IoT-ALE: Demystifying MCUs with Arduino

Nova (aka Justin) King

SCaLE 17x - March 2019

FIGURE 1. The Sunbeam Radiant Control toaster.

Arduino

- ATMEGA328
- Key parameters [edit]

Parameter	Value
CPU type	8-bit AVR
Performance	20 MIPS at 20 MHz[2]
Flash memory	32 kB
SRAM	2 kB
EEPROM	1 kB
Pin count	28 or 32 pin: PDIP-28, MLF-28, TQFP-32, MLF-32[2]
Maximum operating frequency	20 MHz
Number of touch channels	16
Hardware QTouch Acquisition	No
Maximum I/O pins	23
External interrupts	2
USB Interface	No
USB Speed	–

ESP8266

- Processor: L106 32-bit RISC microprocessor core based on the Tensilica Xtensa Diamond Standard 106Micro running at 80 MHz[5]
- Memory:
  - 32 KiB instruction RAM
  - 32 KiB instruction cache RAM
  - 80 KiB user-data RAM
  - 16 KiB ETS system-data RAM
- External QSPI flash: up to 16 MiB is supported (512 KiB to 4 MiB typically included)
- IEEE 802.11 b/g/n Wi-Fi
  - Integrated TR switch, balun, LNA, power amplifier and matching network
  - WEP or WPA/WPA2 authentication, or open networks
- 16 GPIO pins
- SPI
- I²C (software implementation)[6]
- I²S interfaces with DMA (sharing pins with GPIO)
- UART on dedicated pins, plus a transmit-only UART can be enabled on GPIO2
- 10-bit ADC (successive approximation ADC)

ESP32

- Processors:
    - CPU: Xtensa dual-core (or single-core) 32-bit LX6 microprocessor, operating at 160 or 240 MHz and performing at up to 600 DMIPS
    - Ultra low power (ULP) co-processor
- Memory: 520 KiB SRAM
- Wireless connectivity:
    - Wi-Fi: 802.11 b/g/n
    - Bluetooth: v4.2 BR/EDR and BLE
- Peripheral interfaces:
    - 12-bit SAR ADC up to 18 channels
    - 2 × 8-bit DACs
    - 10 × touch sensors (capacitive sensing GPIOs)
    - Temperature sensor
    - 4 × SPI
    - 2 × I²S interfaces
    - 2 × I²C interfaces
    - 3 × UART
    -

ESP32 Con’t

- SD/SDIO/CE-ATA/MMC/eMMC host controller
- SDIO/SPI slave controller
- Ethernet MAC interface with dedicated DMA and IEEE 1588 Precision Time Protocol support
- CAN bus 2.0
- Infrared remote controller (TX/RX, up to 8 channels)
- Motor PWM
- LED PWM (up to 16 channels)
- Hall effect sensor
- Ultra low power analog pre-amplifier
  -

ESP32 Con’t

- Security:
  - IEEE 802.11 standard security features all supported, including WFA, WPA/WPA2 and WAPI
  - Secure boot
  - Flash encryption
  - 1024-bit OTP, up to 768-bit for customers
  - Cryptographic hardware acceleration: AES, SHA-2, RSA, elliptic curve cryptography (ECC), random number generator (RNG)
- Power management:
  - Internal low-dropout regulator
  - Individual power domain for RTC
  - 5uA deep sleep current
  - Wake up from GPIO interrupt, timer, ADC measurements, capacitive touch sensor interrupt

Your devices and networking

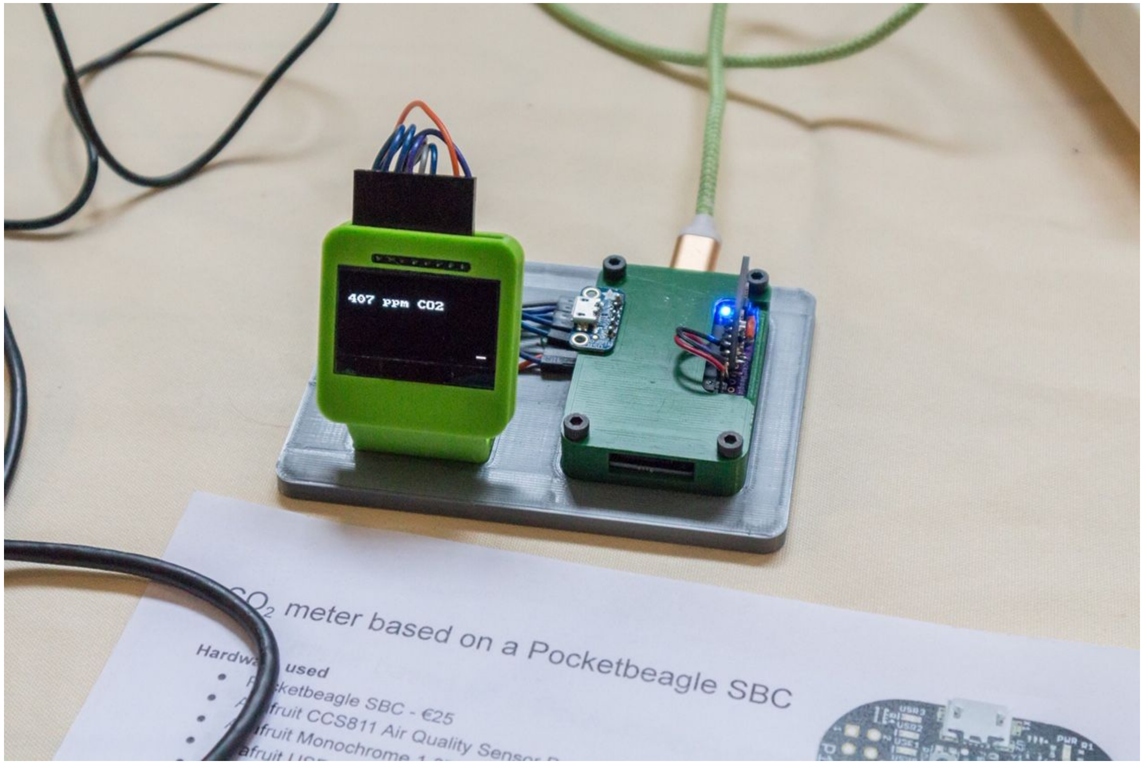
Hybrid solution: Local access + cloud access

Your devices and networking

Cloud only access, no local network

Your devices and networking

No access because you forgot to install the wifi firmware :)



Labs

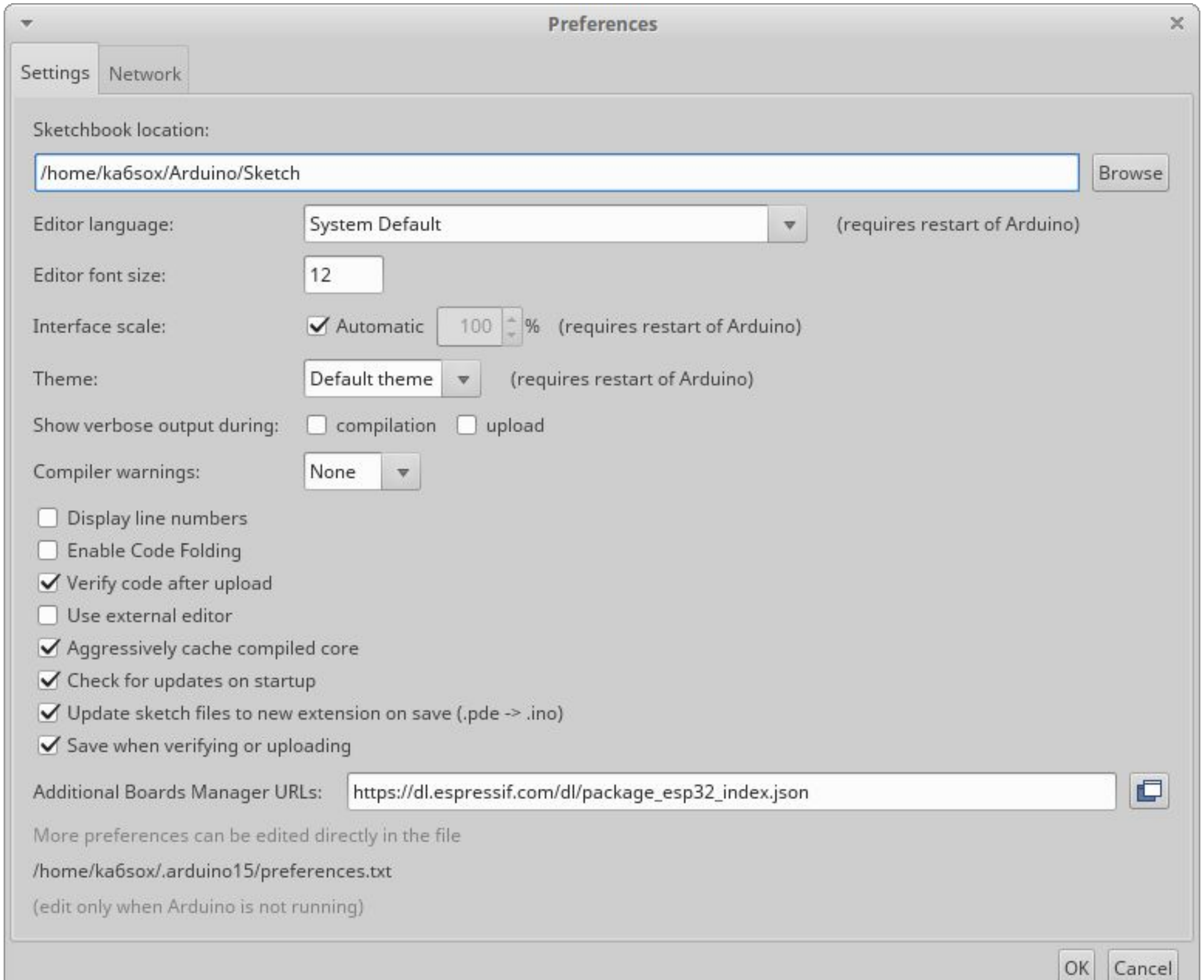
- IDE/Board Setup
  - Install Python if needed
  - Install Arduino IDE
  - Install ESP32 board interface
- Blinky
  - Open and upload to board
- WiFi
  - Open from examples menu
  - Upload
- Sensors
  - Install library from library manager
  - Open example
  - Modify example to work with the current board

IDE Setup

- https://www.arduino.cc/en/Guide/Linux
    - `sudo chmod 666 /dev/ttyUSB0` if it won't upload
- https://www.arduino.cc/en/Guide/Windows
- https://www.arduino.cc/en/Guide/MacOSX

