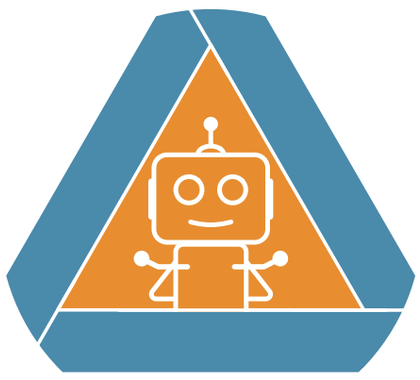
Better Electronics with Jupyter Notebooks

Chris Osterwood
Founder, Capable Robot Components
osterwood@capablerobot.com

http://capablerobot.com
http://github.com/capablerobot

http://github.com/osterwood
@osterwood



Capable
Robot
Components

What are Jupyter Notebooks?

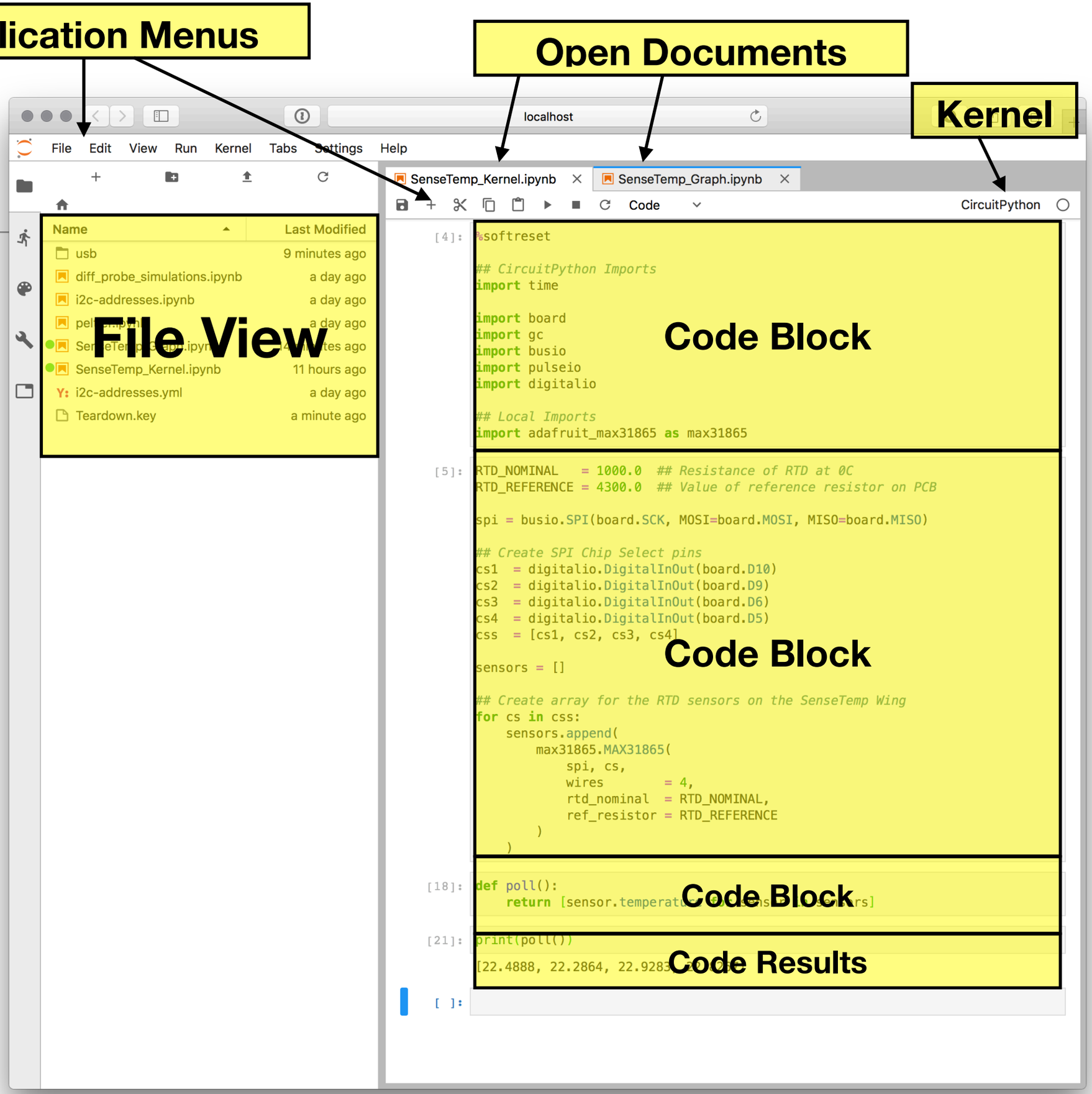
- Web-based development & execution environment
- Support for many different runtimes / languages thru “kernels” which execute code (provided by frontend) in a backend, and which return results to the frontend.

- **Main advantage of “normal” code execution is interleaving of program and results in a single document.**
- **Results can be live.**
- **Results can be formatted.**

