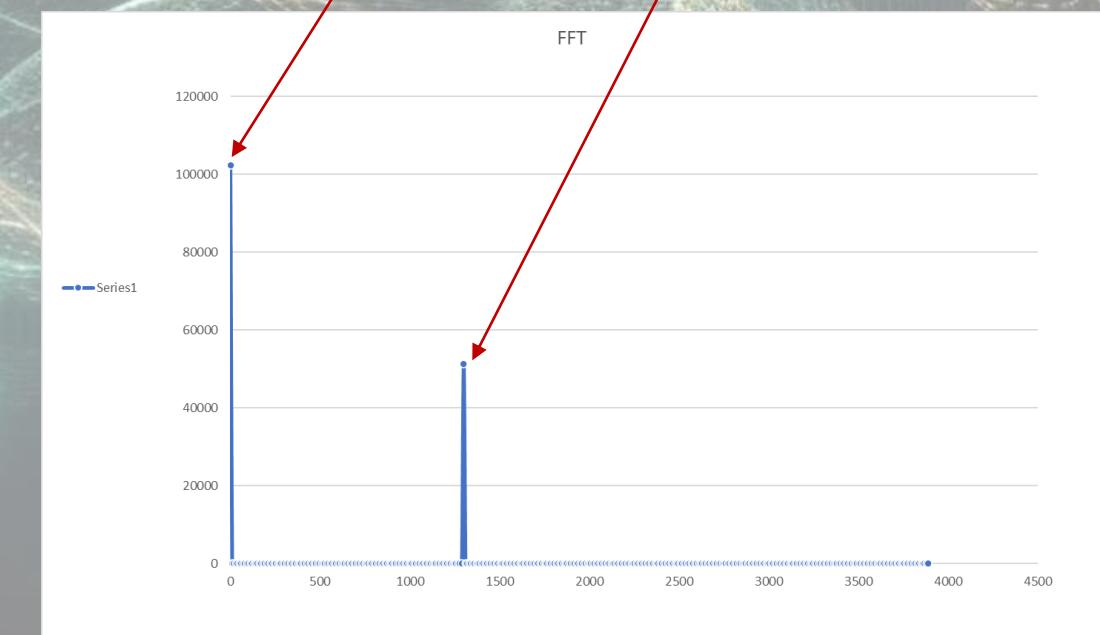
0 Hertz (No DC)