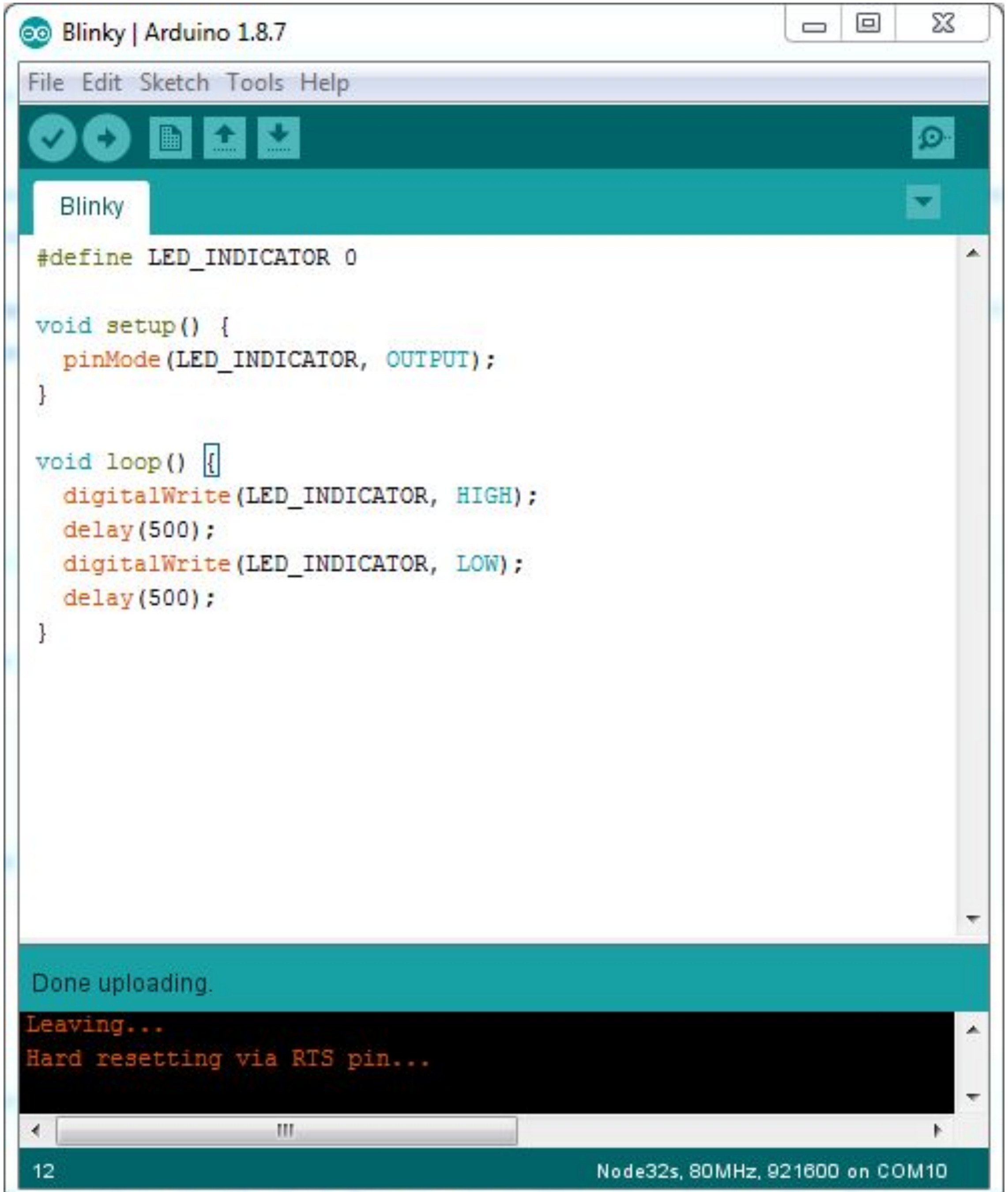
Setting up the ESP32 board drivers

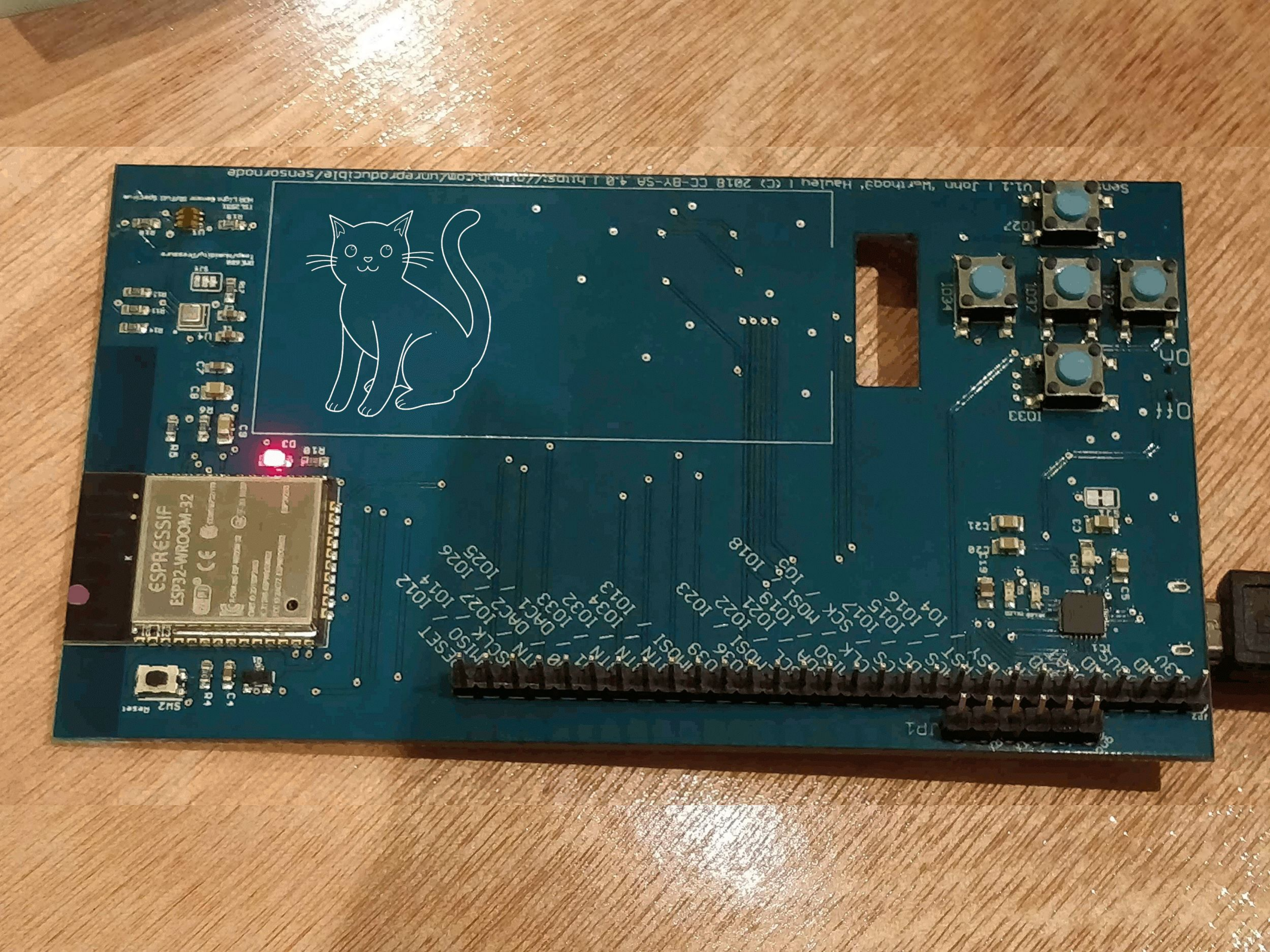
(https://dl.espressif.com/dl/package_esp32_index.json)



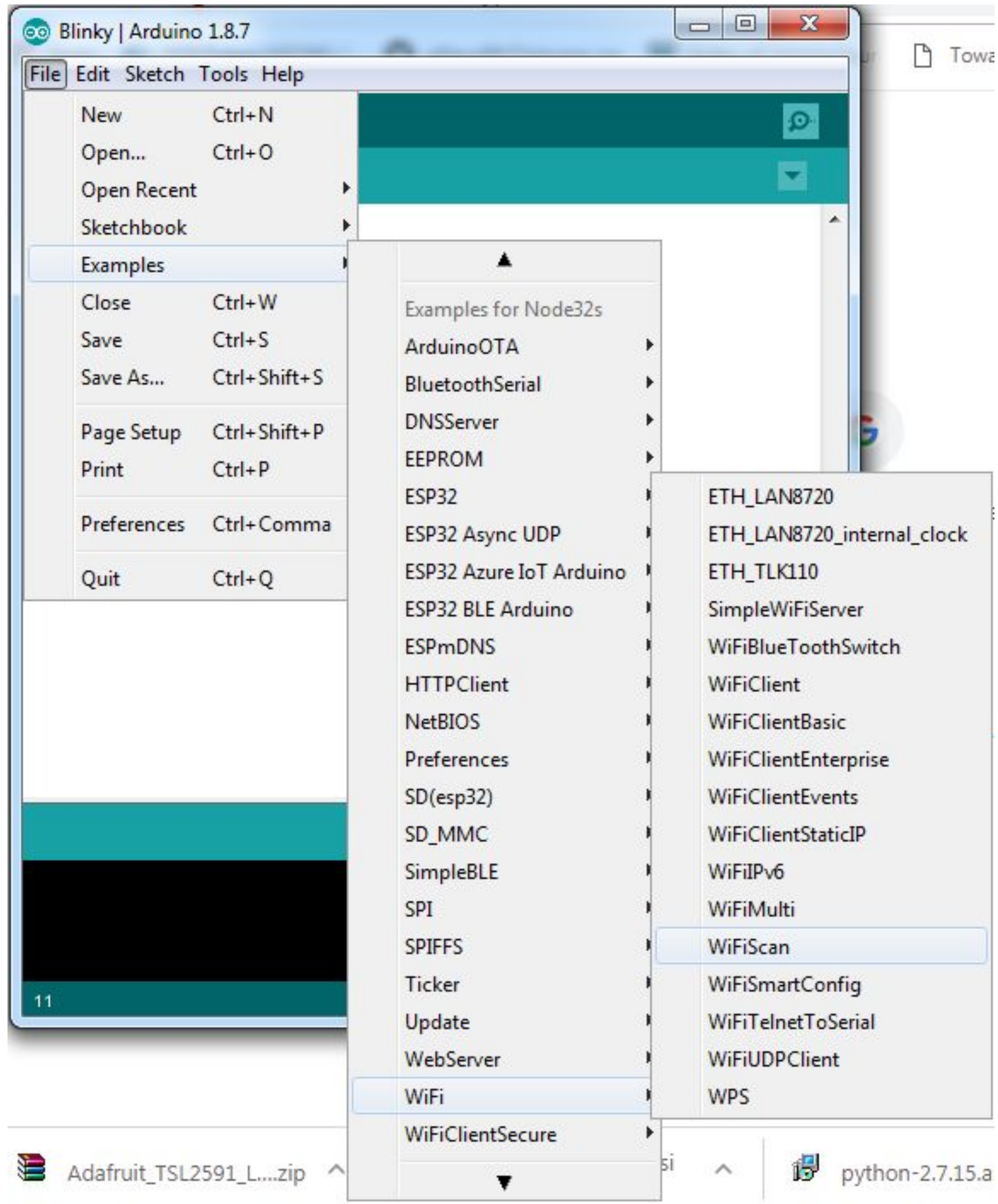
Blinky

- File > Open
- Open the Blinky file in the Blinky folder
- Upload the program to the board
- `sudo chmod 666 /dev/ttyUSB0`
  if it won't upload

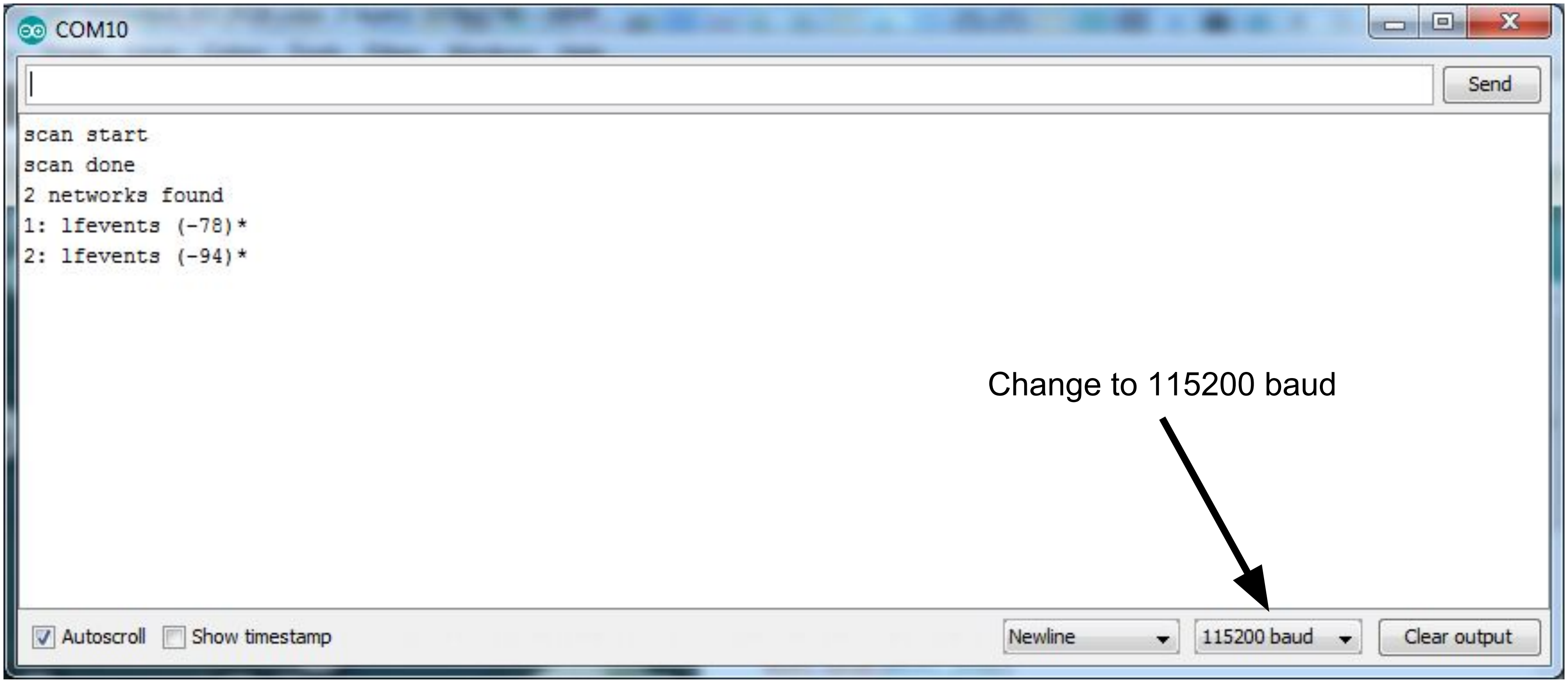

Blinky | Arduino 1.8.7
File Edit Sketch Tools Help
Blinky
#define LED_INDICATOR 0
void setup() {
pinMode(LED_INDICATOR, OUTPUT);
}
void loop() {
digitalWrite(LED_INDICATOR, HIGH);
delay(500);
digitalWrite(LED_INDICATOR, LOW);
delay(500);
}
Done uploading.
Leaving...
Hard resetting via RTS pin...
12
Node32s, 80MHz, 921600 on COM10


ESPRESSIF
ESP32-WROOM-32

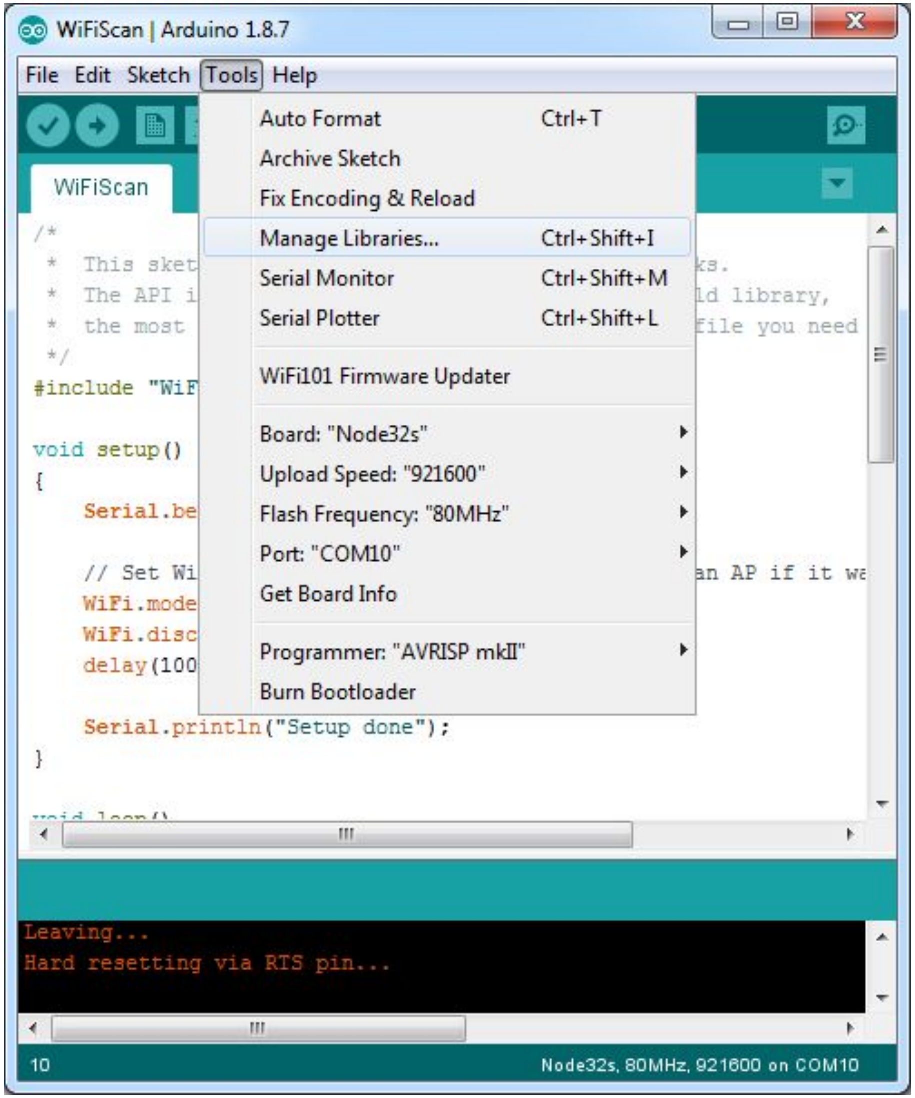
Wifi Scan


Blinky | Arduino 1.8.7
File Edit Sketch Tools Help
New Ctrl+N
Open... Ctrl+O
Open Recent
Sketchbook
Examples
Close Ctrl+W
Save Ctrl+S
Save As... Ctrl+Shift+S
Page Setup Ctrl+Shift+P
Print Ctrl+P
Preferences Ctrl+Comma
Quit Ctrl+Q
Examples for Node32s
ArduinoOTA
BluetoothSerial
DNSServer
EEPROM
ESP32
ESP32 Async UDP
ESP32 Azure IoT Arduino
ESP32 BLE Arduino
ESPmDNS
HTTPClient
NetBIOS
Preferences
SD(esp32)
SD_MMC
SimpleBLE
SPI
SPIFFS
Ticker
Update
WebServer
WiFi
WiFiClientSecure
ETH_LAN8720
ETH_LAN8720_internal_clock
ETH_TLK110
SimpleWiFiServer
WiFiBlueToothSwitch
WiFiClient
WiFiClientBasic
WiFiClientEnterprise
WiFiClientEvents
WiFiClientStaticIP
WiFiIPv6
WiFiMulti
WiFiScan
WiFiSmartConfig
WiFiTelnetToSerial
WiFiUDPClient
WPS
11
Adafruit_TSL2591_L....zip
python-2.7.15.a

