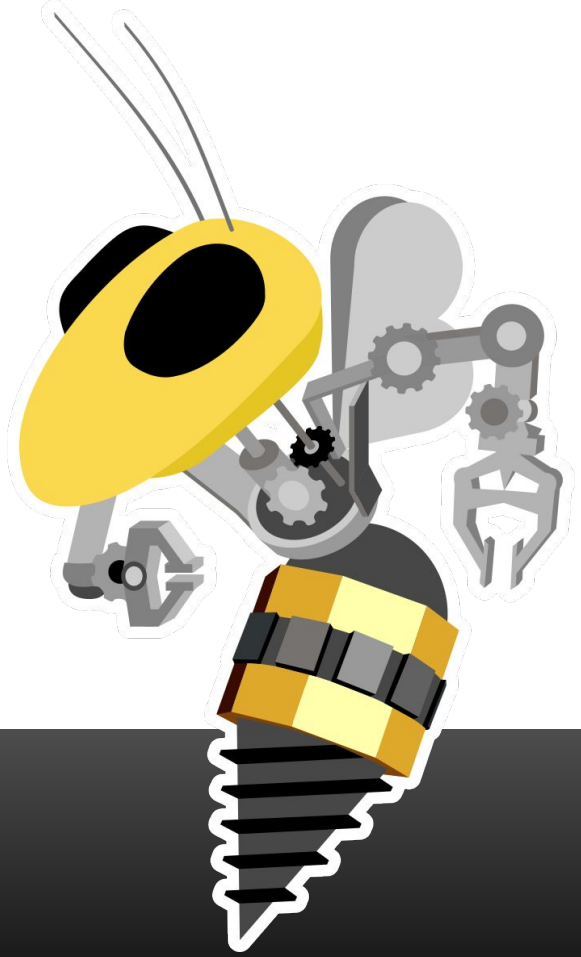
Welcome!

Electrical/Firmware Training
Week 1



RoboJackets
Competitive Robotics at Georgia Tech

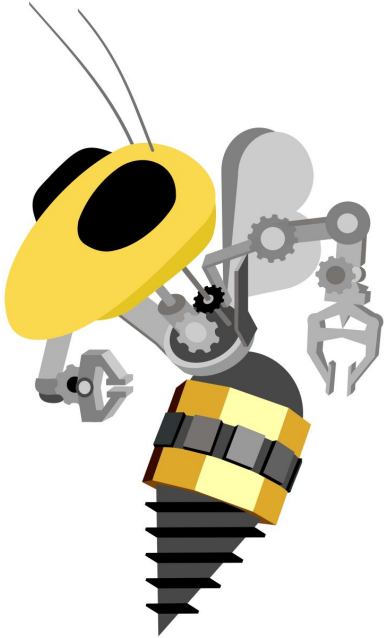
www.robojackets.org

Last Week!

- Introductions
- What is RoboJackets Electrical/Firmware?
- Logistics
- Electrical Basics

This Week!

- Microcontrollers
- Why Firmware?
- C++, Part 1
  - Variables in C++
  - Arithmetic & Making Comparisons
  - If / Else
- Prototyping

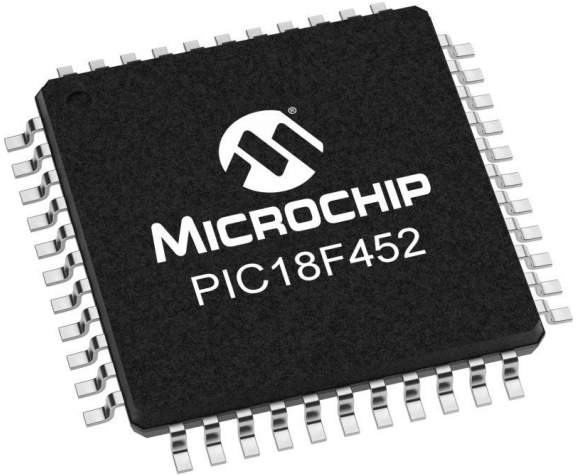


Microcontrollers

aka MCU

What is a Computer?

What is a Microcontroller (MCU)?