Jupyter Lab

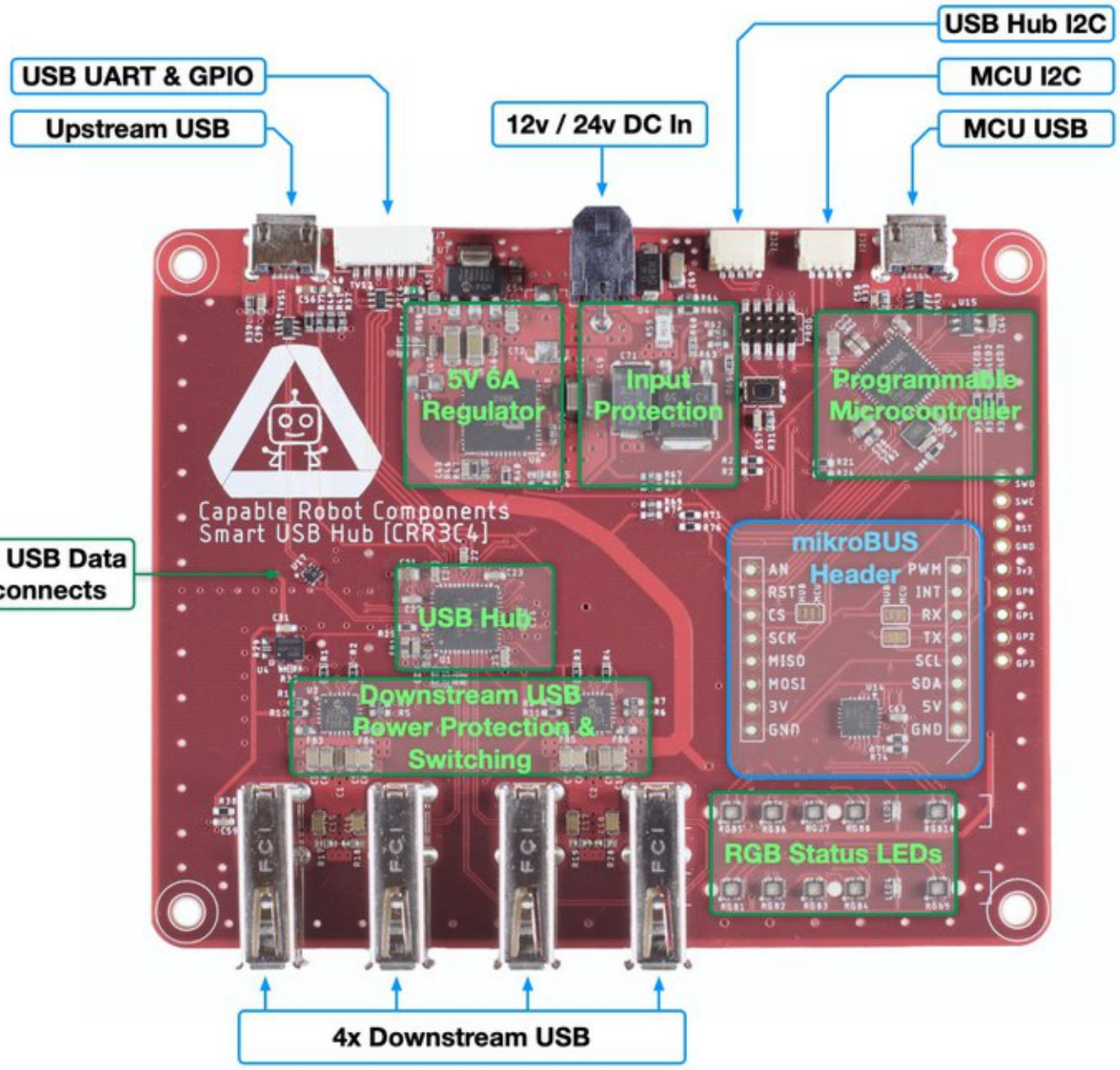
- New generation of Jupyter Notebook
- Still in active development, but very useable and fully featured.
- Not all extensions are supported yet.

- Blocks can be:
  - Code : Executable
  - Markdown : Edit in plain text, render in rich text.
  - Raw : Plain text
- Blocks can be executed in order, or one at a time.



