GNU Radio Tutorials

Labs 1 – 5

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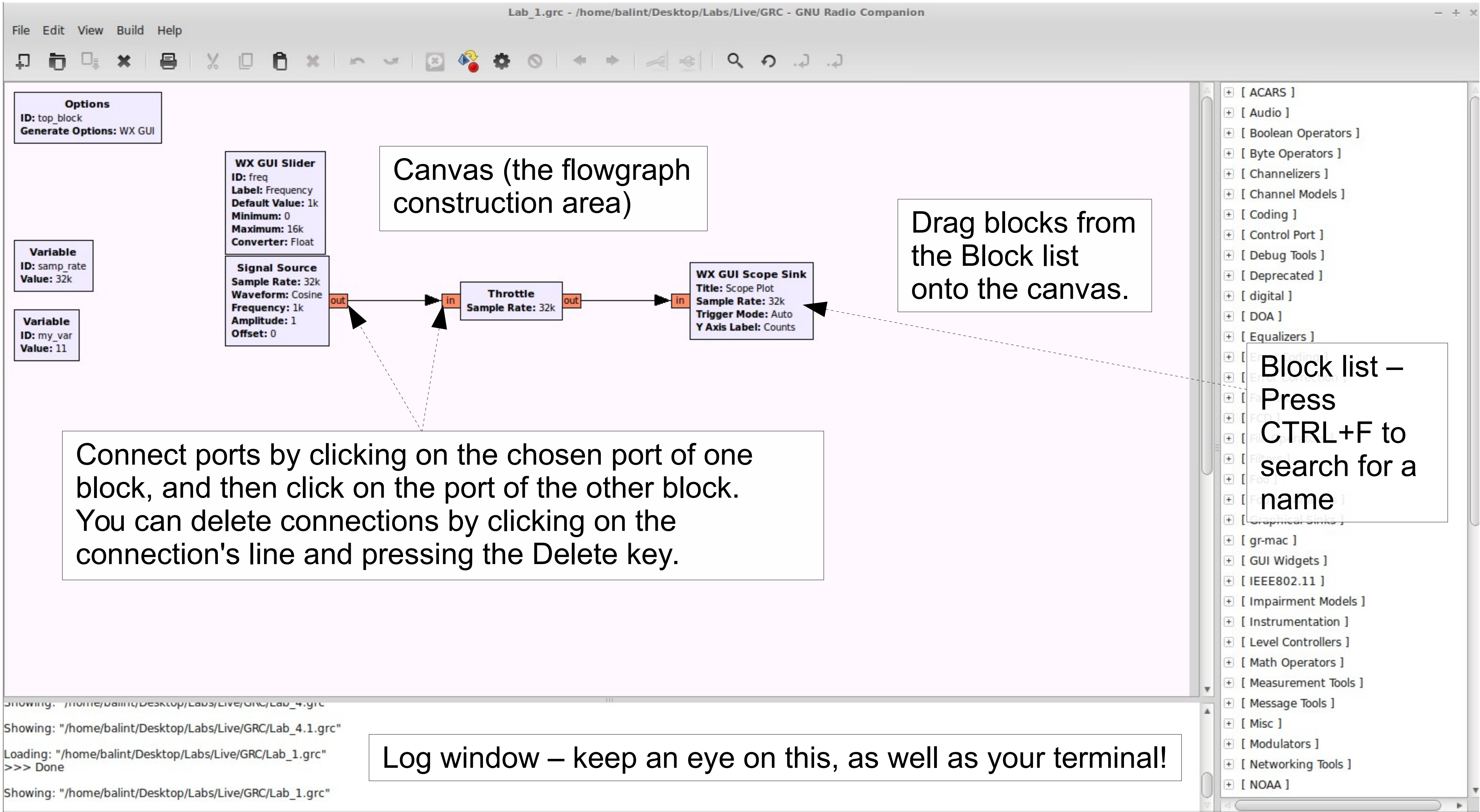
Lab 1

- Open GNU Radio Companion:
  - Open a Terminal/Console/Command Prompt
  - Run 'gnuradio-companion'

Lab 1


Lab_1.grc - /home/balint/Desktop/Labs/Live/GRC - GNU Radio Companion
File
Edit
View
Build
Help
[ACARS]
[Audio]
[Boolean Operators]
[Byte Operators]
[Channelizers]
[Channel Models]
[Coding]
[Control Port]
[Debug Tools]
[Deprecated]
[digital]
[DOA]
[Equalizers]
[gr-mac]
[GUI Widgets]
[IEEE802.11]
[Impairment Models]
[Instrumentation]
[Level Controllers]
[Math Operators]
[Measurement Tools]
[Message Tools]
[Misc]
[Modulators]
[Networking Tools]
[NOAA]
out
in
out
in

Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Canvas (the flowgraph construction area)

Drag blocks from the Block list onto the canvas.

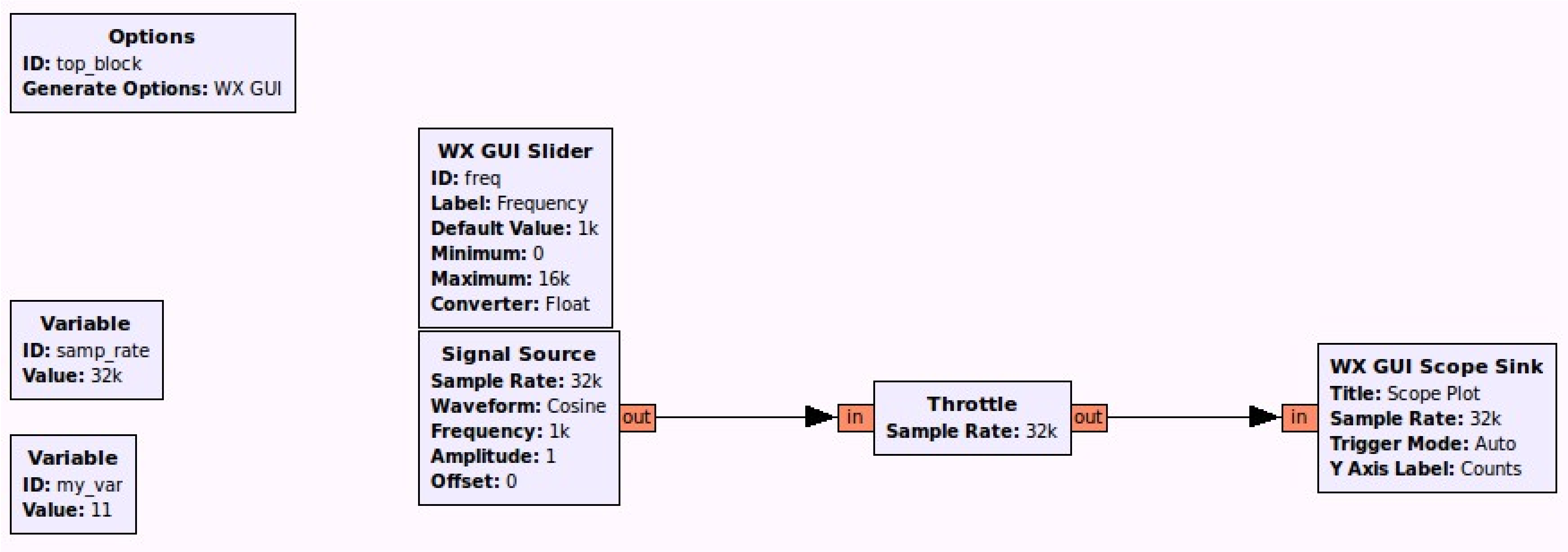
Block list – Press CTRL+F to search for a name

Connect ports by clicking on the chosen port of one block, and then click on the port of the other block. You can delete connections by clicking on the connection's line and pressing the Delete key.

```
Showing: "/home/balint/Desktop/Labs/Live/GRC/Lab_4.grc"

Showing: "/home/balint/Desktop/Labs/Live/GRC/Lab_4.1.grc"

Loading: "/home/balint/Desktop/Labs/Live/GRC/Lab_1.grc"
>>> Done

Showing: "/home/balint/Desktop/Labs/Live/GRC/Lab_1.grc"
```

Log window – keep an eye on this, as well as your terminal!

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

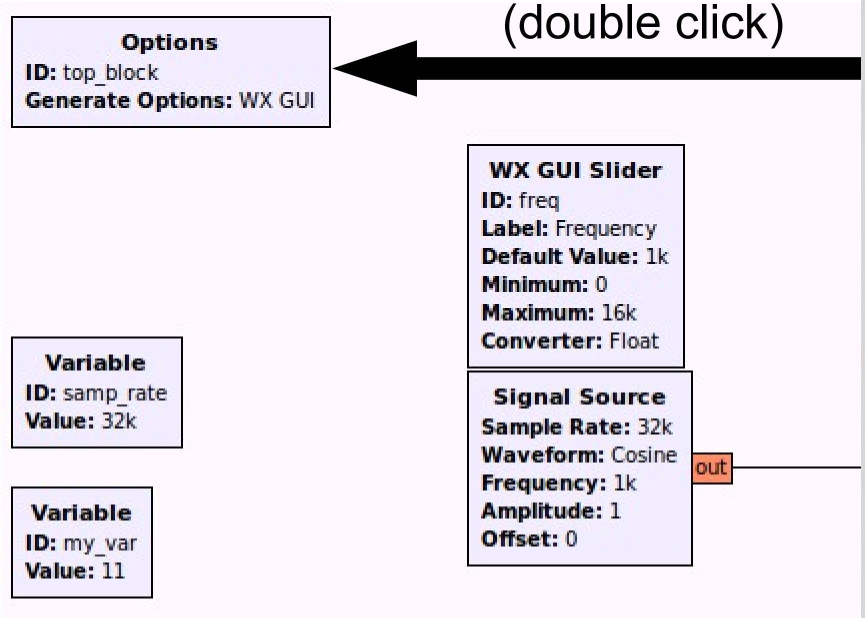
Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Create a sine wave & inspect the generated samples with a (time-domain) Scope Sink

Lab 1



Options
ID: top_block
Generate Options: WX GUI

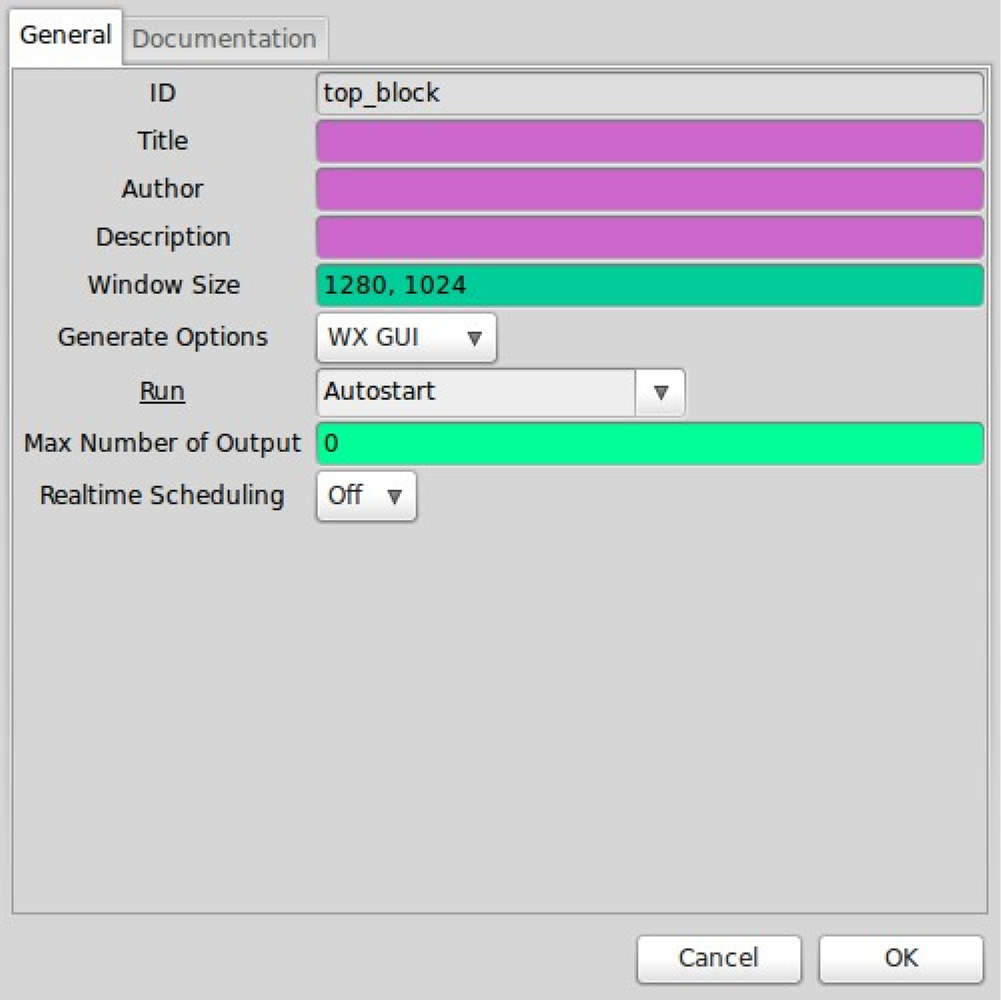
WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Variable
ID: my_var
Value: 11

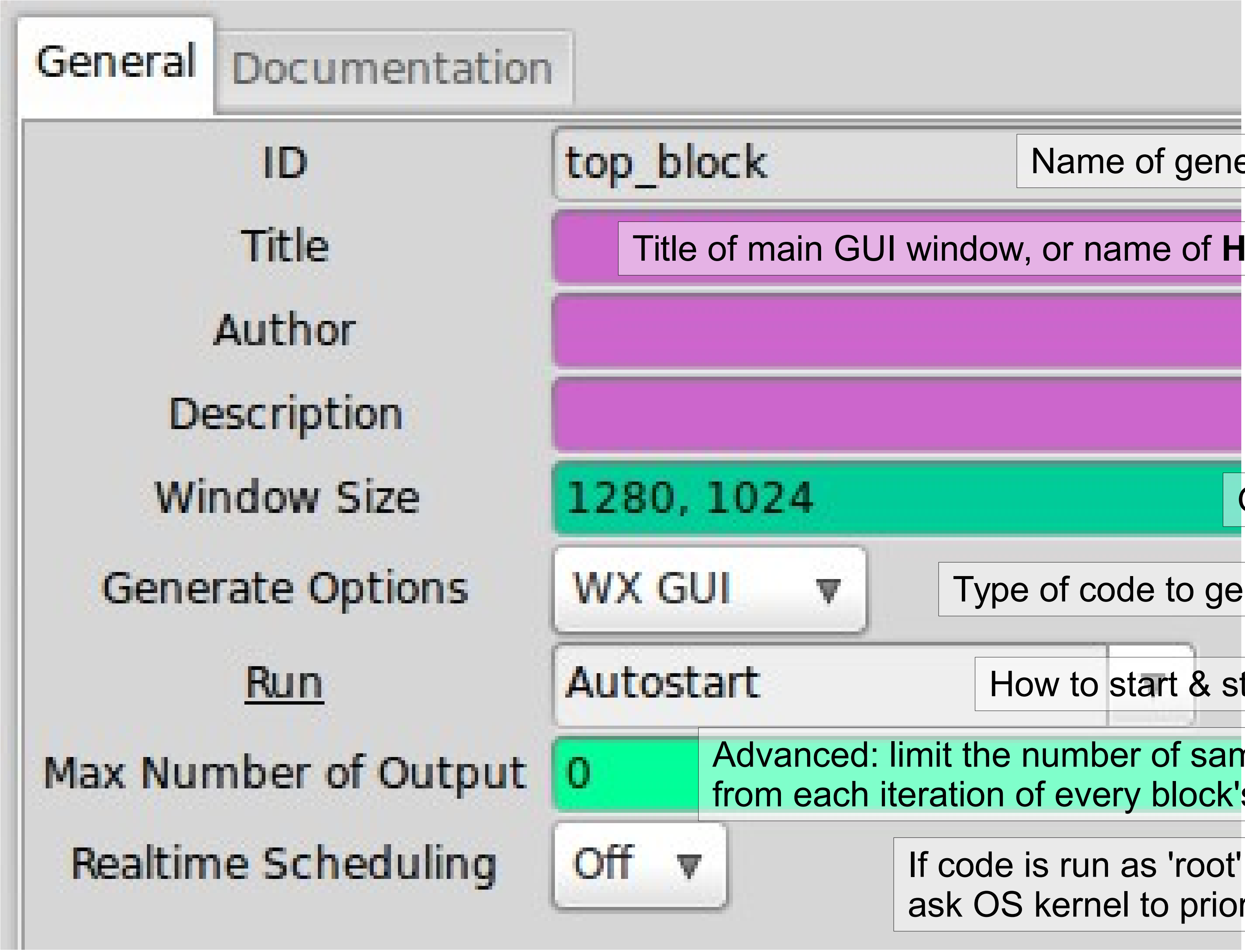
(double click)



ID: top_block
Title:
Author:
Description:
Window Size: 1280, 1024
Generate Options: WX GUI
Run: Autostart
Max Number of Output: 0
Realtime Scheduling: Off

'Options' block is used to set global parameters

Lab 1



General | Documentation

ID: top_block

Title:

Author:

Description:

Window Size: 1280, 1024

Generate Options: WX GUI

Run: Autostart

Max Number of Output: 0

Realtime Scheduling: Off

Name of generated Python file

Title of main GUI window, or name of **Hier**archical block

GRC canvas size

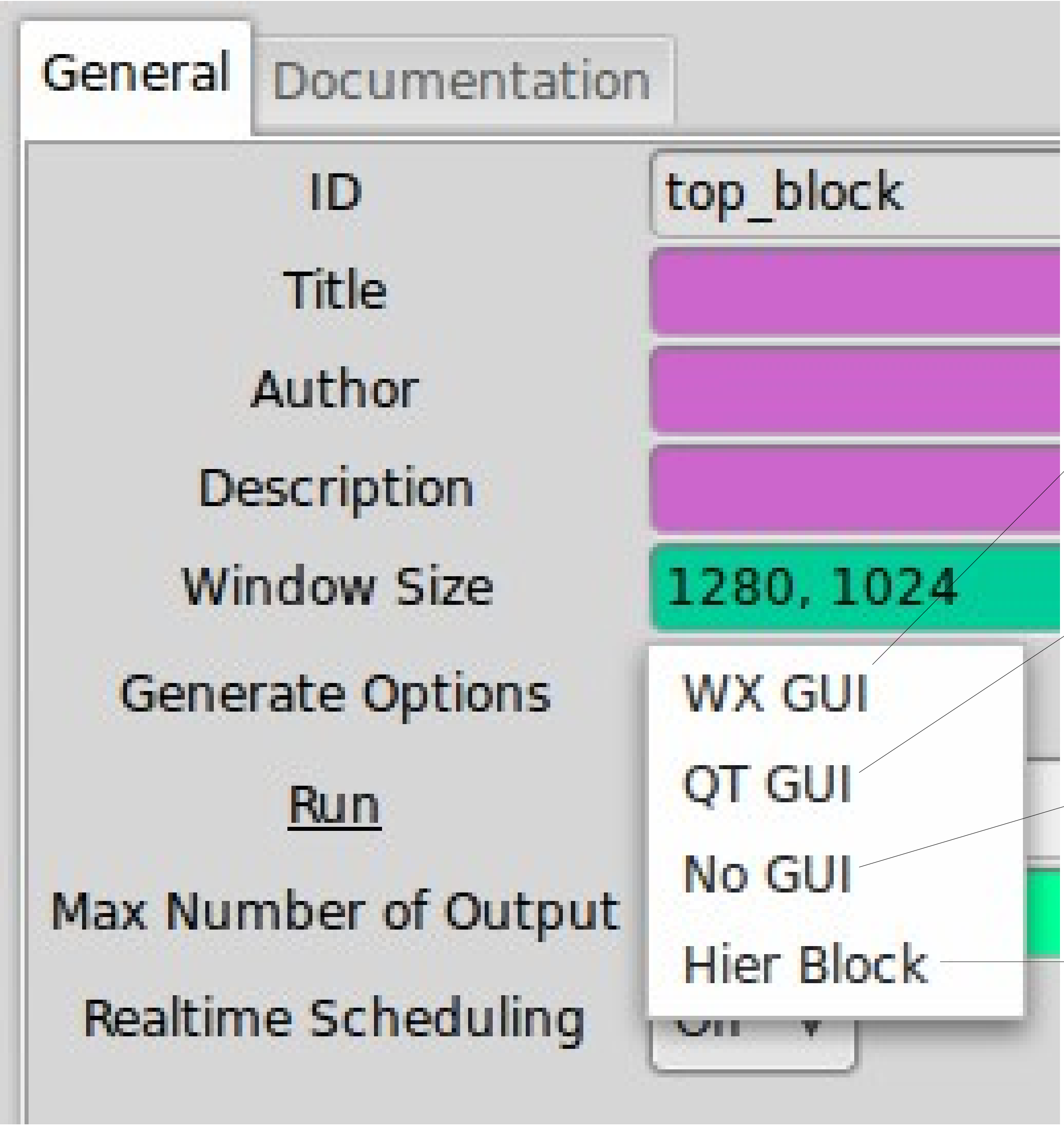
Type of code to generate (see next)

How to start & stop the flowgraph

Advanced: limit the number of samples output from each iteration of every block's work function

If code is run as 'root' (e.g. with 'sudo') ask OS kernel to prioritise this process

Lab 1


General
Documentation

ID: top_block
Title:
Author:
Description:
Window Size: 1280, 1024
Generate Options:
Run
Max Number of Output
Realtime Scheduling

WX GUI
QT GUI
No GUI
Hier Block

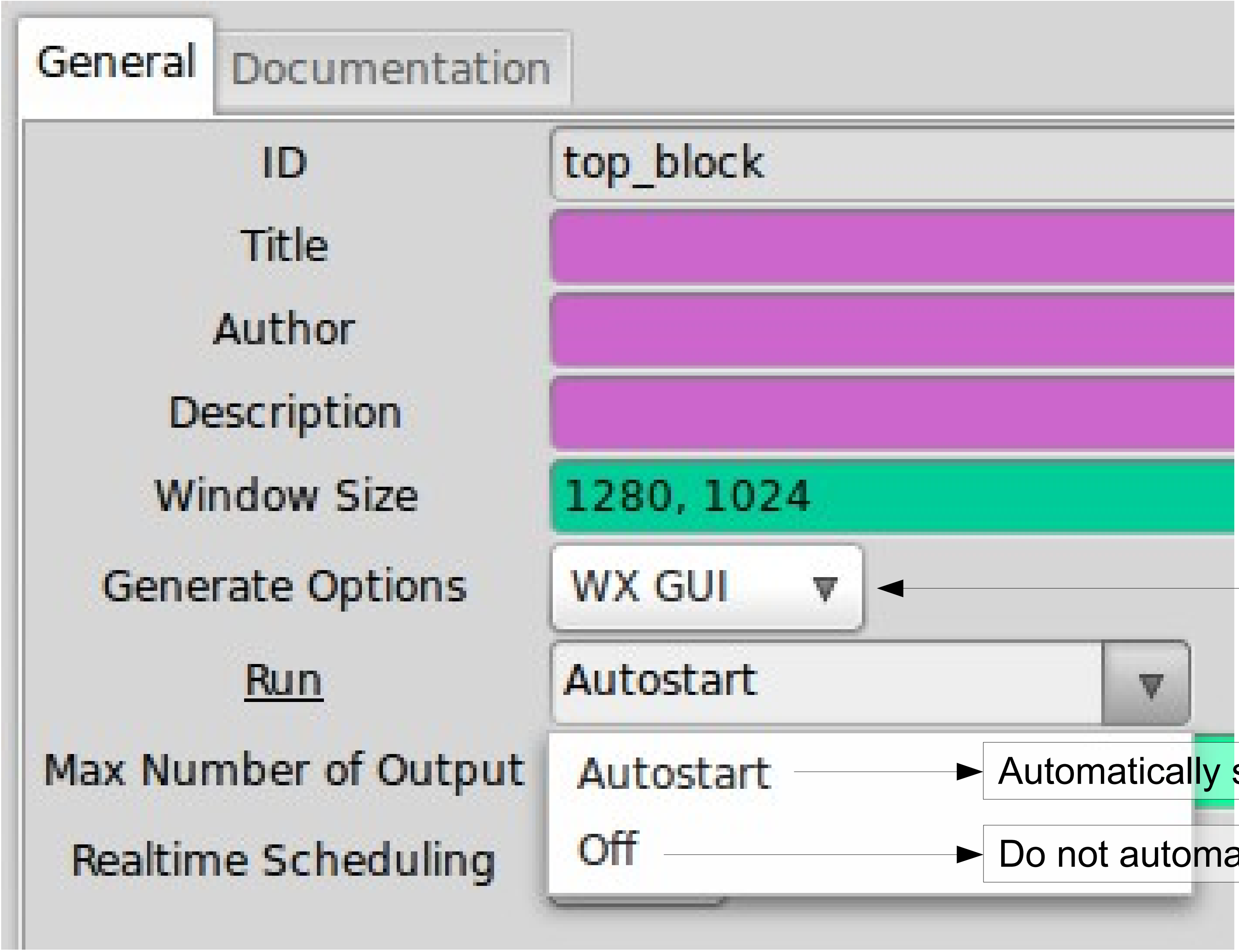
GUI app using WX toolkit
(use WX GUI blocks)

GUI app using Qt toolkit
(use Qt GUI blocks)

Command-line app without GUI
(text-based, run in a console)

Create a **Hier**archical block
that will appear in the block list
(a reusable component, not an app
– use Pad Source/Sink blocks to
expose ports, and Parameter blocks
to expose configuration variables)

Lab 1



ID: top_block

Title

Author

Description

Window Size: 1280, 1024

Generate Options: WX GUI

Run: Autostart

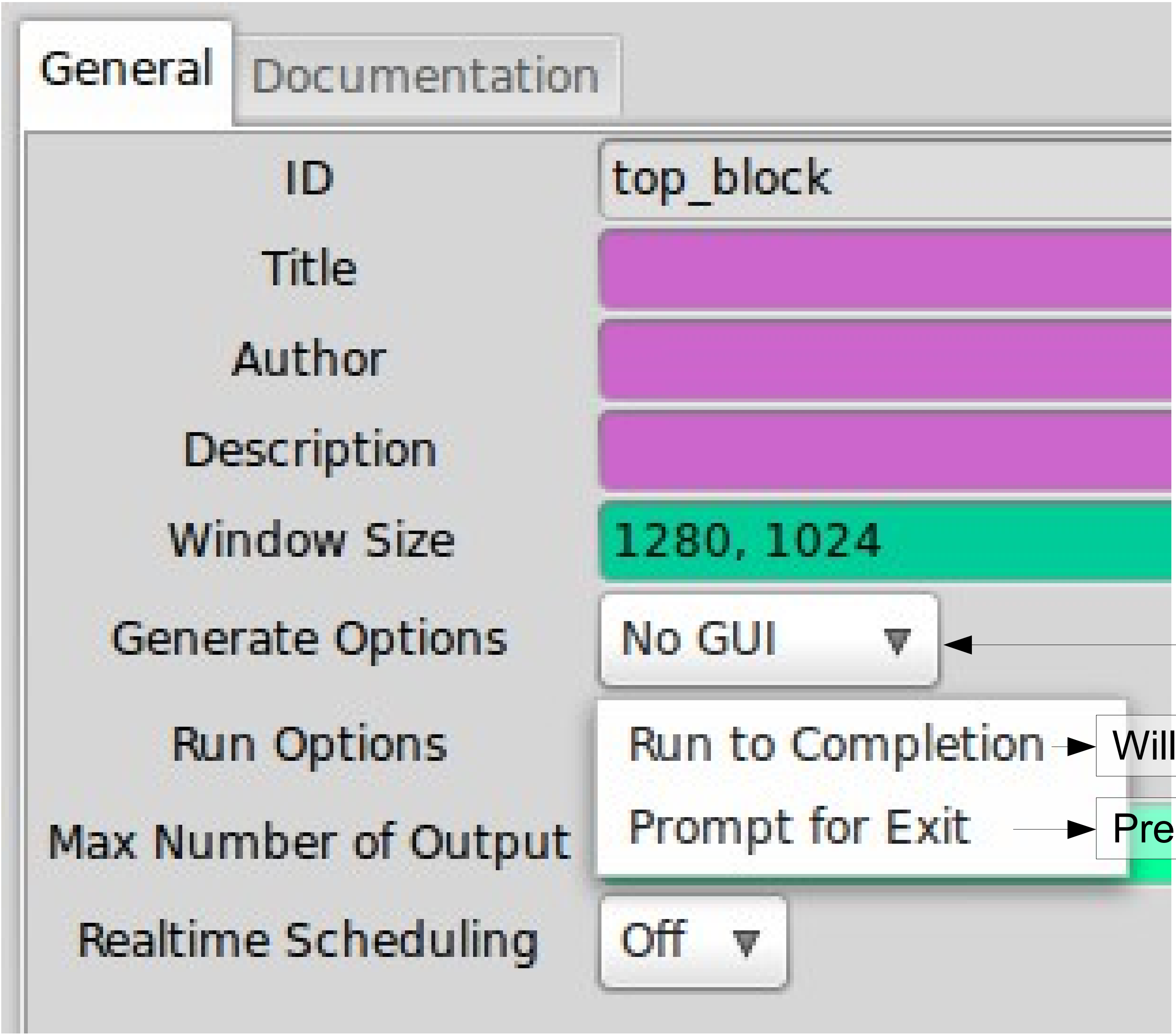
Max Number of Output

Realtime Scheduling

Autostart → Automatically start flowgraph

Off → Do not automatically start flowgraph

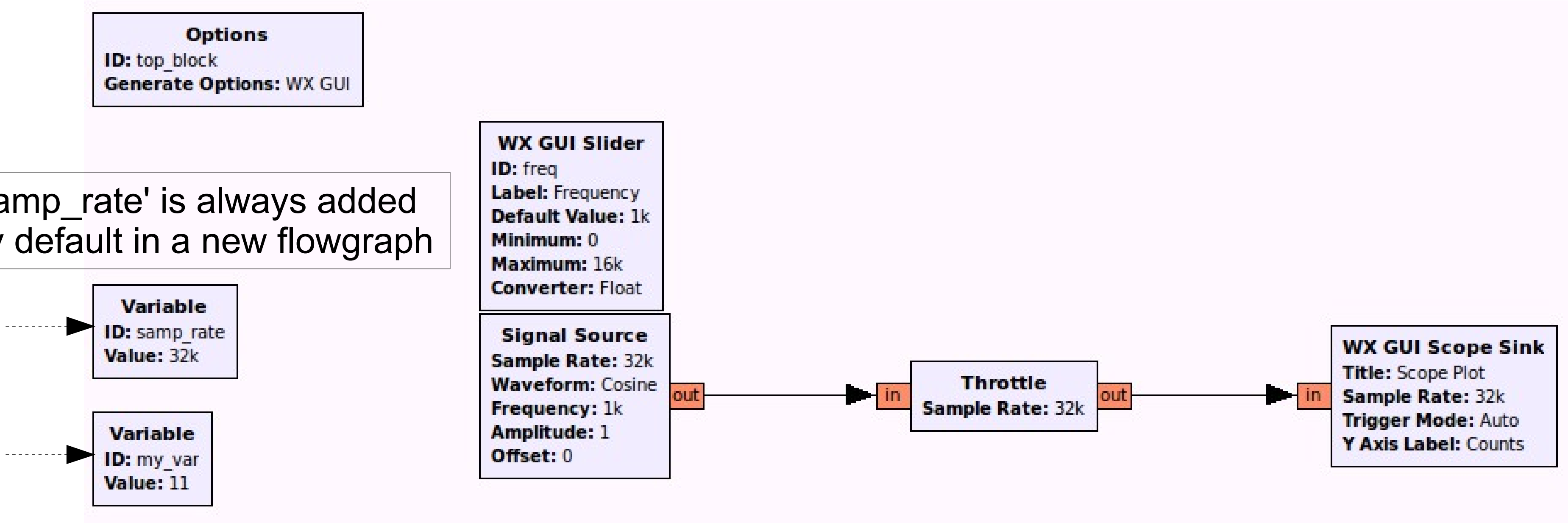
Lab 1



ID: top_block
Title:
Author:
Description:
Window Size: 1280, 1024
Generate Options: No GUI
Run Options:
- Run to Completion → Will automatically exit if/when done
- Prompt for Exit → Pressing ENTER will exit

Max Number of Output
Realtime Scheduling: Off

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

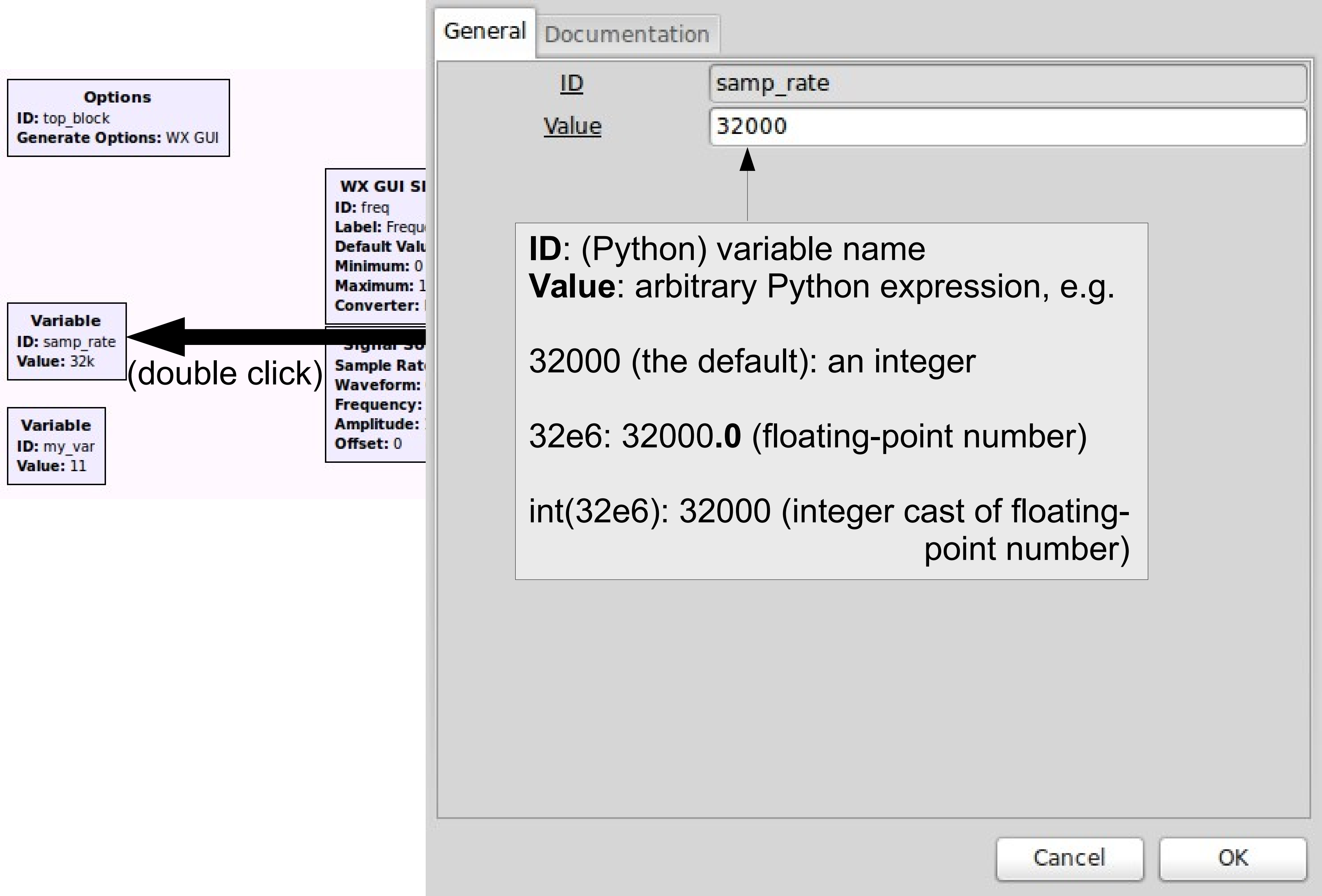
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

'samp_rate' is always added by default in a new flowgraph

Variable: a block that contains an arbitrary Python expression.

You can refer to it in another block by its **ID**.

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Sl
ID: freq
Label: Frequ
Default Valu
Minimum: 0
Maximum: 1
Converter:

Sample Rat
Waveform:
Frequency:
Amplitude:
Offset: 0

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

(double click)

ID: samp_rate
Value: 32000

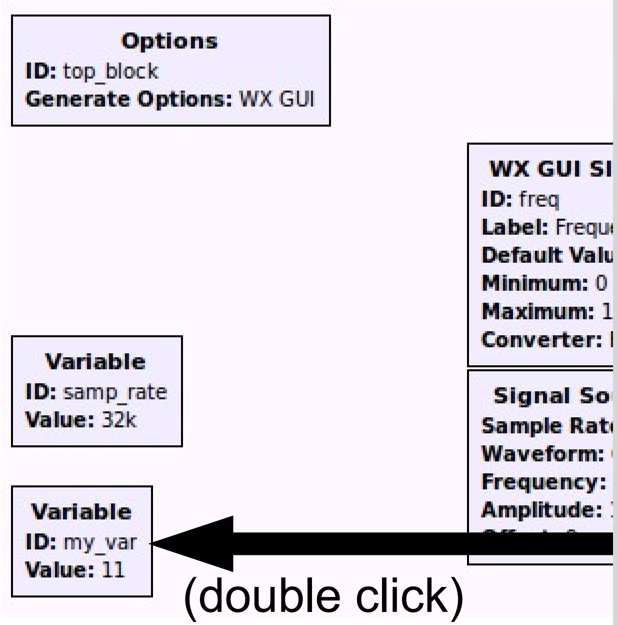
ID: (Python) variable name
Value: arbitrary Python expression, e.g.

32000 (the default): an integer

32e6: 32000**.0** (floating-point number)

int(32e6): 32000 (integer cast of floating-point number)

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Sl
ID: freq
Label: Frequ
Default Valu
Minimum: 0
Maximum: 1
Converter:

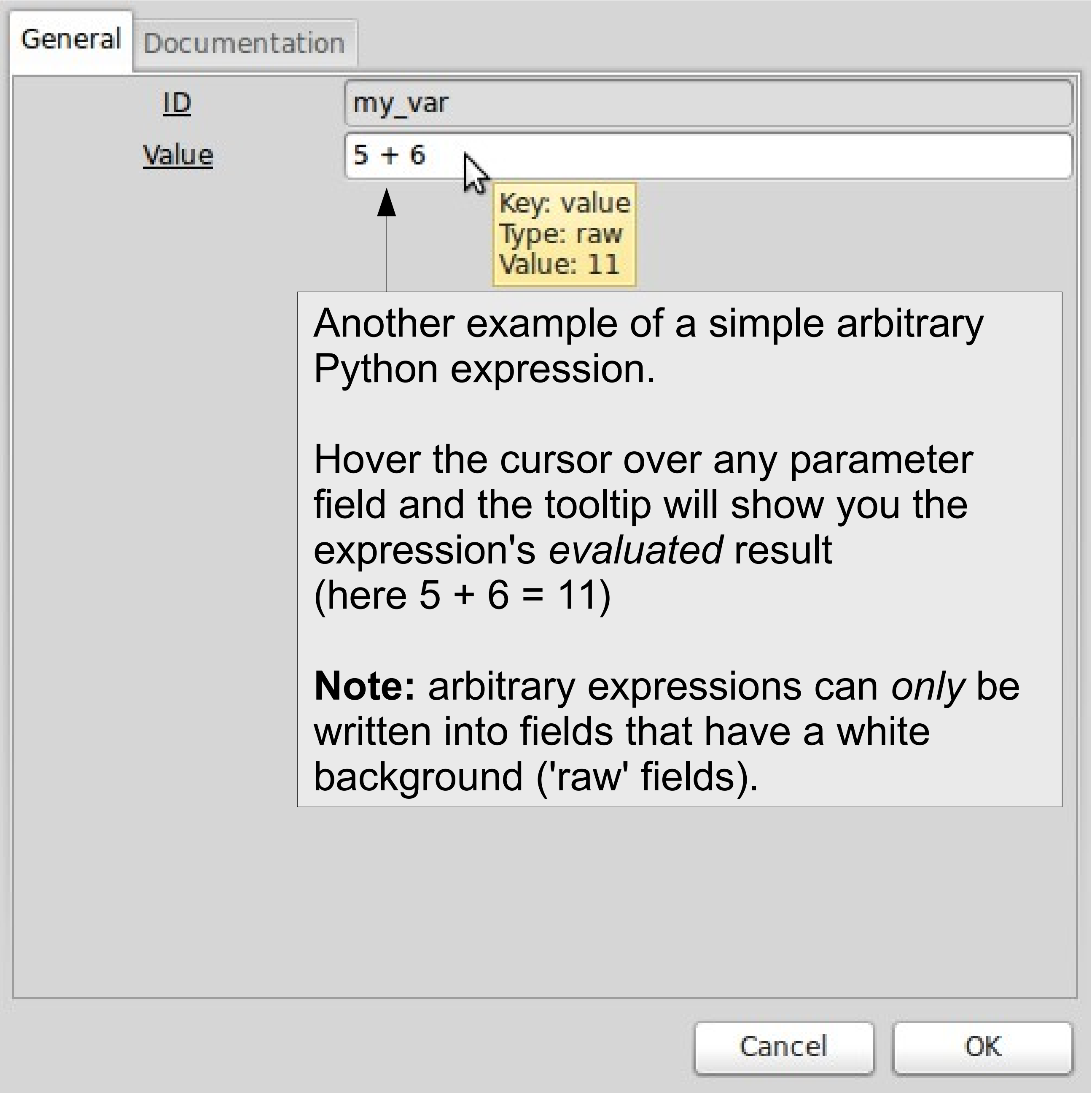
Variable
ID: samp_rate
Value: 32k

Signal So
Sample Rat
Waveform:
Frequency:
Amplitude:

Variable
ID: my_var
Value: 11

(double click)

'my_var' is just for show here (it doesn't actually do anything useful in this flowgraph).