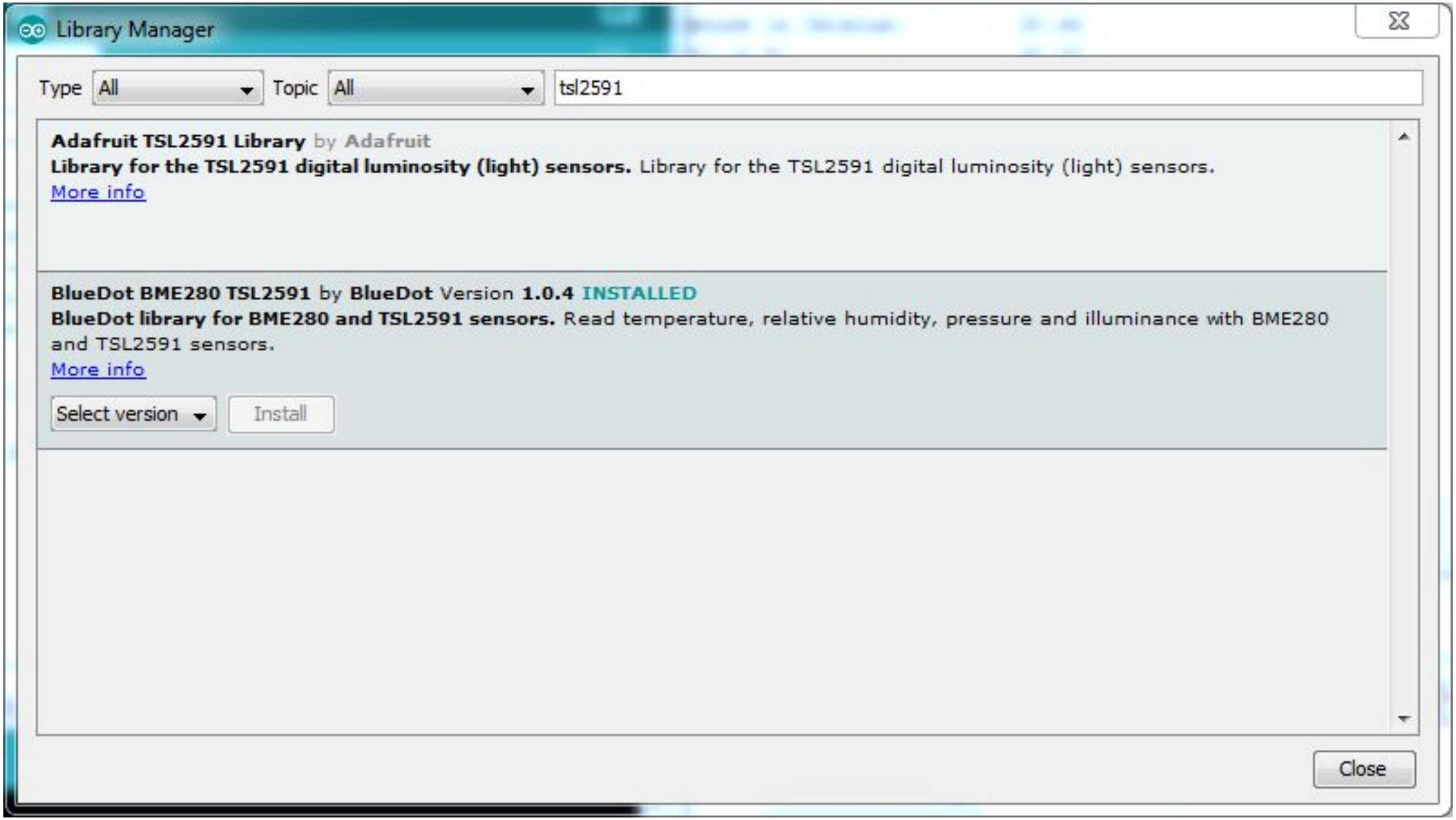
Wifi Monitor (Tools > Serial Monitor)



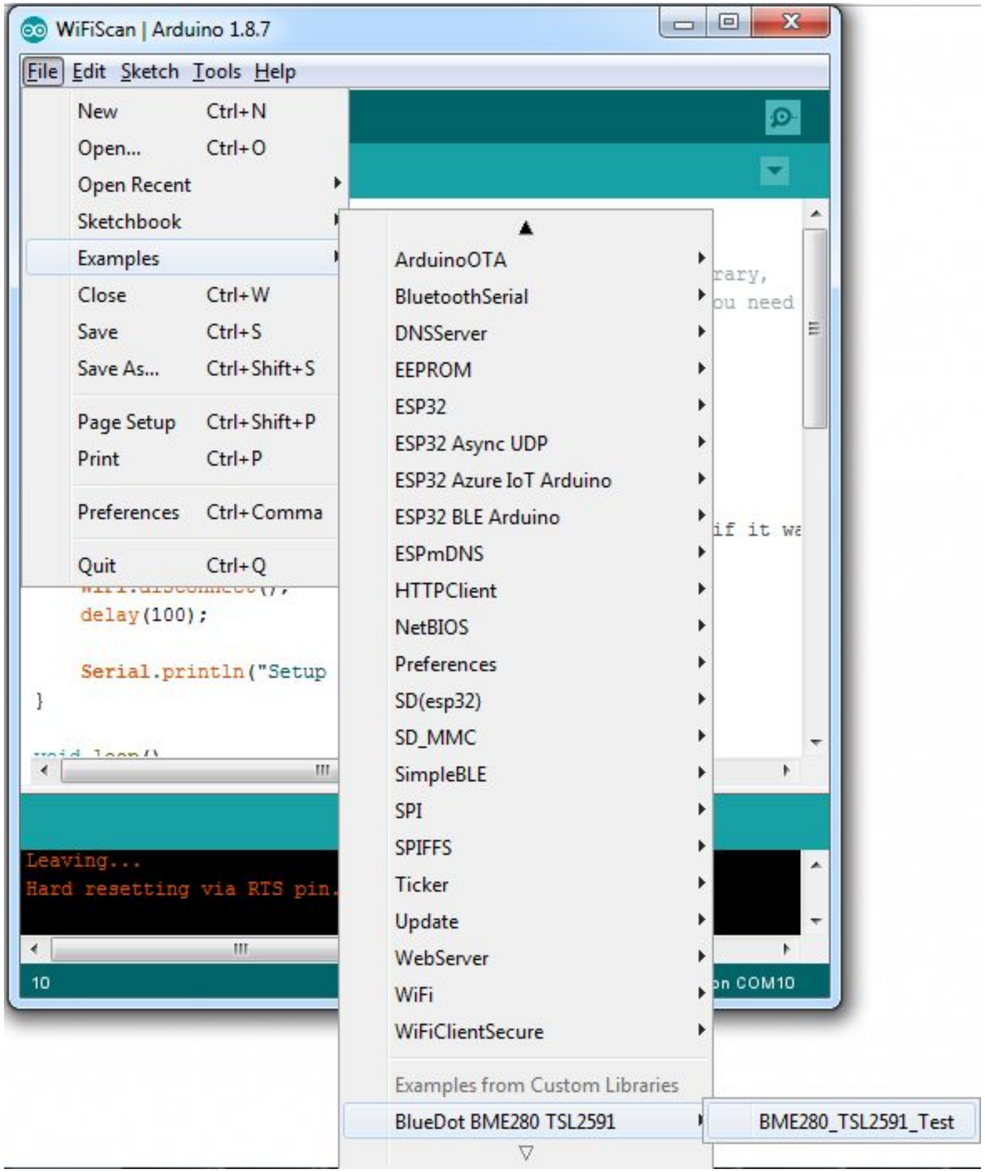
Library Manager (for sensors)



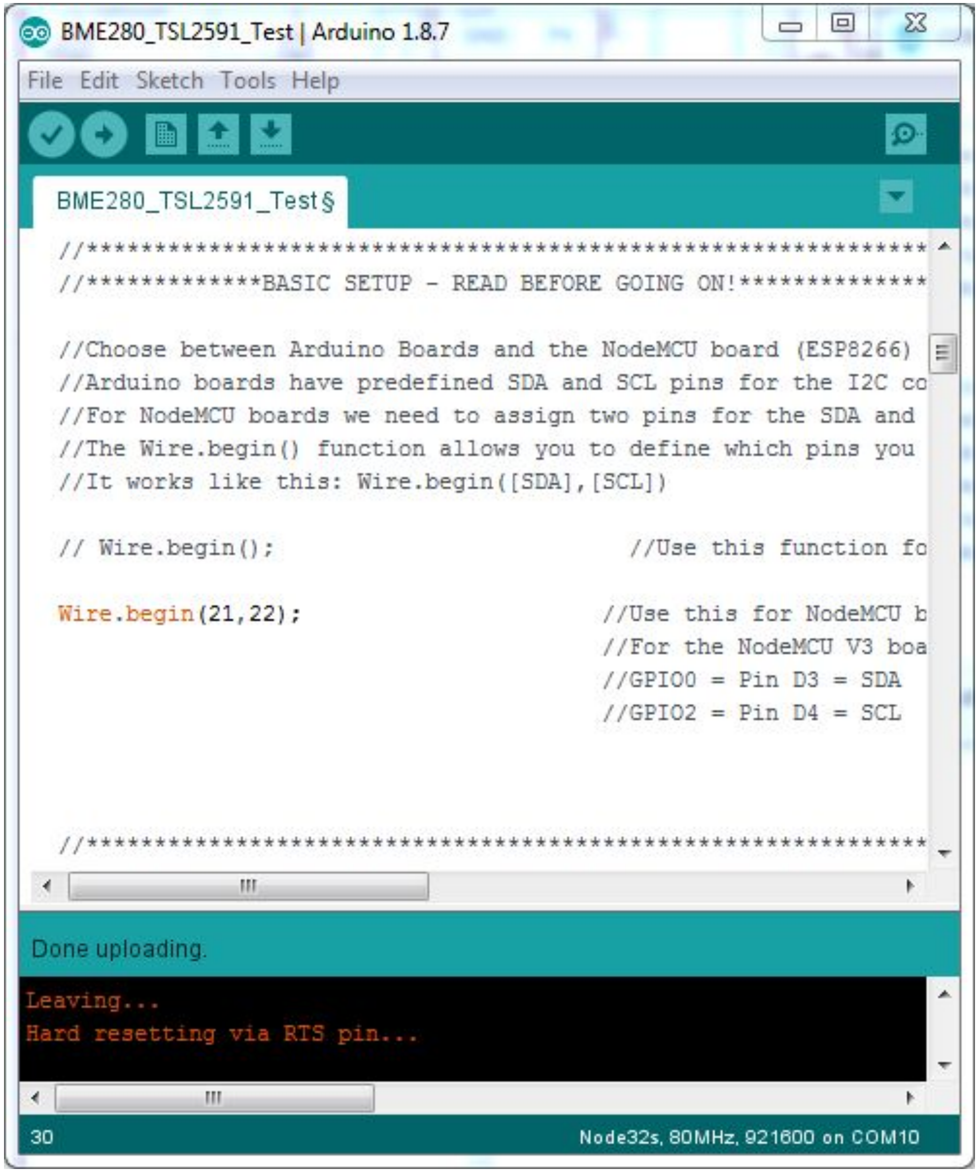
Sensors Library Installation



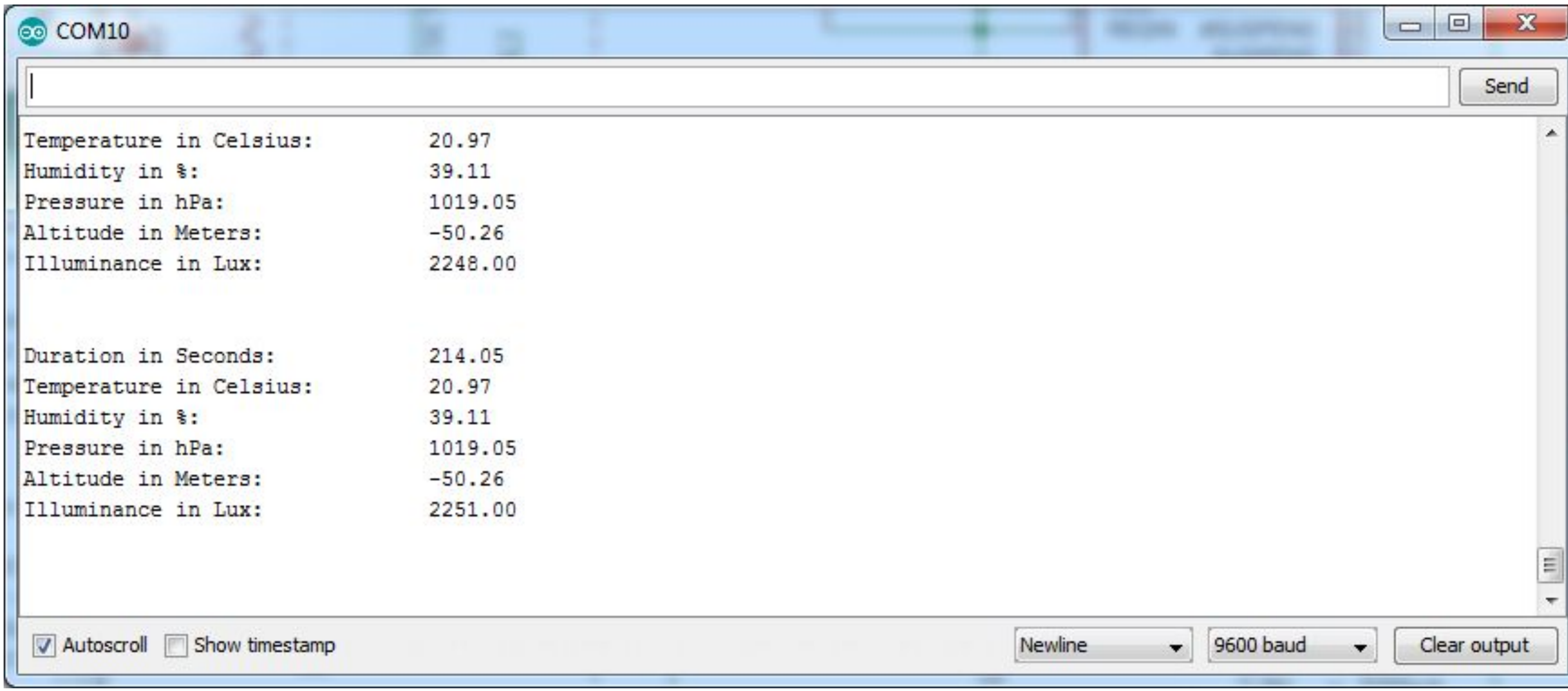
Sensors Library Example



Modifying it to Work



Expected Output



Examples I Used:

github.com/chromenova/ sensornodeexamples

IoT-ALE:
Discovering Tiny Snakes

IoT development without the need to compile
(mostly)

