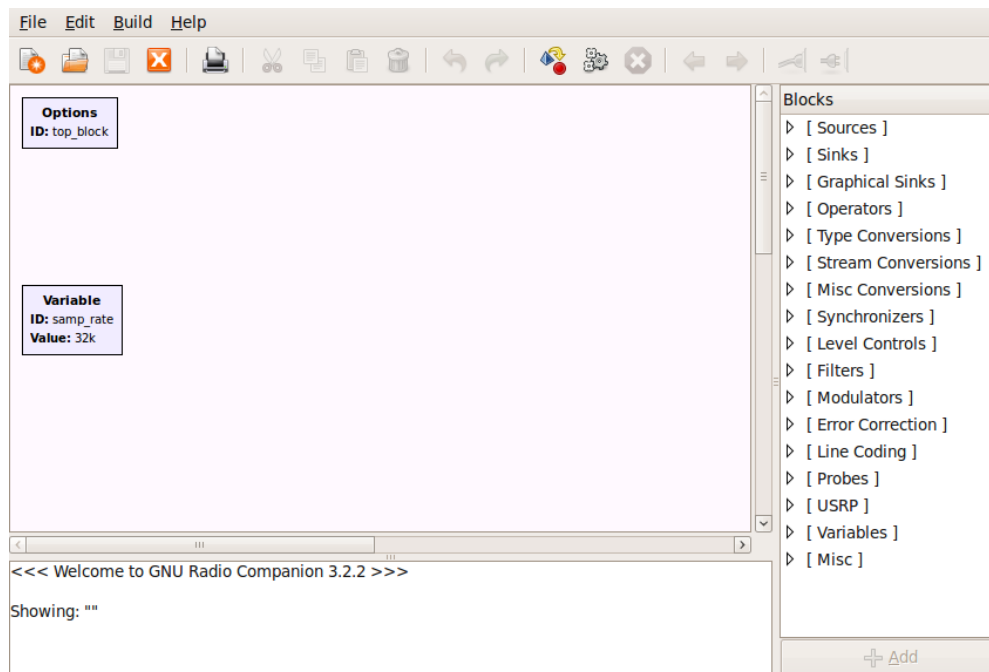


Using GNU Radio Companion: Tutorial 1

GNU Radio Companion (GRC) is a graphical user interface that allows you to build GNU Radio flow graphs. It is an excellent way to learn the basics of GNU Radio. This is the first in a series of tutorials that will introduce you to the use of GRC.

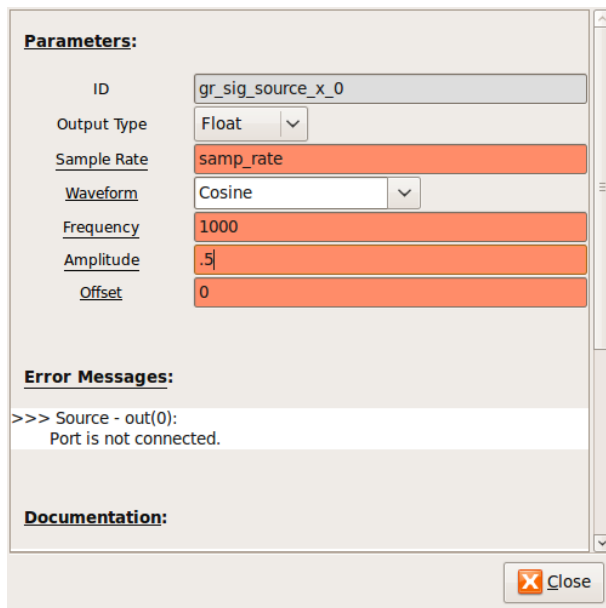
1. Open a terminal window using: Applications > Accessories > Terminal. At the prompt type:
`grc`

An untitled GRC window similar to the one below should open.



2. Double click on the Options block. This block sets some general parameters for the flow graph. Leave the ID as top_block. Type in a project title (such as Tutorial 1) and author. Set Generate Options to WX GUI, Run to Autostart, and Realtime Scheduling to Off. Then close the properties window. The other block that is present is the Variable block. It is used to set the sample rate. That will be discussed later in the tutorial.
3. On the right side of the window is a list of the blocks that are available. By expanding any of the categories (click on triangle to the left) you can see the blocks available. Explore each of the categories so that you have an idea of what is available.

