ECE 531 | Lab 2 - Getting Started on PlutoSDR

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Course: ECE 531 | Software Defined Radio

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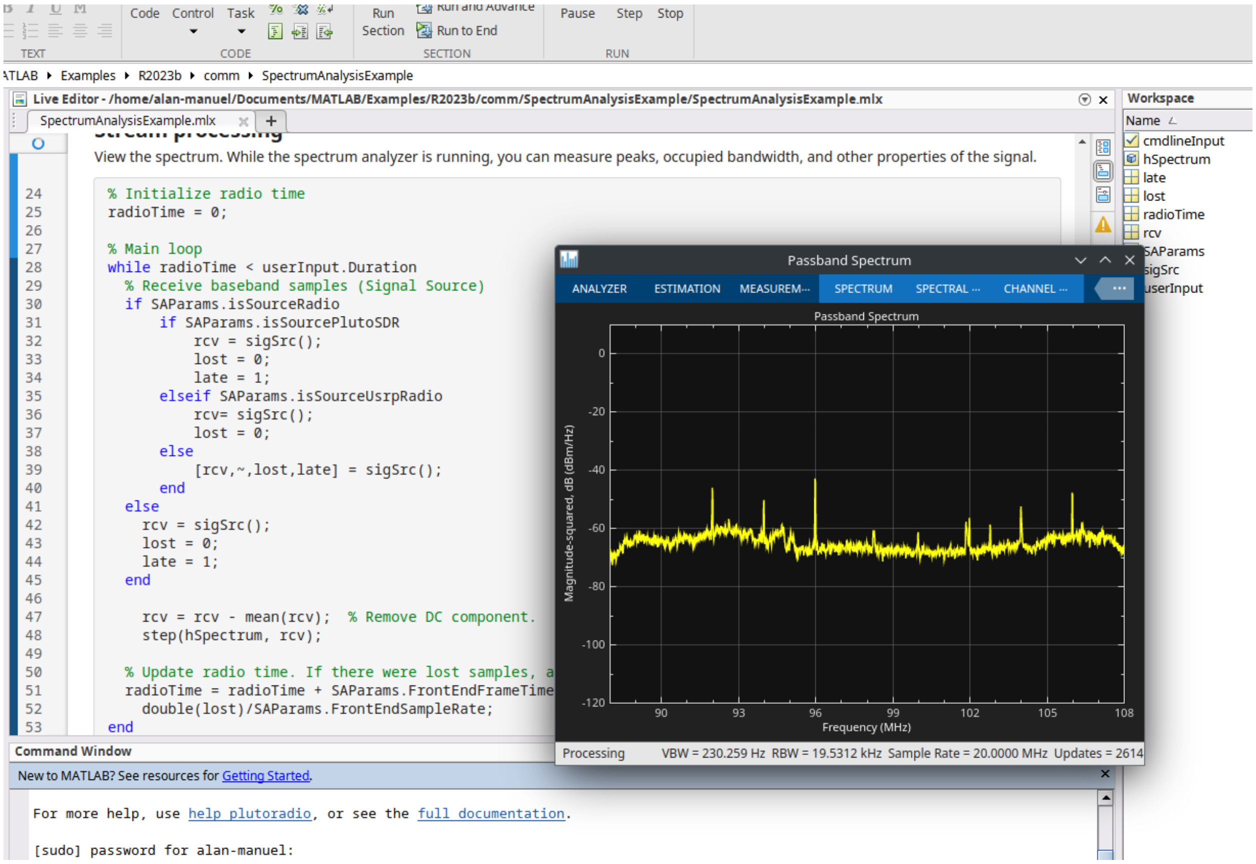
Contents

2 | Required Software

Matlab

I can run one of the example programs on my linux computer with matlab installed:

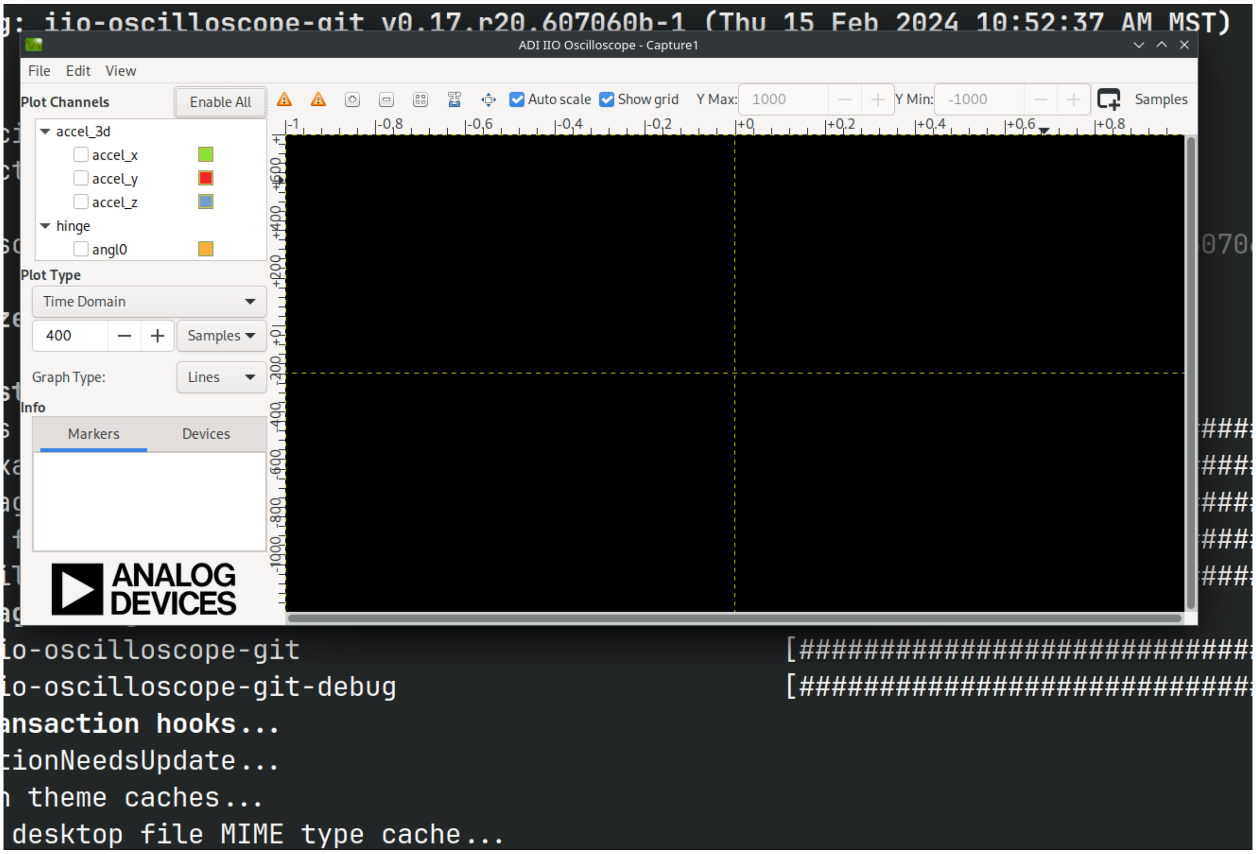


This is actually surprising because getting Matlab installed on my computer was difficult (I don't use Ubuntu).

GNU Radio

GNU radio was working fine last lab.

IIO-Scope IIO-Scope was installed and is working fine.



SSH Connection

The ssh connection to the pluto was working fine as well:

```
85 days until graduation
[alan-manuel@thinkpad lab-2]$ pluto-connect
root@192.168.2.1's password:
Welcome to:
______ _       _        _________________
| ___ \ |     | |      /  ___|  _  \ ___ \
| |_/ / |_   _| |_ ___ \ `--.| | | | |_/ /
|  __/| | | | | __/ _ \ `--. \ | | |    /
| |   | | |_| | || (_) /\__/ / |/ /| |\ \
\_|   |_|\__,_|\__\___/\____/|___/ \_| \_|

v0.38
https://wiki.analog.com/university/tools/pluto
#
```

3 | Industrial Input/Output (IIO)

Here is my `iio_info -s` output on my local computer.

```
[alan-manuel@thinkpad lab-2]$ iio_info -s
Available contexts:
        0: 192.168.2.1 (Analog Devices PlutoSDR Rev.C (Z7010-AD9363A)), serial=10447376de0b0017fbff3400ab8198c14e [ip:pluto.local]
        1:                                                                                  thinkpad,nvme,acpitz on LENOVO) [local:]
        2: 0456:b673 (Analog Devices Inc. PlutoSDR (ADALM-PLUTO)), serial=10447376de0b0017fbff3400ab8198c14e [usb:3.8.5]
[alan-manuel@thinkpad lab-2]$
```

And here is my output on the pluto:

```
# iio_info -s
Available contexts:
        0: 192.168.2.1 (Analog Devices PlutoSDR Rev.C (Z7010-AD9363A)), serial=10447376de0b0017fbff3400ab8198c14e [ip:pluto.local]
        1: (cf-ad9361-dds-core-lpc,xadc,cf-ad9361-lpc,one-bit-adc-dac,ad9361-phy,adi-iio-fakedev on Analog Devices PlutoSDR Rev.C (Z7010/AD9363)) [local:]
#
```

We can see that the iio on my laptop outputs the USB Pluto as well as the local ip for the Pluto (in addition to the local laptop) whereas the output on my Pluto outputs the local host to the ssh server as well as the system on the Pluto itself (and all of the iio devices on the Pluto).