John ‘Warthog9’ Hawley

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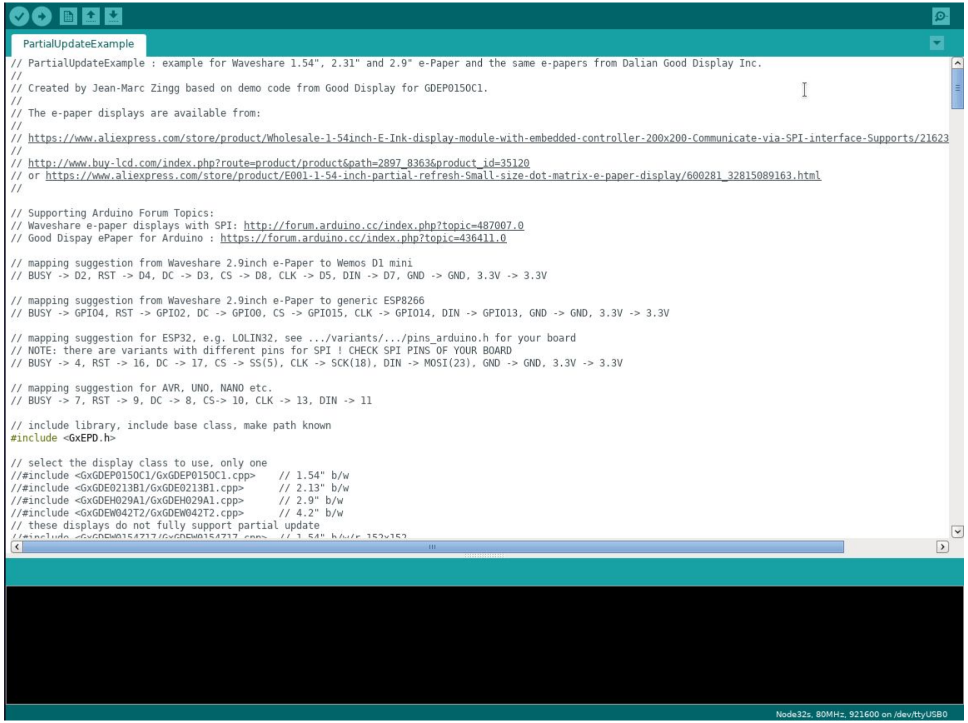
Quick: MicroPython vs. CircuitPython?

MicroPython

circuit python

Why is this different?



Why is this different?

- Quick, iterative, development
- Most of the advantages of Python
- 0 to blinking LED very quick
- Mostly no need to compile anything
- Lots of default functionality, and upip (library / package management!)

Why is this possible?

- Same reason IoT is becoming ubiquitous
  - MCUs & CPUs are getting more powerful, and cheaper
- ESP32 on the SensorNode cost $5.10 to place on the board.
  - Dual Core
  - Wifi (802.11b/g/n up to 150Mbps 2.4GHz)
  - Bluetooth (v4.2 BR/EDR & BLE)
  - 4MB of flash
  - 520KB RAM
- There's lots of competition in this space

Flashing MicroPython:

With the VM:

- Select the VM, plug in SensorNode
  - Should cause it to attach to the VM, if it's not *VM -> Removable Devices* and attach it
- Helper script (specific to this tutorial)

  flash_sensornode.sh
  - Sets Serial port (usually /dev/ttyUSB0)
  - Fully erases the flash on the ESP32
    - *esptool.py --chip esp32 --port "${USBPORT}" erase_flash*
  - Flashes MicroPython
    - *esptool.py --chip esp32 \ --port "${USBPORT}" --baud 460800 \ write_flash -z 0x1000 "${flash_file}"*

Without the VM:

- Serial Drivers
  - Linux: Driver in Most Distros
  - Windows / Mac:

    Install Silicon Mechanics CP2104
    https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers
- Download / Install esptool
  - This requires Python
  - Linux:

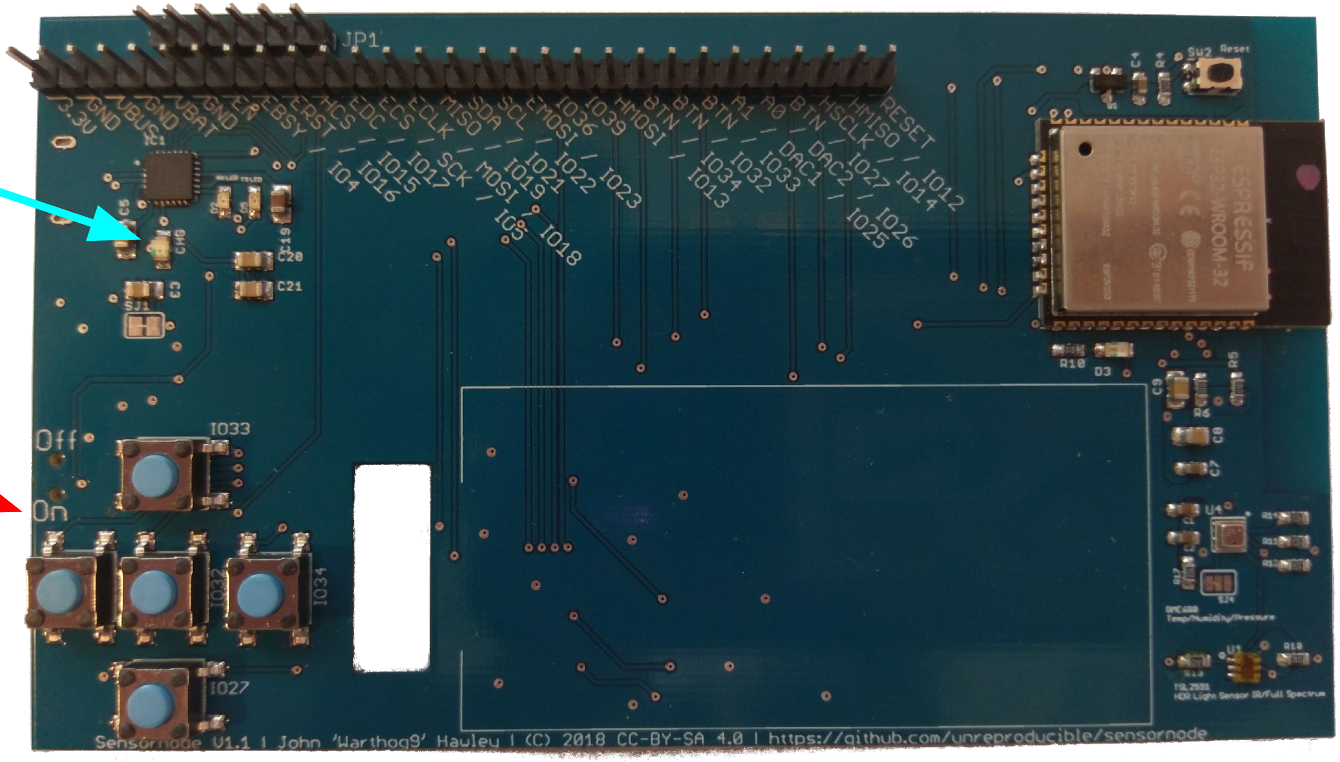
    distro packages are available
  - Windows / Mac:

    use pypi to install
- Download MicroPython & Upload it to the board
  - http://micropython.org/download#esp32
  - esptool.py --chip esp32 \
    --port /dev/ttyUSB0 erase_flash && \
    esptool.py --chip esp32 --port \
    /dev/ttyUSB0 write_flash -z 0x1000 \
    <path to micropython .bin>

Make Sure the SensorNode is 'on'

Blinking
Charge
Indicator

Off / On
Switch



Helpful tip:

If there's a flashing light on the board it's on (it's the charging indicator light).
If it's solid, it's off.

The switch is on the side with the USB port:

- Down = On
- Up = Off

Breaking down the flash commands

```
esptool.py \
    --chip esp32 \                  # Identifies which chip variant we are dealing with
    --port /dev/ttyUSB0 \           # Identifies which port the serial device is on
    erase_flash \                   # Erases the flash area of the chip
&& \                                #     (not including the boot loader area)
esptool.py \
    --chip esp32 \                  # Identifies which chip variant we are dealing with
    --port /dev/ttyUSB0 \           # Identifies which port the serial device is on
    write_flash \                   # Indicates to write to the flash chip
    -z 0x1000 \                     # Indicates WHERE on the flash chip to write to
    <path to micropython .bin>      # What to flash to the chip
```

What this should look like:

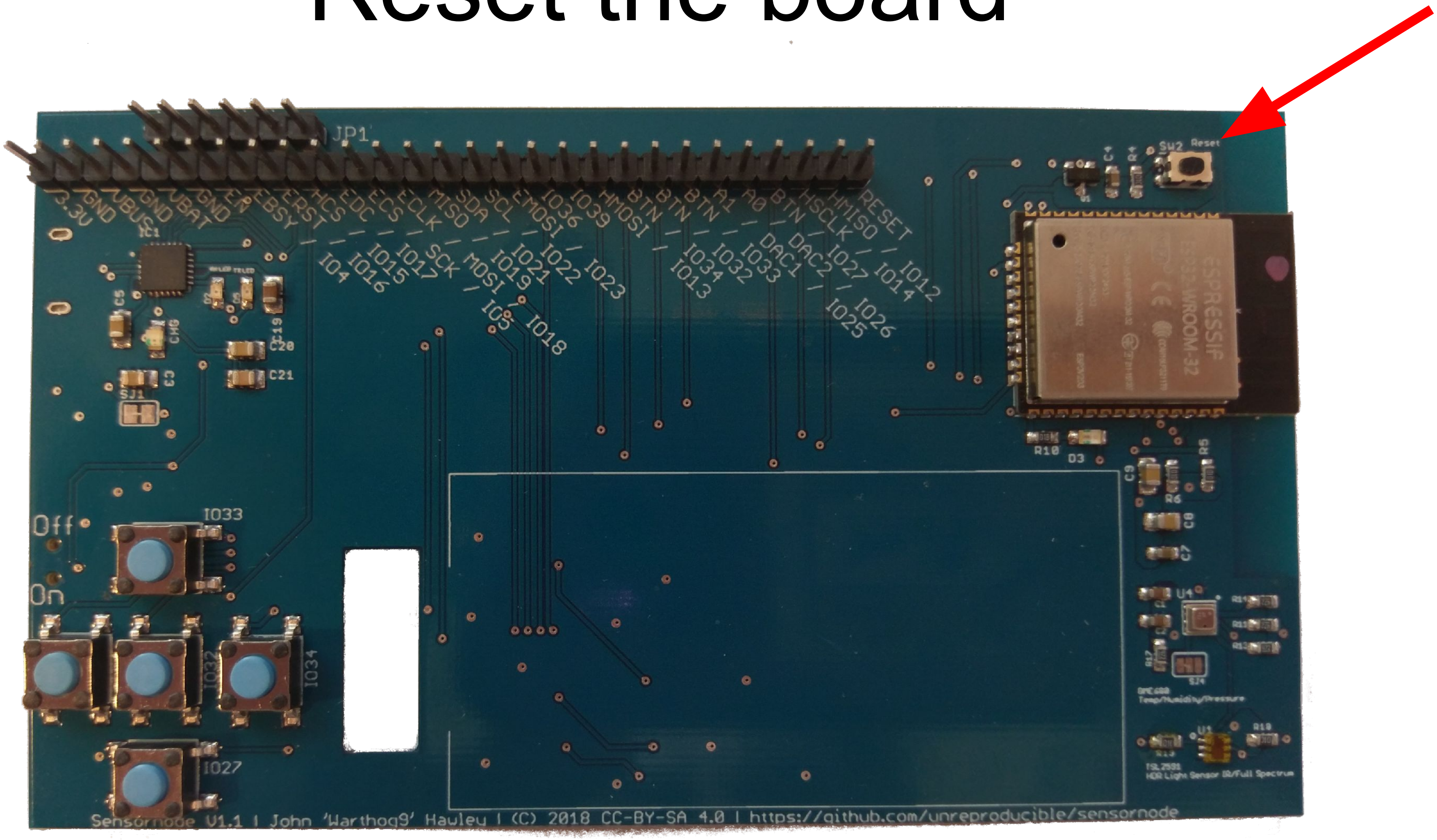
```
[root@tutorial-base ~]# dmesg | tail -n 8
[...]
[86344.904683] cp210x 2-2.1:1.0: cp210x converter detected
[86344.915286] usb 2-2.1: cp210x converter now attached to
ttyUSB0
[root@tutorial-base ~]# ./flash_sensornode.sh
Flash File: esp32-20190214-v1.10-98-g4daee3170.bin
esptool.py v2.7-dev
Serial port /dev/ttyUSB0
Connecting.....
Chip is ESP32D0WDQ6 (revision 1)
Features: WiFi, BT, Dual Core, Coding Scheme None
MAC: 30:ae:a4:86:c7:64
Uploading stub...
Running stub...
Stub running...
Erasing flash (this may take a while)...
Chip erase completed successfully in 4.4s
Hard resetting via RTS pin...
esptool.py v2.7-dev
Serial port /dev/ttyUSB0
Connecting......
Chip is ESP32D0WDQ6 (revision 1)
Features: WiFi, BT, Dual Core, Coding Scheme None
MAC: 30:ae:a4:86:c7:64
Uploading stub...
Running stub...
Stub running...
Changing baud rate to 460800
Changed.
Configuring flash size...
Auto-detected Flash size: 4MB
Compressed 1133232 bytes to 714809...
Wrote 1133232 bytes (714809 compressed) at 0x00001000 in
18.6 seconds (effective 488.0 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
[root@tutorial-base ~]#
```

Open up the serial console

- Minicom:
  - minicom -D /dev/ttyUSB0 --baudrate 115200 (to exit <ctrl>c-q)
- Screen:
  - screen /dev/ttyUSB0 115200n8 (to exit <ctrl>c-A \)
- Windows: use PuTTY