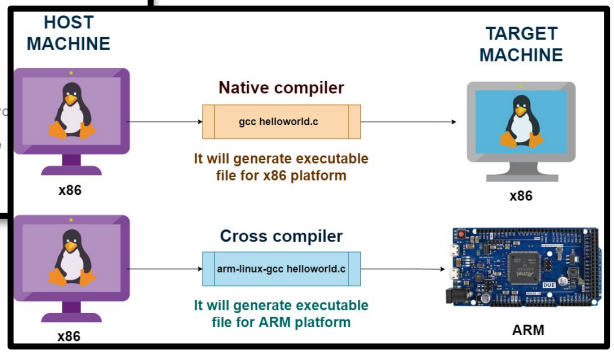


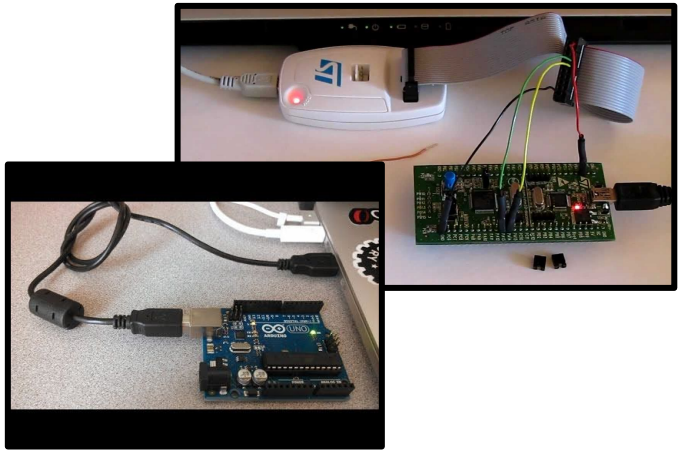
Website: https://www.microchip.com/en-us/product/PIC18F452#
Datasheet:
https://ww1.microchip.com/downloads/aemDocuments/documents/MCU08/ProductDocuments/DataSheets/39564c.pdf

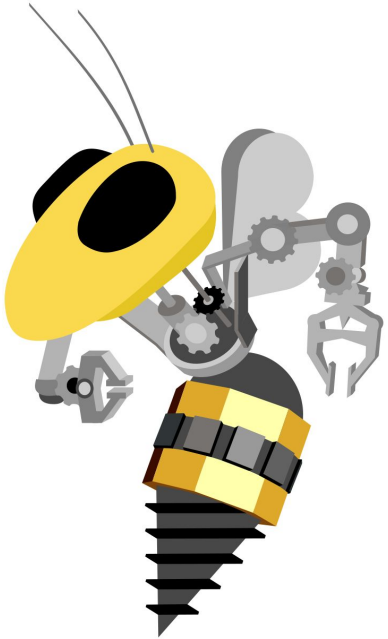

RESET
AREF
GND
13
12
~11
~10
~9
8
7
~6
~5
4
~3
2
TX→1
RX←0
DIGITAL (PWM~)
UNO
ON
ARDUINO
TX
RX
ICSP
POWER
ANALOG IN
IOREF
RESET
3.3V
5V
GND
Vin
A0
A1
A2
A3
A4
A5
ARDUINO.CC

Programming a MCU

```
Blink §
/*
  Blink
  Turns on an LED on for one second, then off for one second, repeatedly.

  This example code is in the public domain.
 */
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on (HIGH is the vo
  delay(1000);               // wait for a second
  digitalWrite(led, LOW);    // turn the LED off by making the
  delay(1000);               // wait for a second
}
```







Why do we need firmware?

Firmware

From Wikipedia, the free encyclopedia

In computing, **firmware** is a specific class of computer software that provides the low-level control for a device's specific hardware. Firmware, such as the BIOS of a personal computer, may contain basic functions of a device, and may provide hardware abstraction services to higher-level software such as operating systems. For less complex devices, firmware may act as the device's complete operating system, performing all control, monitoring and data manipulation functions. Typical examples of devices containing firmware are embedded systems (running embedded software), home and personal-use appliances, computers, and computer peripherals.

Firmware is held in non-volatile memory devices such as ROM, EPROM, EEPROM, and Flash memory. Updating firmware requires ROM integrated circuits to be physically replaced, or EPROM or flash memory to be reprogrammed through a special procedure.[1] Some firmware memory devices are permanently installed and cannot be changed after manufacture. Common reasons for updating firmware include fixing bugs or adding features to the device.