We can use

```
iio_attr -d --uri ip:192.168.2.1
```

To display the attributes of the device.

```
[alan-manuel@thinkpad lab-2]$ iio_attr -d --uri ip:192.168.2.1
IIO context has 6 devices:
        iio:device0, ad9361-phy: found 18 device attributes
        iio:device1, xadc: found 1 device attributes
        iio:device2, one-bit-adc-dac: found 0 device attributes
        iio:device3, cf-ad9361-dds-core-lpc: found 2 device attributes
        iio:device4, cf-ad9361-lpc: found 2 device attributes
        iio:device5, iio-axi-tdd-0: found 17 device attributes
```

After catting the name we can see the following output (in addition to all of the contents in this directory)

```
in_voltage0_hardwaregain_available          out_voltage0_hardwaregain_available
in_voltage0_rf_port_select                  out_voltage0_rf_port_select
in_voltage0_rssi                            out_voltage0_rssi
in_voltage2_offset                          out_voltage2_raw
in_voltage2_raw                             out_voltage2_scale
in_voltage2_scale                           out_voltage3_raw
in_voltage_bb_dc_offset_tracking_en         out_voltage3_scale
in_voltage_filter_fir_en                    out_voltage_filter_fir_en
in_voltage_gain_control_mode_available      out_voltage_rf_bandwidth
in_voltage_quadrature_tracking_en           out_voltage_rf_bandwidth_available
in_voltage_rf_bandwidth                     out_voltage_rf_port_select_available
in_voltage_rf_bandwidth_available           out_voltage_sampling_frequency
in_voltage_rf_dc_offset_tracking_en         out_voltage_sampling_frequency_available
in_voltage_rf_port_select_available         power
in_voltage_sampling_frequency               rssi_gain_step_error
in_voltage_sampling_frequency_available     rx_path_rates
multichip_sync                              subsystem
name                                        trx_rate_governor
of_node                                     trx_rate_governor_available
out_altvoltage0_RX_LO_external              tx_path_rates
out_altvoltage0_RX_LO_fastlock_load         uevent
out_altvoltage0_RX_LO_fastlock_recall       xo_correction
out_altvoltage0_RX_LO_fastlock_save         xo_correction_available
out_altvoltage0_RX_LO_fastlock_store
# pwd && cat name
/sys/bus/iio/devices/iio:device0
ad9361-phy
#
```

```
cd /sys/bus/iio/devices/
```

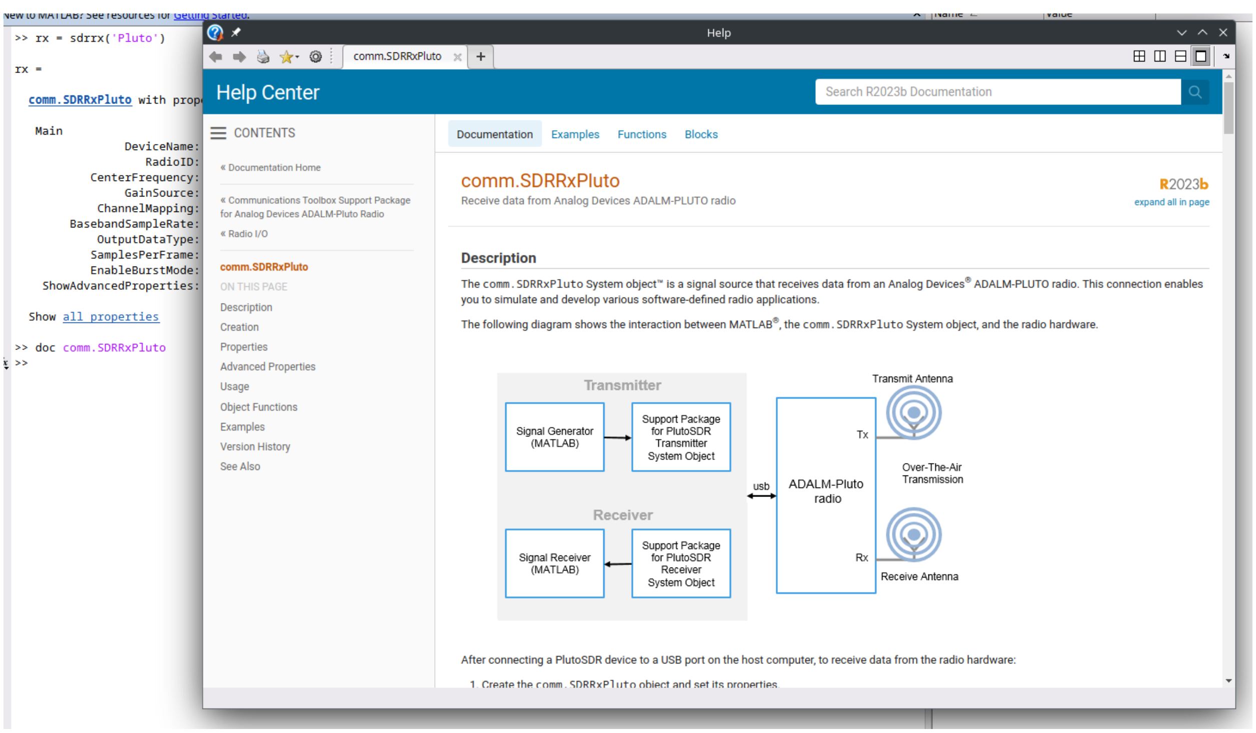
All of those files, I assume, are used to control the values of the outputs of components. We can use IIO Oscilloscope for debugging these values as well.

4 | Radio Setup and Environmental Noise Observations

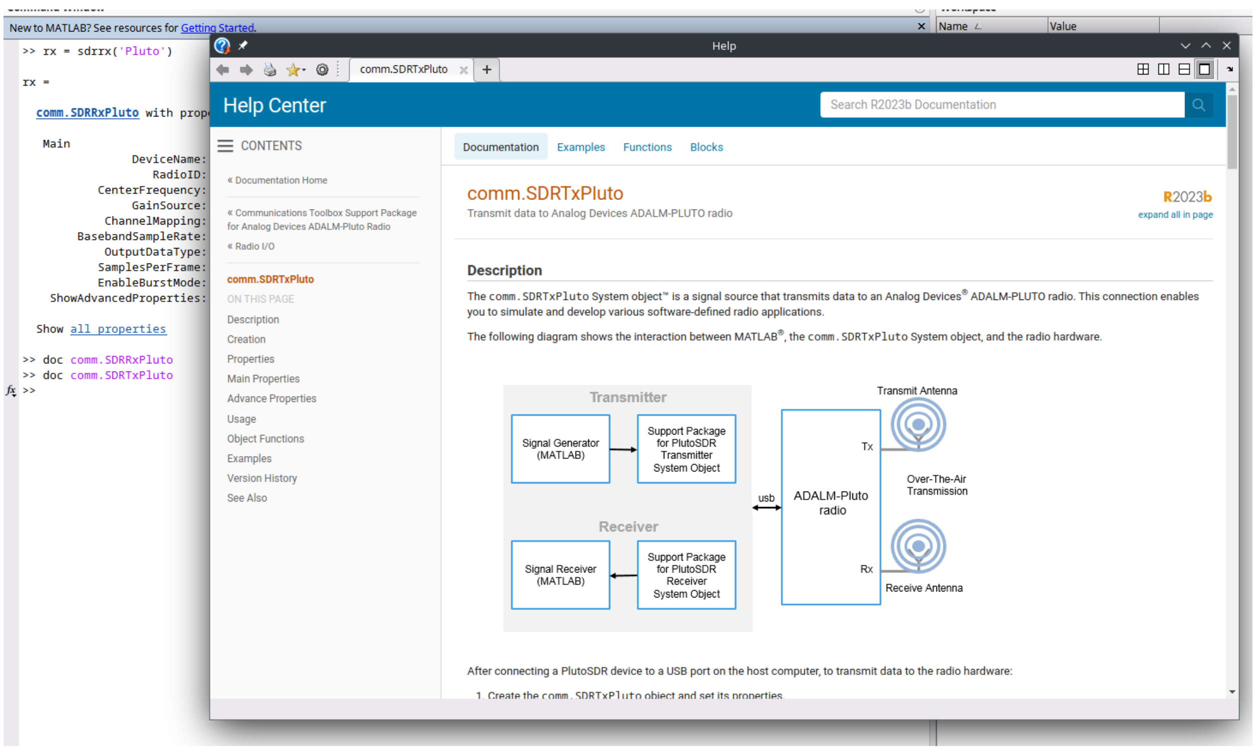
Entering the command into MATLAB

```
>> rx = sdrrx('Pluto')

rx =

  comm.SDRRxPluto with properties:

   Main
                 DeviceName: 'Pluto'
                    RadioID: 'usb:0'
            CenterFrequency: 2.4000e+09
                 GainSource: 'AGC Slow Attack'
             ChannelMapping: 1
         BasebandSampleRate: 1000000
             OutputDataType: 'int16'
            SamplesPerFrame: 20000
            EnableBurstMode: false
   ShowAdvancedProperties: false

  Show all properties

>> |
```