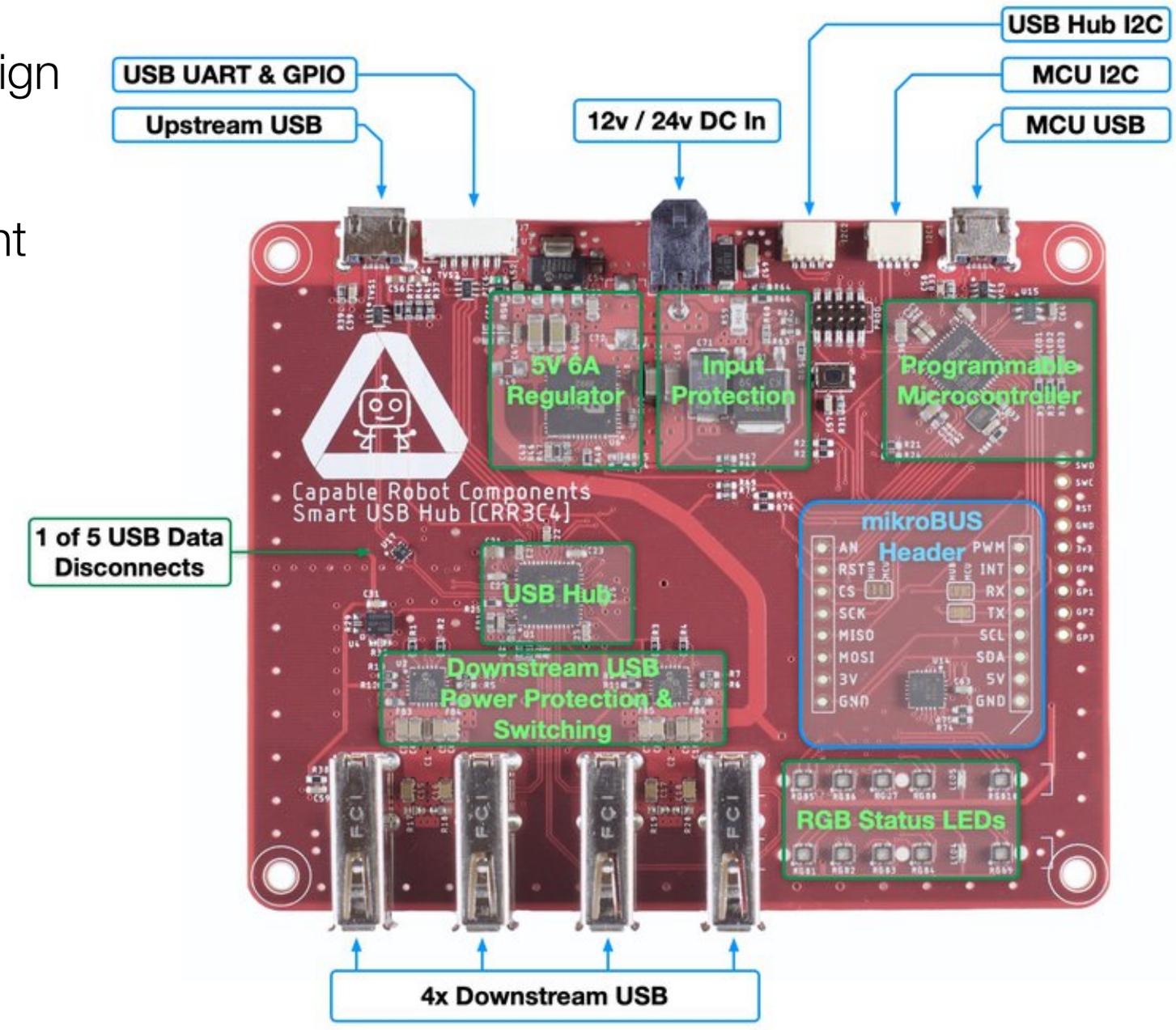
Programmable USB Hub

- Launched on Crowd Supply today!
- 4 Port High Speed USB Hub, that is also:
  - A CircuitPython based development board.
  - A bridge between your computer and I2C (via Sparkfun Qwiic connectors), GPIO, and SPI (via its mikroBUS header).
- A power supply, providing 6 A of 5 V power to downstream devices and 13 mA resolution monitoring (per-port). Port power is individually limitable and switchable.
- A USB to TTL Serial adapter.
- A flexible embedded electronics test and development tool. USB data pairs are individually switchable, allowing you to emulate device removal and insertion via software.



Programmable USB Hub

- Juypter used for:
  - I2C address assignment / conflict resolution
  - Input protection calculations & design
  - 5V DC regulator design
  - Device testing & driver development



I2C Address Assignment / Conflict Resolution

i2c-address.py

```
        self.devices = []
        self.taken = {}

    def add(self, name):
        if name in self.data:
            addr = self.data[name]
            self.devices.append([name, addr, 7 - addr.count(0) - addr.count(1)])
        else:
            raise Exception("Cannot find device: {}".format(name))

    def solve(self):
        ## Iterate through the selected devices by the number of adjustable bits
        for dev in sorted(self.devices, key=lambda d: d[2]):
            incr = 0

            while True:

                try:
                    bits = resolve(dev[1], incr)
                except Exception:
                    print("WARN : Cannot resolve {}, no free addresses".format(dev[0]))
                    break
                address = numeric_addr(bits)

                if address not in self.taken:
                    self.taken[address] = dev + [bits]
                    break

                incr += 1

        return self.taken

    def print(self):
        for addr, dev in self.taken.items():

            print("{} @ {}".format(dev[0], hex(addr)))
            print("\t", dev[1])
            print("\t", dev[3])
            print()

devices = Devices()

devices.add('TLC59116')
devices.add('TLC59116')
devices.add('UCS2113-1')
devices.add('UCS2113-2')
devices.add('MCP23008')
devices.add('24AA025E48')
devices.add('ATECC508A')
devices.add('MCP9808')

devices.solve()
devices.print()
```

Line 13, Column 1 — 2 misspelled words — Spaces: 4 — Python

```
> python3 i2c-address.py
UCS2113-1 @ 0x57
        [1, 0, 1, 0, 1, 1, 1]
        [1, 0, 1, 0, 1, 1, 1]

UCS2113-2 @ 0x58
        [1, 0, 1, 1, 0, 0, 0]
        [1, 0, 1, 1, 0, 0, 0]

ATECC508A @ 0x60
        [1, 1, 0, 0, 0, 0, 0]
        [1, 1, 0, 0, 0, 0, 0]

24AA025E48 @ 0x50
        [1, 0, 1, 0, 0, 'A1', 'A0']
        [1, 0, 1, 0, 0, 0, 0]

MCP23008 @ 0x20
        [0, 1, 0, 0, 'A2', 'A1', 'A0']
        [0, 1, 0, 0, 0, 0, 0]

MCP9808 @ 0x18
        [0, 0, 1, 1, 'A2', 'A1', 'A0']
        [0, 0, 1, 1, 0, 0, 0]

TLC59116 @ 0x61
        [1, 1, 0, 'A3', 'A2', 'A1', 'A0']
        [1, 1, 0, 0, 0, 0, 1]

TLC59116 @ 0x62
        [1, 1, 0, 'A3', 'A2', 'A1', 'A0']
        [1, 1, 0, 0, 0, 1, 0]
```

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devices.solve()
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```

