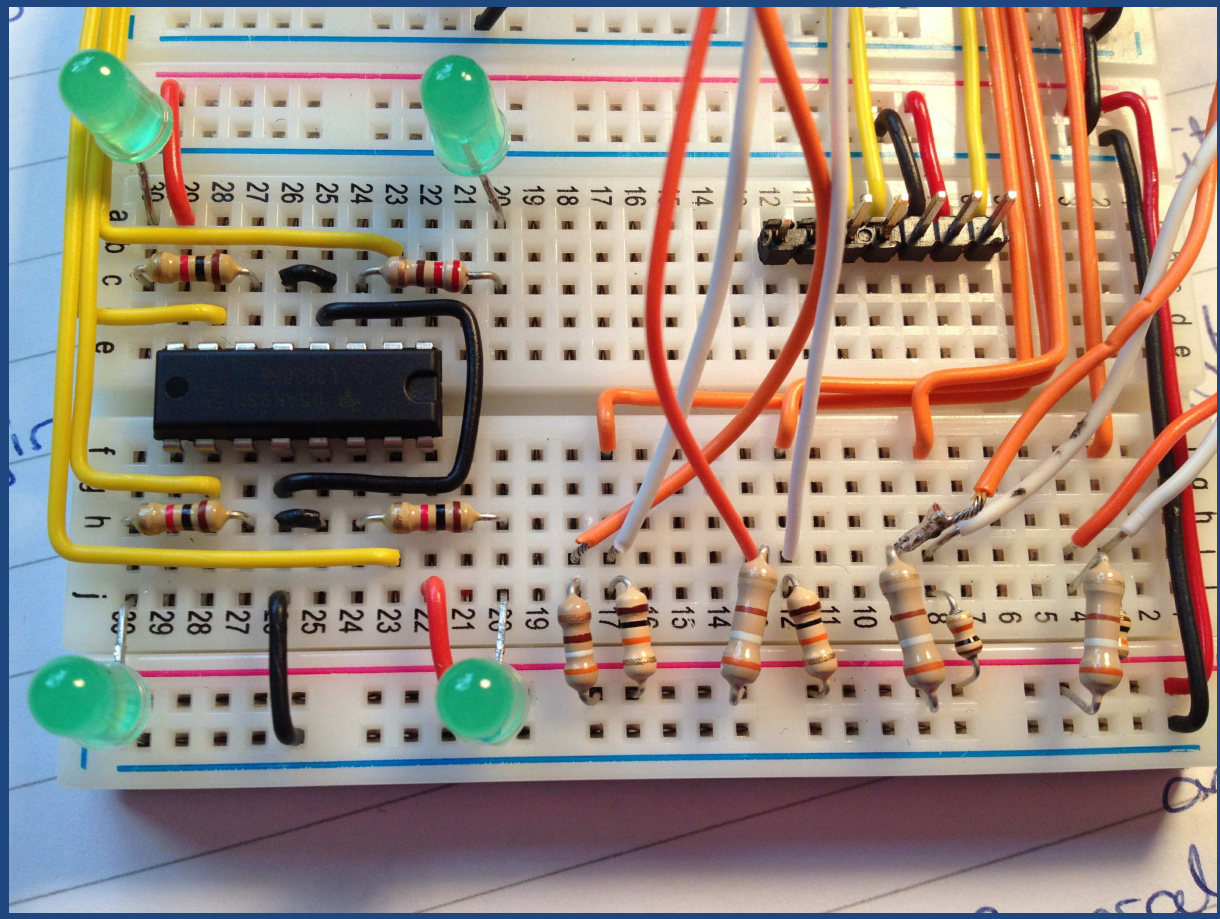
Intro to Electronics

(For us software people)



Topics

- What grade 9 physics do I need to remember?
  = V, A, Ω
- Connecting wires into circuits
- What components go into our circuits?
- How (*not to*) fry your board!

Basic Theory

Voltage

- Voltage
  ..
  - It is the..

- We use only direct current (DC) voltages in our electronics.

Voltage	
Symbol	V
Units	Volts [V]
Our Usual Range	0V to +3.3V

Current

- (Conventional) Current

  ..

  - Current flow is driven by voltage.
- Current flows from higher voltage to lower voltage (from + to -)

Current	
Symbol	`I`
Units	Amps [A]
Our Usual Range	1A powers BBG; GPIO ~3mA

Note: electrons actually flow opposite direction: - to +;
It was discovered later that electrons have negative charge

Resistance

- Resistance
  ..
- Resistance defined as V / **I**
  (inferred from the resistance the current sees across a voltage)

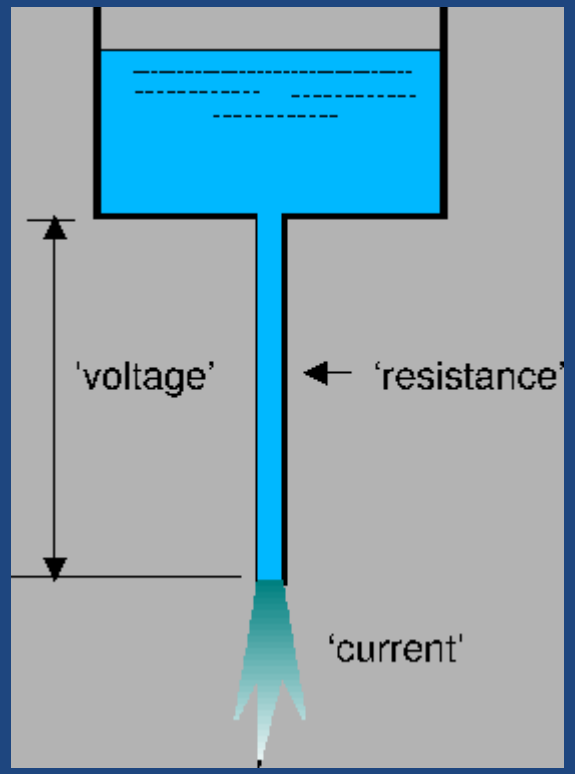
I am engineer of Borg;
<1 Ohms Resistance
is Futile

Resistance	
Symbol	R
Units	Ohms [Ω]
Our Usual Range	100Ω to 10,000Ω

Pipe Analogy

- Water tank draining water through pipe
  - Voltage: height (higher is higher potential)
  - Current: amount of water flow
  - Resistance: size of pipe
    (bigger pipe gives less resistance)
- Relationship (Ohm's law)

```
V = I * R
V / R = I
```