ID: my_var
Value: 5 + 6

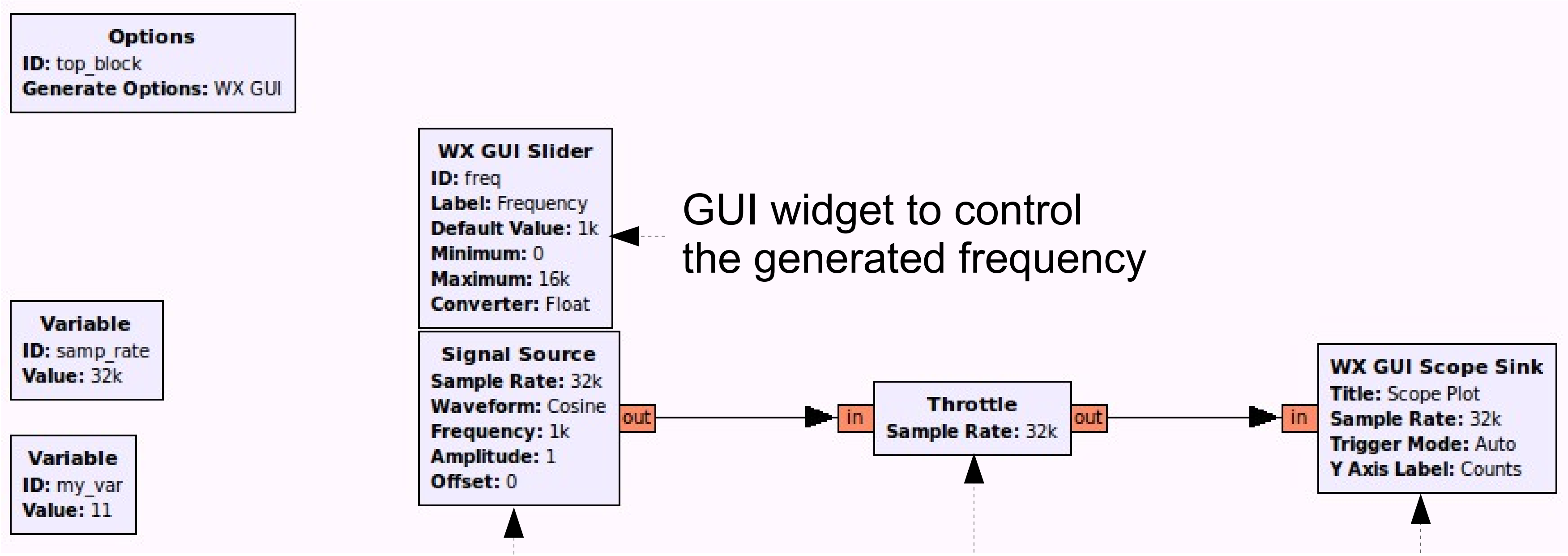
Key: value
Type: raw
Value: 11

Another example of a simple arbitrary Python expression.

Hover the cursor over any parameter field and the tooltip will show you the expression's *evaluated* result (here 5 + 6 = 11)

Note: arbitrary expressions can *only* be written into fields that have a white background ('raw' fields).

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

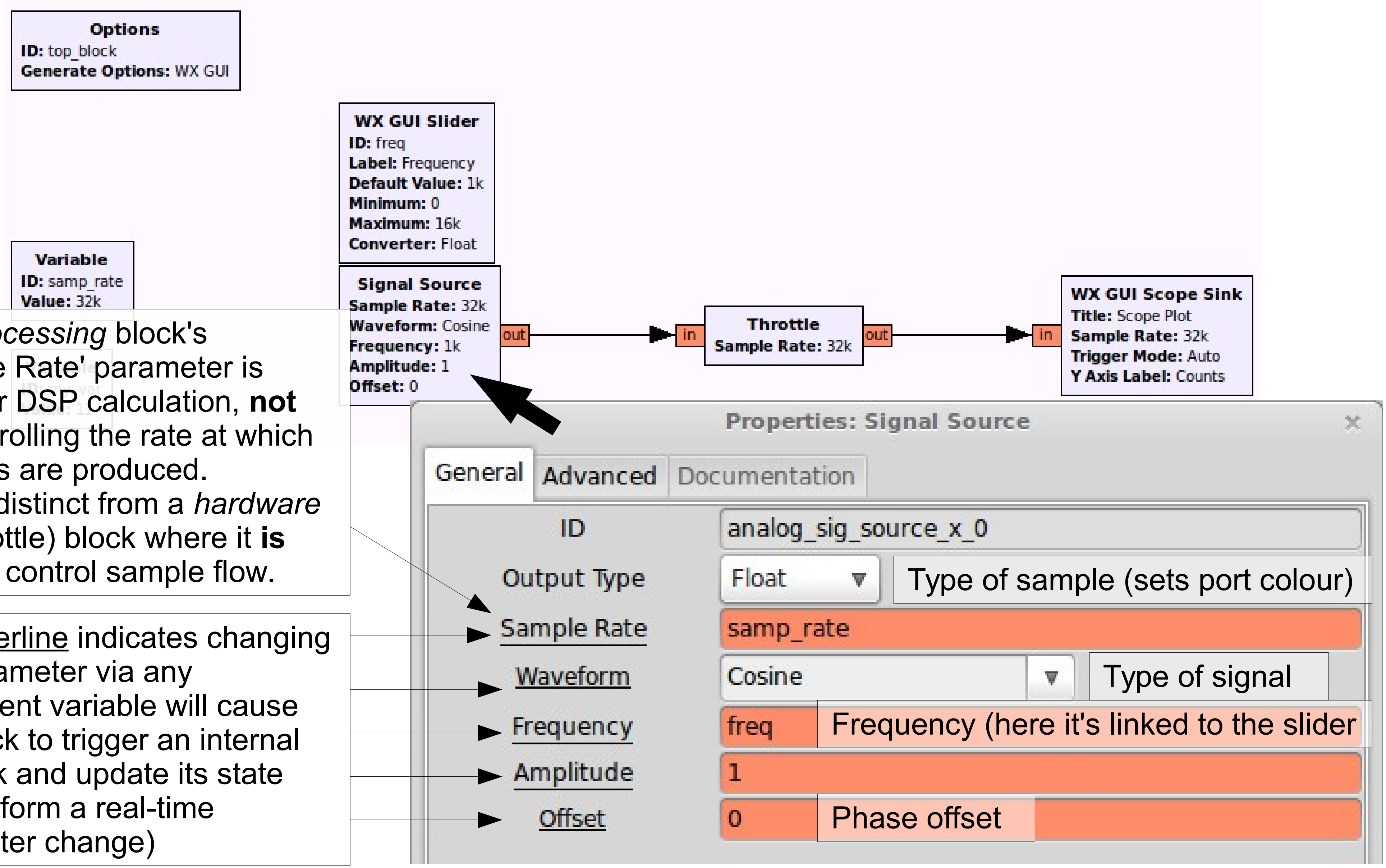
GUI widget to control the generated frequency

Synthesises a sine wave

GUI widget to plot samples in the time-domain

Will throttle the rate at which samples pass through this block (thus setting the rate at which samples pass through the whole flow graph).

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Any *processing* block's 'Sample Rate' parameter is used for DSP calculation, **not** for controlling the rate at which samples are produced.
This is distinct from a *hardware* (or Throttle) block where it **is** used to control sample flow.

Properties: Signal Source

ID: analog_sig_source_x_0
Output Type: Float
Sample Rate: samp_rate
Waveform: Cosine
Frequency: freq
Amplitude: 1
Offset: 0

Type of sample (sets port colour)

Type of signal

Frequency (here it's linked to the slider

Phase offset

An underline indicates changing the parameter via any dependent variable will cause the block to trigger an internal callback and update its state (i.e. perform a real-time parameter change)

Sample Rate (DSP)

- If calculating a sine wave where a given frequency *in Hertz* is desired, you actually need to know the sample rate too. This is because the mathematical representation requires both values to calculate the individual sample amplitude at any specific point in time.
- The actual sample rate value used can be anything. It just so happens you'll usually use the same value as in the rest of your flowgraph so that everything will be consistent (operate in the same sample rate domain).

Sample Rate (DSP)

- Think of it as being used to calculate the discrete step size from one sample to the next within a DSP operation (e.g. the time step when calculating the amplitude of the next sample in the sine wave generator)

Sample Rate (Hardware)

- Distinct from mathematical (DSP) calculation, sample rate also refers to the rate at which samples pass through the flowgraph.
- If there is no rate control, hardware clock or throttling mechanism, the samples will be generated, pass through the flowgraph and be consumed as fast as possible (i.e. the flowgraph will be CPU bound).
- This is desirable if you want to perform some fixed DSP on stored data as quickly as possible (e.g. read from a file, resample and write it back).

Sample Rate (Hardware)

- Only a block that represents some underlying hardware with its own clock (e.g. USRP, sound card), or the Throttle Block, will use 'Sample Rate' to set that hardware clock, and therefore have the effect of applying rate control to the samples in the flowgraph.
- A Throttle Block will simply apply host-based timing (against the 'wall clock') to control the rate of the samples it produces (i.e. samples that it makes available on its outputs to downstream blocks).

Sample Rate (Hardware)

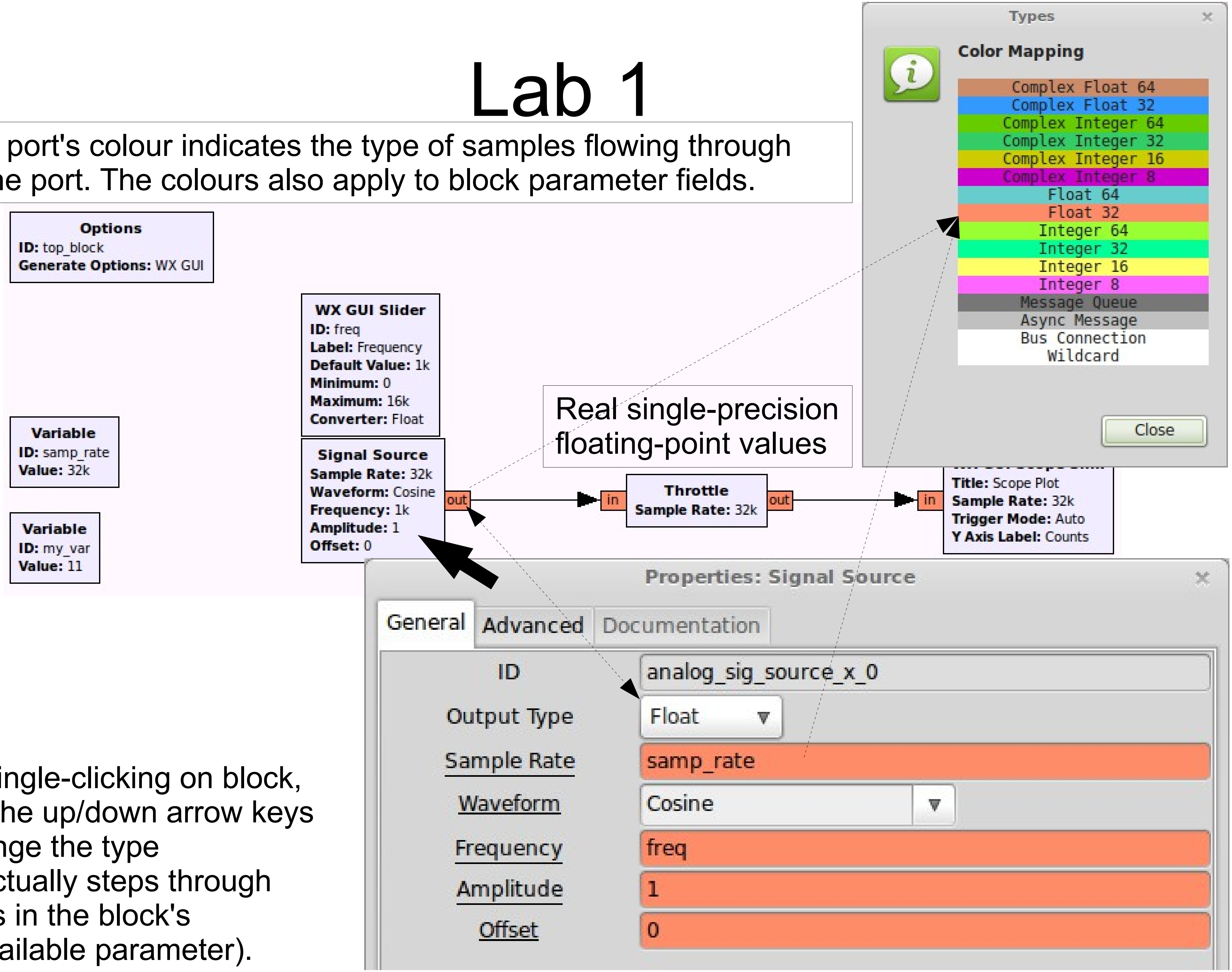
- A hardware Sink block will consume samples at a fixed rate (relative to the wall clock)
- The Throttle Block, or a hardware Sink block, will apply 'back pressure' to the upstream blocks (the rate of work of the upstream blocks will be limited by the throttling effect of this rate-controlling block)
- A hardware Source block will produce samples at a fixed rate (relative to the wall clock)

Sample Rate (Hardware)

- In general, there should only ever be one block in a flowgraph that has the ability to throttle sample flow.
- Otherwise you need to be very careful with multiple, unsynchronised clock sources: they will eventually go out of sync and cause overflows/underruns as their production/consumption rates will differ.
  - This is the 'two clock' problem (discussed later)
  - Work arounds: allow non-blocking I/O, and/or tweak resampling rates to account for the clock offsets

Lab 1

A port's colour indicates the type of samples flowing through the port. The colours also apply to block parameter fields.



Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Real single-precision floating-point values

Types

Color Mapping

Complex Float 64
Complex Float 32
Complex Integer 64
Complex Integer 32
Complex Integer 16
Complex Integer 8
Float 64
Float 32
Integer 64
Integer 32
Integer 16
Integer 8
Message Queue
Async Message
Bus Connection
Wildcard

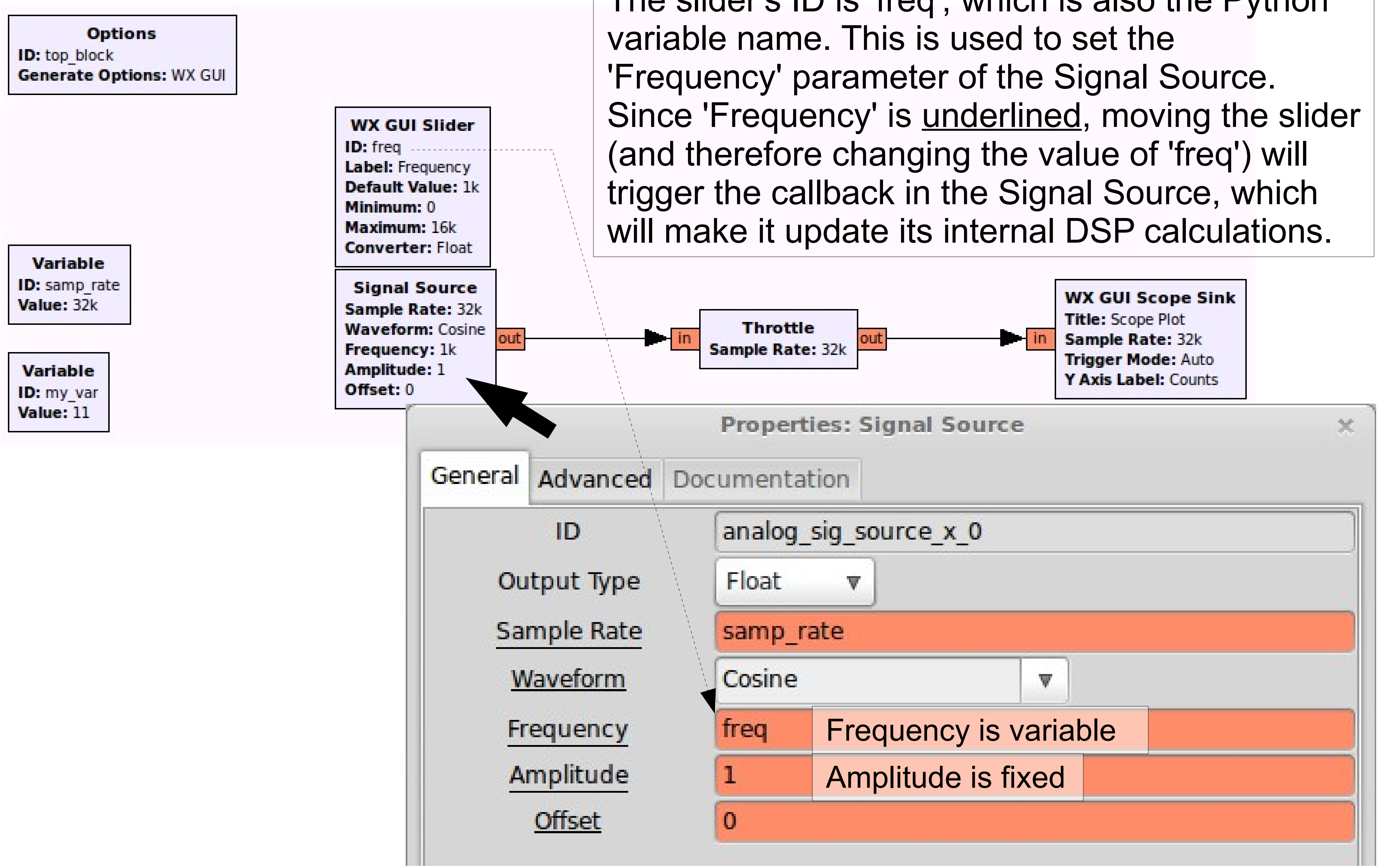
Properties: Signal Source

ID	analog_sig_source_x_0
Output Type	Float
Sample Rate	samp_rate
Waveform	Cosine
Frequency	freq
Amplitude	1
Offset	0

Tip:
After single-clicking on block, press the up/down arrow keys to change the type (this actually steps through options in the block's first available parameter).

Lab 1

The slider's ID is 'freq', which is also the Python variable name. This is used to set the 'Frequency' parameter of the Signal Source. Since 'Frequency' is underlined, moving the slider (and therefore changing the value of 'freq') will trigger the callback in the Signal Source, which will make it update its internal DSP calculations.



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

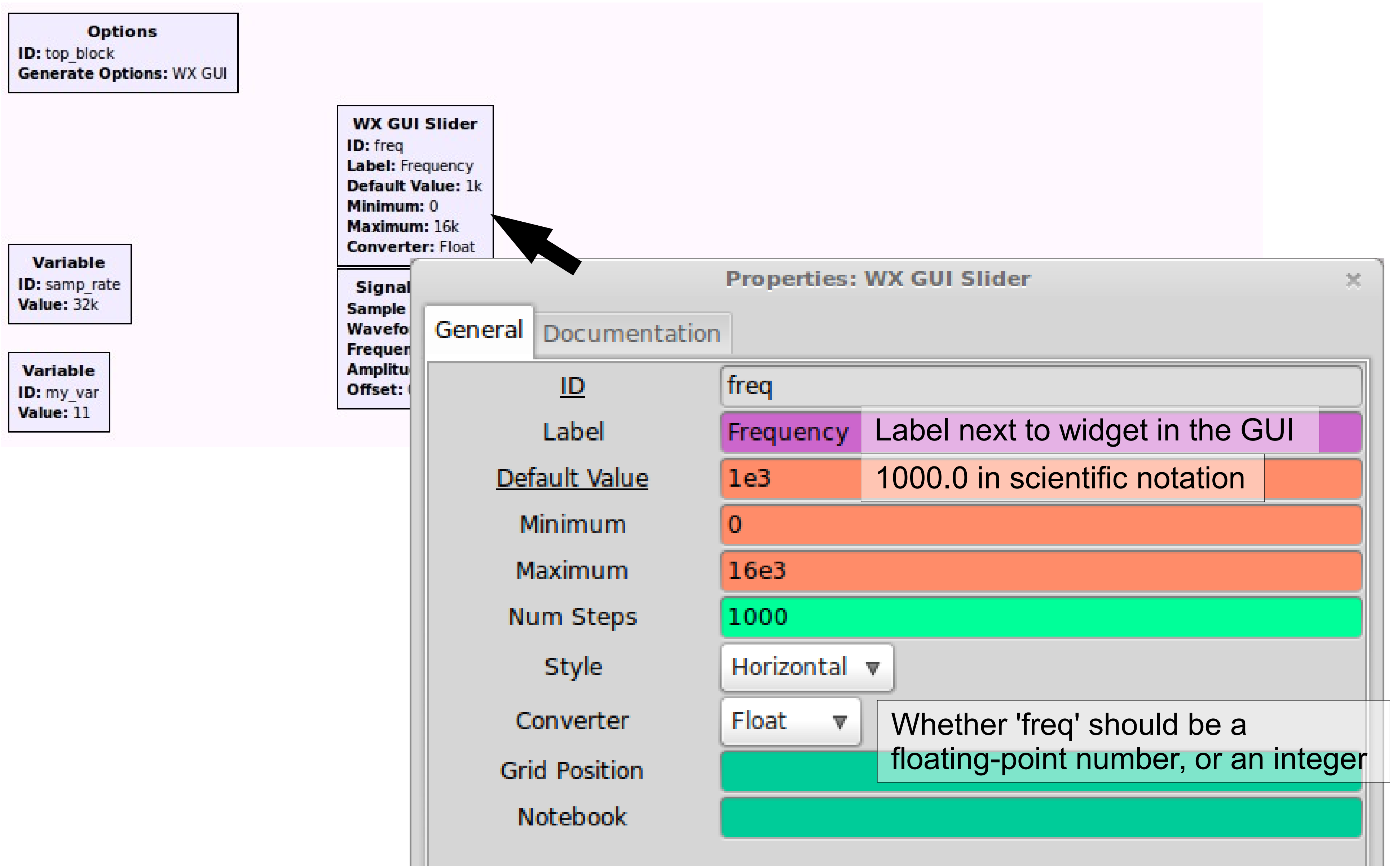
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

ID: analog_sig_source_x_0
Output Type: Float
Sample Rate: samp_rate
Waveform: Cosine
Frequency: freq
Amplitude: 1
Offset: 0

Frequency is variable

Amplitude is fixed

Lab 1



Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

Signal
Sample
Wavefo
Frequen
Amplitu
Offset: (

Properties: WX GUI Slider

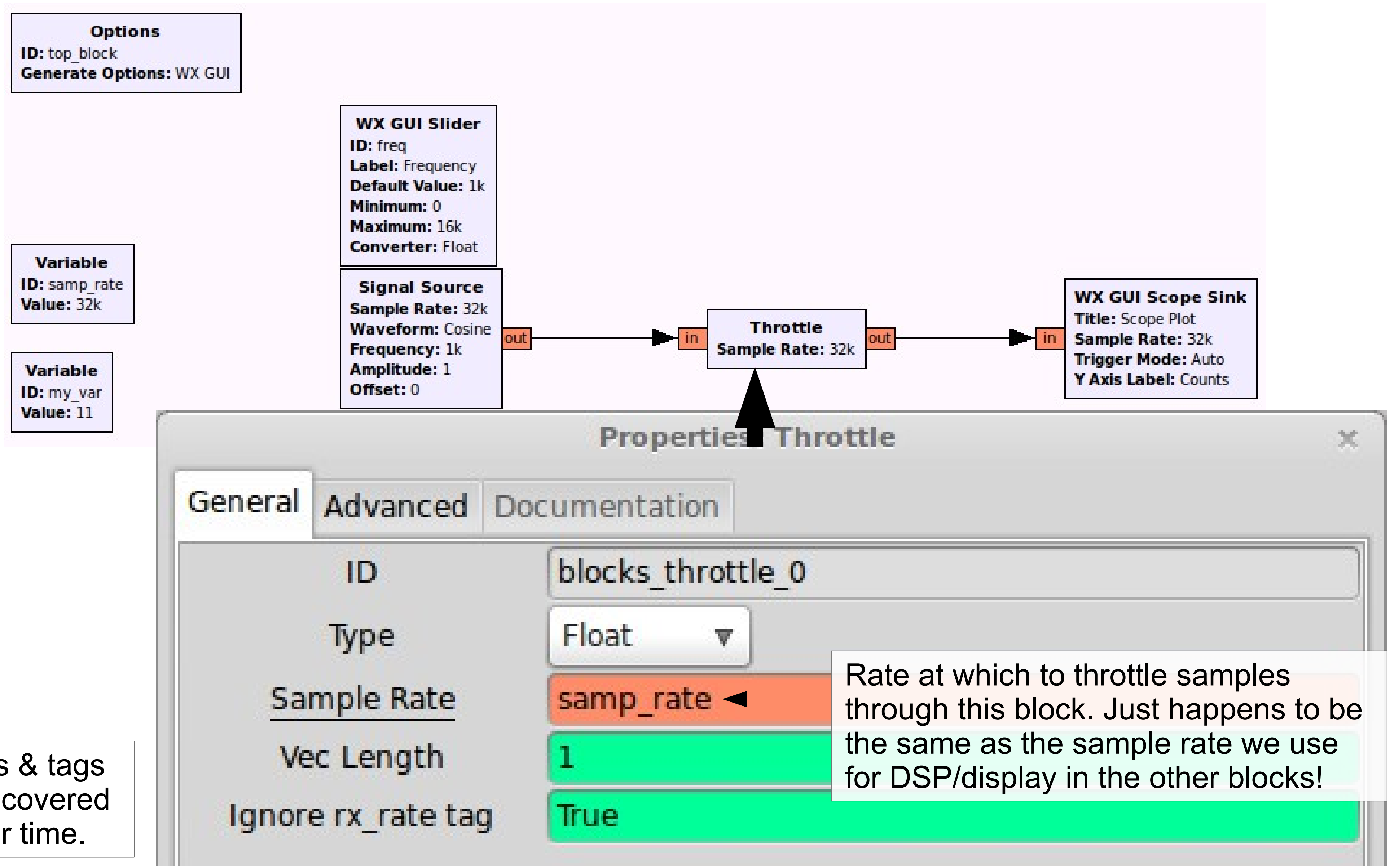
ID	freq
Label	Frequency
Default Value	1e3
Minimum	0
Maximum	16e3
Num Steps	1000
Style	Horizontal
Converter	Float
Grid Position	
Notebook	

Label next to widget in the GUI

1000.0 in scientific notation

Whether 'freq' should be a floating-point number, or an integer

Lab 1



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

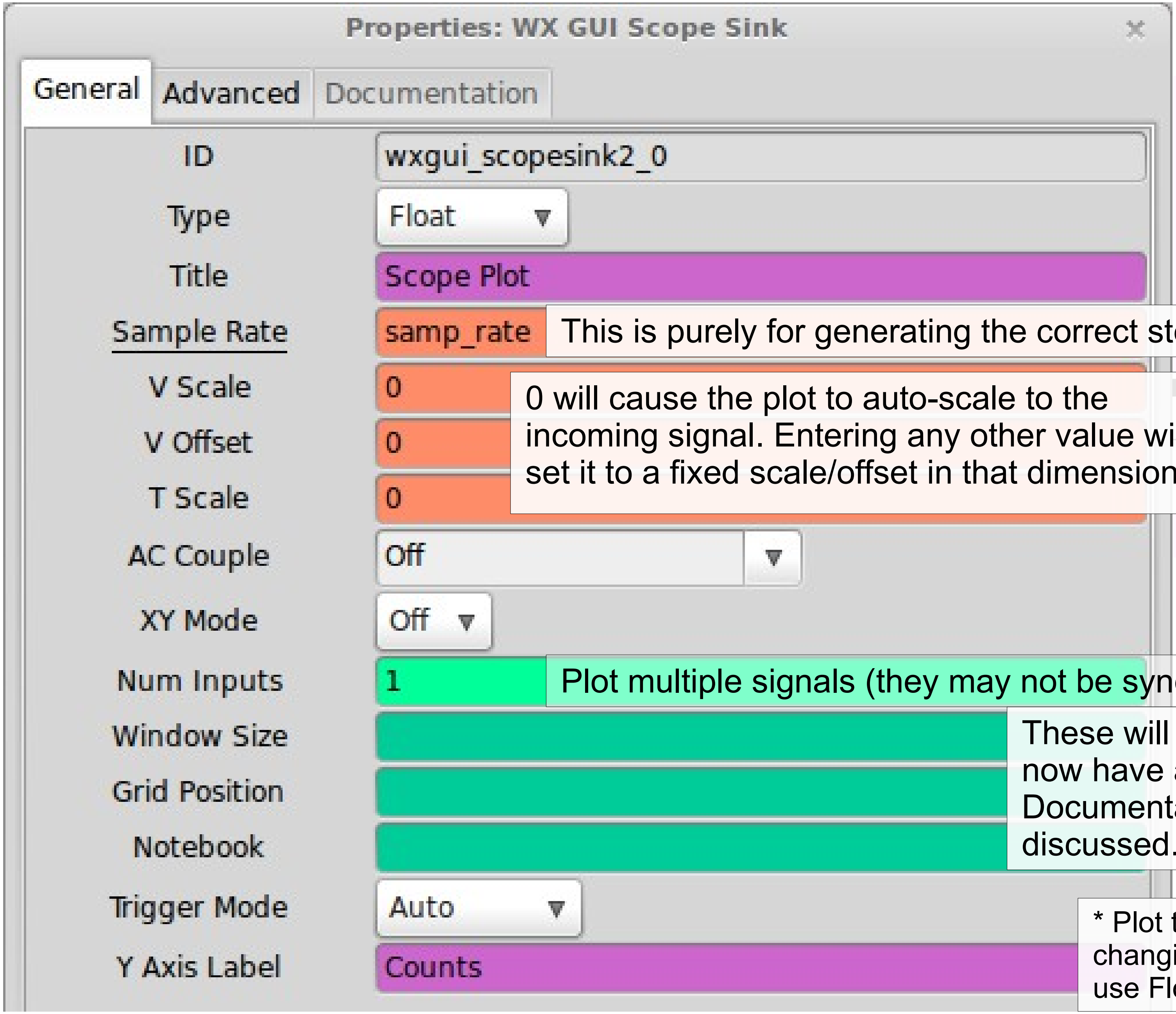
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

ID	blocks_throttle_0
Type	Float
Sample Rate	samp_rate
Vec Length	1
Ignore rx_rate tag	True

Rate at which to throttle samples through this block. Just happens to be the same as the sample rate we use for DSP/display in the other blocks!

Vectors & tags will be covered another time.

Lab 1

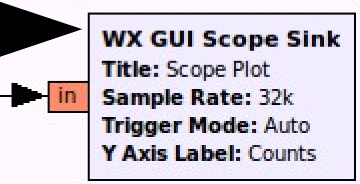


Properties: WX GUI Scope Sink

ID: wxgui_scopesink2_0
Type: Float
Title: Scope Plot
Sample Rate: samp_rate
V Scale: 0
V Offset: 0
T Scale: 0
AC Couple: Off
XY Mode: Off
Num Inputs: 1
Window Size:
Grid Position:
Notebook:
Trigger Mode: Auto
Y Axis Label: Counts

This is purely for generating the correct step sizes on the drawn X-axis!

0 will cause the plot to auto-scale to the incoming signal. Entering any other value will set it to a fixed scale/offset in that dimension.



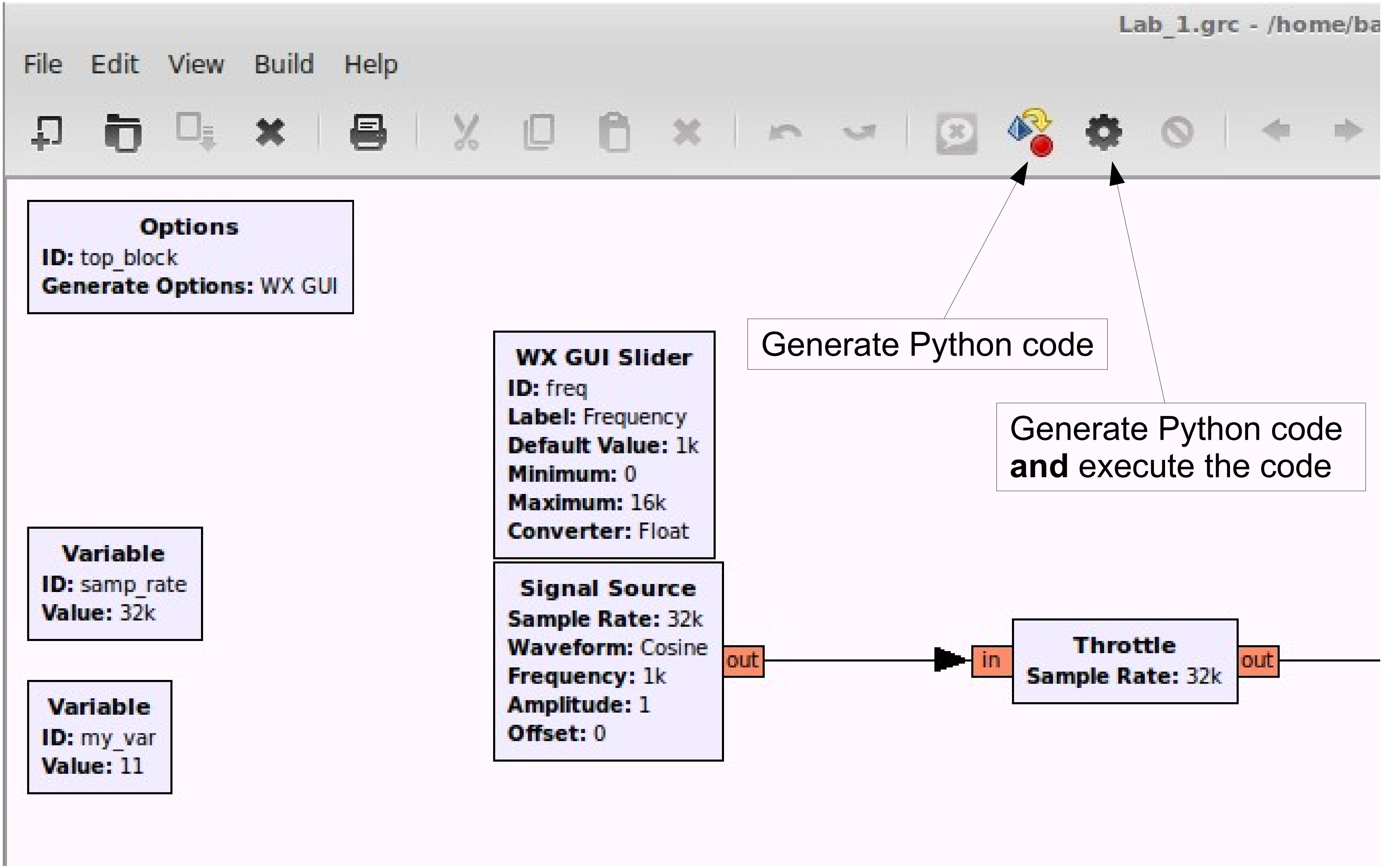
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Plot multiple signals (they may not be synchronised when drawn*!)

These will be covered later, but for now have a look at the Documentation tab where they are discussed.

* Plot two Float streams in sync by changing Scope's Type to Complex, and use Float to Complex block beforehand.

Lab 1


Lab_1.grc - /home/ba
File
Edit
View
Build
Help
out
in
out

Options
ID: top_block
Generate Options: WX GUI

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Variable
ID: samp_rate
Value: 32k

Variable
ID: my_var
Value: 11

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

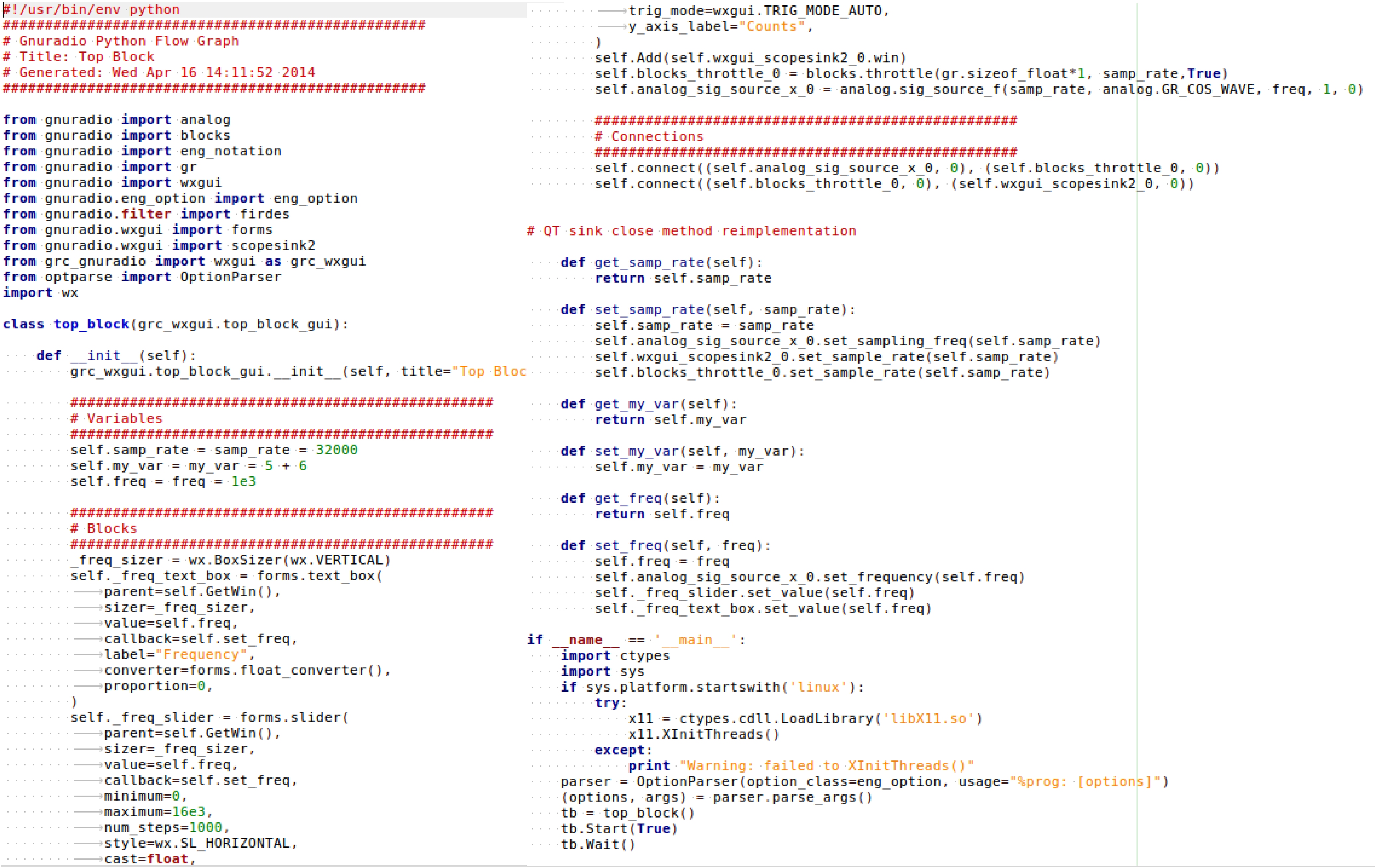
Throttle
Sample Rate: 32k

Generate Python code

Generate Python code **and** execute the code

Lab 1

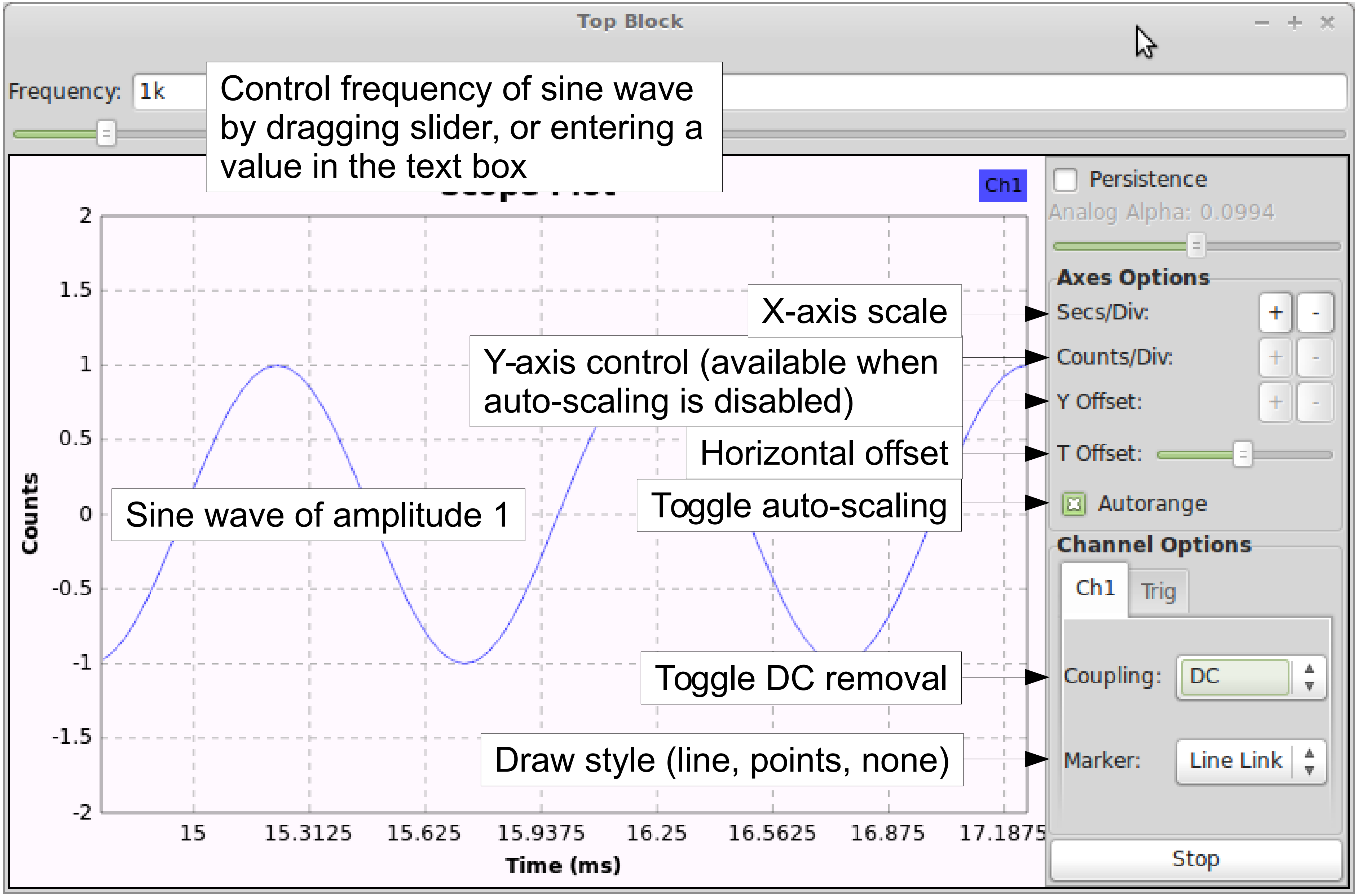
Python code generated by GRC



```python
#!/usr/bin/env python
##################################################
# Gnuradio Python Flow Graph
# Title: Top Block
# Generated: Wed Apr 16 14:11:52 2014
##################################################

from gnuradio import analog
from gnuradio import blocks
from gnuradio import eng_notation
from gnuradio import gr
from gnuradio import wxgui
from gnuradio.eng_option import eng_option
from gnuradio.filter import firdes
from gnuradio.wxgui import forms
from gnuradio.wxgui import scopesink2
from grc_gnuradio import wxgui as grc_wxgui
from optparse import OptionParser
import wx

class top_block(grc_wxgui.top_block_gui):

    def __init__(self):
        grc_wxgui.top_block_gui.__init__(self, title="Top Bloc

        ##################################################
        # Variables
        ##################################################
        self.samp_rate = samp_rate = 32000
        self.my_var = my_var = 5 + 6
        self.freq = freq = 1e3

        ##################################################
        # Blocks
        ##################################################
        _freq_sizer = wx.BoxSizer(wx.VERTICAL)
        self._freq_text_box = forms.text_box(
            parent=self.GetWin(),
            sizer=_freq_sizer,
            value=self.freq,
            callback=self.set_freq,
            label="Frequency",
            converter=forms.float_converter(),
            proportion=0,
        )
        self._freq_slider = forms.slider(
            parent=self.GetWin(),
            sizer=_freq_sizer,
            value=self.freq,
            callback=self.set_freq,
            minimum=0,
            maximum=16e3,
            num_steps=1000,
            style=wx.SL_HORIZONTAL,
            cast=float,
```

```python
            trig_mode=wxgui.TRIG_MODE_AUTO,
            y_axis_label="Counts",
        )
        self.Add(self.wxgui_scopesink2_0.win)
        self.blocks_throttle_0 = blocks.throttle(gr.sizeof_float*1, samp_rate,True)
        self.analog_sig_source_x_0 = analog.sig_source_f(samp_rate, analog.GR_COS_WAVE, freq, 1, 0)

        ##################################################
        # Connections
        ##################################################
        self.connect((self.analog_sig_source_x_0, 0), (self.blocks_throttle_0, 0))
        self.connect((self.blocks_throttle_0, 0), (self.wxgui_scopesink2_0, 0))


# QT sink close method reimplementation

    def get_samp_rate(self):
        return self.samp_rate

    def set_samp_rate(self, samp_rate):
        self.samp_rate = samp_rate
        self.analog_sig_source_x_0.set_sampling_freq(self.samp_rate)
        self.wxgui_scopesink2_0.set_sample_rate(self.samp_rate)
        self.blocks_throttle_0.set_sample_rate(self.samp_rate)

    def get_my_var(self):
        return self.my_var

    def set_my_var(self, my_var):
        self.my_var = my_var

    def get_freq(self):
        return self.freq

    def set_freq(self, freq):
        self.freq = freq
        self.analog_sig_source_x_0.set_frequency(self.freq)
        self._freq_slider.set_value(self.freq)
        self._freq_text_box.set_value(self.freq)

if __name__ == '__main__':
    import ctypes
    import sys
    if sys.platform.startswith('linux'):
        try:
            x11 = ctypes.cdll.LoadLibrary('libX11.so')
            x11.XInitThreads()
        except:
            print "Warning: failed to XInitThreads()"
    parser = OptionParser(option_class=eng_option, usage="%prog: [options]")
    (options, args) = parser.parse_args()
    tb = top_block()
    tb.Start(True)
    tb.Wait()
```

