# SOFTWARE-DEFINED EVERYTHING

kate temkin / michael ossmann
supercon 2019

## Katherine/Kate Temkin (@ktemkin):

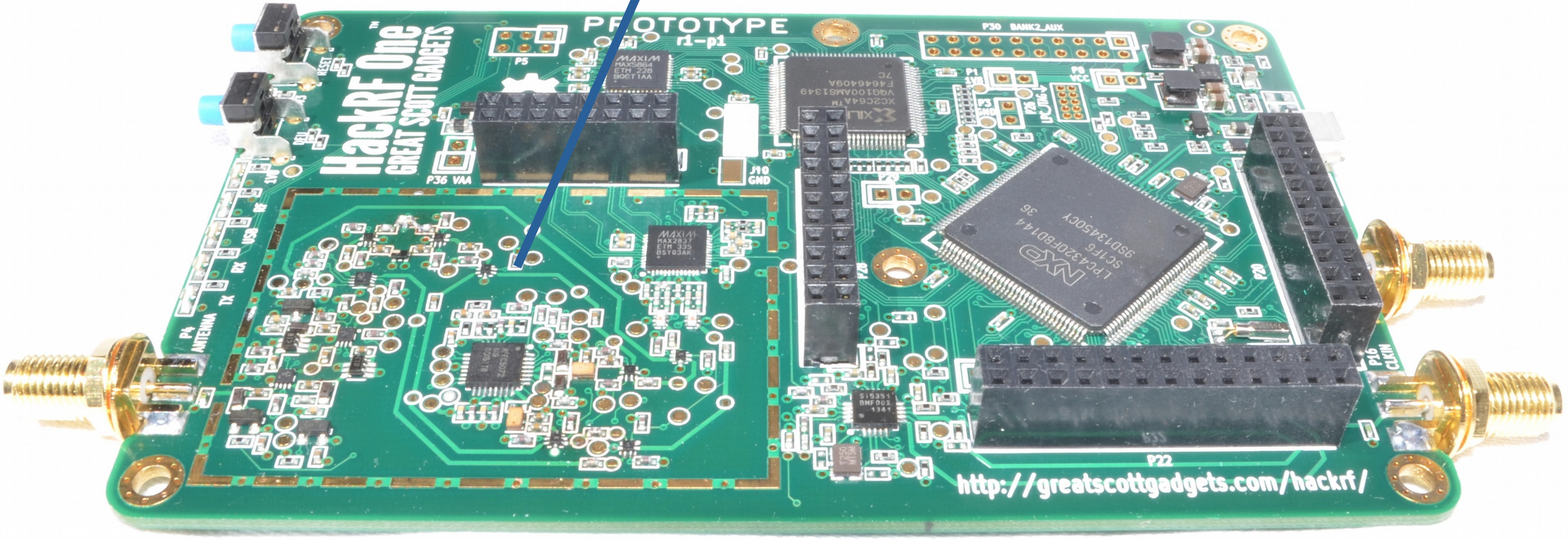
- ~~software lead~~ hardware hacker at Great Scott Gadgets
- open-source-tool-builder
- educational (reverse) engineer

## Michael Ossmann (@michaelossmann):

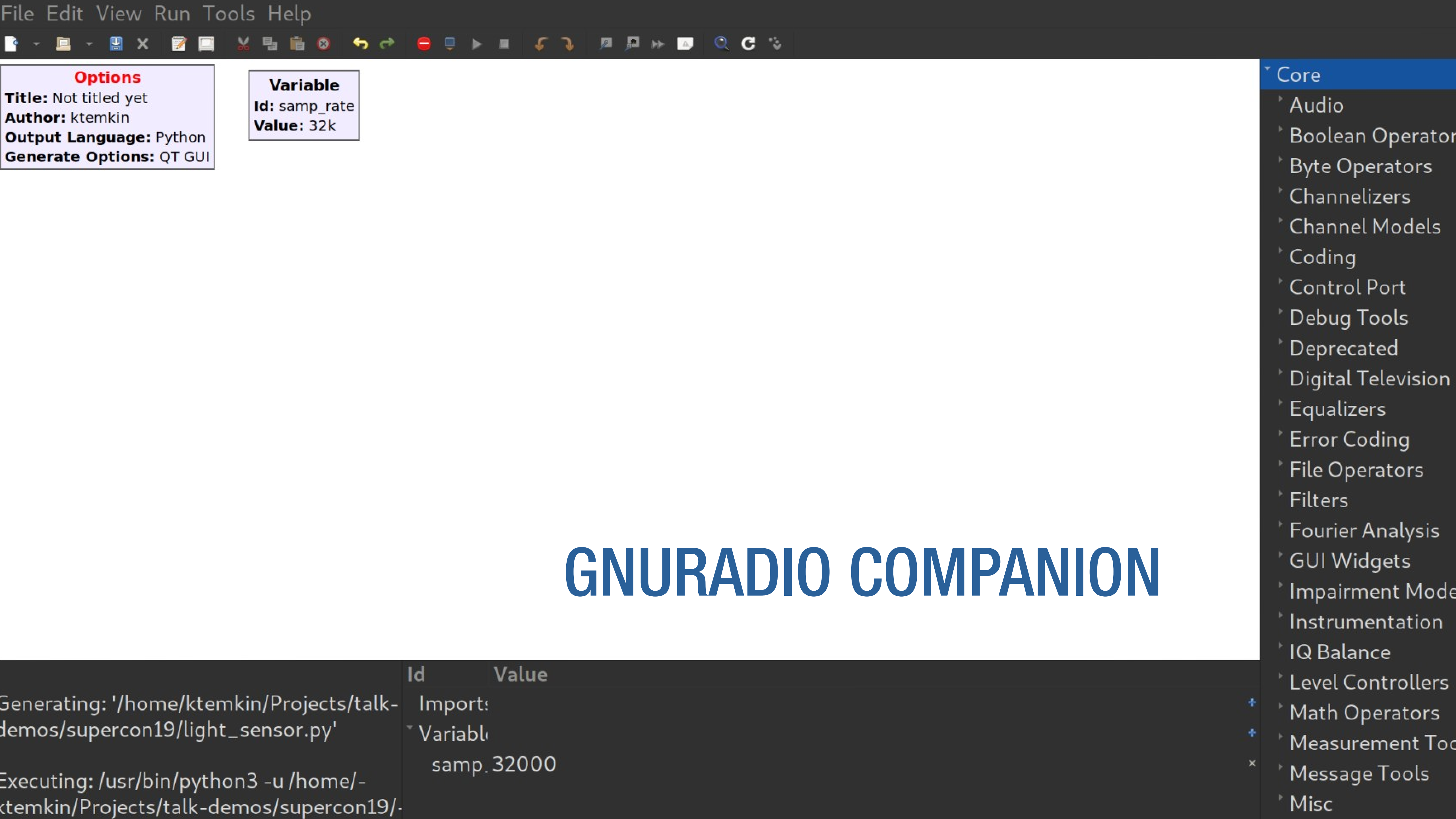
- founder of Great Scott Gadgets
- Software-Defined Radio enthusiast, educator
- hardware designer