Ohm's Law Examples: **V=IR**

1) 1V across 1Ω; find current

2) 5V across a 1kΩ resistor; find current

3) 2A through 10Ω; find voltage

4) 3.3V through 0Ω; find current

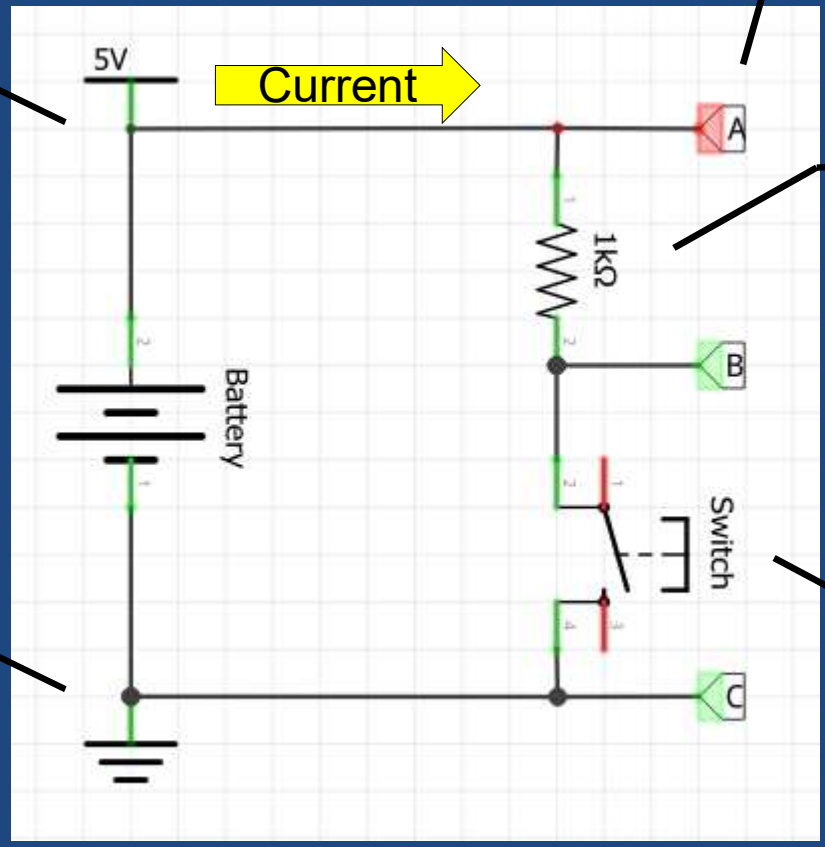
5) 3.3V at 0A, find resistance

Units

- Mega: 1,000,000
  - Mega-ohms: 1,000,000Ω = 1MΩ
- Kilo: 1,000
  - Kilo-ohms: 1,000Ω = 1kΩ
- Milli: 1/1,000
  - Milliamps: 0.001A = 1 mA
  - Millivolts: 0.100 V = 100 mV
- Micro: 1/1,000,000
  - Microamps: 1A = 1,000,000 μA
  - Microvolts: 1V = 1,000,000 μV

Circuits

Sample Circuit



Power:
VDD or VCC

Ground:
GND or

GPIO connections
to CPU for reading
- Current ~0A in/out of CPU when reading

Resistor
- Coloured bands tell ohms
- Not directional

Switch
Open: ∞Ω
Closed: 0Ω

Solving Circuits

- Each components in circuit

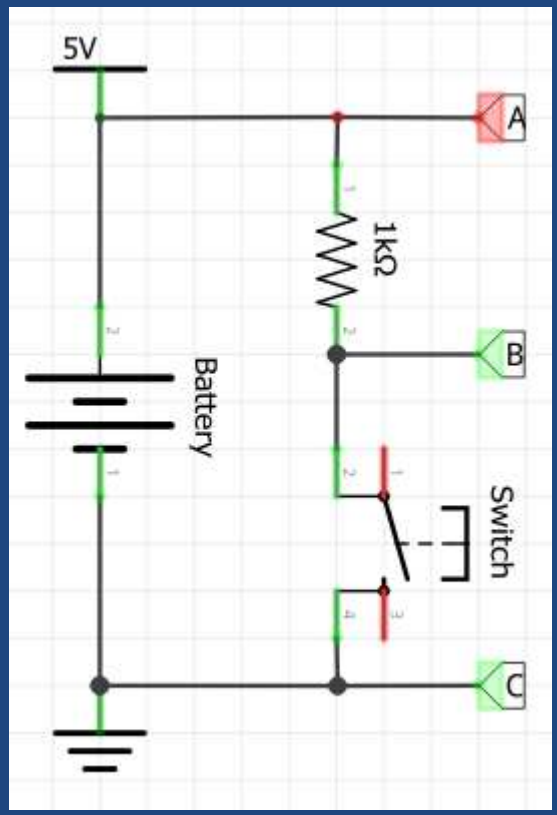
  ..

  - Wires assumed to be 0Ω
  - Sum of all voltages lost in circuit =..
  -

- Usual approach to solving a single path circuit
  1. Find the voltage of the source
  2. Find resistance of the circuit
     = sum resistances of each series component
  3. Solve current

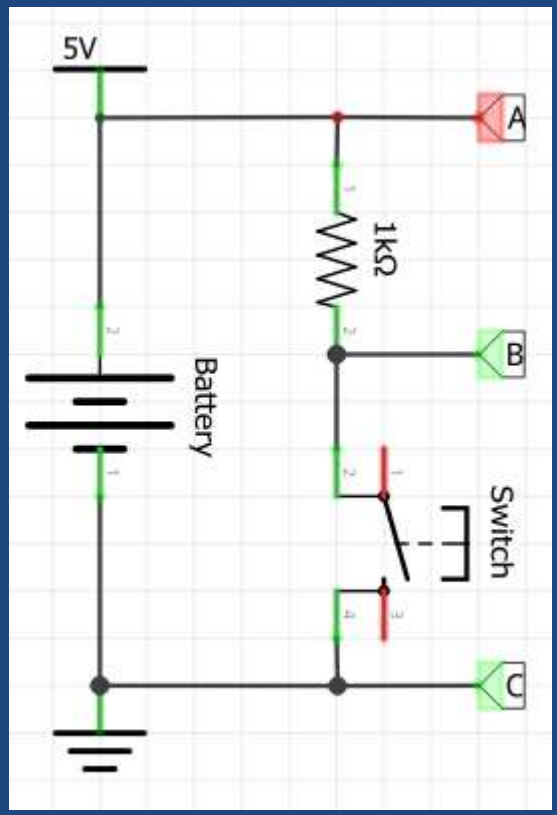
Solving Circuits Examples

- With switch open (not connected), solve:
  - Resistance of circuit
  - Current through switch
  - Current through resistor
  - A's voltage
  - B's voltage
  - C's voltage