Example: RoboCup

High-level Decisions

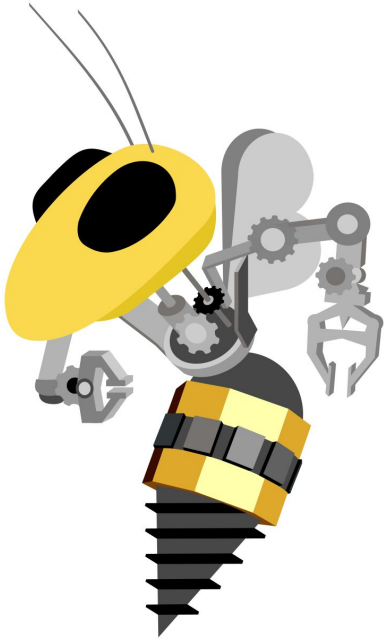
- Where am I in the world?
- Where are my teammates / opponents / goals?
- Where should I move?
- If I have the ball, when and where should I kick it and how hard?

Low-level Decisions

- How do I instruct the motors to spin at the desired speed?
- How do I instruct the kicker to kick at a certain time, in a certain direction, with the desired intensity?

Why aren't Low-level decisions made by a "software computer?"

- Speed
  - Counting encoder ticks <<< Computer vision algorithm
- Space
  - MCUs are small, PCs are not
- Overkill
  - Some robots don't need to make complicated decisions
  - PC would be $$$ to replace
- Convenience
  - Robotics hardware + software APIs cater to MCUs



What should I choose?
Electrical or Firmware?

Electrical

Circuit Design

- Competition requires X
- Solution: This motor / sensor / indicator / communication module solves X!
- What circuit is needed to support the solution?
- Circuit schematic!

Electrical

Circuit Design

PCB Design (EAGLE CAD)

- Circuit Schematic → PCB

Electrical

Circuit Design
PCB Design (EAGLE CAD)

Physical Electrical Work

- Crimping
- Soldering
- Cutting
- Heat Shrinking
- Making replacement parts

Firmware

(1) What are inputs / outputs to MCU?

(2) What peripherals does my MCU need to send / receive data?

(3) Do I need to transform the data?

(4) Circuit prototyping

(5) How do I program the MCU to handle inputs / outputs?

(6) How does the MCU interact with software?

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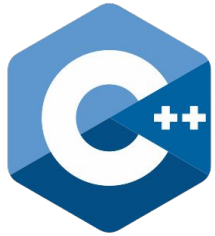
Intro to C++

A programming language



C is more readable assembly…
C++ is an object-oriented hack of C.

– imprecise quotation of Jim Rehg

https://github.com/RoboJackets/firmware-training

Go to Google Colab linkat bottom of page!

C++ Variables & Types

- int → integers (e.g. 12, -17)
- double → floating point or decimal numbers (e.g. 1.23)
- char → single characters (e.g. “s”, “D”)
- string → text (e.g. “Hello world”)
- bool → logical values (e.g. true/false)

```
//set up and
//assign a
//value like below
int i = 5;
//you can also set
//up a variable
//without initially
//assigning a value
bool rain;
rain = false;
```