Reset the board



On the serial console...

```
ets Jun  8 2016 00:22:57

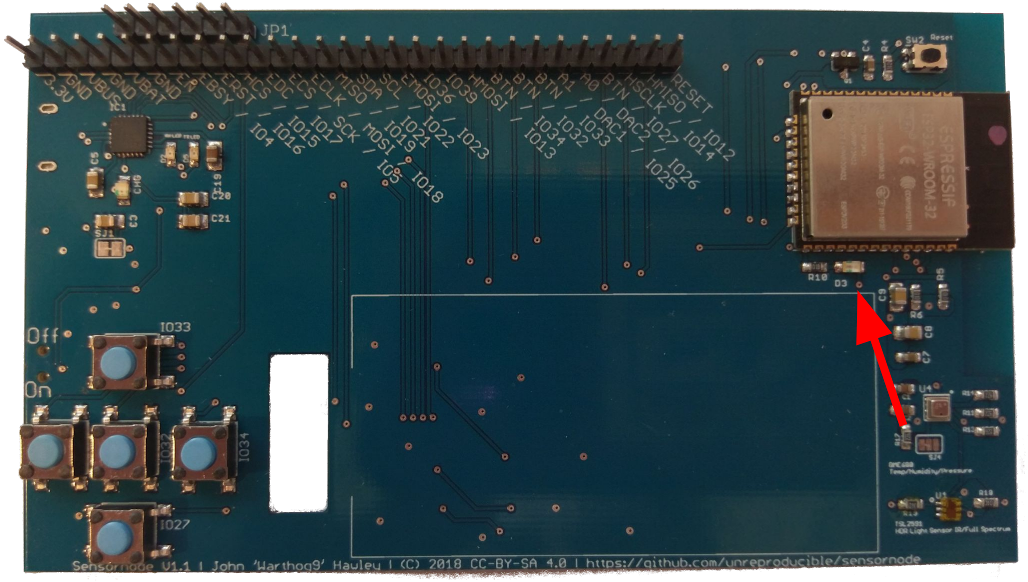
rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0018,len:4
load:0x3fff001c,len:5060
load:0x40078000,len:8788
ho 0 tail 12 room 4
load:0x40080400,len:6772
entry 0x40081610
I (428) cpu_start: Pro cpu up.
I (428) cpu_start: Application information:
I (428) cpu_start: Compile time:     12:32:34
I (430) cpu_start: Compile date:     Feb 14 2019
I (436) cpu_start: ESP-IDF:          v3.3-beta1-268-g5c88c5996
I (442) cpu_start: Single core mode
I (447) heap_init: Initializing. RAM available for dynamic allocation:
I (454) heap_init: At 3FFAE6E0 len 00001920 (6 KiB): DRAM
I (460) heap_init: At 3FFB92B0 len 00026D50 (155 KiB): DRAM
I (466) heap_init: At 3FFE0440 len 0001FBC0 (126 KiB): D/IRAM
I (472) heap_init: At 40078000 len 00008000 (32 KiB): IRAM
I (479) heap_init: At 40092834 len 0000D7CC (53 KiB): IRAM
I (485) cpu_start: Pro cpu start user code
I (55) cpu_start: Starting scheduler on PRO CPU.
OSError: [Errno 2] ENOENT
MicroPython v1.10-98-g4daee3170 on 2019-02-14; ESP32 module with ESP32
Type "help()" for more information.
>>>
```

Quick *Hello World!*

```
>>> print("Hello World!")
Hello World!
>>>
```

Now to Blink an LED!

```
>>> import machine
>>> led_pin = machine.Pin(0, machine.Pin.OUT)
>>> led_pin.on()
>>> led_pin.off()
```



Note: You'll quickly find the on() turns the LED off, and off() turns the LED on. To "Fix"

```
>>> led = machine.Signal( led_pin, invert=True)
>>> led.off()
>>> led.on()
```

Some interesting things to note

- boot.py
  - executed on every start, good for setting up the board (good place for wifi settings for example)
- main.py
  - Run after boot.py, think of it like the autoexec.bat
- It’s possible to upload more files to the board
  - Ampy - https://github.com/adafruit/ampy
- Tab completion works in the repl prompt
- <ctrl>+e at the repl prompt puts you into “paste” mode

Disconnect From Serial before trying file transfers!

- Minicom:
  - to exit: *<ctrl>c-q*
- Screen:
  - to exit: *<ctrl>c-A \ y*
- Putty:
  - Hit the X and close the application

Where to go from here

Setup Wifi in client mode

- ampy --port /dev/ttyUSB0 get boot.py | tee boot.py

```
# This file is executed on every boot (including wake-boot from deepsleep)
#import esp
#esp.osdebug(None)
#import webrepl
#webrepl.start()
```

- Add to boot.py:

```
# This file is executed on every boot (including wake-boot from deepsleep)
#import esp
#esp.osdebug(None)
#import webrepl
#webrepl.start()
import network
sta = network.WLAN(network.STA_IF)
sta.active(True)
sta.connect("ALE", "Penguins")
```

- ampy --port /dev/ttyUSB0 put boot.py

Re-connect to Serial and check:

- ```
  >>> sta.ifconfig()
  ('192.168.123.456', '255.255.255.0', '192.168.123.1', '192.168.123.1')
  >>> sta.status()
  1010
  >>> sta.isconnected()
  True
  >>>
  ```

- ```
  >>> import socket
  >>> addr_info = socket.getaddrinfo("towel.blinkenlights.nl", 23)
  >>> addr = addr_info[0][-1]
  >>> s = socket.socket()
  >>> s.connect(addr)
  >>> while True:
  …       data = s.recv(500)
  …       print(str(data, 'utf8'), end=’’)
  …
  …
  …
  ```
  <ctrl>+c will stop the while loop

One more thing to note, but not try here...

- Access Point Mode (can be used with client mode at the same time, albeit slowly)
    - ```
      >>> ap = network.WLAN(network.AP_IF)
      >>> ap.active(True)
      >>> #ap.config(essid="network-name", authmode=network.AUTH_WPA_WPA2_PSK,
      password="abcdabcdabcd")
      ```
    - Can be added to boot.py, same as the client information
      ```

Links to more resources

- https://github.com/unreproducible/tinysnakes
- https://docs.micropython.org/en/latest/esp8266/tutorial/intro.html
(note: most of the ideas are the same, the boards ARE different)
- https://boneskull.com/micropython-on-esp32-part-1/
- https://www.cnx-software.com/2017/10/16/esp32-micropython-tutorials/

- Any questions before you start this on your own?

John ‘Warthog9’ Hawley | warthog9@eaglescrag.net | @warty9

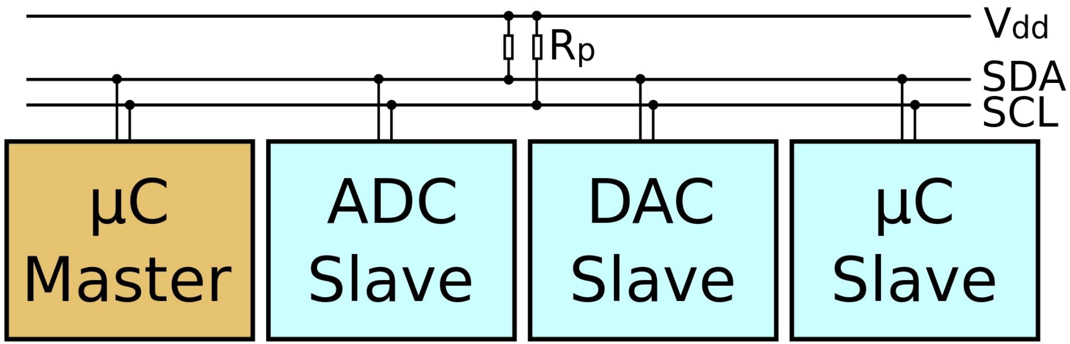
IoT-ALE:
Reading Sensor Data with I2C

Jon Mason

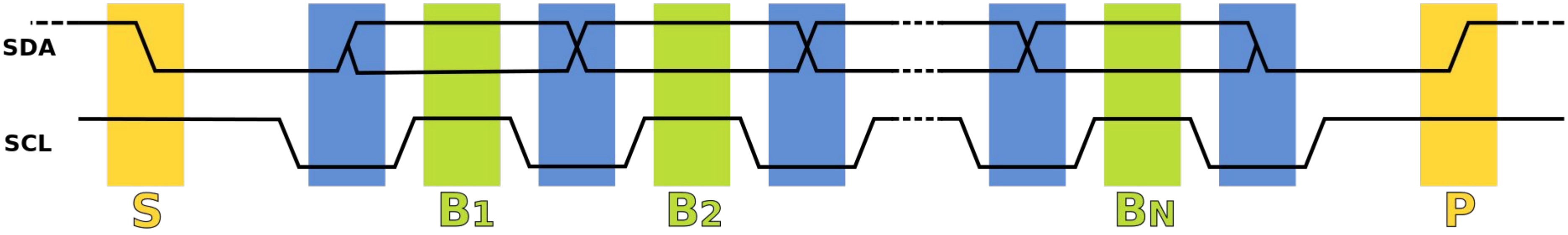
SCaLE 17x - March 2019

I2C Some background

- Released in 1982
- Bus Protocol
- Devices use addresses
- 2-pins needed
  - Clock (scl)
  - Data (sda)
- SCL & SDA pulled-up against voltage to ship (Vdd)
  - Level shifting can be complicated to get right
- Upwards of 3.4Mbps
  - More realistically: ~1Mbps
  - Most devices communicate in Kbps
- SMBus is derived from, but not identical to, I2C
  - Devices may claim to be one or the other not really consistent



What this looks like on the bus:

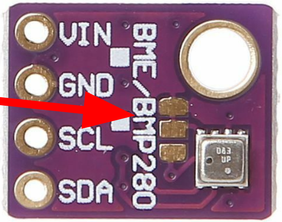


1. Data transfer is initiated with a *start* bit (S) signaled by SDA being pulled low while SCL stays high.
2. SCL is pulled low, and SDA sets the first data bit level while keeping SCL low (during blue bar time).
3. The data are sampled (received) when SCL rises for the first bit (B1). For a bit to be valid, SDA must not change between a rising edge of SCL and the subsequent falling edge (the entire green bar time).
4. This process repeats, SDA transitioning while SCL is low, and the data being read while SCL is high (B2, ...Bn).
5. The final bit is followed by a clock pulse, during which SDA is pulled low in preparation for the *stop* bit.
6. A *stop* bit (P) is signaled when SCL rises, followed by SDA rising.

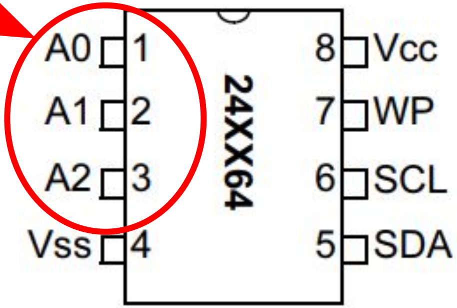
Addresses

- Device specific implementation
- Some devices only provide a single address
  - One device per-bus
- Address on the bus “needs” to be unique
- 7-bit address normal
  - 128 Devices normally
  - 10-bit exists, very little uses it
  - 10-bit gives you 1008 devices (reserved addresses)

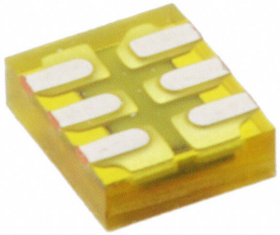
Two Addresses Selectable



Eight Addresses Selectable



TSL2591
No selectable Address



I2Cdetect (Linux)

```
$ i2cdetect -y -r 1
 0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- 56 -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- 68 -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- —-
```

Devices at:

- 0x56
- 0x68

- I2C is ***NOT*** discoverable, detection is not guaranteed
- Random probing can cause systems to crash - you are warned

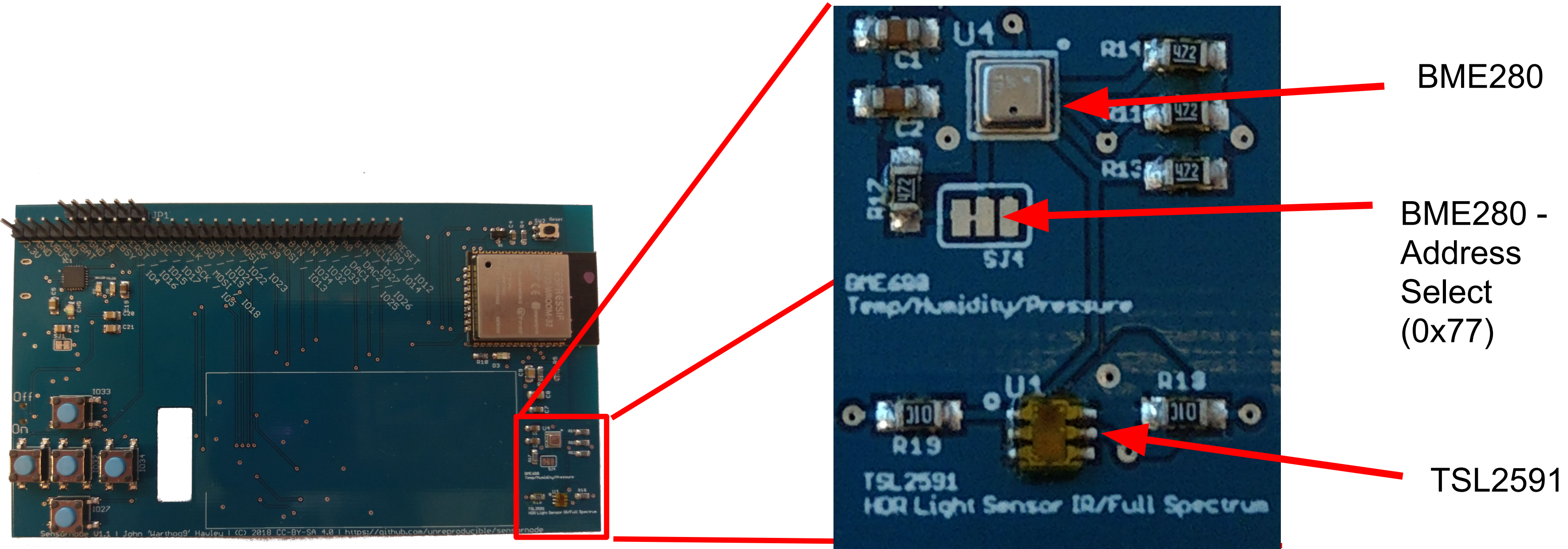
SensorNode has 2 x I2C devices:

BME280

- Temperature
- Humidity
- Relative Pressure

TSL2591

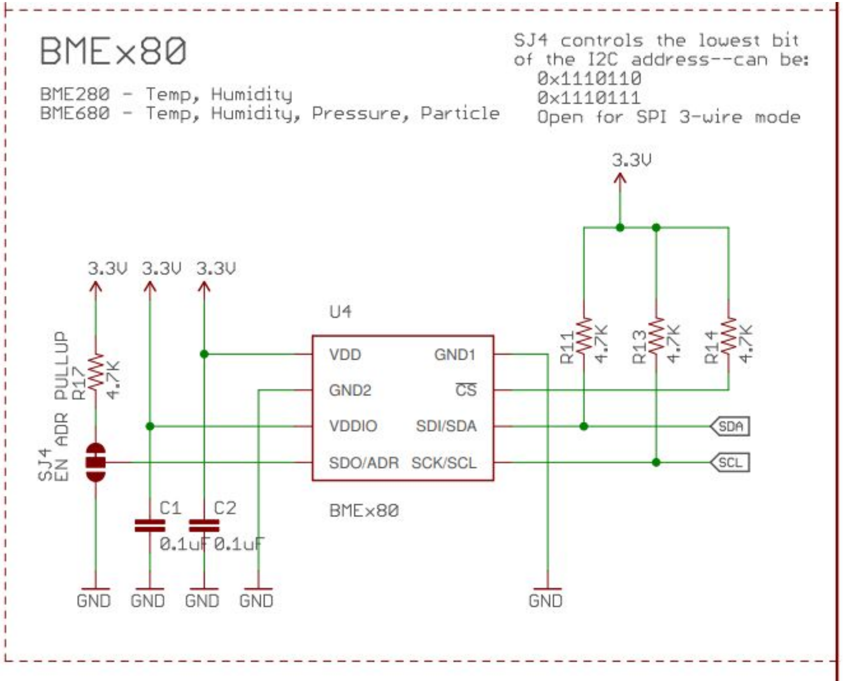
- Full Spectrum Light Sensor
- IR Spectrum Light Sensor



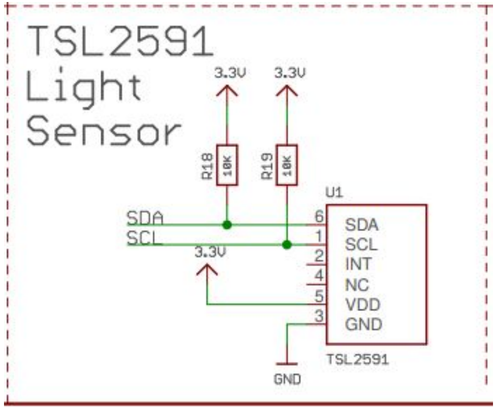
Figuring out Address - See the Schematic(s)

https://github.com/unreproducible/sensornode/blob/master/Schematic%20-%20sensornode.pdf

BME280:

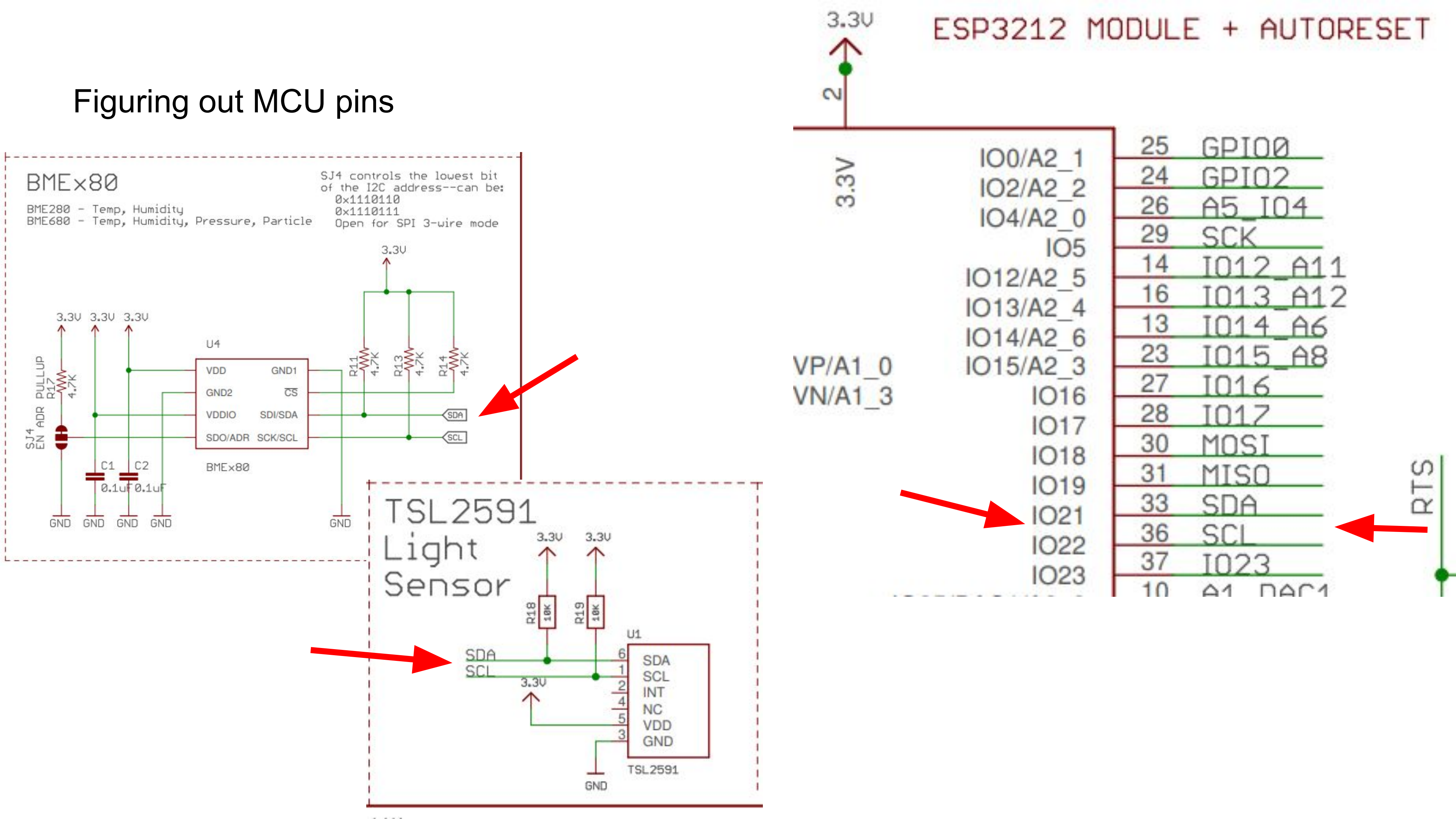


TSL2591



Ordering Code	Address	Interface
TSL25911FN	0x29	$I^2C\ V_{bus} = V_{DD}$ Interface
TSL25913FN*	0x29	$I^2C\ V_{bus} = 1.8V$

Figuring out MCU pins



Time to read some data

1. Exit screen

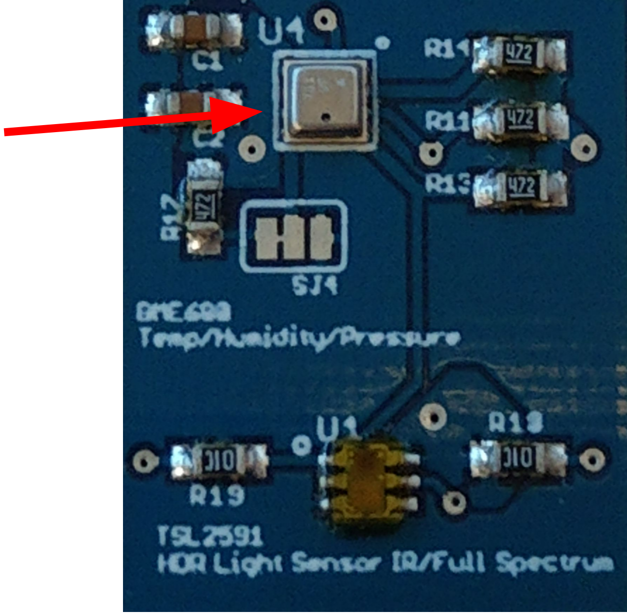
2. Upload the following using ampy:
   # ampy --port /dev/ttyUSB0 put sensornode-stuff/src/bme280.py
   # ampy --port /dev/ttyUSB0 put sensornode-stuff/src/tsl2591.py
   # ampy --port /dev/ttyUSB0 put sensornode-stuff/src/usmbus
   - Note the last one is a directory

3. Open up the serial port again

Confirm file upload

```
>>> import os
>>> os.listdir()
['boot.py', 'bme280.py', 'tsl2591.py', 'usmbus']
>>>
```

BME280 - Environment Sensor




```
>>> from machine import Pin, I2C
>>> import machine
>>> import bme280

>>> pin_i2c_scl      = 22
>>> pin_i2c_sda      = 21

>>> bme280_address  = 0x77

>>> sensor_i2c = I2C( scl=Pin(pin_i2c_scl), sda=Pin(pin_i2c_sda) )

>>> bme = bme280.BME280( i2c=sensor_i2c, address=bme280_address )

>>> bme.values
('26.84C', '1015.59hPa', '17.71%')
>>>
```

TSL2591 - Light Sensor


```
>>> import tsl2591
>>> tsl = tsl2591.Tsl2591()
>>> tsl.get_full_luminosity()
(58, 14)
>>>
```

The TSL2591 driver is a very setup than the BME280. The I2C bus, and address, are hard
Coded into the driver:

```
    def __init__(self, scl_pinno=22, sda_pinno=21):
        self.i2c = I2C(scl=Pin(scl_pinno, Pin.IN),
                       sda=Pin(sda_pinno, Pin.IN))
```

It also makes use of more SMBus like support (usmbus)

Places to find more information on I2C:

- https://i2c.info/
- https://en.wikipedia.org/wiki/I%C2%B2C
- https://ae-bst.resource.bosch.com/media/_tech/media/datasheets/BST-BME280-DS002.pdf
- https://cdn-shop.adafruit.com/datasheets/TSL25911_Datasheet_EN_v1.pdf

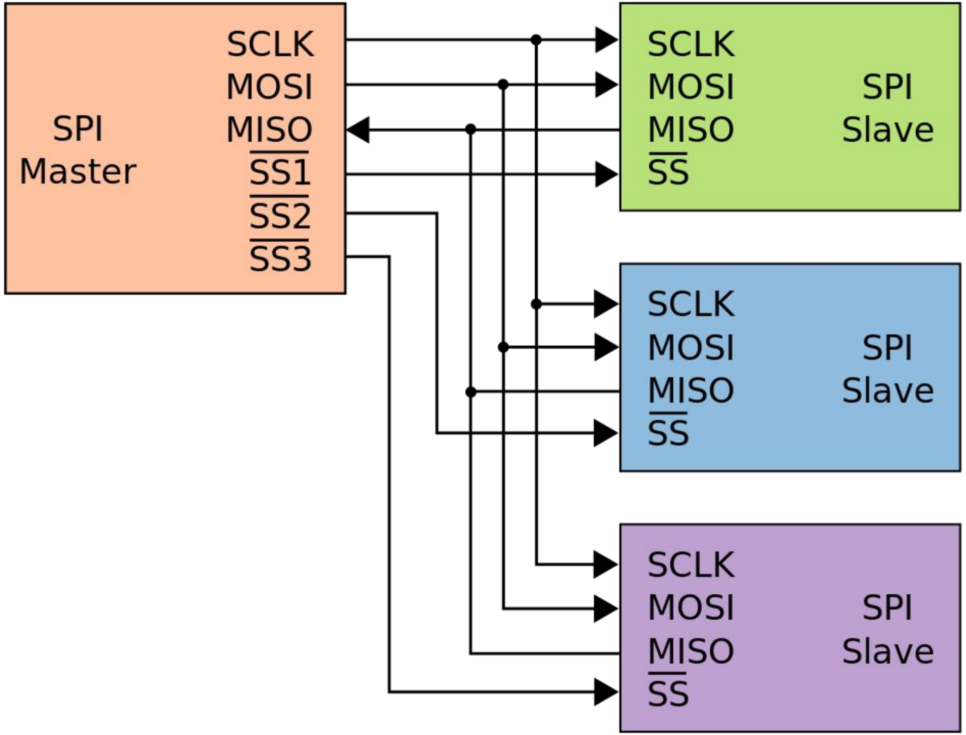
IoT-ALE:
Reading and Writing to SPI SDcards

Nisha Kumar

SCaLE 17x - March 2019

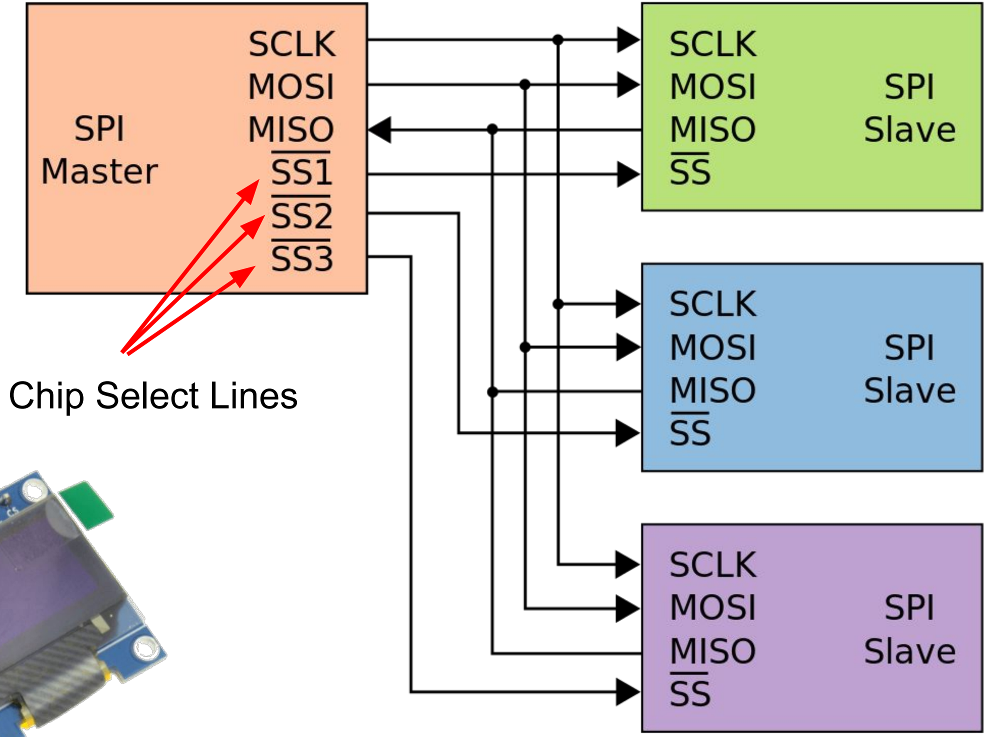
SPI Background

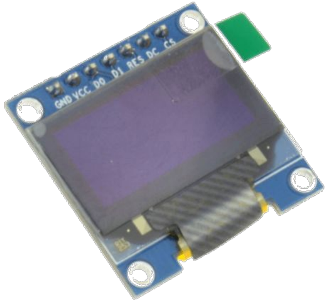
- Not a hard defined standard like I2C
  - Ubiquitous despite no hard standard
  - Data on the bus is effectively device unique
  - Quad SPI can add 2 more data lines, uncommonly used
- Faster than I2C
  - Possible to go >10Mbps
- Duplex communications
  - Master Out Slave In (MOSI)
  - Master In Slave Out (MISO)
- Hardwired device selection

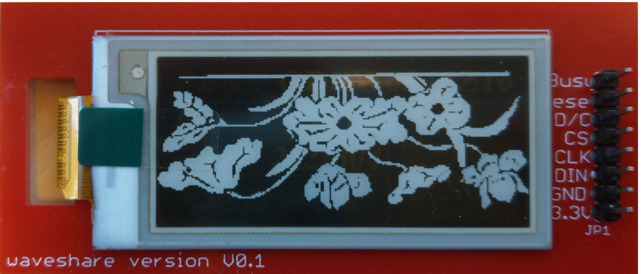


Where this gets messy...