**software defined**: specialized stuff made without specialized hardware

SOFTWARE DEFINED RADIO

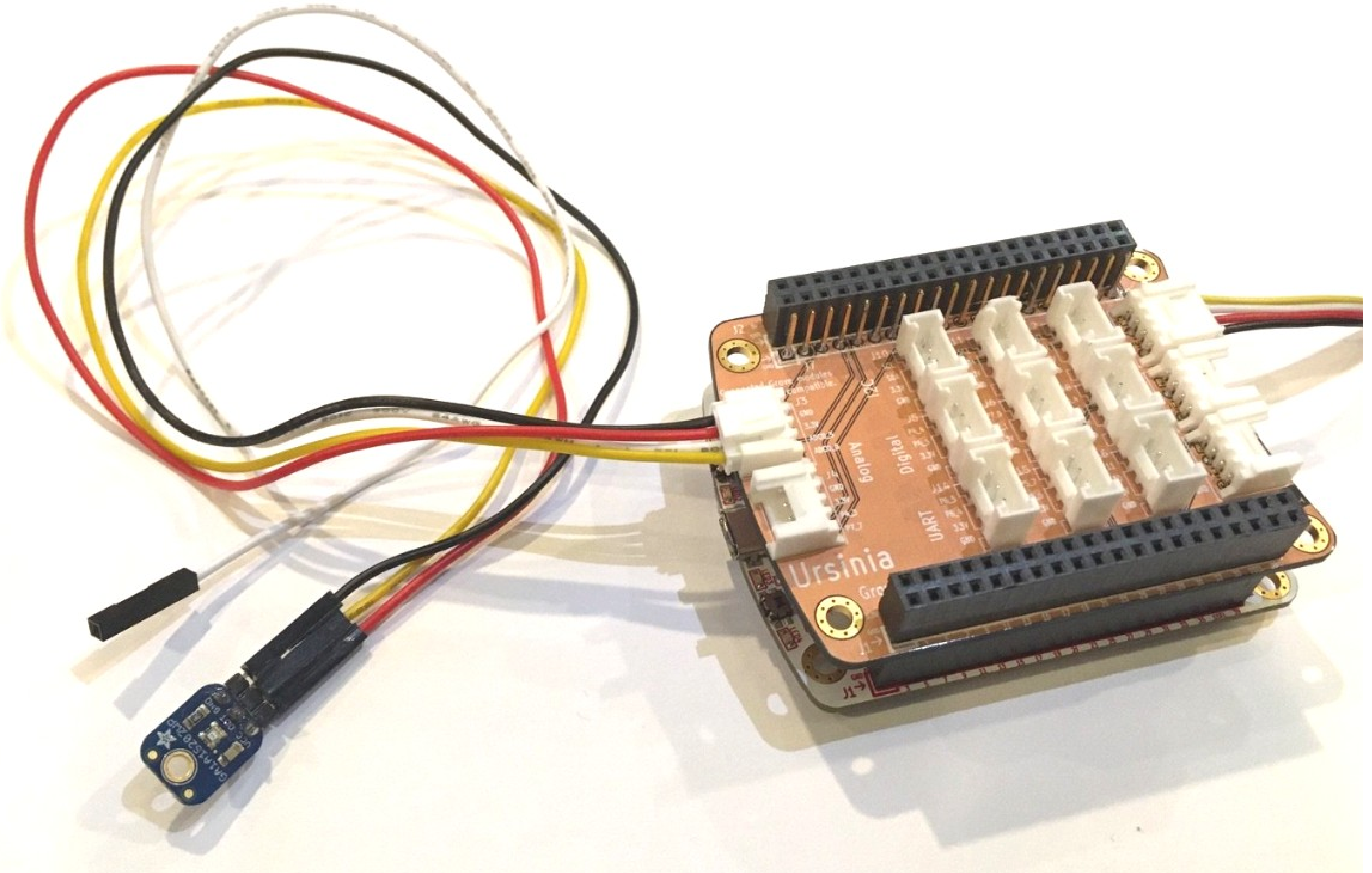


# GNURADIO COMPANION



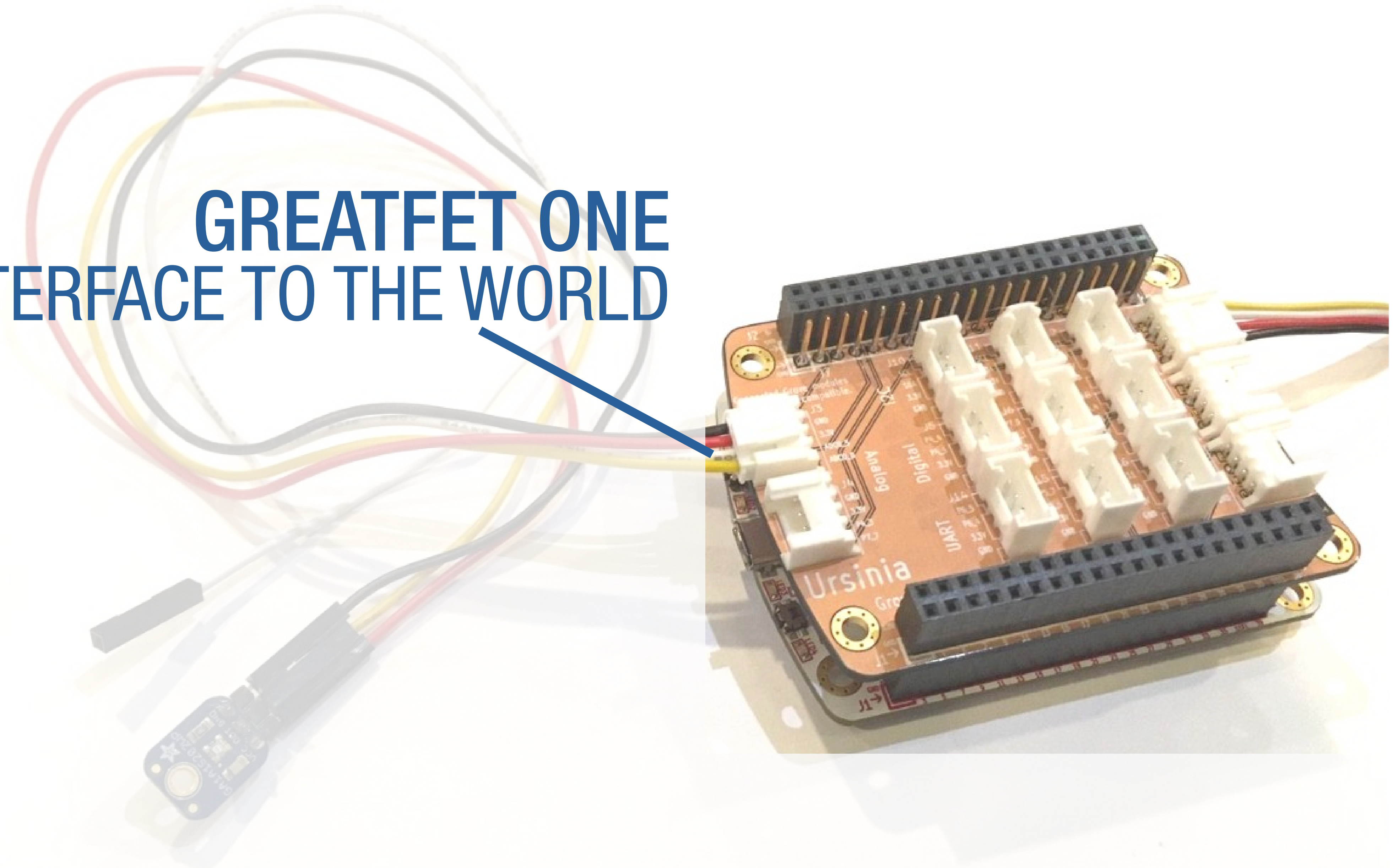
[time domain demo]

[frequency domain demo]