C++ Arithmetic Operators

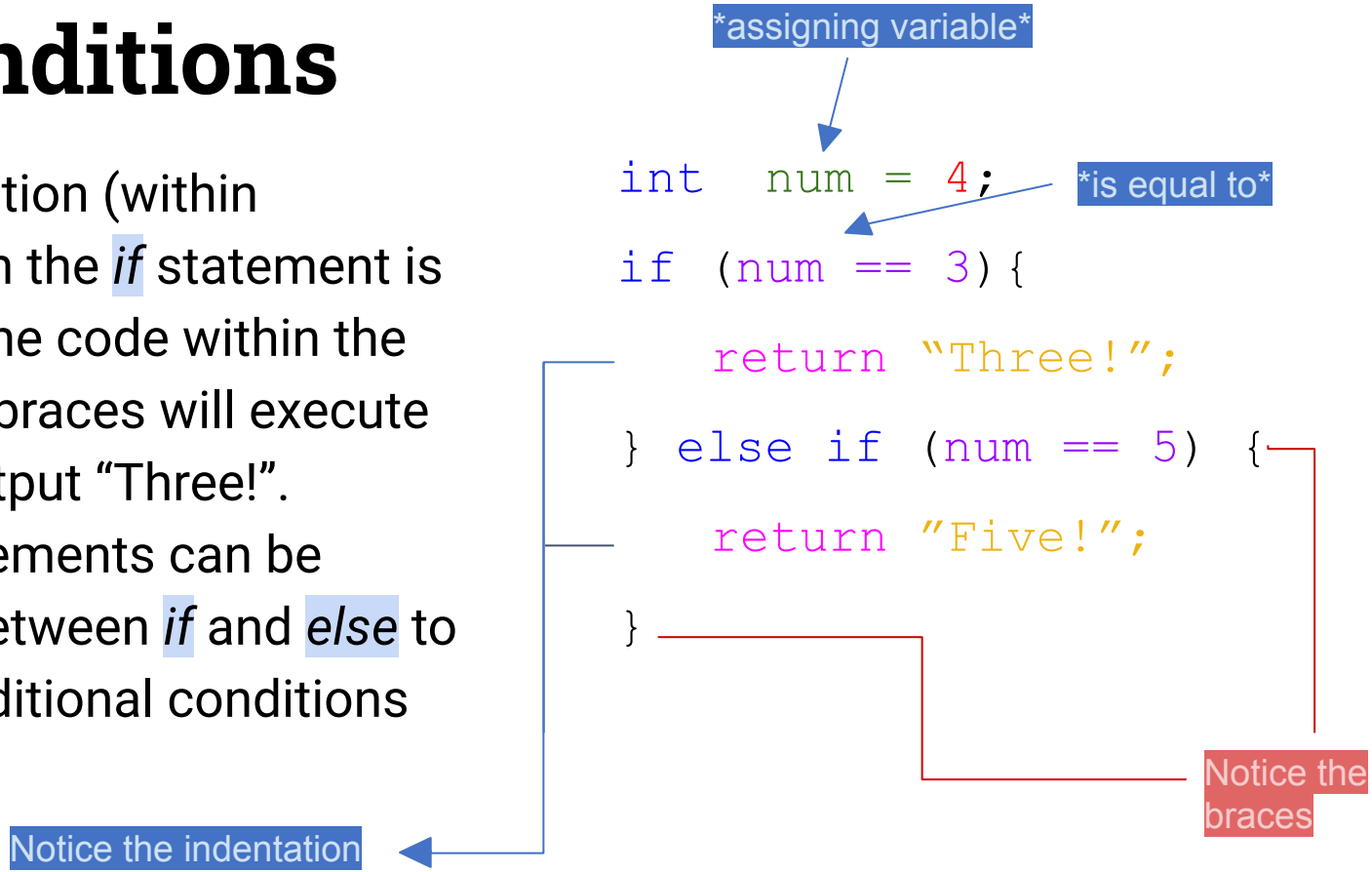
- + → Addition
- - → Subtraction
- * → Multiplication
- / → Division
- % → Modulo (produces the remainder e.g. 9 % 4 >> 1)

C++ Relational Operations

- == → Equal to
- != → Not equal to
- > → Greater than
- < → Less than
- >= → Greater than or equal to
- <= → Less than or equal to