1300 Hertz (AC)

Frequency Spectrum & Filtering

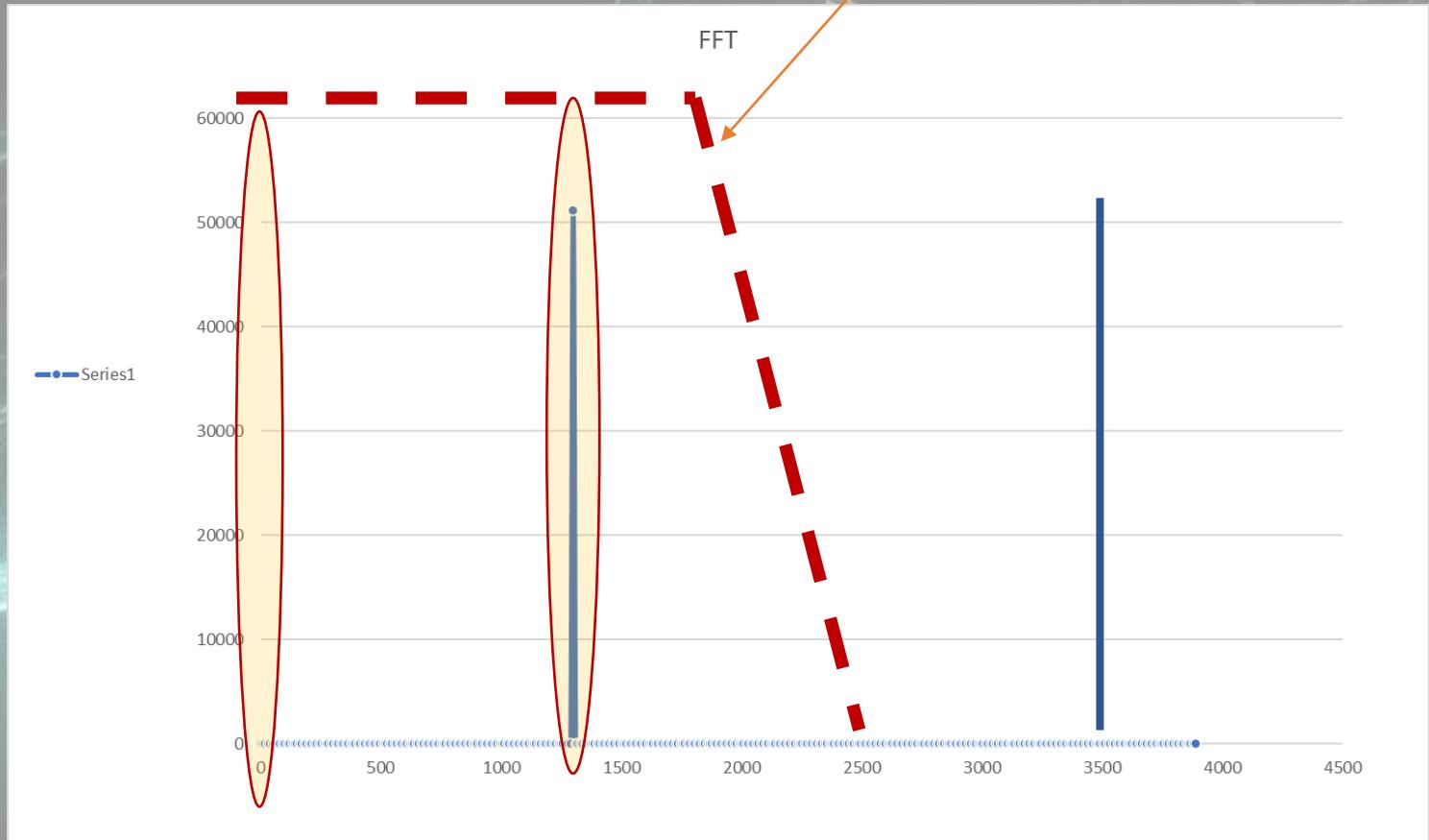


Unipolar. With DC Offset



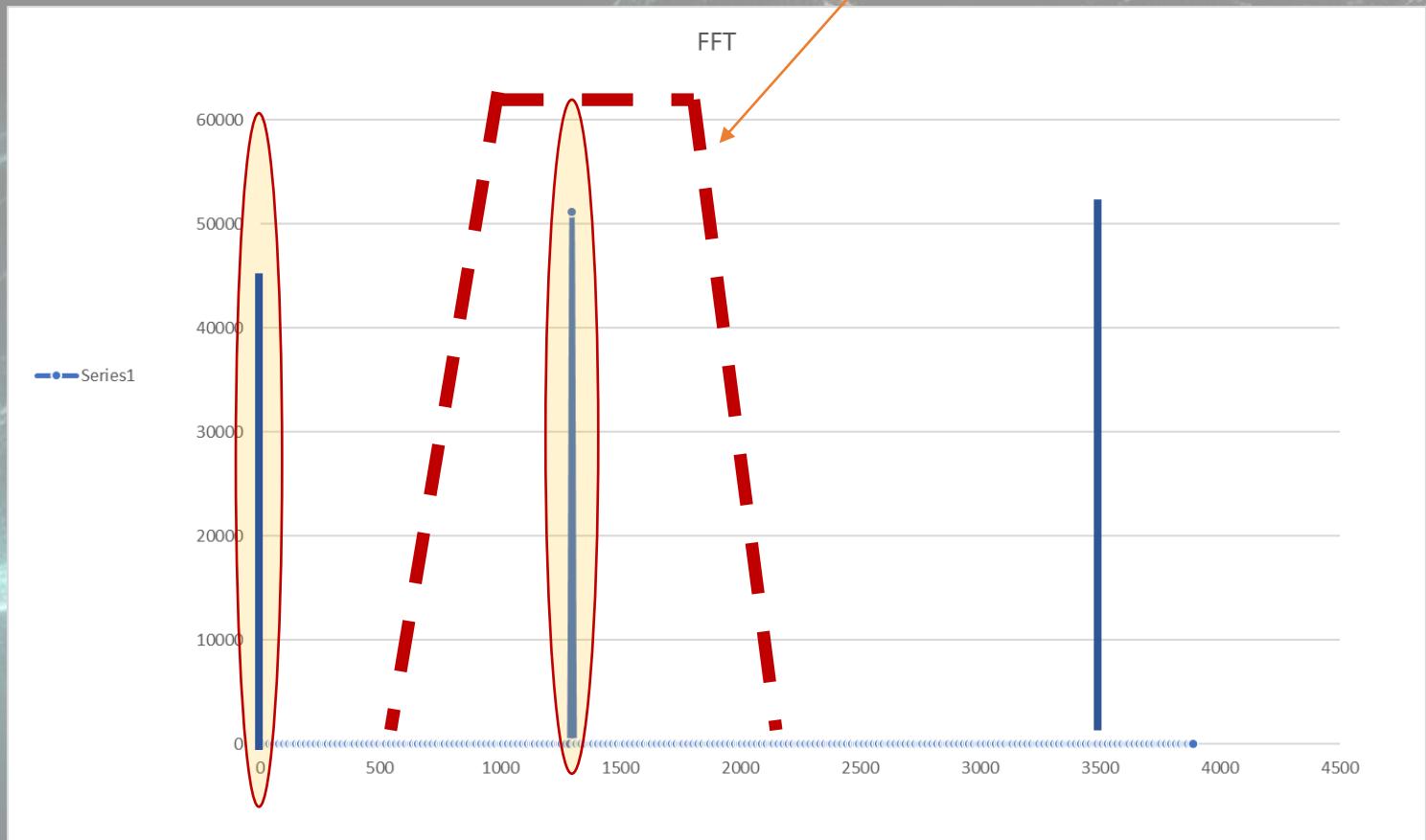
Frequency Spectrum & Filtering

Dual frequency with
no DC Offset

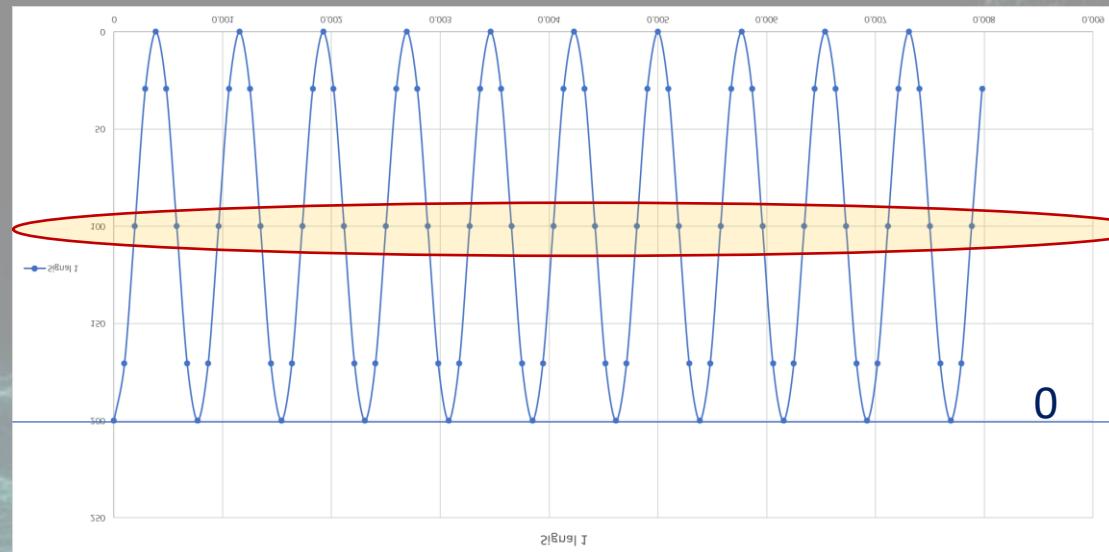


Frequency Spectrum & Filtering

Dual frequency with DC Offset

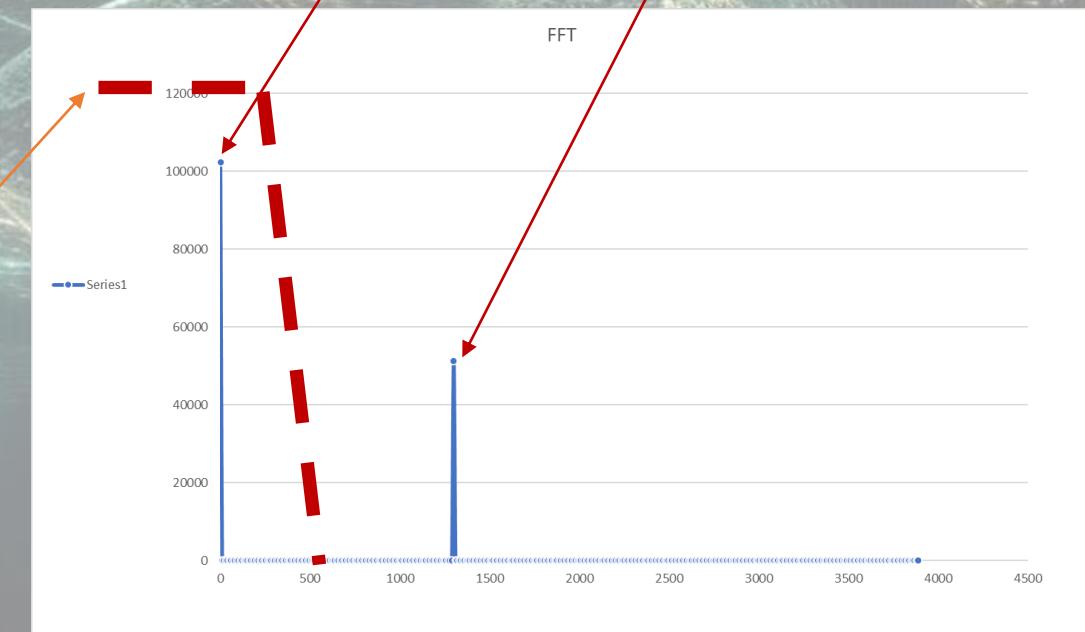


Is there a DC offset Present?



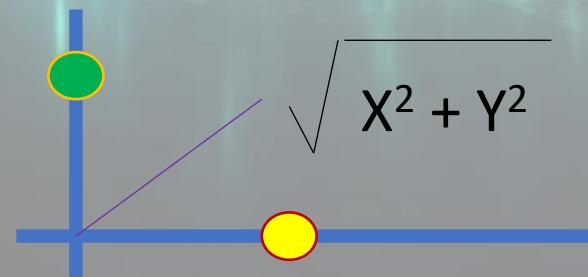
Unipolar. With DC Offset

LPF



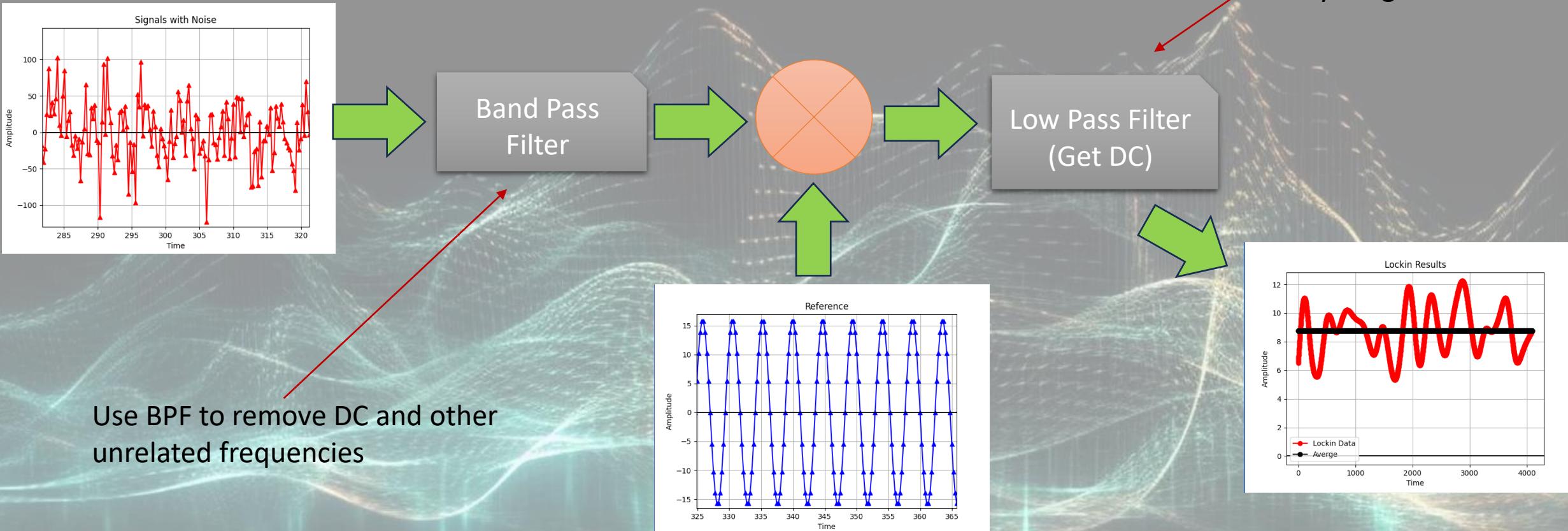
Lockin Amplifier and DC

- ✓ Noise is typical bipolar and typically has a DC average of 0. No DC offset!!
- ✓ Signal with noise x Reference signal with no noise
 - ✓ Signal x Reference = Signal + DC offset
 - ✓ Noise will not contribute to DC offset
- ✓ The Trick
 - ✓ Only works for repetitive unmodulated signals
 - ✓ Reference signal must be the same frequency
 - ✓ After multiplying signal x reference any DC present means the signal was detected!!
- ✓ To account for phase, use quadrature reference signal (orthogonal reference signals) and take the magnitude of the results



In mathematics, the **Pythagorean theorem** or **Pythagoras' theorem** is a fundamental relation in Euclidean geometry between the three sides of a **right triangle**. It states that the area of the **square** whose side is the **hypotenuse** (the side opposite the **right angle**) is equal to the sum of the areas of the squares on the other two sides.

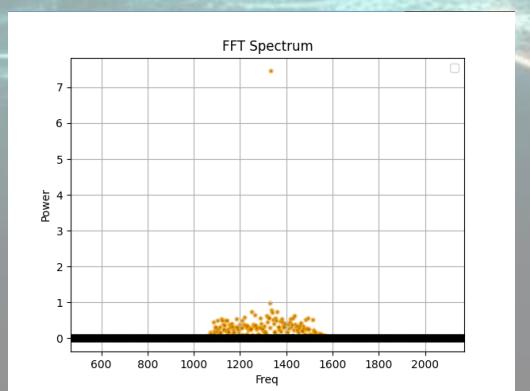
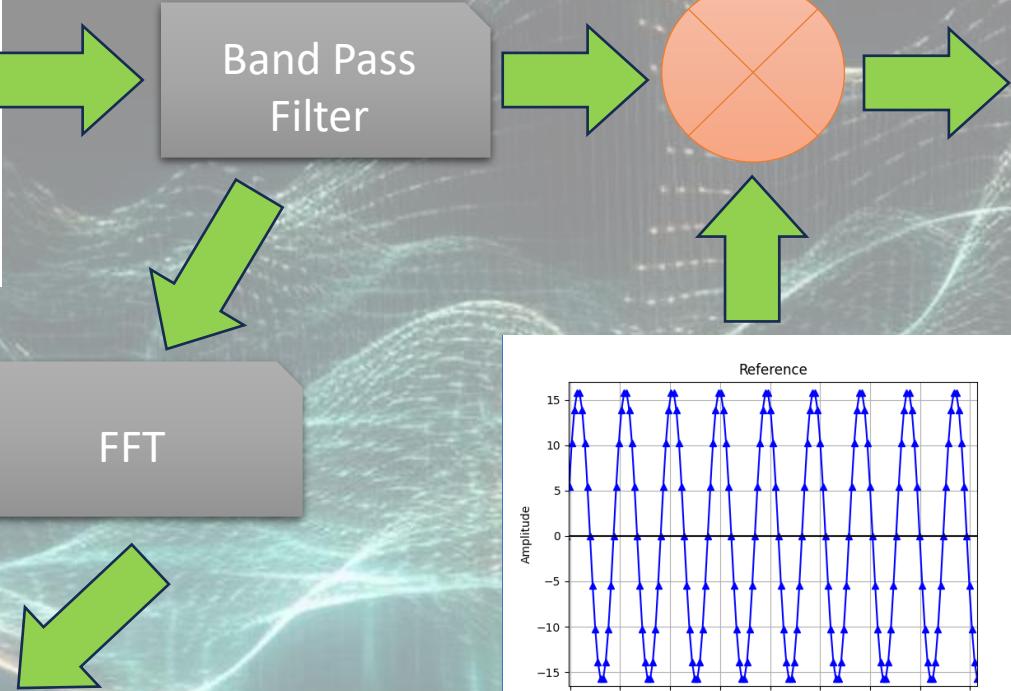
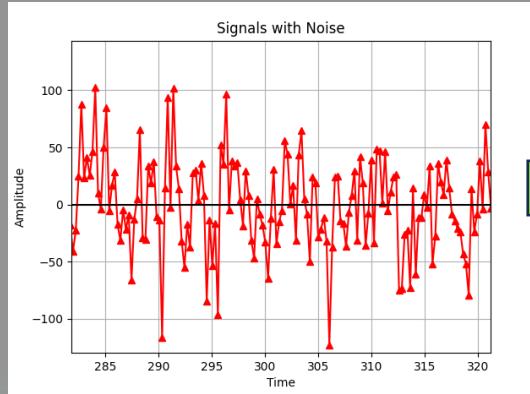
Lock In Amplifier: Process