4. Open the Sources category and double click on the Signal Source. Note that a Signal Source block will now appear in the main window. Double click on the block and the properties window will open. Adjust the settings to match those as shown in the figure below and close the window. This Signal Source is now set to output a real valued 1KHz sinusoid with an amplitude of .5.

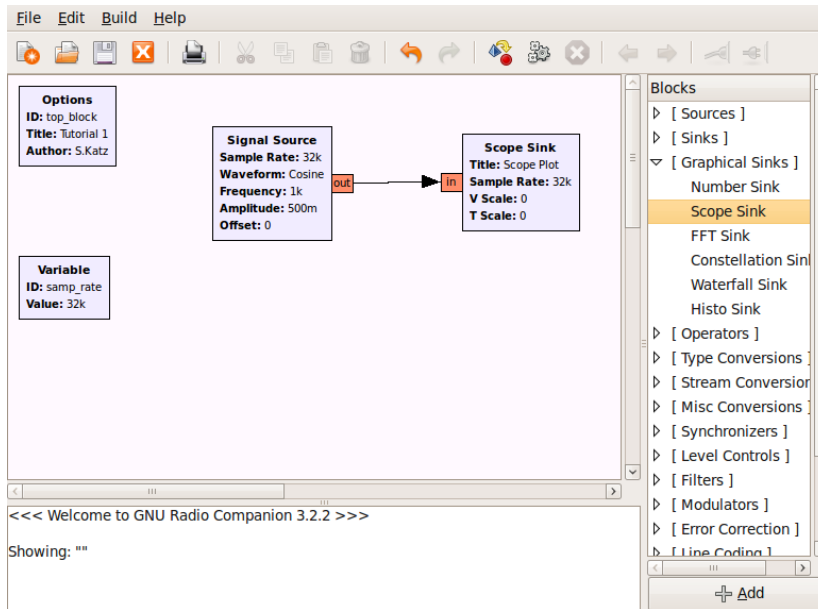


The screenshot shows the 'Parameters' window for a Signal Source block. The window has a title bar and a 'Close' button at the bottom right. The 'Parameters' section includes the following fields:

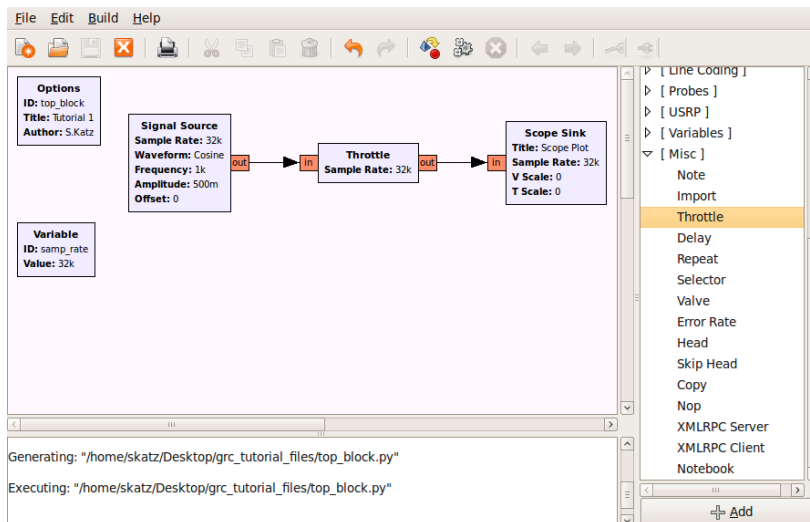
Parameter	Value
ID	gr_sig_source_x_0
Output Type	Float
Sample Rate	samp_rate
Waveform	Cosine
Frequency	1000
Amplitude	.5
Offset	0

Below the parameters is an 'Error Messages' section with the text: '>>> Source - out(0): Port is not connected.' At the bottom is a 'Documentation' section.

5. In order to view this wave we need one of the graphical sinks. Expand the Graphical Sink category and double click on the Scope Sink. It should appear in the main window. Double click on the block and change the Type to Float. Leave the other Parameters at their default values and close the properties window.
6. In order to connect these two blocks, click once on the “out” port of the Signal Source, and then once on the “in” port of the Scope Sink. The following flow graph should be displayed.