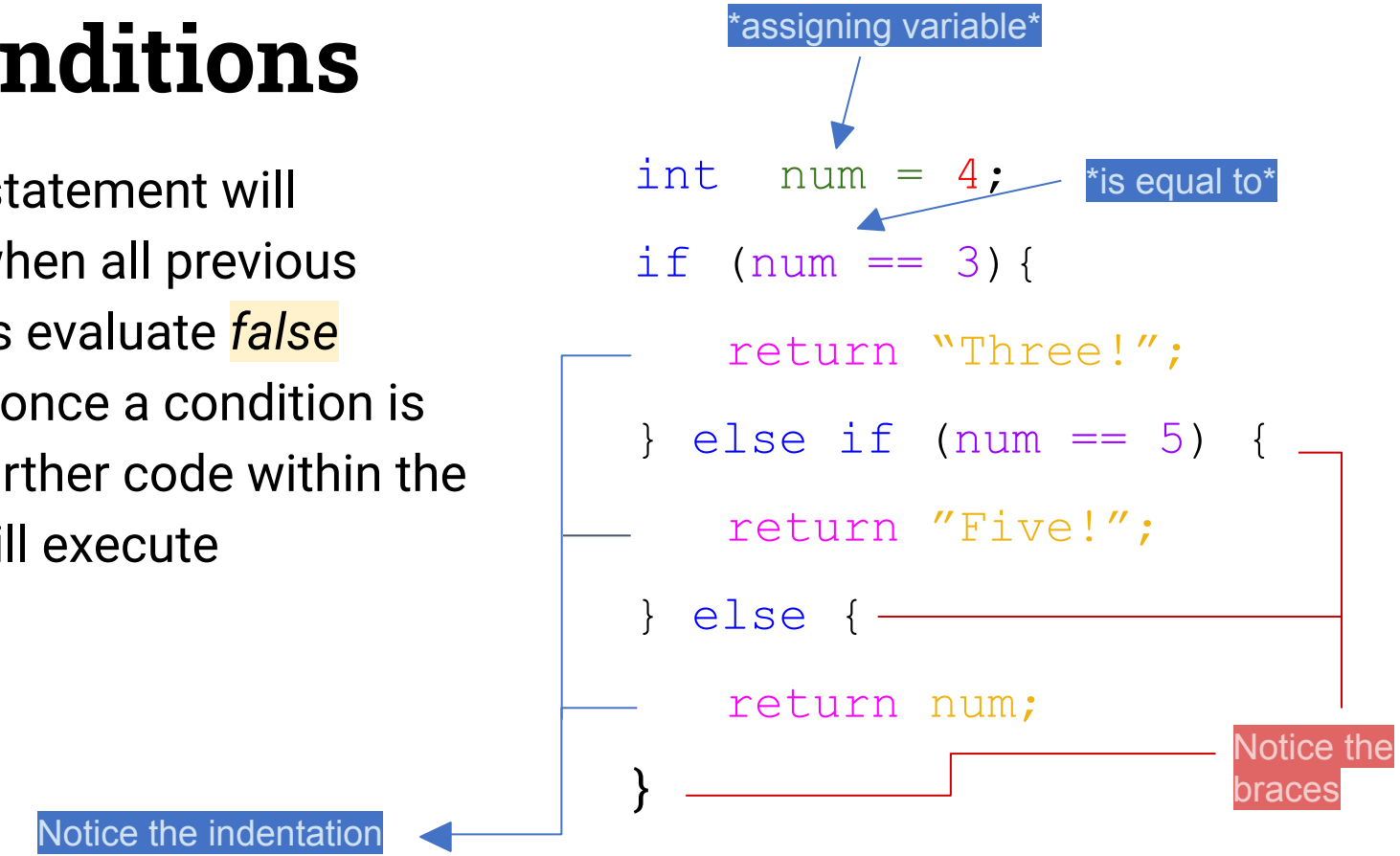
C++ Conditions

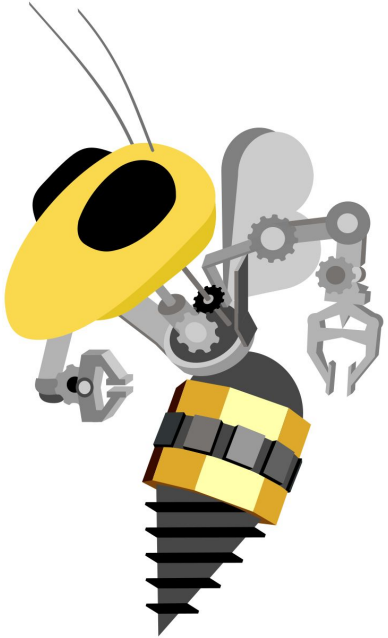
- If the condition (within brackets) in the *if* statement is *true*, then the code within the first set of braces will execute and will output “Three!”.
- *Else if* statements can be added in between *if* and *else* to provide additional conditions



C++ Conditions

- The *else* statement will execute when all previous conditions evaluate *false*
- Note that once a condition is met, no further code within the if block will execute