Line 13, Column 1 — 2 misspelled words — Spaces: 4 — Python

```
> python3 i2c-address.py
WARN : Cannot resolve ATECC508A, no free addresses
UCS2113-1 @ 0x57
        [1, 0, 1, 0, 1, 1, 1]
        [1, 0, 1, 0, 1, 1, 1]

UCS2113-2 @ 0x58
        [1, 0, 1, 1, 0, 0, 0]
        [1, 0, 1, 1, 0, 0, 0]

ATECC508A @ 0x60
        [1, 1, 0, 0, 0, 0, 0]
        [1, 1, 0, 0, 0, 0, 0]

24AA025E48 @ 0x50
        [1, 0, 1, 0, 0, 'A1', 'A0']
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        [0, 0, 1, 1, 'A2', 'A1', 'A0']
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TLC59116 @ 0x61
        [1, 1, 0, 'A3', 'A2', 'A1', 'A0']
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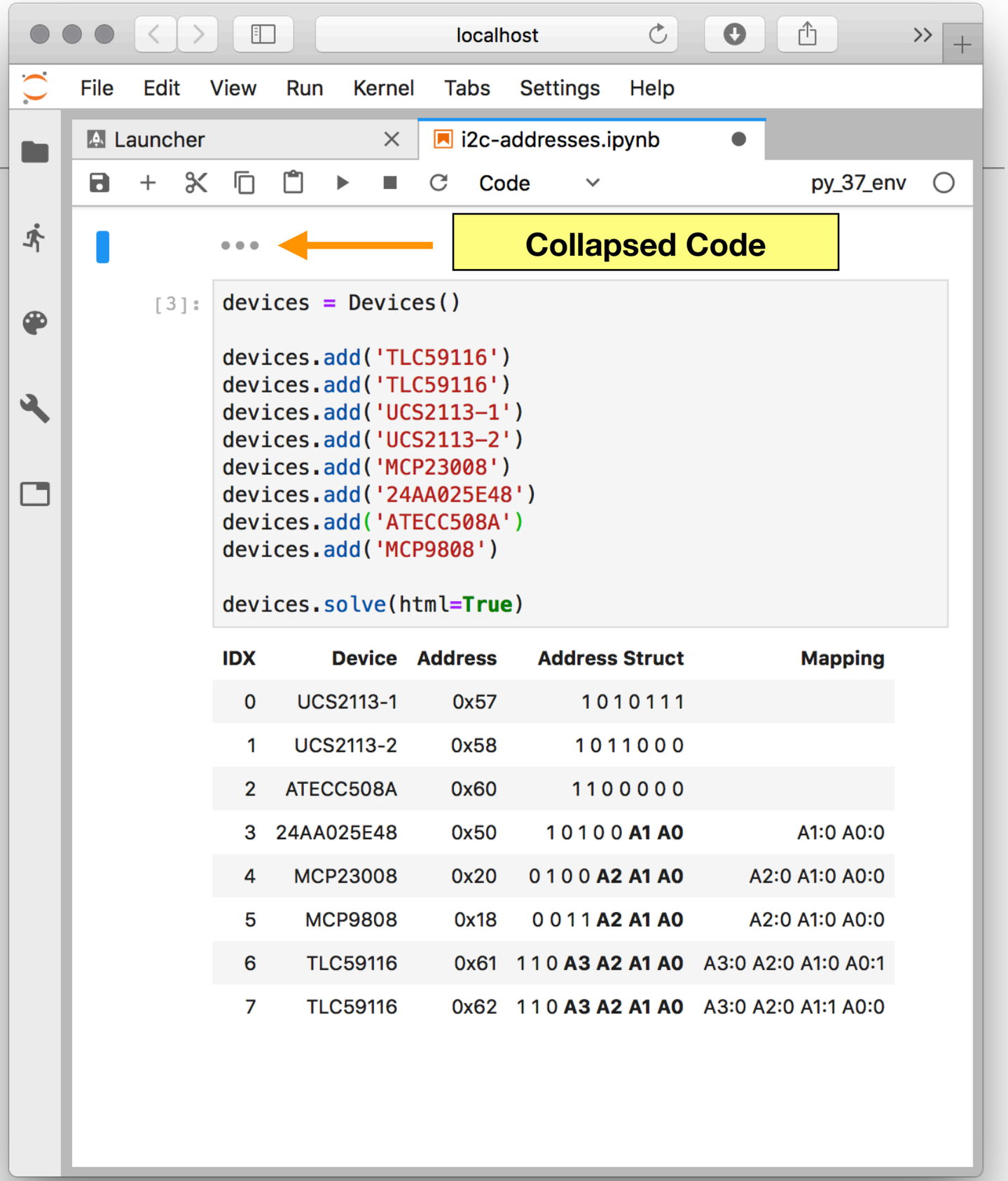
TLC59116 @ 0x62
        [1, 1, 0, 'A3', 'A2', 'A1', 'A0']
        [1, 1, 0, 0, 0, 1, 0]
```

I2C Address Assignment / Conflict Resolution

- Results can now be displayed and formatted richly in an HTML table

- Code which solves I2C address assignment can be collapsed & hidden from view when not being edited.

- Python Mustache library used for HTML templating



IDX	Device	Address	Address Struct	Mapping
0	UCS2113-1	0x57	1 0 1 0 1 1 1	
1	UCS2113-2	0x58	1 0 1 1 0 0 0	
2	ATECC508A	0x60	1 1 0 0 0 0 0	
3	24AA025E48	0x50	1 0 1 0 0 **A1 A0**	A1:0 A0:0
4	MCP23008	0x20	0 1 0 0 **A2 A1 A0**	A2:0 A1:0 A0:0
5	MCP9808	0x18	0 0 1 1 **A2 A1 A0**	A2:0 A1:0 A0:0
6	TLC59116	0x61	1 1 0 **A3 A2 A1 A0**	A3:0 A2:0 A1:0 A0:1
7	TLC59116	0x62	1 1 0 **A3 A2 A1 A0**	A3:0 A2:0 A1:1 A0:0

