Introduction to Software Defined Radios

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`https://gitlab.com/surligas/sdr-tutorial`

`https://gitlab.com/surligas/gr-tutorial`

What is a Software Defined Radio?

According to ITU-R SM.2152, Software-defined Radio (SDR) is:

> A radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard."

Software Defined Radios

The key characteristics are:

- Multiple communication standards support
- Easy and economic upgrades
- More sophisticated RF devices ➔ **Cognitive Radios**
- Easy and rapid development, testing and deployment of new telecommunication standards
- Flexibility

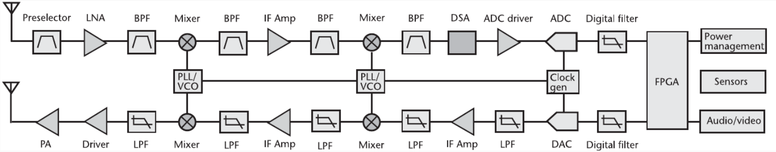
Software Defined Radios

Depending on the application requirements software may run in various execution environments

SDR: The hardware side

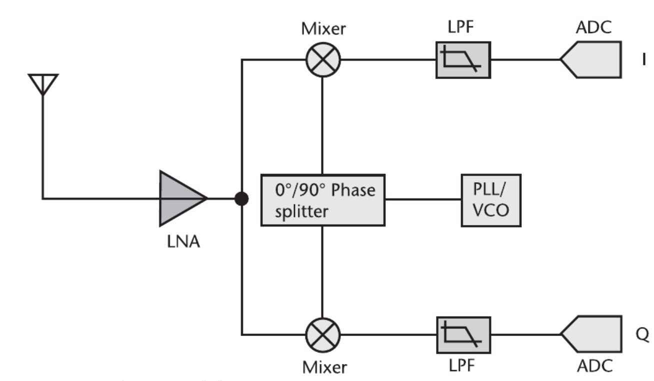
A typical SDR hardware architecture

SDR: The hardware side



A Superheterodyne transceiver

SDR: The hardware side



A Zero-IF front-end

SDR: The hardware side

Direct sampling receiver

SDR: The software side

Complete SDR Platforms:

- GNU Radio
- Matlab Simulink
- Pothos SDR

Libraries:

- Liquid-dsp
- VOLK
- itpp

SDR: The software side

- Software language can be arbitrary
- For realtime applications C/C++
  - Often assisted by Single Instruction Multiple Data (SIMD)
- If the requirements are strict enough, FPGAs are used
  - High throughput
  - Low latency, low jitter
  - Predictable timings

Introduction to GNU Radio

What is GNU Radio?

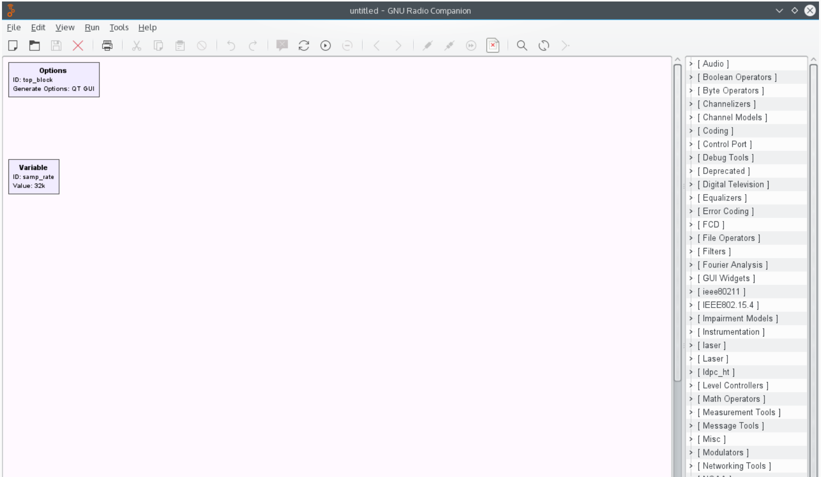
- GNU Radio is an open-source platform that provides signal processing blocks to implement software radios
- Core written in C/C++, some Python bindings
- Provides a GUI called **GNU Radio Companion (GRC)** to easily create software radio programs
- `www.gnuradio.org`