Prototyping

Breadboard and Arduino Uno

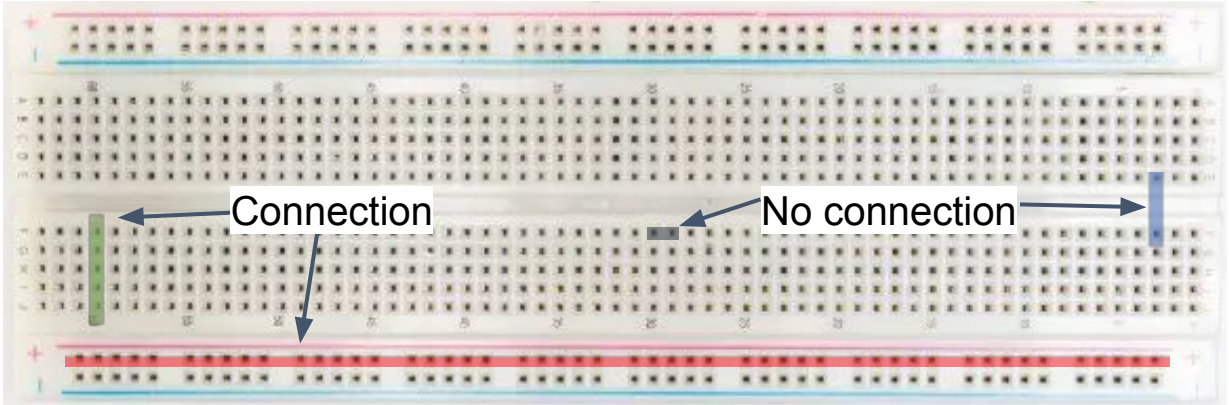
Prototype basic circuit designs with **Breadboards**

Breadboards help you connect electrical components to build basic circuits.

Terminals are the vertical columns. Each terminal is independent from the other

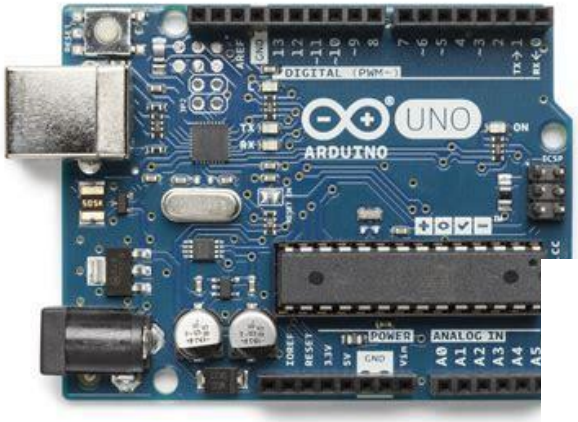
Power rails are use to connect the power supply to the breadboard. The horizontal pins on each power rail are connected.

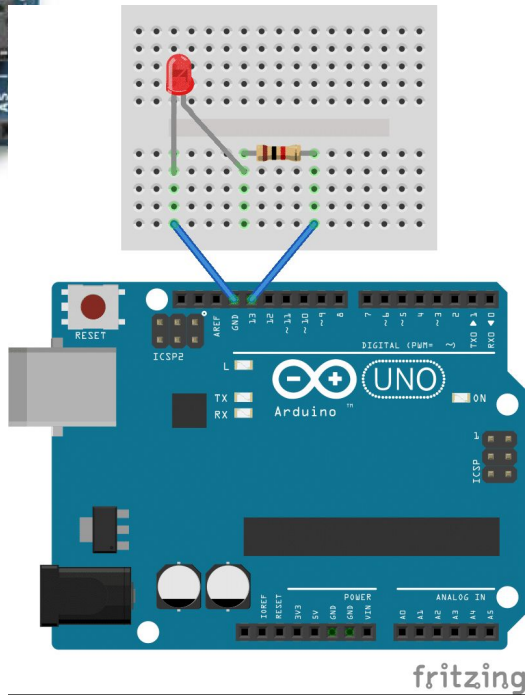
Top half and bottom half of the breadboard are independent from each other.