7. You may have noticed a warning in the message window indicating that the flow graph may not have flow control. Add a Throttle block between the source and the sink as shown in the figure below. Make sure to change the Throttle Type to Float. Note that before you do that, the Generate flow graph icon cannot be selected. This is because there is an error in the flow graph. Generate and execute the flow graph to confirm that it still works.

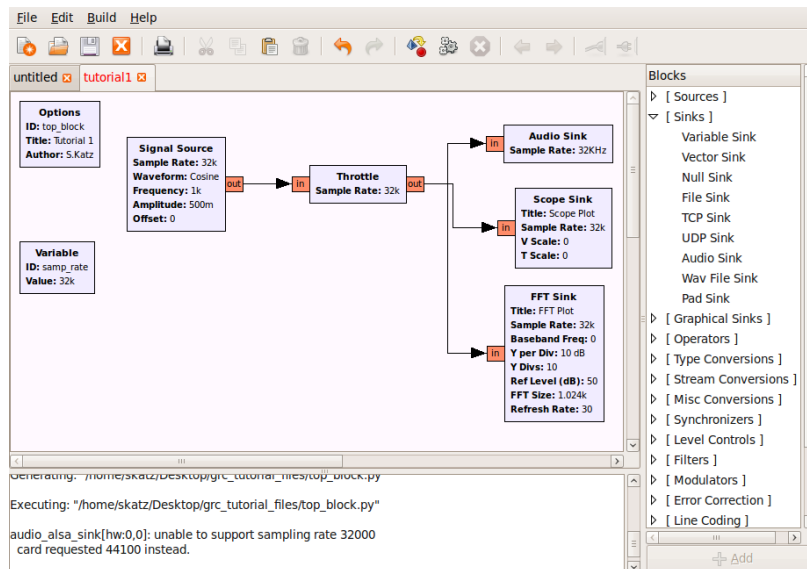


8. In order to observe the operation of this simple system we must generate the flow graph and then execute it. Click first on the “Generate the flow graph” icon. A box will come up in which you enter the name of the file. Name this file: tutorial1.grc and save.

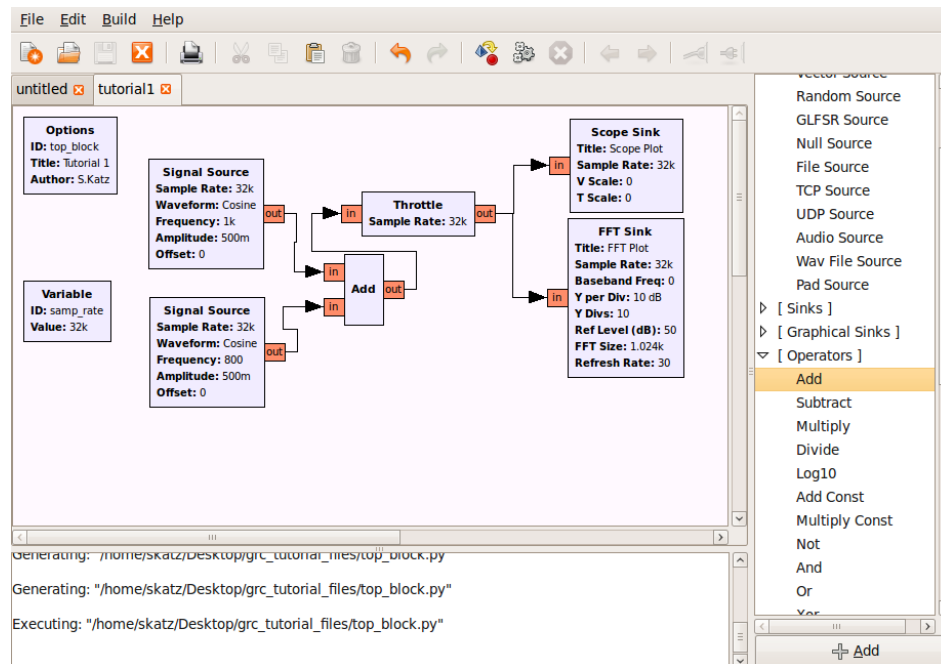
9. Click the “Execute the flow graph” icon. A scope plot should open displaying several cycles of the sinusoid. Confirm that the frequency and amplitude match the value that you expect. Experiment with the controls on the scope plot.
10. Change the Channel Options, Marker setting to Dot Large. Now you can see the actual sample values. Recall that the Variable block set the sampling rate to 32000 samples/second or 32 samples/ms. Note that there are in fact 32 samples within one cycle of the wave.
11. Close the Scope Plot and reduce the sample rate to 10000 by double clicking on the Variable block. Re-generate and execute the flow graph. Note that there are now fewer points per cycle. How low can you drop the sample rate? Recall that the Nyquist sampling theorem requires that we sample at more than two times the highest frequency. Experiment with this and see how the output changes as you drop below the Nyquist rate.
12. Close the Scope Plot and change the sample rate back to 32000. Add an FFT Sink (under Graphical Sinks) to your window. Change the Type to Float and leave the remaining parameters at their default values.
13. Connect this to the output of the Signal Source by clicking on the out port of the Signal Source and then the in port of the FFT Sink. Generate and execute the flow graph. You should observe the scope as before along with an FFT plot correctly showing the frequency of the input at 1KHz. Close the output windows.
14. Explore the other Graphical Sinks (Number Sink, Waterfall Sink, and Histo Sink) to see how they display the Signal Source.
15. Create the flow graph shown below. The Audio Sink is found in the Sinks category. Generate and execute the flow graph. The graphical display of the scope and FFT should open as before. However, now you should also hear the 1KHz tone. The Audio Sink block