Lab 1


Top Block
Ch1
☐ Persistence
Axes Options
Secs/Div: + -
Counts/Div: + -
Y Offset: + -
T Offset:
☒ Autorange
Channel Options
Ch1
Trig
Stop
Counts
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
15
15.3125
15.625
15.9375
16.25
16.5625
16.875
17.1875
Time (ms)

Frequency: 1k

Analog Alpha: 0.0994

Coupling: DC

Marker: Line Link

Control frequency of sine wave by dragging slider, or entering a value in the text box

X-axis scale

Y-axis control (available when auto-scaling is disabled)

Horizontal offset

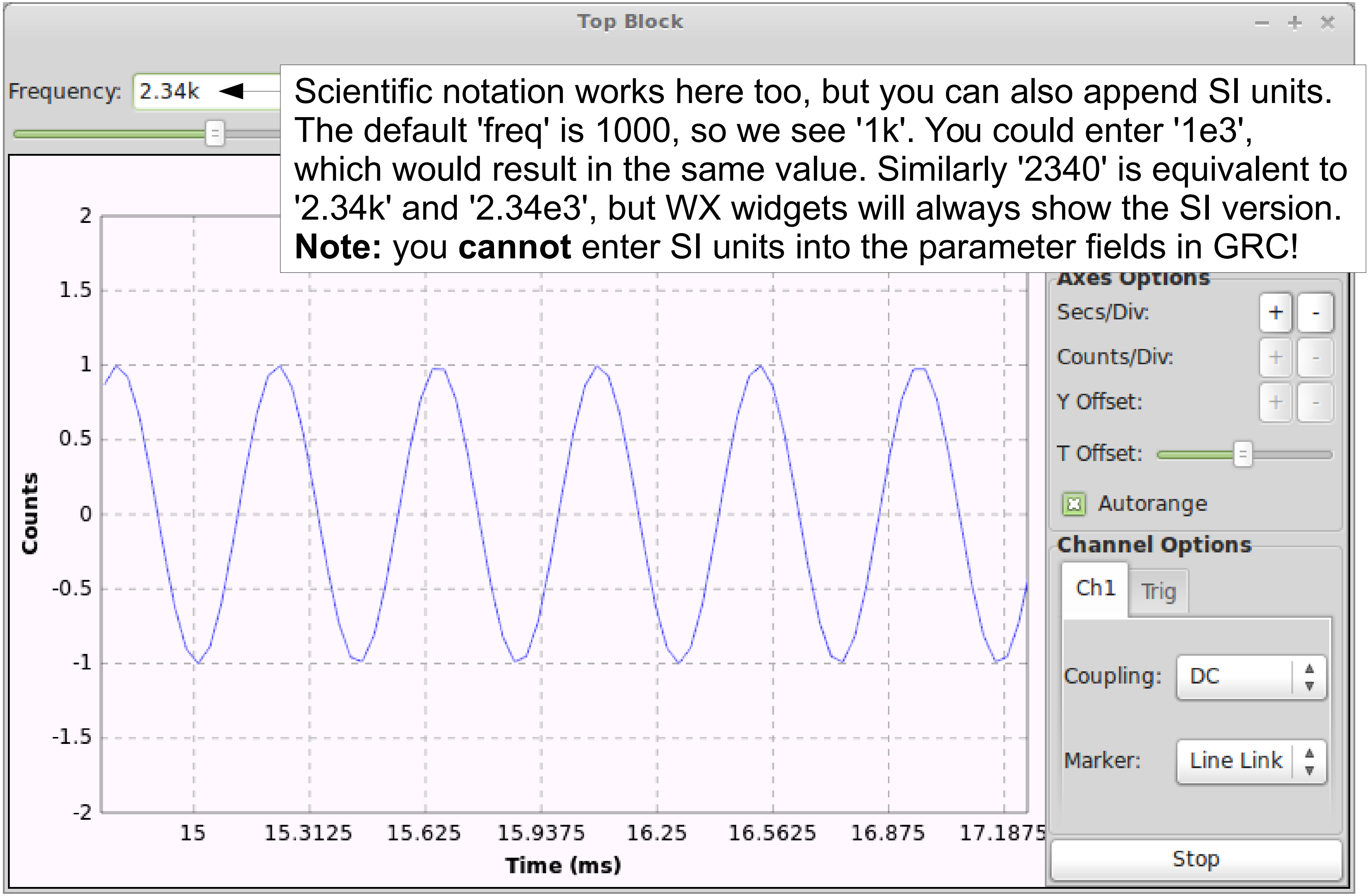
Toggle auto-scaling

Sine wave of amplitude 1

Toggle DC removal

Draw style (line, points, none)

Lab 1



Top Block
Counts
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
15
15.3125
15.625
15.9375
16.25
16.5625
16.875
17.1875
Time (ms)
Axes Options
Secs/Div: + -
Counts/Div: + -
Y Offset: + -
T Offset:
☒ Autorange
Channel Options
Ch1
Trig
Stop

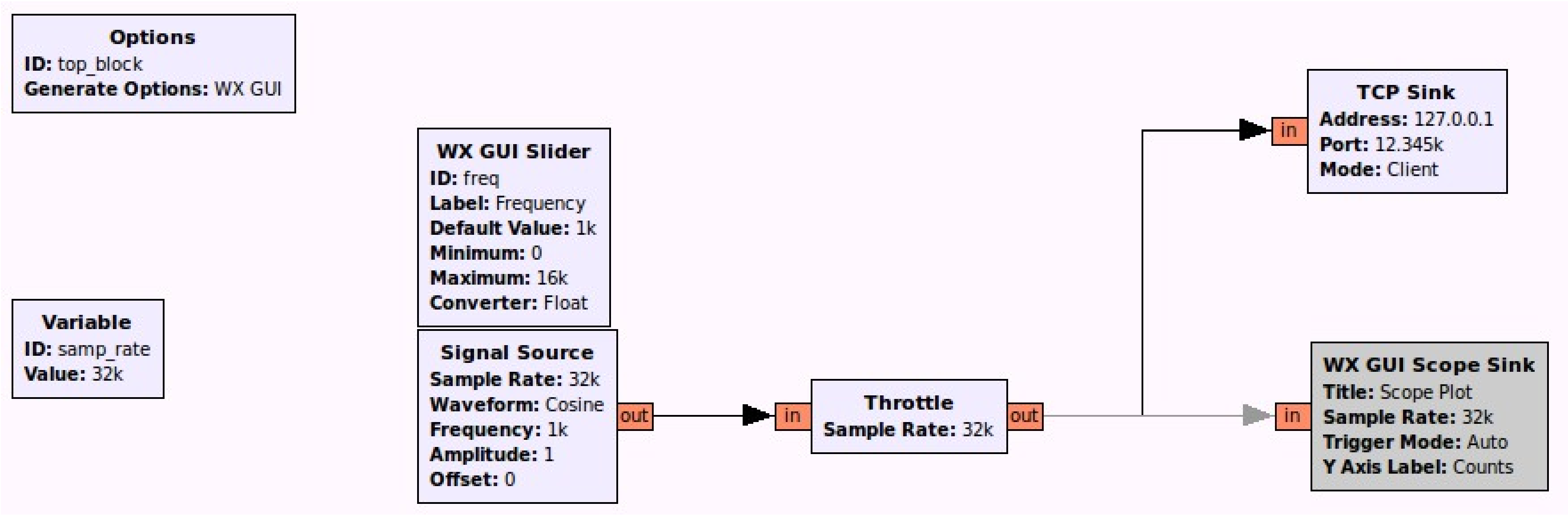
Frequency: 2.34k

Coupling: DC

Marker: Line Link

Scientific notation works here too, but you can also append SI units. The default 'freq' is 1000, so we see '1k'. You could enter '1e3', which would result in the same value. Similarly '2340' is equivalent to '2.34k' and '2.34e3', but WX widgets will always show the SI version. **Note:** you **cannot** enter SI units into the parameter fields in GRC!

Lab 1: TCP Client (producer)



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

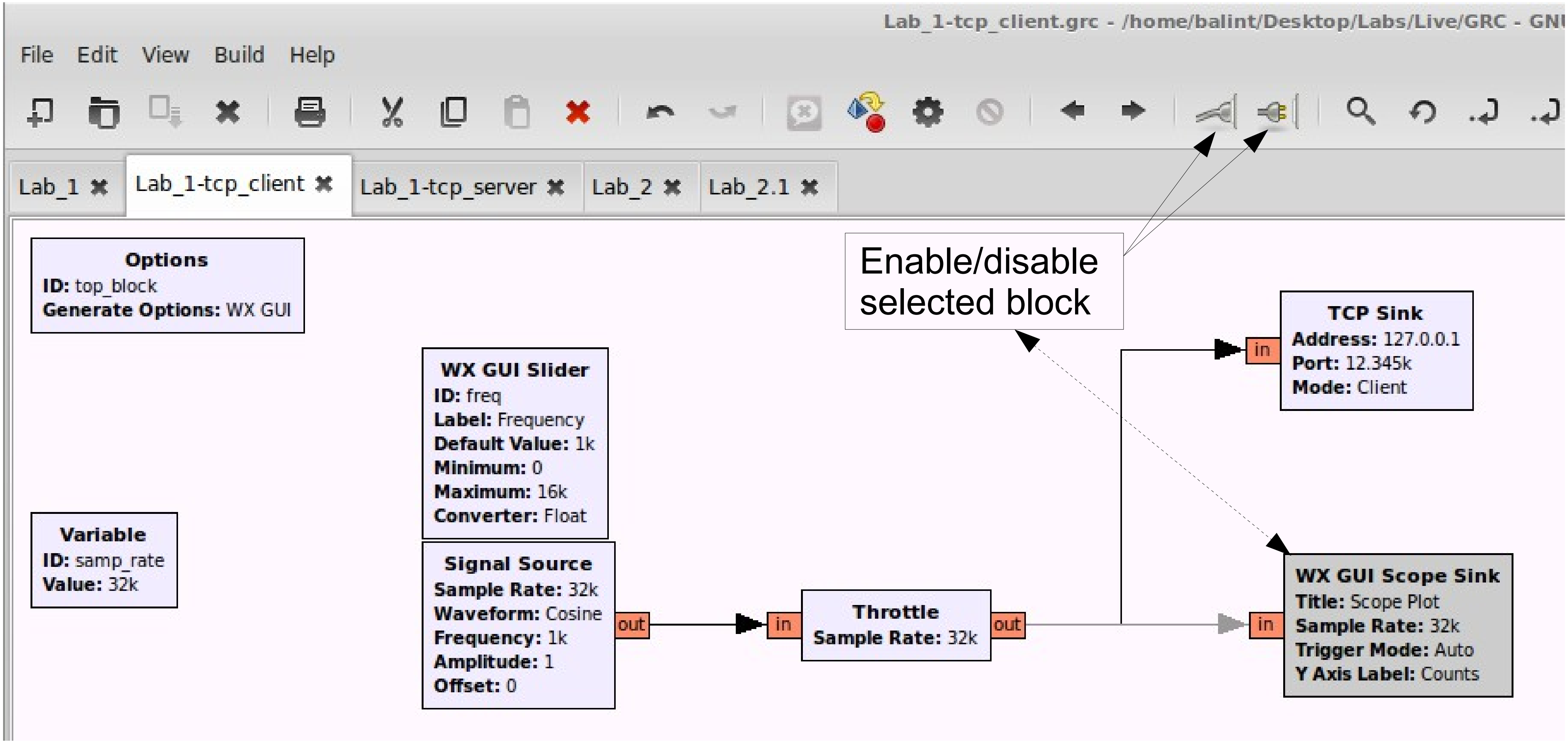
Throttle
Sample Rate: 32k

TCP Sink
Address: 127.0.0.1
Port: 12.345k
Mode: Client

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Create a sine wave & transmit generated samples over a TCP connection

Lab 1: TCP Client (producer)


Lab_1-tcp_client.grc - /home/balint/Desktop/Labs/Live/GRC -
File
Edit
View
Build
Help
Lab_1
Lab_1-tcp_client
Lab_1-tcp_server
Lab_2
Lab_2.1
in
out
in
out
in
in

Enable/disable selected block

Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

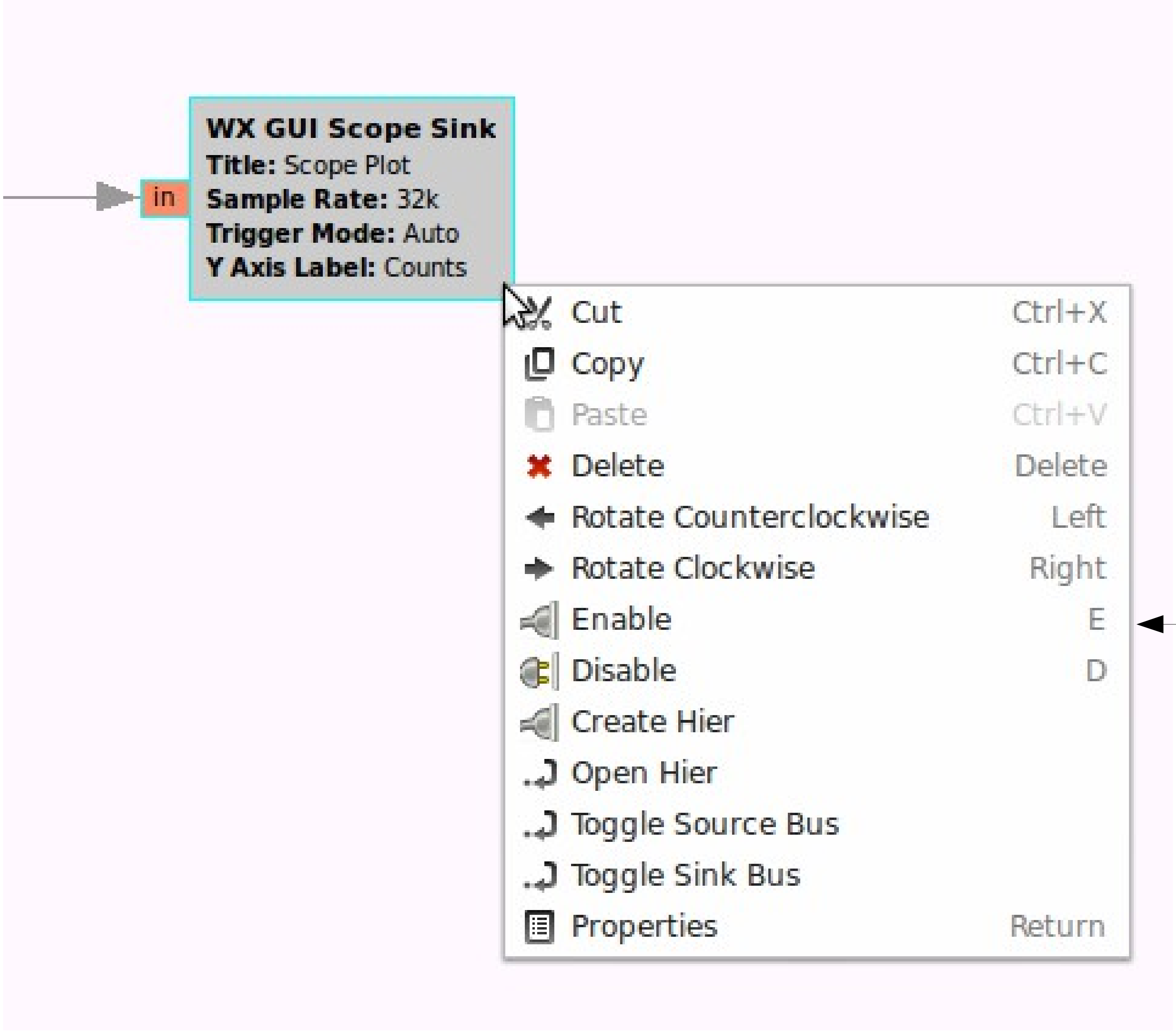
Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 32k

TCP Sink
Address: 127.0.0.1
Port: 12.345k
Mode: Client

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Lab 1: TCP Client (producer)

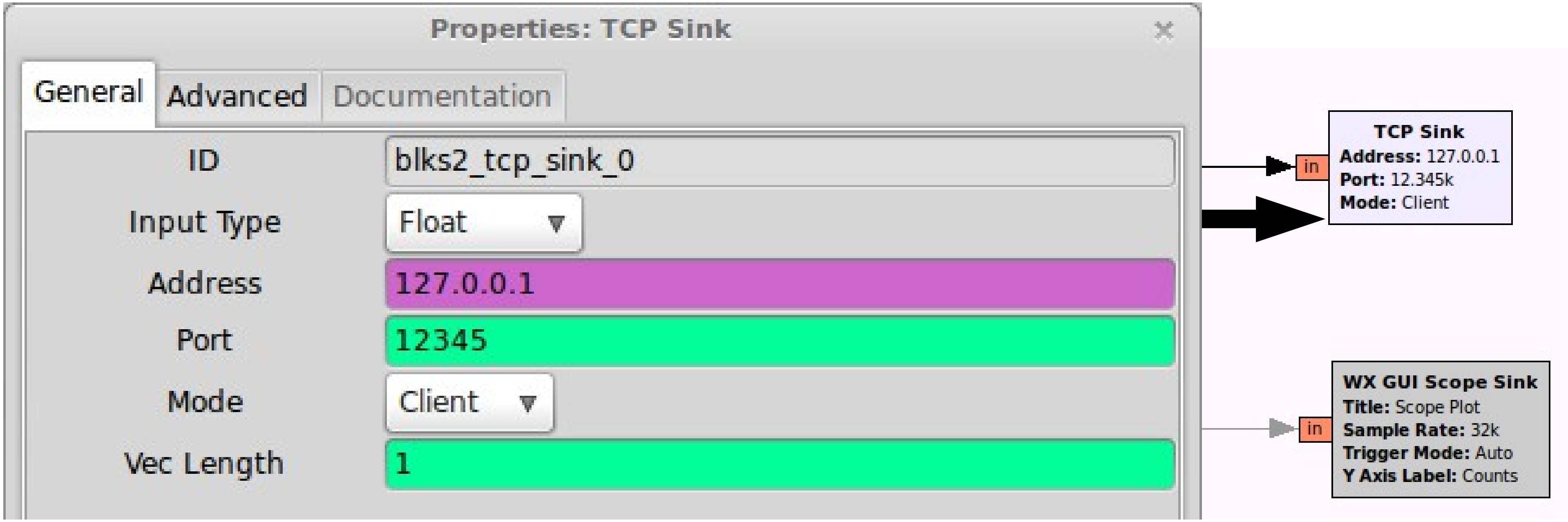


WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

in
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Delete Delete
Rotate Counterclockwise Left
Rotate Clockwise Right
Enable E
Disable D
Create Hier
Open Hier
Toggle Source Bus
Toggle Sink Bus
Properties Return

Tip:
Make note of the keyboard shortcuts in the block context menu.

Lab 1: TCP Client (producer)



Properties: TCP Sink

ID	blks2_tcp_sink_0
Input Type	Float
Address	127.0.0.1
Port	12345
Mode	Client
Vec Length	1

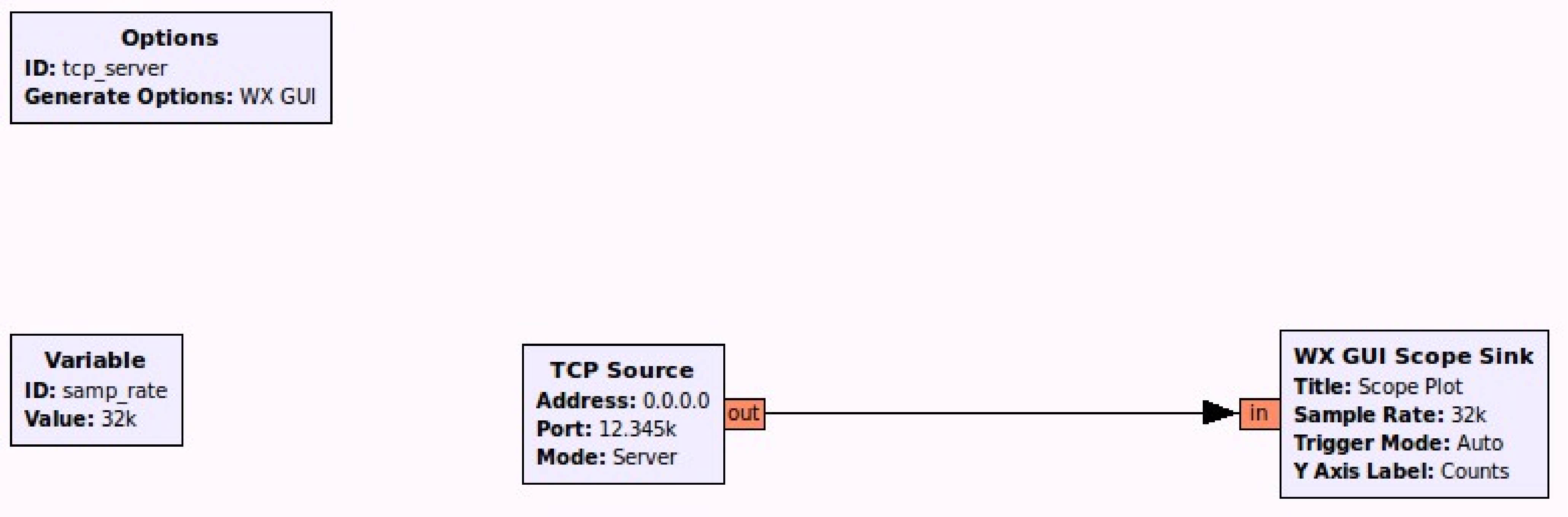
TCP Sink
Address: 127.0.0.1
Port: 12.345k
Mode: Client

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Tip:
The flowgraph will not start unless a TCP connection is established. If the TCP connection fails, a Python exception will be thrown and program will not start.

* The current TCP Source/Sink implementation does not work on Windows

Lab 1: TCP Server (consumer)



Options
ID: tcp_server
Generate Options: WX GUI

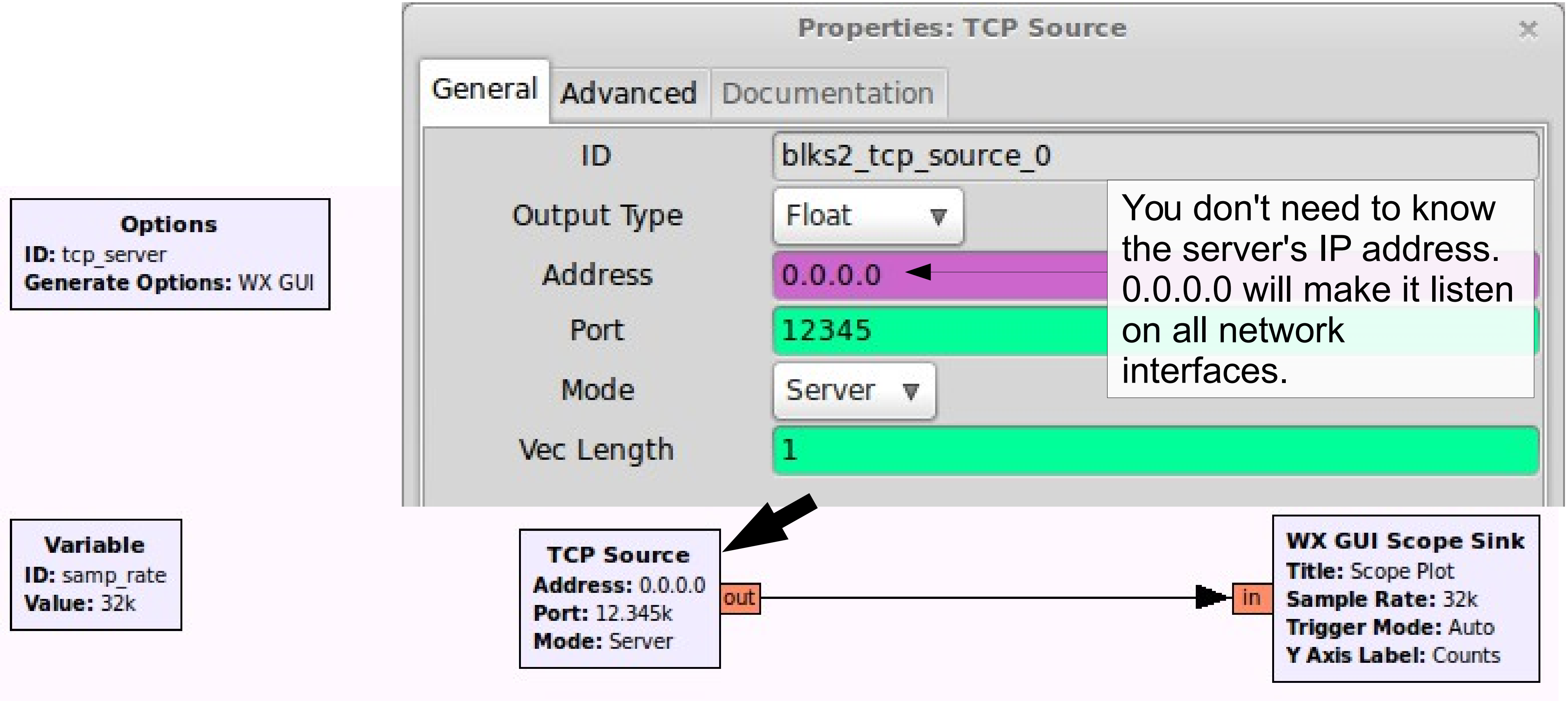
Variable
ID: samp_rate
Value: 32k

TCP Source
Address: 0.0.0.0
Port: 12.345k
Mode: Server

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

Receive samples from an incoming TCP connection and plot on a Scope Sink

Lab 1: TCP Server (consumer)


Properties: TCP Source
General
Advanced
Documentation
out
in

ID: blks2_tcp_source_0
Output Type: Float
Address: 0.0.0.0
Port: 12345
Mode: Server
Vec Length: 1

You don't need to know the server's IP address. 0.0.0.0 will make it listen on all network interfaces.

Options
ID: tcp_server
Generate Options: WX GUI

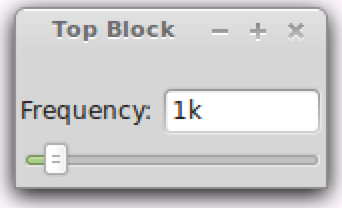
Variable
ID: samp_rate
Value: 32k

TCP Source
Address: 0.0.0.0
Port: 12.345k
Mode: Server

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
Trigger Mode: Auto
Y Axis Label: Counts

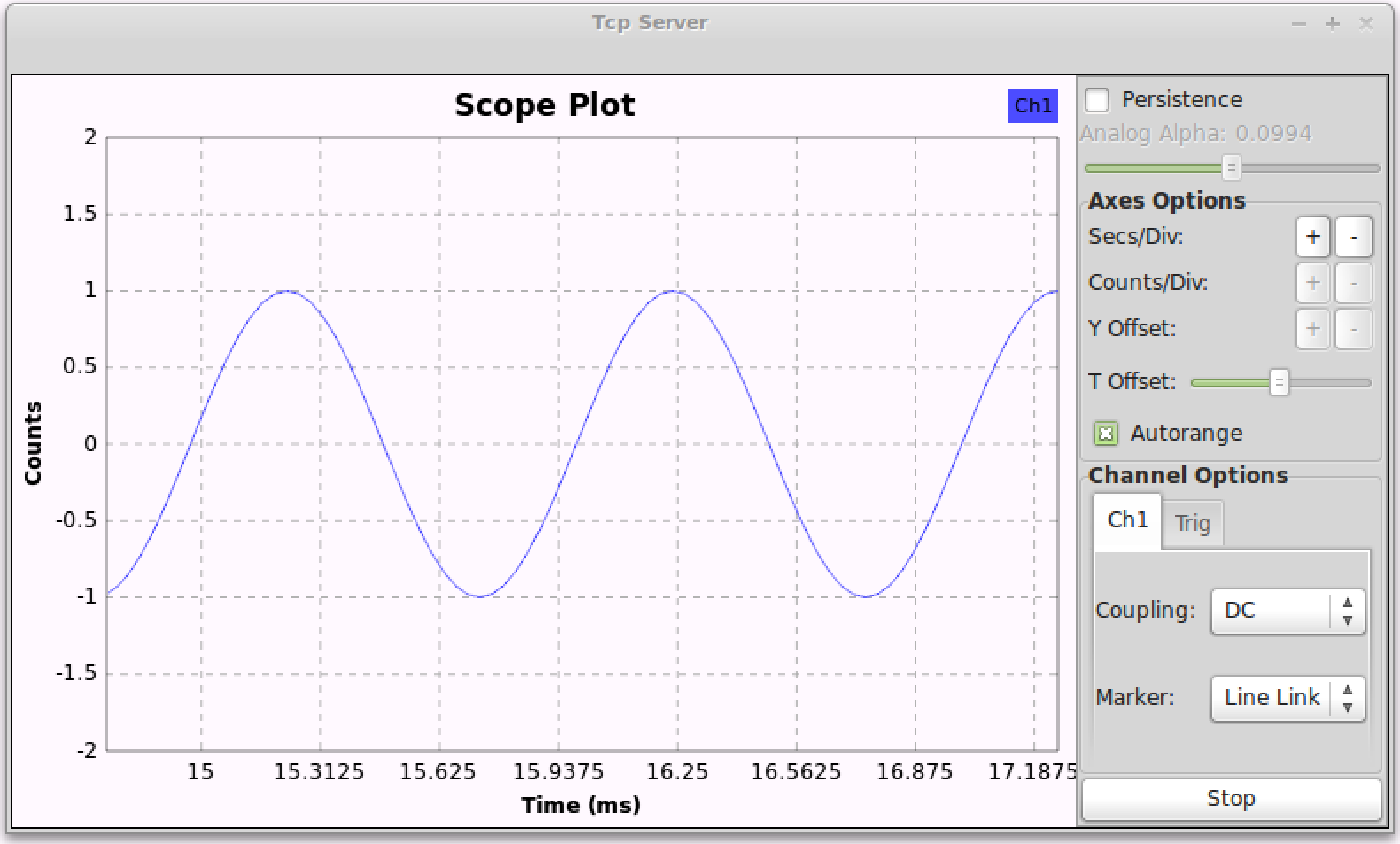
Tip:
The flowgraph will not start until a TCP connection is accepted.
In this case the GUI will not appear until the client has connected.

Lab 1: TCP Server & Client



Frequency: 1k

Client (producer)


Tcp Server
Scope Plot
Ch1
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Counts
15
15.3125
15.625
15.9375
16.25
16.5625
16.875
17.1875
Time (ms)
Axes Options
Secs/Div:
Counts/Div:
Y Offset:
T Offset:
Channel Options
Ch1
Trig
Stop

☐ Persistence

Analog Alpha: 0.0994

☒ Autorange

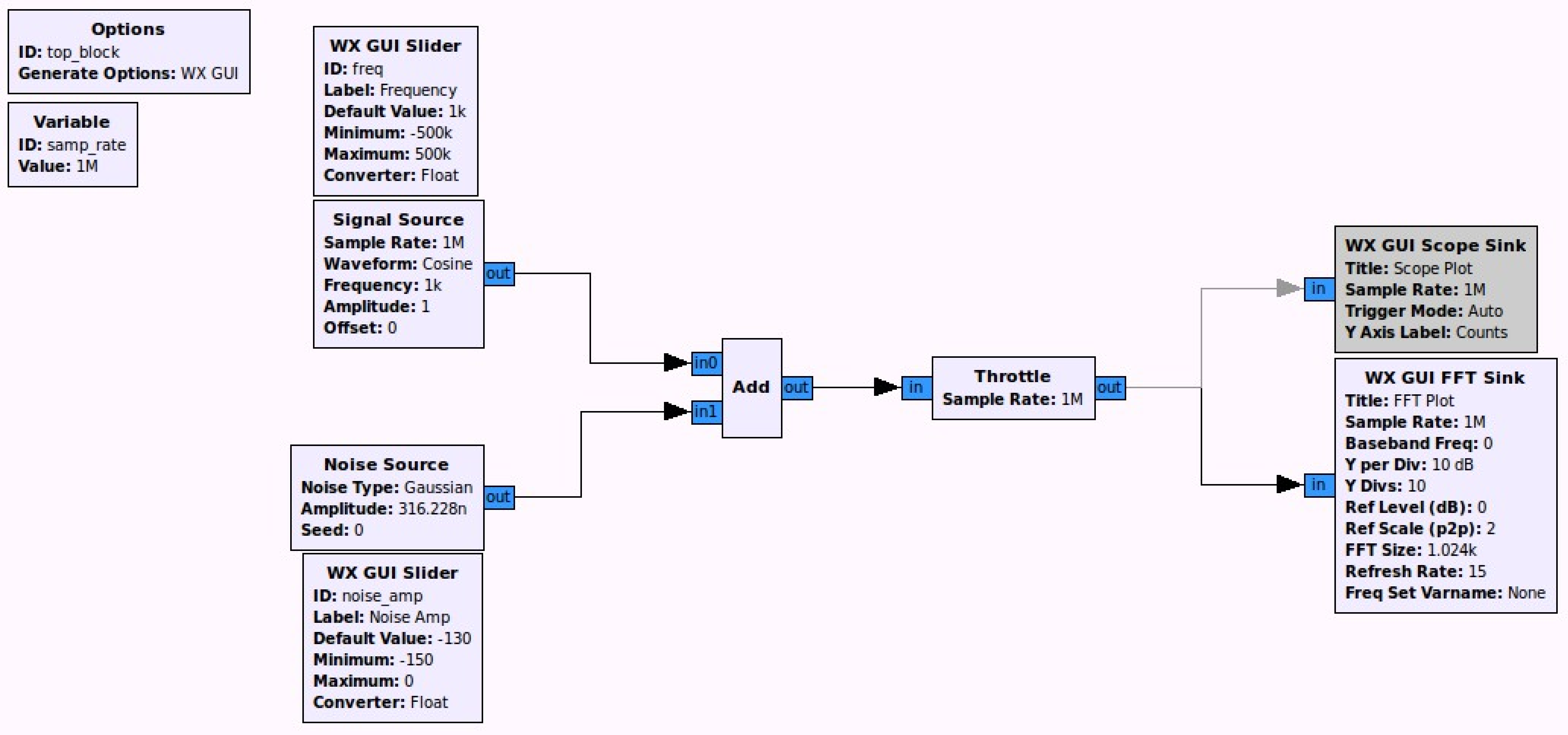
Coupling: DC

Marker: Line Link

Server (consumer)

Tip: you can run each application separately on two network-connected machines.
Just change the client's destination IP address to the machine on which the server is running.

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: -500k
Maximum: 500k
Converter: Float

Signal Source
Sample Rate: 1M
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Noise Source
Noise Type: Gaussian
Amplitude: 316.228n
Seed: 0

WX GUI Slider
ID: noise_amp
Label: Noise Amp
Default Value: -130
Minimum: -150
Maximum: 0
Converter: Float

Add

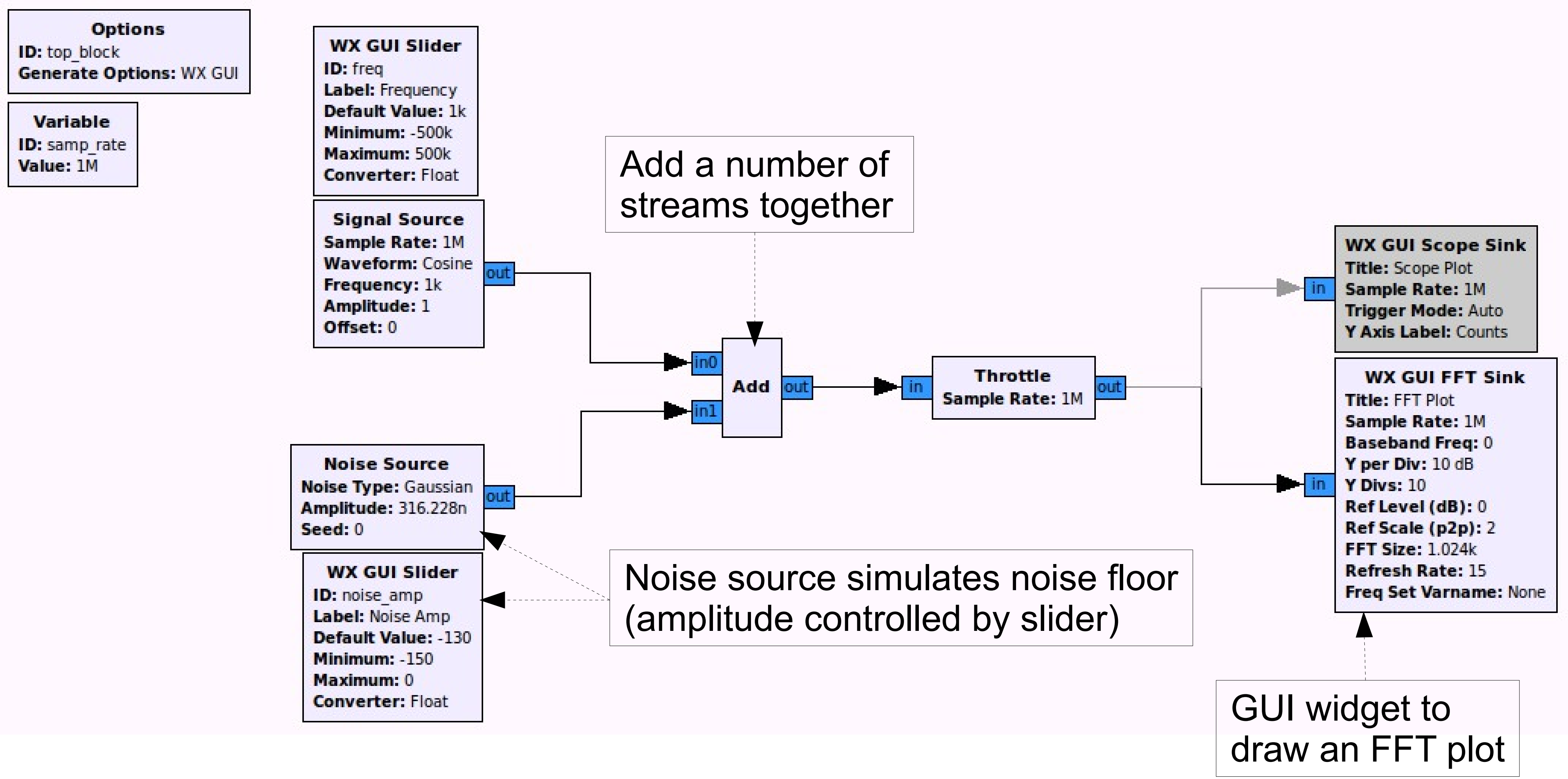
Throttle
Sample Rate: 1M

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 1M
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 1M
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Generate a sine wave & some noise, add both, and plot the resulting signal in the frequency domain.

