CpE 5430 / EE 5430 / SysEng 5323 Wireless Networks
Lab assignment A.1

IMPORTANT: the installation from source (GIT -> compile/make) is REQUIRED to continue Advanced GNU Radio Module (Lab Module C)! If you plan to work on Advanced Ns3 Lab Module only, then you can install GNU Radio from repositories (e.g. "apt install gnuradio" on Ubuntu)

1. Setup the GNU Radio (preferred version 3.8 from the main branch, but 3.9 should also be acceptable)

   Setup Ubuntu on Win10 using WSL/WSL2 (https://docs.microsoft.com/en-us/windows/wsl/install-win10 , https://wiki.ubuntu.com/WSL). Then install dependencies for the GNU Radio (https://wiki.gnuradio.org/index.php/UbuntuInstall). Finally, download and install GNU Radio source code (https://wiki.gnuradio.org/index.php/InstallingGR#From_Source). Also install Xorg based server for Win10 (e.g. https://sourceforge.net/projects/vcxsrv/)

   Note that there is a potential errors/issues occurring:

   A) due to Qt5 library issues – to solve it execute following command:

   ```
   strip --remove-section=.note.ABI-tag /usr/lib/x86_64-linux-gnu/libQt5Core.s
   ```

   B) PYTHON library path -> check https://wiki.gnuradio.org/index.php/ModuleNotFoundError#B._Finding_the_Python_library

   C) Set Python and library environmental settings (https://wiki.gnuradio.org/index.php/ModuleNotFoundError#B._Finding_the_Python_library) e.g.:

   ```
   export PYTHONPATH=/usr/local/lib/python3/dist-packages:$PYTHONPATH

   export LD_LIBRARY_PATH=/usr/local/lib:$LD_LIBRARY_PATH
   ```

   D) The Linux files (home folder) can be found in C:\Users**YOUR_USERNAME**\AppData\Local\Packages\CanonicalGroupLimited.Ubuntu20.04onWindows_79rhkp1fndgsc\LocalState\rootfs\home**YOUR_USERNAME**

   The files in Linux have to be properly setup (access control). If downloading/changing through Win10 – you may need to change permissions – useful commands:

   ```
   ls -al

   chmod a+rw filename.ext

   chmod a+rw *
   ```

--or--

   Create an Ubuntu virtual machine. Here is a link to a tutorial: http://www.wikihow.com/Install-Ubuntu-on-VirtualBox Contact your TA for a special iso image and substitute this image for the one mentioned in the tutorial. **We do not recommend this method because GNU Radio has been known to have graphical bugs inside virtual machines.**

--or--

Use the Linux servers on campus network (check it.mst.edu for guidance to use these) Note: the GNU Radio installation have not been verified for most recent versions.

2. Download GNU Radio files from the Canvas (e.g. .GRC projects)
3. Launch GNU Radio Companion (GRC) by one of the following methods:
    a. Open a terminal and type “gnuradio-companion”.
        i. Make sure to run the Xorg server (XLaunch in Windows menu for VcXsrv)
        ii. Set the paths (see above)