- While fast, it's not easy to implement
- Chip select lines can get very expensive, very quickly
- Some devices need more than the minimum 4* wires







* Minimum is based on duplex operation, some devices are write or read only and you only need 3 wires then

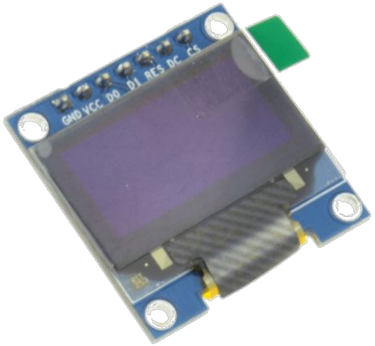
SPI Screens, cases in point as “odd”

E-link

- SPI Like Interface
- Busy pin
- Reset pin
- Data/Command (DC) pin
- Write-only device (MOSI)
- 8-pins (including Vcc & GND)

OLED Screen

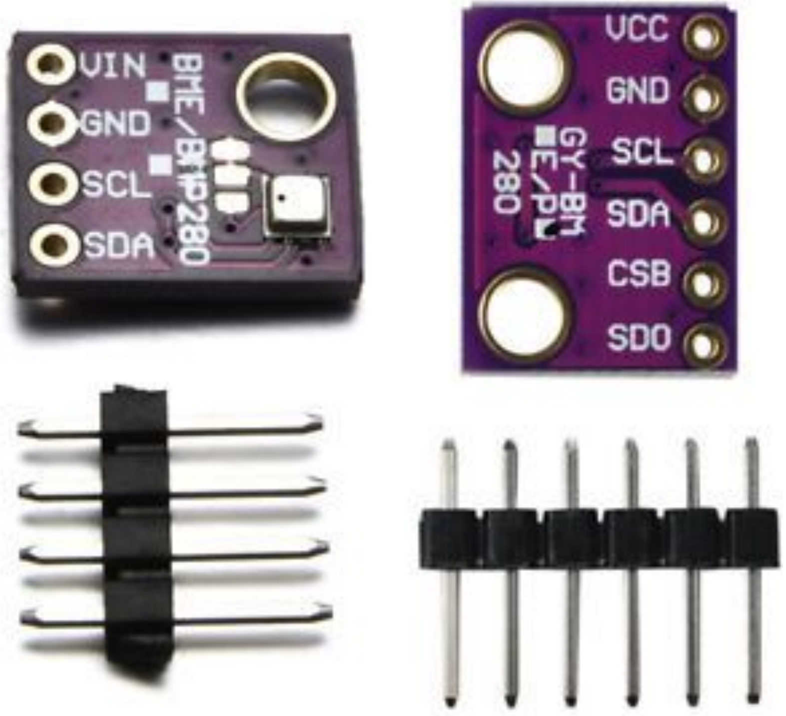
- SPI Like interface
- Write-only device (MOSI)
- Reset pin
- Data/Command (DC) pin
- 7-pins (including Vcc & GND)



Normal SPI Device

BME280 (SPI mode)

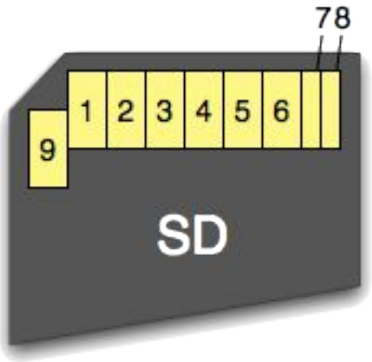
- CSB - Chip Select
- SCL - Clock
- SDA - MOSI (serial data in)
- SDO - MISO (serial data out)
- GND - Ground
- VCC - Power



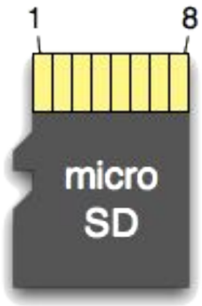
I2C SPI

SDcards and SPI

- SDcards have two basic modes:
  - SD mode
  - SPI mode
- SPI mode disadvantages:
  - Slower transfers (no parallel data)
  - ‘U’ modes aren’t supported
- SPI mode advantages:
  - Easier to implement
  - Less hardware needed
  - Simpler interface



Pin	SD	SPI
1	CD/DAT3	CS
2	CMD	DI
3	VSS1	VSS1
4	VDD	VDD
5	CLK	SCLK
6	VSS2	VSS2
7	DAT0	DO
8	DAT1	X
9	DAT2	X



Pin	SD	SPI
1	DAT2	X
2	CD/DAT3	CS
3	CMD	DI
4	VDD	VDD
5	CLK	SCLK
6	VSS	VSS
7	DAT0	DO
8	DAT1	X

Hardware vs. Software Implementation

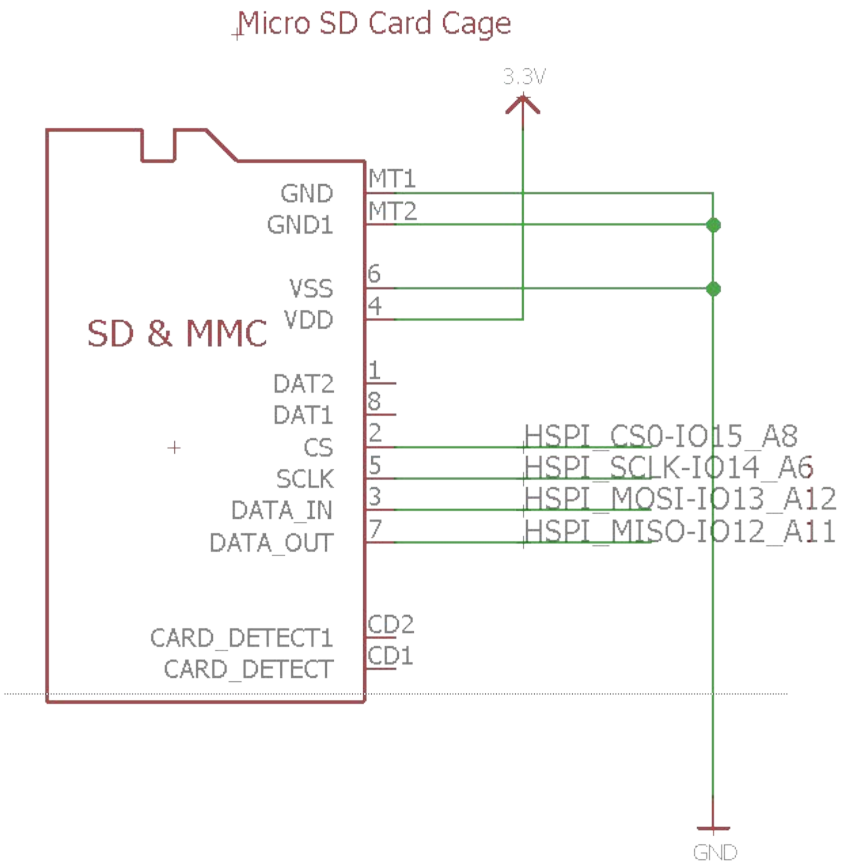
Hardware:

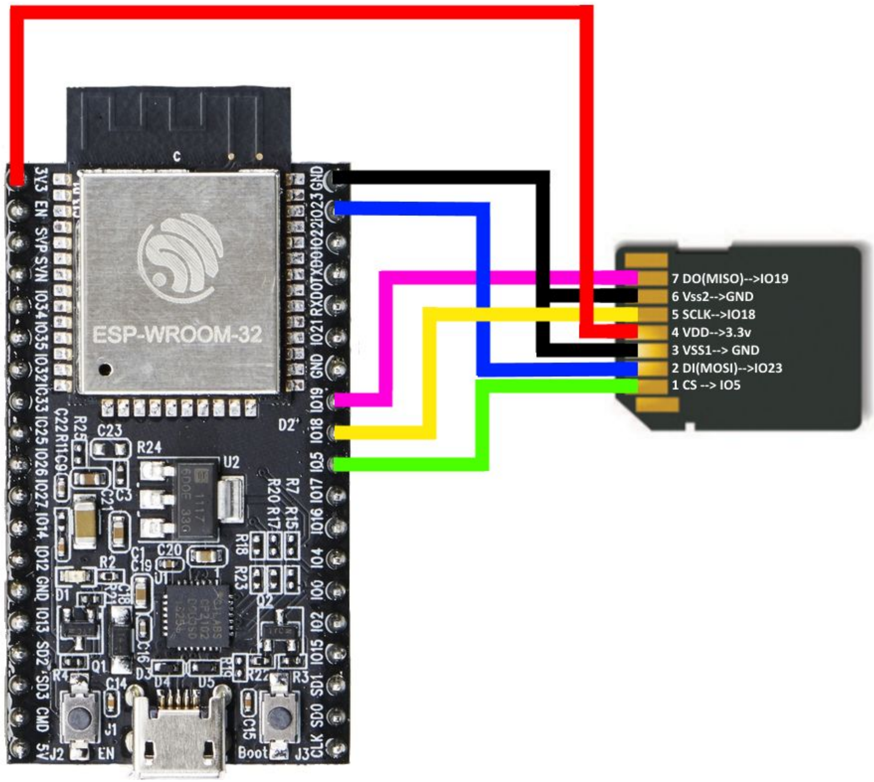
- 4 SPI Busses
  - SPI0 - typically dedicated to Flash
  - SPI1 - tied to same pins as SPI0
  - HSPI (SPI2)
    - CS: 15
    - SCLK: 14
    - MISO: 12
    - MOSI: 13
    - QUADWP: 2
    - QUADHD: 4
  - VSPI (SPI3)
    - CS: 5
    - SCLK: 18
    - MISO: 19
    - MOSI: 23
    - QUADWP: 22
    - QUADHD: 21

Software

- Any pins will do
- Bitbanged in software / timers
- SensorNode uses:
  - CS: 15
  - SCLK: 14
  - MISO: 12
  - MOSI: 13
  - QUADWP: -
  - QUADHD: -

Wiring up an SDcard to an MCU





Prep work for using the SDcard

1. Exit screen

2. Upload the following using ampy:
   # ampy --port /dev/ttyUSB0 put sensornode-stuff/src/sdcard.py

3. Open up the serial port again

Lets look at some code - Setup the SPI Interface

Software (use this on SensorNode)

```
>>> from machine import Pin, SPI
>>> cs = Pin(15, Pin.OUT)
>>> mosi = Pin(13, Pin.OUT)
>>> miso = Pin(12, Pin.IN)
>>> sck = Pin(14, Pin.OUT)
>>> spi_bus = SPI(sck = sck,
mosi = mosi, miso = miso)
```

Hardware (for comparison only)

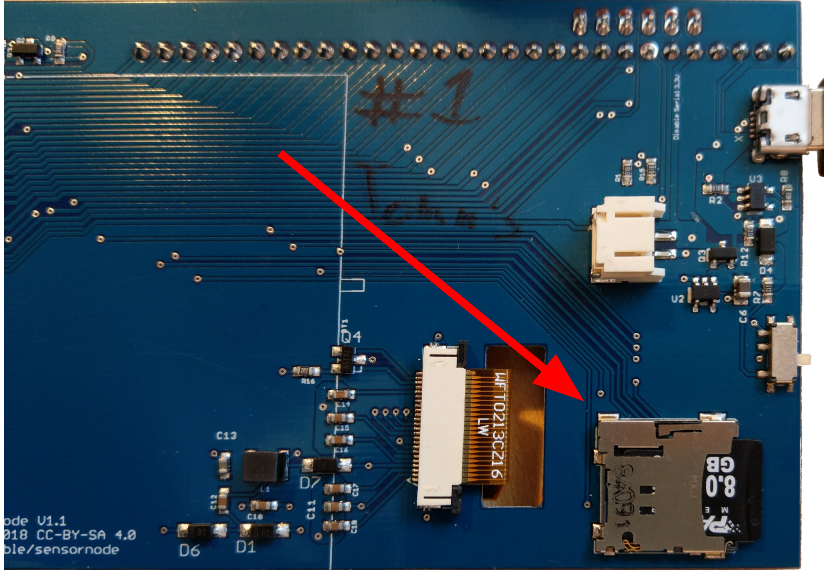
```
>>> from machine import Pin, SPI
>>> cs = Pin(15, Pin.OUT)
>>> spi_bus = SPI(2)
```

Adding the SD card to the mix

1. Plug in the SD card
    - SD Card is on the back behind the buttons

2. Add the following:

```
>>> import sdcard
>>> sd = sdcard.SDCard( spi_bus, cs)
>>>
```



What this looks like, without the SD card in place:

```
>>> sd = sdcard.SDCard( spi_bus, cs)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "sdcard.py", line 54, in __init__
  File "sdcard.py", line 82, in init_card
OSError: no SD card
>>>
```

Mounting the SDCard

- You mount it to the filesystem like Unix / Linux
- >>> import os
  >>> os.mount(sd, ‘/sd’)
  >>> os.listdir(‘/’)
  ['sd', 'boot.py', 'bme280.py', 'sdcard.py', 'tsl2591.py', 'usmbus']
  >>> os.listdir('/sd')
  ['MISC', 'DCIM', 'old']
  >>>

Contents here will likely be empty unless you’ve
Put things on the card already

Reading & Writing to the SD card

```
>>> f = open("/sd/demofile.txt", "a")
>>> f.write("Hello World!")
12
>>> f.close()
>>> f = open("/sd/demofile.txt", "r")
>>> f.read()
'Hello World!'
>>>
```