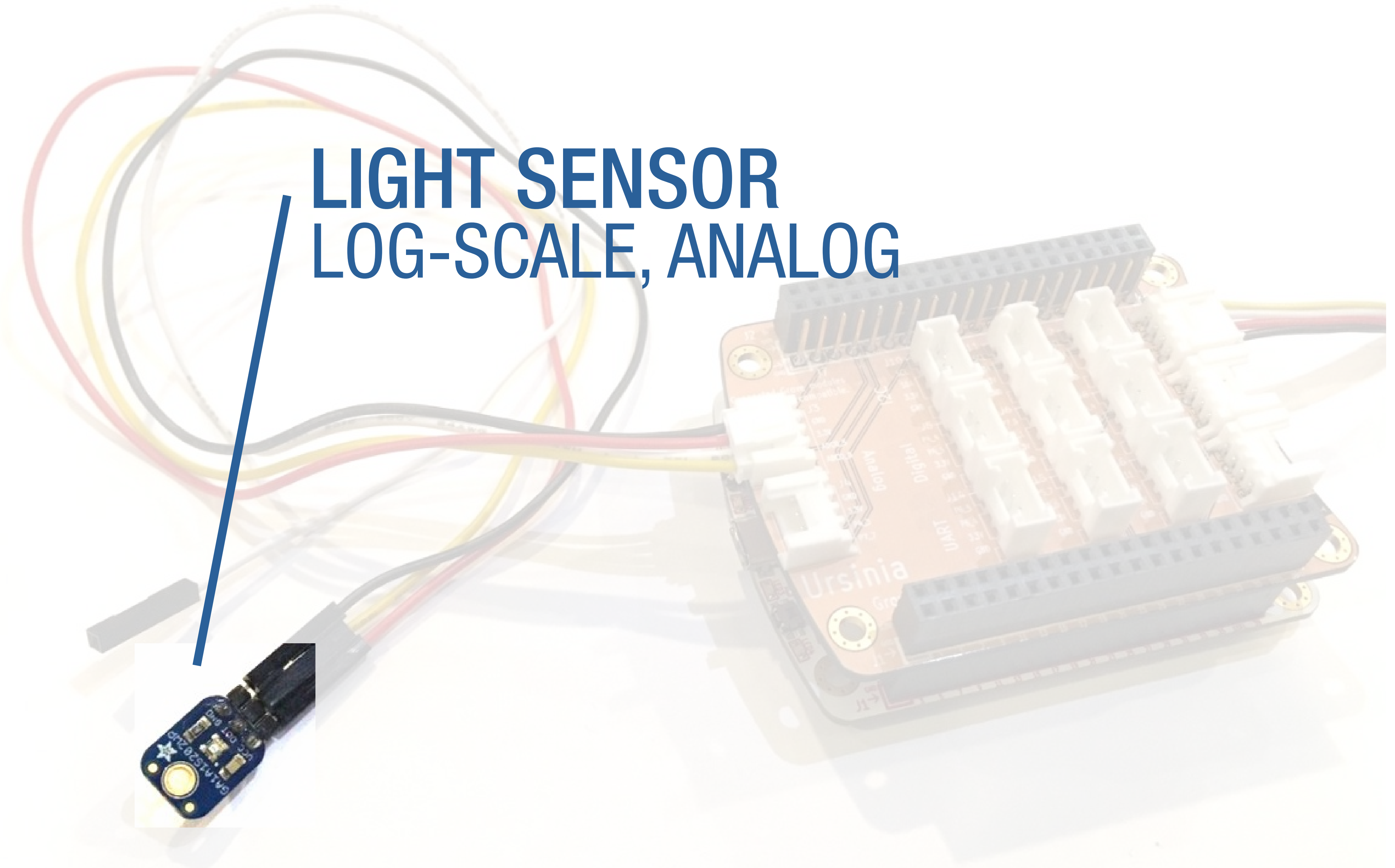

Ursinia
Analog
Digital
UART

# GREATFET ONE

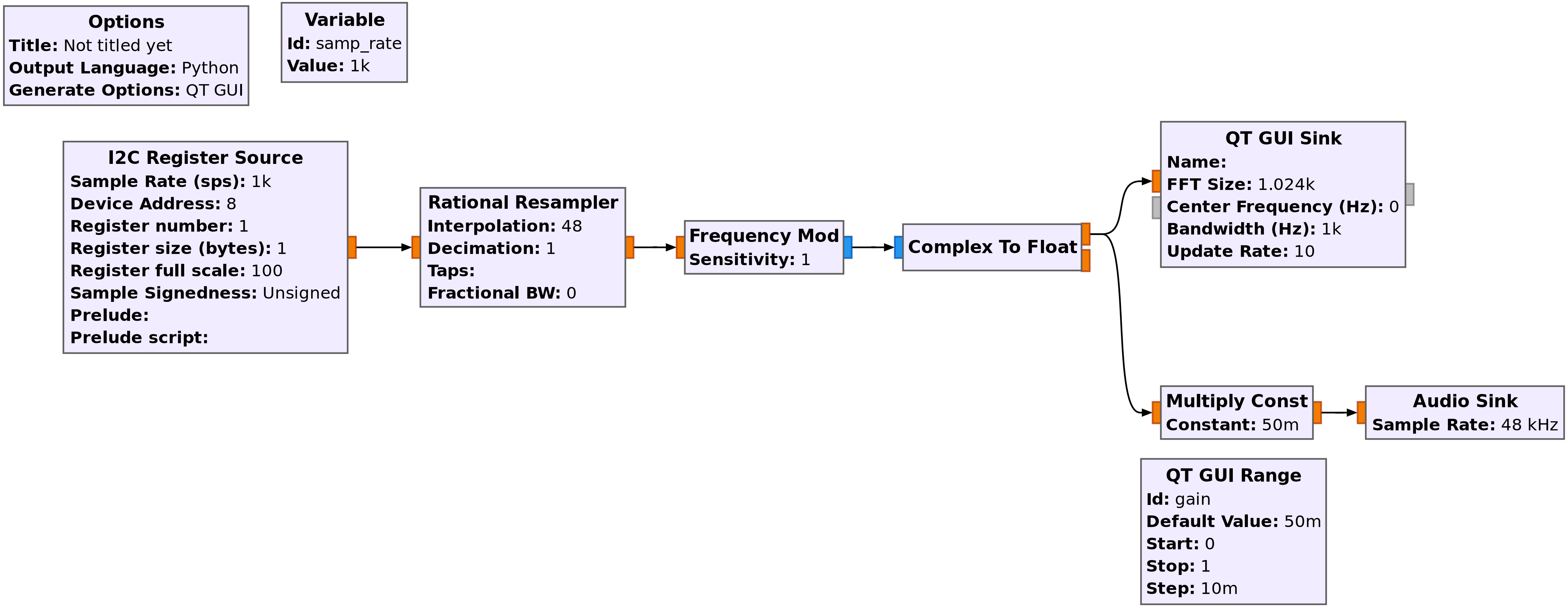
## USB INTERFACE TO THE WORLD



# LIGHT SENSOR
LOG-SCALE, ANALOG

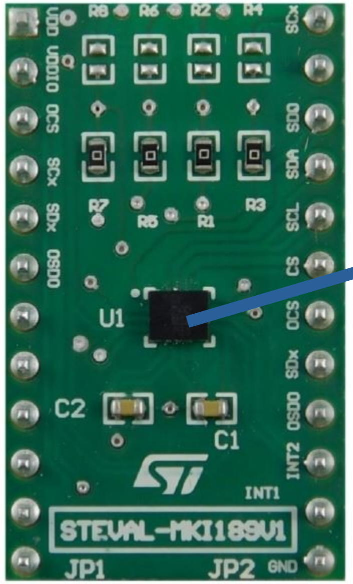


[interfacing demo]