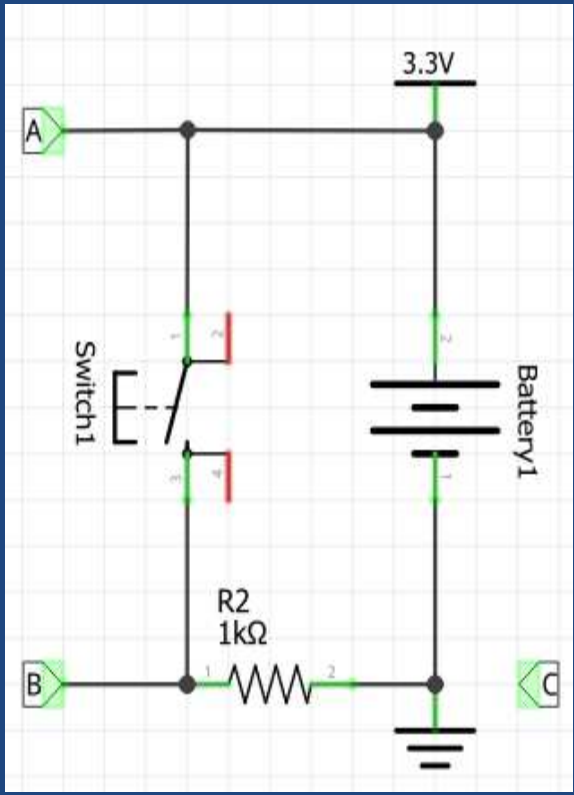


Solving Circuits Examples (cont)

- With switch closed (connected), solve:
  - Resistance of circuit
  - Current (through resistor or switch)
  - A's voltage
  - B's voltage
  - C's voltage

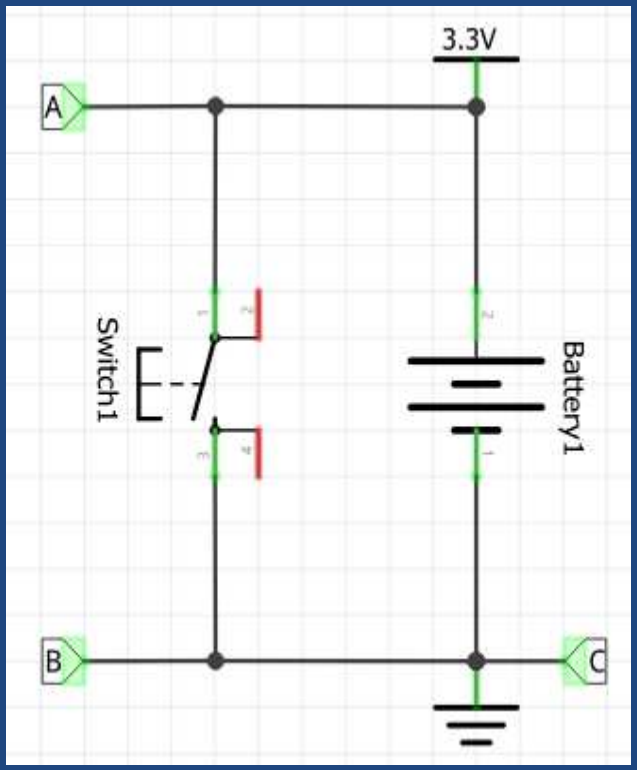


Exercise #1



	Switch Closed	Switch Open
I through Resistor		
I through Switch		
V at ‘A’		
V at ‘B’		
V at ‘C’		

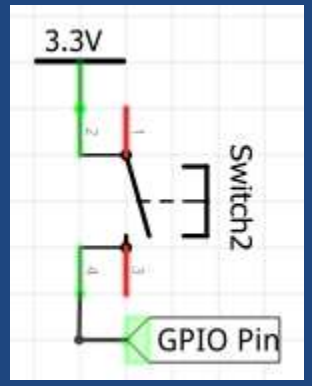
Exercise #2



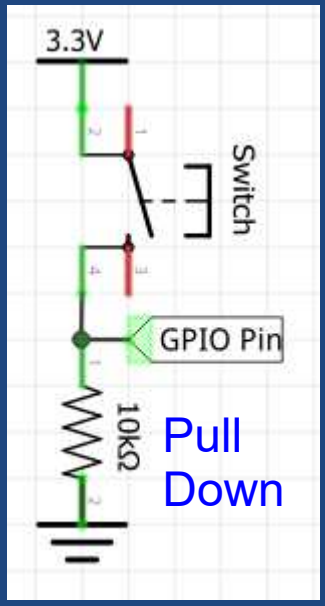
	Switch Closed	Switch Open
I through Switch		
V at ‘A’		
V at ‘B’		
V at ‘C’		

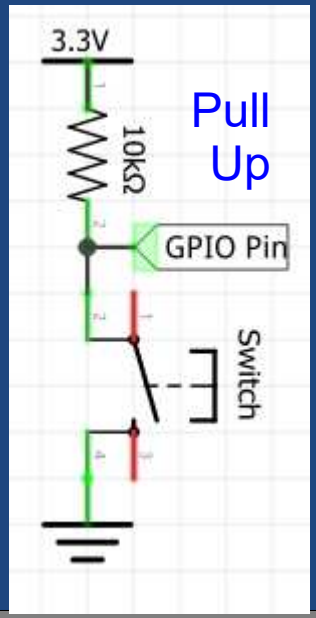
Pull-up / Pull-down

- What does ‘GPIO Pin’ read when:
  - switch closed? ..
  - switch open? ..



- Solution
  - Pull-down resistor: ..
  - Pull-up resistor:
    add large value resistor to 3.3v



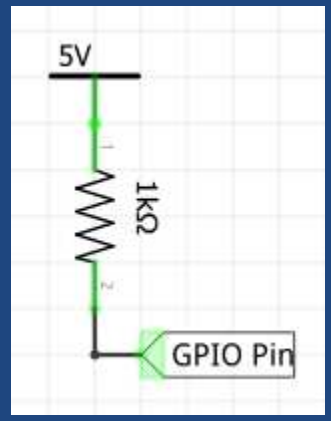


Exercise: Smoke and Divider

- If GPIO Pin is an input pin on the BBG, what does this circuit do?
  - Assume 0A current into input GPIO

  ..

  ..