Pulling up the documentation for the pluto:

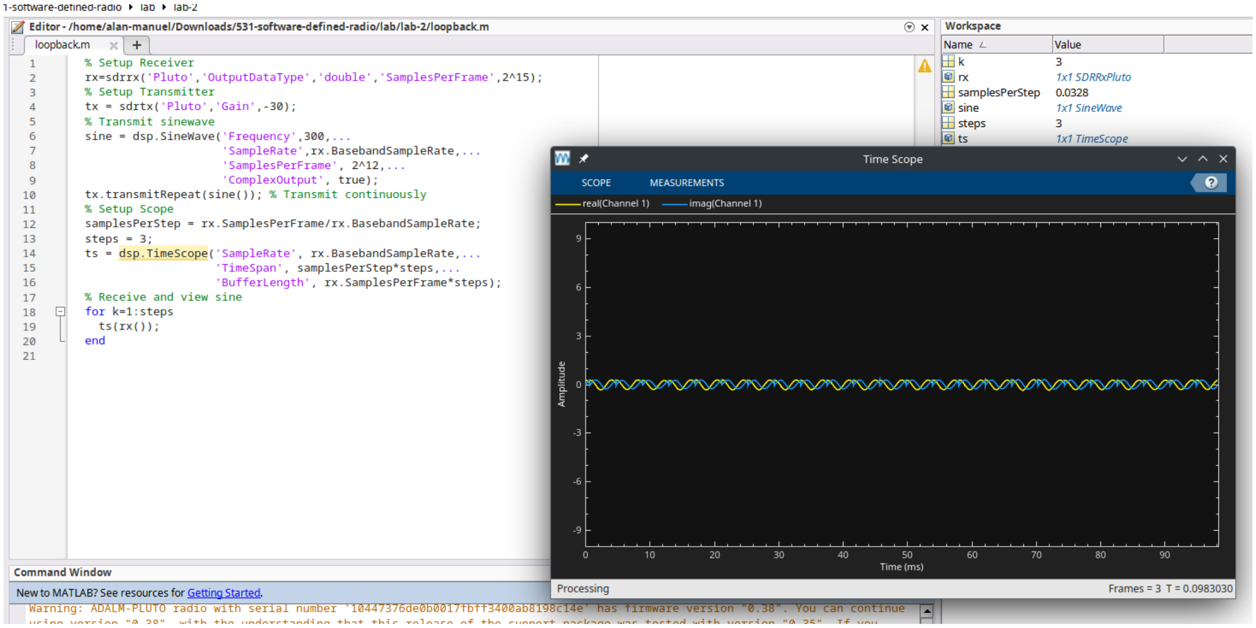


SDRR:

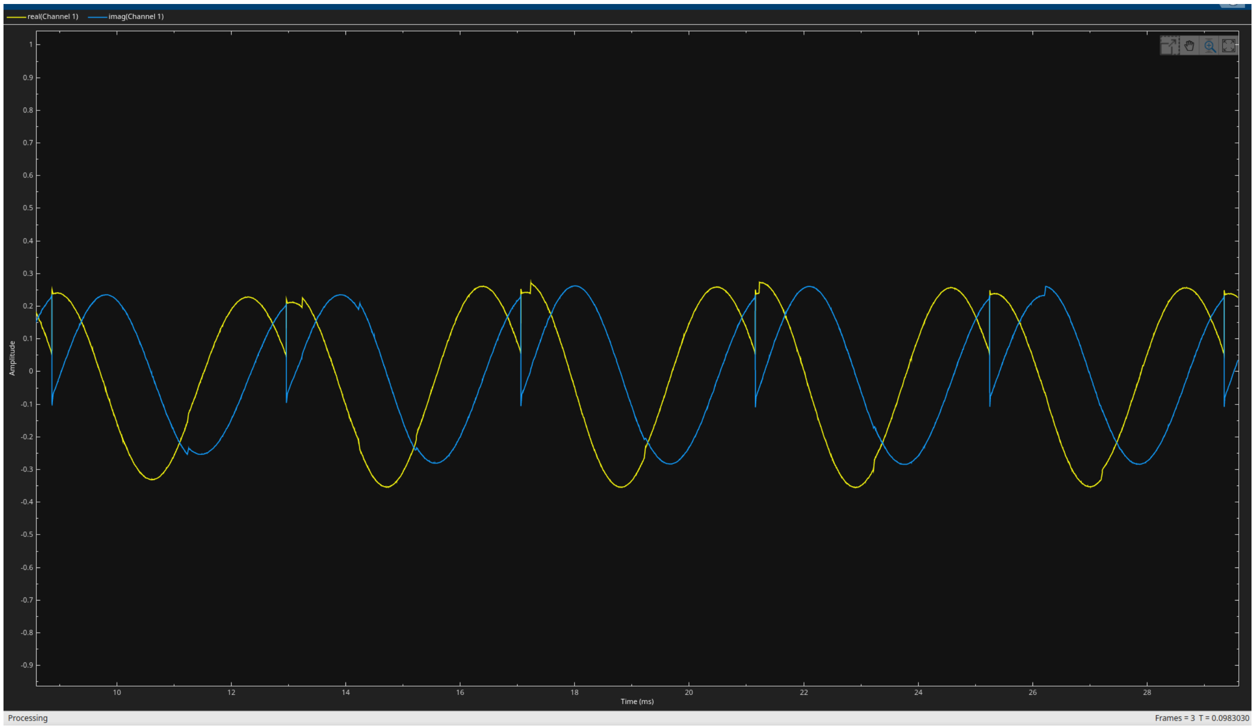
SDRT: 

loopback.m

After connecting the coaxial cable, I was able to run the provided `loopback.m` script and recieved the following output:

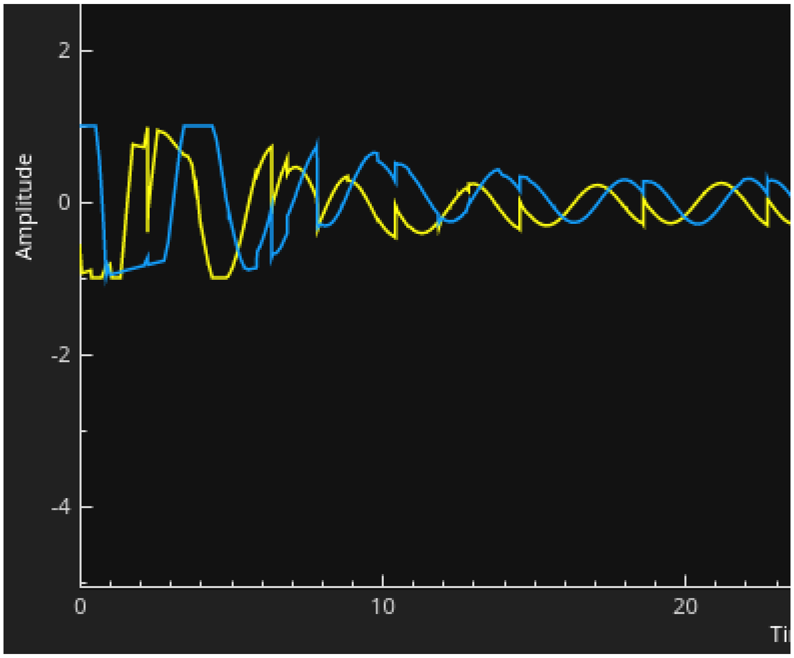


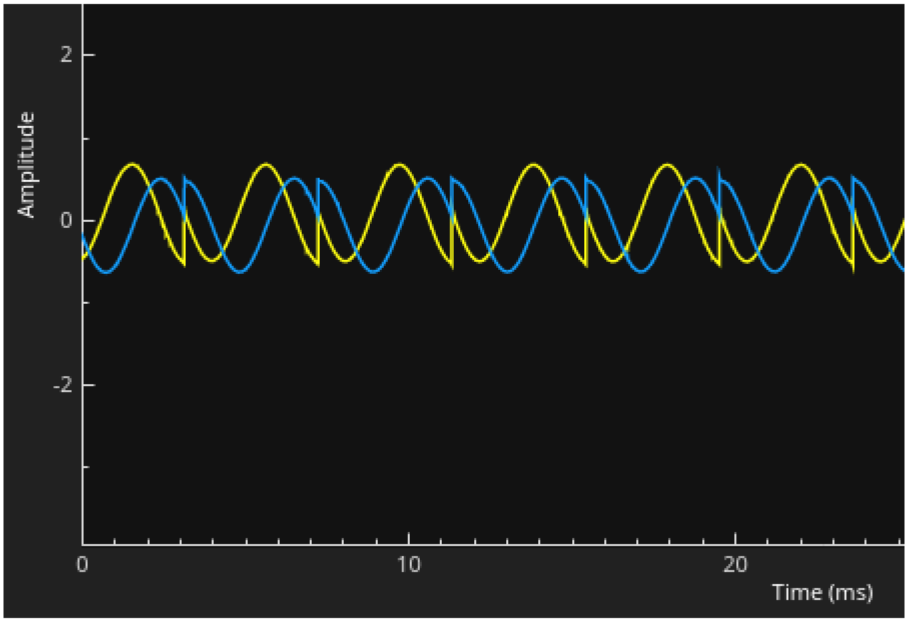
Zooming in on the waveform we can see this:



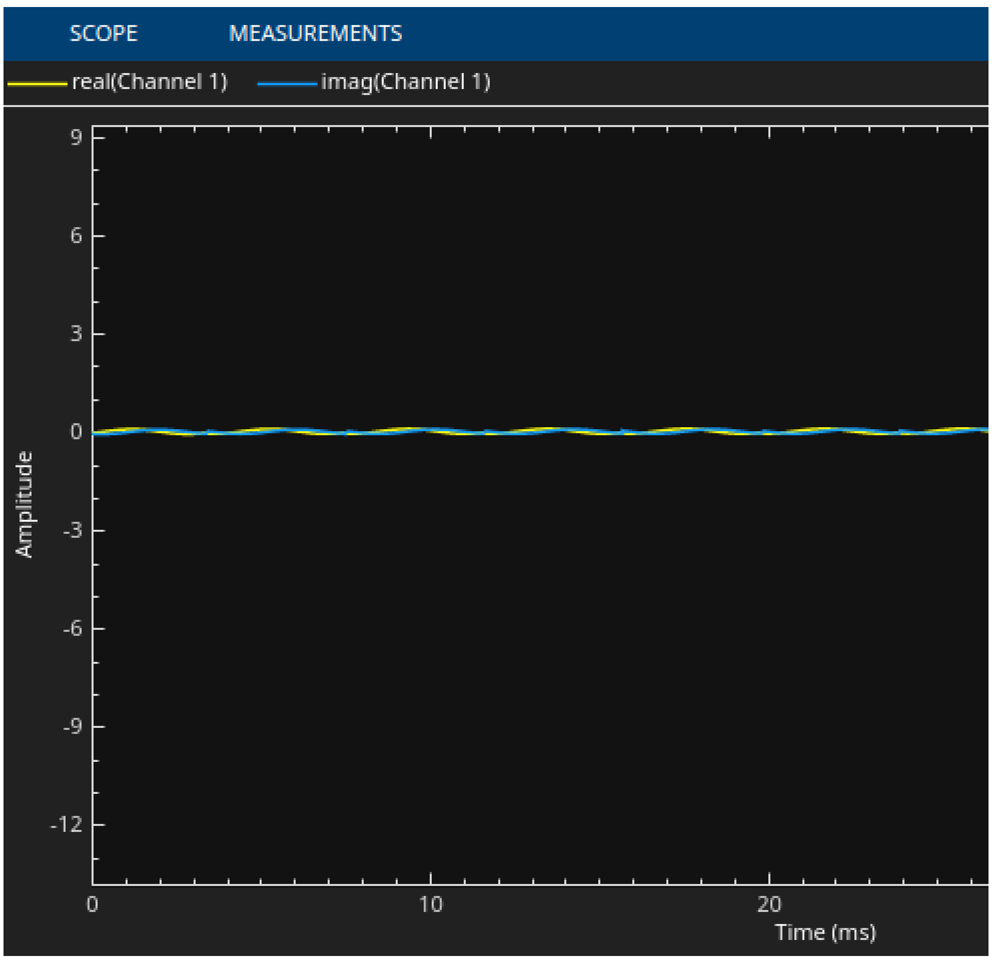
Modifying the Script

1. Modifying the samplitude of the sine wave

Slow Attack: 



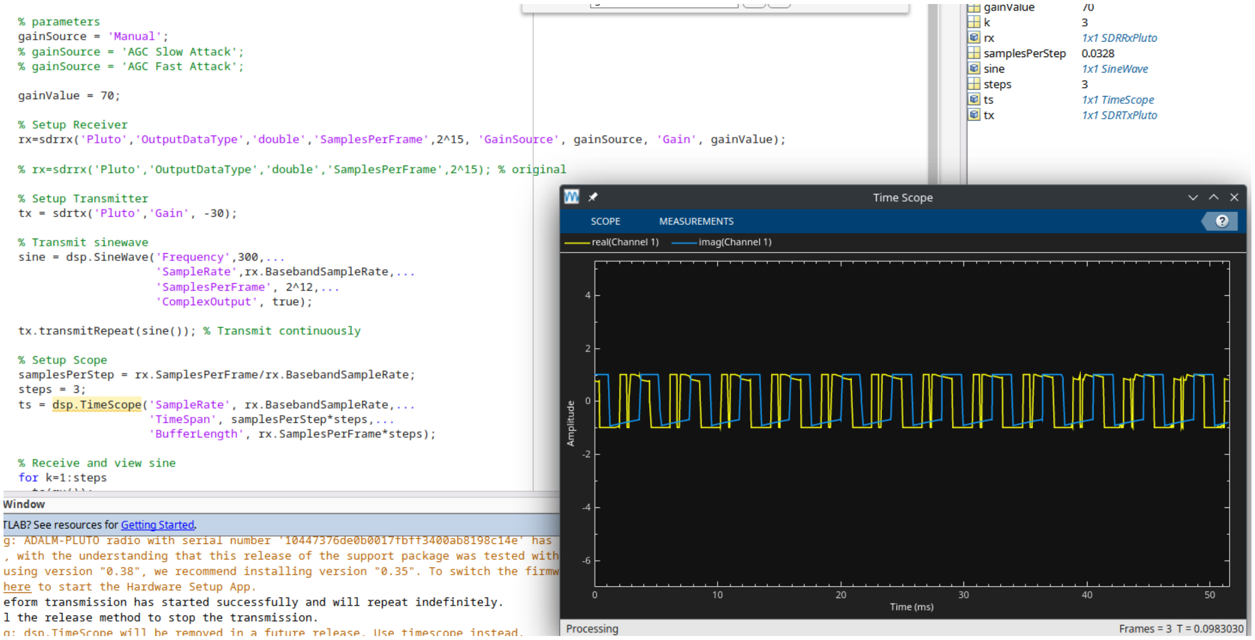
Fast Attack:



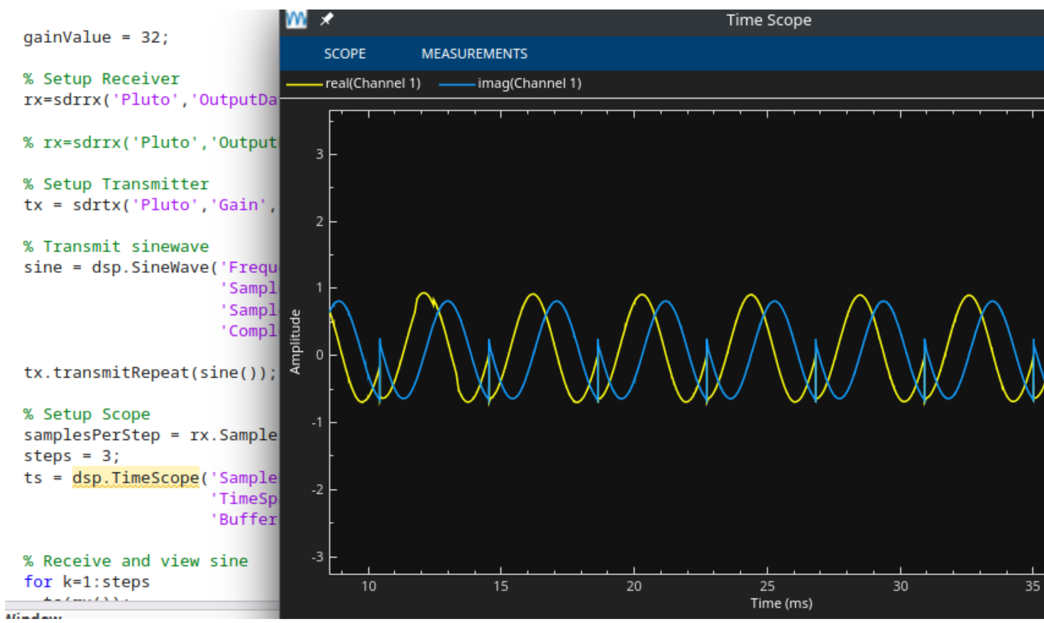
Manual:

The gain value must be set at this point.