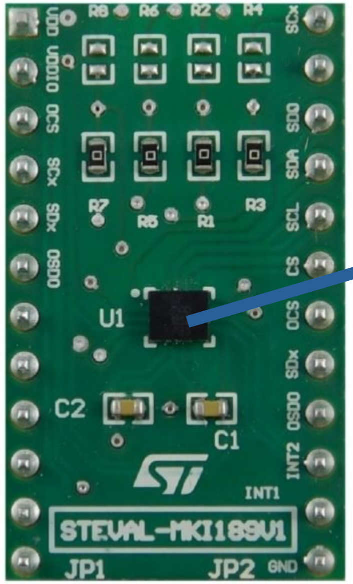


Options
Title: Not titled yet
Output Language: Python
Generate Options: QT GUI
Variable
Id: samp_rate
Value: 1k
I2C Register Source
Sample Rate (sps): 1k
Device Address: 8
Register number: 1
Register size (bytes): 1
Register full scale: 100
Sample Signedness: Unsigned
Prelude:
Prelude script:
Rational Resampler
Interpolation: 48
Decimation: 1
Taps:
Fractional BW: 0
Frequency Mod
Sensitivity: 1
Complex To Float
QT GUI Sink
Name:
FFT Size: 1.024k
Center Frequency (Hz): 0
Bandwidth (Hz): 1k
Update Rate: 10
Multiply Const
Constant: 50m
Audio Sink
Sample Rate: 48 kHz
QT GUI Range
Id: gain
Default Value: 50m
Start: 0
Stop: 1
Step: 10m

[more sensors]