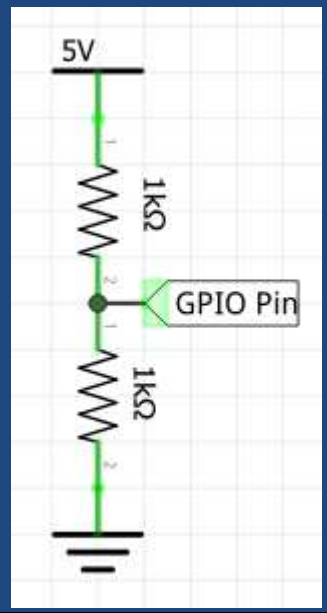


- What does GPIO Pin read?

  ..

  ..

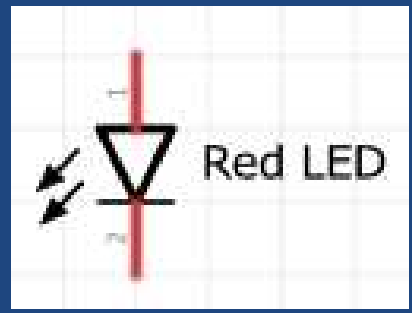
  Intuition: ..



LEDs and Breadboards

LED

- LED = Light Emitting Diode
  - LEDs require a current to turn on: the more current, the bright.
  - Too much current: damage it.



- Details
  - Diodes only allow current to flow one way: in direction of arrow.
  - Don’t wire an LED in backwards.
  - We’ll treat LEDs as a current device, not affecting V
    (LEDs have a voltage drop across them of ~0.7V
    We’ll ignore this in this course.)

LED (cont)

- If ‘GPIO Out A’ is set to 1 (3.3V), what is current through ‘Red LED’?
  - Safe case: Assume no LED voltage drop.

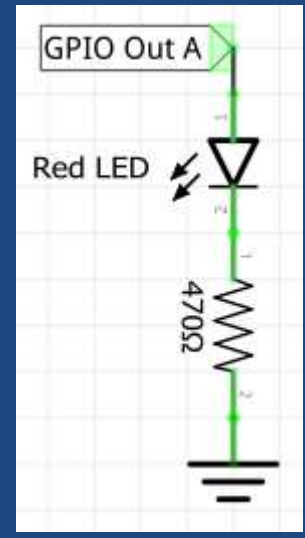
    ..

    ..
- Current Limiting Resistor
  - Added to reduce current through circuit.
- What resistor should you use if the LED requires 5mA to turn on? (3.3V source, no LED voltage drop)

  ..

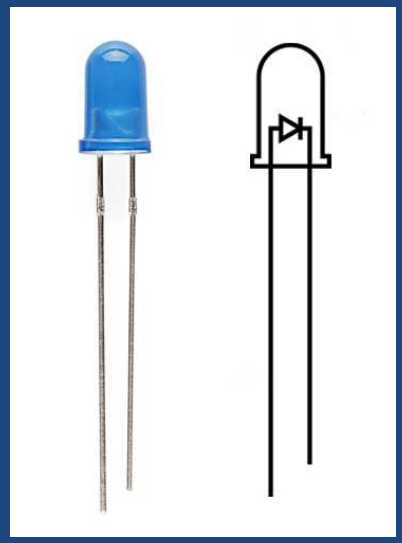
  ..

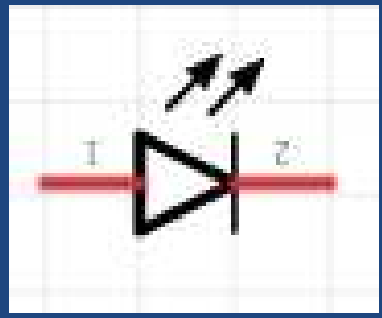
  ..



LED wiring

- LEDs must be wired in correct direction to turn on
  - Longer lead (wire) is + side (Anode)
  - Shorter lead (wire) is – side (Cathode)
- In reverse, they block all current
  until voltage exceeds their maximum reverse voltage, at which point the LED could be damaged.



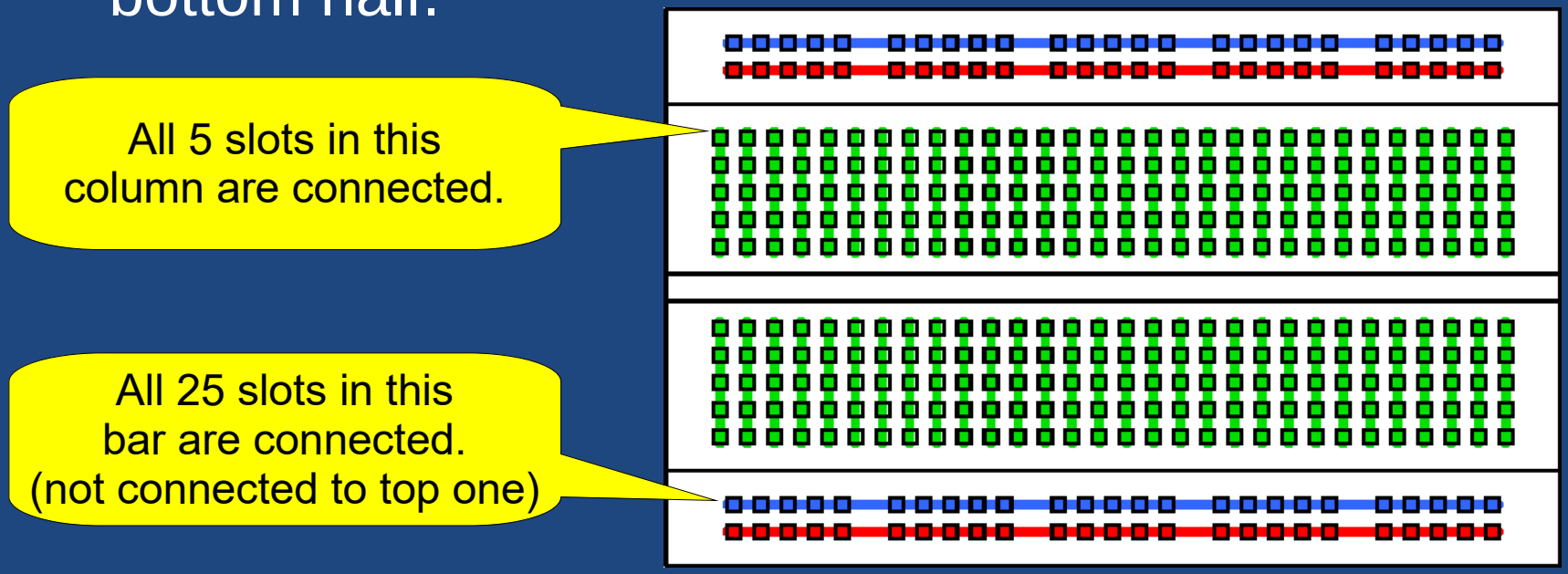


Review Questions

- Suggested circuit drawing questions
  (try on your own time)
  - Draw a circuit which turns on an LED when you press a button.
  - Draw a circuit which turns on an LED when you set a GPIO pin to high.
  - Draw a circuit which turns on an LED when you set a GPIO pin to low.