- It is highly recommended to install GNU Radio from the provided packages of your distribution
  - **Ubuntu-Debian:** *apt-get install gnuradio gnuradio-dev*
  - **Fedora:** *yum install gnuradio gnuradio-devel*
  - **OpenSUSE:** *zypper in gnuradio gnuradio-devel*
  - Pre-build Win64 images are also available

More info at
`https://wiki.gnuradio.org/index.php/InstallingGR`

The first GNU Radio application

- Lets write our first software radio application with GNU Radio
- Firstly, open **GNU Radio Companion** or **GRC**

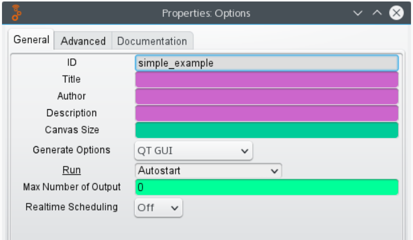


The first GNU Radio application

- This is the working area of GNU Radio
- A program based on GNU Radio is a scenario with multiple processing units connected each other. It is commonly called **Flowgraph**
- Each processing unit is called **Block**
- Ready to use blocks can be found at the left side of GRC window
    - **Ctrl+F** function is supported!

The first GNU Radio application

- The option block contains several parameters related with the flowagraph
- To reveal the properties of each block, double click on it
- The important to remember:
  - **ID:** The name of the Python executable that is going to be generated
  - **Generate Options:** QT GUI in case our flowgraph has a GUI element, NO GUI otherwise

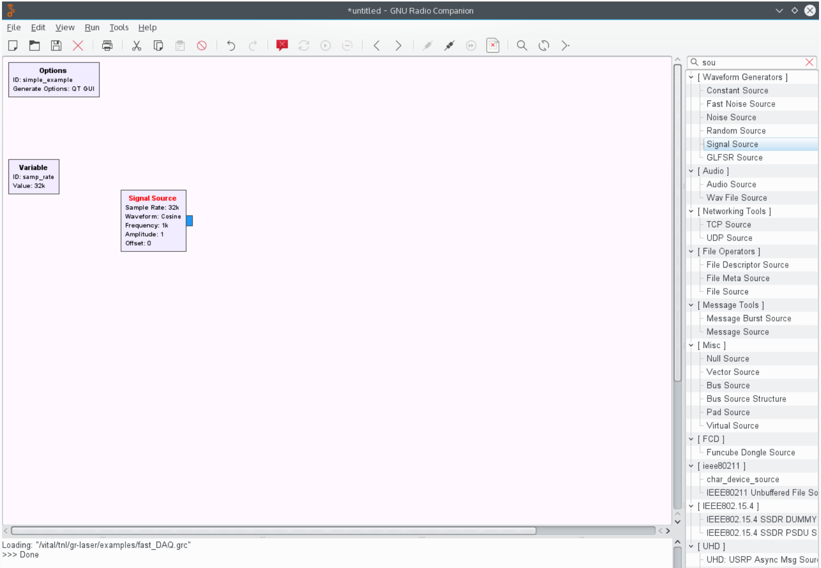


The first GNU Radio application

- Now lets do some real work!
- Suppose we want to add two **float** signals into one and plot them at the time domain each one and their sum
- The first signal A will be a cosine with frequency of 2 kHz and the second signal B will be a sine of frequency 5 kHz
- Their maximum amplitude should be 1
- Search for a block called **Signal Source**
- Drag and drop it at the working area

The first GNU Radio application

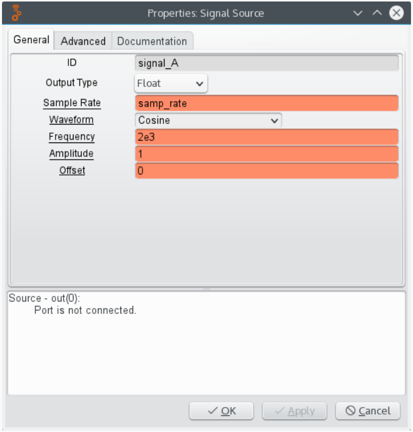
- The result:

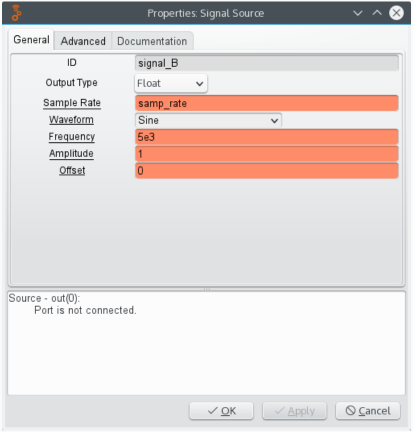


The first GNU Radio application

- Drag and drop or copy and paste (yeah Ctrl+C - Ctrl+V works on blocks!) and the second **Signal Source**

- Lets set properly their parameters by double click on each one





The first GNU Radio application

- Is our flowgraph ready? **NO!**
- Each flowgraph should have at least one **source** block and at least one **sink**
- Sources are blocks with only outputs. They only produce items
- On the other hand, sinks have only inputs. They only consume items
- We want to plot the time domain of the signals, so import a **QT Time Sink block**

The first GNU Radio application

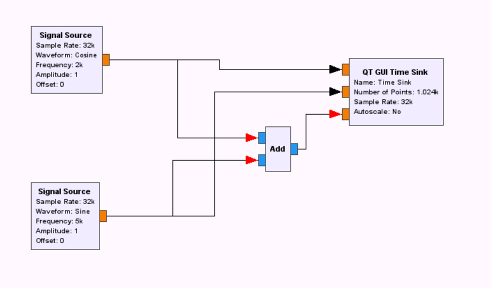
- Make the appropriate configuration at the time sink block
- Float inputs, 3 different inputs, proper labels e.t.c

The first GNU Radio application

- Now we want to connect the output of each signal to the corresponding input of the time sink
- Piece of cake! Just click on the desired source and then at the target sink port!
- A connection is created. Move wherever you want the blocks. The connection follows!
- But wait! We want also the sum of Signal A and Signal B. No problem! Bring in an **Add block**.

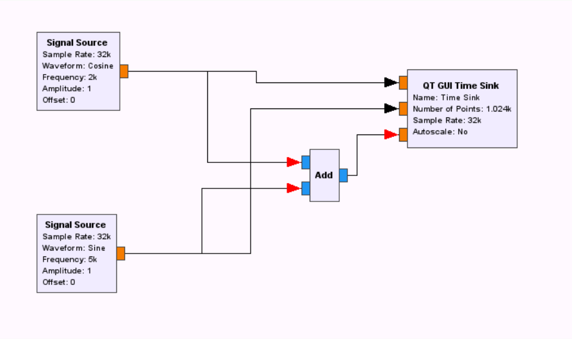
The first GNU Radio application

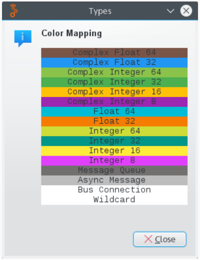
- After connecting the addition block you may end in a situation depicted in the figure below
- Connections marked with read arrows are wrong and the flowgraph can not be generated into an executable



The first GNU Radio application

- In GNU Radio two connected ports **MUST** have the same size and type
- Each port's data type is marked with a different color
- To see the color mapping go to **Help** ⇒ **Types**

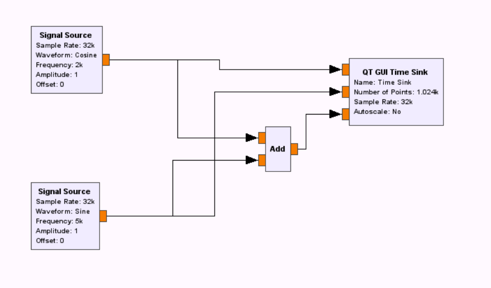




The first GNU Radio application

- Just alter the data type of the addition block by changing its properties

- Input/output data types can by altered also by selecting the desired block and pressing the ↑↓keys



