Learning Objective 2.3: I can install GNU Radio and use GNU Radio Companion (GRC) to build, inspect, and run a basic flowgraph.

Learning Objective 2.4: I can capture a real RF signal using an SDR and interpret its time- and frequency-domain representations.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate).

1. **Reading a flowgraph.** A classmate's flowgraph has a Signal Source, a Throttle, and a QT GUI Frequency Sink. GRC draws the arrow from the Throttle to the sink in red and will not run.

   (a) The source and throttle ports are blue and the sink's input is orange. What is wrong, and what are two ways to fix it?

   The source and throttle carry complex samples (blue) and the sink expects floats (orange); connected ports must have the same type. Either set the sink's type to complex, or insert a conversion block such as Complex to Mag or Complex to Real between them.

   (b) The classmate then replaces the Signal Source with a PlutoSDR Source and keeps the Throttle. Explain why the Throttle should come out.

   The PlutoSDR delivers samples at exactly its sample rate, so the hardware already paces the flowgraph. A throttle only exists to pace a flowgraph with no hardware, and with an SDR it adds a second, competing clock that can drop samples.

2. **Complex sampling and aliasing.** A complex signal source runs at $f_s = 32$ kHz.

   (a) What range of frequencies can the samples represent?

   $$-\frac{f_s}{2} \text{ to } +\frac{f_s}{2} = -16 \text{ to } +16 \text{ kHz}$$

-16 to $+16$ kHz

   (b) Where does the frequency sink show a 40 kHz tone, and a -20 kHz tone?

   $$40 - 32 = 8 \text{ kHz}$$
   $$-20 + 32 = 12 \text{ kHz}$$

40 kHz:	8 kHz
-20 kHz:	12 kHz

   (c) A PlutoSDR samples at 2.4 MS/s centered on 100.1 MHz. What band does the display show? Suppose a strong station at 102.1 MHz leaks past the Pluto's filters unattenuated. Where does it appear?

   The display spans 100.1 ± 1.2 MHz, 98.9 to 101.3 MHz. The station is $+2.0$ MHz from center, outside the ± 1.2 MHz window, so it aliases to $2.0 - 2.4 = -0.4$ MHz from center:

   $$100.1 - 0.4 = 99.7 \text{ MHz}$$

band:	98.9 to 101.3 MHz
alias:	99.7 MHz

   (d) Explain why complex samples show twice the bandwidth of real samples at the same rate.

   Real samples cannot tell a positive frequency from a negative one, so they represent only 0 to $f_s/2$, with a mirror image below zero. Complex samples record the direction of rotation, so $+f$ and $-f$ are different signals and the full $-f_s/2$ to $+f_s/2$ is usable.

3. **Recording and reading IQ.** A File Sink records complex samples.

   (a) Find the size of a 5 s capture at 2.4 MS/s.

   $5 \times 2.4 \times 10^6 \times 8$ bytes $= 96$ MB

   96 MB

   (b) You play the capture back through a File Source into a QT GUI Sink, with no other blocks. The flowgraph uses a whole processor core and the display races. What block is missing, and what do you set it to?

   A Throttle, set to the capture's sample rate, 2.4 MS/s. A File Source has no hardware to pace it, so without a throttle it reads samples as fast as the laptop can.

   (c) A teammate sends only the file `capture.cfile`. Name the two numbers you need before the file is useful, and explain why.

   The sample rate and the center frequency. The file holds raw I and Q values with no header: without the sample rate the time and frequency axes have no scale, and without the center frequency the frequency axis has no reference.

4. **Gain and the DC spike.** A PlutoSDR runs the L5 FM flowgraph, with the gain set to Manual.

   (a) With the gain at 0 dB, only the strongest station shows, and the noise floor does not move when you raise the gain a little. What is happening, and what do you change?

   The gain is too low: weak stations sit below the converter's own noise, which sets the floor. Raise the gain until the floor rises a few dB, which shows the antenna's noise now sits above the converter's.

   (b) With the gain at maximum, copies of a strong station appear at frequencies where nothing transmits. Name the problem and the fix.

   Overload: the strong station drives the converter past full scale, and the clipping creates spurious signals. Lower the gain until the copies disappear, keeping it high enough that the noise floor sits a few dB above the converter's own.

   (c) A student tunes the PlutoSDR exactly onto a weak narrowband signal. With DC tracking off, the signal hides in a spike at the center of the display; with DC tracking on, it looks weakened and distorted. Explain both, and the fix.

   The spike is the receiver's own DC offset, which appears at 0 Hz, the center frequency, in every zero-IF SDR. DC tracking subtracts its estimate of what sits at 0 Hz, so it removes the offset and can eat into a signal sitting there too. Tuning the SDR a little off the signal moves the signal away from the center, where neither touches it.

Documentation: _____