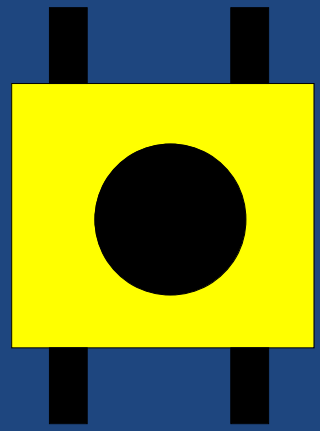
Breadboard

- Breadboard used to wire circuits without soldering
  - + and - bars on both top and bottom
  - Columns of 5 slots all connected.
  - Columns on top half not connected to columns on bottom half.

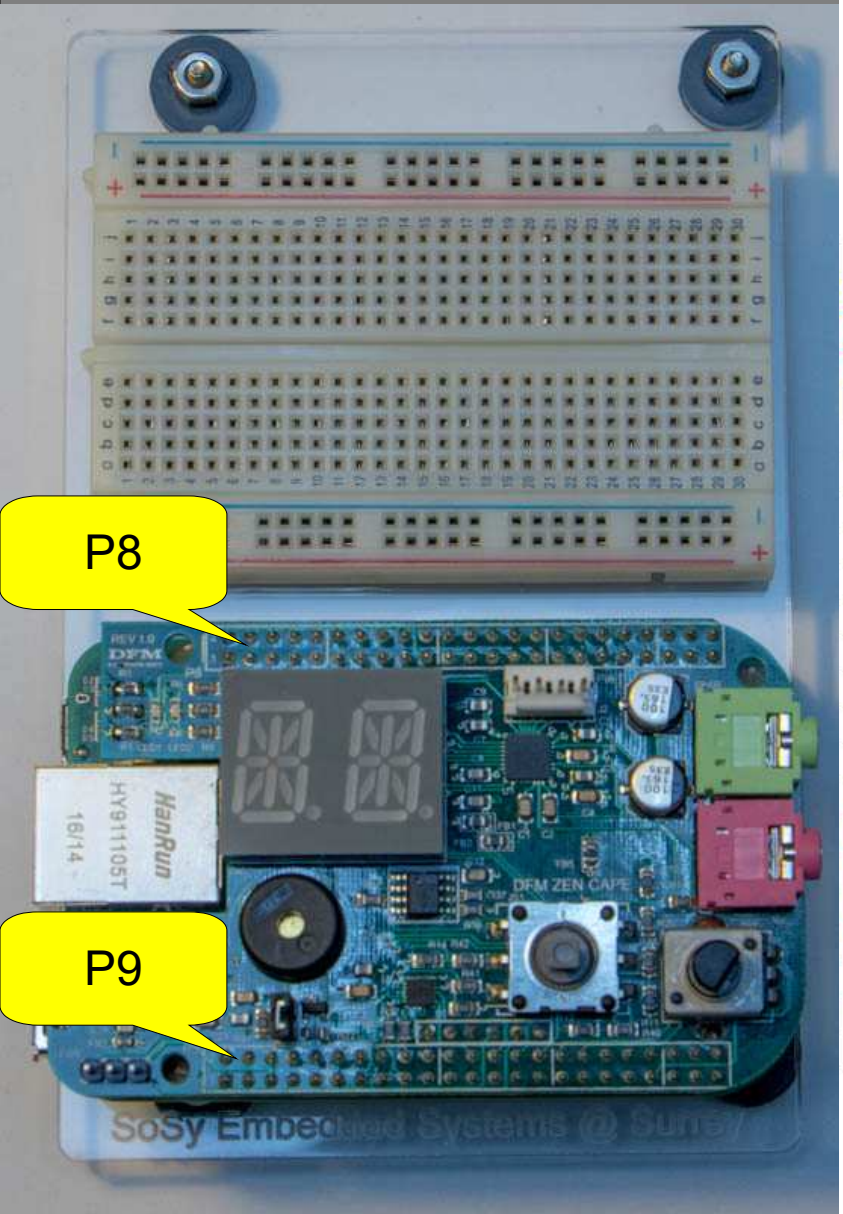


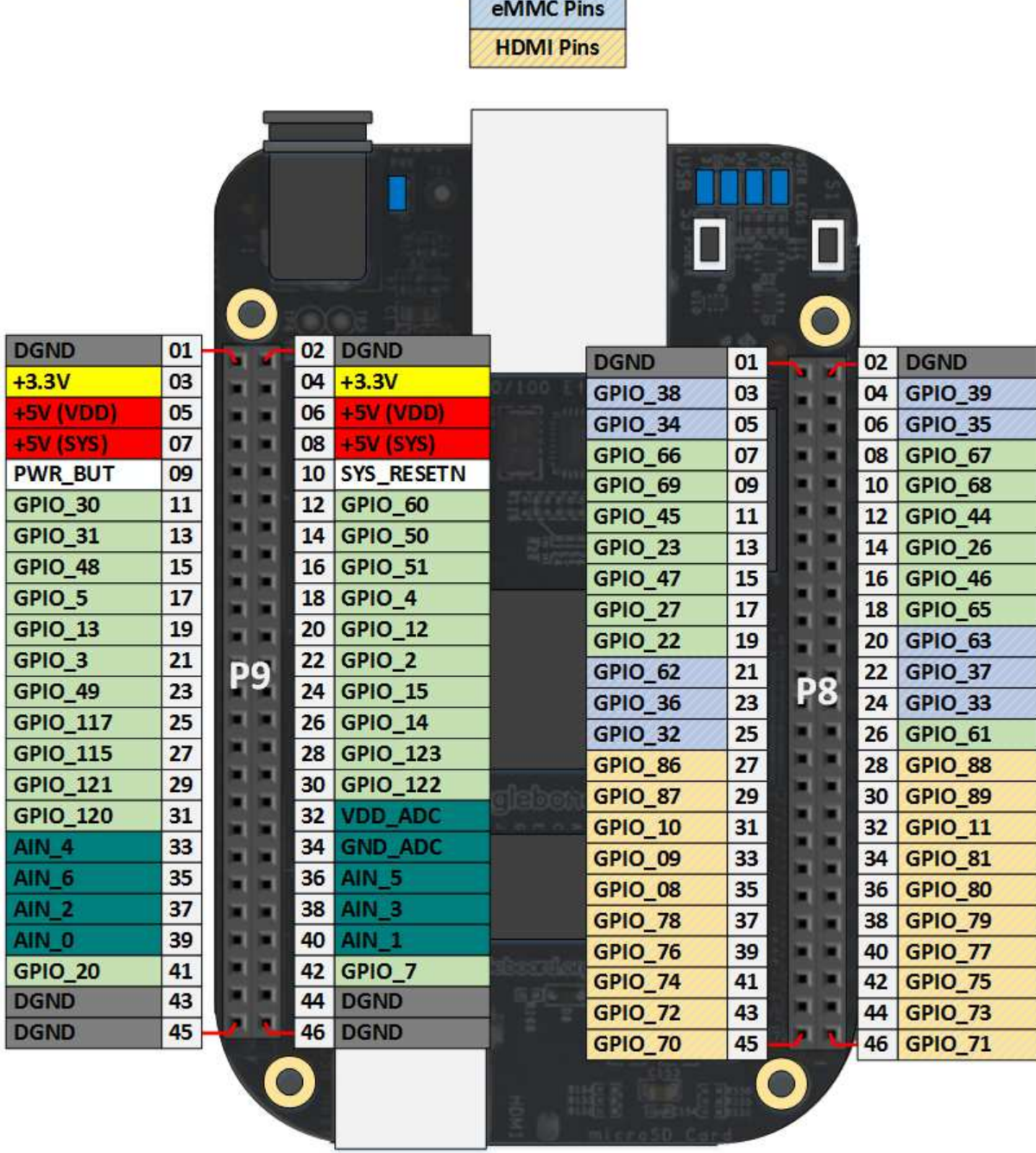
Push Button

- Our Push Buttons
  - 4 pins (2 top, 2 bottom)
  - Pressing button shorts (0 ohms) across top pins; and across bottom pins.



Pins



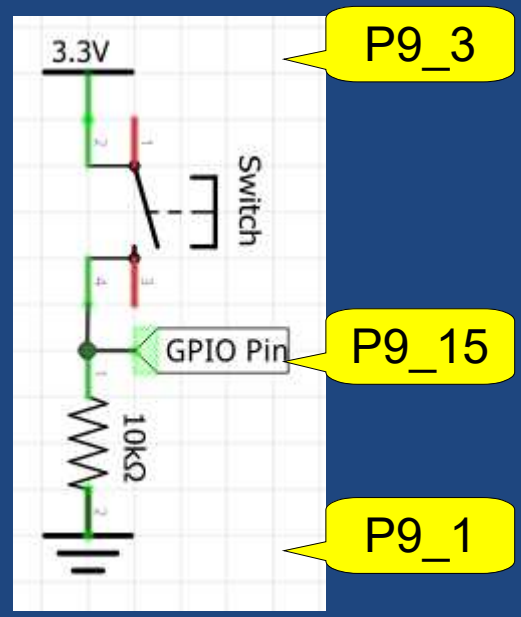


DGND	01	02	DGND
+3.3V	03	04	+3.3V
+5V (VDD)	05	06	+5V (VDD)
+5V (SYS)	07	08	+5V (SYS)
PWR_BUT	09	10	SYS_RESETN
GPIO_30	11	12	GPIO_60
GPIO_31	13	14	GPIO_50
GPIO_48	15	16	GPIO_51
GPIO_5	17	18	GPIO_4
GPIO_13	19	20	GPIO_12
GPIO_3	21	22	GPIO_2