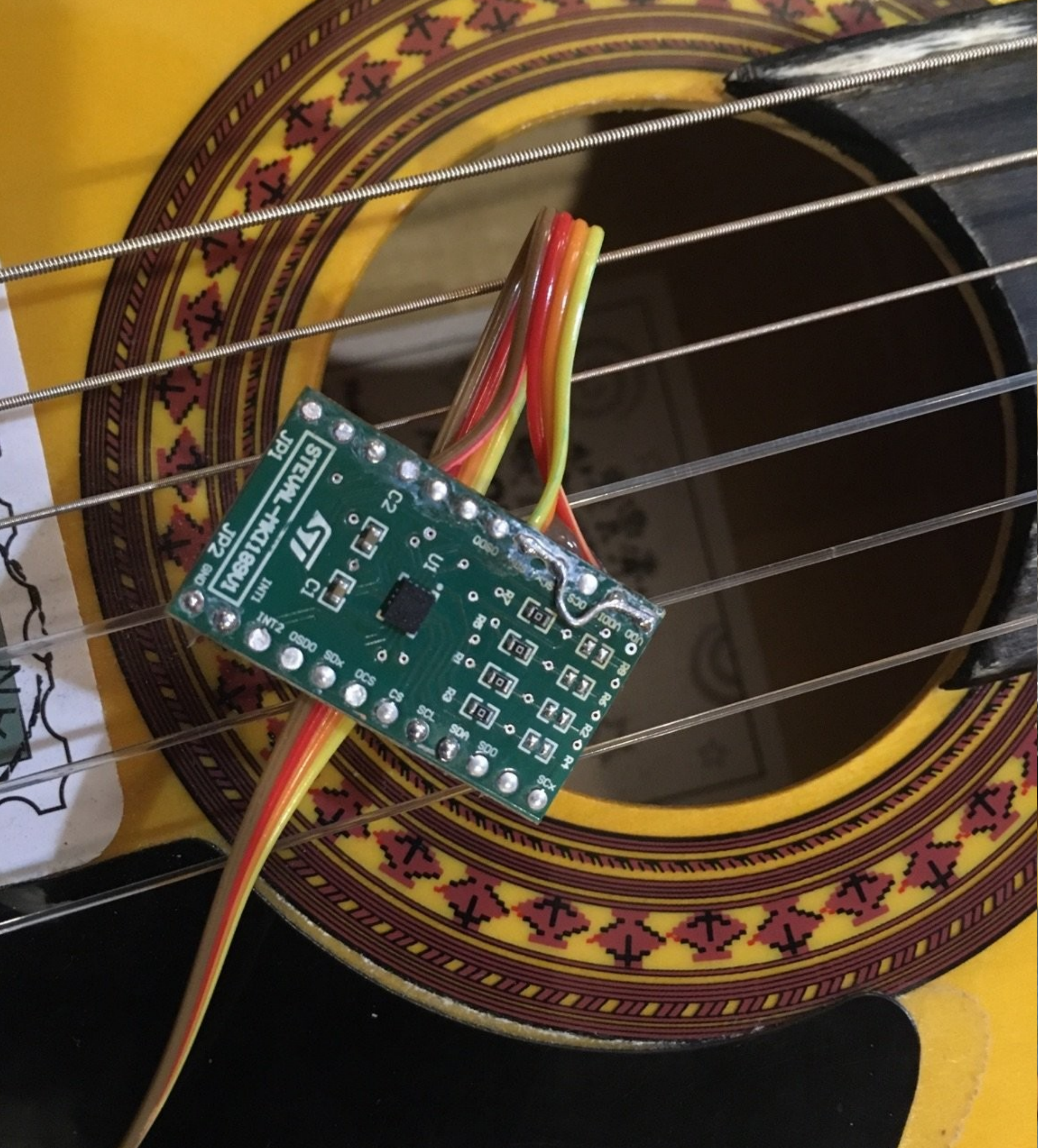

LSM6DSM
ACCELEROMETER

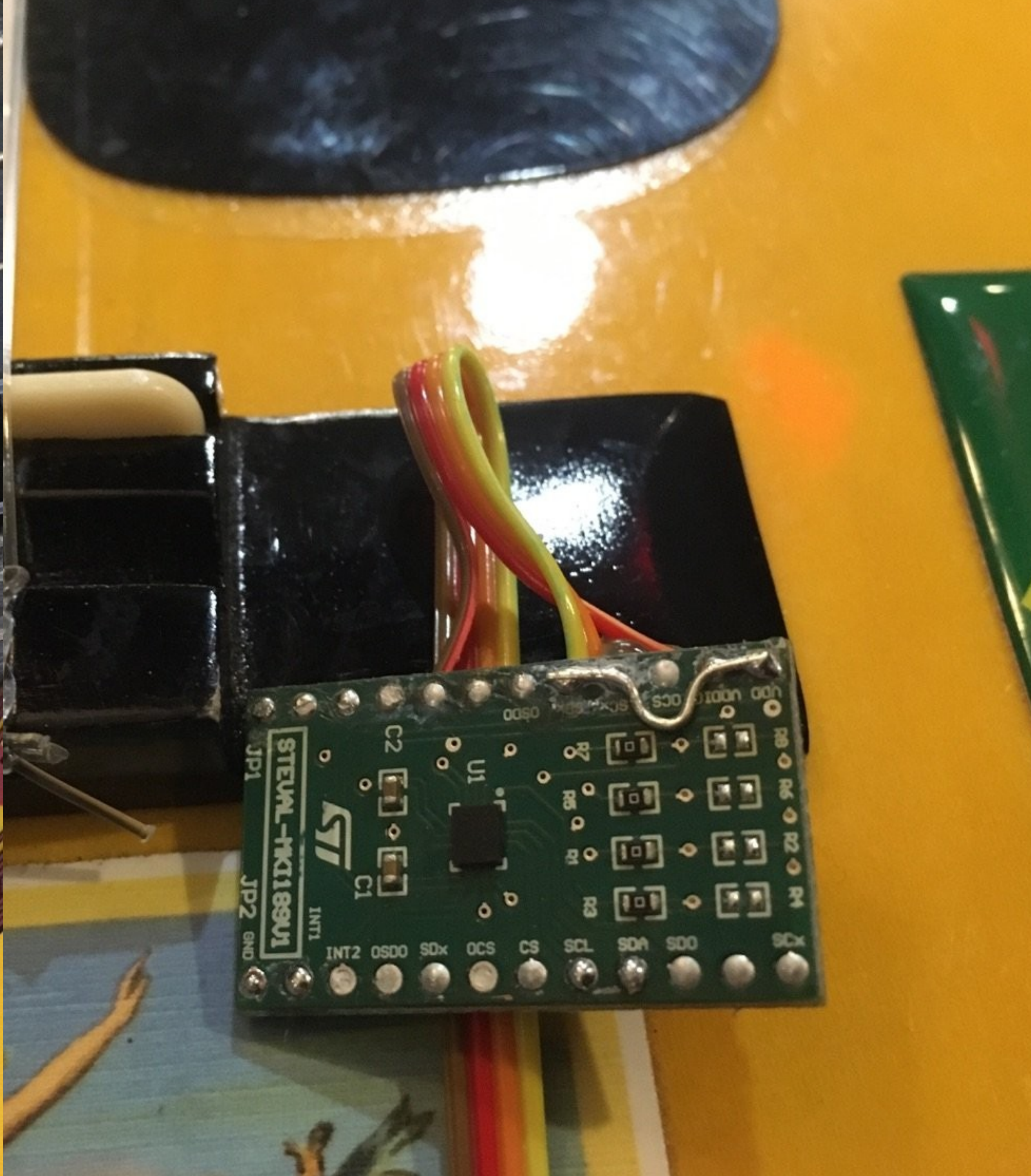


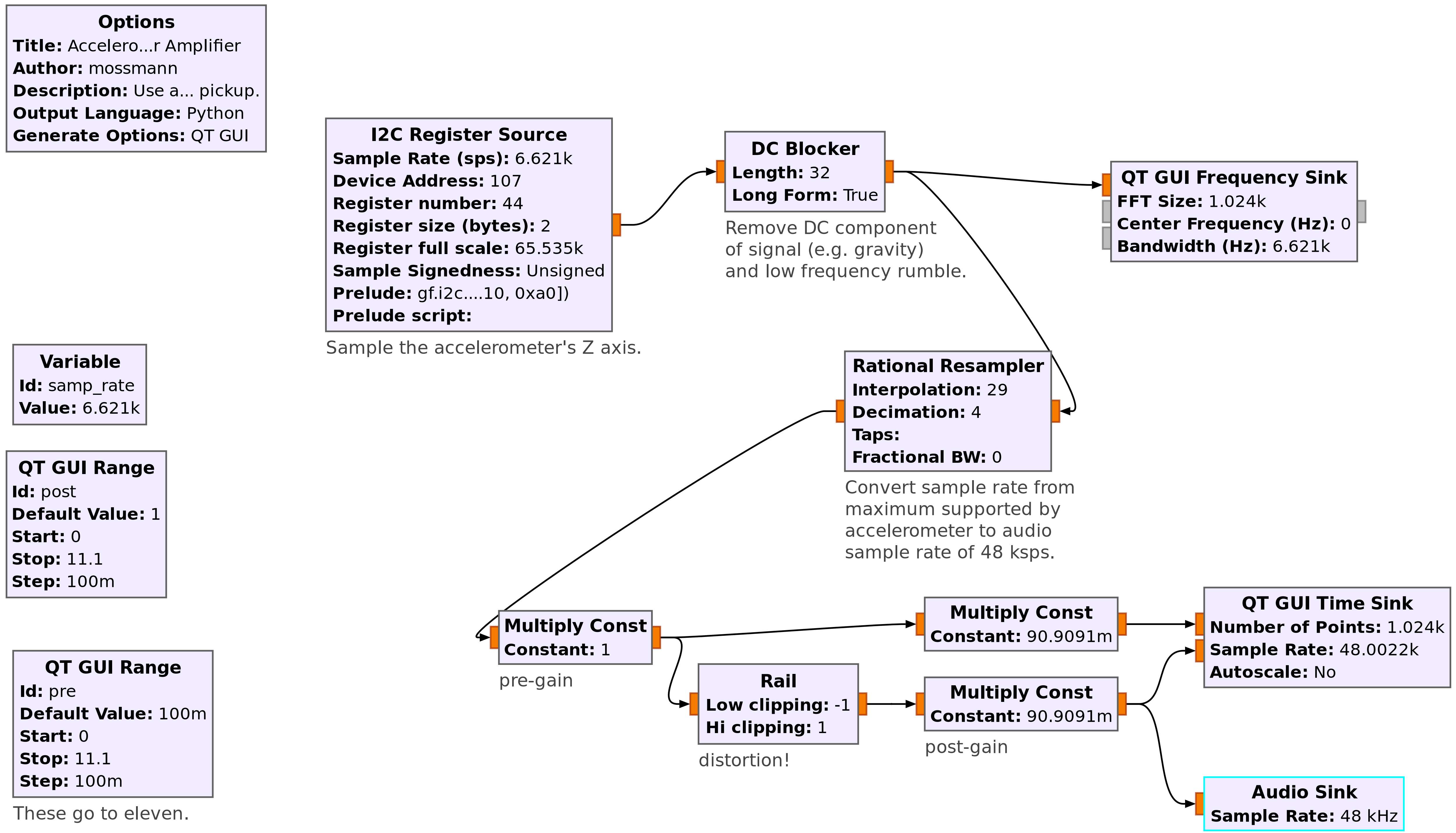

LSM6DSM

~~ACCELEROMETER~~

MICROPHONE


STEVAL-MKI189V1
JP1
JP2
C1
C2
U1
GND
INT1
INT2
OSDO
SDx
OCS
CS
SCL
SDA
SDO
SCx
VDD


STEVAL-MKI189V1
JP1
JP2
C1
C2
U1
GND
INT1
INT2
OSDO
SDx
OCS
CS
SCL
SDA
SDO
SCx
VDDIO
VDD
R1
R2
R3
R4
R5
R6
R7
R8


Options
Title: Accelero...r Amplifier
Author: mossmann
Description: Use a... pickup.
Output Language: Python
Generate Options: QT GUI
I2C Register Source
Sample Rate (sps): 6.621k
Device Address: 107
Register number: 44
Register size (bytes): 2
Register full scale: 65.535k
Sample Signedness: Unsigned
Prelude: gf.i2c....10, 0xa0])
Prelude script:
Sample the accelerometer's Z axis.
DC Blocker
Length: 32
Long Form: True
Remove DC component of signal (e.g. gravity) and low frequency rumble.
QT GUI Frequency Sink
FFT Size: 1.024k
Center Frequency (Hz): 0
Bandwidth (Hz): 6.621k
Variable
Id: samp_rate
Value: 6.621k
Rational Resampler
Interpolation: 29
Decimation: 4
Taps:
Fractional BW: 0
Convert sample rate from maximum supported by accelerometer to audio sample rate of 48 ksps.
QT GUI Range
Id: post
Default Value: 1
Start: 0
Stop: 11.1
Step: 100m
Multiply Const
Constant: 1
pre-gain
Multiply Const
Constant: 90.9091m
QT GUI Time Sink