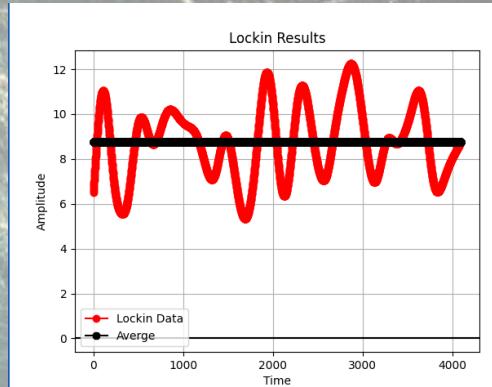
Use BPF to remove DC and other unrelated frequencies

Because of phase of Reference and Sample, you need to use quadrature. Convolution with Sine and Cosine

Lock In Amplifier with FFT



Because of phase of Reference and Sample, you need to use quadrature. Convolution with Sine and Cosine



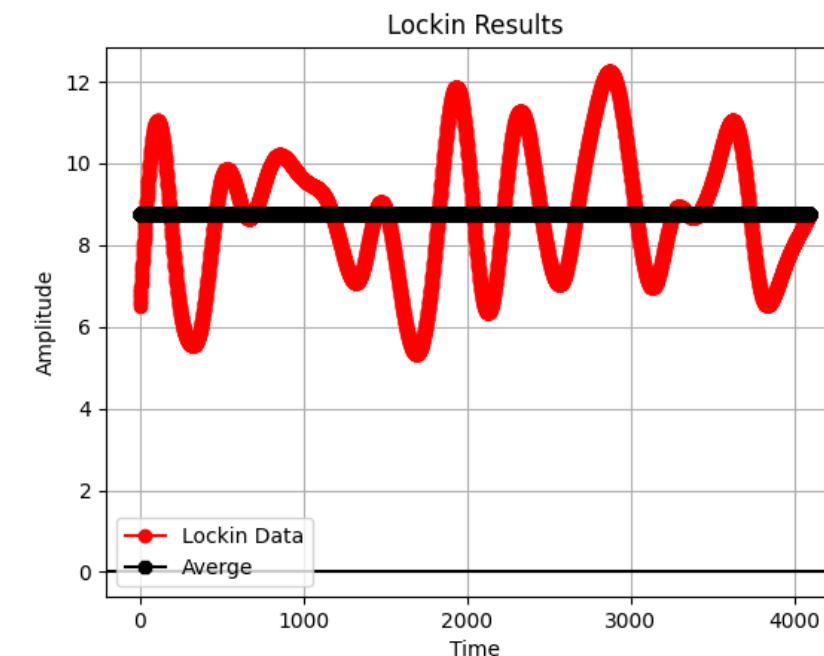
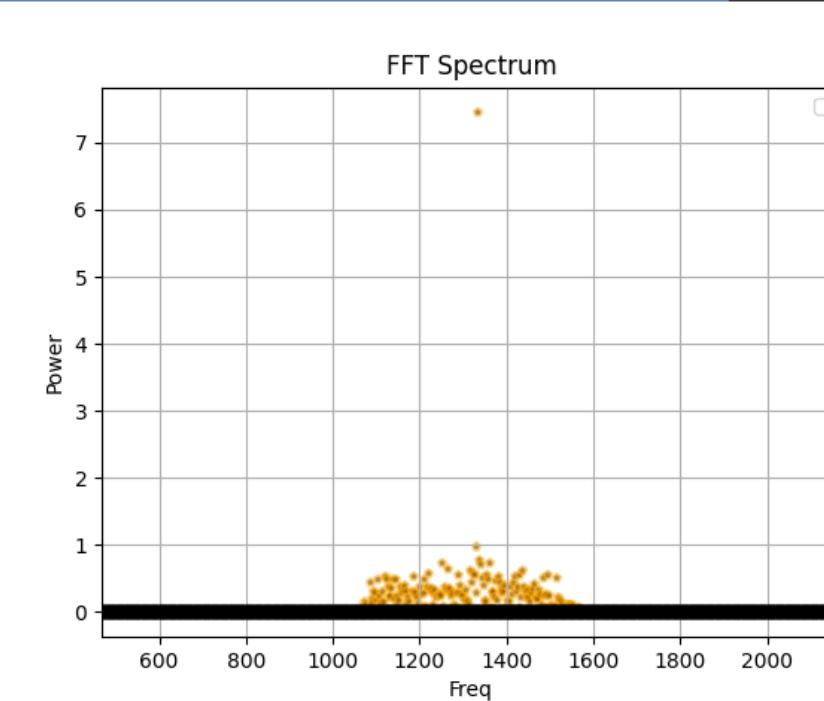
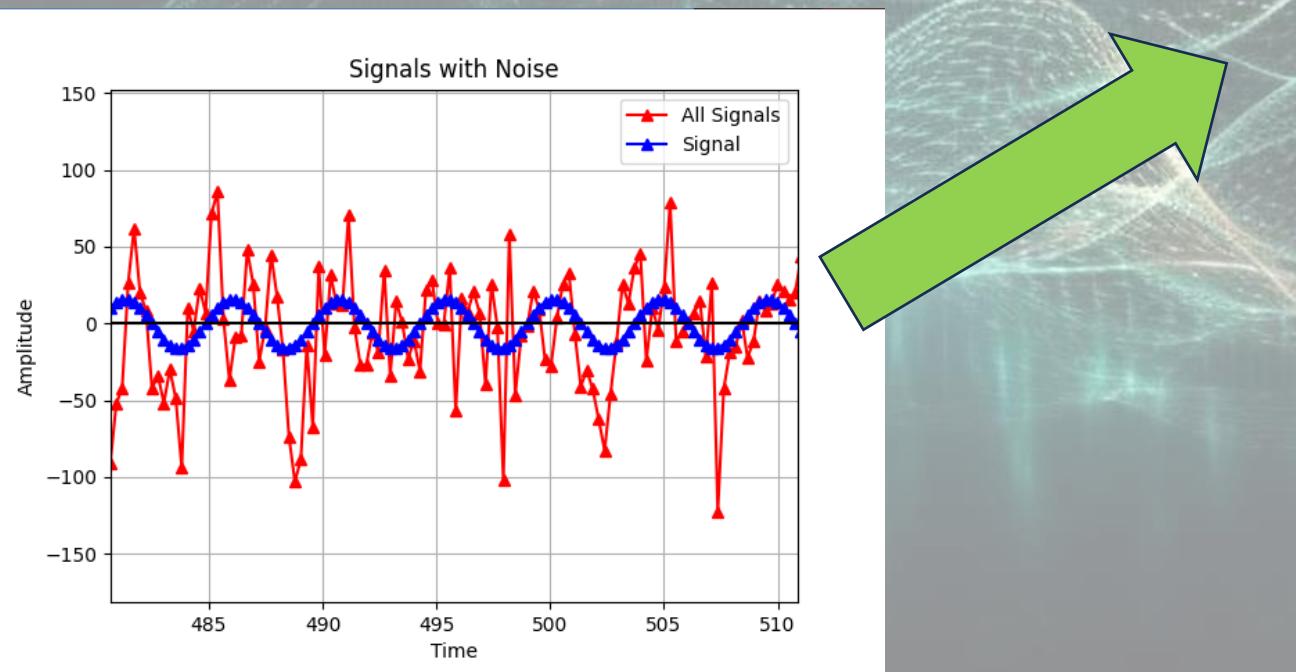
Lock In Amplifier: Testing

Python program to:

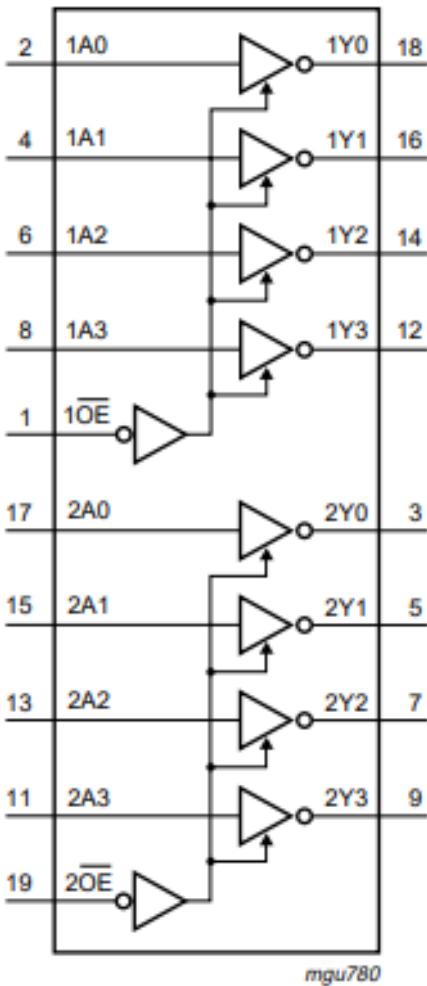
1. Generate data
✓ 1300, 2300, 1000, noise
2. BP Filter
3. FFT
4. Lockin (Mult + DC LPF)

```
sampleFrequency = 24000
maxSignalAmplitude = 16
signalDCOffset = 0
maxNoiseAmplitude = maxSignalAmplitude*2
noiseDCOffset = 0

generateData()
notchFilterSetup()
chebyFilterSetup()
butterFilterSetup()
filterData ()
#getNoiseFloor()
performFFTOnData ()
lockInAmplifier ()
```