Setting the gain value to 70 causes this square-wave looking output output:

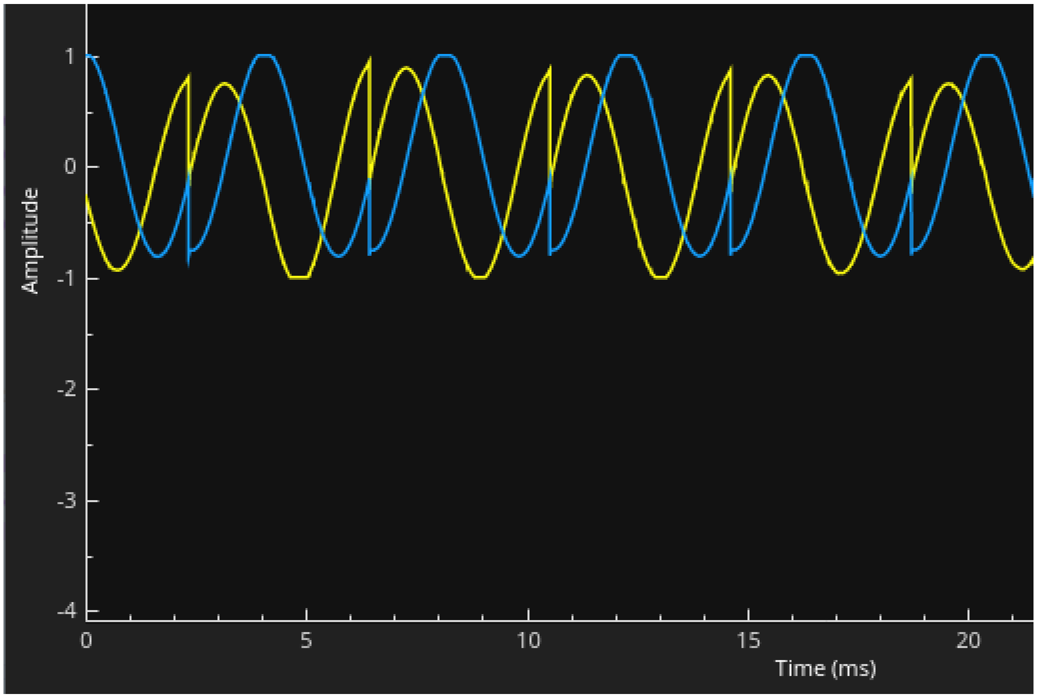


The square-wave-like signal likely happens because of railing on the output/input hardware.



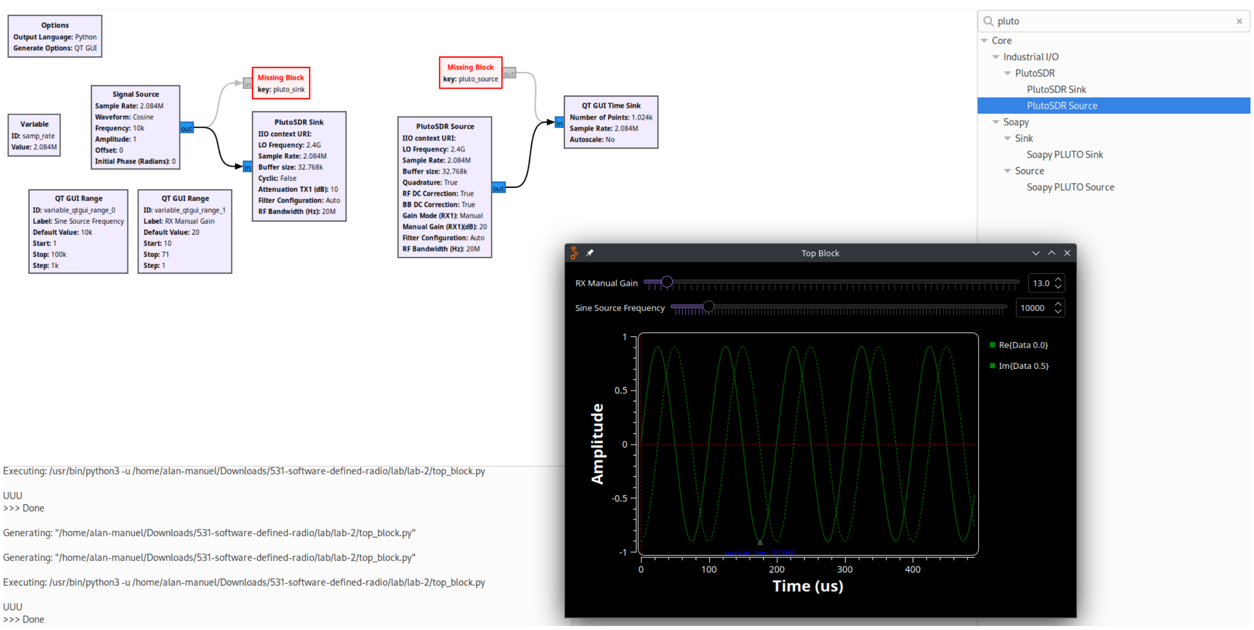
Here is the output when gain is 32.

Breakdown begins to occur at about 34 for the gain value.



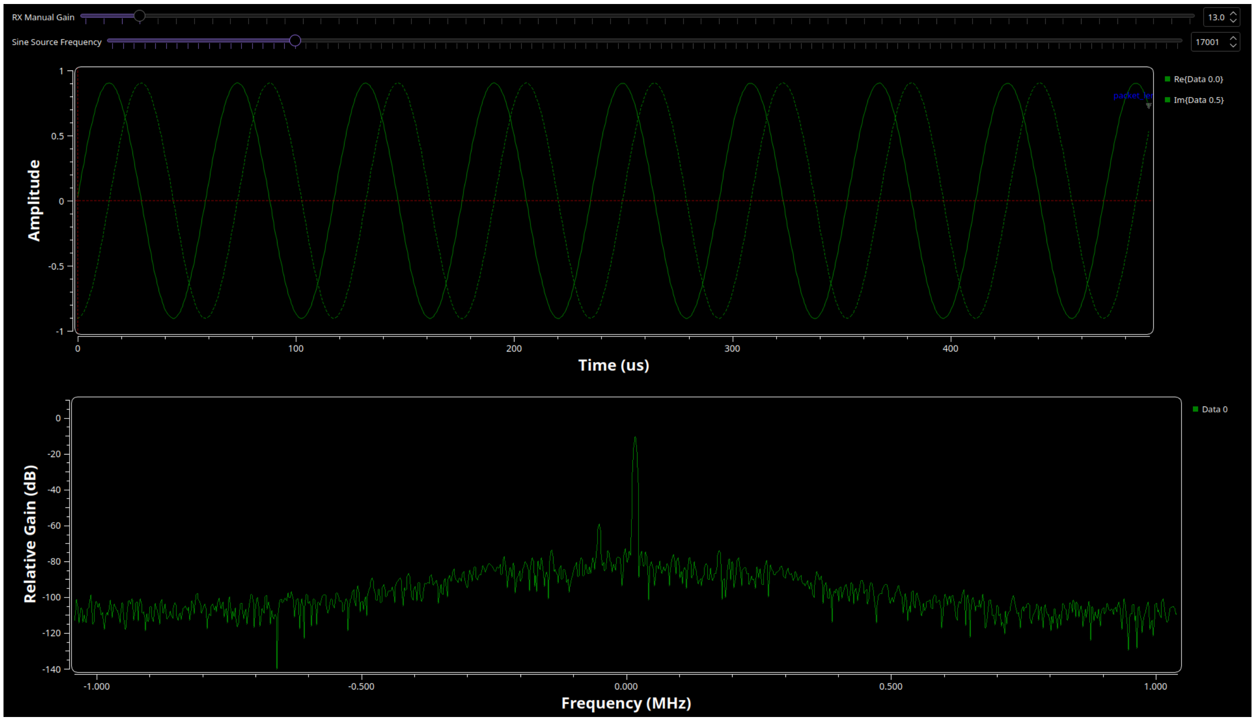
GNU Radio Loopback

Here is the output when generating the SFG and running the generated python scripts:

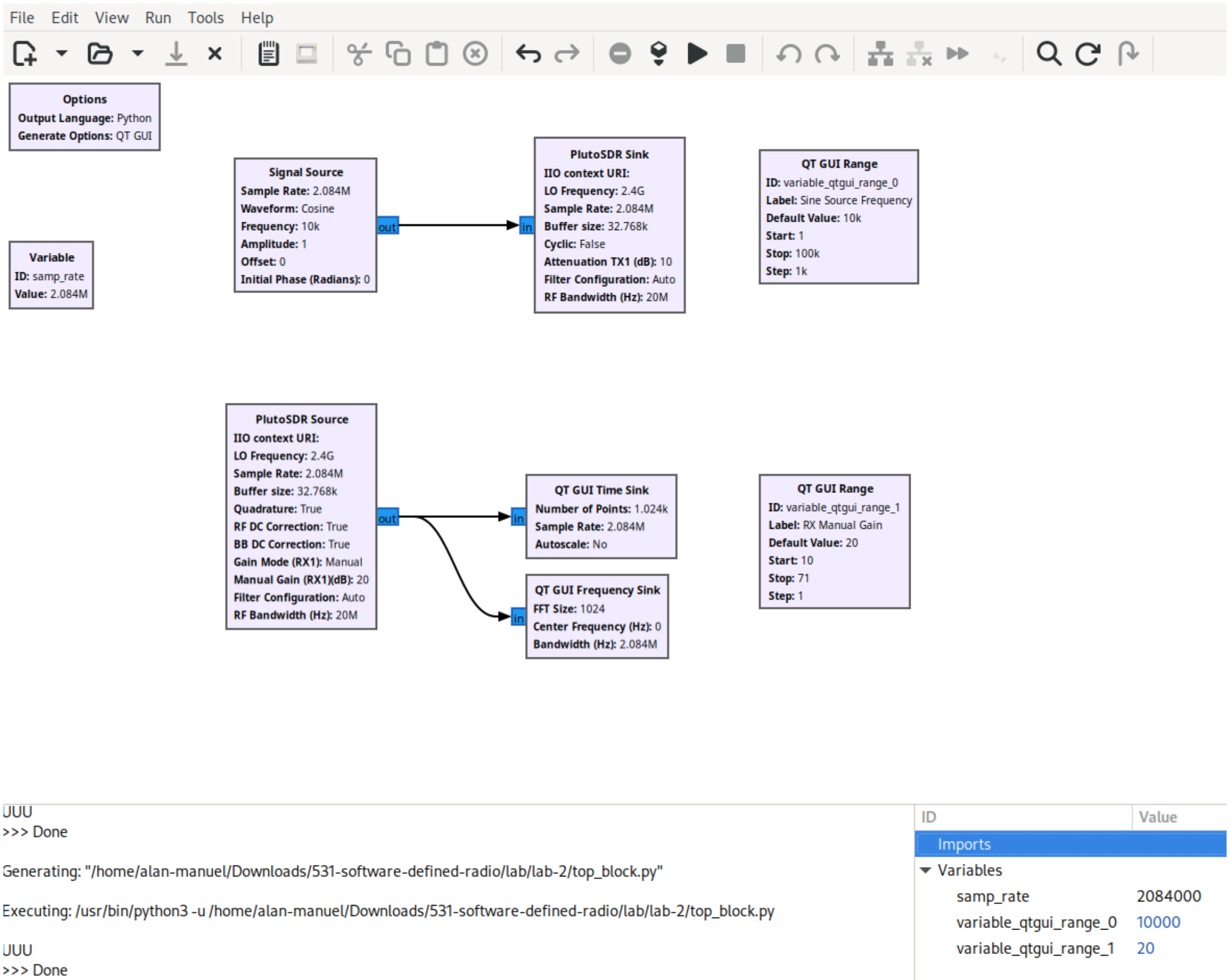


1. I added the pluto by searching for the module on the right.
2. I control the gain of the signal by using the gui variable (assigned it inside the pluto block by changing the gain mode, similar to the matlab method)

Adding a frequency sink (so that it matches the document while also including the time sink gives this output):



Here is the SFG from gnuradio:

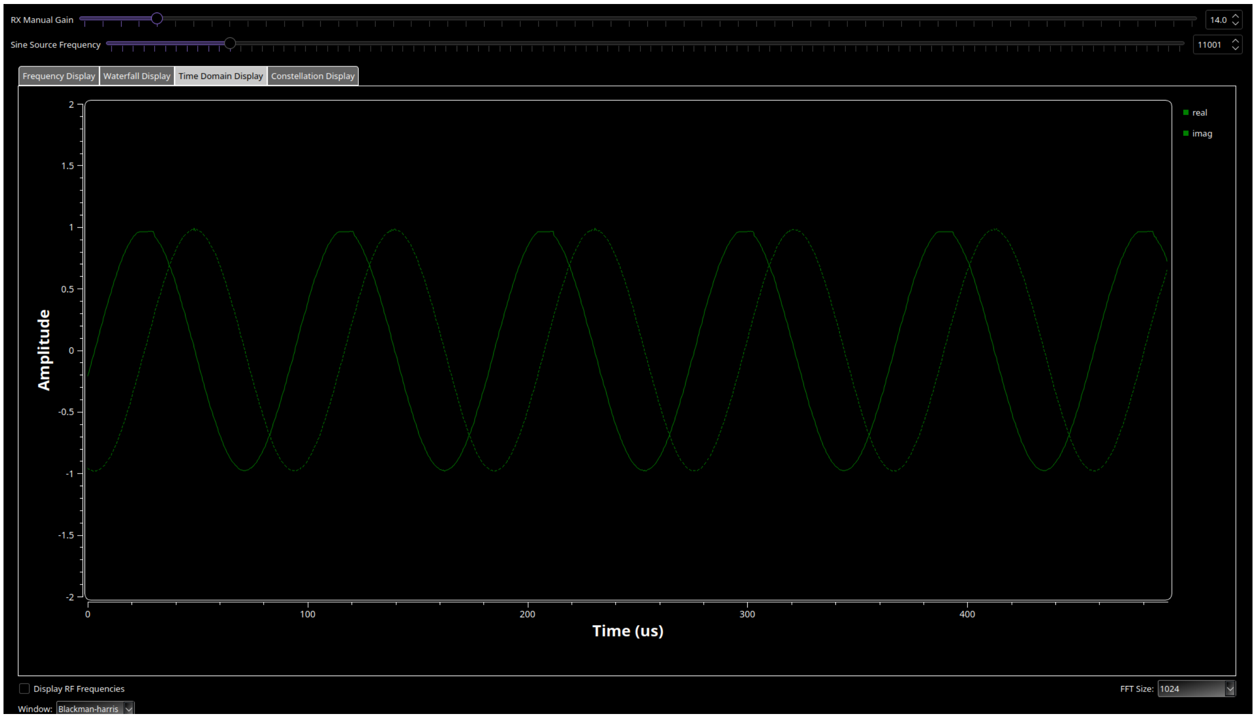


Double-click on each PlutoSDR block (source and sink) to look at the block properties.

- What is the RF Bandwidth? What does this property control in the PlutoSDR?
  - **RD bandwidth is the total frequency range that the SDR (in this case, the Pluto) is able to receive at any given time.**
- What is the "Cyclic" boolean selection for in the PlutoSDR Sink block?
  - **The Cyclic boolean selection for the PlutoSDR is used for turning on cyclic mode. This allows the first buffer of samples to be repreated on the program until the program is stopped. This allows the rest of the program to execute while the PlutoSDR blocks stop.**
- What does the Manual Gain control in the PlutoSDR source? What other strategies are available?
  - **The manual gain value controls the gain of the transmitter output.**

Adjust the RX gain. At what value does the received signal begin to distort or clip? Run the flowgraph. Note: you may have to enter change the Device URI. On some operating systems libIIO finds the first available device when this field is left blank.

In my case there was no need to configure the URI. Linux did that for me.



As you can see in the image above, the signal starts to distort at about 14 for the Rx gain value.