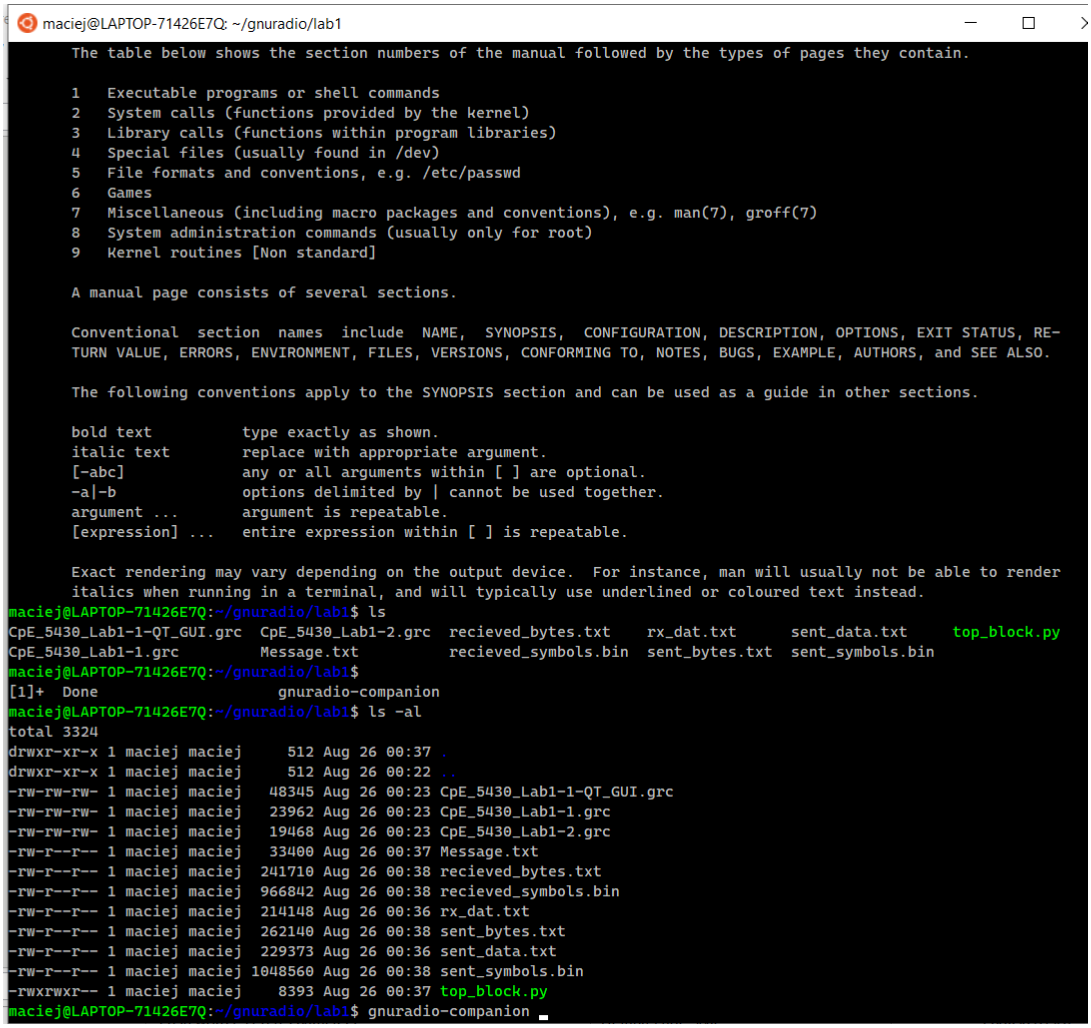


Figure 1 - Launch GRC via terminal

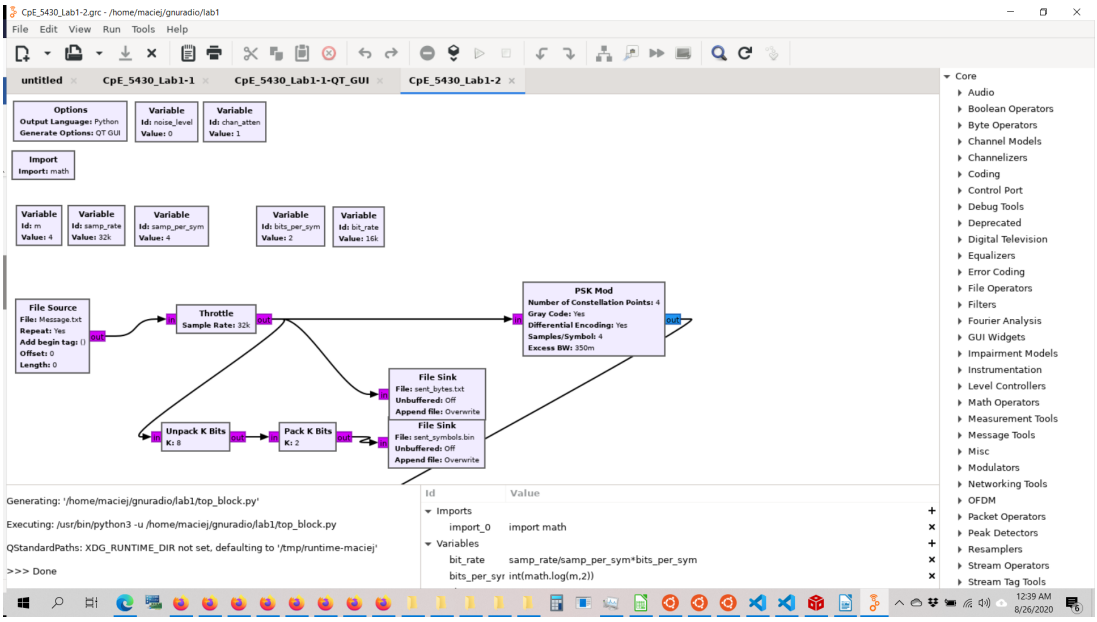
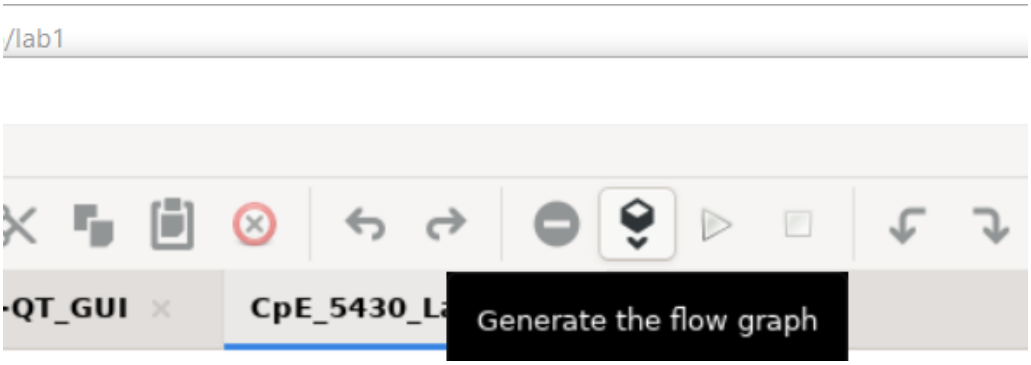
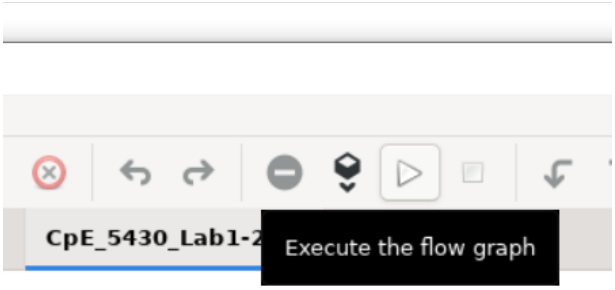


Figure 1 – View of the GNU Radio Companion GUI

4. Click File->Open… and navigate to the “CpE_5430_Lab-A-1-QT_GUI.grc” file from the filesystem and open it.
5. Familiarize yourself with this flow graph by Identifying sources, sinks, and function blocks, and variables.
6. Click the “Generate flow graph button” (it looks like a blue pyramid and a red circle with a yellow arrow between them). Notice the notifications at the bottom of the window. Status messages will show up here periodically. Also, if a flow graph has any errors or warnings, they will also show up here.



7. Check your working directory on your flash drive and notice a python file was generated for you called “top_block.py”. This is the actual python script that will execute in the next step when we run the flow graph. In the future labs we will be editing this file directly. Now return to GRC.
8. Run the flow graph by clicking on the “Execute flow graph button” (it looks like a set of gears). **This button looks disabled but it is not.**



9. A tabbed window will open containing three graphs: a complex time domain wave form graph (an oscilloscope), an FFT graph of the frequency domain, and a constellation sink showing in phase and quadrature phase components of the signal. As the program runs you will notice these graphs changing with time.