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: -500k
Maximum: 500k
Converter: Float

Signal Source
Sample Rate: 1M
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Noise Source
Noise Type: Gaussian
Amplitude: 316.228n
Seed: 0

WX GUI Slider
ID: noise_amp
Label: Noise Amp
Default Value: -130
Minimum: -150
Maximum: 0
Converter: Float

Throttle
Sample Rate: 1M

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 1M
Trigger Mode: Auto
Y Axis Label: Counts

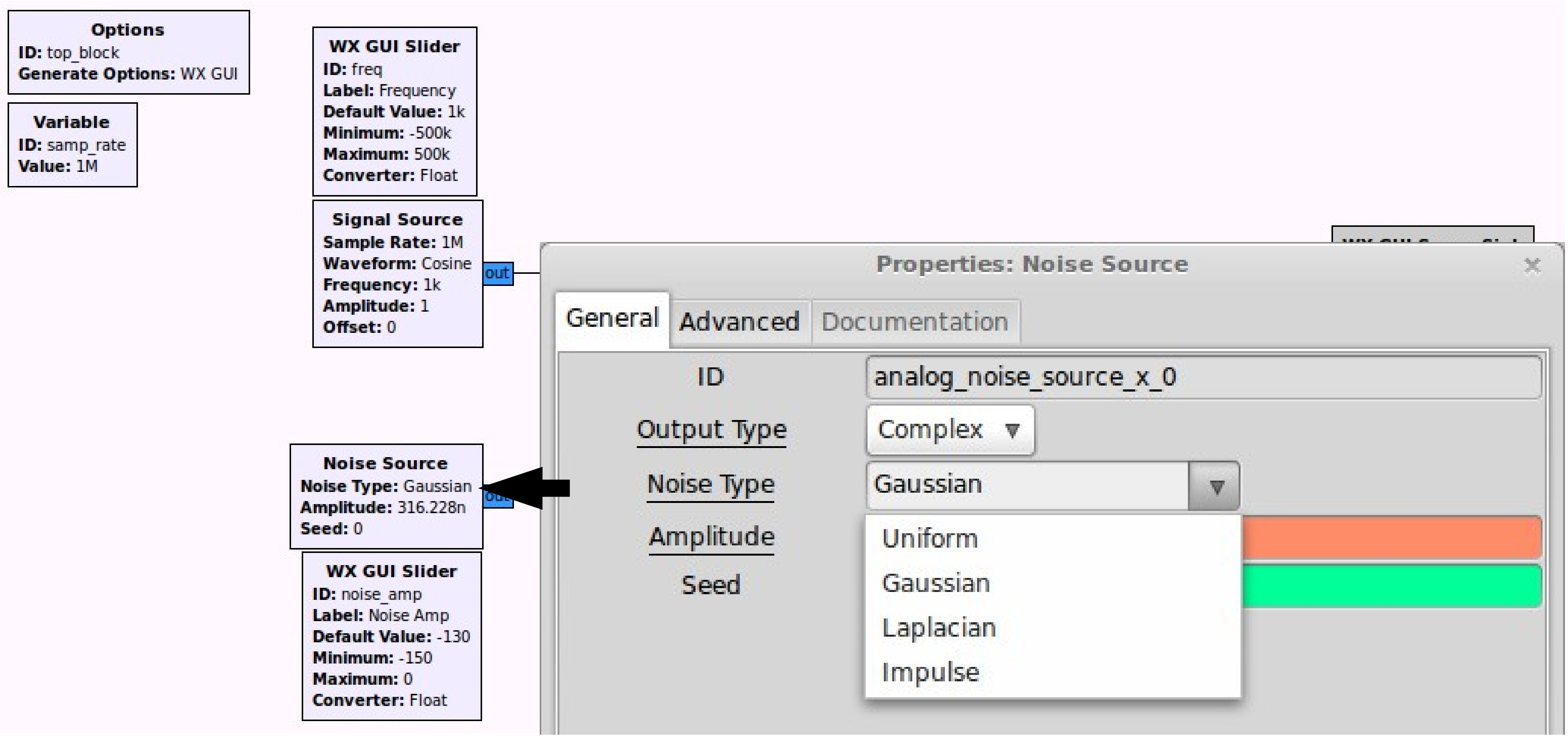
WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 1M
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Add a number of streams together

Noise source simulates noise floor (amplitude controlled by slider)

GUI widget to draw an FFT plot

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: -500k
Maximum: 500k
Converter: Float

Signal Source
Sample Rate: 1M
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Noise Source
Noise Type: Gaussian
Amplitude: 316.228n
Seed: 0

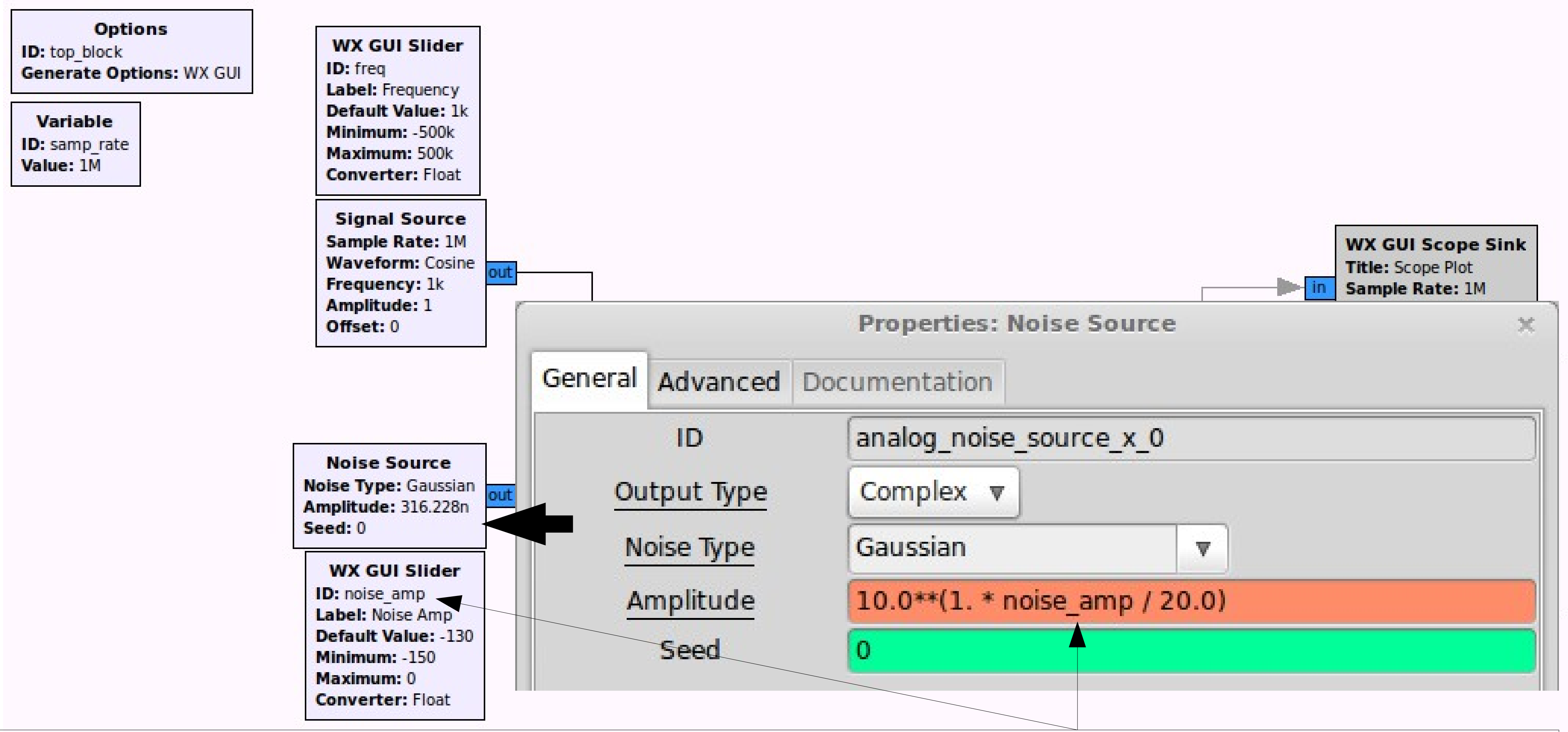
WX GUI Slider
ID: noise_amp
Label: Noise Amp
Default Value: -130
Minimum: -150
Maximum: 0
Converter: Float

Properties: Noise Source

ID: analog_noise_source_x_0
Output Type: Complex
Noise Type: Gaussian
Amplitude
Seed

out
out
General
Advanced
Documentation
Uniform
Gaussian
Laplacian
Impulse

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: -500k
Maximum: 500k
Converter: Float

Signal Source
Sample Rate: 1M
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 1M

Noise Source
Noise Type: Gaussian
Amplitude: 316.228n
Seed: 0

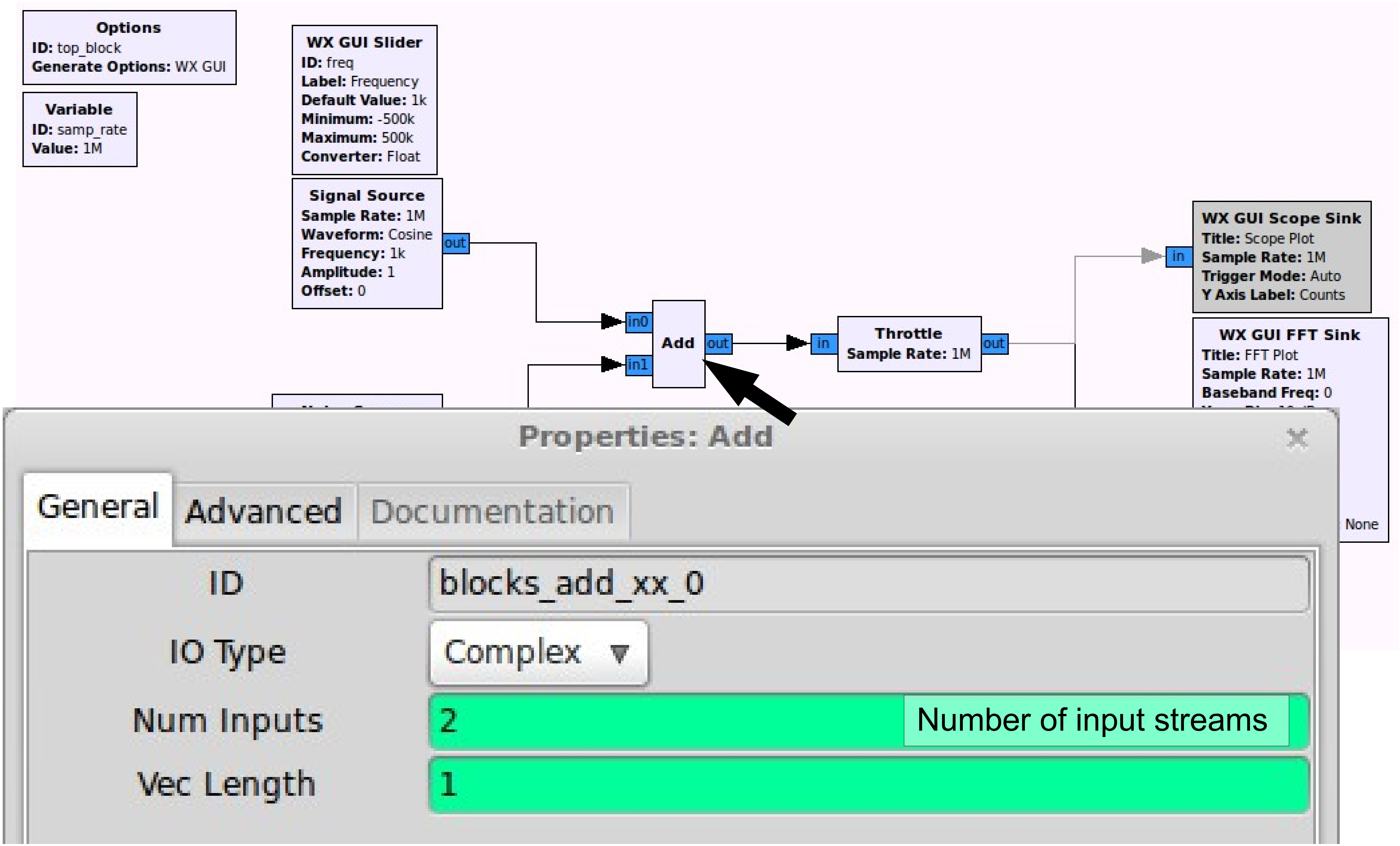
WX GUI Slider
ID: noise_amp
Label: Noise Amp
Default Value: -130
Minimum: -150
Maximum: 0
Converter: Float

Properties: Noise Source

ID	analog_noise_source_x_0
Output Type	Complex
Noise Type	Gaussian
Amplitude	10.0**(1. * noise_amp / 20.0)
Seed	0

'noise_amp' is the slider value, which (here) we interpret in dB, as opposed to a linear sample ampltitude value (e.g. '1.0').
Therefore we need to convert the value in dB to an actual linear ampltiude value ('volts') for use by the block (i.e. reverse the 'log10' function). The decimal points are added to force Python to compute with floating-point values (otherwise it would round and produce integers).

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: -500k
Maximum: 500k
Converter: Float

Signal Source
Sample Rate: 1M
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0

Throttle
Sample Rate: 1M

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 1M
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 1M
Baseband Freq: 0

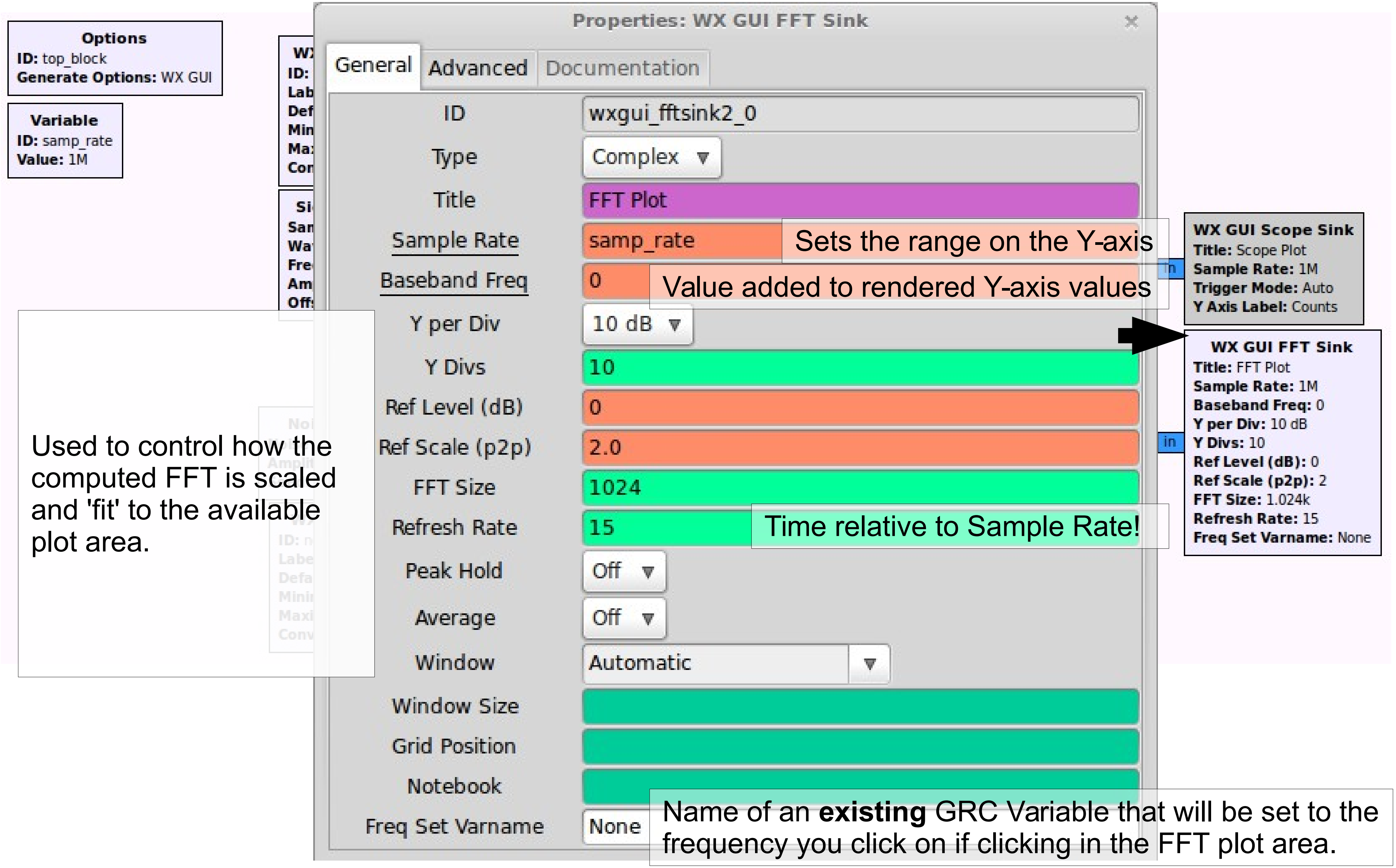
Properties: Add

ID: blocks_add_xx_0
IO Type: Complex
Num Inputs: 2
Vec Length: 1

Number of input streams

out
in0
in1
Add
out
in
out
in
None
General
Advanced
Documentation

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

Properties: WX GUI FFT Sink

ID: wxgui_fftsink2_0
Type: Complex
Title: FFT Plot
Sample Rate: samp_rate
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2.0
FFT Size: 1024
Refresh Rate: 15
Peak Hold: Off
Average: Off
Window: Automatic
Window Size:
Grid Position:
Notebook:
Freq Set Varname: None

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 1M
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 1M
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Sets the range on the Y-axis

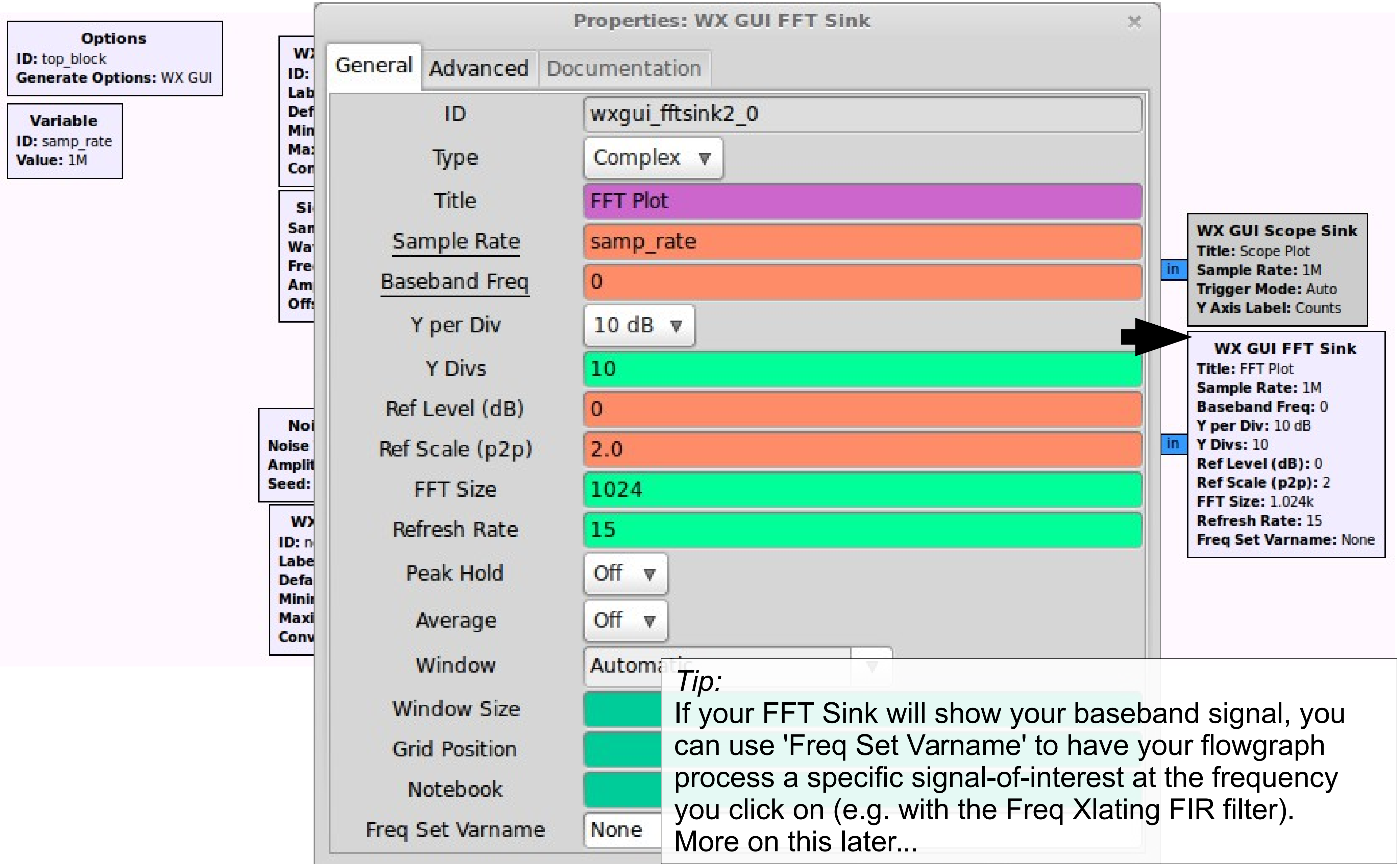
Value added to rendered Y-axis values

Used to control how the computed FFT is scaled and 'fit' to the available plot area.

Time relative to Sample Rate!

Name of an **existing** GRC Variable that will be set to the frequency you click on if clicking in the FFT plot area.

Lab 2



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 1M

Properties: WX GUI FFT Sink

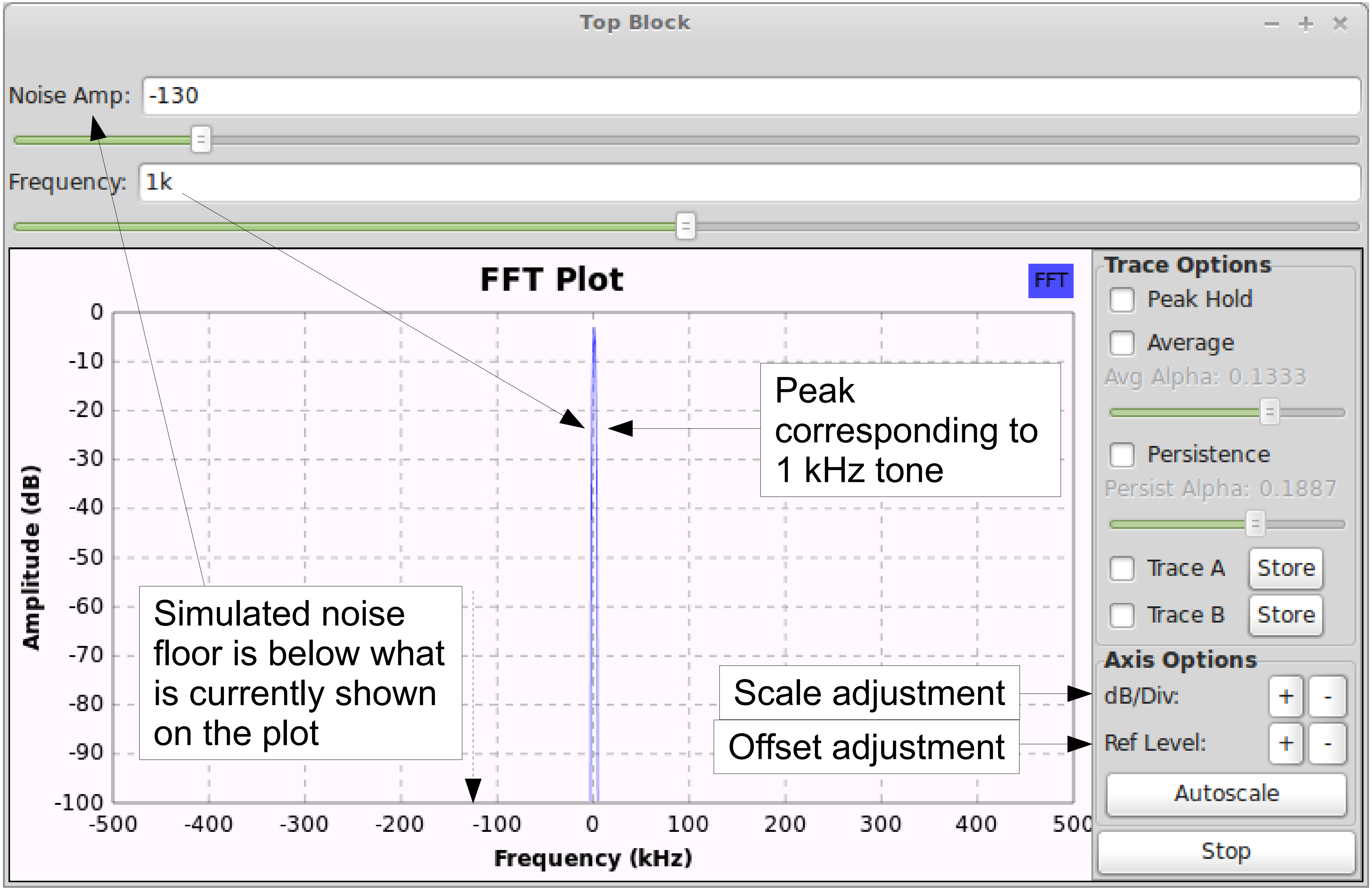
ID: wxgui_fftsink2_0
Type: Complex
Title: FFT Plot
Sample Rate: samp_rate
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2.0
FFT Size: 1024
Refresh Rate: 15
Peak Hold: Off
Average: Off
Window: Automa
Window Size
Grid Position
Notebook
Freq Set Varname: None

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 1M
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 1M
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Tip:
If your FFT Sink will show your baseband signal, you can use 'Freq Set Varname' to have your flowgraph process a specific signal-of-interest at the frequency you click on (e.g. with the Freq Xlating FIR filter). More on this later...

Lab 2



Noise Amp: -130

Frequency: 1k

Top Block
FFT Plot
FFT
Amplitude (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (kHz)
Trace Options
☐ Peak Hold
☐ Average
Avg Alpha: 0.1333
☐ Persistence
Persist Alpha: 0.1887
☐ Trace A
Store
☐ Trace B
Store
Axis Options
dB/Div:
+
-
Ref Level:
+
-
Autoscale
Stop

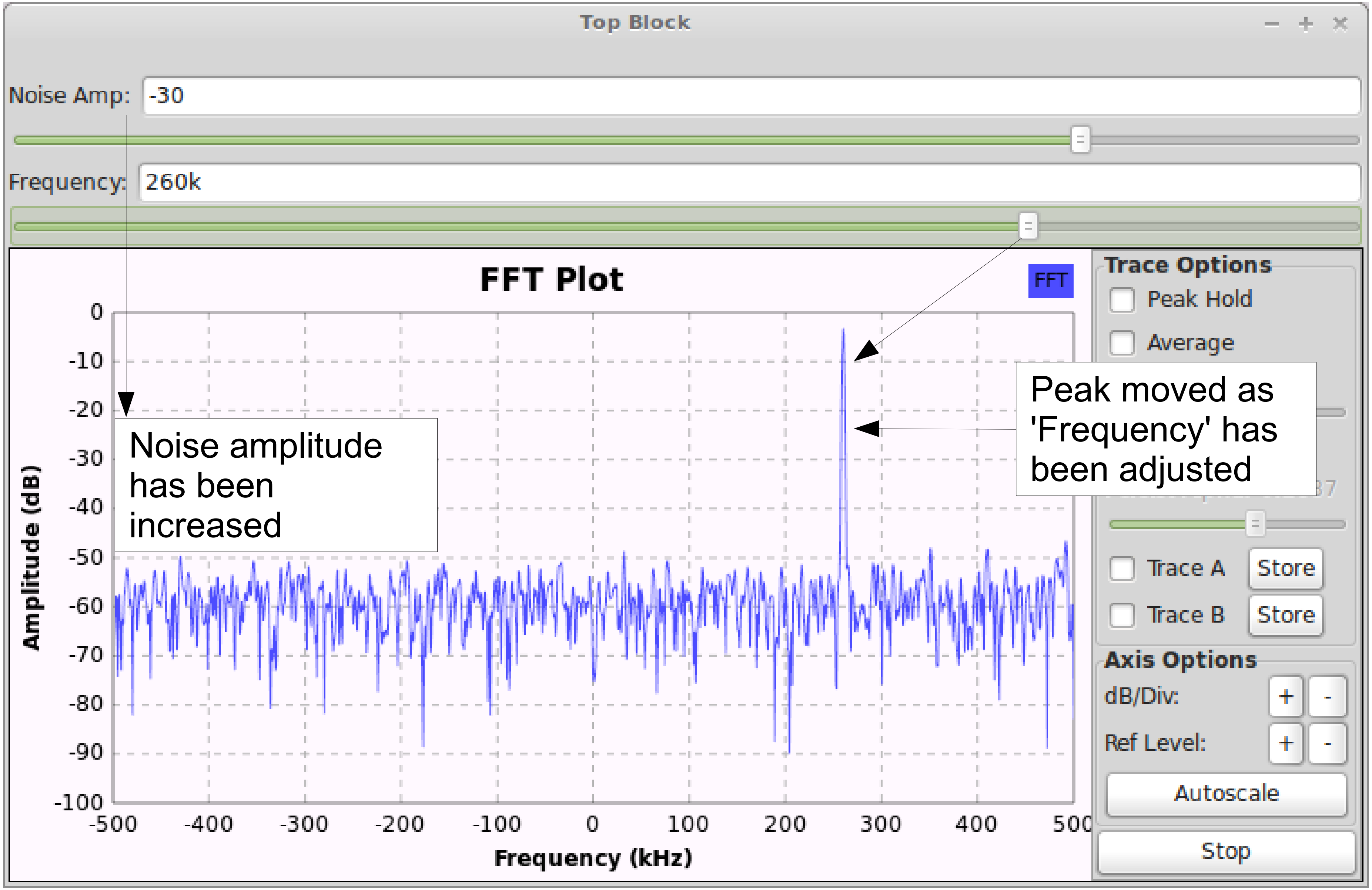
Peak corresponding to 1 kHz tone

Simulated noise floor is below what is currently shown on the plot

Scale adjustment

Offset adjustment

Lab 2


Top Block
FFT Plot
FFT
Amplitude (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (kHz)
Trace Options
☐ Peak Hold
☐ Average
☐ Trace A
Store
☐ Trace B
Store
Axis Options
dB/Div:
+
-
Ref Level:
+
-
Autoscale
Stop

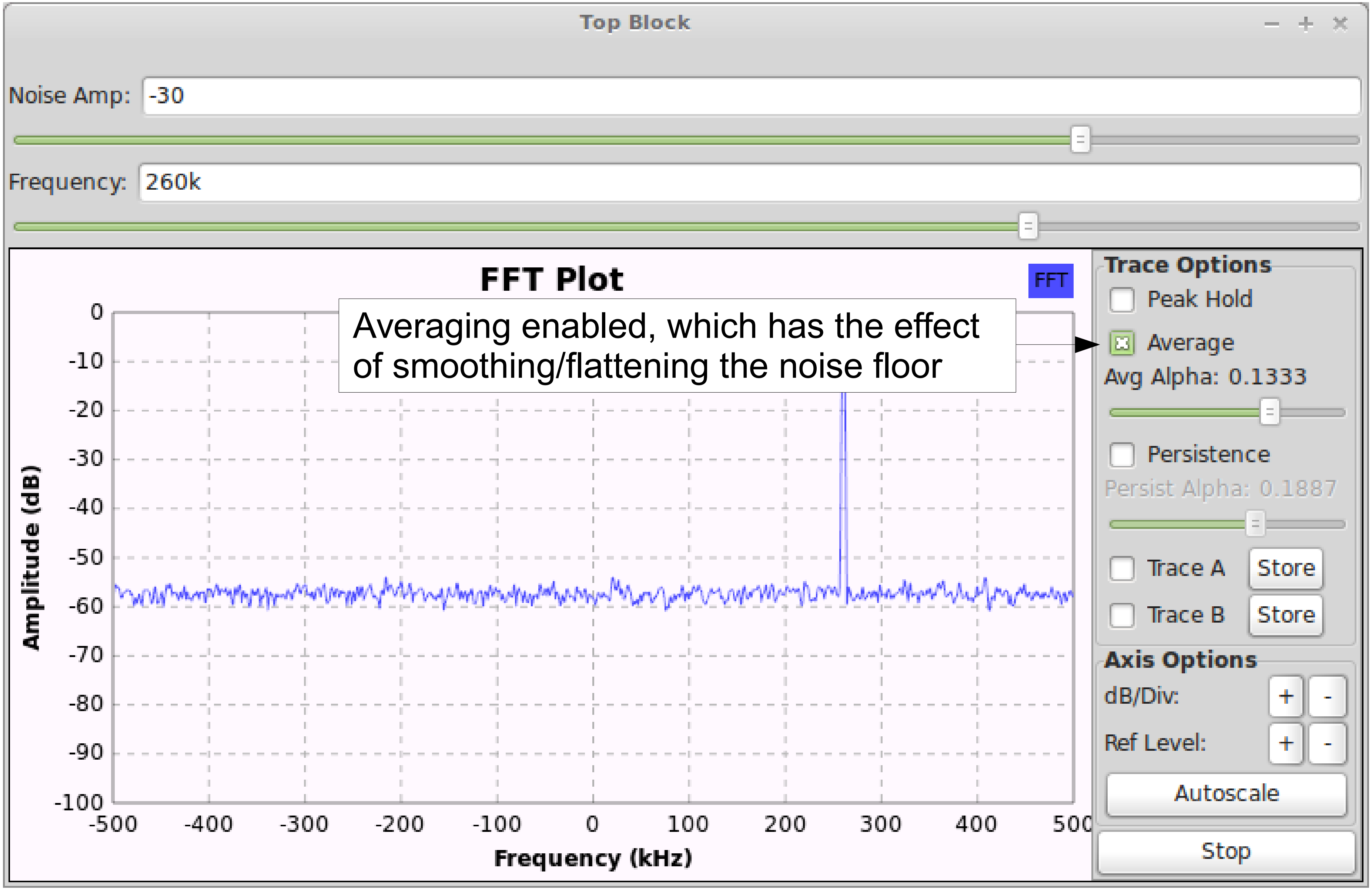
Noise Amp: -30

Frequency: 260k

Noise amplitude has been increased

Peak moved as 'Frequency' has been adjusted

Lab 2



Averaging enabled, which has the effect of smoothing/flattening the noise floor

Noise Amp: -30

Frequency: 260k

☐ Peak Hold

☒ Average

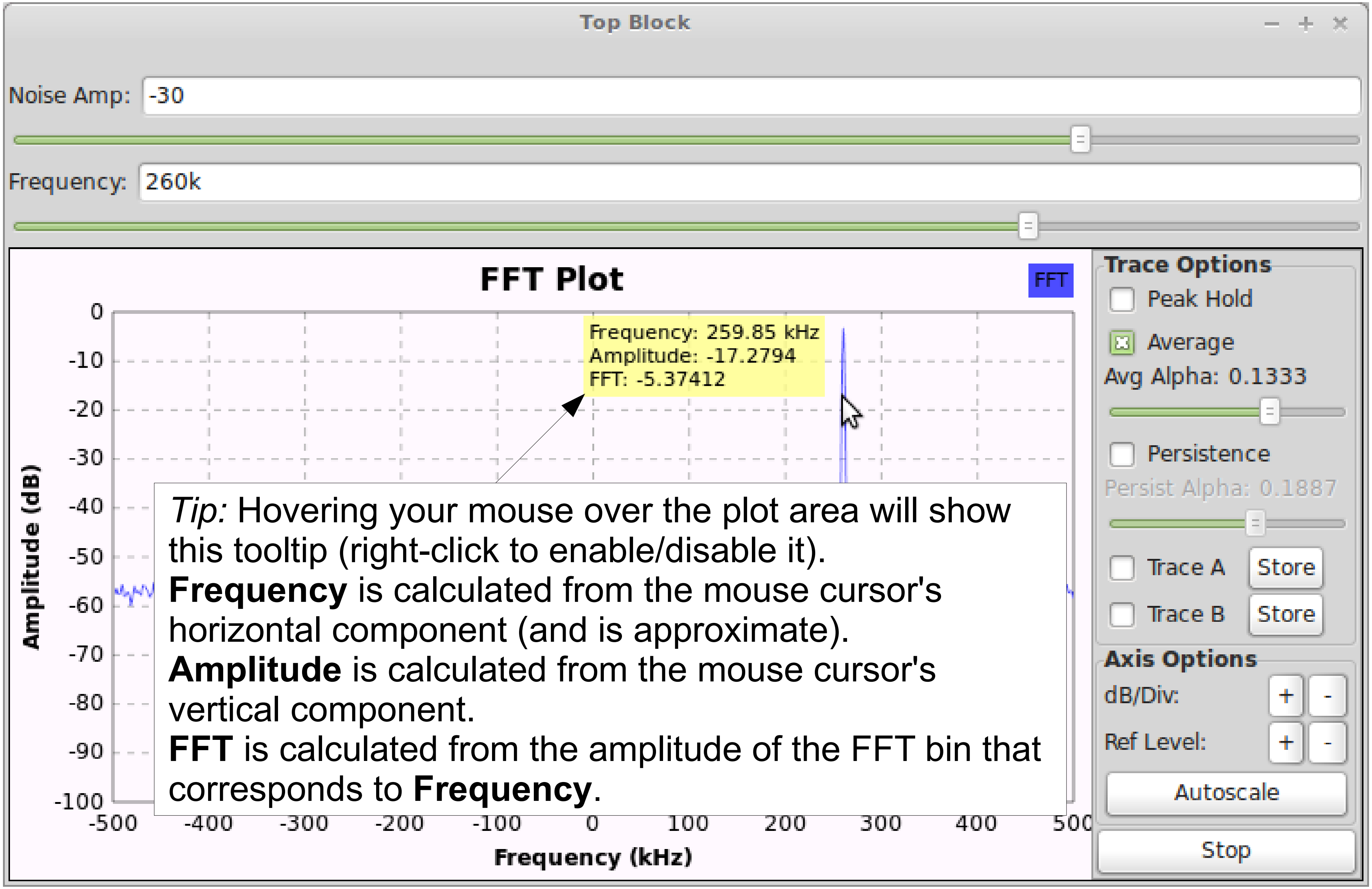
Avg Alpha: 0.1333

☐ Persistence

Persist Alpha: 0.1887

Top Block
FFT Plot
FFT
Amplitude (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (kHz)
Trace Options
Trace A
Store
Trace B
Store
Axis Options
dB/Div:
+
-
Ref Level:
+
-
Autoscale
Stop

Lab 2


Top Block
FFT Plot
FFT
Amplitude (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (kHz)
Trace Options
☐ Peak Hold
☒ Average
☐ Persistence
☐ Trace A
Store
☐ Trace B
Store
Axis Options
dB/Div:
+
-
Ref Level:
+
-
Autoscale
Stop

Noise Amp: -30

Frequency: 260k

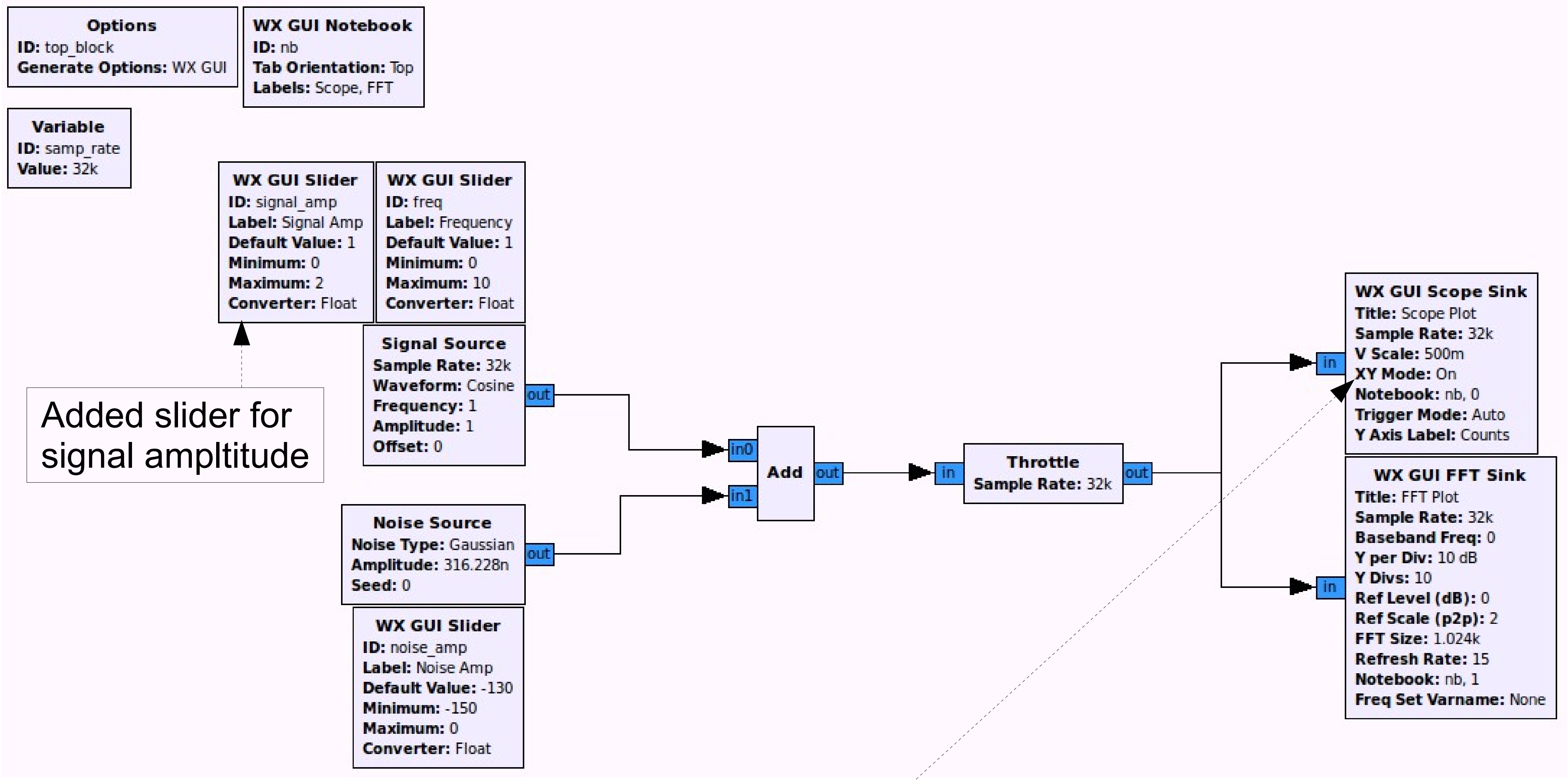
Frequency: 259.85 kHz
Amplitude: -17.2794
FFT: -5.37412

Avg Alpha: 0.1333

Persist Alpha: 0.1887

Tip: Hovering your mouse over the plot area will show this tooltip (right-click to enable/disable it).
Frequency is calculated from the mouse cursor's horizontal component (and is approximate).
Amplitude is calculated from the mouse cursor's vertical component.
FFT is calculated from the amplitude of the FFT bin that corresponds to **Frequency**.