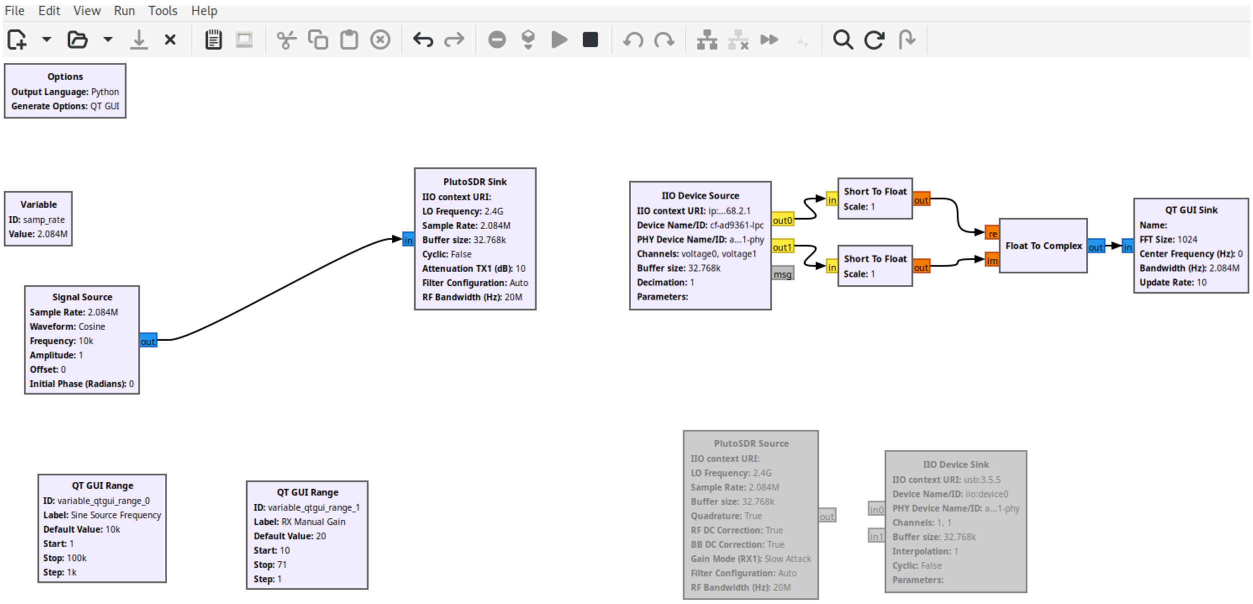
Replace the "QT Time Sink" block with a "QT GUI Sink". Explore the options provided by the new sink block. What happens if you increase the number of averages? Why does the frequency response change when you change the window function? Changing the number of averages takes an average of the past number of calculated data points for that field which allows the wave forms to look cleaner. If I'm not mistaken, this is behaving like a lo-pass filter on the data points.

The reason for the frequency response changing when I change the windows is because each window has different spectral leakage parameters that affect the value that is sampled from the ADC.

What is the transmitted RF frequency of the sinusoid? The transmiitted RF frequency of the sinusoid is 10k. This is becuase that is the settin on the GUI slider. However when I change the GUI slider the frequency changes to the corresponding frequency.

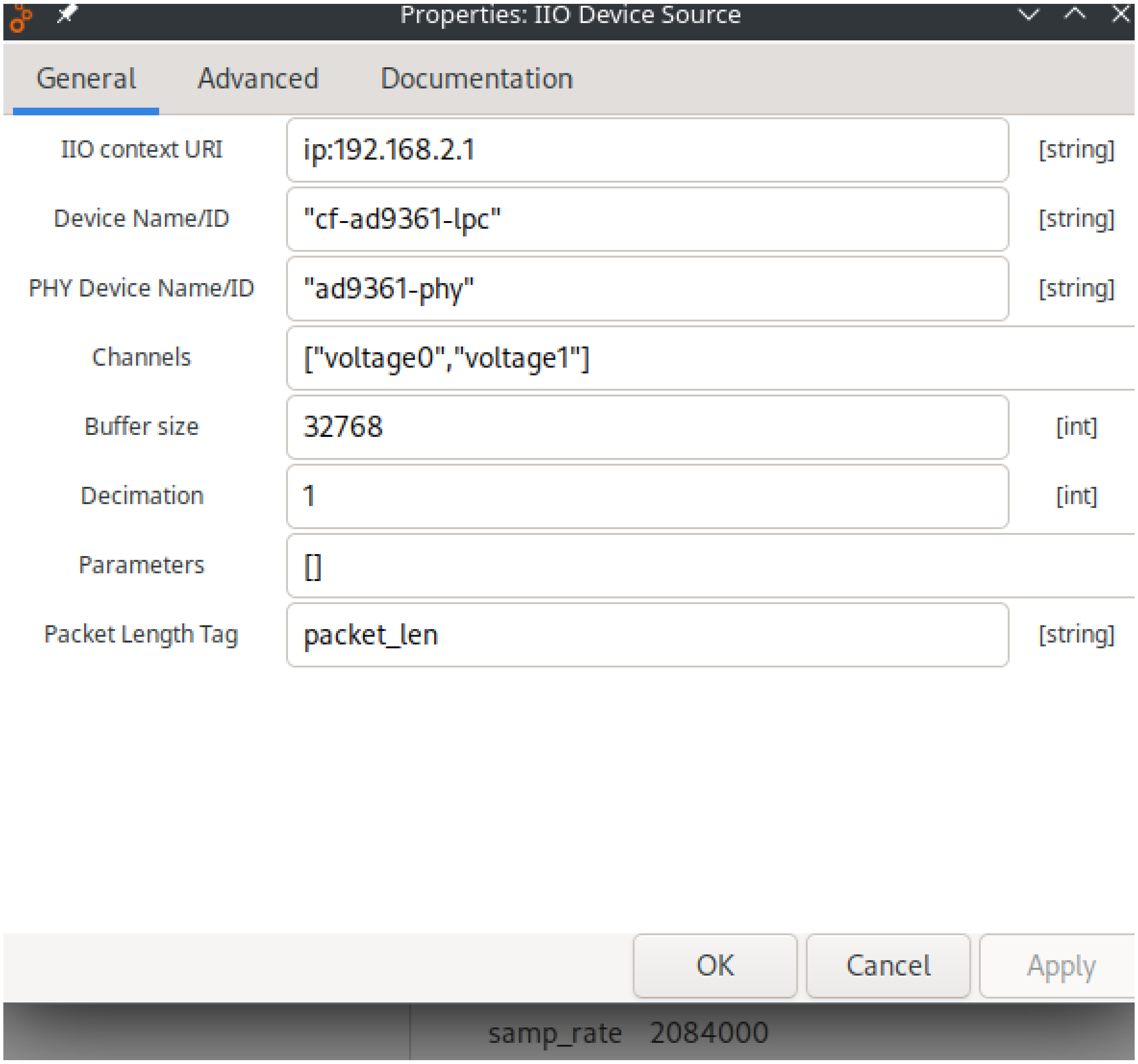
4.1.3 | Using a Custom IO Block

Below is a screenshot of the signal flow graph in GNU radio:



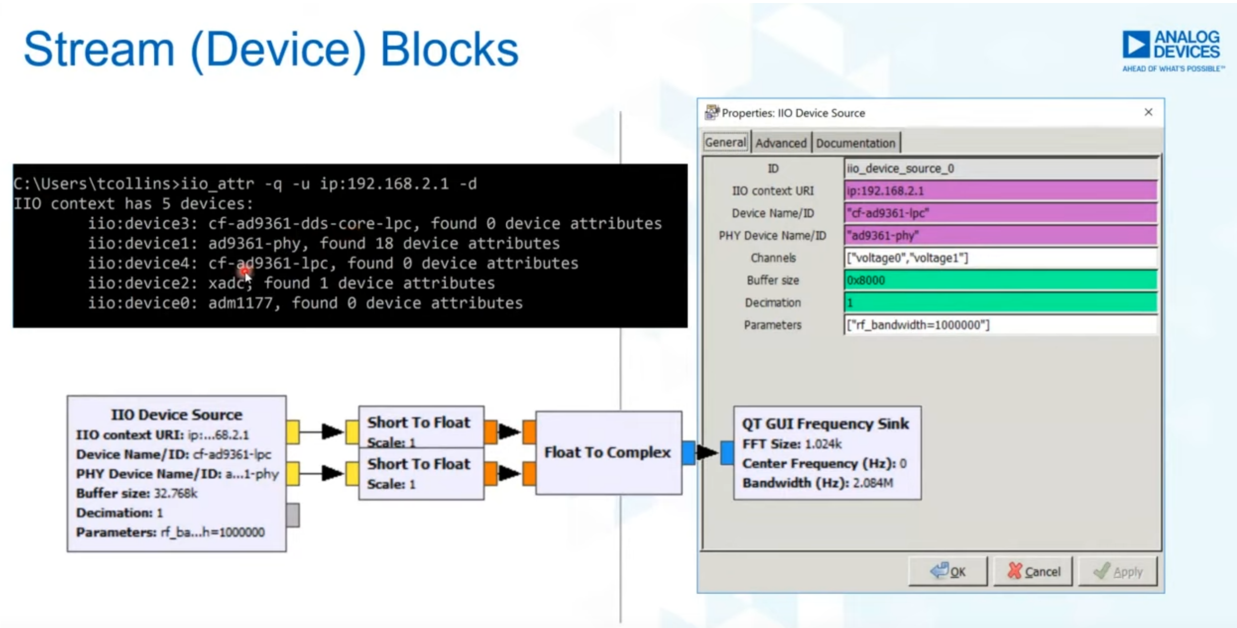
As you can see, the IIO device source block has many parameters.