Arduino Uno

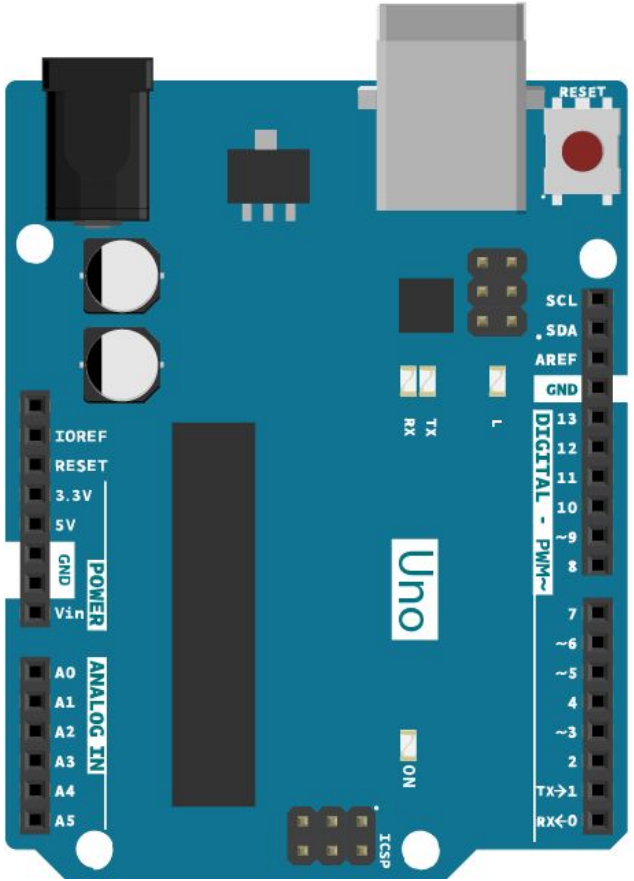
Microcontroller with I/O ports to control electronics





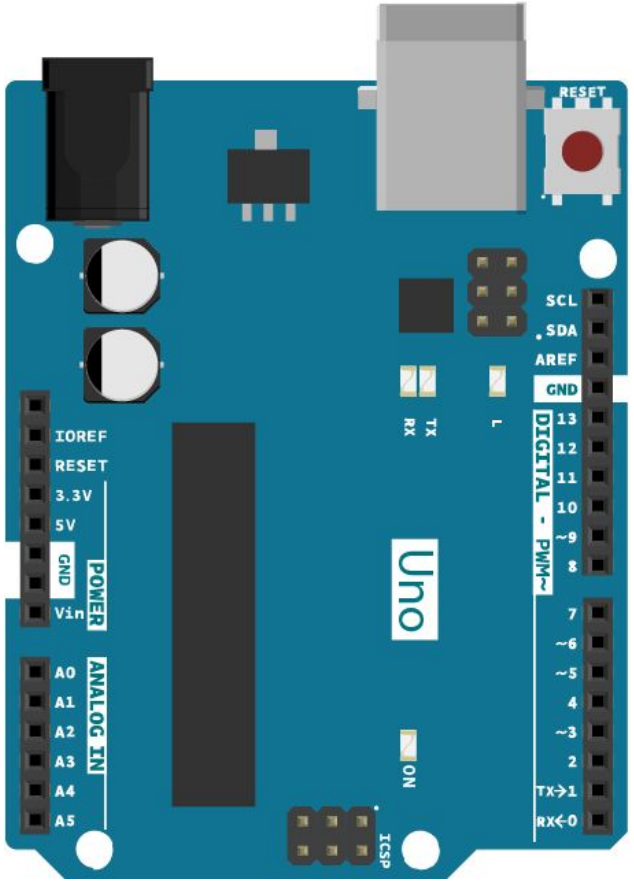
Arduino Board Explained

- **Power**: an Arduino can be powered using a USB cable or a Barrel Jack. Use between 6V and 12V
- **GND** can connect components to Ground
- **5V** & **3.3V**: supplies power to components
- **ANALOG IN**: A0 - A5 pins can read values from analog sensors
- **DIGITAL** pins cans be used as input from components (like switches) or output to components (like LEDs)
- **PWM**: some pins have a tilde (~) symbol next to it for Pulse Width Modulation (PWM) to simulate analog output.



Arduino Board Explained

- **AREF**: used to set external reference voltage between 0V and 5V for analog input. You would mostly ignore this.
- **RESET** (button): temporarily connects reset pin to ground to restart code. Useful when you cannot reset with a computer.
- **Built-in LED**: a mounted LED that can be programmed to blink.