Lab 2: XY Mode



Options
ID: top_block
Generate Options: WX GUI

WX GUI Notebook
ID: nb
Tab Orientation: Top
Labels: Scope, FFT

Variable
ID: samp_rate
Value: 32k

WX GUI Slider
ID: signal_amp
Label: Signal Amp
Default Value: 1
Minimum: 0
Maximum: 2
Converter: Float

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1
Minimum: 0
Maximum: 10
Converter: Float

Added slider for signal ampltitude

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1
Amplitude: 1
Offset: 0

Noise Source
Noise Type: Gaussian
Amplitude: 316.228n
Seed: 0

WX GUI Slider
ID: noise_amp
Label: Noise Amp
Default Value: -130
Minimum: -150
Maximum: 0
Converter: Float

Add

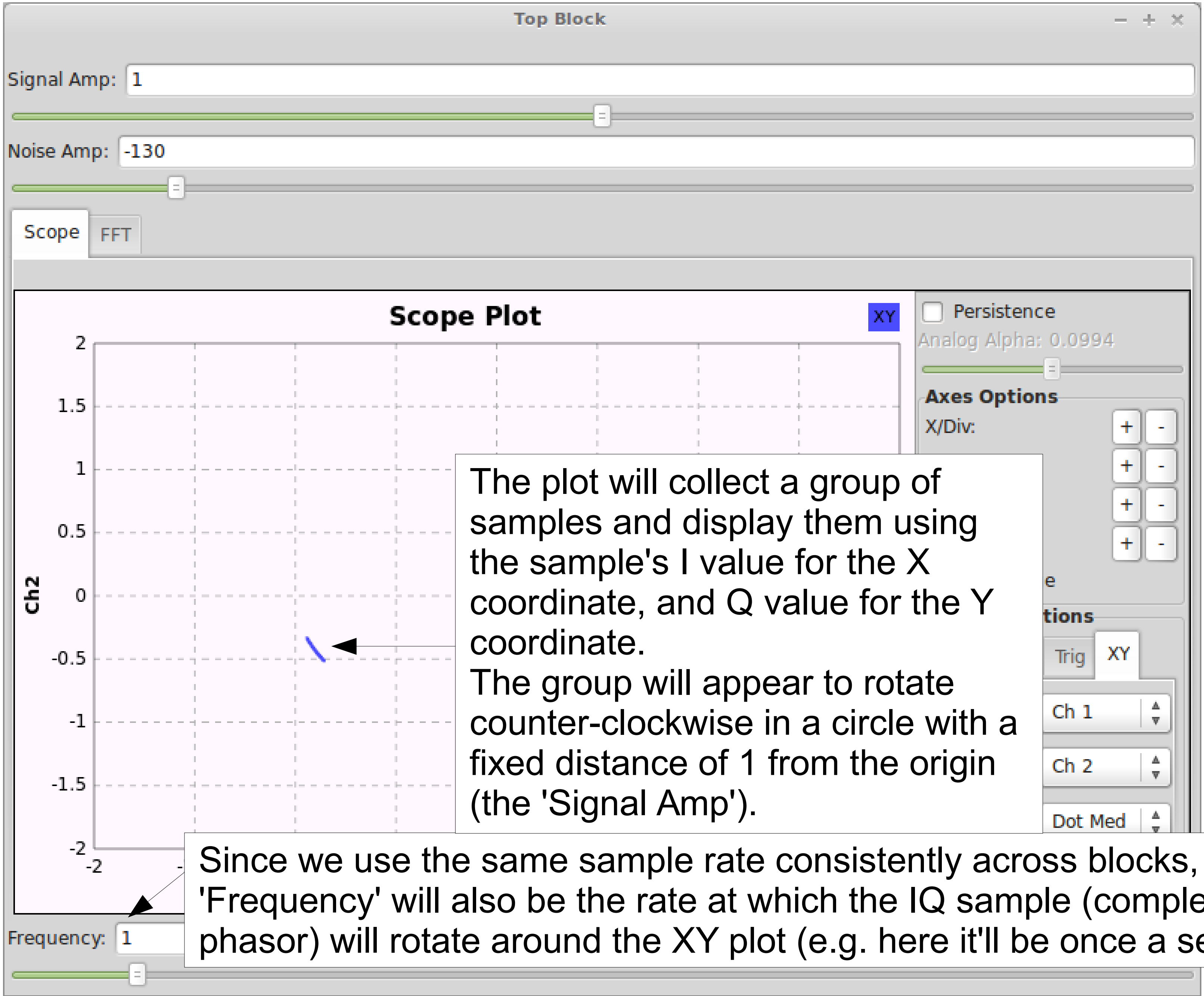
Throttle
Sample Rate: 32k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
V Scale: 500m
XY Mode: On
Notebook: nb, 0
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 32k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Notebook: nb, 1
Freq Set Varname: None

Use a Scope Sink in XY Mode so we can observe the characteristics of an IQ (quadrature) signal

Lab 2: XY Mode


Top Block
Scope
FFT
Scope Plot
XY
Ch2
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
Persistence
Analog Alpha: 0.0994
Axes Options
X/Div:
+
-
e
tions
Trig
XY
Ch 1
Ch 2
Dot Med

Signal Amp: 1

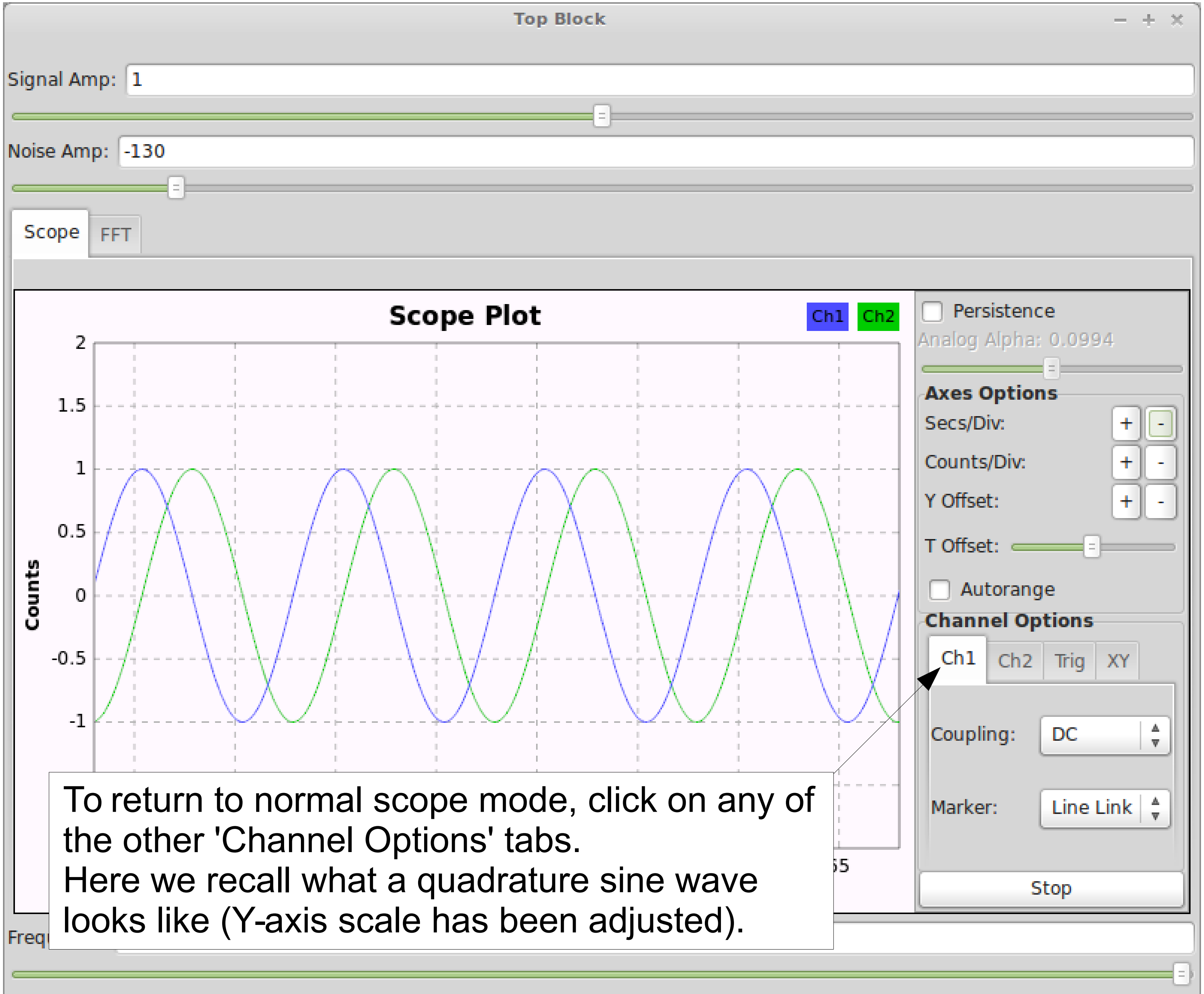
Noise Amp: -130

Frequency: 1

The plot will collect a group of samples and display them using the sample's I value for the X coordinate, and Q value for the Y coordinate.
The group will appear to rotate counter-clockwise in a circle with a fixed distance of 1 from the origin (the 'Signal Amp').

Since we use the same sample rate consistently across blocks, 'Frequency' will also be the rate at which the IQ sample (complex phasor) will rotate around the XY plot (e.g. here it'll be once a second).

Lab 2: XY Mode



Signal Amp: 1

Noise Amp: -130

Analog Alpha: 0.0994

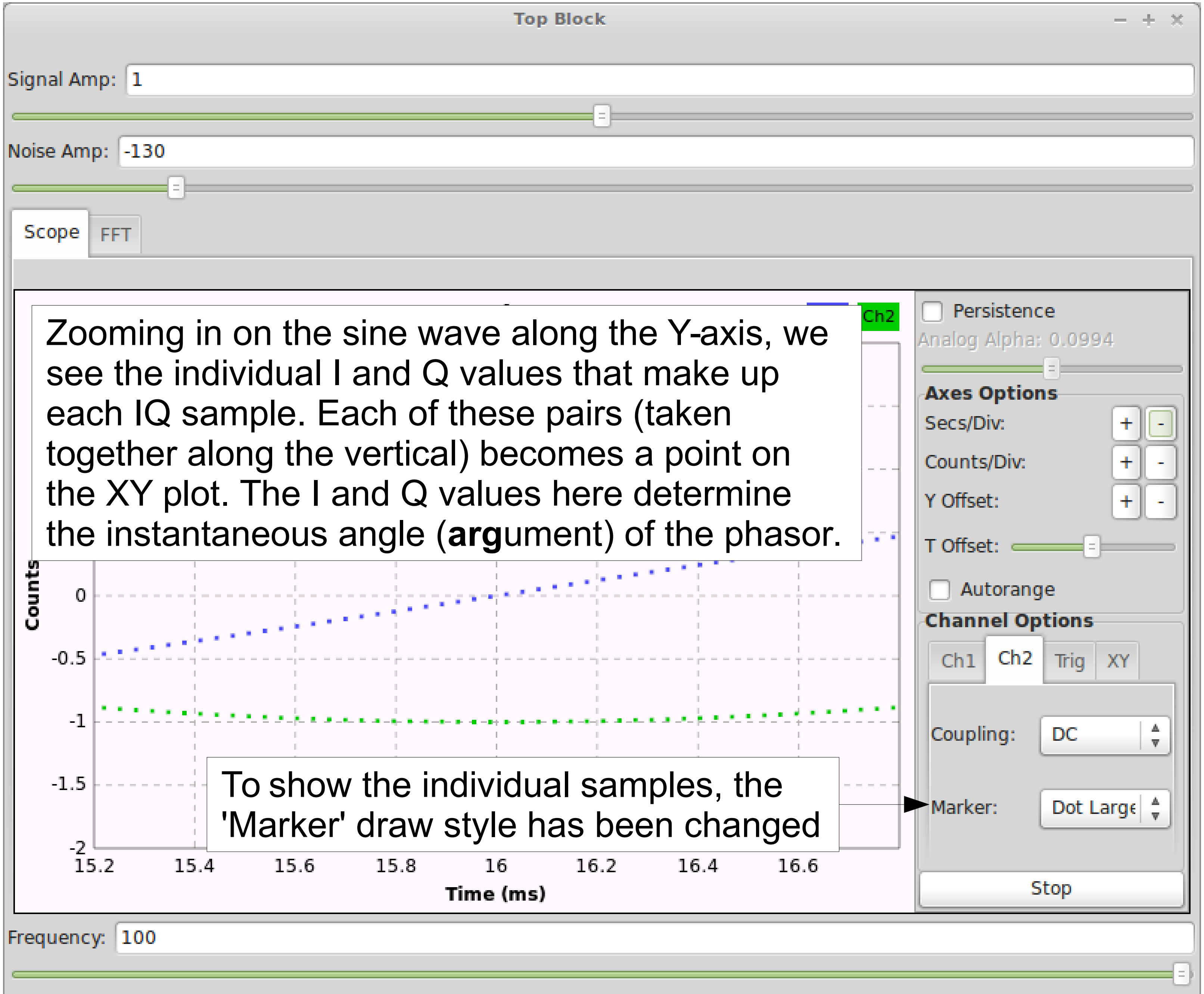
Coupling: DC

Marker: Line Link

Top Block
Scope
FFT
Scope Plot
Ch1
Ch2
2
1.5
1
0.5
0
-0.5
-1
Counts
55
☐ Persistence
Axes Options
Secs/Div:
Counts/Div:
Y Offset:
T Offset:
+
-
☐ Autorange
Channel Options
Ch1
Ch2
Trig
XY
Stop
Freq

To return to normal scope mode, click on any of the other 'Channel Options' tabs.
Here we recall what a quadrature sine wave looks like (Y-axis scale has been adjusted).

Lab 2: XY Mode



Zooming in on the sine wave along the Y-axis, we see the individual I and Q values that make up each IQ sample. Each of these pairs (taken together along the vertical) becomes a point on the XY plot. The I and Q values here determine the instantaneous angle (**arg**ument) of the phasor.

To show the individual samples, the 'Marker' draw style has been changed

Top Block

Signal Amp: 1

Noise Amp: -130

☐ Persistence

Analog Alpha: 0.0994

☐ Autorange

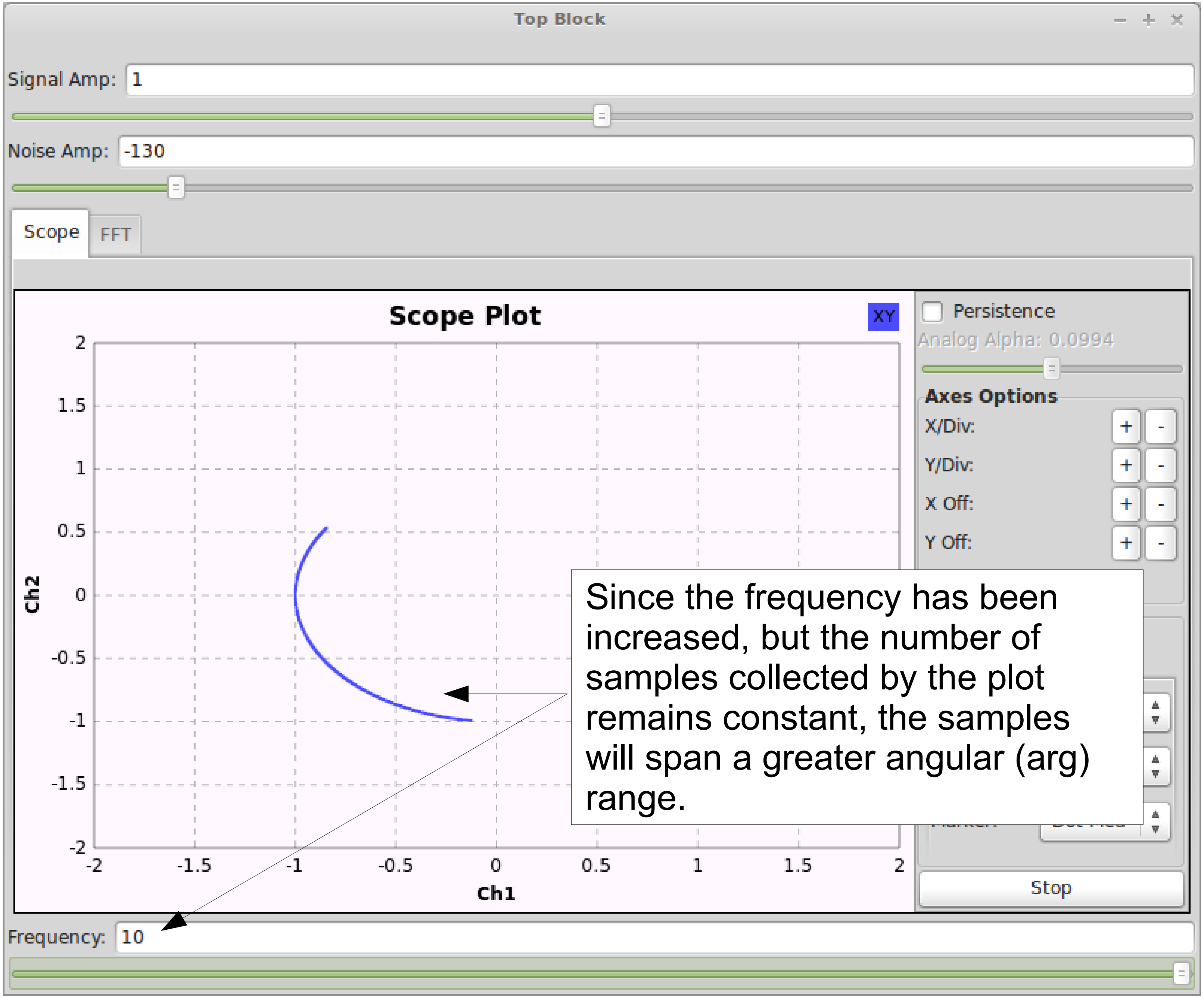
Coupling: DC

Marker: Dot Large

Frequency: 100

Scope
FFT
Ch2
Counts
0
-0.5
-1
-1.5
-2
15.2
15.4
15.6
15.8
16
16.2
16.4
16.6
Time (ms)
Axes Options
Secs/Div:
Counts/Div:
Y Offset:
T Offset:
Channel Options
Ch1
Ch2
Trig
XY
Stop

Lab 2: XY Mode


Top Block
Scope
FFT
Scope Plot
XY
Ch2
Ch1
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Analog Alpha: 0.0994
Axes Options
X/Div:
Y/Div:
X Off:
Y Off:
+
-
Stop

Signal Amp: 1

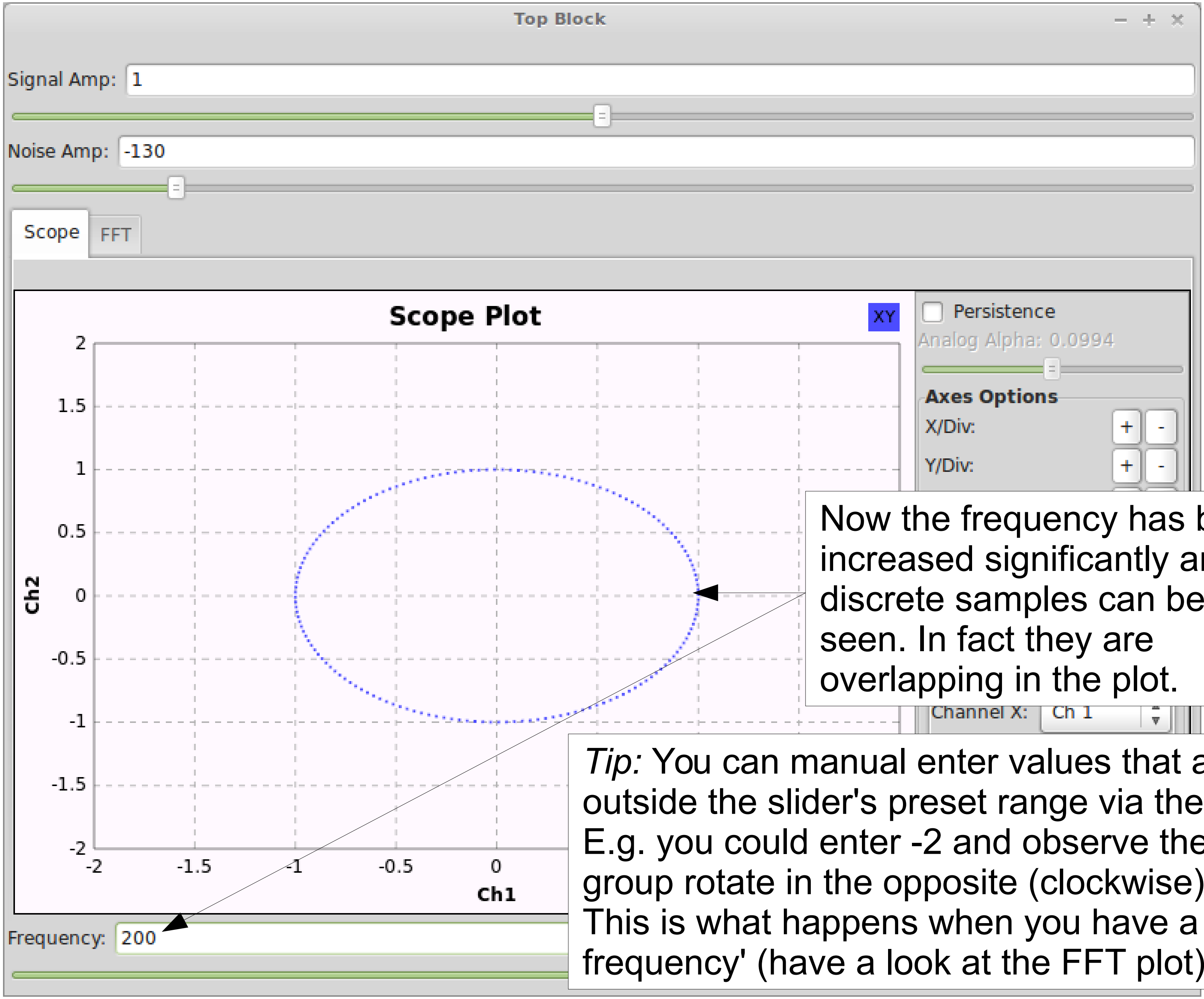
Noise Amp: -130

☐ Persistence

Frequency: 10

Since the frequency has been increased, but the number of samples collected by the plot remains constant, the samples will span a greater angular (arg) range.

Lab 2: XY Mode


Top Block
Scope
FFT
Scope Plot
XY
☐ Persistence
Analog Alpha: 0.0994
Axes Options
X/Div: + -
Y/Div: + -
Ch2
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
Ch1

Signal Amp: 1

Noise Amp: -130

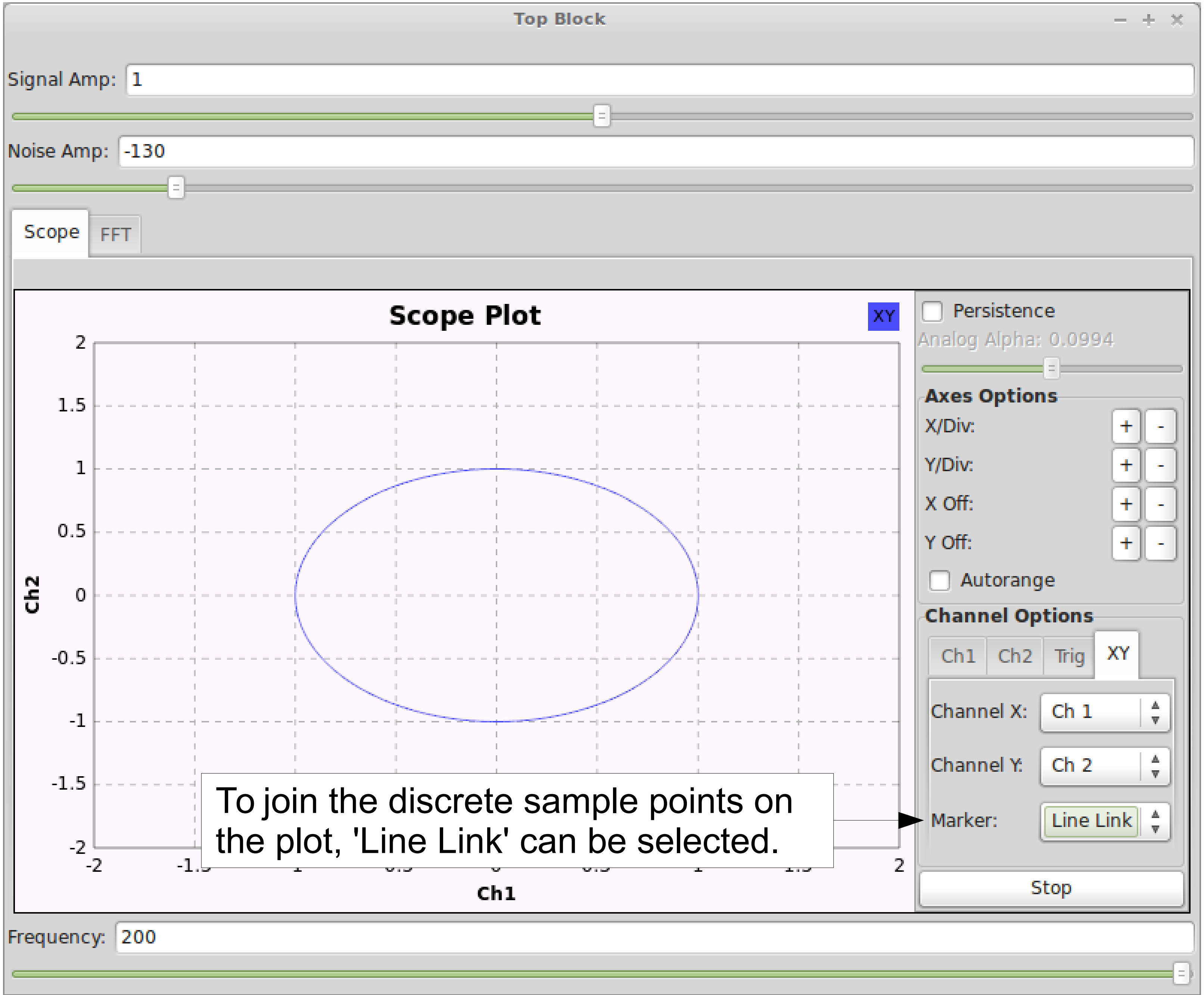
Channel X: Ch 1

Frequency: 200

Now the frequency has been increased significantly and the discrete samples can be seen. In fact they are overlapping in the plot.

Tip: You can manual enter values that are outside the slider's preset range via the text box. E.g. you could enter -2 and observe the sample group rotate in the opposite (clockwise) direction. This is what happens when you have a 'negative frequency' (have a look at the FFT plot).

Lab 2: XY Mode


Top Block
Scope
FFT
Scope Plot
XY
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Ch2
-2
2
Ch1
Persistence
Axes Options
X/Div:
Y/Div:
X Off:
Y Off:
Autorange
Channel Options
Ch1
Ch2
Trig
XY
Stop

Signal Amp: 1

Noise Amp: -130

Analog Alpha: 0.0994

Channel X: Ch 1

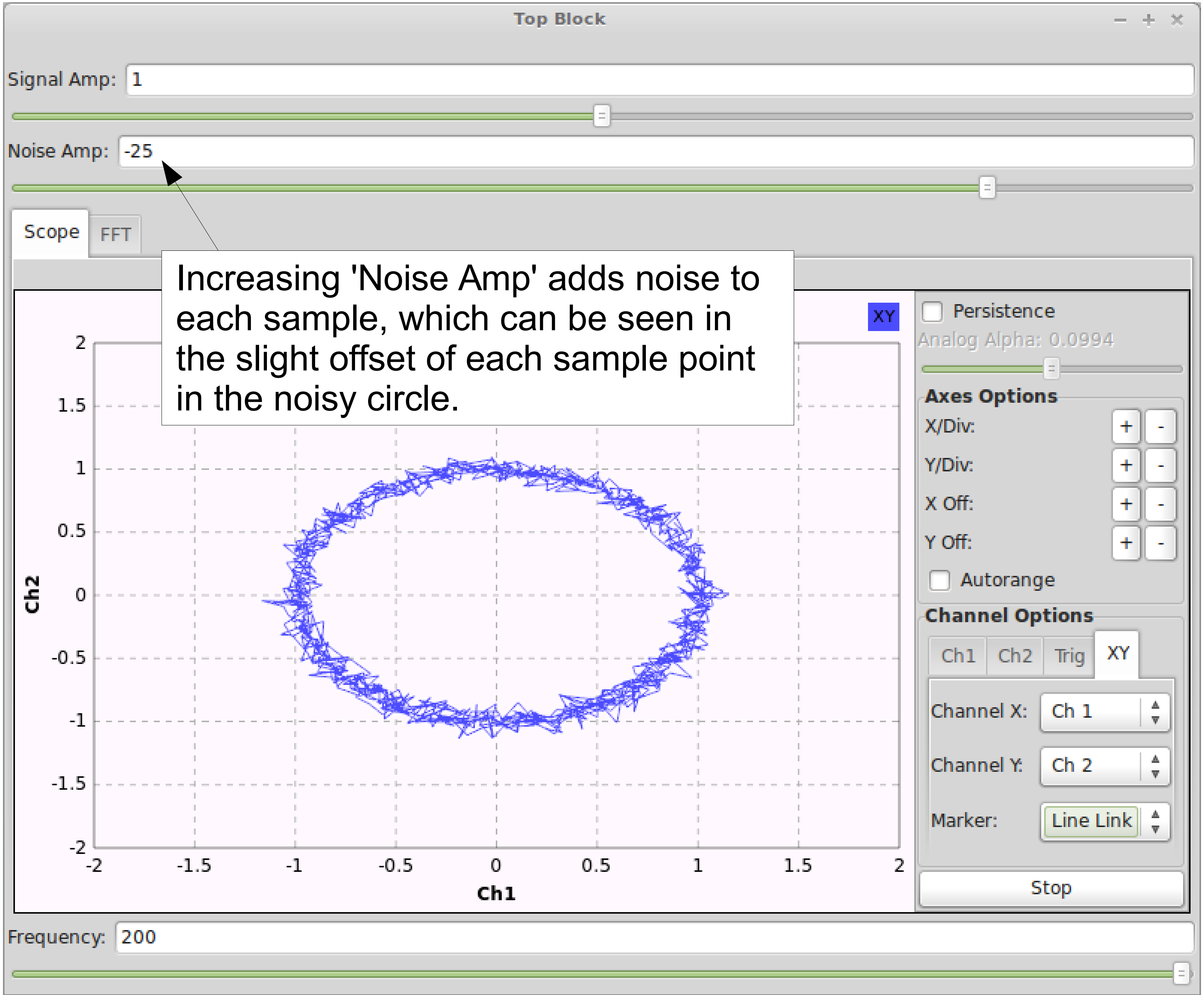
Channel Y: Ch 2

Marker: Line Link

Frequency: 200

To join the discrete sample points on the plot, 'Line Link' can be selected.

Lab 2: XY Mode


Top Block
Scope
FFT
XY
Ch2
Ch1
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
☐ Persistence
Axes Options
X/Div:
Y/Div:
X Off:
Y Off:
+
-
☐ Autorange
Channel Options
Ch1
Ch2
Trig
XY
Stop

Signal Amp: 1

Noise Amp: -25

Analog Alpha: 0.0994

Channel X: Ch 1

Channel Y: Ch 2

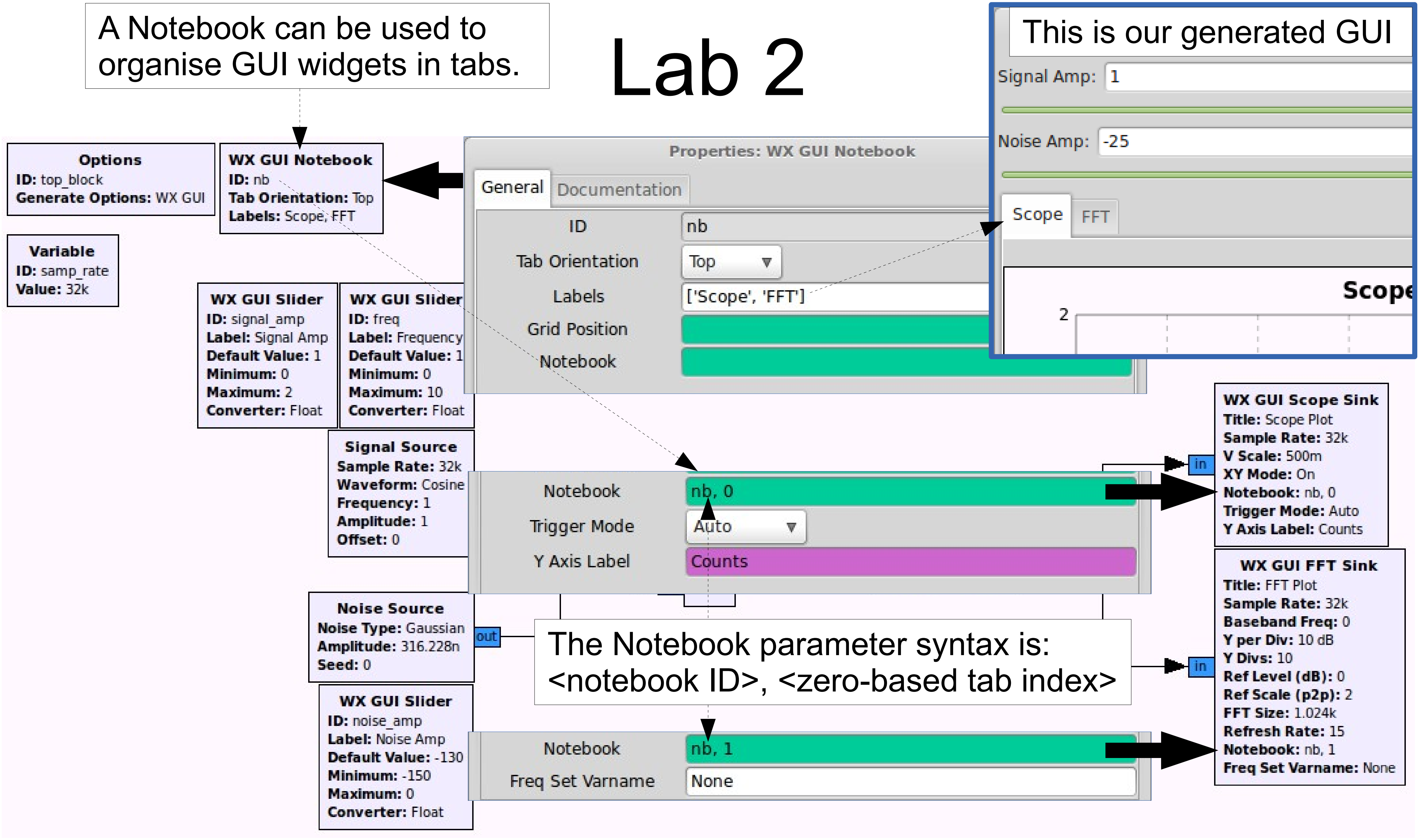
Marker: Line Link

Frequency: 200

Increasing 'Noise Amp' adds noise to each sample, which can be seen in the slight offset of each sample point in the noisy circle.

Lab 2

A Notebook can be used to organise GUI widgets in tabs.



This is our generated GUI

Signal Amp: 1

Noise Amp: -25

Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Notebook
ID: nb
Tab Orientation: Top
Labels: Scope, FFT

Properties: WX GUI Notebook

ID	nb
Tab Orientation	Top
Labels	['Scope', 'FFT']
Grid Position	
Notebook	

WX GUI Slider
ID: signal_amp
Label: Signal Amp
Default Value: 1
Minimum: 0
Maximum: 2
Converter: Float

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1
Minimum: 0
Maximum: 10
Converter: Float

Signal Source
Sample Rate: 32k
Waveform: Cosine
Frequency: 1
Amplitude: 1
Offset: 0

Notebook	nb, 0
Trigger Mode	Auto
Y Axis Label	Counts

Noise Source
Noise Type: Gaussian
Amplitude: 316.228n
Seed: 0

WX GUI Slider
ID: noise_amp
Label: Noise Amp
Default Value: -130
Minimum: -150
Maximum: 0
Converter: Float

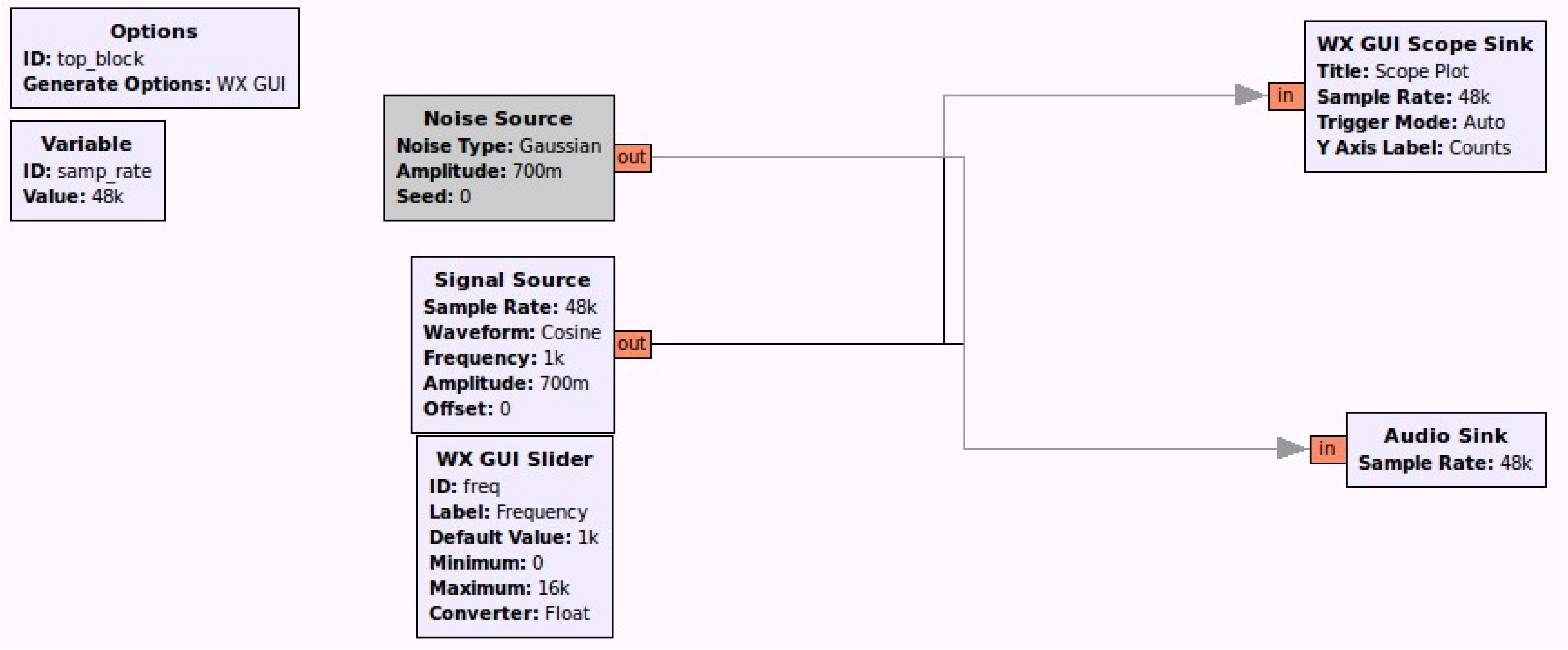
The Notebook parameter syntax is:
<notebook ID>, <zero-based tab index>

Notebook	nb, 1
Freq Set Varname	None

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 32k
V Scale: 500m
XY Mode: On
Notebook: nb, 0
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 32k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Notebook: nb, 1
Freq Set Varname: None

Lab 3: Audio



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 48k

Noise Source
Noise Type: Gaussian
Amplitude: 700m
Seed: 0

Signal Source
Sample Rate: 48k
Waveform: Cosine
Frequency: 1k
Amplitude: 700m
Offset: 0

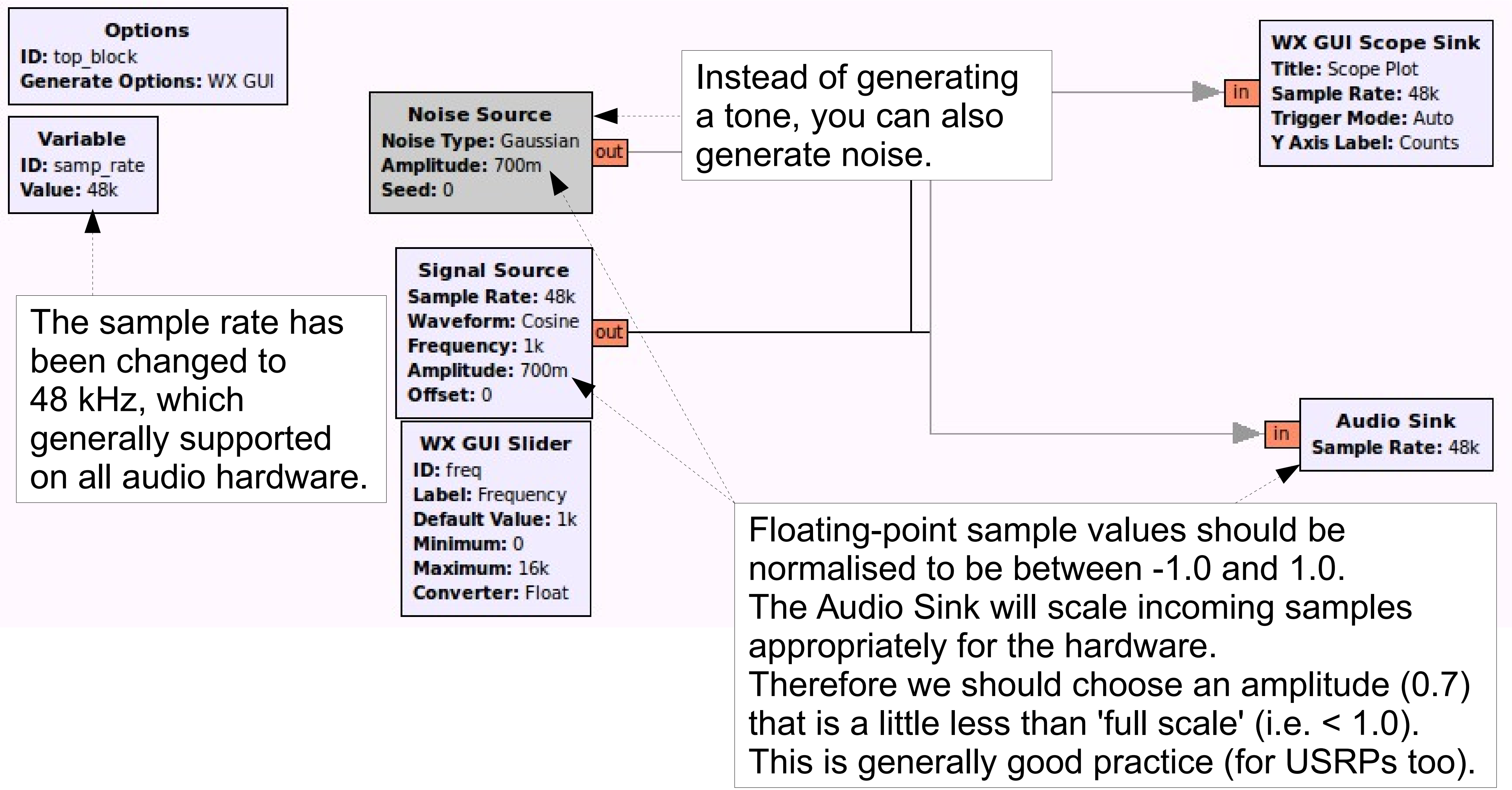
WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
Trigger Mode: Auto
Y Axis Label: Counts

Audio Sink
Sample Rate: 48k

Output a single tone from the computer's soundcard

Lab 3: Audio



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 48k

Noise Source
Noise Type: Gaussian
Amplitude: 700m
Seed: 0

Signal Source
Sample Rate: 48k
Waveform: Cosine
Frequency: 1k
Amplitude: 700m
Offset: 0

WX GUI Slider
ID: freq
Label: Frequency
Default Value: 1k
Minimum: 0
Maximum: 16k
Converter: Float

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
Trigger Mode: Auto
Y Axis Label: Counts

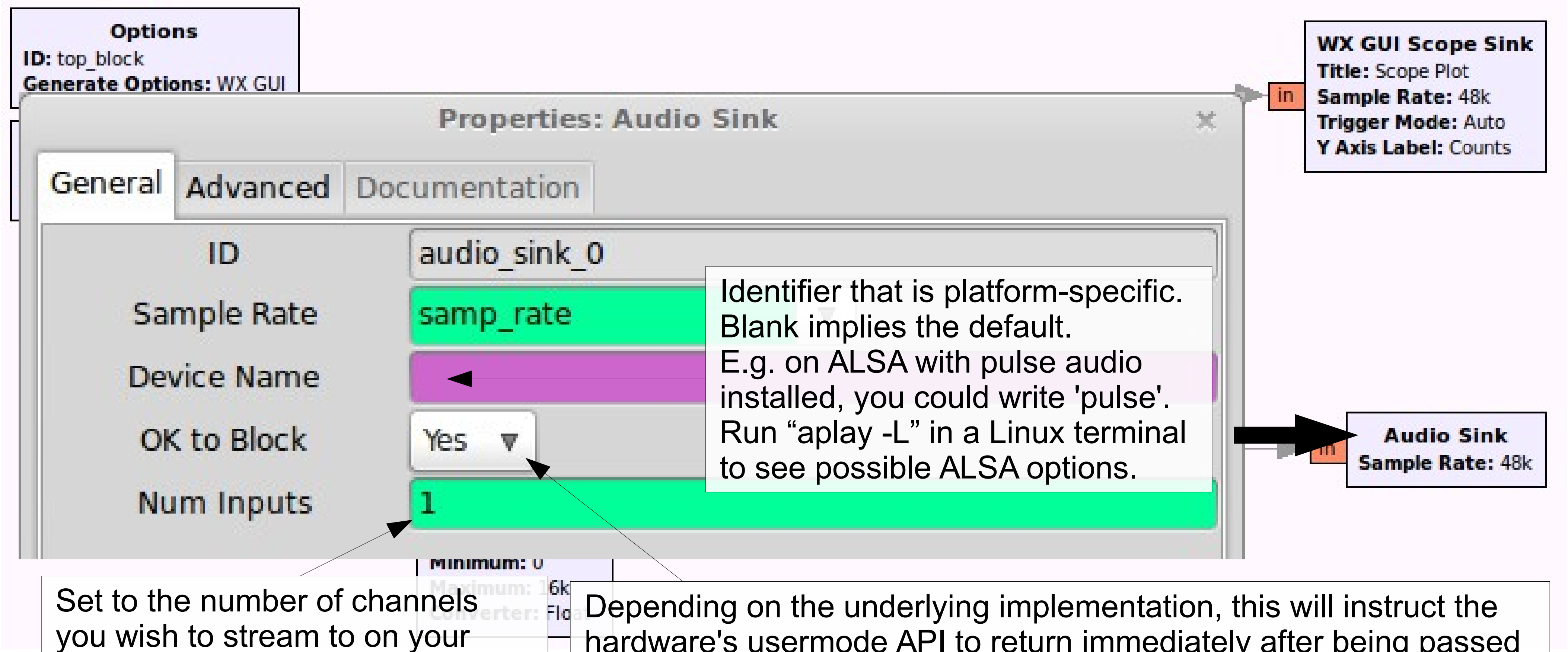
Audio Sink
Sample Rate: 48k

Instead of generating a tone, you can also generate noise.