Number of Points: 1.024k
Sample Rate: 48.0022k
Autoscale: No
Rail
Low clipping: -1
Hi clipping: 1
distortion!
Multiply Const
Constant: 90.9091m
post-gain
QT GUI Range
Id: pre
Default Value: 100m
Start: 0
Stop: 11.1
Step: 100m
These go to eleven.
Audio Sink
Sample Rate: 48 kHz

# Sonic Nirvana: Using MEMS Accelerometers as Acoustic Pickups in Musical Instruments

By Rob O'Reilly, Alex Khenkin, and Kieran Harney

## Introduction

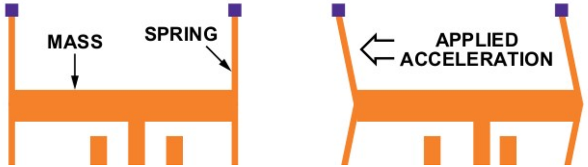
MEMS[1] (microelectromechanical systems) technology builds on the core fabrication infrastructure developed for silicon integrated circuits. Micromechanical structures are created by etching defined patterns on a silicon substrate to form sensor elements or mechanical actuators that can move fractions of a micron. Pressure sensors, one of the first high volume MEMS applications, now monitor pressure in hundreds of millions of engine manifolds and tires; and MEMS accelerometers have been used for over 15 years for airbag deployment, rollover detection, and automotive alarm systems.

MEMS accelerometers[2] are also used for motion sensing in consumer applications, such as video games and cell phones. MEMS micromirror optical actuators are used in overhead projectors, HDTVs, and digital theater presentations. In recent years, MEMS microphones[3] have begun to proliferate the broad consumer market, including cell phones, Bluetooth headsets, personal computers, and digital cameras.