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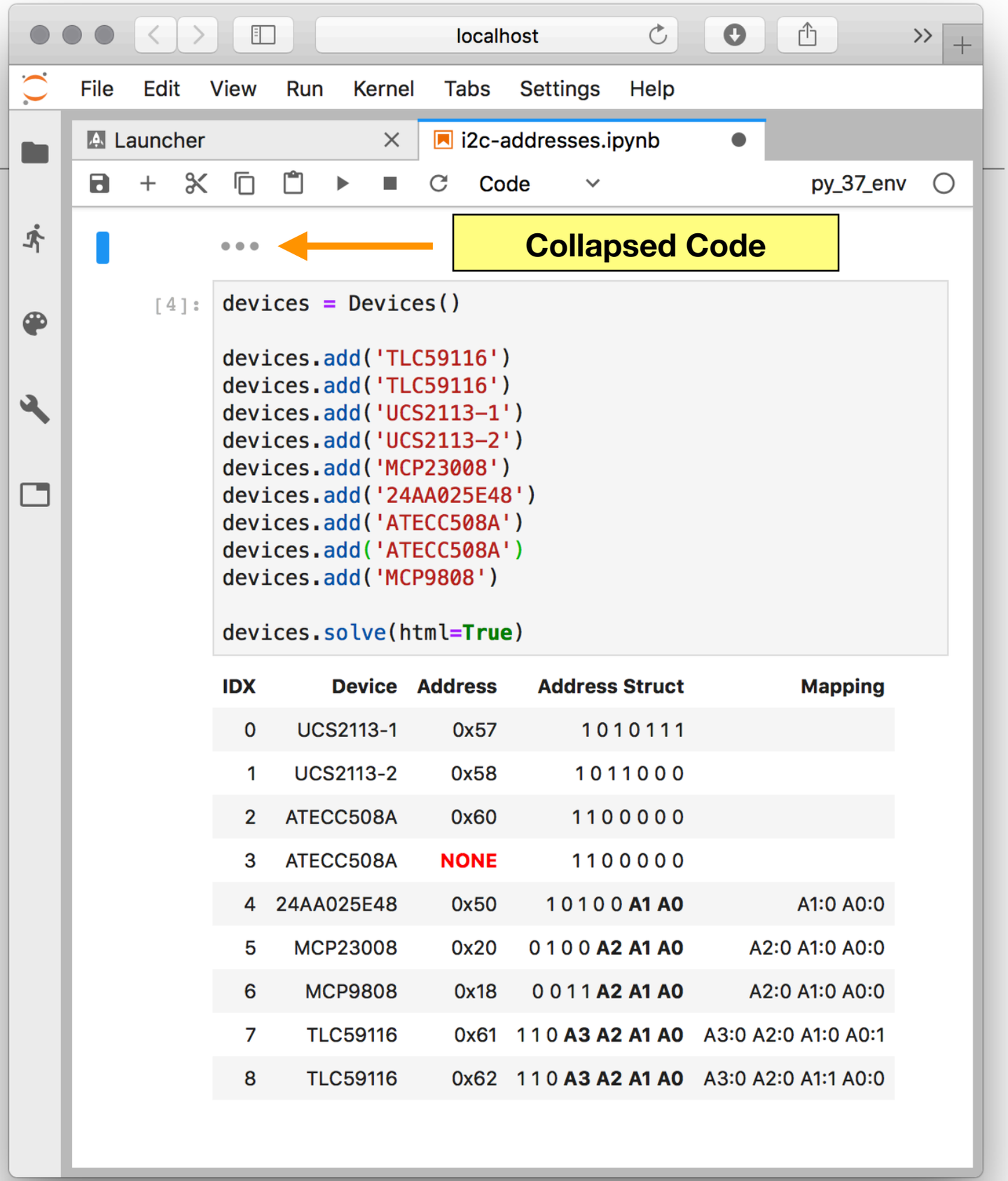
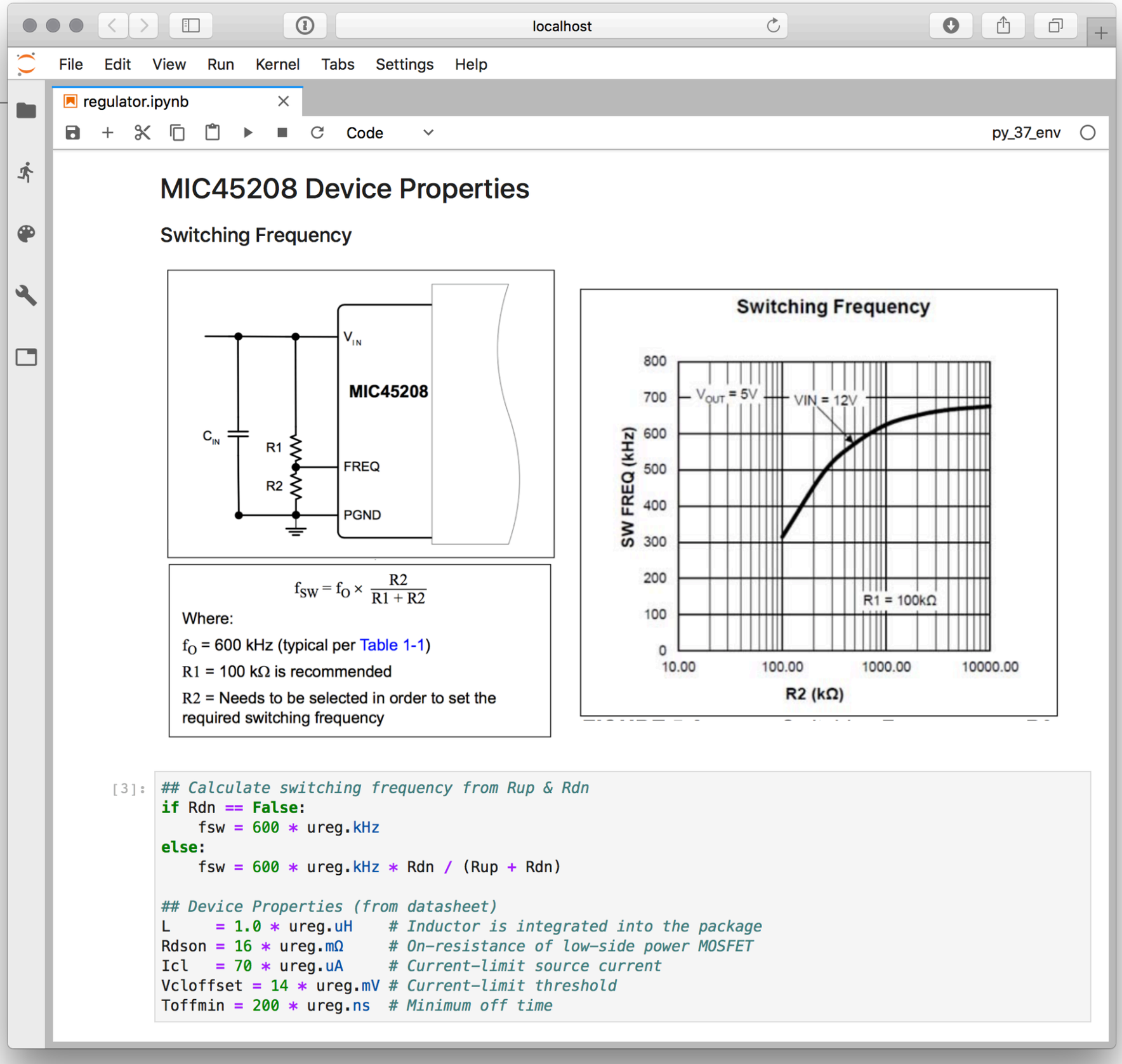


IDX	Device	Address	Address Struct	Mapping
0	UCS2113-1	0x57	1 0 1 0 1 1 1	
1	UCS2113-2	0x58	1 0 1 1 0 0 0	
2	ATECC508A	0x60	1 1 0 0 0 0 0	
3	ATECC508A	NONE	1 1 0 0 0 0 0	
4	24AA025E48	0x50	1 0 1 0 0 **A1 A0**	A1:0 A0:0
5	MCP23008	0x20	0 1 0 0 **A2 A1 A0**	A2:0 A1:0 A0:0
6	MCP9808	0x18	0 0 1 1 **A2 A1 A0**	A2:0 A1:0 A0:0
7	TLC59116	0x61	1 1 0 **A3 A2 A1 A0**	A3:0 A2:0 A1:0 A0:1
8	TLC59116	0x62	1 1 0 **A3 A2 A1 A0**	A3:0 A2:0 A1:1 A0:0

DC Regulator Design

Important excerpts from the data sheet can be embedded in the notebook via image tags inside of Markdown Blocks