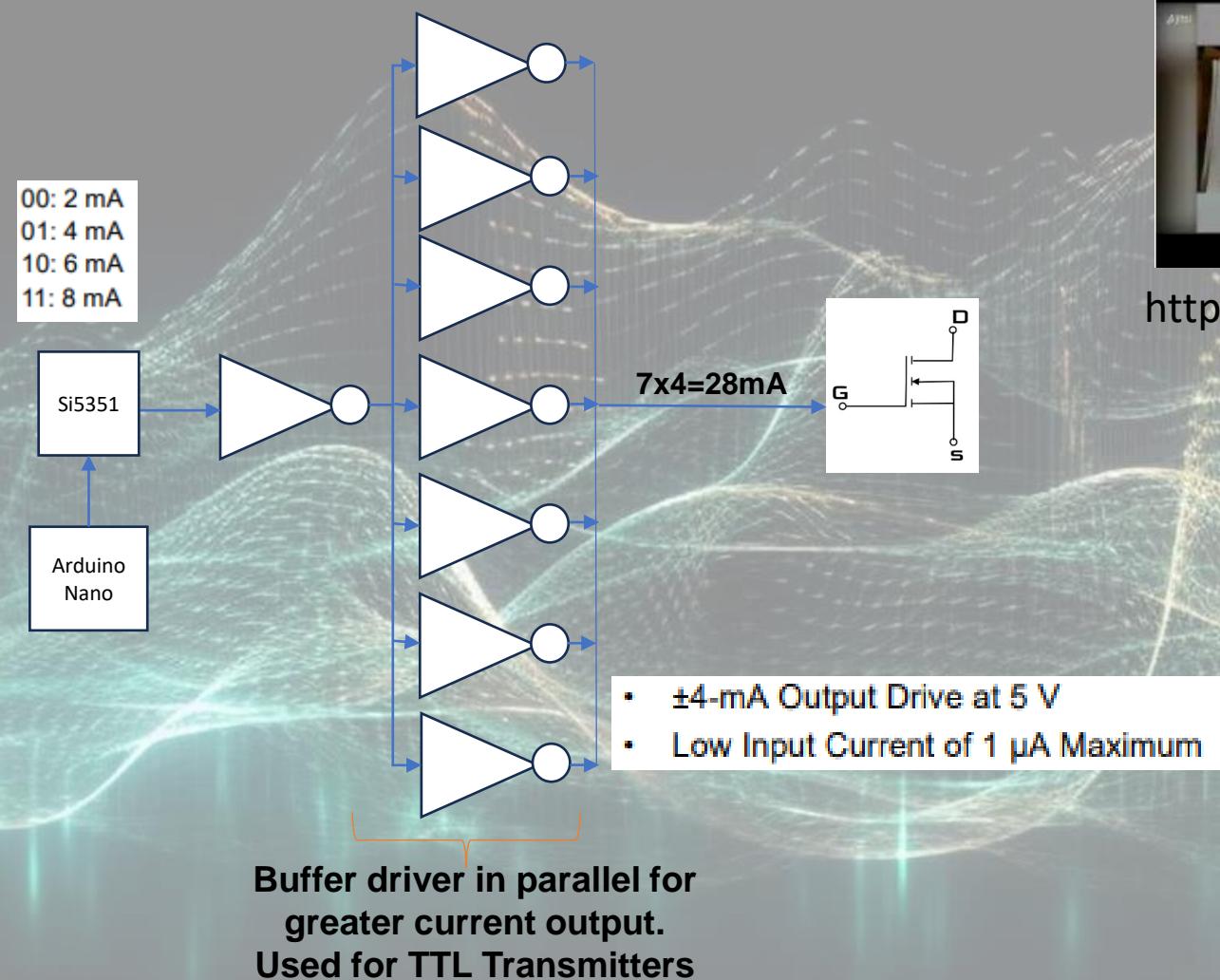
MILLER EFFECT: INCREASE CURRENT



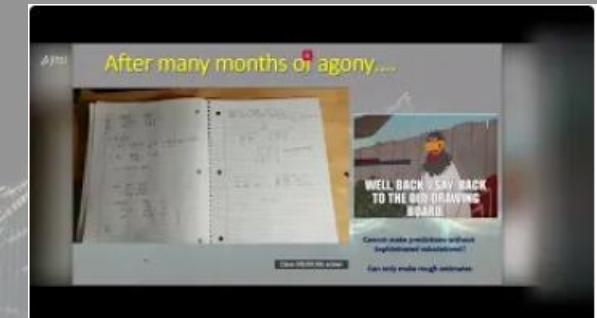
74HC240; 74HCT240

Octal buffer/line driver; 3-state; inverting

The **74HC** family has High-speed CMOS circuitry, combining the speed of TTL with the very low power consumption of the

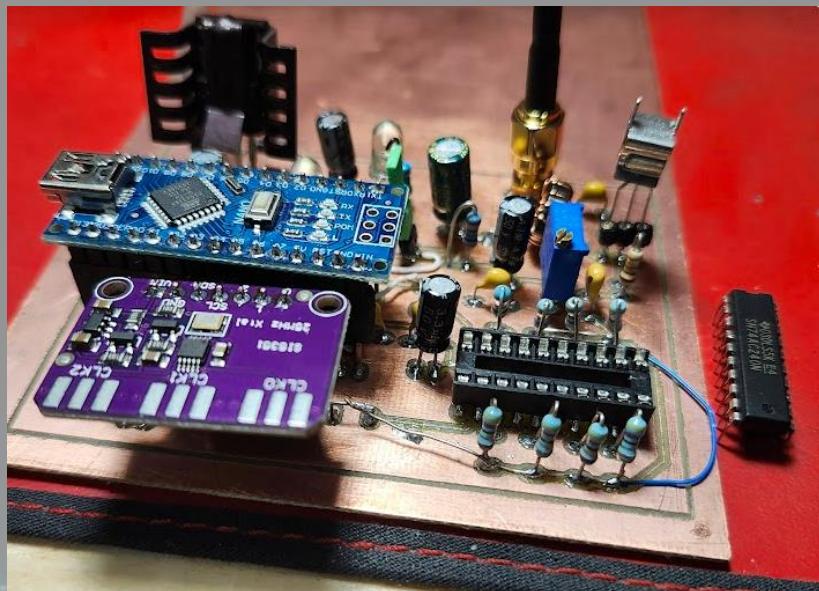


The Si5351A/B/C features various output current drives ranging from 2 to 8 mA (default). It is recommended to configure the trace characteristics as shown in Figure 18 when an output drive setting of 8 mA is used.



<https://youtu.be/GQgFSifZV3E>

MILLER EFFECT: INCREASE CURRENT



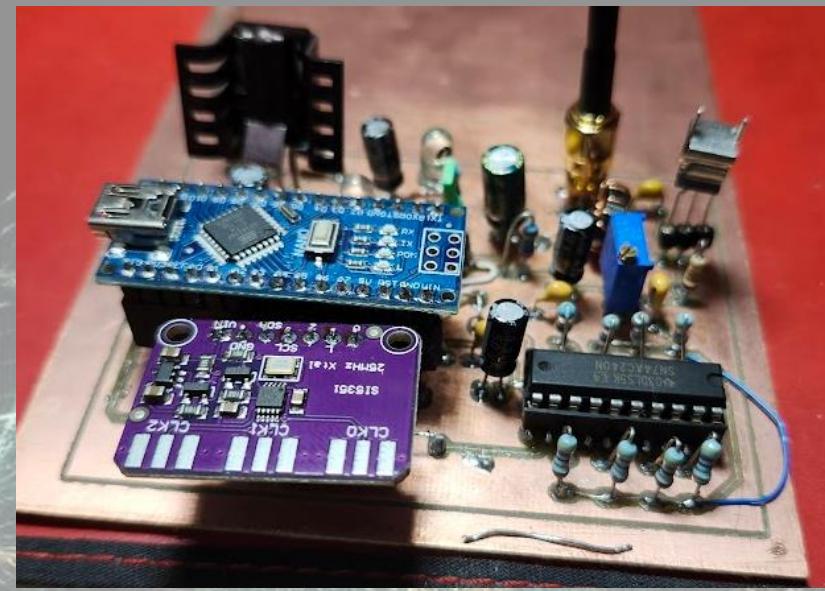
Si5351 driving BS170 MOSFET

Without 74HC240 Drivers				
Frequency (MHz)	Output (dBm)	Output (Watts)	Highest Harmonic (dBm)	Harmonic Attenuation
7	30.6	1.1	-21	-51.6
14	29.4	0.87	-21	-50.4
20	26.9	0.49	-24	-50.9
30	26.6	0.45	-24	-50.6