This article describes some of the key technologies deployed in MEMS accelerometer products and discusses how this technology can bring a new dimension to acoustic transducers.

## MEMS Accelerometer Technology

The core element of a typical MEMS accelerometer is a moving beam structure composed of two sets of fingers: one set is fixed to a solid ground plane on a substrate; the other set is attached to a known mass mounted on springs that can move in response to an applied acceleration. This applied acceleration (Figure 1) changes the capacitance between the fixed and moving beam fingers.[4]




formed from single-crystal silicon, or from polysilicon that is deposited at very high temperatures on the surface of a single-crystal silicon wafer. Structures with very different mechanical characteristics can be created using this flexible technology. One mechanical parameter than can be controlled and varied is spring stiffness. The mass of the sense element and the damping of the structure can also be modified by design. Sensors can be produced to measure fractions of one *g* or hundreds of *g*'s with bandwidths as high as 20 kHz.

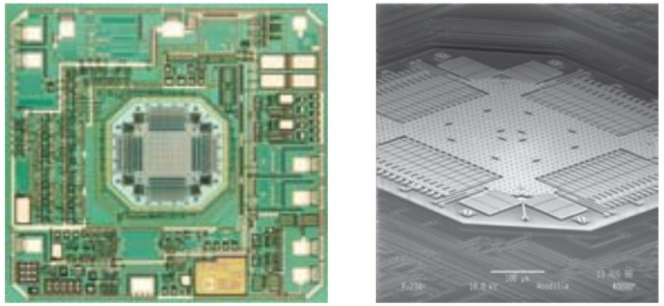


Figure 3. ADXL202 ±2 *g* accelerometer.