Arduino IDE Explained

- IDE aka integrated development environment
- Programs written using Arduino Software (IDE) are called **sketches**.

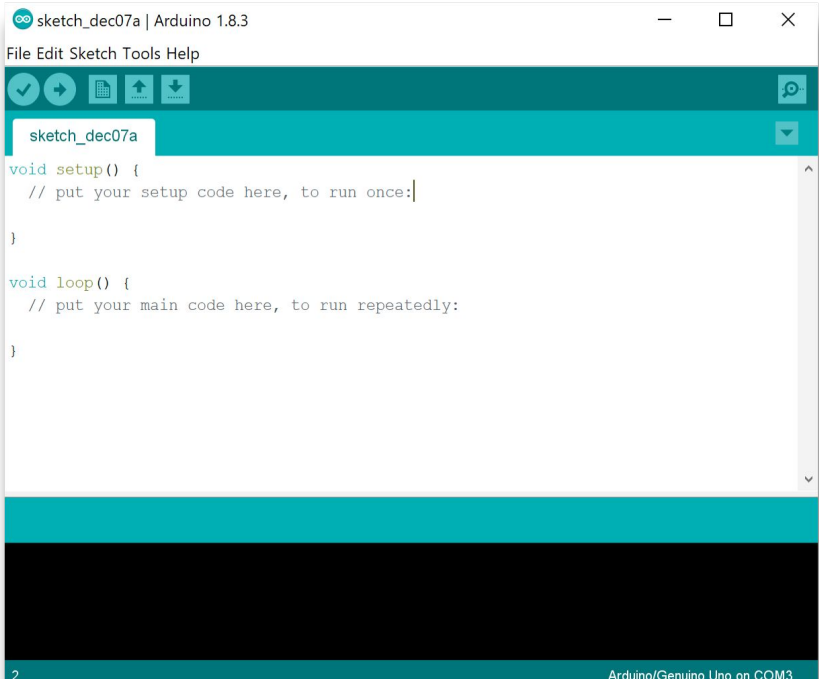
Verify checks for errors and *compiles* code

Upload *compiles* and *uploads* code

New creates new sketch

Save saves your sketch

Serial Monitor displays print outputs



Arduino IDE Explained

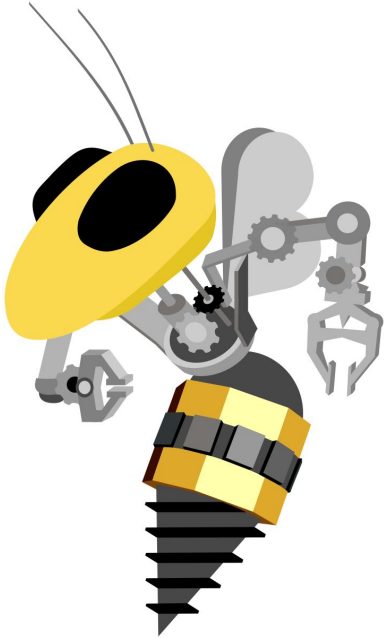
- void setup()
  - *initialize* variables and *define* pins
  - Runs once
- void loop()
  - write code to read from and write to pins
  - Runs multiple times
- The Arduino IDE has a lot of built-in *libraries* that boils down complex tasks into simple functions. You can add libraries to your sketch using #include
  - **Sketch > Import Library**
- The code used in Arduino IDE is very similar to C++

Common Arduino IDE Functions

- pinMode(pin, mode); //goes in void setup()
  - Configures the specified pin to act as an input or output
- digitalWrite(pin, value); //goes in void loop()
  - Write a high (5V) or low (0V) value to a specified pin
- digitalRead(pin); //goes in void loop()
  - Read a high or low value from a specified pin
  - Returns true if voltage is HIGH, or false if it is LOW
- delay(value); //goes in void loop()
  - Pauses code execution for a value—time in milliseconds

Common Arduino Functions

- analogRead(pin); //goes in void loop()
  - Returns an analog value from an analog pin
- Serial.print(); //goes in void loop()
  - Used to print values in serial monitor and to see if your code is being executed → Useful for debugging.
  - Requires Serial.begin(value); in void setup



Lab

LEDs and Buttons

Lab Setup

This week we will build a simple circuit to light up LEDs and we will use an Arduino Nano to control which LEDs light up.