Let's go through them:

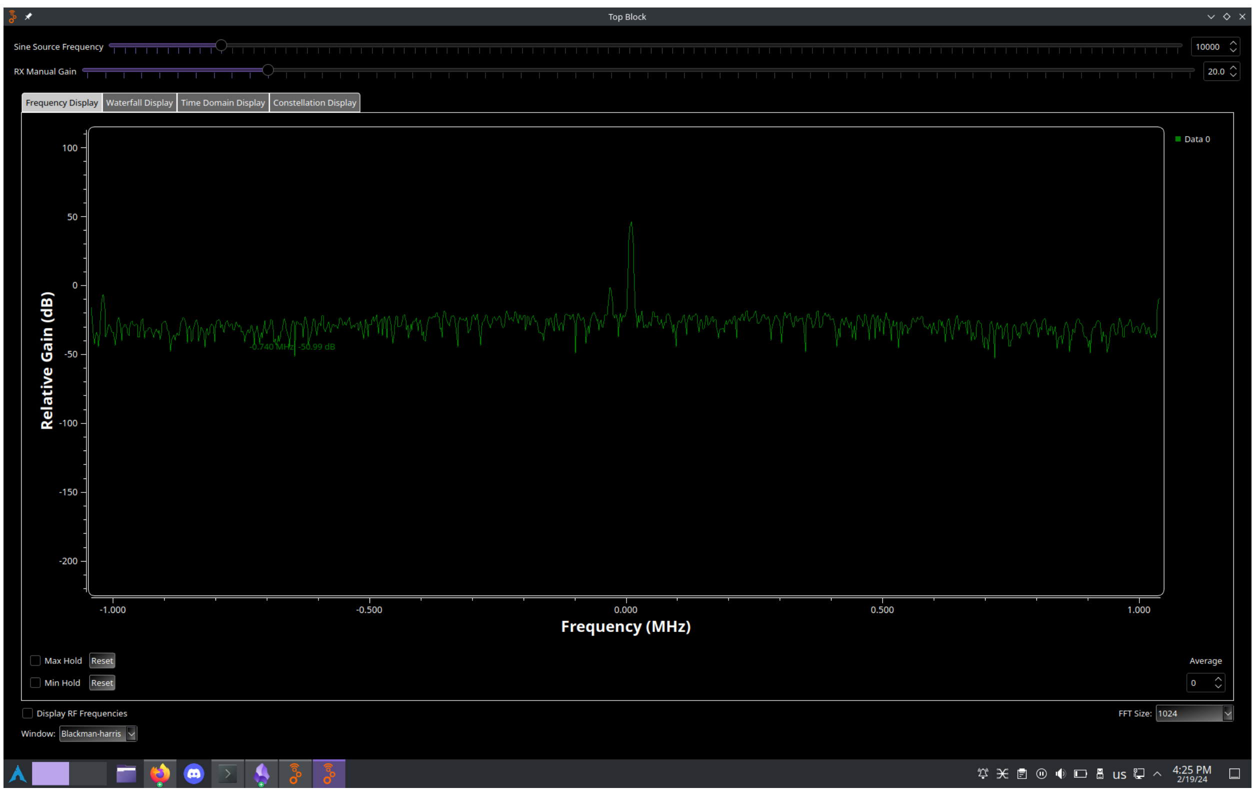


`ip:192.168.2.1 // this is how your computer communicates with the pluto`

The way that I was able to do this was by following a workshop done by ADI.



Here is the output of the gui.



4.2 | Measurements and the Radio

Using the gain settings to change the amplitude of the signal

This is a gain value of 10 on the transmit signal.

Statistics							
real(Channel 1)	Max	Min	Peak to Peak	Mean	Standard De...	Median	RMS
Time (ms)	2.0308e+1	1.4840e+0					
Value	8.3496e-2	-6.6406e-2	1.4990e-1	5.5967e-5	5.0347e-2	-1.2695e-2	5.0325e-2

The RMS value in this case is: $5.5.0325 \times 10^{-2}$

When using the gain value at 20:

Statistics						
real(Channel 1)	Max	Min	Peak to Peak	Mean	Standard De...	Median
Time (ms)	9.5085e+1	9.7572e+1				
Value	2.1729e-1	-1.8359e-1	4.0088e-1	1.1013e-3	1.3177e-1	-1.5625e-2

We can see the RMS value is: 1.3172×10^{-1}

Plugging into the formula:

$$SNR_{dB} = 10 \log_{10} \frac{1.1372 \times 10^{-1} \ - \ 5.50325 \times 10^{-2}}{5.50325 \times 10^{-2}} = 0.2792 \text{ dB}$$

When using the `imnoise` function to add noise to the signal that is transmitted by the pluto, I get this output:

```
noise = imnoise(sine(), 'gaussian', 0.005);
```

Statistics							
real(Channel 1)	Max	Min	Peak to Peak	Mean	Standard De...	Median	RMS
Time (ms)	8.1820e+0	1.6840e+0					
Value	6.0498e-1	-4.6973e-1	1.0747e+0	2.7785e-3	3.7313e-1	-7.5195e-2	3.7297e-1

We get an RMS value of 3.7297×10^{-1}

When getting the rms from the no-noise sinewave: You can see the RMS is 2.8998×10^{-1}

Statistics							
real(Channel 1)	Max	Min	Peak to Peak	Mean	Standard De...	Median	RMS
Time (ms)	1.6896e+1	1.9257e+1					
Value	5.8643e-1	-7.9297e-1	1.3794e+0	-5.1488e-2	2.8550e-1	-2.0020e-2	2.8998e-1

Plugging those values into the equation:

$$SNR_{dB} = 10 \log_{10} \frac{3.7297 \times 10^{-1} \ - \ 2.8998 \times 10^{-1}}{2.8998 \times 10^{-1}} = -5.43342280935 \text{ dB}$$

When using the different methods, I see that the numbers that result are actually quite different. To be honest, I don't know why that's the case...

Conclusions

After doing this lab, I was extremely happy with how well everything seemed to workout in terms of software compatibility.

I've been using Linux for a while now because I prefer using the terminal in my workflow. I feel like this is the first time where linux is actually beneficial to running the programs that are necessary to perform the functions in this course. While installing matlab was a bit of a hurdle, gnuradio was not. All of the libiio components were also easy to install, this was due to the fact that the Arch User Repository had all of the packages that I needed.

Regarding the things that I learned for iio, it was interesting to see how the interfacing between the Pluto device and the computer was done. Using the ssh connection to the IP was nt how I expected it to work. One weird issue that arose was when I used the IIO blocks in gnuradio to connect to the pluto (instead of using the pluto blocks). This caused an issue with my ssh command that warned me about a possible man-in-the-middle attack happening on my computer. A screenshot is shown below of the output from the terminal (note I created an alias to connect to the pluto):

```
[alan-manuel@thinkpad lab-2]$ pluto-connect
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
It is also possible that a host key has just been changed.
The fingerprint for the ED25519 key sent by the remote host is
SHA256:ueGKLfCx+XbvxLR4pvlFyWkb5hyI5DqopG4kulFh3n0.
Please contact your system administrator.
Add correct host key in /home/alan-manuel/.ssh/known_hosts to get rid of this message.
Offending ED25519 key in /home/alan-manuel/.ssh/known_hosts:5
Host key for 192.168.2.1 has changed and you have requested strict checking.
Host key verification failed.
[alan-manuel@thinkpad lab-2]$ █
```

Figure 1: Man in the middle attack in progress?

The way to fix this was by removing the pluto from the known ssh hosts and then connecting to the pluto again.

In addition, trying to interface with the iio blocks was difficult in it's own way. I struggled for a few days to get the blocks to use the correct arguments. Not to mention, there is a lot more that goes into transmitting than receiving.

All in all, learning how to interface with the pluto from the commandline, matlab, and gnudradio was a great experience. I came across many hiccups but am learning a lot more about interfacing with hardware than I thought I would. The fact that using linux has been the pragmatic choice in this class is a huge plus, considering I have some colleagues struggling with VM issues, so it's nice to not worry about those.