directs the signal to the audio card of your computer. Depending on the sampling rate of the audio card in your computer, you may get an error message in the GRC message window:
`Audio_alsa_sink[hw:0,0]: unable to support sampling rate 32000, card requested 44100 instead.`

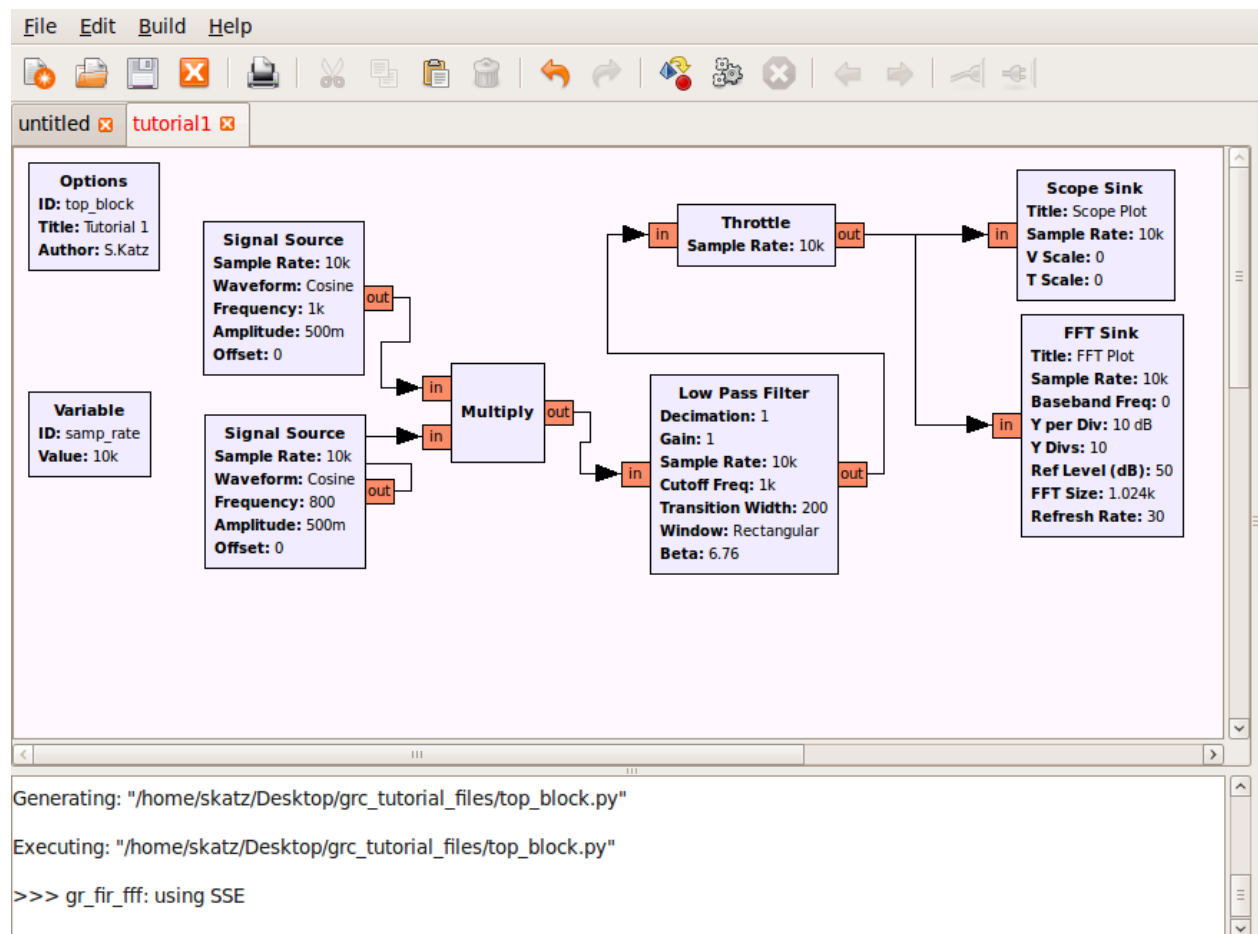
If you do see a message similar to this, stop the execution and double click on the variable block to change the sample rate to 44100 (or whatever your error message indicates). Generate and execute the flow graph again and the error message should be gone.