[3]:
```
## Calculate switching frequency from Rup & Rdn
if Rdn == False:
    fsw = 600 * ureg.kHz
else:
    fsw = 600 * ureg.kHz * Rdn / (Rup + Rdn)

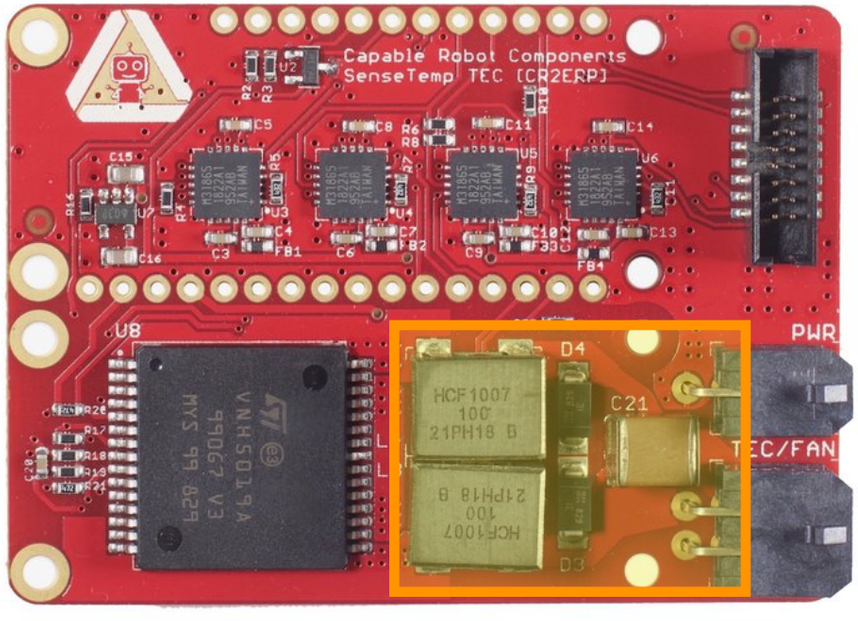
## Device Properties (from datasheet)
L     = 1.0 * ureg.uH    # Inductor is integrated into the package
Rdson = 16 * ureg.mΩ     # On-resistance of low-side power MOSFET
Icl   = 70 * ureg.uA     # Current-limit source current
Vcloffset = 14 * ureg.mV # Current-limit threshold
Toffmin = 200 * ureg.ns  # Minimum off time
```