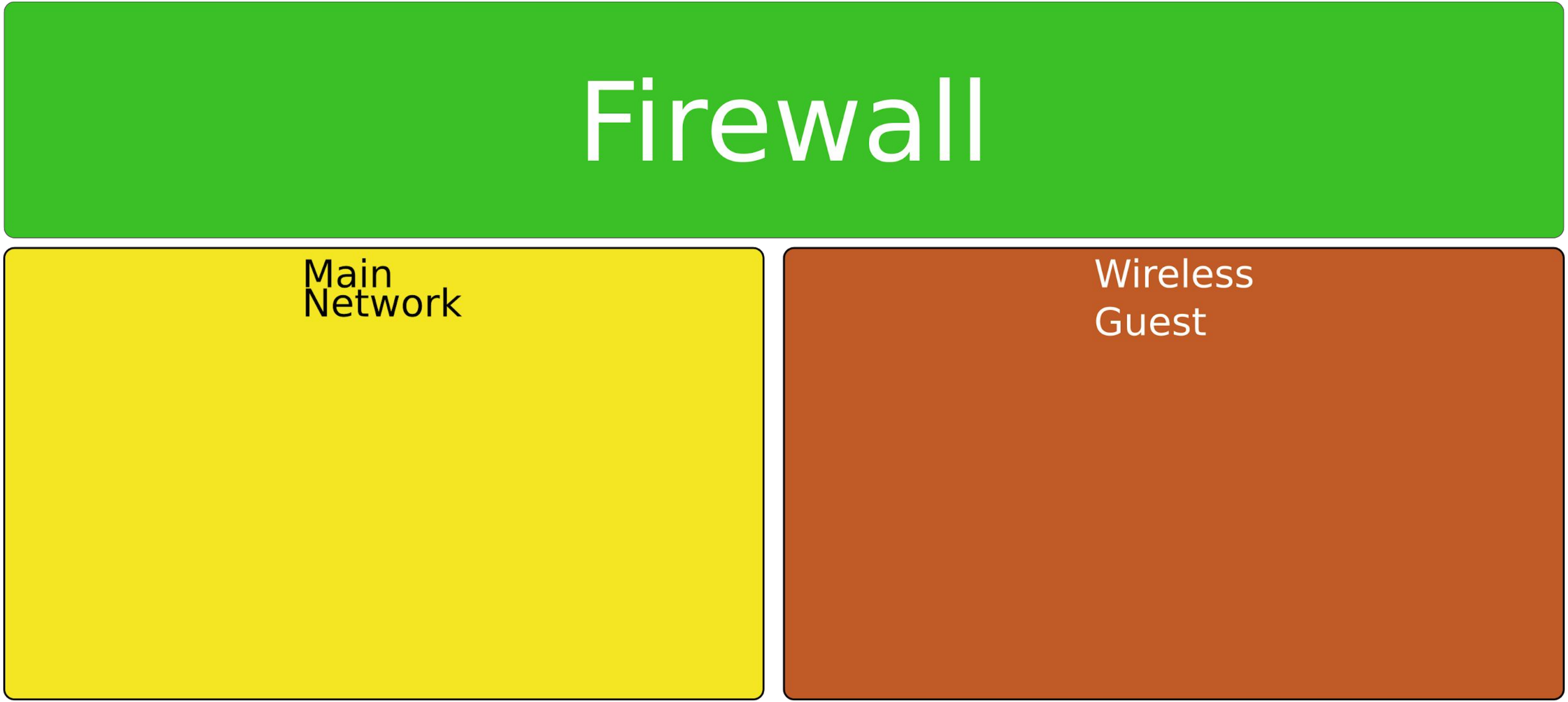
IoT-ALE:
Connecting to the Internet MQTT

putting the I in IoT

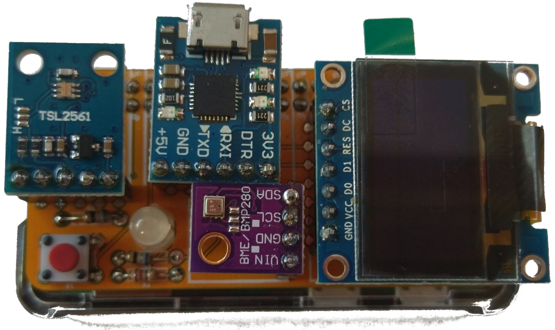
John ‘Warthog9’ Hawley

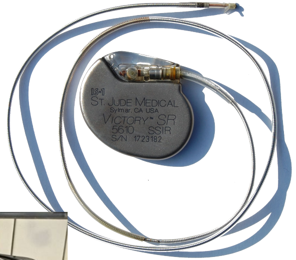
SCaLE 17x - March 2019

Let us lay some ground works…
What most “home” networks look like:



More Groundwork: IoT devices

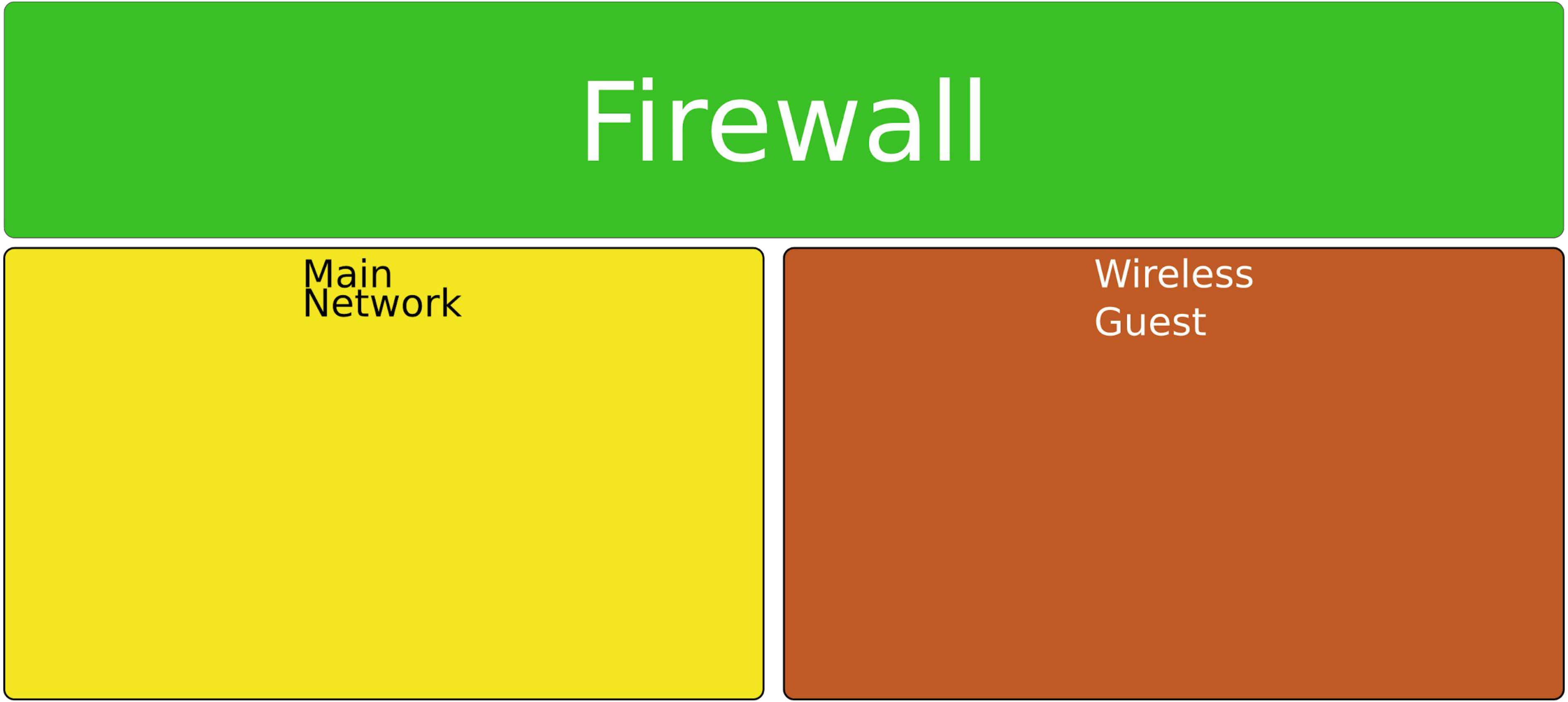




Typical ways devices connect to the Internet

- Through a Gateway:
    - Bluetooth
    - Z-wave
    - 802.11.6
    - Zigbee
    - IR
    - Smoke Signals
    - Carrier Pigeons
- Directly:
    - Wifi
    - Ethernet
- Using:
    - IPv4
    - IPv6

Lets come back to this for a minute to talk about IPv4 vs. IPv6



Local Access vs. Remote Access

- IPv4 - Local
  - Direct Access
  - Straight Forward
  - Mostly ubiquitous support
- IPv4 - Remote
  - NAT traversal
  - Punching holes in firewalls
  - Port Forwarding
  - UPNP
  - Cloud reverse proxies
- IPv6 - Local
  - Direct Access
  - Straight Forward
  - Getting more ubiquitous but not there
- IPv6 - Remote
  - Direct Access
  - Punching holes in firewalls
  - UPNP
  - Cloud based IP lookup (and/or reverse proxies)

Some general words of caution...

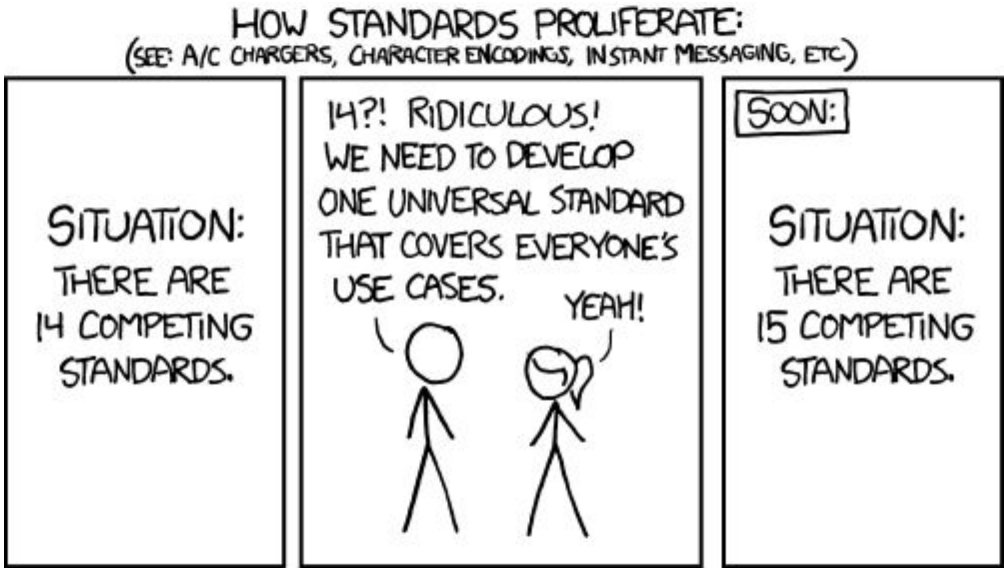
- Think about what you are using the Internet for
- Be mindful of where your services live
- Sometimes UX the user can use may make you less secure
- Always change the default passwords!
- Make it possible to do things without auto-discovery
- Don’t always assume you are on the same network as the device
- Upgrade schemes need to be done

Shifting gears & talk about how to talk to the devices

But the real advantage to IoT is the I - Internet!

Lots of good ways to do this…

- MQTT
- Liota
- AMQP
- STOMP
- RabbitMQ
- REST
- WAMP
- ZeroMQ
- Java Message Service (JMS)
- CoAP
- CLOUD!
- XMPP-IOT
- XMPP
- etc…..



https://xkcd.com/927/

- CC-BY-NC 2.5

Now lets talk about something to try

- MQTT - Mosquitto, MQTT broker, good for local passing of data
- Think of it as a message bus on the network
- Clients Subscribe to Topics that can be hierarchical, and listen to the Topic
    - /myhome/groundfloor/livingroom/temperature for example
    - You can listen at any level of the hierarchy, anything below your level will be filtered to you
    - Wildcards, +, are allowed /myhome/+/temperature
- Devices Publish data to topics
    - The data is freeform, the receiving end is expected to interpret it

Lets just try listening...

On your laptop/VM:

yum install mosquitto

apt-get install mosquitto-clients

then

```
     mosquitto_sub \
          -h 10.100.0.5 \
          -t “pugnose/temp/core0” \
          -u "ale" \
          -P "Penguins"
```

Expected output:

```
+67.0°C
```

What’s running on “pugnose”:

```
while [[ 1 ]];do \
     mosquitto_pub \
          -h 10.100.0.5 \
          -t “pugnose/temp/core0” \
          -m "$( \
               sensors | \
               grep "Core 0" | \
               tr " " "\n" | \
               grep "°" | \
               head -n 1 \
          )" \
          -u "ale" \
          -P "Penguins"; \
          sleep 10;\
done
```

Listening from the IoT device (subscribing)

From the repl prompt:

```
>>> from umqtt.simple import MQTTClient
>>> import socket
>>> import time
>>> from ubinascii import hexlify
>>> CLIENT_ID = hexlify(machine.unique_id())
>>> def sub_cb(topic, msg):
...     print((topic, msg))
...
...
...
>>> c.set_callback(sub_cb)
>>> c = MQTTClient(CLIENT_ID,
... “10.100.0.5”)
>>> c.connect()
>>> c.subscribe(b"topic/yourname")
```

```
>>> while True:
...     if True:
...         c.wait_msg()
...     else:
...         c.check_msg()
...         time.sleep(1)
...
...
...
>>> c.disconnect()
```

From your VM / Laptop

```
mosquitto_pub \
     -h 10.100.0.5 \
     -t “topic/yourname” \
     -m "Hello YourName" \
     -u "ale" \
     -P "Penguins"
```

Publishing from the IoT device

From the repl prompt:

```
>>> from umqtt.simple import MQTTClient
>>> import socket
>>> from ubinascii import hexlify
>>> CLIENT_ID = hexlify(machine.unique_id())
>>> c = MQTTClient(CLIENT_ID,
... “10.100.0.5”)
>>> c.connect()
>>> c.publish(b"topic/yourname",
... b"hello from mpy")
>>> c.disconnect()
```

On your laptop/VM:

yum install mosquitto

apt-get install mosquitto-clients

then

```
mosquitto_sub \
     -h 10.100.0.5 \
     -t “topic/yourname” \
     -u "ale" \
     -P "Penguins"
```

For the way advanced!

```
from umqtt.simple import MQTTClient
from machine import Pin
from ubinascii import hexlify
import machine
import micropython
led = Pin(0, Pin.OUT, value=1)
SERVER = "10.100.0.5"
CLIENT_ID = hexlify(machine.unique_id())
TOPIC = b"topic/yourname"
state = 0
def sub_cb(topic, msg):
    global state
    print((topic, msg))
    if msg == b"on":
        led.value(0)
        state = 1
    elif msg == b"off":
        led.value(1)
        state = 0
    elif msg == b"toggle":
        led.value(state)
        state = 1 - state

def main(server=SERVER):
    c = MQTTClient(CLIENT_ID, server)
    c.set_callback(sub_cb)
    c.connect()
    c.subscribe(TOPIC)
    print("Connected %s, sub to %s topic"
    % (server, TOPIC))

    try:
        while 1:
            c.wait_msg()
    finally:
        c.disconnect()
```