~8mA drive into 50R load

At least 3x
Current increase

Getting over 1W across HF
band with more current
from 74HC240 driver

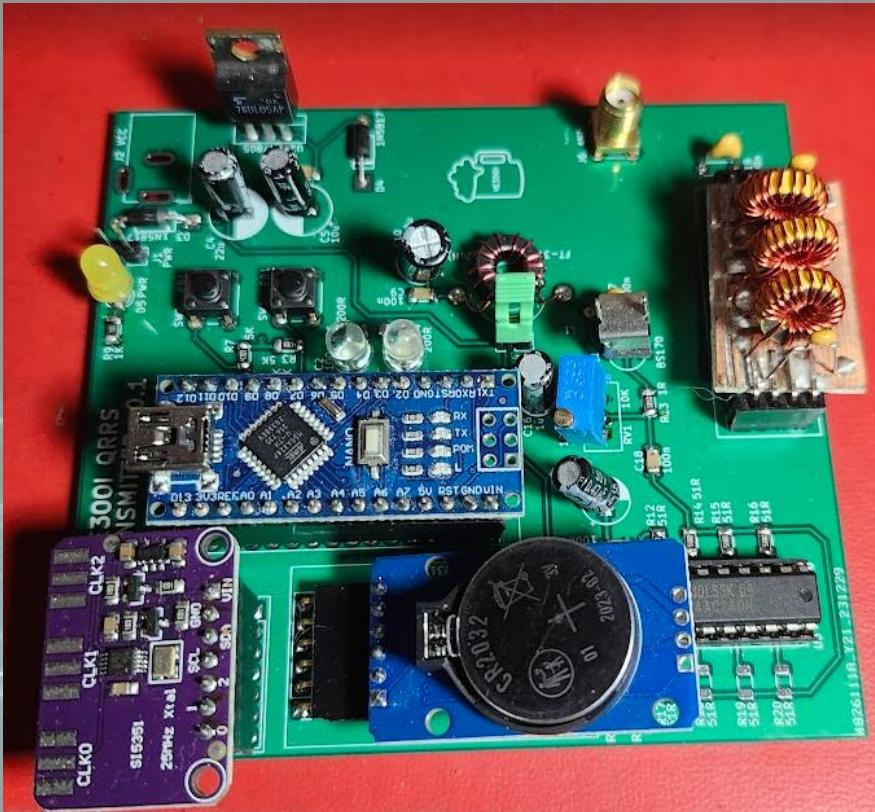


Si5351 & 74HC140 driving BS170 MOSFET

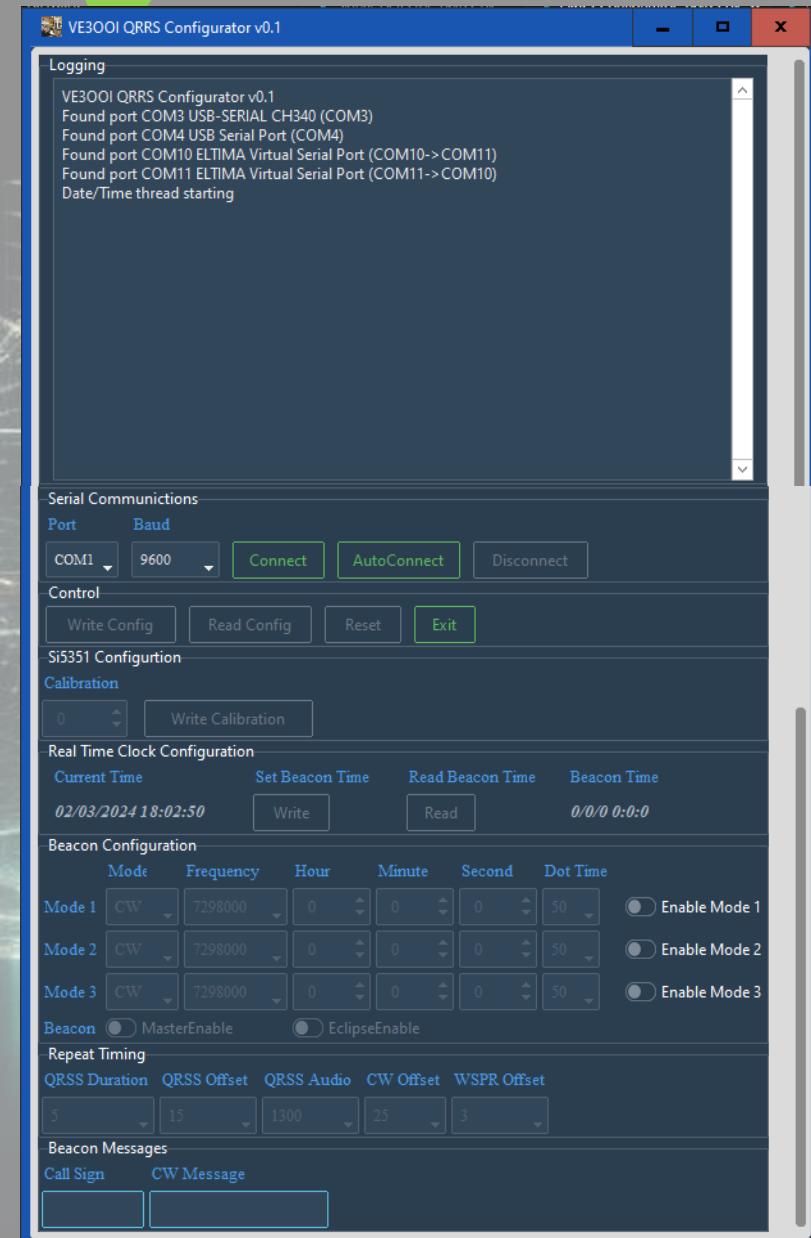
With 74HC240 Drivers				
Frequency (MHz)	Output (dBm)	Output (Watts)	Highest Harmonic (dBm)	Harmonic Attenuation
7	32.8	1.9	-20	-52.8
14	31.8	1.5	-20	-51.8
20	31.2	1.3	-21	-52.2
30	30.5	1.1	-21	-51.5

~28mA drive into ?? load

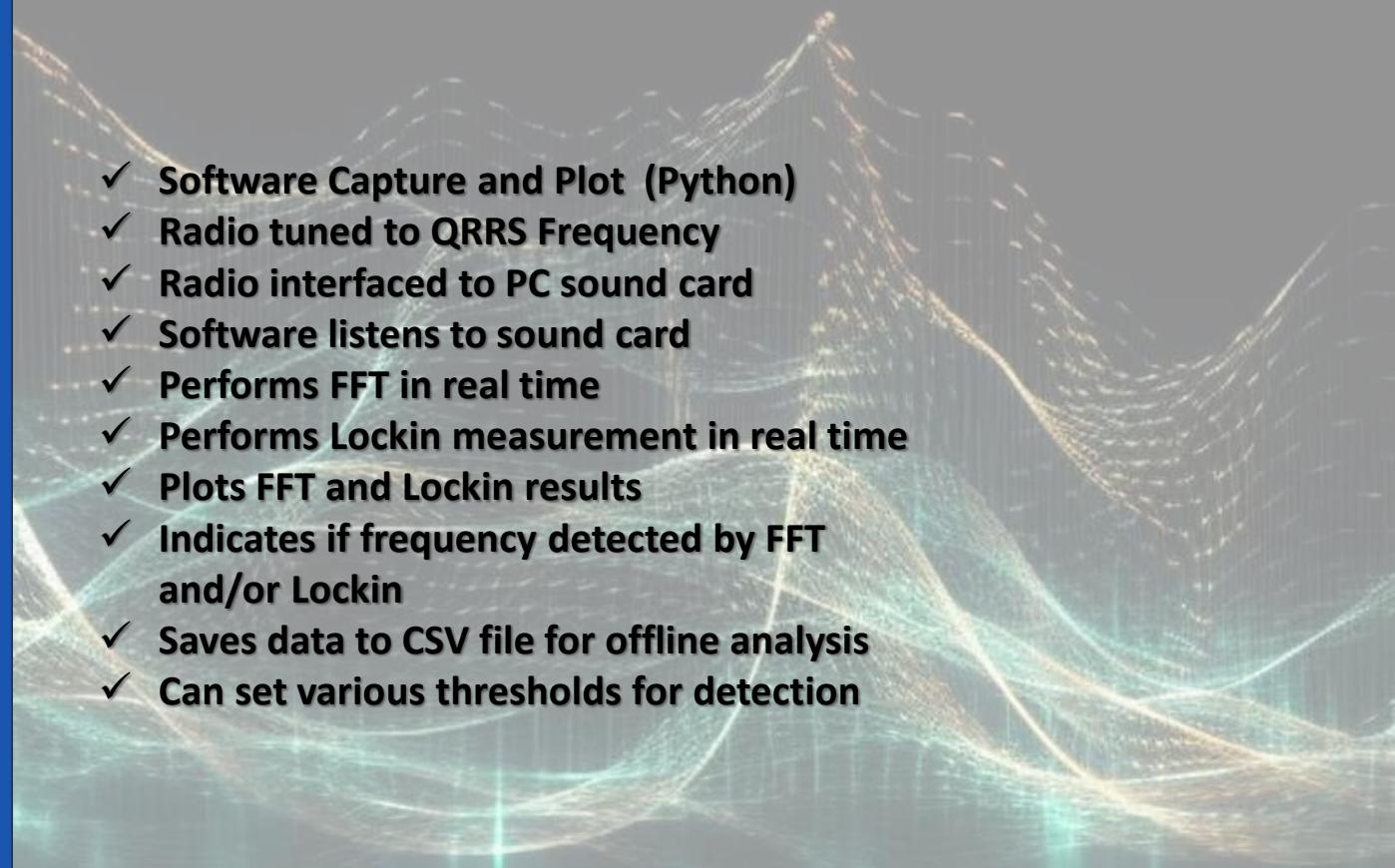
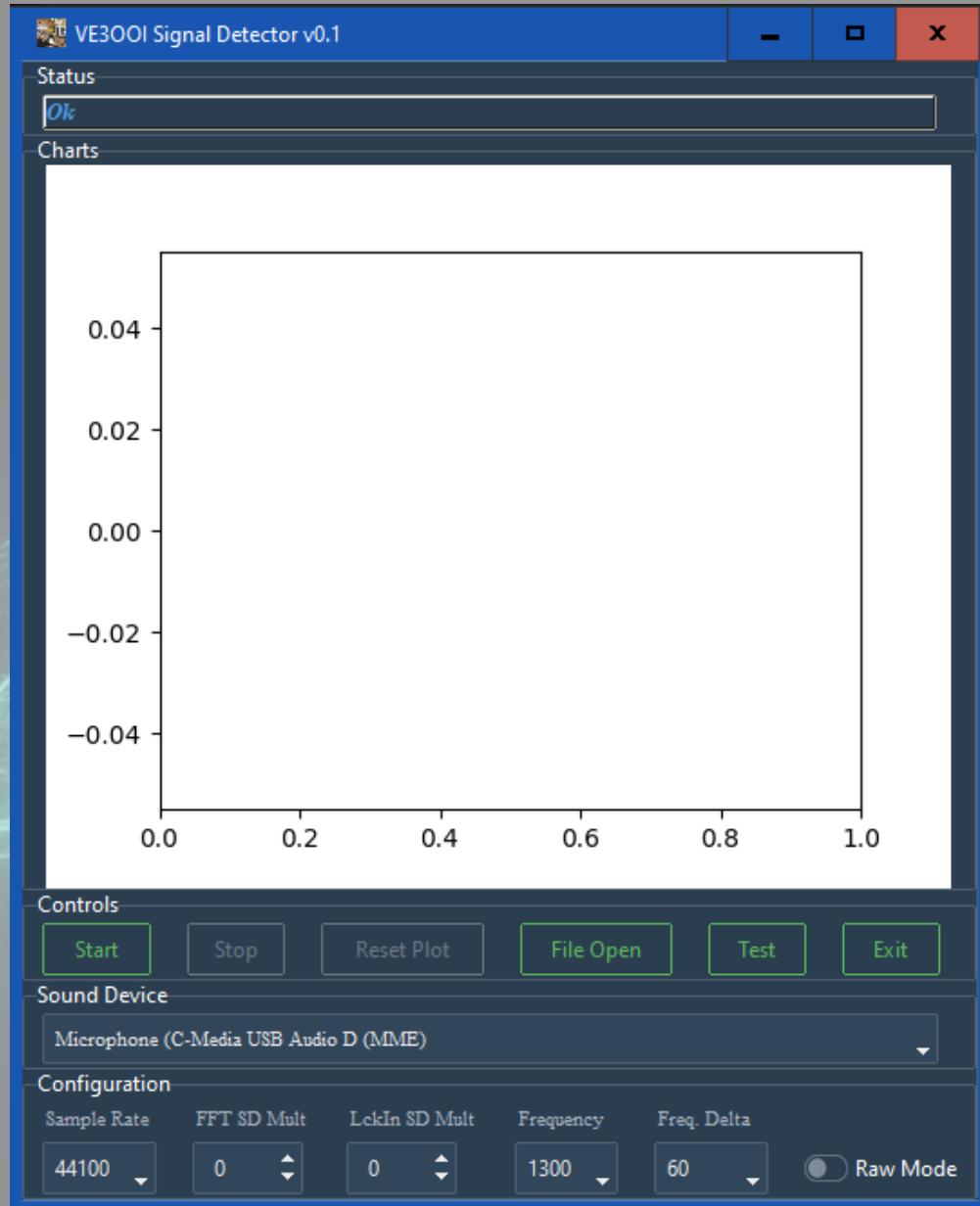
Lock In Amplifier: Configuration