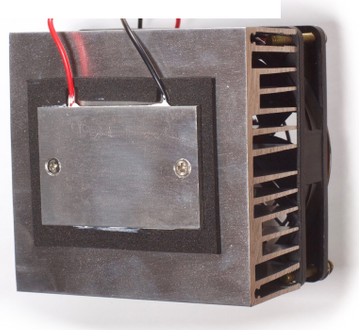
Live Graphing Demos

- USB Hub Current Monitor
- SenseTemp

Spice Simulation
TEC Controller

- DC motor driver (PWM based)
- Non-inductive load : Peltier Element
- What inductors, diodes, & capacitors are needed to make the motor driver happy?





```
import math
import numpy as np
import matplotlib.pyplot as plt

from PySpice.Unit import *

from PySpice.Probe.Plot import plot
from PySpice.Spice.Netlist import Circuit
from PySpice.Spice.Library import SpiceLibrary
from PySpice.Doc.ExampleTools import find_libraries

spice_library = SpiceLibrary('/Users/chris/Dropbox/Books/spicelib/')

circuit = Circuit('TEC Model')
circuit.include(spice_library['SMA6J12A'])

# 100 us -> 10 kHz
#  50 us -> 20 kHz
source = circuit.PulseVoltageSource('input', 'pwm', circuit.gnd,
                                    initial_value=0@u_V, pulsed_value=12@u_V,
                                    pulse_width=1@u_us, period=50@u_us)

## TEC is 12V, 5A -> 2.4 ohm
r_tec = 2.4@u_Ω
inductor = 10@u_uH

Rtec = circuit.R('TEC', 'TECP', 'TECM', r_tec)
L1 = circuit.L(1, 'pwm', 'TECP', inductor)
L2 = circuit.L(2, circuit.gnd, 'TECM', inductor)

C5 = circuit.C(5, 'TECP', 'TECM', 2*47@u_uF)

circuit.X('D1', 'SMA6J12A', 'TECP', 'snub')
circuit.X('D2', 'SMA6J12A', 'snub', 'TECM')

Rtec.minus.add_current_probe(circuit)

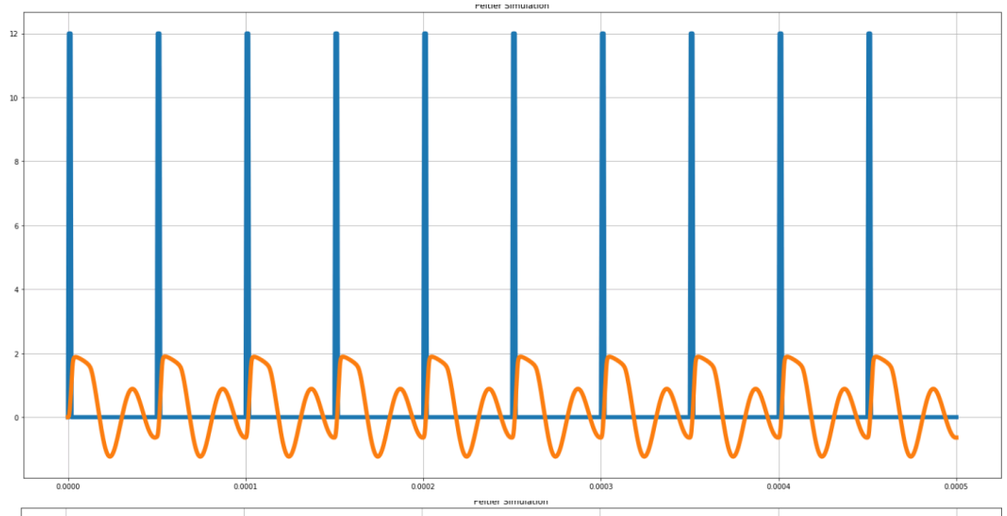
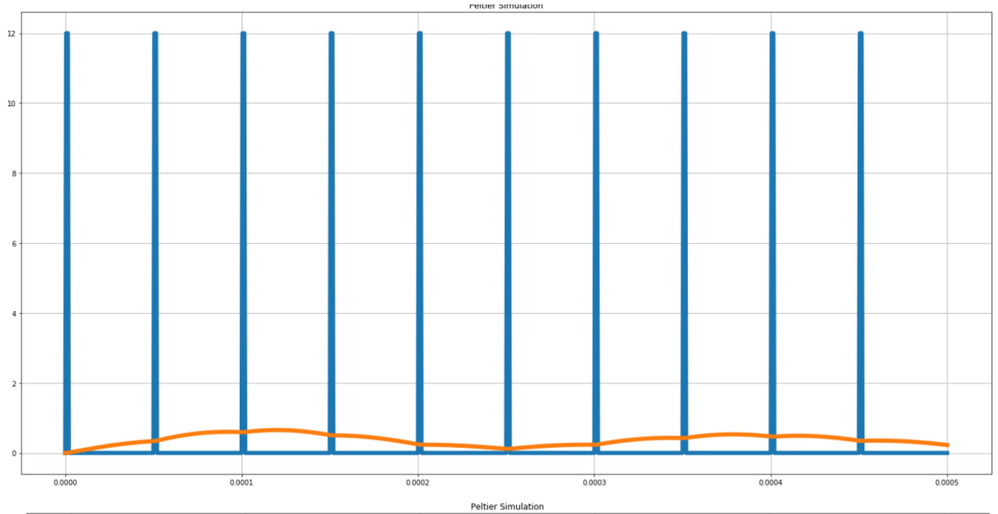
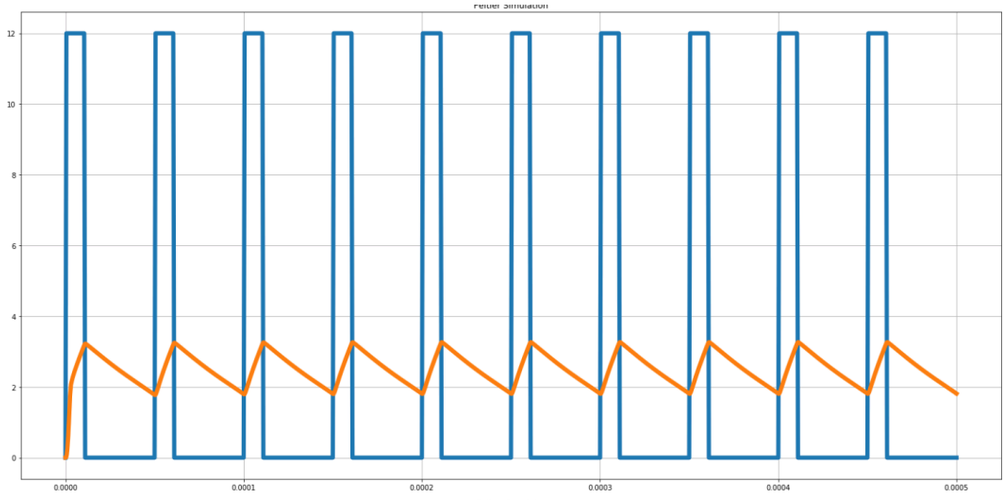
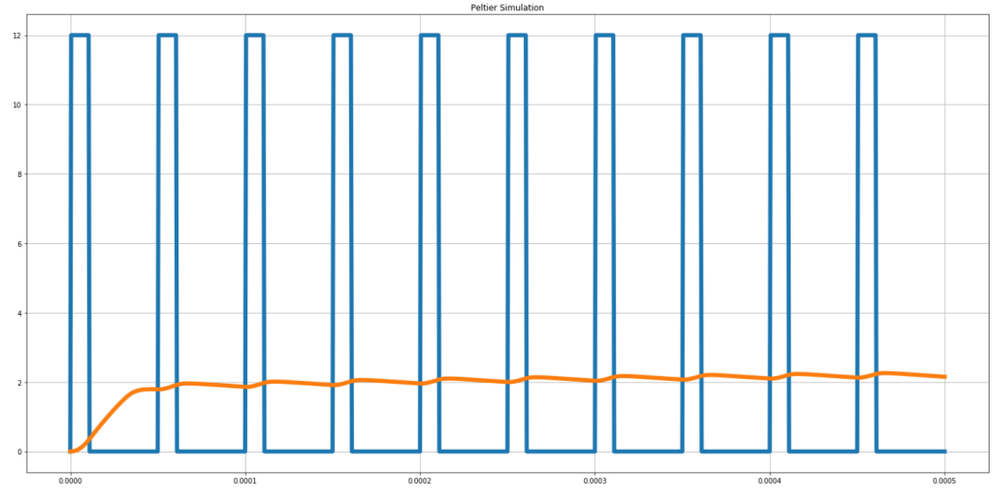
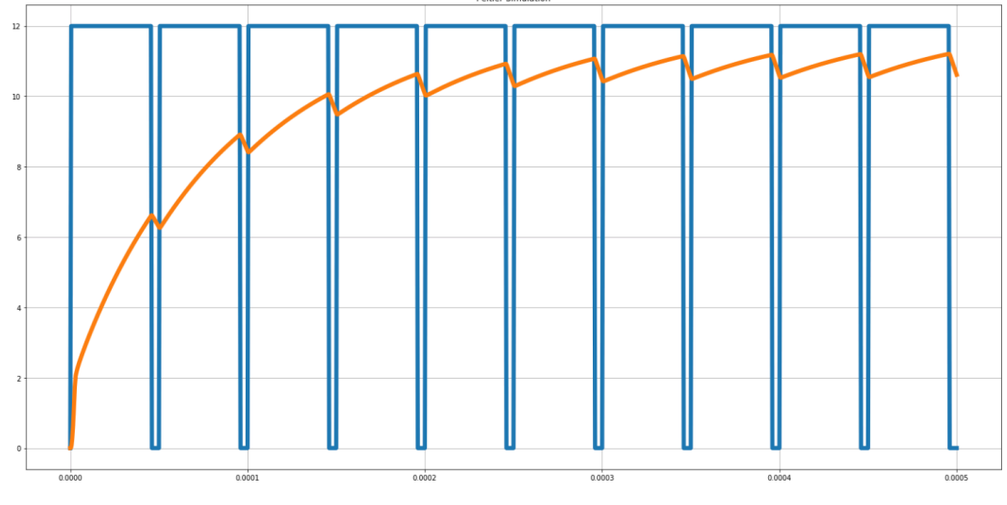
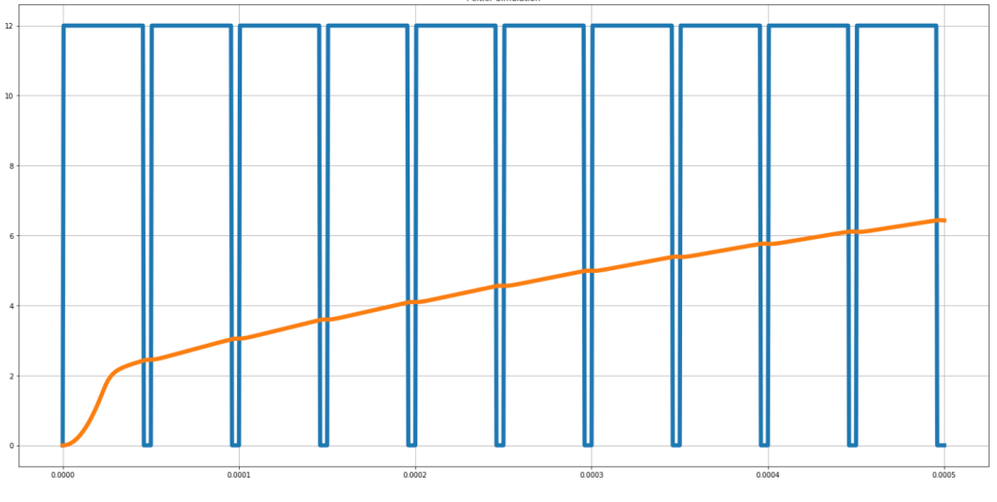
simulator = circuit.simulator(temperature=25, nominal_temperature=25)
step_time = source.period / 100
analysis = simulator.transient(step_time=step_time, end_time=source.period*10)

figure = plt.figure(1, (20, 10))

plot(analysis['pwm'])
plot(analysis['TECP'] - analysis['TECM'])

plt.title("Peltier Simulation")
plt.grid()
plt.legend(('VIN', 'VTEC'), loc=(.8,.8))
plt.tight_layout()
plt.show()
```