The first GNU Radio application: Throttling

- No we are ready to generate the executable of the flowgraph
- To do this, click the **Generate** button
- You may need to save the flowgraph file first
- Unfortunately, during the generation of the executable a warning message appears

Warning: This flow graph may not have flow control: no audio or RF hardware blocks found. Add a Misc⇒Throttle block to your flow graph to avoid CPU congestion.

The first GNU Radio application: Throttling

- Lets explain this warning
- The flowgraph does not include any hardware device with a specific rate of producing or consuming samples
- There is no way to slow down the flowgraph. It will execute in maximum speed taking all the CPU resources
- With all the CPU resources saturated, the host computer becomes unusable
- The solution is the use of a **Throttle Block**

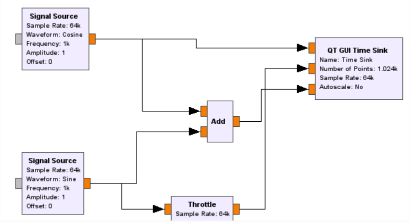
Note!

When performing simulations, each flowgraph should have at least one throttle block.

The first GNU Radio application: Throttling

- Throttle block will slow down each sample at the specified sampling period
- How it works:
  - Assume a sampling rate of 32 KSPS (Kilo-Samples per Second)
  - This means that the system should be able process 32000 samples each second
  - If the CPU freely executed the flowgraph may produce more samples per second
  - Throttle block, slows down the processing of samples by sleeping an amount of time after each sample
  - In our case the sample duration is $\frac{1}{32000} = 31.25$ microseconds

The first GNU Radio application: Throttling



- Add the throttle block and generate the flowgraph again
- Execute the flowgraph either pressing the **Execute** button, or running the generated python file form command line
- Show time!

The first GNU Radio application

Question 1

Almost every block takes as argument the sampling rate. Why? How the sampling rate is chosen?

Question 2

If the sampling rate is increased, how the throttle block will react? How about the CPU?

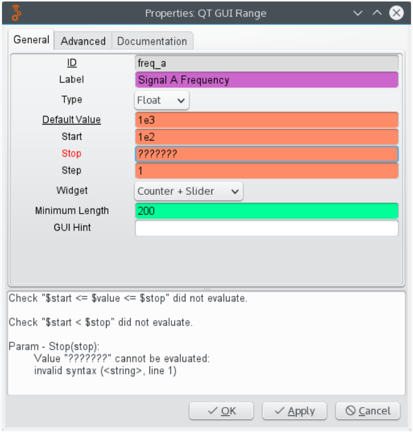
The first GNU Radio application: Interacting with user input

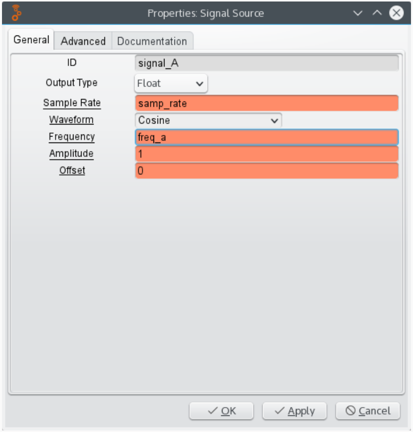
- Ok, that was a nice first example but a little boring
- Lets take as parameter the frequency of each signal
- To achieve that insert two QT GUI Range widgets
- Each one will specify the frequency of the corresponding signal source

The first GNU Radio application: Interacting with user input

- ID is used as variable name
- At the desired block, place the ID of the corresponding GUI widget at the parameter field
- As user changes from the graphical slider the frequency, the new value is automatically passed to the corresponding block

The first GNU Radio application: Interacting with user input





The first GNU Radio application: Interacting with user input

Question

Which should be the stop frequency at the slider properties?