GPIO_49	23	24	GPIO_15
GPIO_117	25	26	GPIO_14
GPIO_115	27	28	GPIO_123
GPIO_121	29	30	GPIO_122
GPIO_120	31	32	VDD_ADC
AIN_4	33	34	GND_ADC
AIN_6	35	36	AIN_5
AIN_2	37	38	AIN_3
AIN_0	39	40	AIN_1
GPIO_20	41	42	GPIO_7
DGND	43	44	DGND
DGND	45	46	DGND

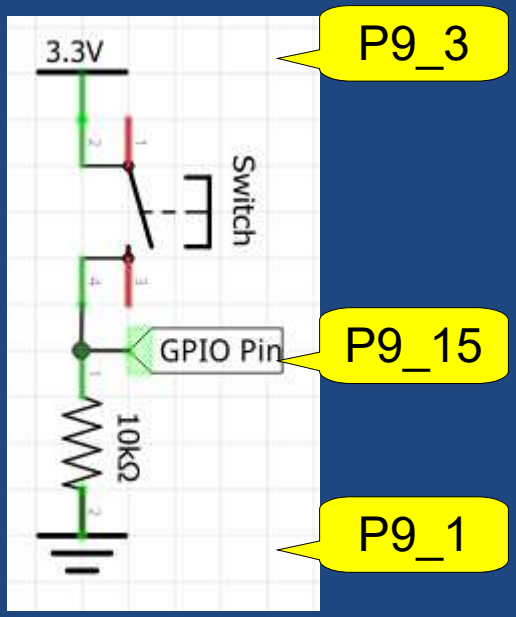
DGND	01	02	DGND
GPIO_38	03	04	GPIO_39
GPIO_34	05	06	GPIO_35
GPIO_66	07	08	GPIO_67
GPIO_69	09	10	GPIO_68
GPIO_45	11	12	GPIO_44
GPIO_23	13	14	GPIO_26
GPIO_47	15	16	GPIO_46
GPIO_27	17	18	GPIO_65
GPIO_22	19	20	GPIO_63
GPIO_62	21	22	GPIO_37
GPIO_36	23	24	GPIO_33
GPIO_32	25	26	GPIO_61
GPIO_86	27	28	GPIO_88
GPIO_87	29	30	GPIO_89
GPIO_10	31	32	GPIO_11
GPIO_09	33	34	GPIO_81
GPIO_08	35	36	GPIO_80
GPIO_78	37	38	GPIO_79
GPIO_76	39	40	GPIO_77
GPIO_74	41	42	GPIO_75
GPIO_72	43	44	GPIO_73
GPIO_70	45	46	GPIO_71