The MEMS sensing element can be connected to the conditioning electronics on the same chip (Figure 3) or on a separate chip (Figure 4). For a single-chip solution, the capacitance of the sense element can be as low as 1 to 2 femtofarads per *g*, which equates to measurement resolution in the attofarad range! In a two-chip structure, the capacitance of the MEMS element must be high enough to overcome the parasitic capacitance effects of the bond wires between the MEMS and the conditioning ASIC (application specific integrated circuit).[5]

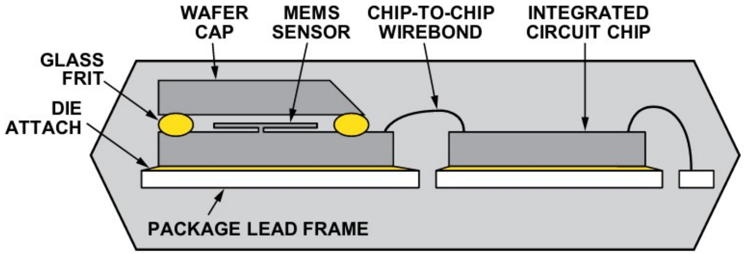



Figure 4. Cross-section of a typical two-chip accelerometer.

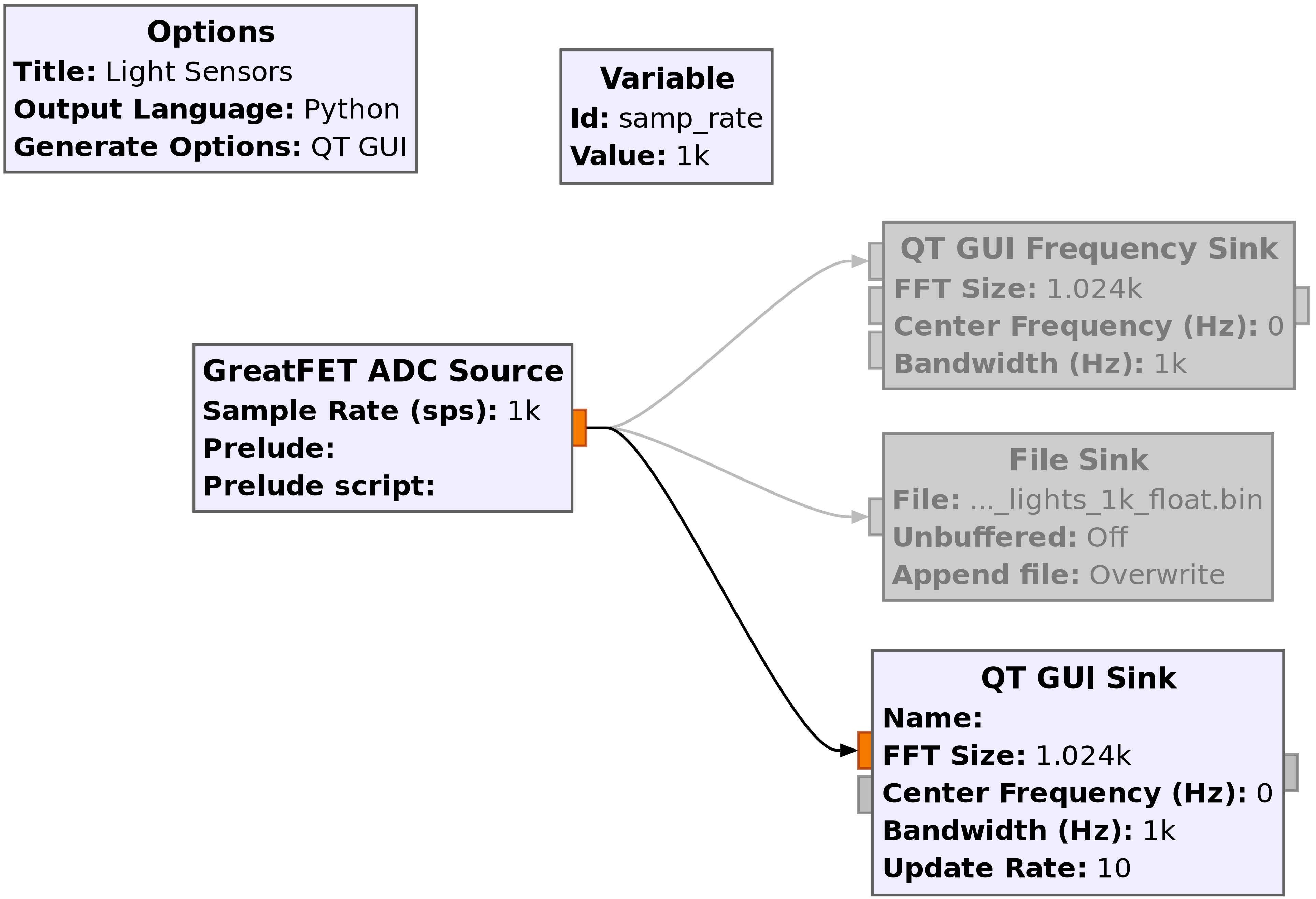
## Accelerometers as Vibration Measurement Sensors

The concept of using vibration sensing transducers as acoustic

All code & demos are online!

https://github.com/greatscottgadgets/greatfet
https://github.com/ktemkin/presentations

# QUESTIONS?


Options
Title: Light Sensors
Output Language: Python
Generate Options: QT GUI
Variable
Id: samp_rate
Value: 1k
GreatFET ADC Source
Sample Rate (sps): 1k
Prelude:
Prelude script:
QT GUI Frequency Sink
FFT Size: 1.024k
Center Frequency (Hz): 0
Bandwidth (Hz): 1k
File Sink
File: ..._lights_1k_float.bin
Unbuffered: Off
Append file: Overwrite
QT GUI Sink
Name:
FFT Size: 1.024k
Center Frequency (Hz): 0
Bandwidth (Hz): 1k
Update Rate: 10