10. When working with digital radio modulation in GNU Radio, we have three parameters to control bitrate: sample rate, order "M", and samples per symbol. These three parameters can be manipulated to produce the following equations:

$$\log_2 M = \frac{bits}{symbol} \quad (1)$$

$$sample\ rate = \frac{samples}{second} \quad (2)$$

$$bit\ rate = \ sample\ rate * \frac{symbols}{sample} * \frac{bits}{symbol} \quad (3)$$

Purely for your information:
To transmit information wirelessly, we typically bury the information in a radio wave by modifying level of the amplitude, phase, or frequency parameters of a radio wave. In digital modulation, we define the level or levels in discrete steps. The total number of discrete steps is usually called the order of the modulation or "M". For example, Phase shift keying (PSK) modulation with M = 2 (2 levels) would be called 2-ary PSK or Binary PSK (BPSK). BPSK has 2 levels meaning we need 1 bit to describe which level is being presented. It is possible to send more than one bit of information simultaneously if we make M a large number or more generally equation 1. Since the modulation block is sending more than one bit per time instance, we say we are transmitting a multi-bit symbol.

To calculate effective bit error rate, we must consider sampling rate theorem. The speed at which GNU Radio runs is the sampling rate. Nyquist sampling theorem tells us we must sample at rate of greater than twice the speed of the event we are trying to observe. GNU Radio takes

care of this us, but we must tell it how many samples per symbol we want. The minimum GNU Radio allows is 2 samples per symbol (close enough to Nyquist). With this in mind we can derive the above equations.

11. The "CpE_5430_Lab-A-1-QT_GUI.grc" file is configured for:
    a. M=2 or BPSK
    b. 2 samples per symbol
    c. 32k samples per second.
12. Now, notice there are two sliders present at the bottom of the window: noise voltage and channel attenuation. These sliders correspond to user defined variables. For your lab report, make changes to the two sliders and make observations about how they affect each graph. You may want to include annotated screen shots.
13. Now, we will change the modulation to 4-ary PSK also called quadrature phase shift keying (QPSK). Double click each block in the flow graph to configure its settings. Where it applies, set M = 4 and samples per symbol t = 4 (setting samples per symbol = 4 maintains the same bitrate as the previous step see eq. 3).
    a. In both the PSK Mod and PSK Demod blocks, M is referred to as "Number of constellation Points".
    b. The GUI Constellation sink lists "M" as well as "Constellation Size". In this case don't change Constellation size but do set M = 4. Also, change the 2 in Symbol rate to 4. This value (2 or 4) is the samples per symbol.
    c. Don't change Pack K Bits this will be explained in part II.
14. Repeat step 14 and make observations about the differences between BPSK and QPSK. Annotated screen shots are also encouraged here as well.
15. Future flow graphs will be more complex. Changing the same setting in each block is time consuming. To make this simpler, we'll use a variable.
    a. On the right-hand side of GRC is the module library, scroll down and click the arrow next to "Variables" to expand it.
    b. Double click "Variable" to add a Variable block to the flow graph.
    c. Change its ID to sample_per_sym and its value to 2.
    d. Repeat step c. and create a variable for M with a value of 4.
    e. Go through each block like in step 15 and replace previously entered numbers with variable IDs.

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For your lab report

- Observations from GNU Radio setup and simple simulation
- Tabulate simple metrics – transmitted/generated bytes, duration of simulation (in simulation time, NOT real-time), error count
- Briefly explain the tabulated results.

Additional Notes

- Those experienced with shell scripting or python scripting are encouraged to automate this process
- Highly recommended GNU Radio video tutorial series: http://www.youtube.com/watch?v=N9SLAnGlGQs&list=PL618122BD66C8B3C4
- Tutorial from gnuradio.org: https://wiki.gnuradio.org/index.php/HowToUse , https://wiki.gnuradio.org/index.php/TutorialsWritePythonApplications
- Installation Instructions for the daring: https://wiki.gnuradio.org/index.php/InstallingGR