- ✓ Software Configurator (Python)
- ✓ Uses RTC for timing
- ✓ Send CW For RBN
- ✓ Send WSPR for WSPRnet
- ✓ Send QRSS
- ✓ Defined time to start and repeat
- ✓ Send mixed mode
 - E.g., CW then QRSS



Lock In Amplifier: Data Capture

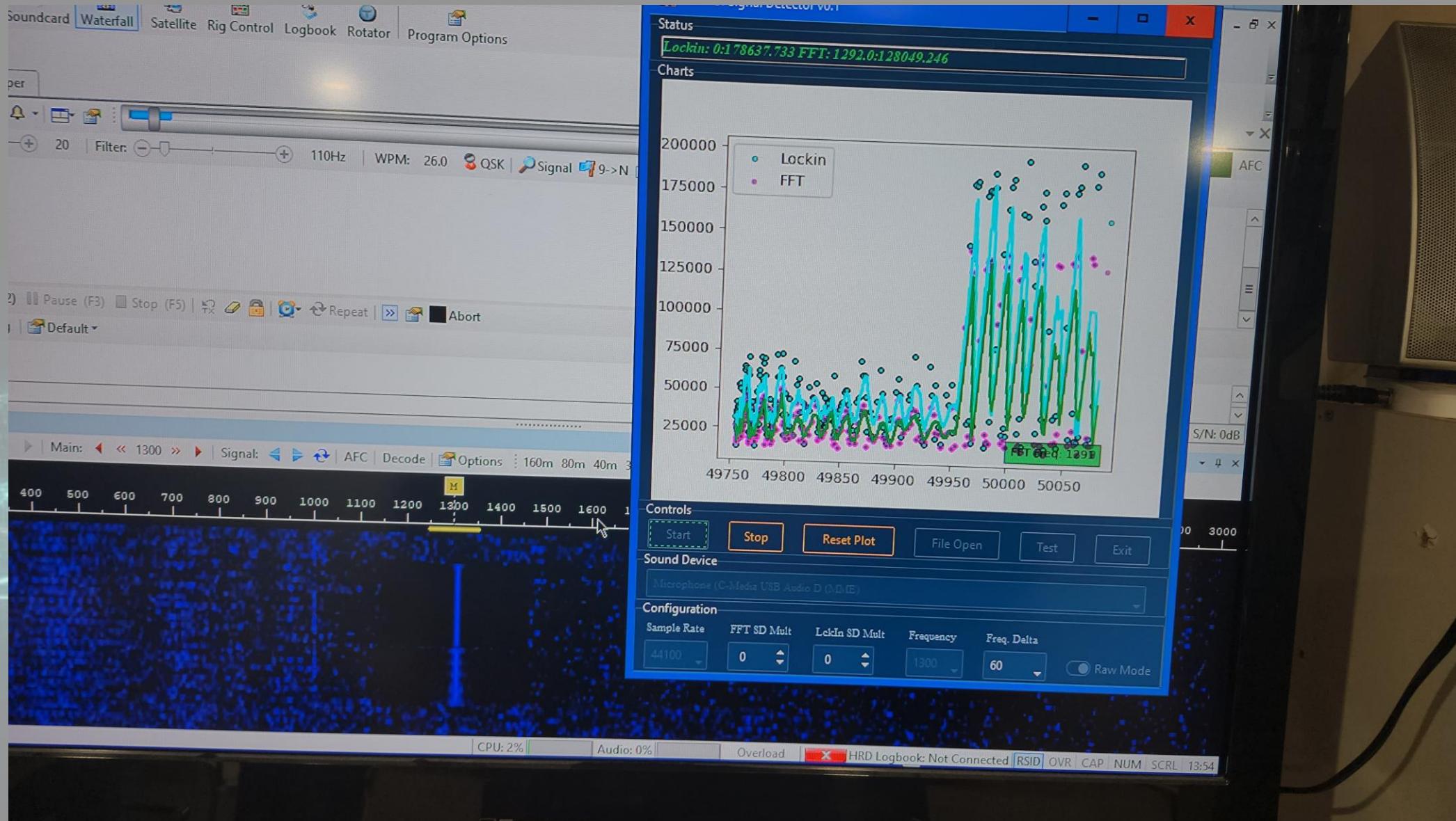


- ✓ Software Capture and Plot (Python)
- ✓ Radio tuned to QRSS Frequency
- ✓ Radio interfaced to PC sound card
- ✓ Software listens to sound card
- ✓ Performs FFT in real time
- ✓ Performs Lockin measurement in real time
- ✓ Plots FFT and Lockin results
- ✓ Indicates if frequency detected by FFT and/or Lockin
- ✓ Saves data to CSV file for offline analysis
- ✓ Can set various thresholds for detection