The sample rate has been changed to 48 kHz, which generally supported on all audio hardware.

Floating-point sample values should be normalised to be between -1.0 and 1.0.
The Audio Sink will scale incoming samples appropriately for the hardware.
Therefore we should choose an amplitude (0.7) that is a little less than 'full scale' (i.e. < 1.0).
This is generally good practice (for USRPs too).

Lab 3: Audio



Options
ID: top_block
Generate Options: WX GUI

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
Trigger Mode: Auto
Y Axis Label: Counts

Properties: Audio Sink

ID: audio_sink_0
Sample Rate: samp_rate
Device Name:
OK to Block: Yes
Num Inputs: 1

Minimum: 0
Maximum: 16k
Converter: Flo

Audio Sink
Sample Rate: 48k

Identifier that is platform-specific.
Blank implies the default.
E.g. on ALSA with pulse audio installed, you could write 'pulse'.
Run “aplay -L” in a Linux terminal to see possible ALSA options.

Set to the number of channels you wish to stream to on your audio hardware (e.g. 2 for stereo)

Depending on the underlying implementation, this will instruct the hardware's usermode API to return immediately after being passed a buffer of audio samples (non-blocking mode), or wait until they are consumed (blocking mode).
See next page for details.

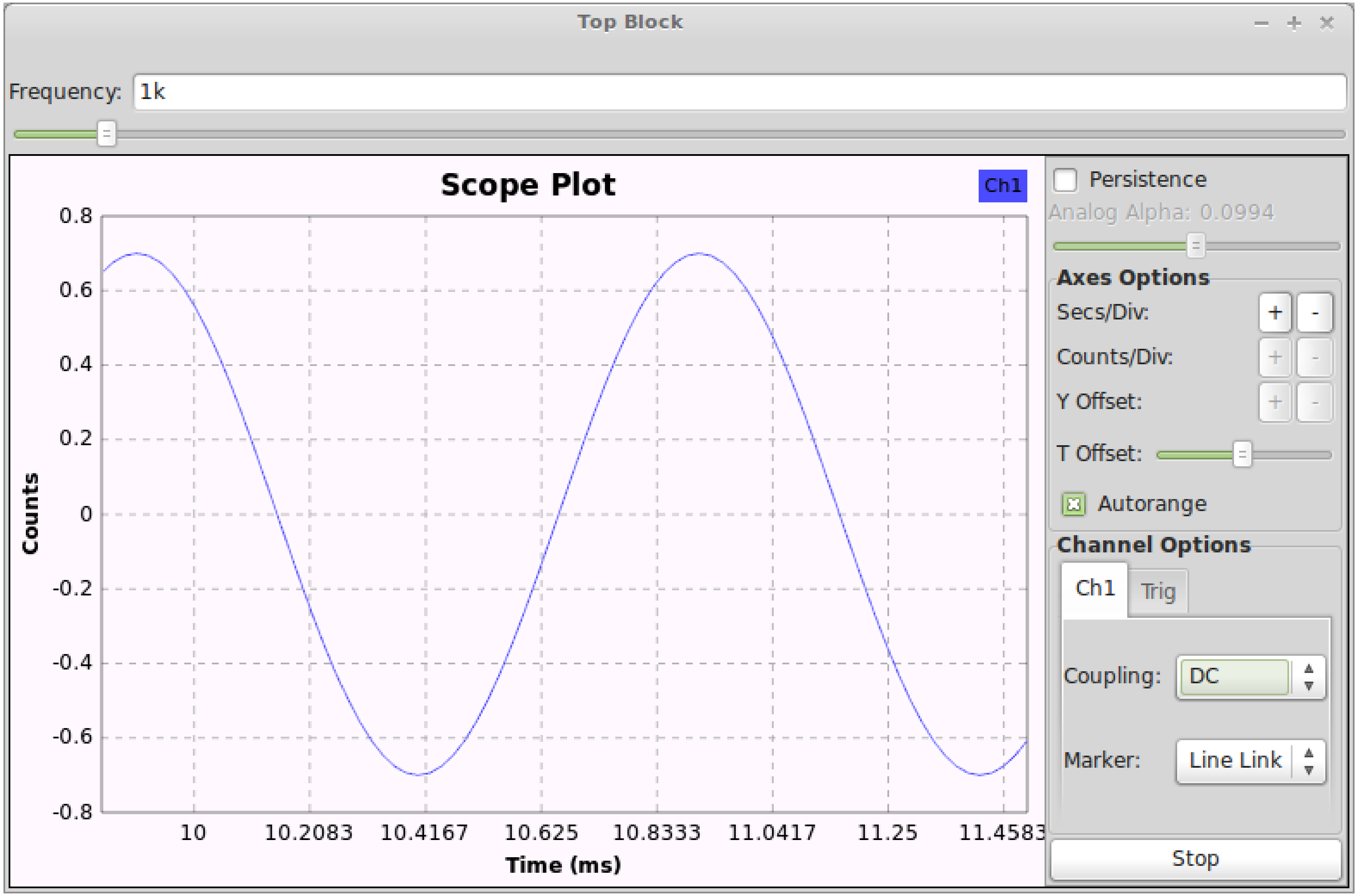
Lab 3: Audio

- Blocking mode ('OK to Block') will apply upstream backpressure, which is good when the Audio Sink is the only hardware device in the flowgraph.
- This can be problematic if the flowgraph source is, for example, a USRP. The source is then also hardware that has its own internal clock and will be throttling the sample production rate while the Audio Sink is throttling consumption with its own unsynchronised clock. This is called the '*two clock*' problem.

Lab 3: Audio

- To workaround this two clock problem, set the Audio Sink to non-blocking mode (*not* 'OK to Block') so that it will never hold up the flowgraph (i.e. not apply backpressure). It will consume samples as normal, but if there is ever an excess (e.g. the USRP is producing samples a little faster than the Audio Sink can consume) it will drop the samples (might cause audio glitches).
- This does not solve the case where samples are being produced *slower* than the Audio Sink's consumption rate (this will produce an underrun: audio will sound choppy and 'aU' will be printed).

Lab 3: Audio



Frequency: 1k

☐ Persistence

Analog Alpha: 0.0994

☒ Autorange

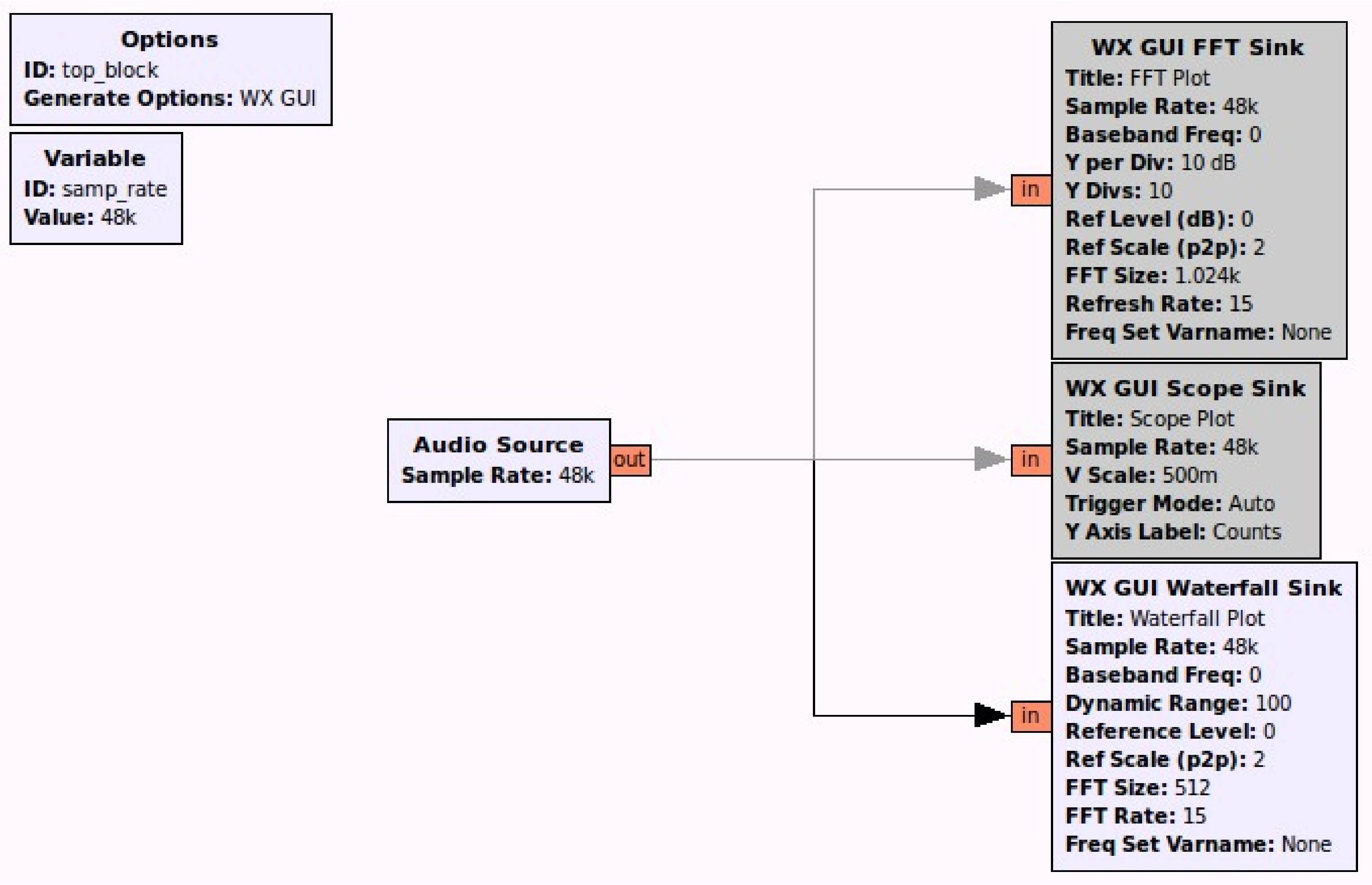
Coupling: DC

Marker: Line Link

Top Block
Scope Plot
Ch1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Counts
10
10.2083
10.4167
10.625
10.8333
11.0417
11.25
11.4583
Time (ms)
Axes Options
Secs/Div:
Counts/Div:
Y Offset:
T Offset:
Channel Options
Ch1
Trig
Stop

Same sine wave as before, but now we hear it emanating from the computer's speakers.

Lab 3: Audio



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 48k

Audio Source
Sample Rate: 48k

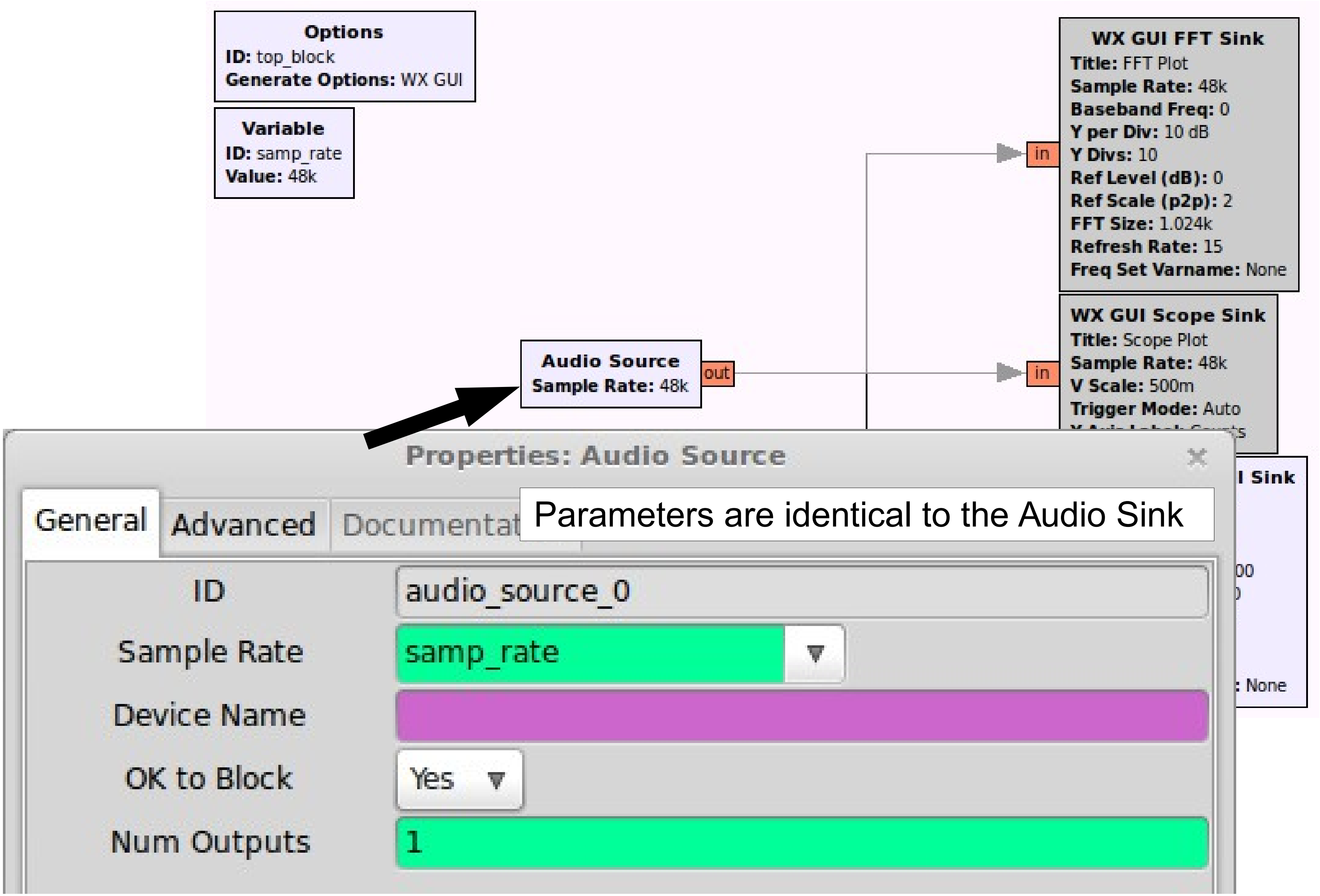
WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 500m
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI Waterfall Sink
Title: Waterfall Plot
Sample Rate: 48k
Baseband Freq: 0
Dynamic Range: 100
Reference Level: 0
Ref Scale (p2p): 2
FFT Size: 512
FFT Rate: 15
Freq Set Varname: None

Visualise the audio sampled by a soundcard on a time-based scrolling FFT (waterfall/spectrogram).

Lab 3: Audio



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 48k

Audio Source
Sample Rate: 48k

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

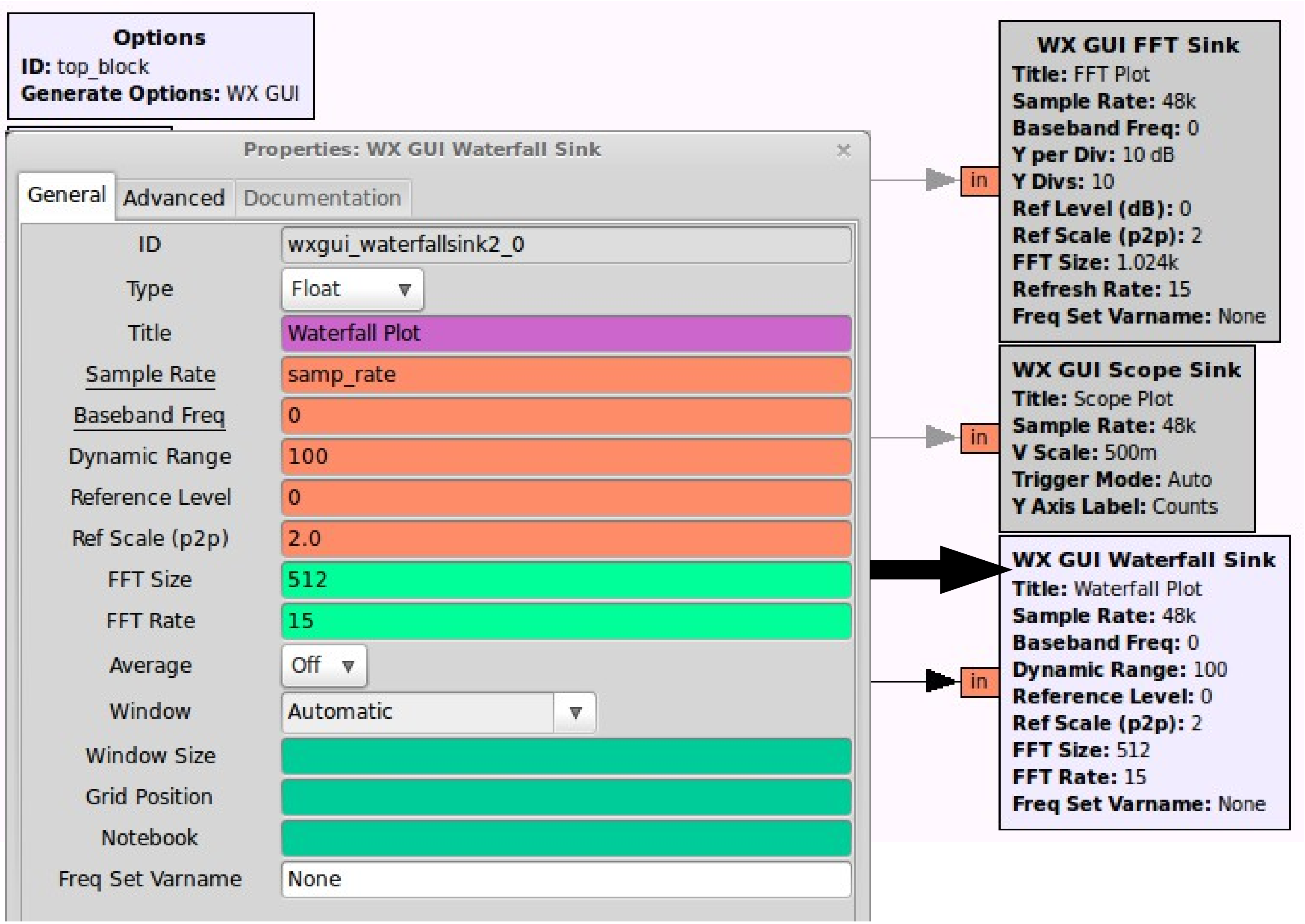
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 500m
Trigger Mode: Auto

Properties: Audio Source

Parameters are identical to the Audio Sink

ID: audio_source_0
Sample Rate: samp_rate
Device Name:
OK to Block: Yes
Num Outputs: 1

Lab 3: Audio



Options
ID: top_block
Generate Options: WX GUI

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

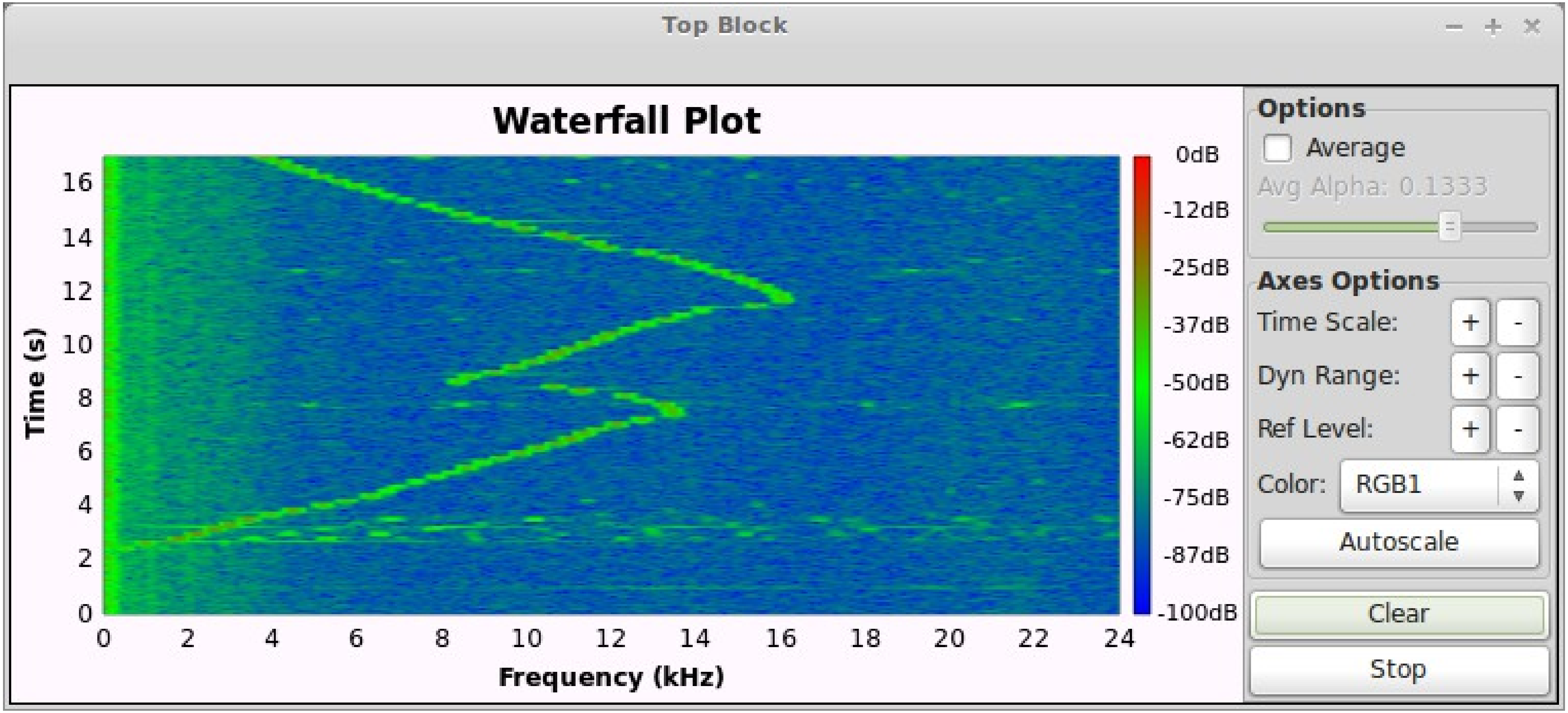
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 500m
Trigger Mode: Auto
Y Axis Label: Counts

WX GUI Waterfall Sink
Title: Waterfall Plot
Sample Rate: 48k
Baseband Freq: 0
Dynamic Range: 100
Reference Level: 0
Ref Scale (p2p): 2
FFT Size: 512
FFT Rate: 15
Freq Set Varname: None

ID	wxgui_waterfallsink2_0
Type	Float
Title	Waterfall Plot
Sample Rate	samp_rate
Baseband Freq	0
Dynamic Range	100
Reference Level	0
Ref Scale (p2p)	2.0
FFT Size	512
FFT Rate	15
Average	Off
Window	Automatic
Window Size	
Grid Position	
Notebook	
Freq Set Varname	None

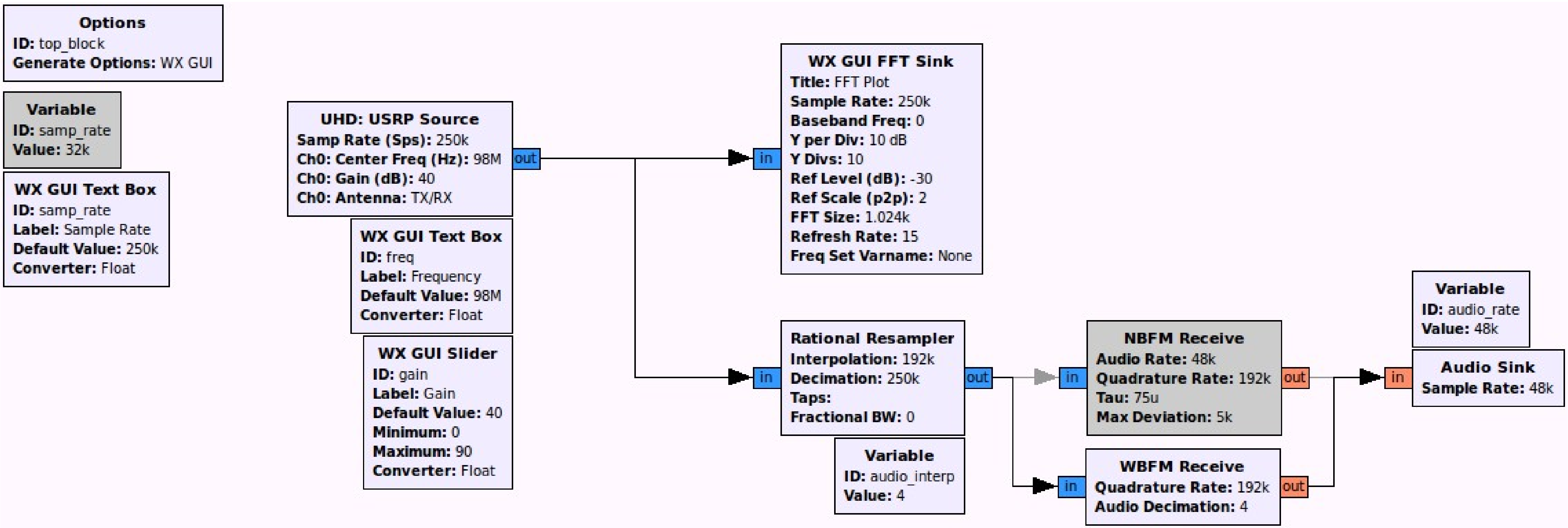
Parameters are identical to the FFT Sink

Lab 3: Audio


Top Block
Waterfall Plot
Time (s)
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Frequency (kHz)
0dB
-12dB
-25dB
-37dB
-50dB
-62dB
-75dB
-87dB
-100dB
Options
☐ Average
Avg Alpha: 0.1333
Axes Options
Time Scale: + -
Dyn Range: + -
Ref Level: + -
Color: RGB1
Autoscale
Clear
Stop

Running the sine wave generator program at the same time, and changing the frequency. This is a rough 'loopback' test where the computer's microphone listens to its speakers.

Lab 4: FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): -30
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 192k
Decimation: 250k
Taps:
Fractional BW: 0

Variable
ID: audio_interp
Value: 4

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

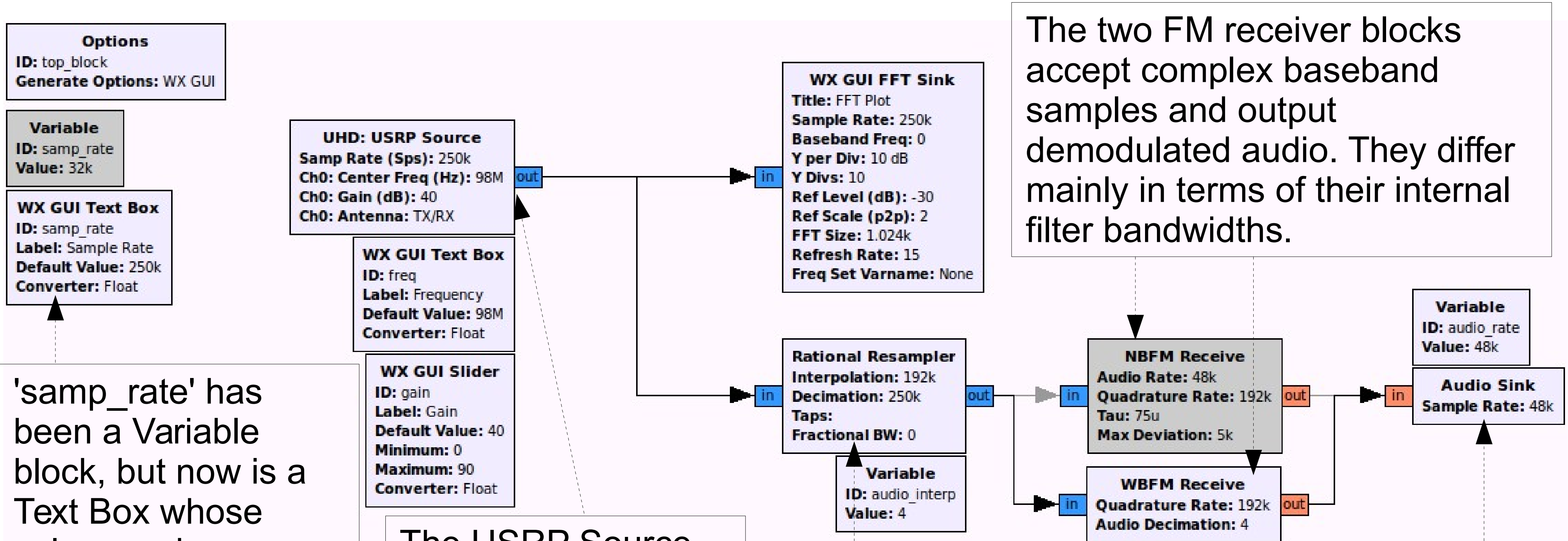
WBFM Receive
Quadrature Rate: 192k
Audio Decimation: 4

Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

Receive a baseband signal using a USRP and listen to it using a narrow- or wide-band FM demodulator

Lab 4: FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): -30
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 192k
Decimation: 250k
Taps:
Fractional BW: 0

Variable
ID: audio_interp
Value: 4

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

WBFM Receive
Quadrature Rate: 192k
Audio Decimation: 4

Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

The two FM receiver blocks accept complex baseband samples and output demodulated audio. They differ mainly in terms of their internal filter bandwidths.

'samp_rate' has been a Variable block, but now is a Text Box whose value can be changed at runtime

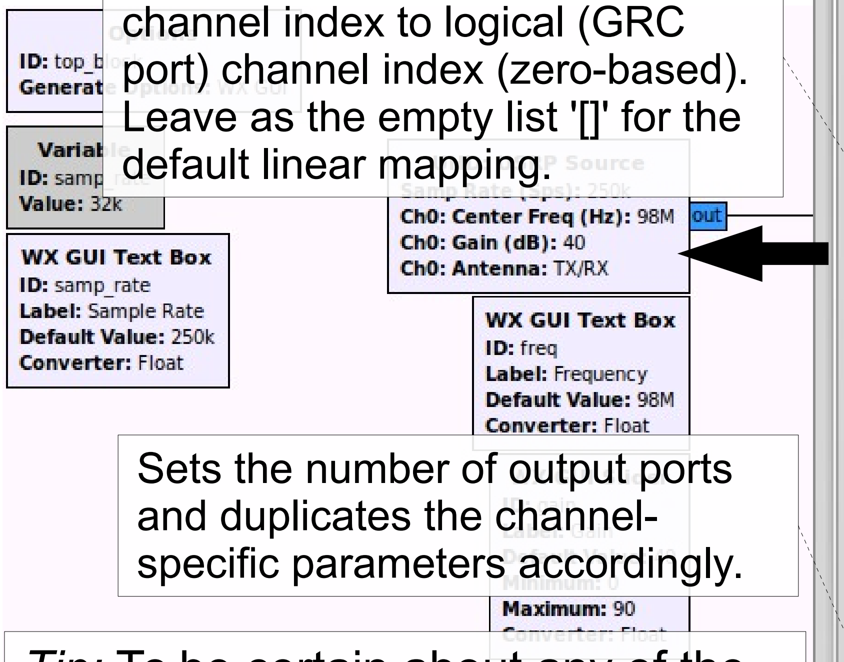
The USRP Source block will produce baseband samples by sampling RF on a selected antenna at a particular frequency, sample rate and gain

A Rational Resampler will adapt the notional rate of a stream by interpolating/decimating overall, as needed.
This is necessary here because USRP rates are not integer multiples of Audio Sink rates.

Disable 'OK to Block' to work around 'two clock' problem

Lab 4: FM RX

Tip: usually all parameters can be left as they are (except for sample rate, frequency, gain and antenna).



ID: top_b

Generat

Variab
ID: samp
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

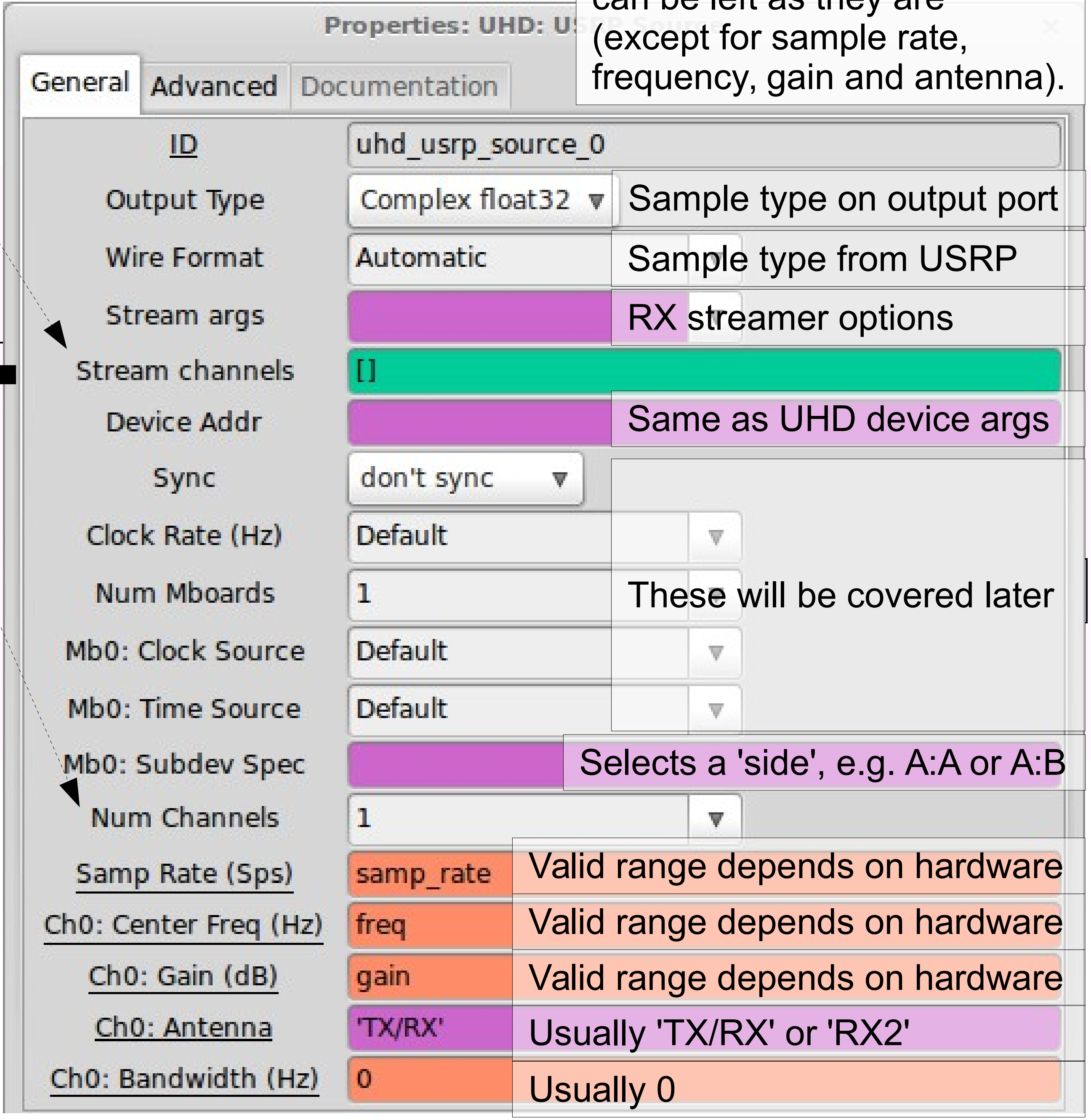
WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

Maximum: 90

Mapping from physical (USRP) channel index to logical (GRC port) channel index (zero-based). Leave as the empty list '[]' for the default linear mapping.

Sets the number of output ports and duplicates the channel-specific parameters accordingly.

Tip: To be certain about any of the possble parameter values, consult the online documentation for your device and/or daughterboard. You can also run 'uhd_usrp_probe' in a terminal for hardware specs. Watch your console during runtime for any warning messages from UHD regarding invalid settings!