- Construct the flow graph shown below. Set the sample rate to 32000. The two Signal Sources should have frequencies of 1000 and 800, respectively. The Add block is found in the Operators category.



17. Generate and execute the flow graph. On the Scope plot you should observe a waveform corresponding to the sum of two sinusoids. On the FFT plot you should see components at both 800 and 1000 Hz. Unfortunately, the FFT plot does not provide enough resolution to clearly see the two distinct components. Note that the maximum frequency displayed on this plot is 16KHz. This is one-half of the 32KHz sample rate. In order to obtain better resolution, we can lower the sample rate. Try lowering the sample rate to 10KHz.
18. Replace the Add block with a Multiply block. What output do you expect from the product of two sinusoids? Confirm your result on the Scope and FFT displays.
19. Modify the flow graph to include a Low Pass Filter block as shown in the figure below. This block is found in the Filters category and is the first Low Pass Filter listed. Recall that the Multiply block outputs a 200Hz and a 1.8KHz sinusoid. We want to create a filter that will pass the 200Hz and block the 1.8KHz component. Set the low pass filter to have a cutoff frequency of 1KHz and a transition width of 200 Hz. Use a Rectangular Window. Generate and execute the flow graph. You should observe that only the 200Hz component passes through the filter. Experiment with the High Pass Filter.



20. Using the same flow graph, change the sample rate variable to 20000. Change the Decimation in the Low Pass Filter to 2. Decimation decreases the number of samples that are processed. A decimation factor of two means that the output of the filter will have a sample rate equal to one-half of the input sample rate, or in this case only 10000 samples/sec. This is a sufficient sample rate for the frequencies that we are dealing with. Generate and execute the flow graph. What frequency do you observe on the FFT? Measure it precisely by letting the cursor hover over the peak of the observed component.
21. You should have observed that the FFT is now measuring a signal around 400 Hz, rather than the expected 200Hz. Why is this error occurring? It is because the sample rate on the FFT has not been adjusted to properly measure its input. Double click on the FFT Sink block and change the sample rate to $\text{samp_rate}/2$. Generate and execute the flow graph. You should now read the correct frequency.

22. Open a file browser in Ubuntu (Places ➔ Home Folder). Go to the directory that contains the GRC file that you have been working on. If you are unsure as to where this is, the path to this file is shown in the bottom portion of the GRC window. In addition to saving a “.grc” file with your flow graph, note that there is also a file titled “top_block.py”. Double click on this block. You will be given the option to Run or Display this file. Select Display. This is the Python file that is generated by GRC. It is this file that is being run when you execute the flow graph. You can modify this file and run it from the terminal window. This allows you to use features that are not included in GRC. Keep in mind that every time you run your flow graph in GRC, it will overwrite the Python script that is generated. So, if you make changes directly in the Python script that you want to keep, save it under another name.