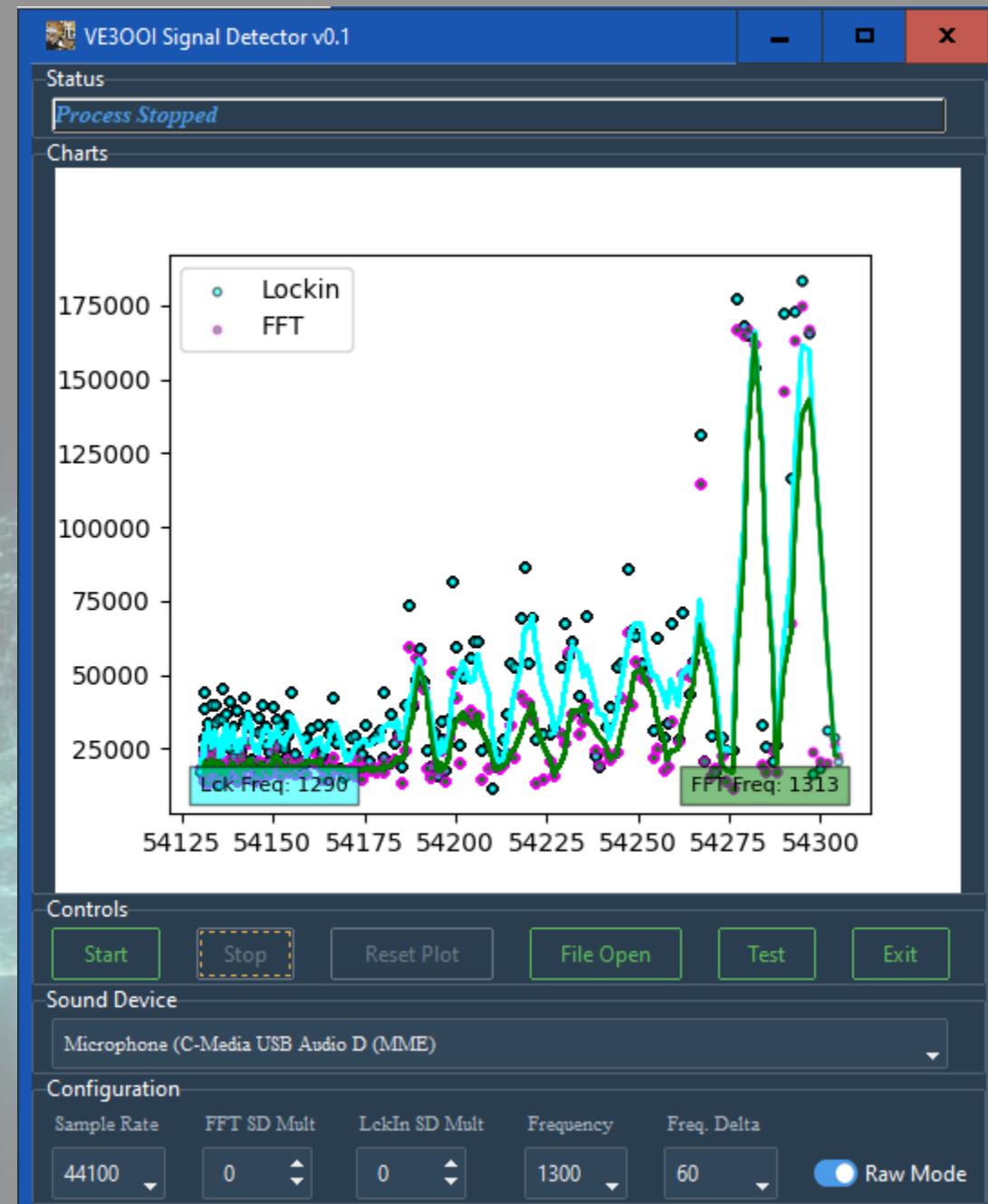
Lock In Amplifier: Data Capture

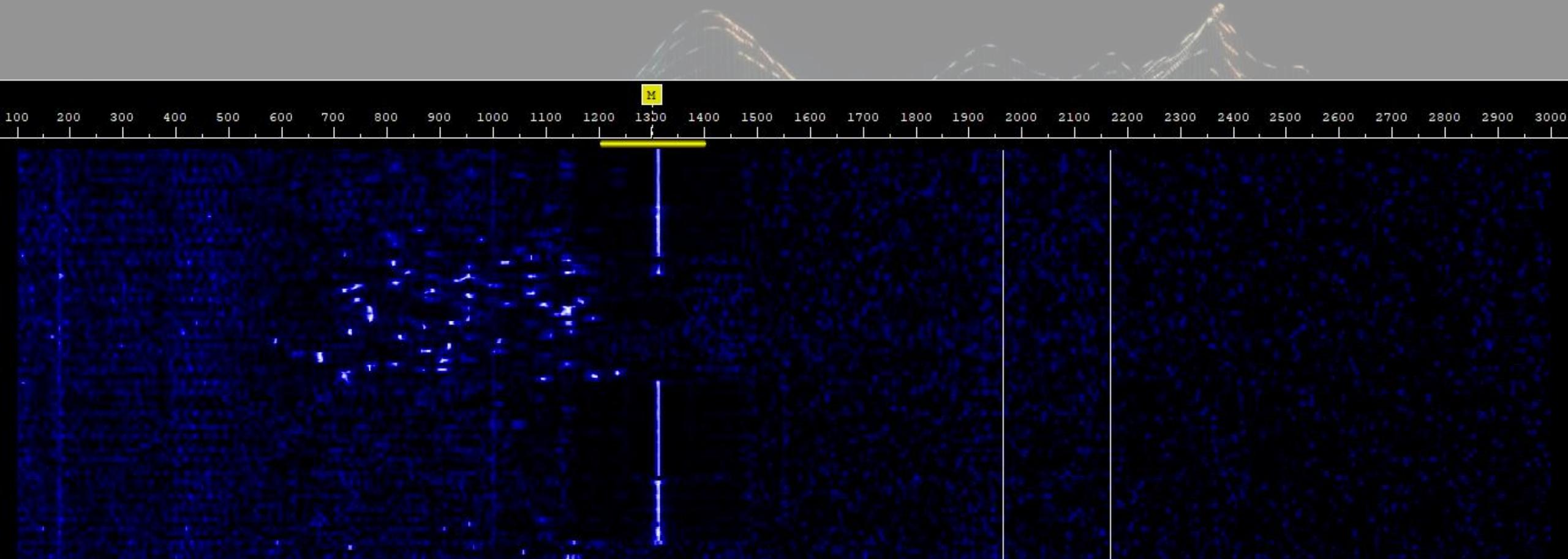


Lock In Amplifier Software

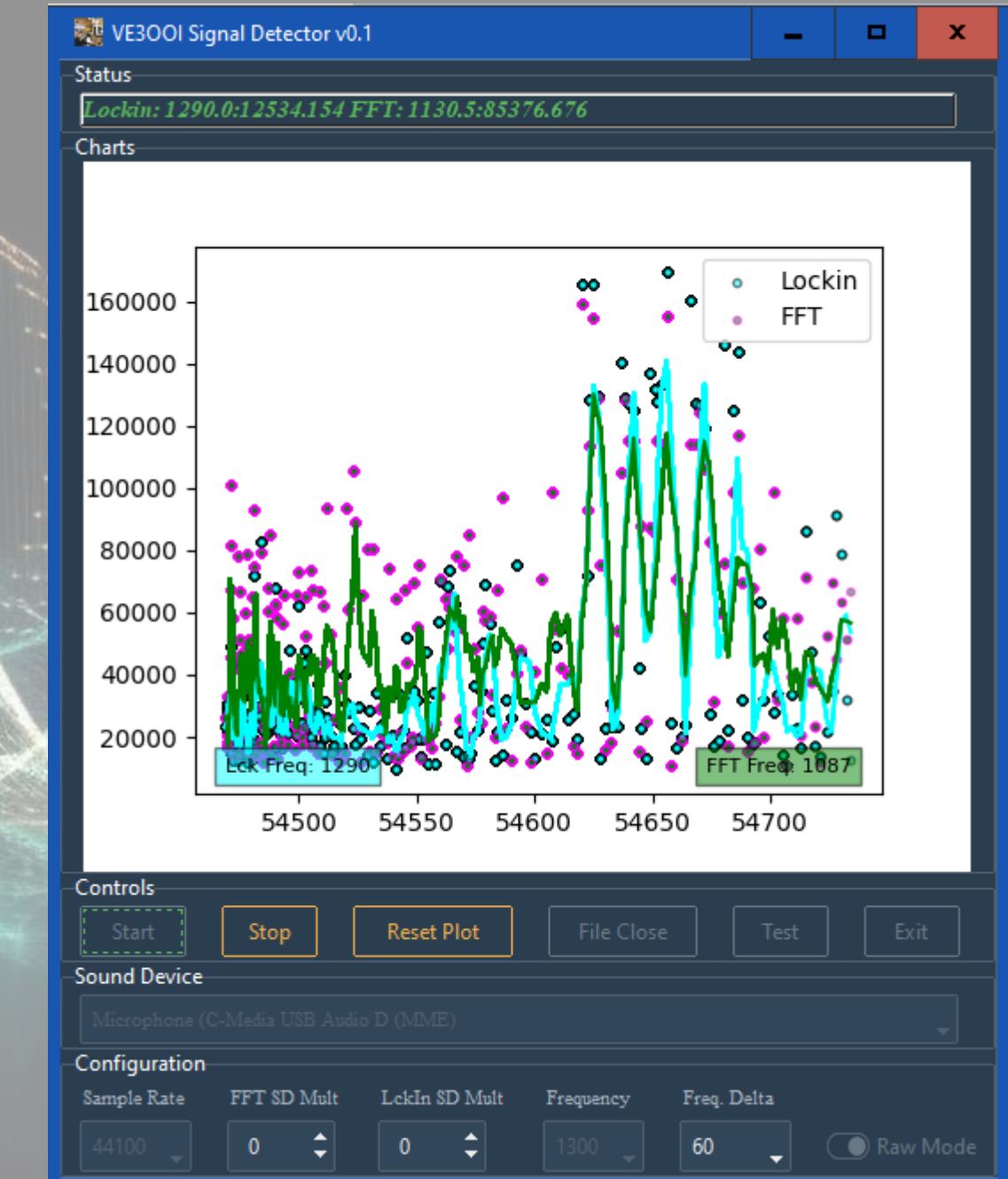
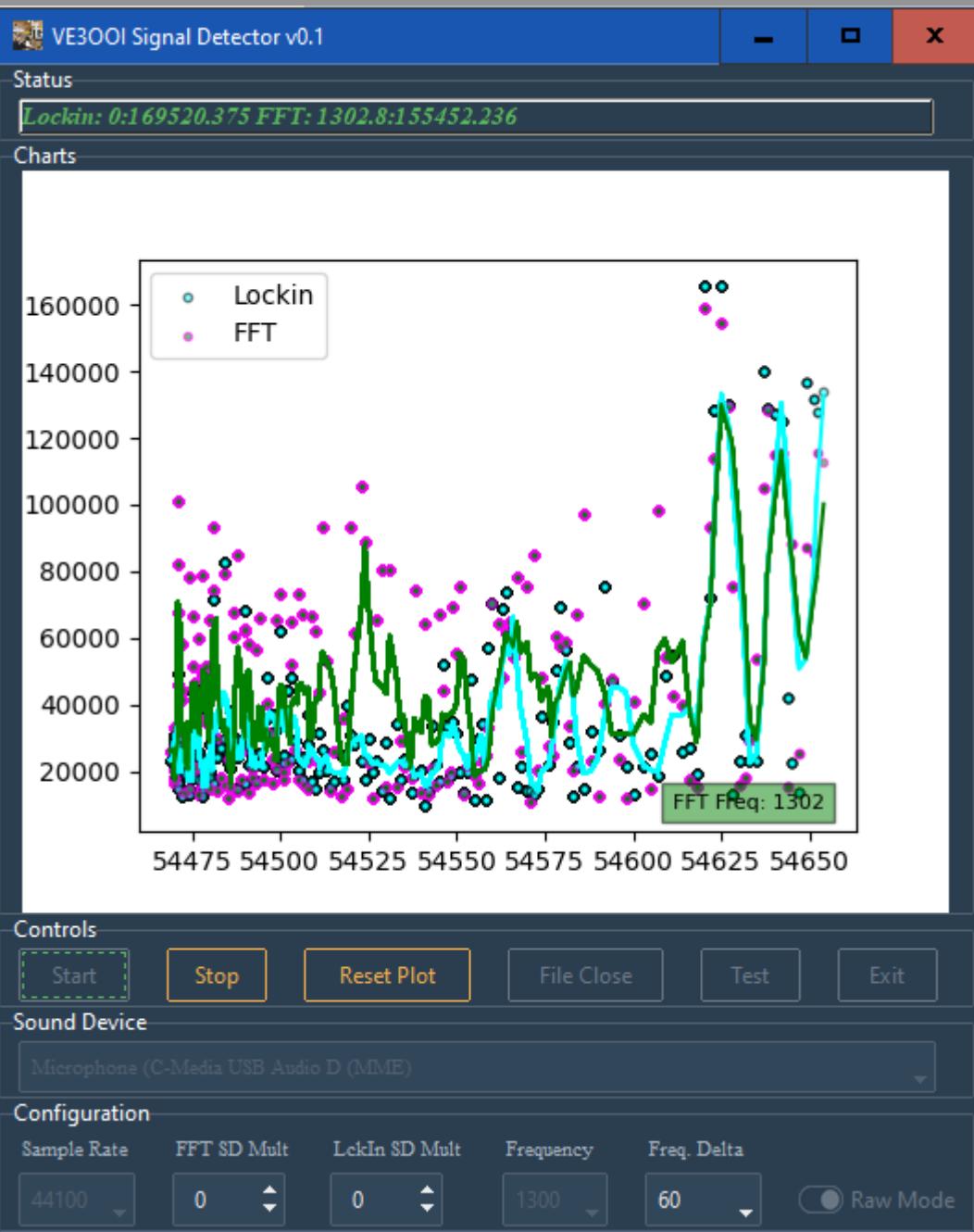