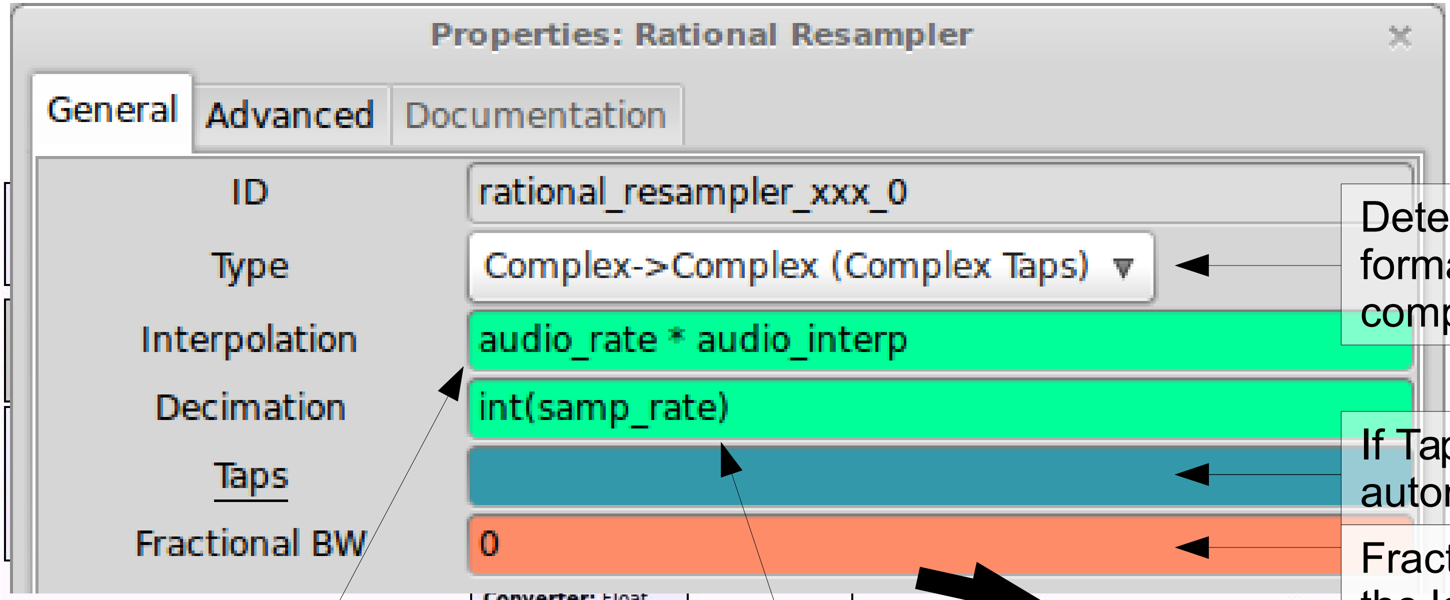


ID	uhd_usrp_source_0	
Output Type	Complex float32 ▼	Sample type on output port
Wire Format	Automatic	Sample type from USRP
Stream args		RX streamer options
Stream channels	[]	
Device Addr		Same as UHD device args
Sync	don't sync ▼	
Clock Rate (Hz)	Default ▼	These will be covered later
Num Mboards	1	
Mb0: Clock Source	Default ▼	
Mb0: Time Source	Default ▼	
Mb0: Subdev Spec		Selects a 'side', e.g. A:A or A:B
Num Channels	1 ▼	
Samp Rate (Sps)	samp_rate	Valid range depends on hardware
Ch0: Center Freq (Hz)	freq	Valid range depends on hardware
Ch0: Gain (dB)	gain	Valid range depends on hardware
Ch0: Antenna	'TX/RX'	Usually 'TX/RX' or 'RX2'
Ch0: Bandwidth (Hz)	0	Usually 0

Lab 4: FM RX

- This example uses the USRP B200
- Valid ranges:
  - Antenna: TX/RX, RX2
  - Frequency: 70 MHz – 6 GHz
  - RX Gain: 0 – 73 (default of ~25 is a good starting point)
  - Sample Rate: 62.5 ksps – 56 Msps (62.5e3 - 56e6)
    - Default **M**aster **C**lock **R**ate = 32e6 (max: 61.44e6)
    - (MCR / sample rate) **must** be an integer, and **should** be divisible by 4 for the best RF performance (flat spectrum)
    - MCR can be changed with “master_clock_rate=X” in Device Addr, where X is new MCR in Hz (e.g. 40e6)
- A 'O' on the console indicates an overrun, and occurs when the host is not able to consume samples quickly enough.

Lab 4: FM RX



ID: rational_resampler_xxx_0
Type: Complex->Complex (Complex Taps)
Interpolation: audio_rate * audio_interp
Decimation: int(samp_rate)
Taps:
Fractional BW: 0

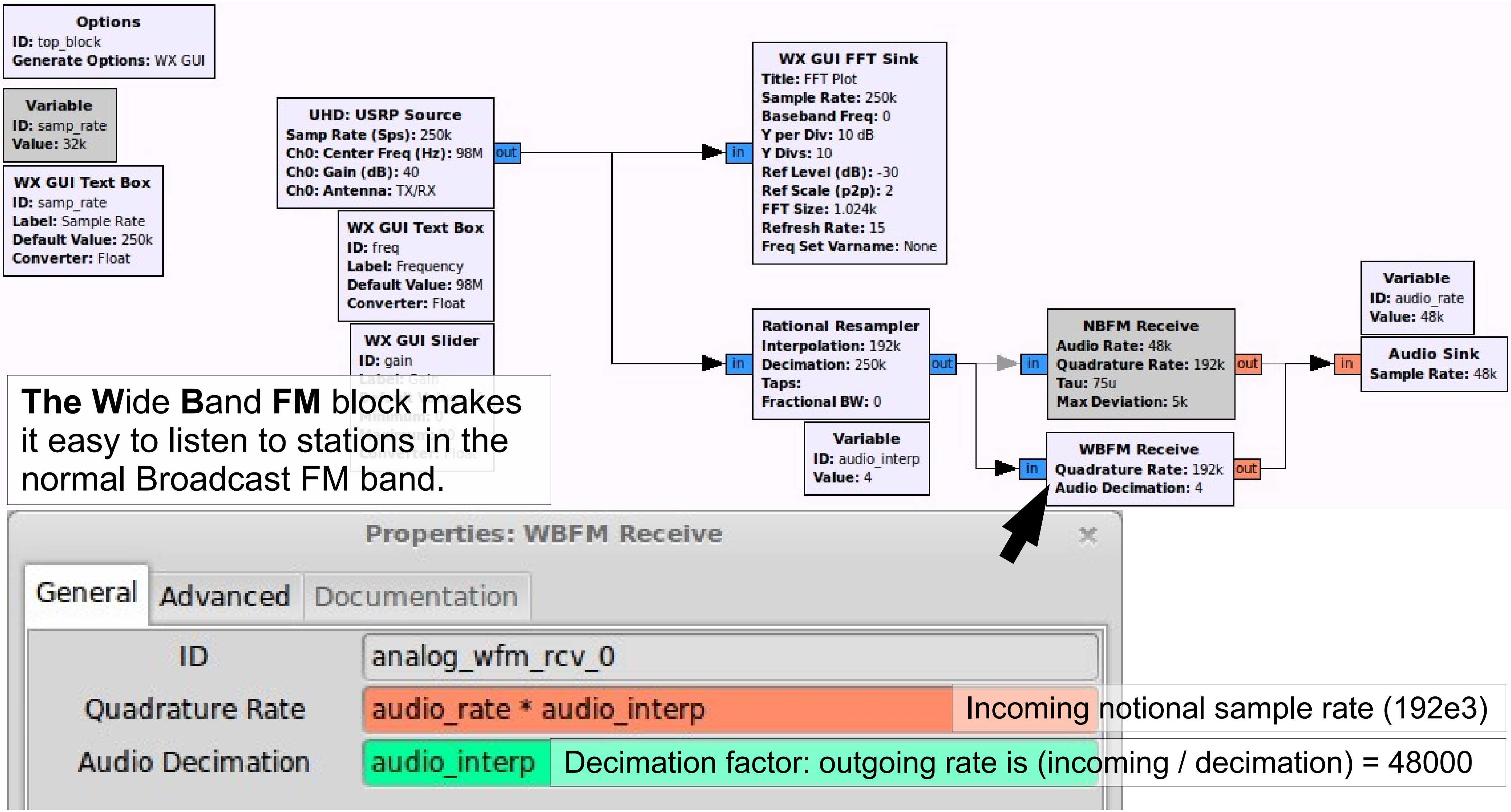
Determine the input & output sample format, and what format (real or complex) the filter taps will be

If Taps is left blank, the taps are automatically computed

Fractional BW affects the shape of the low-pass filter that is generated when no filter taps are supplied. Specifically it determines how steep the low-pass rolloff is. Leaving the default 0 tells the code to select a reasonable default (currently 0.4)

We need to adapt the USRP rate to something suitable for the Audio Sink. The default 'samp_rate' value is 250e3, which sets the rate at which the USRP produces samples. The Audio Sink is configured for a sample (consumption) rate of 48e3, but (250000 / 48000) is not an integer. We can cheat here and set Decimation to be the incoming notional sample rate (250000), and the Interpolation to be a different (non-divisible) outgoing notional sample rate (192000*). The code will calculate the GCD. Since the parameters must be integers, and 'samp_rate' is a floating-point number, we use the Python function 'int' to convert it to an integer.
* 'audio_rate' is multiplied by 4 ('audio_interp') because the demodulator blocks will perform additional decimation (by 4). Specifically the WBFM block should be given a high rate (i.e. high bandwidth signal since FM broadcast channels are 200 kHz wide).

Lab 4: FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: [illegible]
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): -30
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 192k
Decimation: 250k
Taps:
Fractional BW: 0

Variable
ID: audio_interp
Value: 4

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

WBFM Receive
Quadrature Rate: 192k
Audio Decimation: 4

Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

The Wide **B**and **FM** block makes it easy to listen to stations in the normal Broadcast FM band.

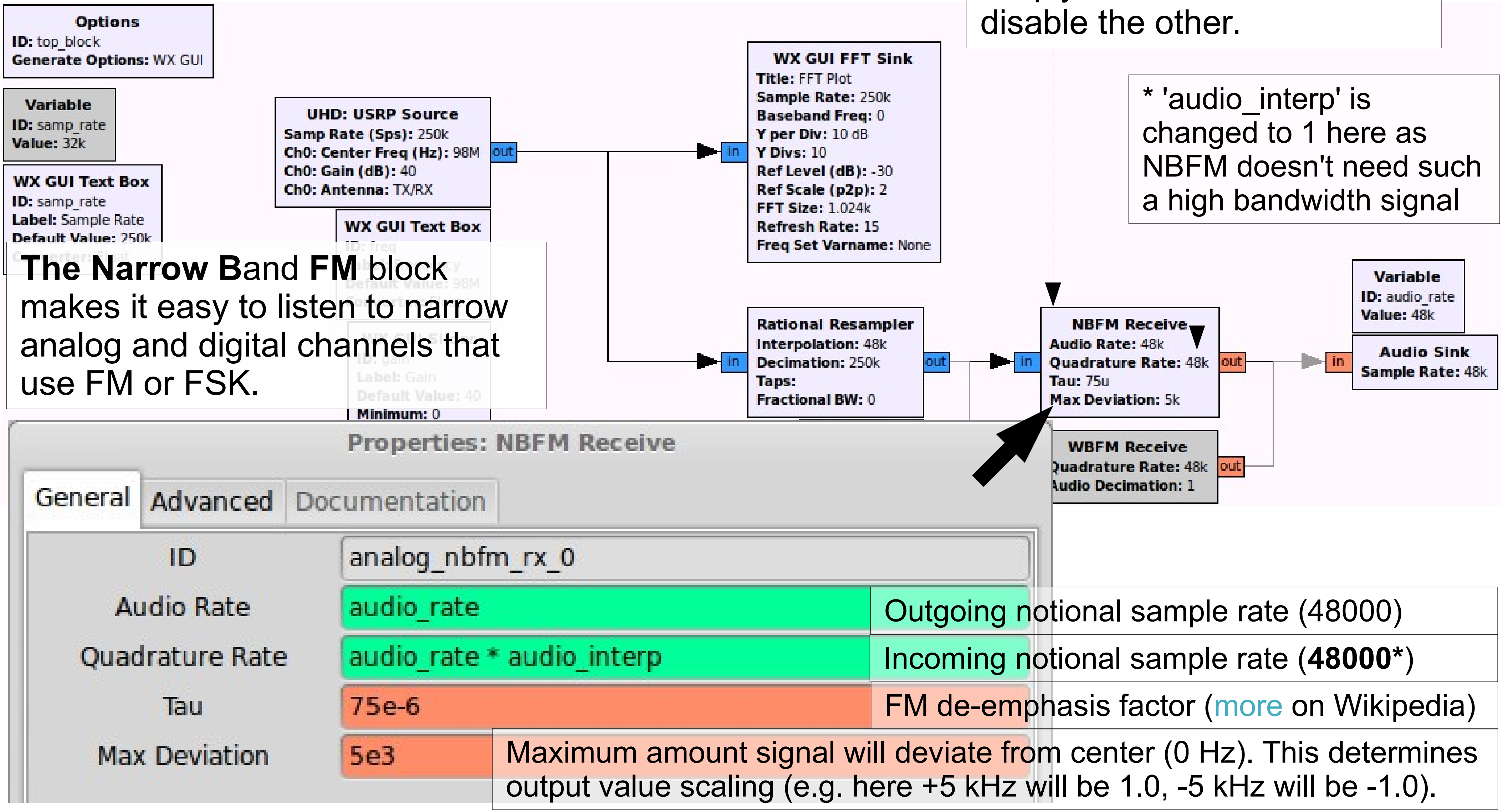
Properties: WBFM Receive

ID: analog_wfm_rcv_0
Quadrature Rate: audio_rate * audio_interp
Audio Decimation: audio_interp

Incoming notional sample rate (192e3)

Decimation factor: outgoing rate is (incoming / decimation) = 48000

Lab 4: FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): -30
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 48k
Decimation: 250k
Taps:
Fractional BW: 0

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 48k
Tau: 75u
Max Deviation: 5k

WBFM Receive
Quadrature Rate: 48k
Audio Decimation: 1

Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

To switch between modulators in this example, simply enable one block and disable the other.

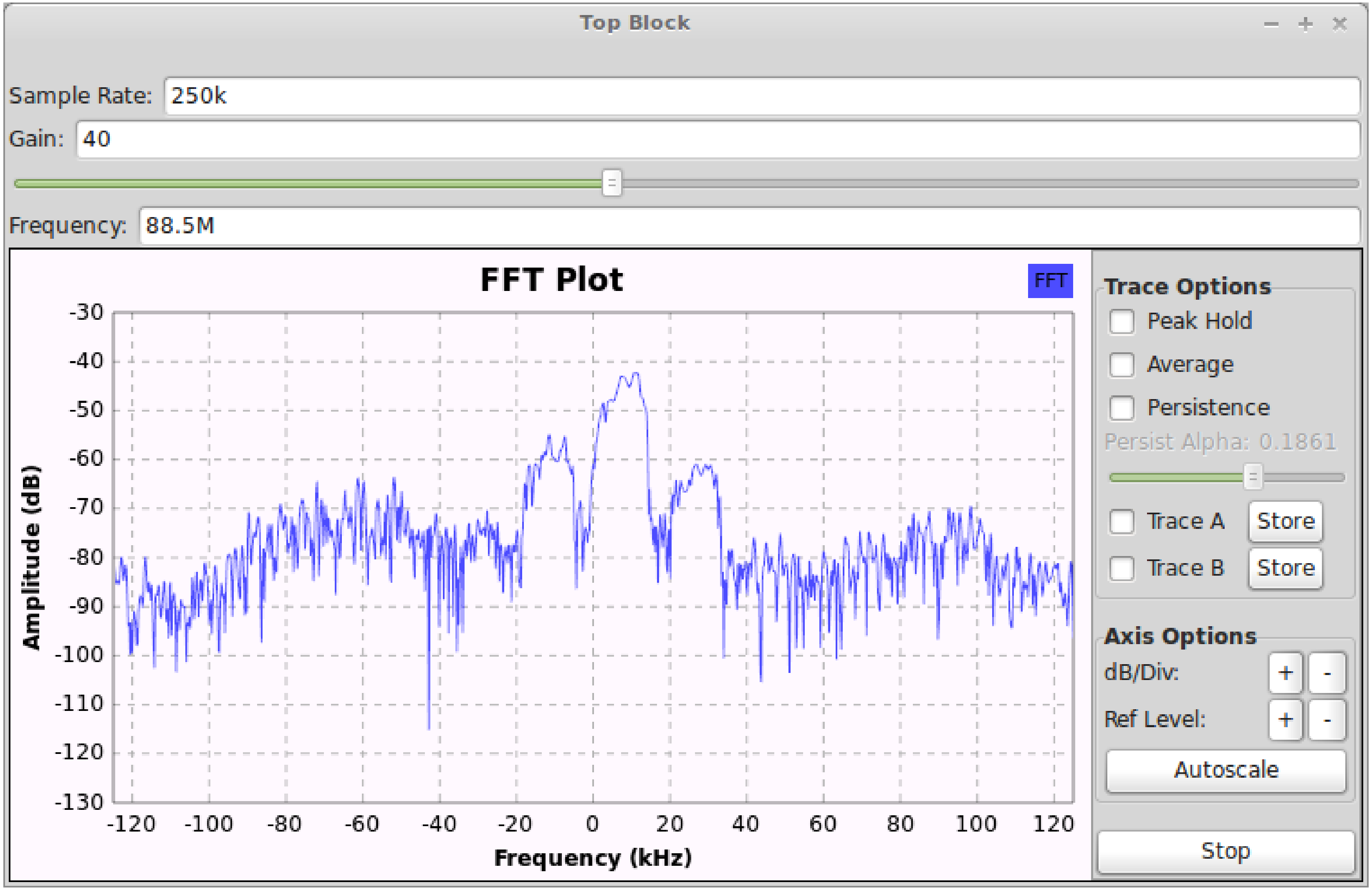
* 'audio_interp' is changed to 1 here as NBFM doesn't need such a high bandwidth signal

The Narrow Band **FM** block makes it easy to listen to narrow analog and digital channels that use FM or FSK.

Properties: NBFM Receive

ID	analog_nbfm_rx_0	
Audio Rate	audio_rate	Outgoing notional sample rate (48000)
Quadrature Rate	audio_rate * audio_interp	Incoming notional sample rate (**48000***)
Tau	75e-6	FM de-emphasis factor (more on Wikipedia)
Max Deviation	5e3	Maximum amount signal will deviate from center (0 Hz). This determines output value scaling (e.g. here +5 kHz will be 1.0, -5 kHz will be -1.0).

Lab 4: FM RX



Sample Rate: 250k

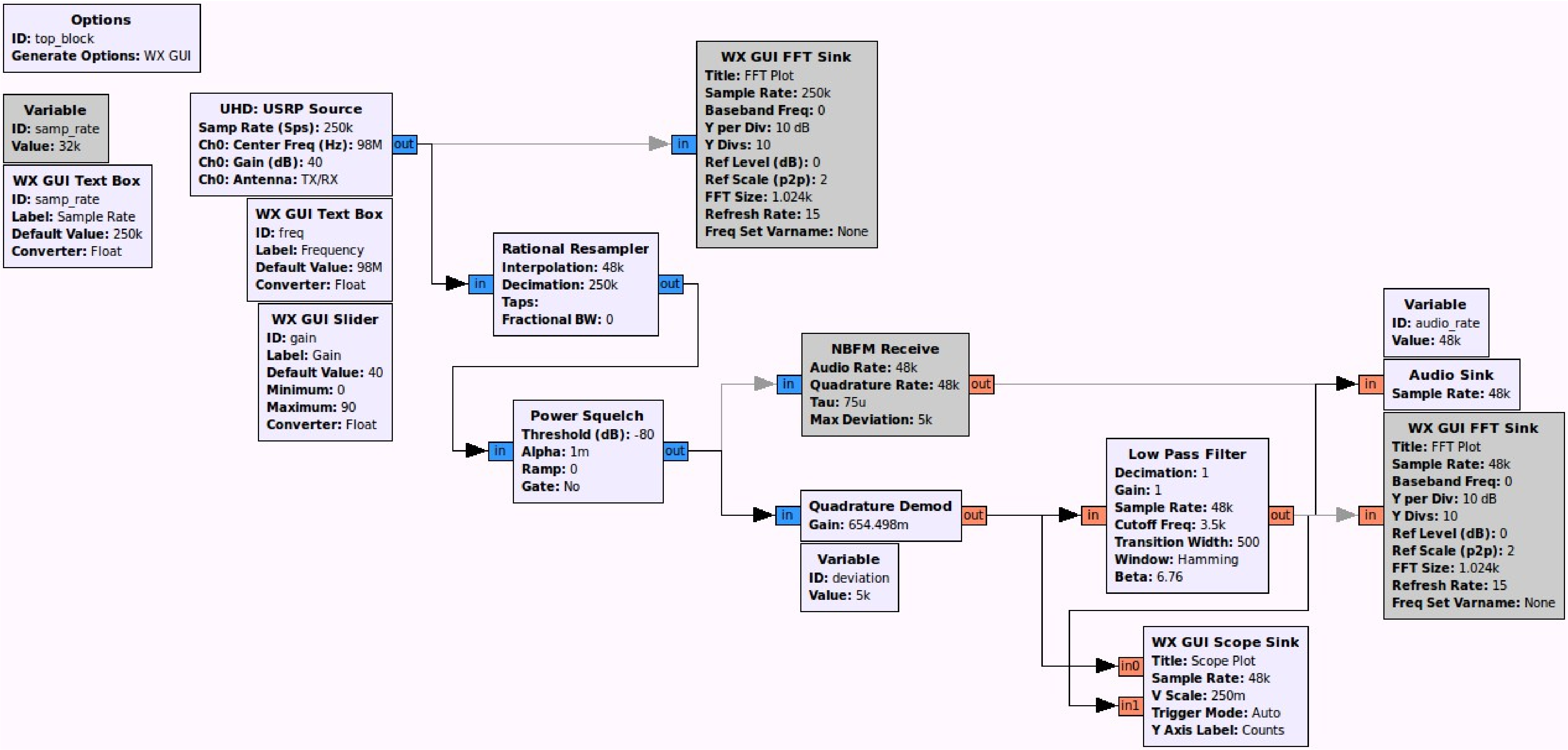
Gain: 40

Frequency: 88.5M

Top Block
FFT Plot
FFT
Amplitude (dB)
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
Frequency (kHz)
Trace Options
☐ Peak Hold
☐ Average
☐ Persistence
Persist Alpha: 0.1861
☐ Trace A
Store
☐ Trace B
Store
Axis Options
dB/Div:
+
-
Ref Level:
+
-
Autoscale
Stop

The baseband spectrum (a local radio station) in shown on the FFT plot, and the signal at the center of the spectrum is demodulated producing audio coming out of the host's soundcard.

Lab 4: Manual FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 48k
Decimation: 250k
Taps:
Fractional BW: 0

Power Squelch
Threshold (dB): -80
Alpha: 1m
Ramp: 0
Gate: No

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 48k
Tau: 75u
Max Deviation: 5k

Quadrature Demod
Gain: 654.498m

Variable
ID: deviation
Value: 5k

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 48k
Cutoff Freq: 3.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 250m
Trigger Mode: Auto
Y Axis Label: Counts

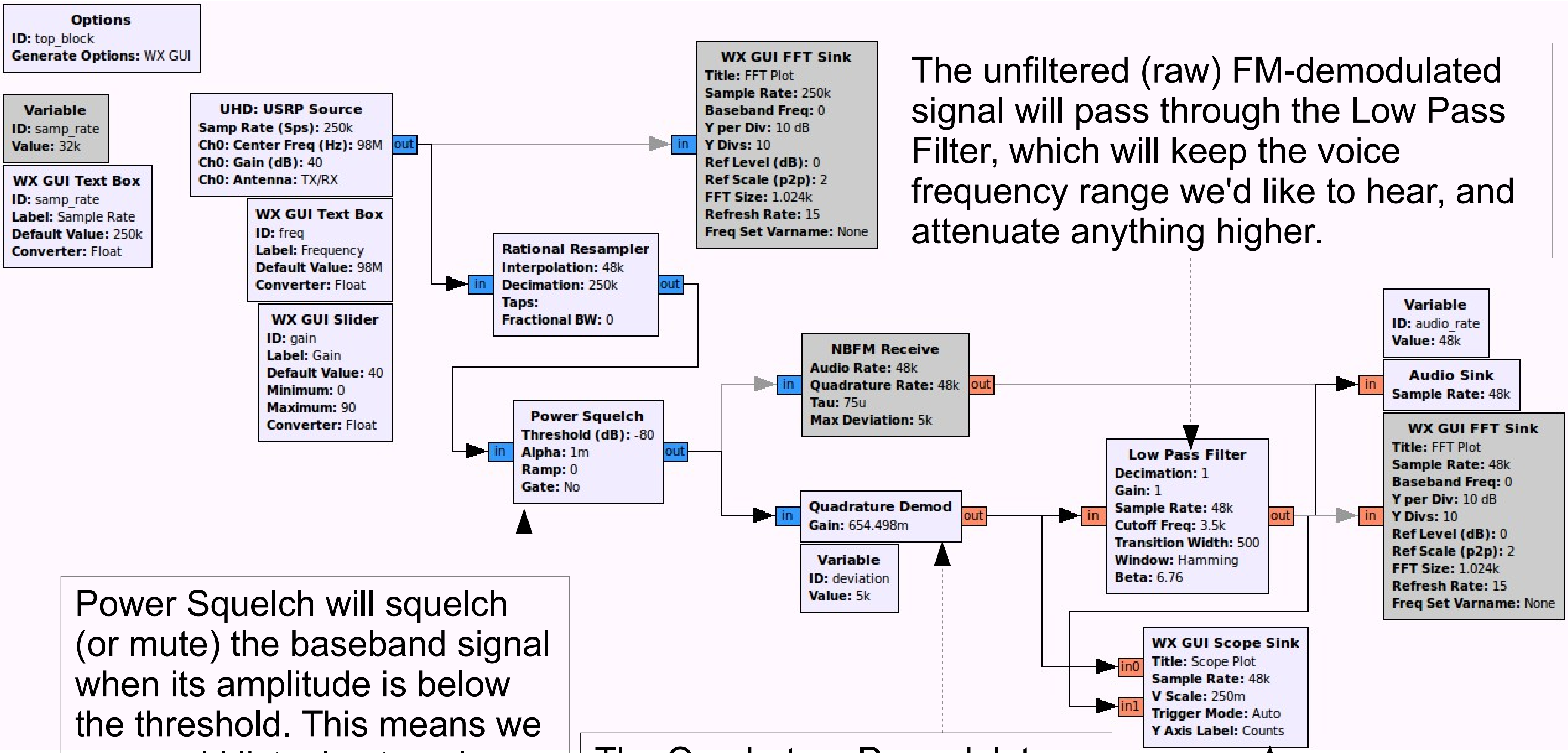
Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Repeat the Narrow Band FM reception example, but perform the individual demodulation steps.

Lab 4: Manual FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 48k
Decimation: 250k
Taps:
Fractional BW: 0

Power Squelch
Threshold (dB): -80
Alpha: 1m
Ramp: 0
Gate: No

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 48k
Tau: 75u
Max Deviation: 5k

Quadrature Demod
Gain: 654.498m

Variable
ID: deviation
Value: 5k

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 48k
Cutoff Freq: 3.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 250m
Trigger Mode: Auto
Y Axis Label: Counts

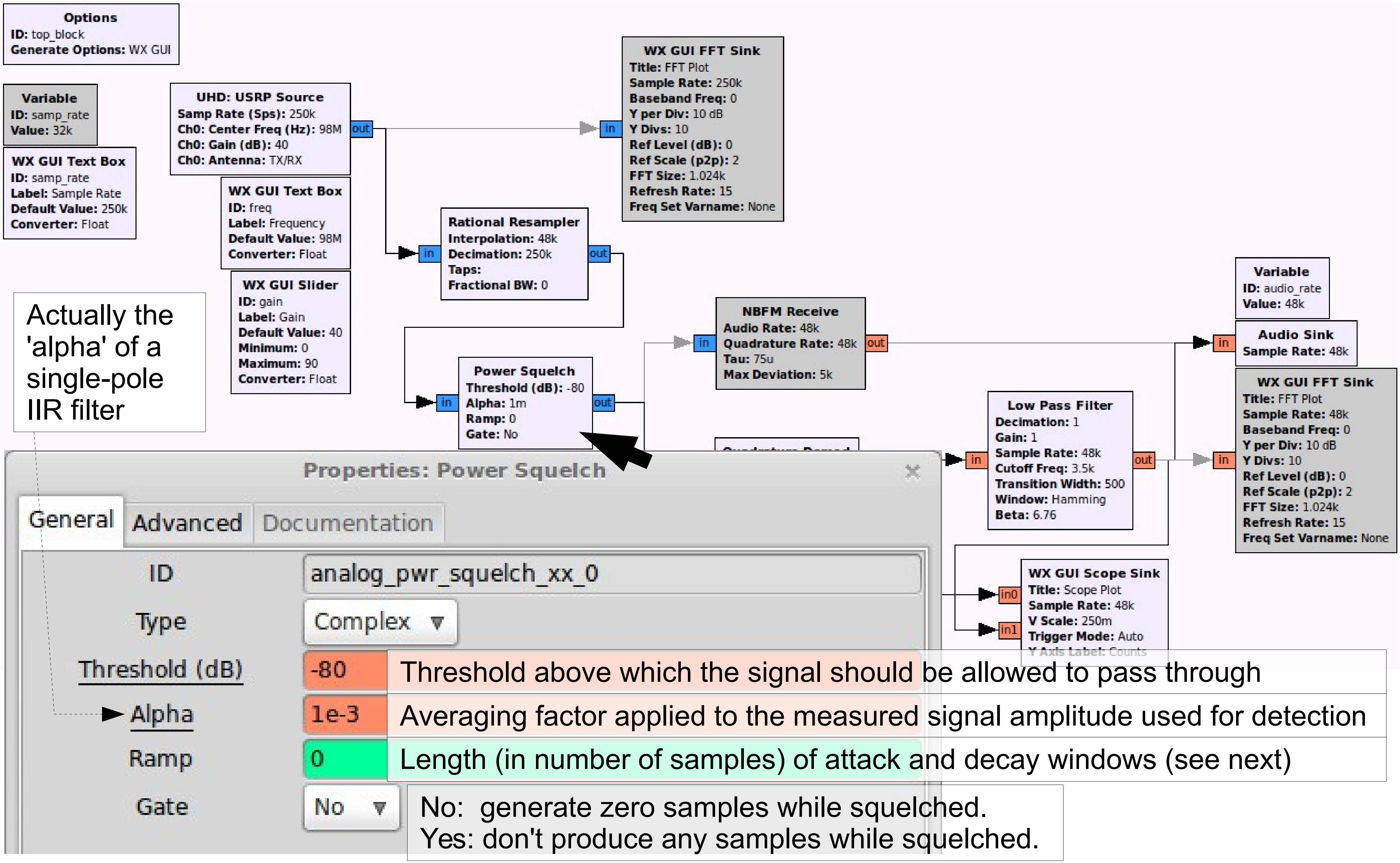
The unfiltered (raw) FM-demodulated signal will pass through the Low Pass Filter, which will keep the voice frequency range we'd like to hear, and attenuate anything higher.

Power Squelch will squelch (or mute) the baseband signal when its amplitude is below the threshold. This means we can avoid listening to noise.

The Quadrature Demodulator is the key part of demodulating an FM signal. The 'deviation' is the maximum frequency shift we expect.

The Scope Sink will plot both the unfiltered and filtered signal.

Lab 4: Manual FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 48k
Decimation: 250k
Taps:
Fractional BW: 0

Power Squelch
Threshold (dB): -80
Alpha: 1m
Ramp: 0
Gate: No

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 48k
Tau: 75u
Max Deviation: 5k

Variable
ID: audio_rate
Value: 48k

Audio Sink
Sample Rate: 48k

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 48k
Cutoff Freq: 3.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

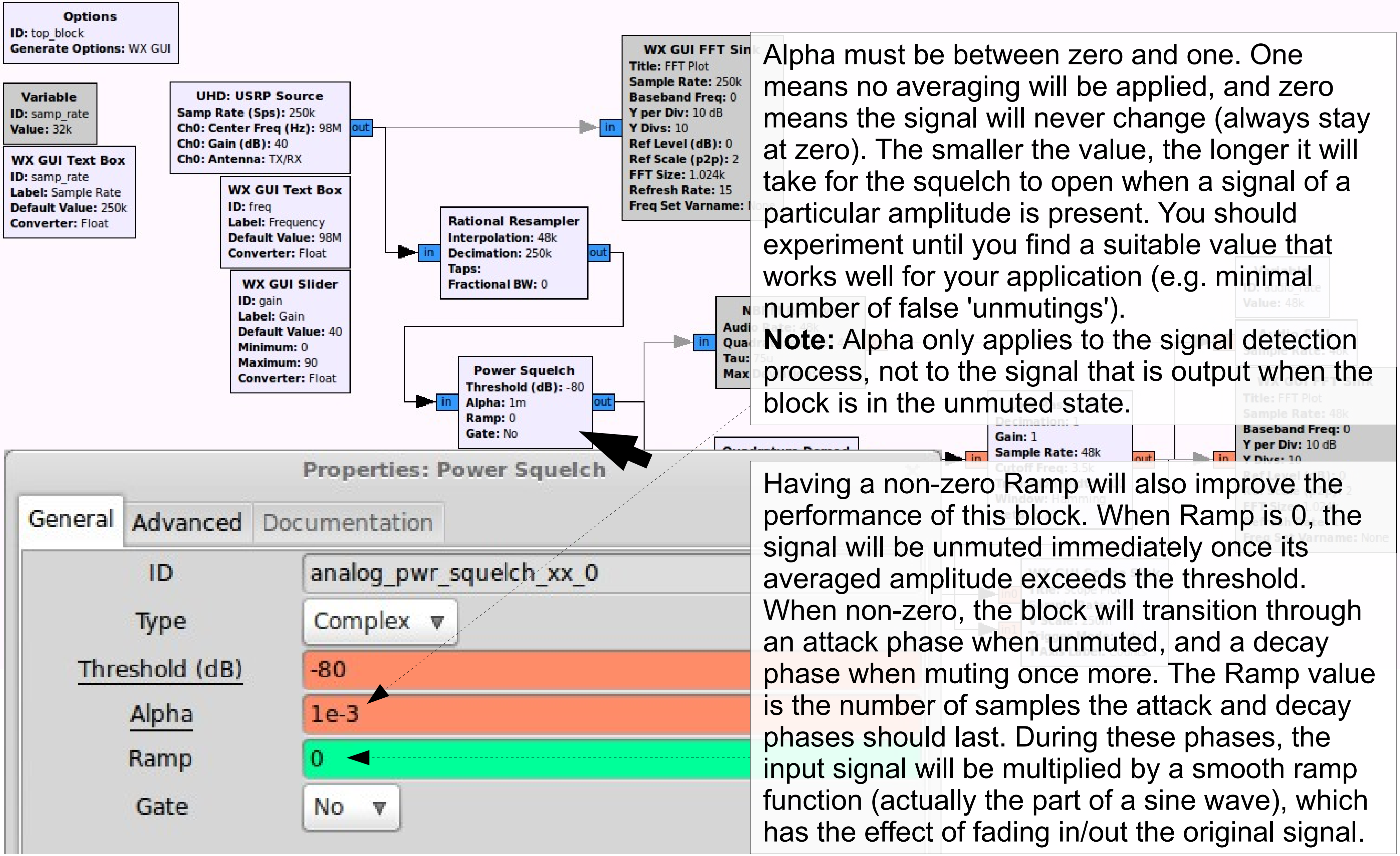
WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 250m
Trigger Mode: Auto
Y Axis Label: Counts

Actually the 'alpha' of a single-pole IIR filter

Properties: Power Squelch

ID	analog_pwr_squelch_xx_0	
Type	Complex	
Threshold (dB)	-80	Threshold above which the signal should be allowed to pass through
Alpha	1e-3	Averaging factor applied to the measured signal amplitude used for detection
Ramp	0	Length (in number of samples) of attack and decay windows (see next)
Gate	No	No: generate zero samples while squelched. Yes: don't produce any samples while squelched.

Lab 4: Manual FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 48k
Decimation: 250k
Taps:
Fractional BW: 0

Power Squelch
Threshold (dB): -80
Alpha: 1m
Ramp: 0
Gate: No

Properties: Power Squelch

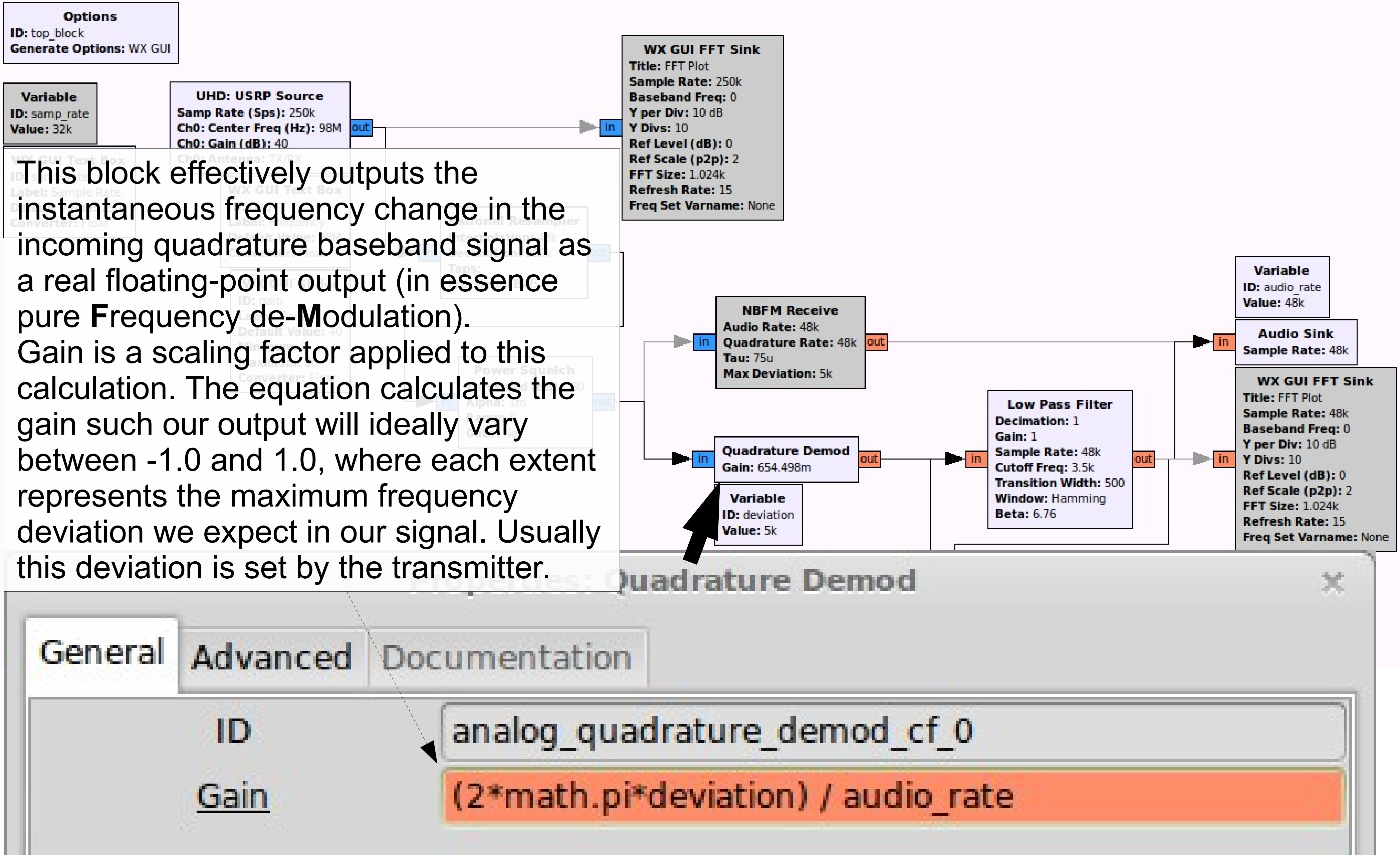
ID: analog_pwr_squelch_xx_0
Type: Complex
Threshold (dB): -80
Alpha: 1e-3
Ramp: 0
Gate: No

Alpha must be between zero and one. One means no averaging will be applied, and zero means the signal will never change (always stay at zero). The smaller the value, the longer it will take for the squelch to open when a signal of a particular amplitude is present. You should experiment until you find a suitable value that works well for your application (e.g. minimal number of false 'unmutings').

Note: Alpha only applies to the signal detection process, not to the signal that is output when the block is in the unmuted state.

Having a non-zero Ramp will also improve the performance of this block. When Ramp is 0, the signal will be unmuted immediately once its averaged amplitude exceeds the threshold. When non-zero, the block will transition through an attack phase when unmuted, and a decay phase when muting once more. The Ramp value is the number of samples the attack and decay phases should last. During these phases, the input signal will be multiplied by a smooth ramp function (actually the part of a sine wave), which has the effect of fading in/out the original signal.

Lab 4: Manual FM RX



This block effectively outputs the instantaneous frequency change in the incoming quadrature baseband signal as a real floating-point output (in essence pure **F**requency de-**M**odulation).
Gain is a scaling factor applied to this calculation. The equation calculates the gain such our output will ideally vary between -1.0 and 1.0, where each extent represents the maximum frequency deviation we expect in our signal. Usually this deviation is set by the transmitter.

Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Variable
ID: audio_rate
Value: 48k

NBFM Receive
Audio Rate: 48k
Quadrature Rate: 48k
Tau: 75u
Max Deviation: 5k

Audio Sink
Sample Rate: 48k

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 48k
Cutoff Freq: 3.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

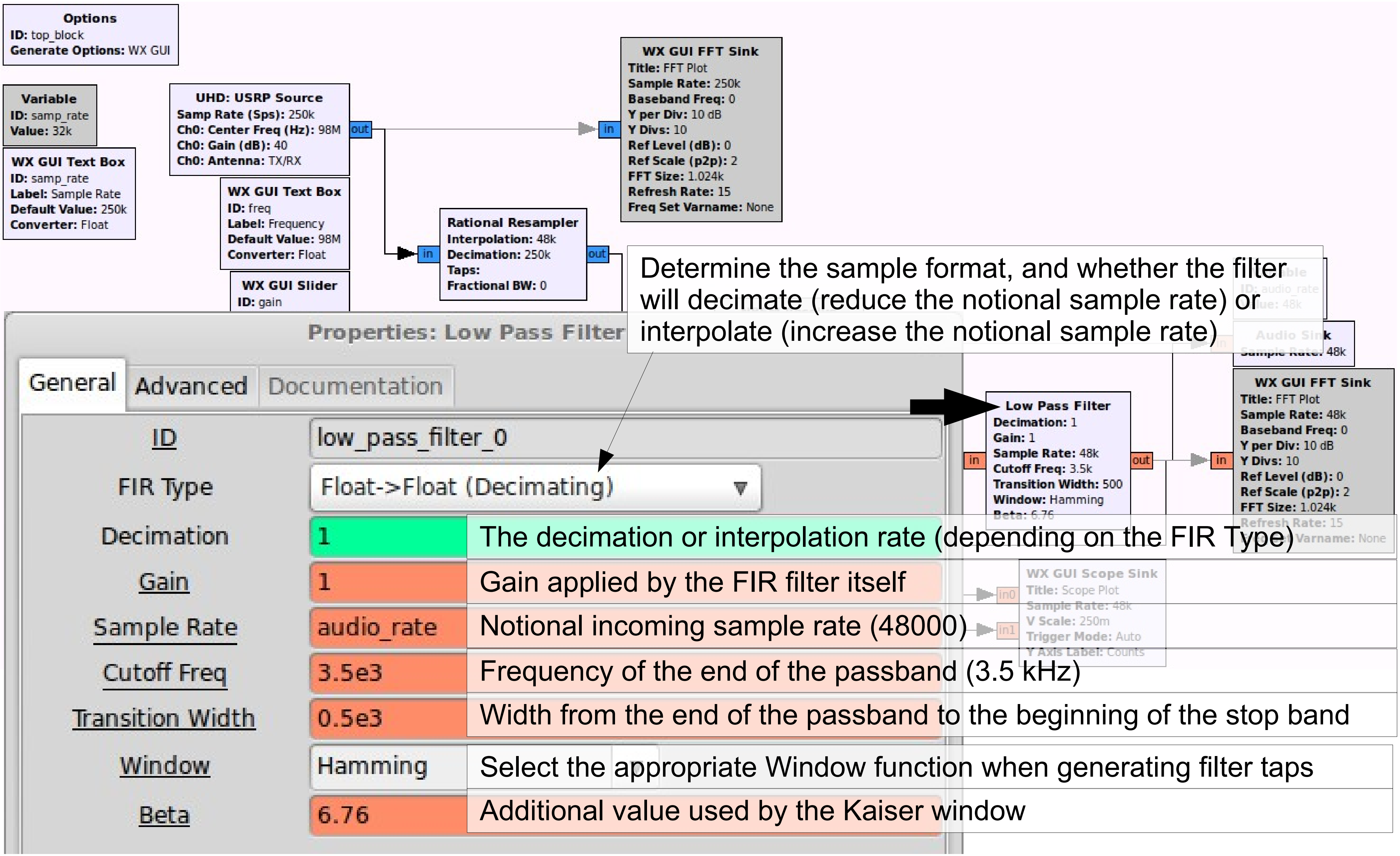
Quadrature Demod
Gain: 654.498m

Variable
ID: deviation
Value: 5k

Properties: Quadrature Demod

ID: analog_quadrature_demod_cf_0
Gain: (2*math.pi*deviation) / audio_rate

Lab 4: Manual FM RX



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: samp_rate
Value: 32k

WX GUI Text Box
ID: samp_rate
Label: Sample Rate
Default Value: 250k
Converter: Float

UHD: USRP Source
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 98M
Ch0: Gain (dB): 40
Ch0: Antenna: TX/RX

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 98M
Converter: Float

WX GUI Slider
ID: gain

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 250k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15
Freq Set Varname: None

Rational Resampler
Interpolation: 48k
Decimation: 250k
Taps:
Fractional BW: 0

ID: audio_rate

Audio Sink
Sample Rate: 48k

Low Pass Filter
Decimation: 1
Gain: 1
Sample Rate: 48k
Cutoff Freq: 3.5k
Transition Width: 500
Window: Hamming
Beta: 6.76

WX GUI FFT Sink
Title: FFT Plot
Sample Rate: 48k
Baseband Freq: 0
Y per Div: 10 dB
Y Divs: 10
Ref Level (dB): 0
Ref Scale (p2p): 2
FFT Size: 1.024k
Refresh Rate: 15

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
V Scale: 250m
Trigger Mode: Auto
Y Axis Label: Counts

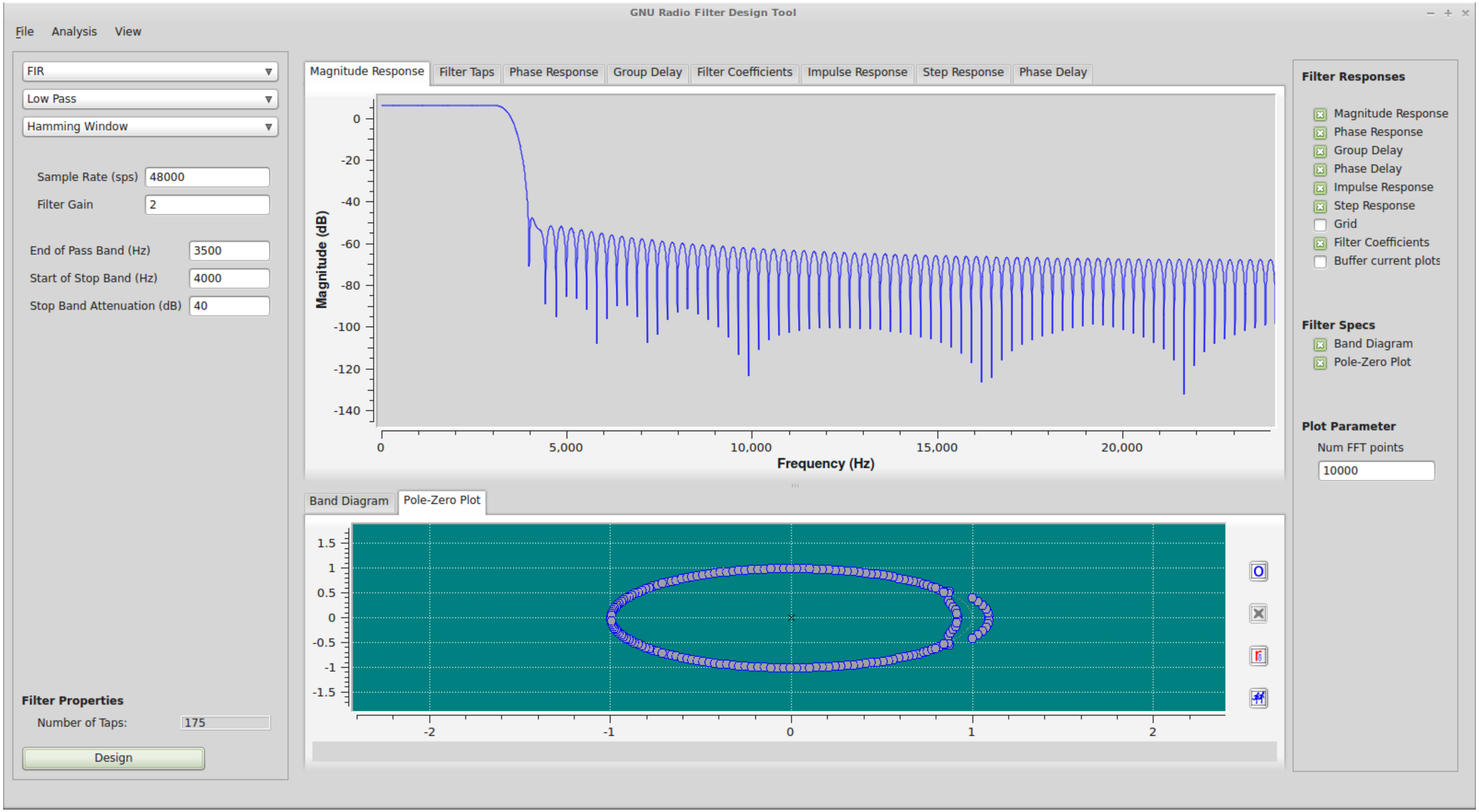
Properties: Low Pass Filter

General | Advanced | Documentation

Determine the sample format, and whether the filter will decimate (reduce the notional sample rate) or interpolate (increase the notional sample rate)

ID	low_pass_filter_0	
FIR Type	Float->Float (Decimating)	
Decimation	1	The decimation or interpolation rate (depending on the FIR Type)
Gain	1	Gain applied by the FIR filter itself
Sample Rate	audio_rate	Notional incoming sample rate (48000)
Cutoff Freq	3.5e3	Frequency of the end of the passband (3.5 kHz)
Transition Width	0.5e3	Width from the end of the passband to the beginning of the stop band
Window	Hamming	Select the appropriate Window function when generating filter taps
Beta	6.76	Additional value used by the Kaiser window

Lab 4: Manual FM RX


GNU Radio Filter Design Tool
File
Analysis
View
Magnitude Response
Filter Taps
Phase Response
Group Delay
Filter Coefficients
Impulse Response
Step Response
Phase Delay
Magnitude (dB)
0
-20
-40
-60
-80
-100
-120
-140
0
5,000
10,000
15,000
20,000
Frequency (Hz)
Band Diagram
Pole-Zero Plot
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-1
0
1
2
Design

FIR

Low Pass

Hamming Window

Sample Rate (sps): 48000

Filter Gain: 2

End of Pass Band (Hz): 3500

Start of Stop Band (Hz): 4000

Stop Band Attenuation (dB): 40

Filter Properties

Number of Taps: 175

Filter Responses

- ☒ Magnitude Response
- ☒ Phase Response
- ☒ Group Delay
- ☒ Phase Delay
- ☒ Impulse Response
- ☒ Step Response
- ☐ Grid
- ☒ Filter Coefficients
- ☐ Buffer current plots

Filter Specs

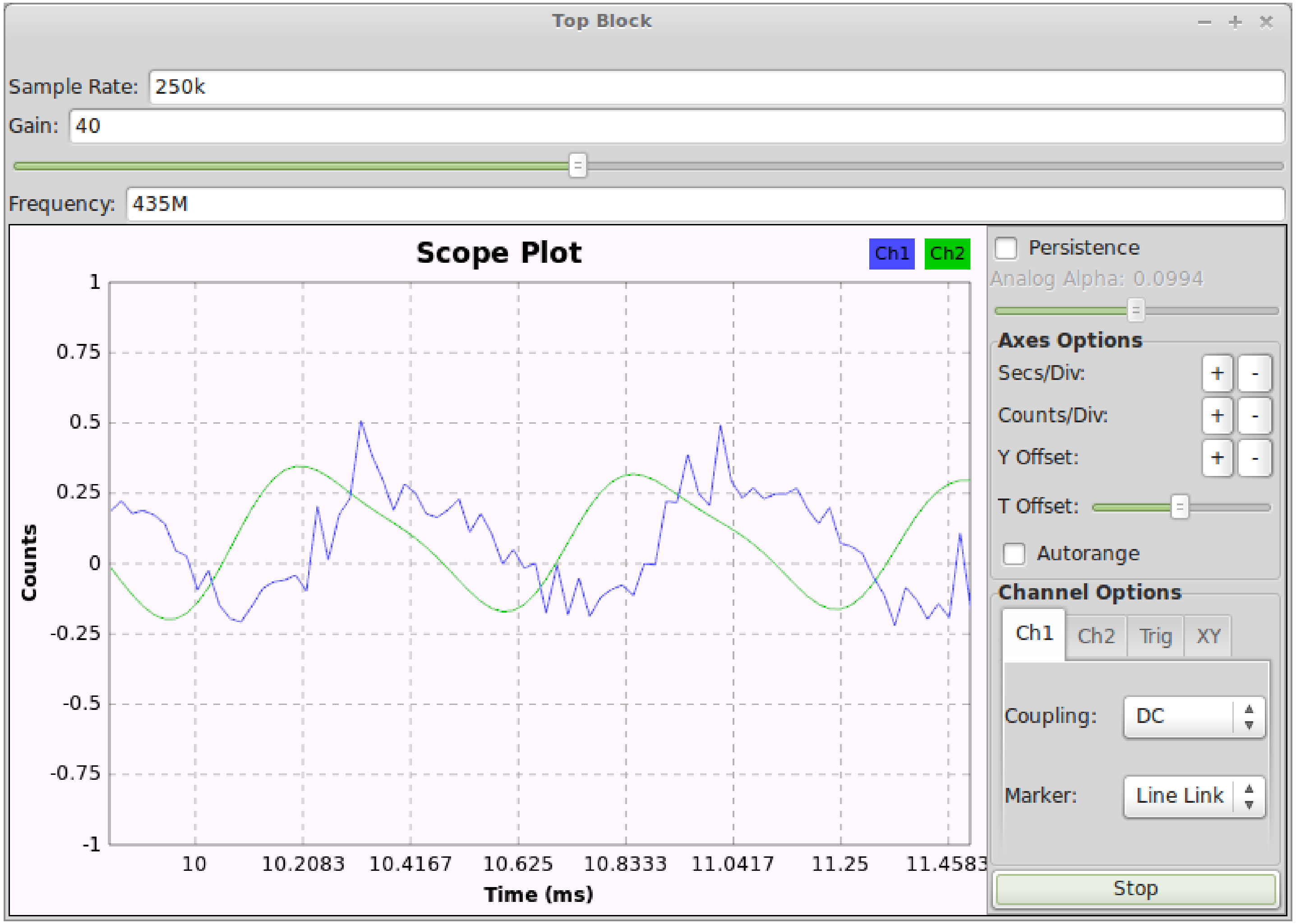
- ☒ Band Diagram
- ☒ Pole-Zero Plot

Plot Parameter

Num FFT points: 10000

The Filter Design Tool (run 'gr_filter_design') is a GUI that allows you to interactively design different types of filters. Once you're happy with your design, you can place an Interpolating/Decimating FIR Filter block into your GRC flowgraph and set its taps using the filter coefficients output by the designer.

Lab 4: Manual FM RX


Top Block
Scope Plot
Ch1
Ch2
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
Counts
10
10.2083
10.4167
10.625
10.8333
11.0417
11.25
11.4583
Time (ms)
☐ Persistence
Axes Options
Secs/Div: + -
Counts/Div: + -
Y Offset: + -
T Offset:
☐ Autorange
Channel Options
Ch1
Ch2
Trig
XY
Stop

Sample Rate: 250k

Gain: 40

Frequency: 435M

Analog Alpha: 0.0994

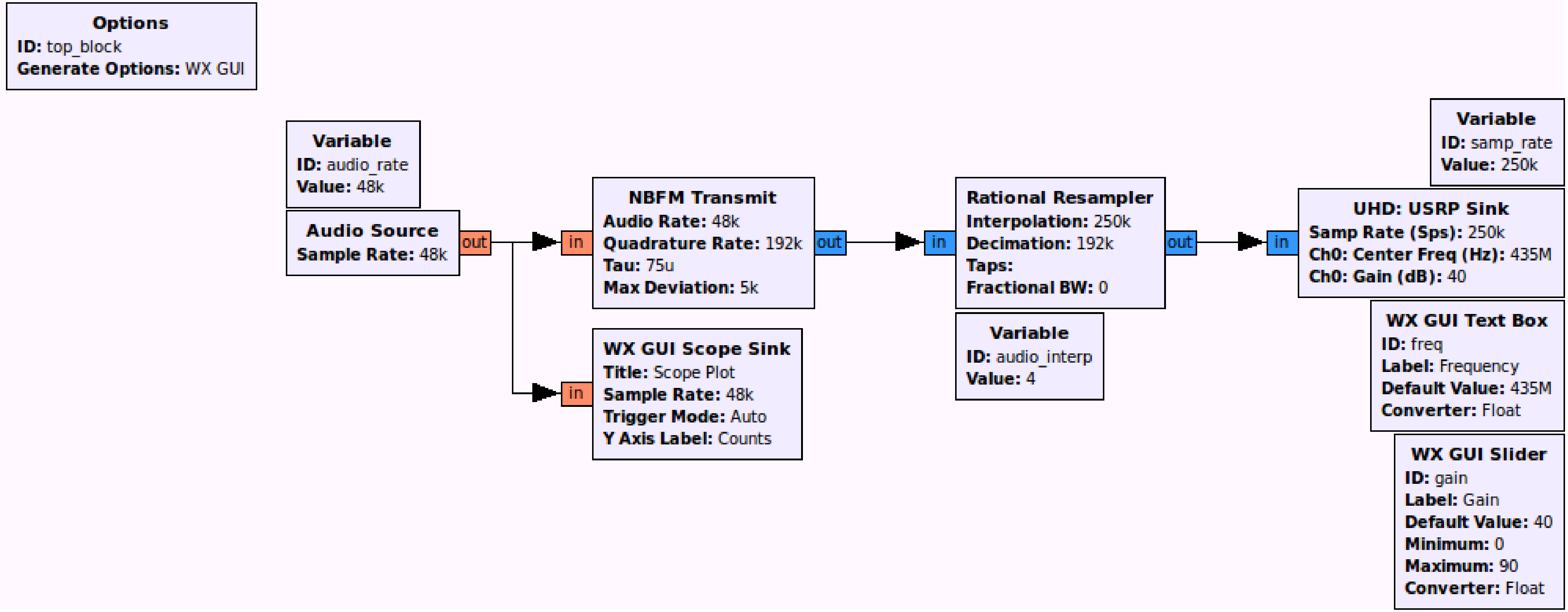
Coupling: DC

Marker: Line Link

The baseband signal will be demodulated as before, however audio will only be heard if there is a strong-enough signal present at the center of the spectrum to open the squelch. The Scope Sink shows the raw demodulated signal (a whistle) in blue, and the low-pass filtered (and therefore slightly delayed) signal in green, which is output to the Audio Sink.

Lab 5: FM TX

You need to have a valid amateur radio (HAM) license to actually transmit on the frequency in this example!



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: audio_rate
Value: 48k

Audio Source
Sample Rate: 48k

NBFM Transmit
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
Trigger Mode: Auto
Y Axis Label: Counts

Rational Resampler
Interpolation: 250k
Decimation: 192k
Taps:
Fractional BW: 0

Variable
ID: audio_interp
Value: 4

Variable
ID: samp_rate
Value: 250k

UHD: USRP Sink
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 435M
Ch0: Gain (dB): 40

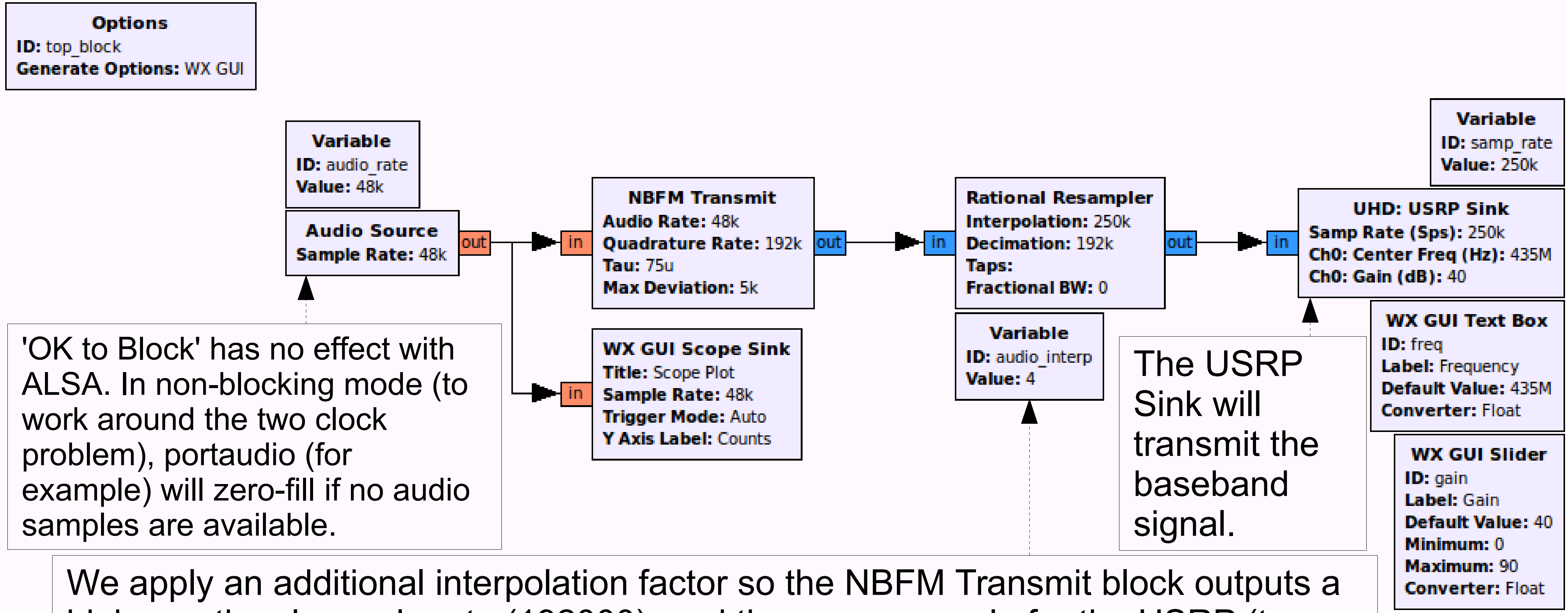
WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 435M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

Sample audio from your soundcard and transmit it from a USRP using a **N**arrow **B**and **FM** carrier.

Lab 5: FM TX

You need to have a valid amateur radio (HAM) license to actually transmit on the frequency in this example!



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: audio_rate
Value: 48k

Audio Source
Sample Rate: 48k

NBFM Transmit
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

WX GUI Scope Sink
Title: Scope Plot
Sample Rate: 48k
Trigger Mode: Auto
Y Axis Label: Counts

Rational Resampler
Interpolation: 250k
Decimation: 192k
Taps:
Fractional BW: 0

Variable
ID: audio_interp
Value: 4

Variable
ID: samp_rate
Value: 250k

UHD: USRP Sink
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 435M
Ch0: Gain (dB): 40

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 435M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

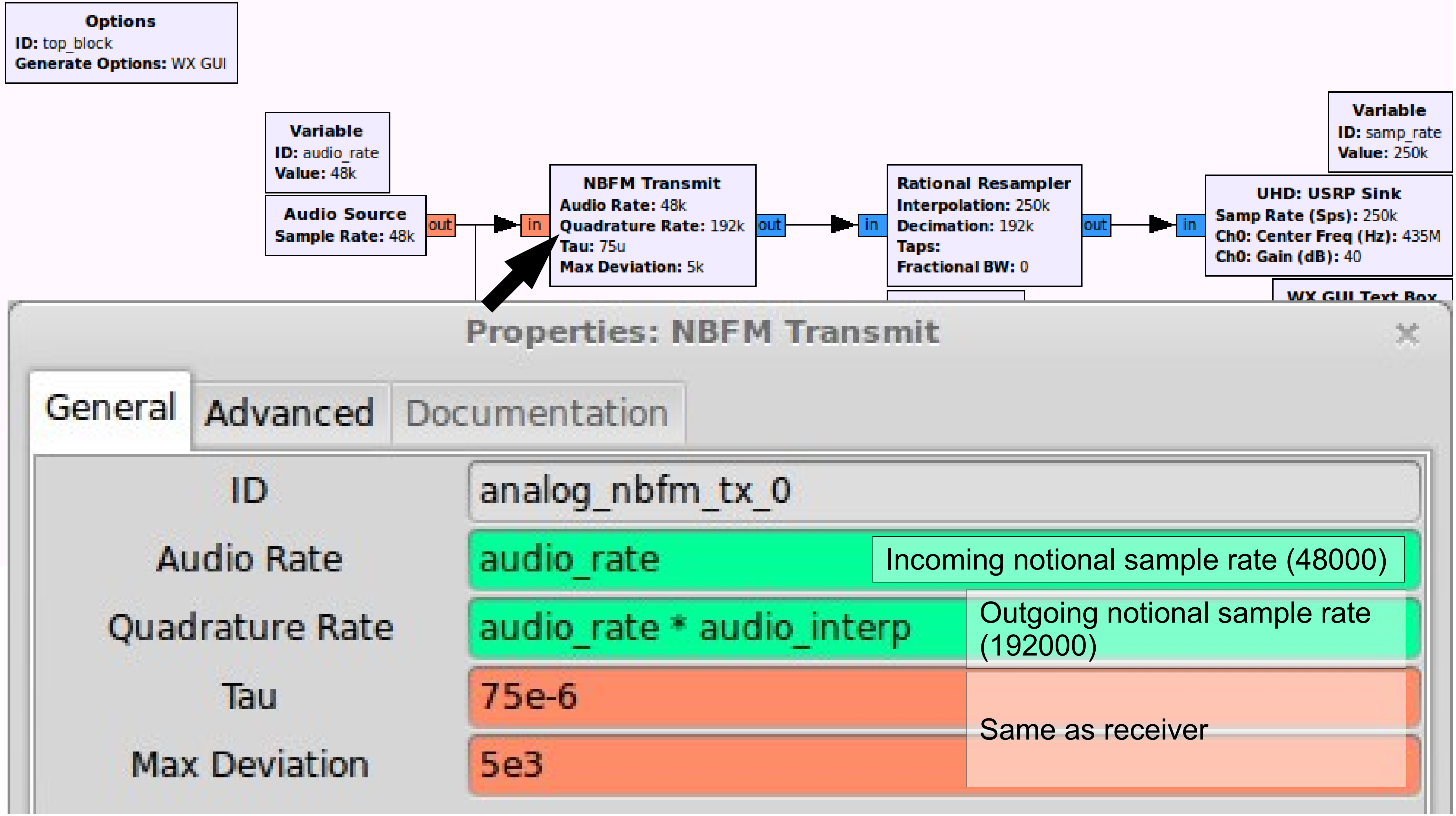
'OK to Block' has no effect with ALSA. In non-blocking mode (to work around the two clock problem), portaudio (for example) will zero-fill if no audio samples are available.

The USRP Sink will transmit the baseband signal.

We apply an additional interpolation factor so the NBFM Transmit block outputs a higher notional sample rate (192000), and then we resample for the USRP (to 250000).
In transmit chain, you will usually be able to control the modulated signal's notional baseband rate (here it is 192000, i.e. prior to resampling for the USRP).
This makes for a tradeoff between a higher-rate, potentially higher-quality synthesised baseband signal (at the expense of processing power), or saving CPU cycles for lower-quality. This choice is usually application-/signal-specific.

Lab 5: FM TX

You need to have a valid amateur radio (HAM) license to actually transmit on the frequency in this example!


out
in
out
in
out
in
Properties: NBFM Transmit
General
Advanced
Documentation

Options
ID: top_block
Generate Options: WX GUI

Variable
ID: audio_rate
Value: 48k

Audio Source
Sample Rate: 48k

NBFM Transmit
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

Rational Resampler
Interpolation: 250k
Decimation: 192k
Taps:
Fractional BW: 0

Variable
ID: samp_rate
Value: 250k

UHD: USRP Sink
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 435M
Ch0: Gain (dB): 40

WX GUI Text Box

ID	analog_nbfm_tx_0
Audio Rate	audio_rate
Quadrature Rate	audio_rate * audio_interp
Tau	75e-6
Max Deviation	5e3

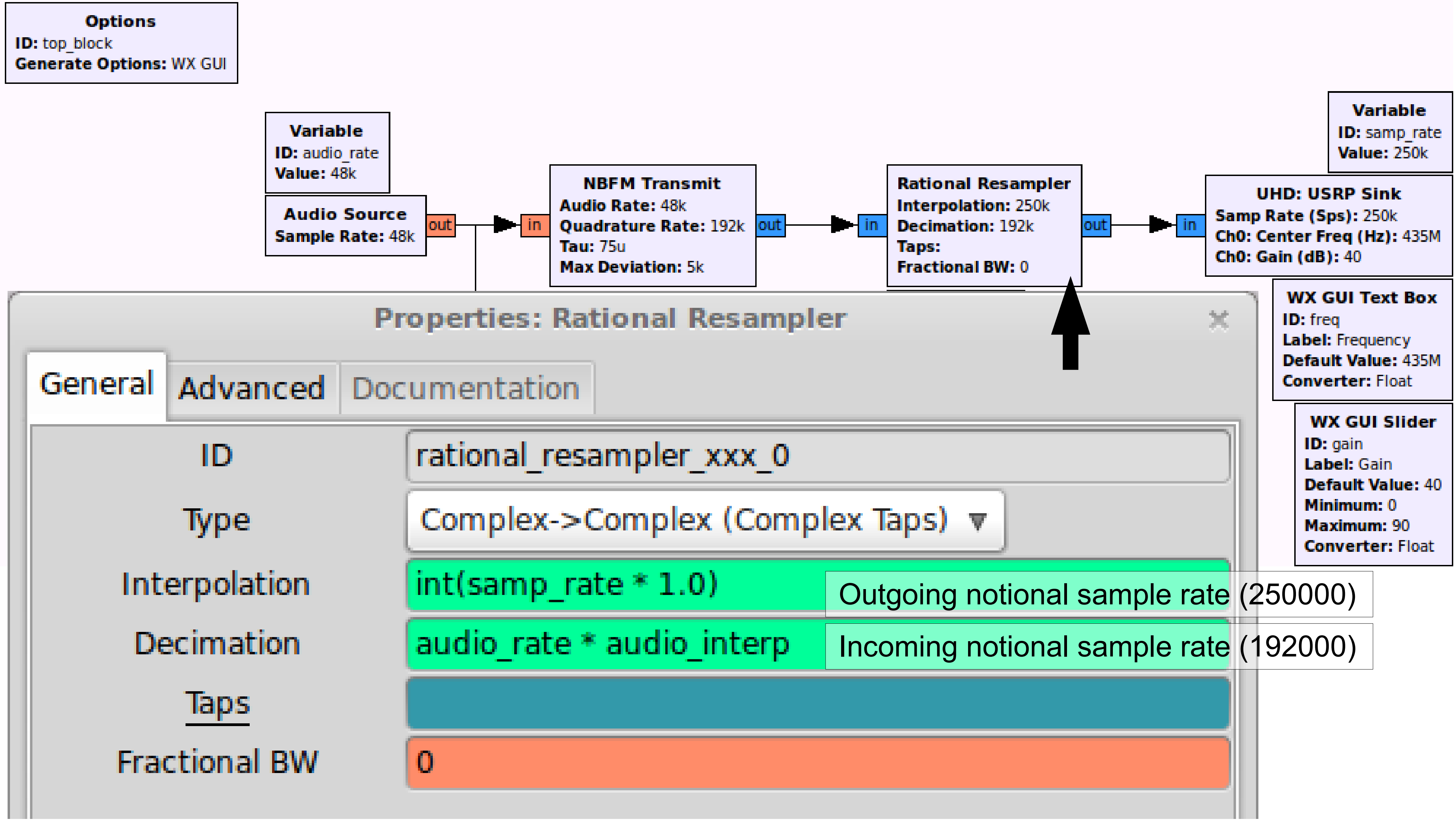
Incoming notional sample rate (48000)

Outgoing notional sample rate (192000)

Same as receiver

Lab 5: FM TX

You need to have a valid amateur radio (HAM) license to actually transmit on the frequency in this example!



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: audio_rate
Value: 48k

Audio Source
Sample Rate: 48k

NBFM Transmit
Audio Rate: 48k
Quadrature Rate: 192k
Tau: 75u
Max Deviation: 5k

Rational Resampler
Interpolation: 250k
Decimation: 192k
Taps:
Fractional BW: 0

Variable
ID: samp_rate
Value: 250k

UHD: USRP Sink
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 435M
Ch0: Gain (dB): 40

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 435M
Converter: Float

WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

Properties: Rational Resampler

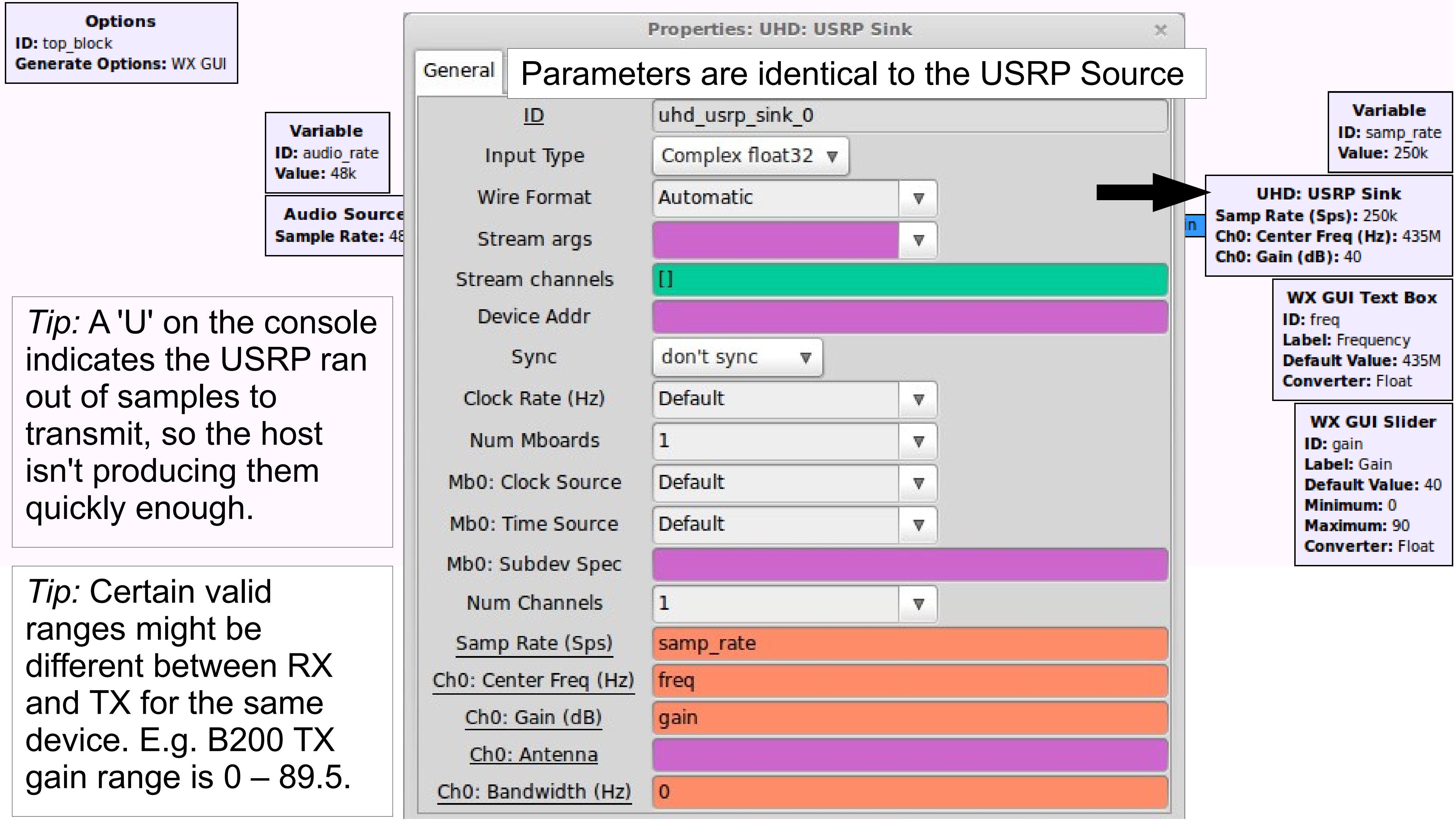
ID: rational_resampler_xxx_0
Type: Complex->Complex (Complex Taps)
Interpolation: int(samp_rate * 1.0)
Decimation: audio_rate * audio_interp
Taps:
Fractional BW: 0

Outgoing notional sample rate (250000)

Incoming notional sample rate (192000)

Lab 5: FM TX

You need to have a valid amateur radio (HAM) license to actually transmit on the frequency in this example!



Options
ID: top_block
Generate Options: WX GUI

Variable
ID: audio_rate
Value: 48k

Audio Source
Sample Rate: 48

Properties: UHD: USRP Sink

General

Parameters are identical to the USRP Source

ID: uhd_usrp_sink_0
Input Type: Complex float32
Wire Format: Automatic
Stream args:
Stream channels: []
Device Addr:
Sync: don't sync
Clock Rate (Hz): Default
Num Mboards: 1
Mb0: Clock Source: Default
Mb0: Time Source: Default
Mb0: Subdev Spec:
Num Channels: 1
Samp Rate (Sps): samp_rate
Ch0: Center Freq (Hz): freq
Ch0: Gain (dB): gain
Ch0: Antenna:
Ch0: Bandwidth (Hz): 0

Variable
ID: samp_rate
Value: 250k

UHD: USRP Sink
Samp Rate (Sps): 250k
Ch0: Center Freq (Hz): 435M
Ch0: Gain (dB): 40

WX GUI Text Box
ID: freq
Label: Frequency
Default Value: 435M
Converter: Float

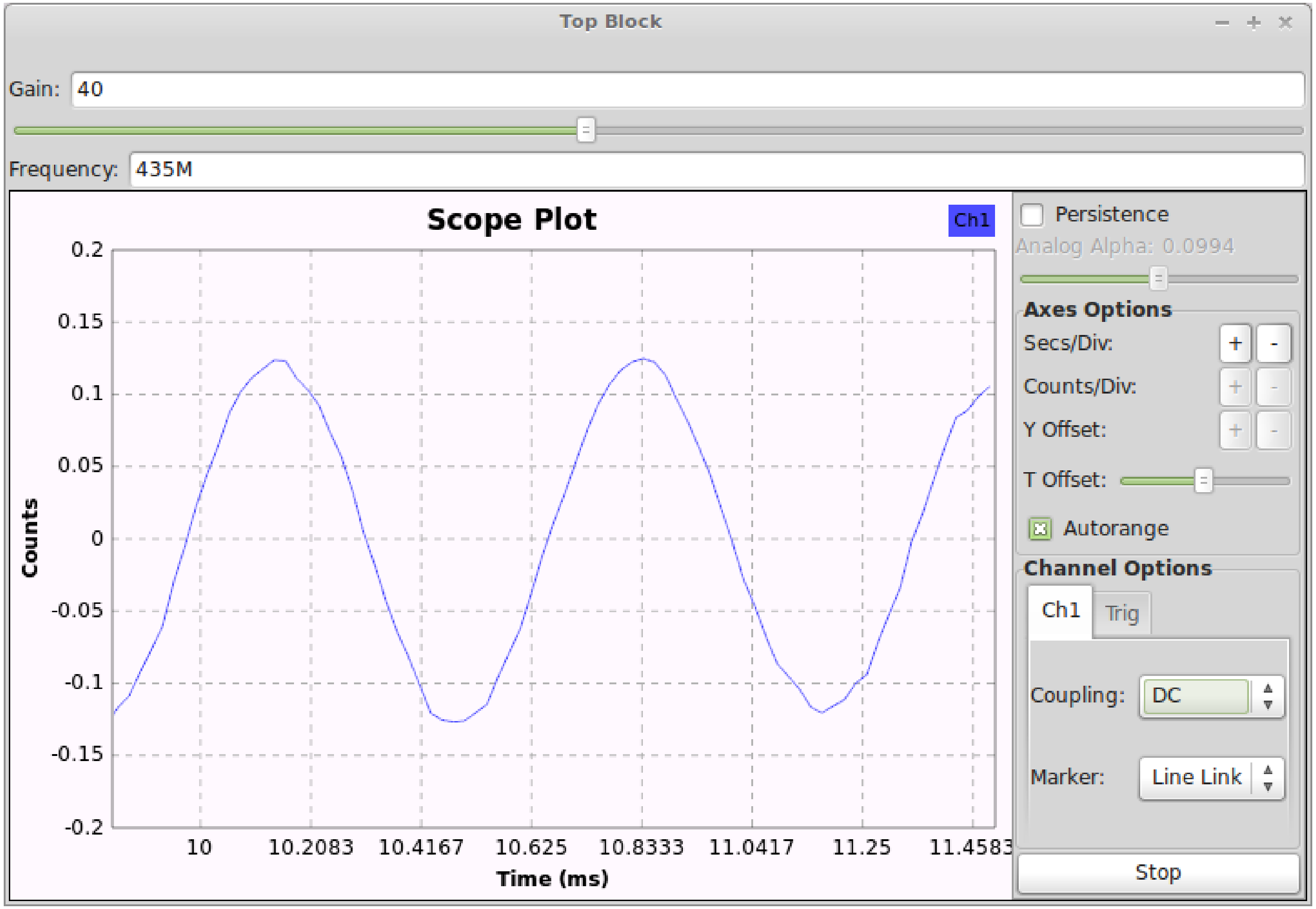
WX GUI Slider
ID: gain
Label: Gain
Default Value: 40
Minimum: 0
Maximum: 90
Converter: Float

Tip: A 'U' on the console indicates the USRP ran out of samples to transmit, so the host isn't producing them quickly enough.

Tip: Certain valid ranges might be different between RX and TX for the same device. E.g. B200 TX gain range is 0 – 89.5.

Lab 5: FM TX

You need to have a valid amateur radio (HAM) license to actually transmit on the frequency in this example!



Top Block

Gain: 40

Frequency: 435M

☐ Persistence

Analog Alpha: 0.0994

☒ Autorange

Coupling: DC

Marker: Line Link

Scope Plot
Ch1
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Counts
10
10.2083
10.4167
10.625
10.8333
11.0417
11.25
11.4583
Time (ms)
Axes Options
Secs/Div:
Counts/Div:
Y Offset:
T Offset:
+
-
Channel Options
Ch1
Trig
Stop

The audio (a whistle) picked up by the sound card will be shown in the scope plot, and transmitted by the USRP at the selected frequency.

Lab 5: FM TX

- If you see lots of the letter 'U' in the console, the transmit chain of the USRP is experiencing underruns: samples cannot be produced quickly enough by the host.
- In this example (under Linux/ALSA) it will occur because of the 'two clock' problem, but cannot be fixed by changing 'OK to Block' since the Audio Source is producing samples that are all being consumed without issue, but it happens to be doing this a little too slowly.

Lab 5: FM TX

- It is possible to cheat by adding a 'fudge', or 'twiddle', factor to the Interpolation rate at the Rational Resampler.
- In the example it was:
  - int(samp_rate * 1.0)
- We can ask the resampler to produce *more* samples for the same number of input samples so that the USRP will always have enough samples to transmit
- The Interpolation rate would become:
  - int(samp_rate * 1.01)
  - The notional output rate was increased by 1% (1.0 + 0.01), which equals = 252500.
The USRP UHD Sink will *still* consume at 250000.

GNU Radio:

http://gnuradio.org/

CGRAN:

http://cgran.org/

Ettus Research:

http://ettus.com/

UHD Docs:

http://files.ettus.com/uhd_docs/doxymanual/html/