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.

<table>
<thead>
<tr>
<th>Voltage</th>
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<tbody>
<tr>
<td>Symbol</td>
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<tr>
<td>Units</td>
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<tr>
<td>Our Usual Range</td>
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</tbody>
</table>
Current

- (Conventional) Current

- Current flow is driven by voltage.

- Current flows from higher voltage to lower voltage (from + to -)

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

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Resistance

- Resistance

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

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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)
  \[ V = I \times R \]
  \[ V / R = I \]
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

- **Milli:** $\frac{1}{1,000}$
  - Milliamps: $1000 \text{ mA} = 1 \text{ A}$
  - Millivolts: $1000 \text{ mV} = 1 \text{ V}$

- **Micro:** $\frac{1}{1,000,000}$
  - Microamps: $1,000,000 \mu\text{A} = 1 \text{ A}$
  - Microvolts: $1,000,000 \mu\text{V} = 1 \text{ V}$

- **Kilo:** $1,000$
  - Kilo-ohms: $1,000\Omega = 1k\Omega$

- **Mega:** $1,000,000$
  - Mega-ohms: $1,000,000\Omega = 1M\Omega$
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: $\infty\Omega$
- 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

<table>
<thead>
<tr>
<th></th>
<th>Switch Closed</th>
<th>Switch Open</th>
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</thead>
<tbody>
<tr>
<td>$I$ through Resistor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I$ through Switch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V$ at ‘A’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V$ at ‘B’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V$ at ‘C’</td>
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![Diagram of a simple circuit with a switch and resistor connected to a battery.]
# Exercise #2

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<th>Switch Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>I through Switch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V at ‘A’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V at ‘B’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V at ‘C’</td>
<td></td>
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![Diagram of an electrical circuit with a switch, a 3.3V voltage source, and a battery.](image)
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 $\sim 0.7V$ 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.

![Diagram showing connections in a breadboard](image)

- All 5 slots in this column are connected.
- All 25 slots in this bar are connected.
  (not connected to top one)
Push Button

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

P9_1

P9_3

P9_15
Alt. Wiring

- Switch
- GPIO Pin

- P9_3
- P9_15
- P9_1

19-10-5
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  [tolerates 0v - 3.3v]
  - A2D  [tolerates 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: \( V = I \times R \)
  – 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!