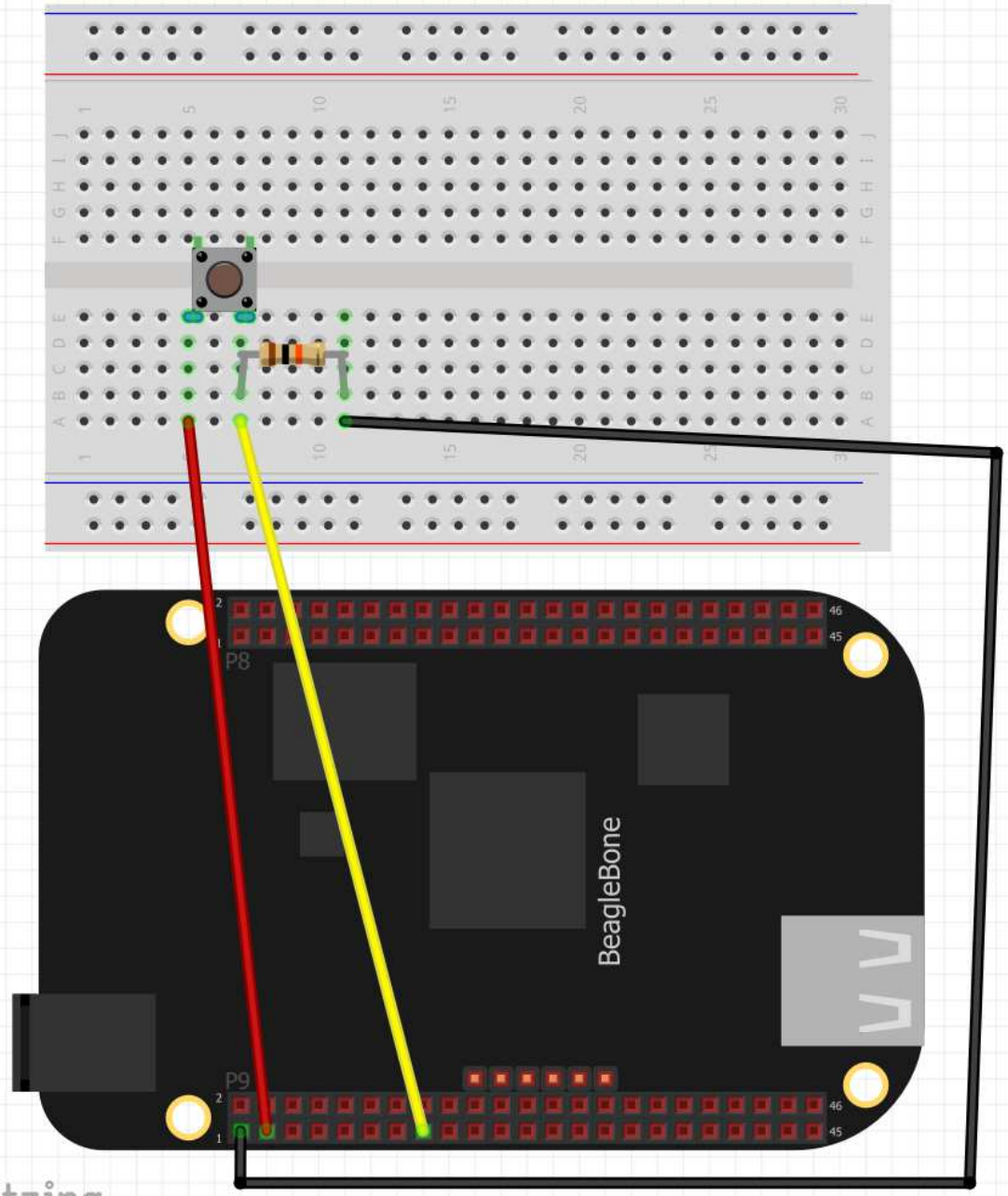
Breadboard Example

- Wire BBG to read if button is pressed
  - Start by drawing circuit.
  - Then pick BBG pins
    - 3.3V: P9_3 or P9_4
    - GPIO Pin: P9_15
    - Gnd: P9_1 or P9_2
  - Finally wire up & test
    - (Next slide)