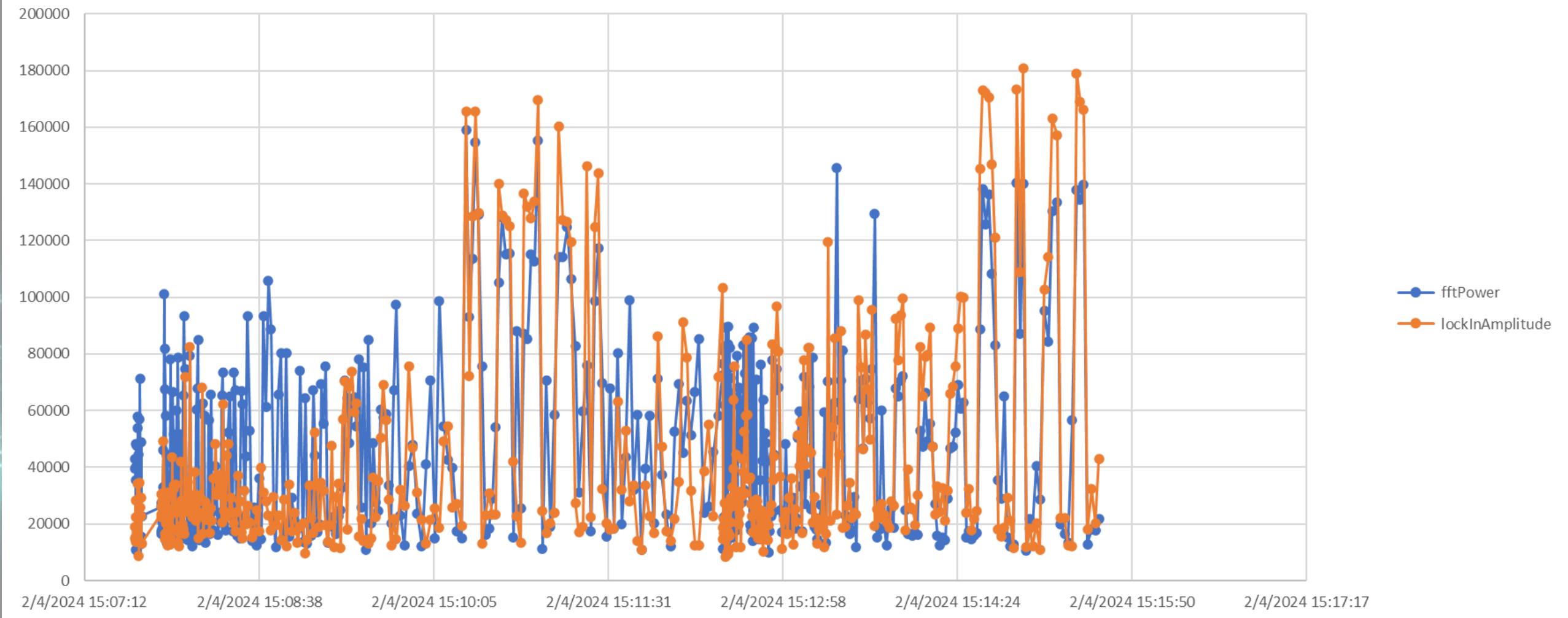


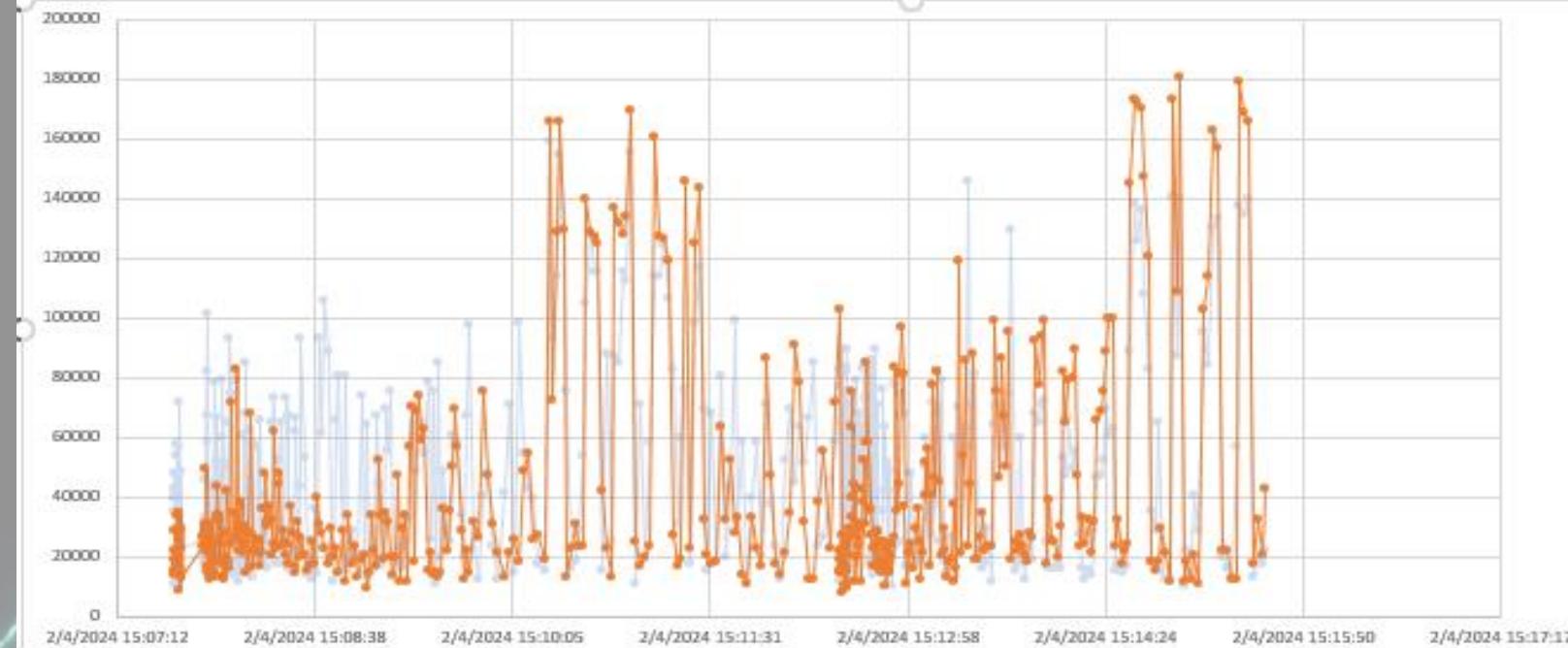
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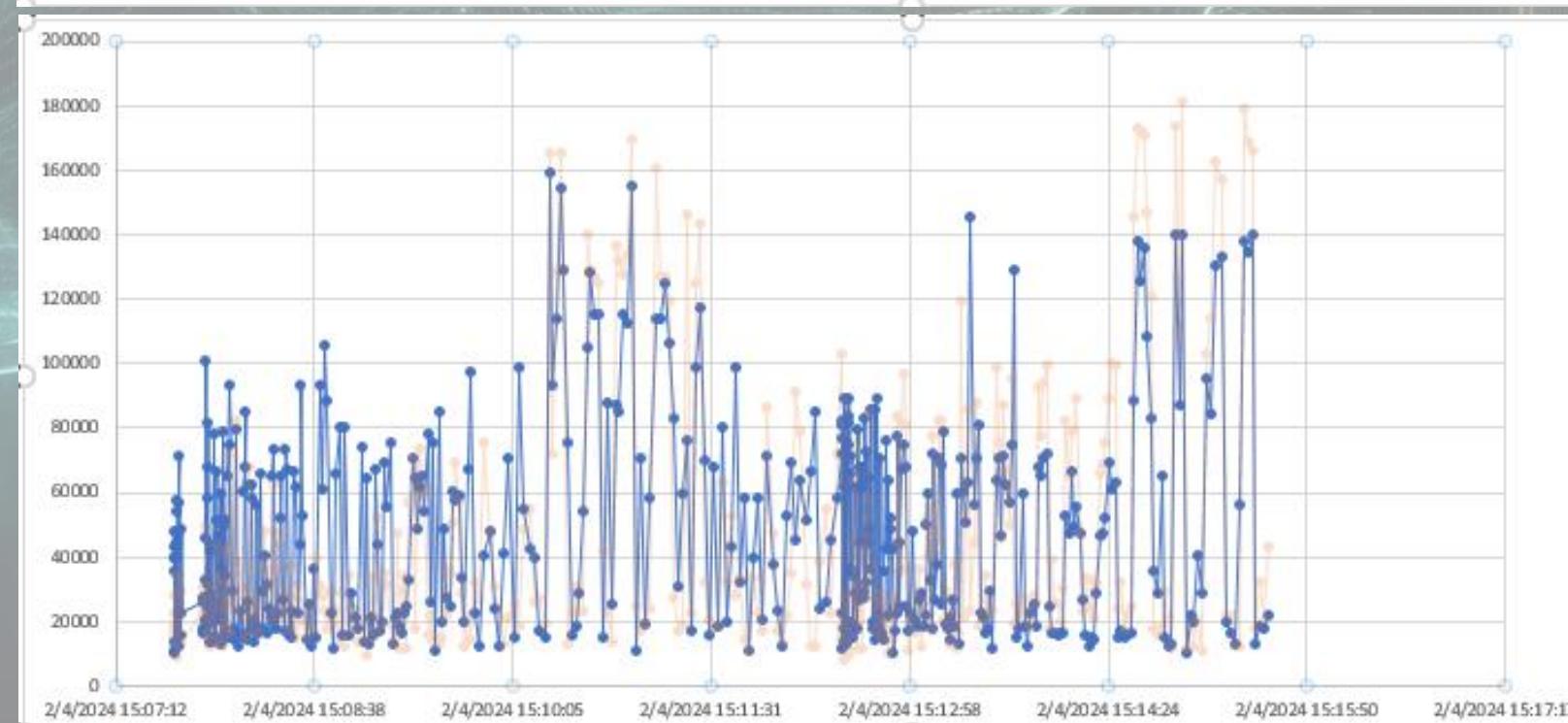
Lock In Amplifier: Results



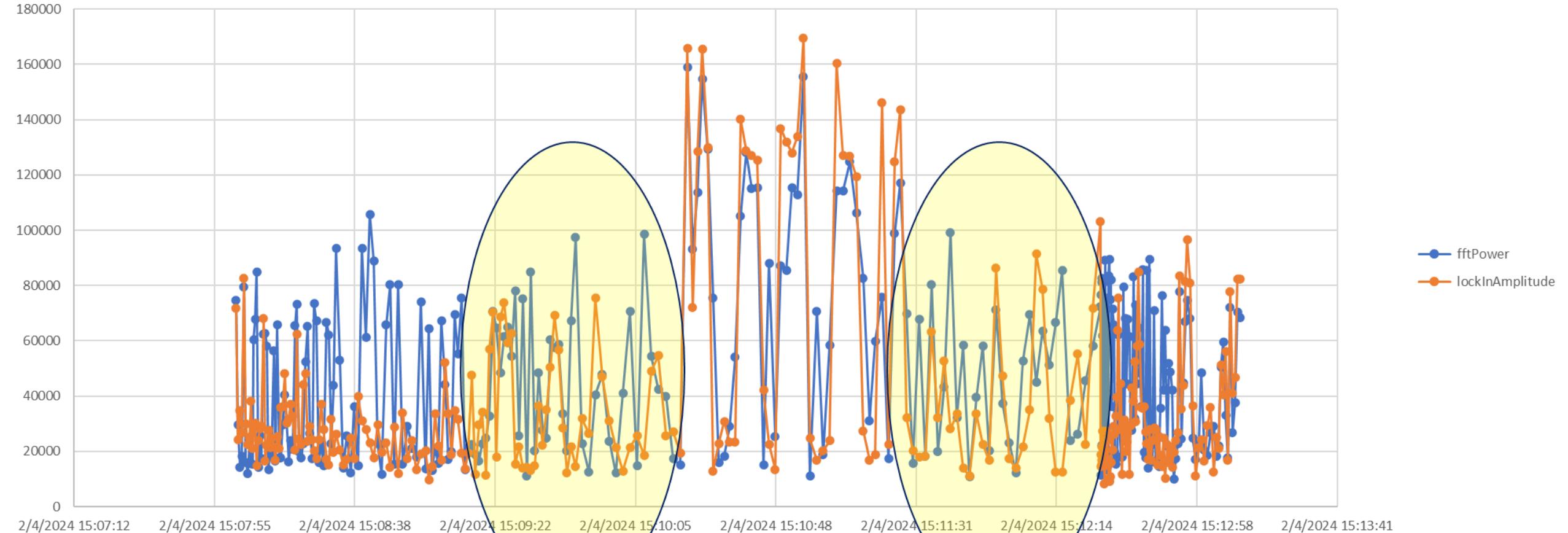




fftPower
lockinAmplitude



fftPower
lockinAmplitude



That's all folks!