Spice Simulation TEC Controller

	1 uH & 8 uF	10 uH & 94 uF
2%		
20%		
95%		

Additional Resources & Tools

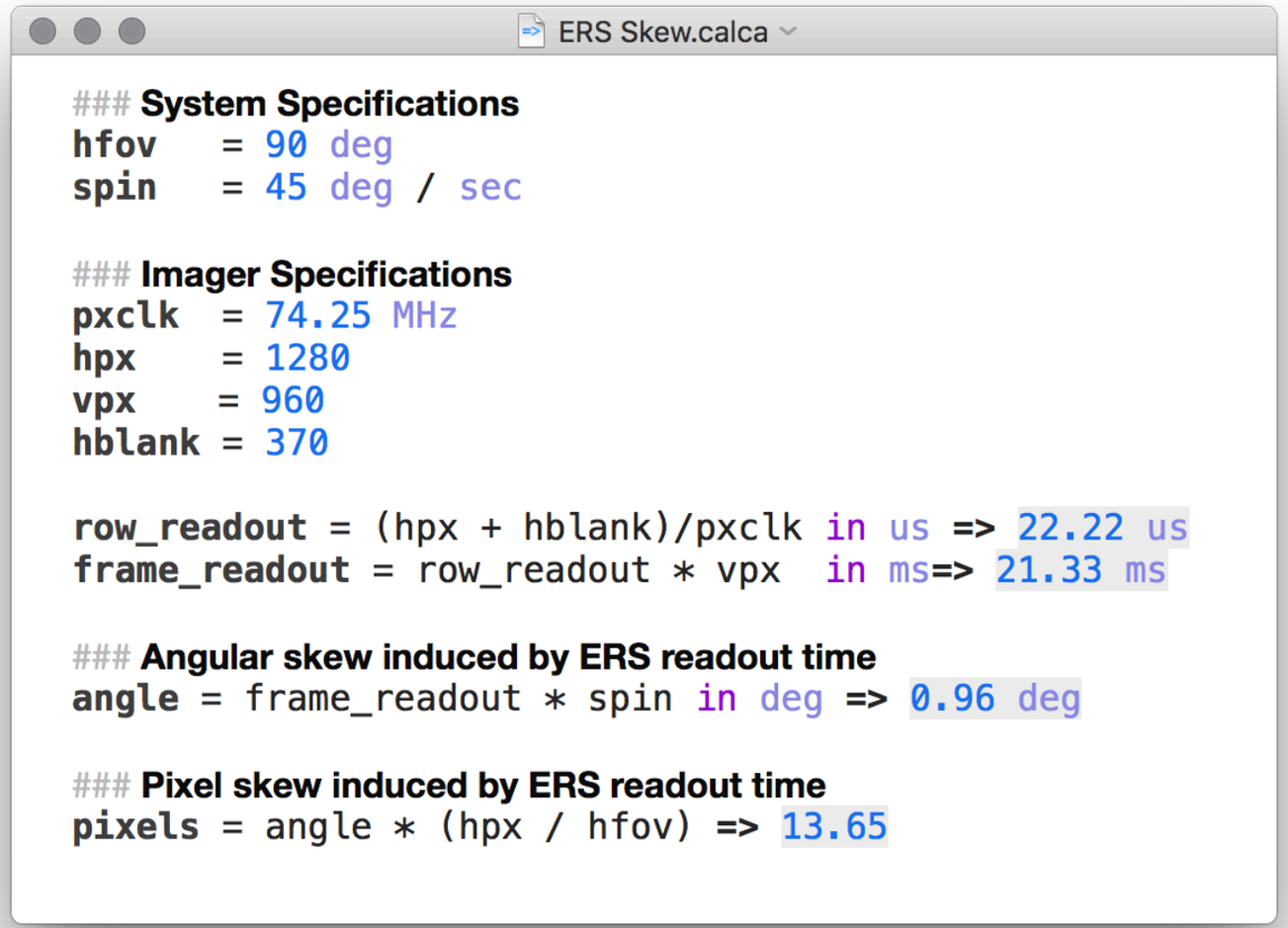
- http://github.com/capablerobot/notebooks

- https://jupyter.org
- https://jupyterlab.readthedocs.io

- https://pint.readthedocs.io
- https://bqplot.readthedocs.io
- https://nbconvert.readthedocs.io

- https://cocalc.com

- https://github.com/olbrich/ruby-units



Calca