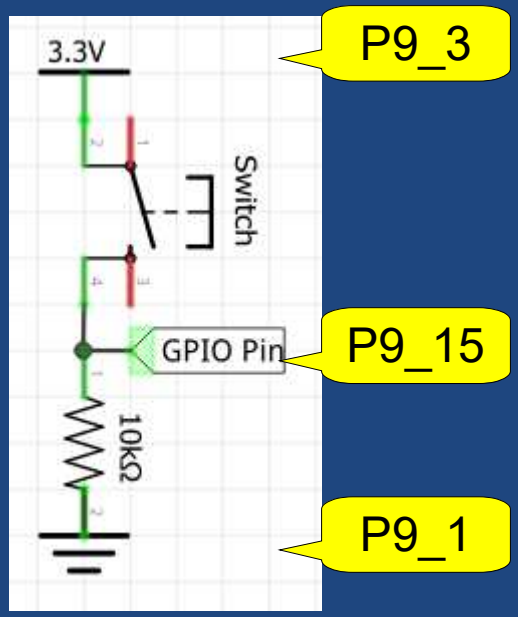


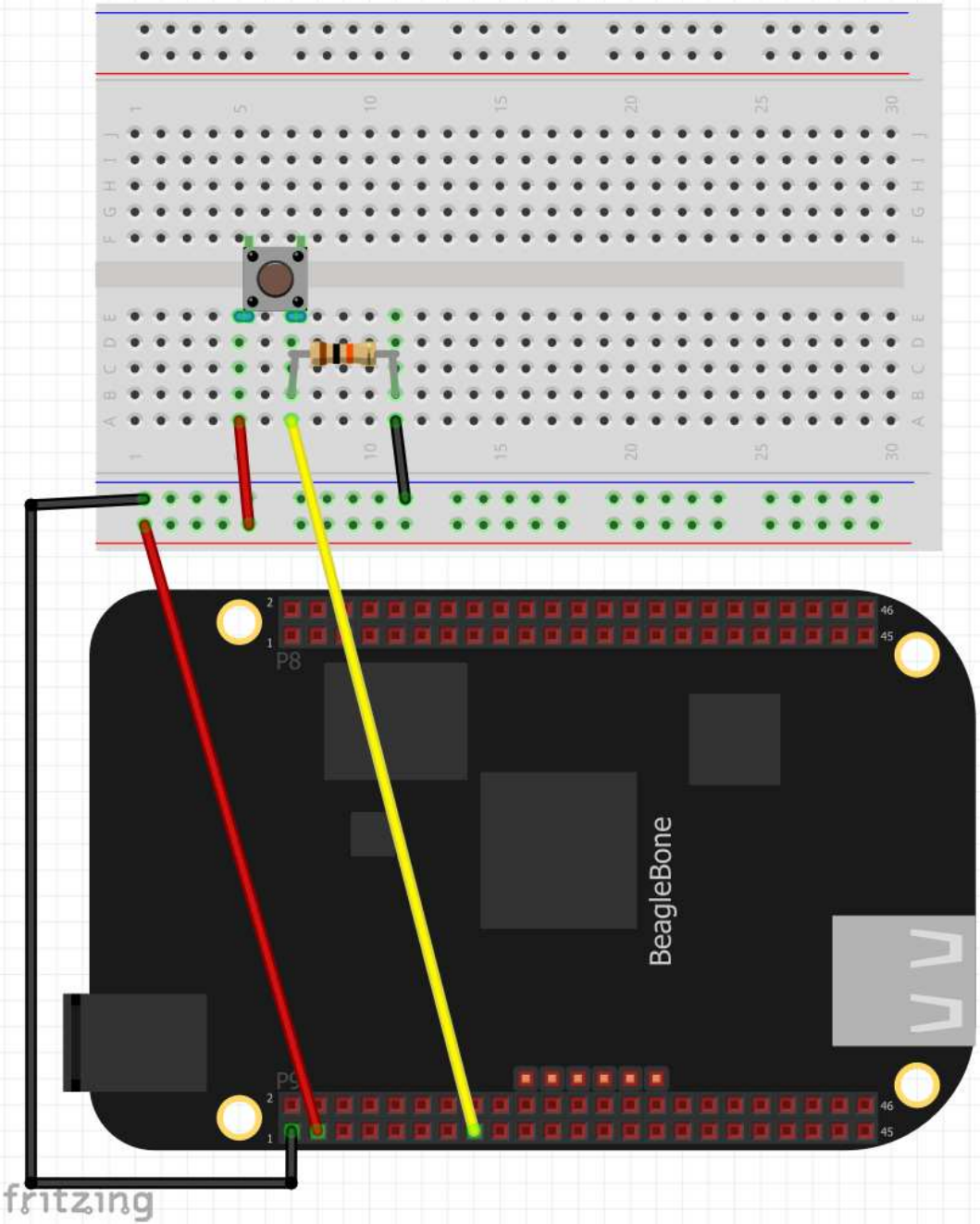
Wiring


3.3V
Switch
GPIO Pin
10kΩ
P9_3
P9_15
P9_1


P8
P9
BeagleBone
fritzing

Alt. Wiring

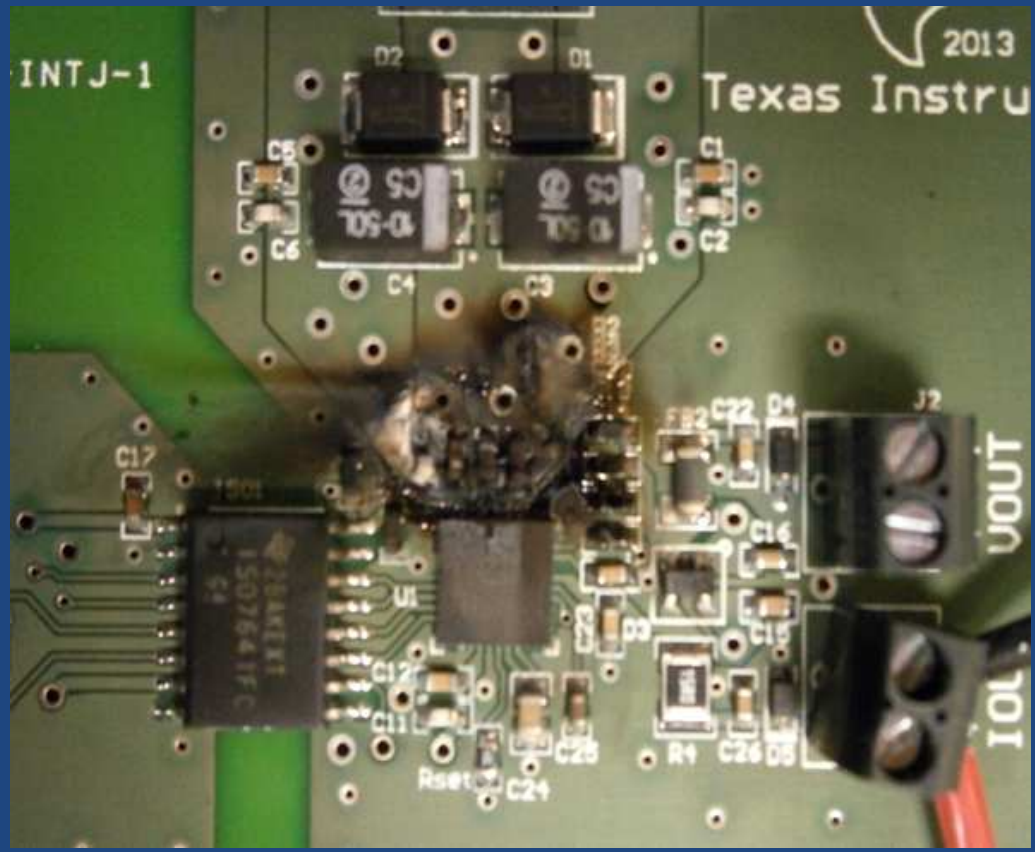

3.3V
Switch
GPIO Pin
10kΩ
P9_3
P9_15
P9_1


P8
BeagleBone
fritzing

Power

- GPIO pins give +3.3V
  - Can source 6mA (current out of pin)
  - Can sink 8mA (current into pin)
- A2D reference gives +1.8V
- USB gives +5V
  - VDD_5V is powered from USB directly
  - SYS_5V is through on-board voltage regulator

How to damage your board



How to fry your BeagleBone

- Draw too much current from 3.3v
  - total current to BBG < 500mA
  - ..
- Over-current GPIO pins
  - Can source 6mA (current out of pin)
  - Can sink 8mA (current into pin)
- Apply too much voltage to CPU pin
  - GPIO [tollerates 0v - 3.3v]
  - A2D [tollerates 0v - 1.8v]

Other Systems

- Raspberry Pi
  - may tolerate higher voltages if current is low; not so with BBG
  - Don't let GPIO go > 3.3V, even at low current
- Arduinos run at 5V
  - Many Arduino peripherals need level shifters to work with BBG's 3.3V GPIO
- 12V Fans
  - It's 12V! Be careful! Use a relay to turn on/off
- Motors
  - Need a motor driver chip to turn drive the motor

Tips

1) Draw out your circuit on paper before wiring it.
2) Wire your circuit with the power off.
3) Double check wiring before powering on!
   - Not as easy as “recompile” to fix HW errors.
4) If it does not work, don’t just try things till it works.

Summary

- Ohm's Law: `V = I * R`
  - Solve a circuit by finding resistance across a voltage to solve the current.
- Components
  - Switches: Open or closed
  - LED: current turns on
  - Resistor
- Be mindful of HW limits:
  don't fry your board!