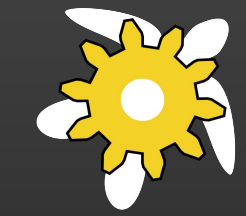

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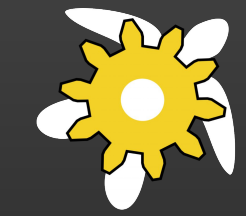
ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Electronics and Soldering

TURTLE Hatchling



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Electronics

American Wire Gauge

Logarithmic Scale ranging from 0000 to 40

We have AWG 12 (9.3 Amps), 18 (2.3 Amps), 22 (0.92 Amps)

Wire Traits -

- Max Current - Increases as gauge gets smaller
- Conductive Diameter - Increases as gauge gets smaller
- Cross-sectional Area - Increases as gauge gets smaller
- Resistance - Decreases as gauge gets smaller
- Max Frequency - Decreases as gauge gets smaller

Wire Core

Solid Core

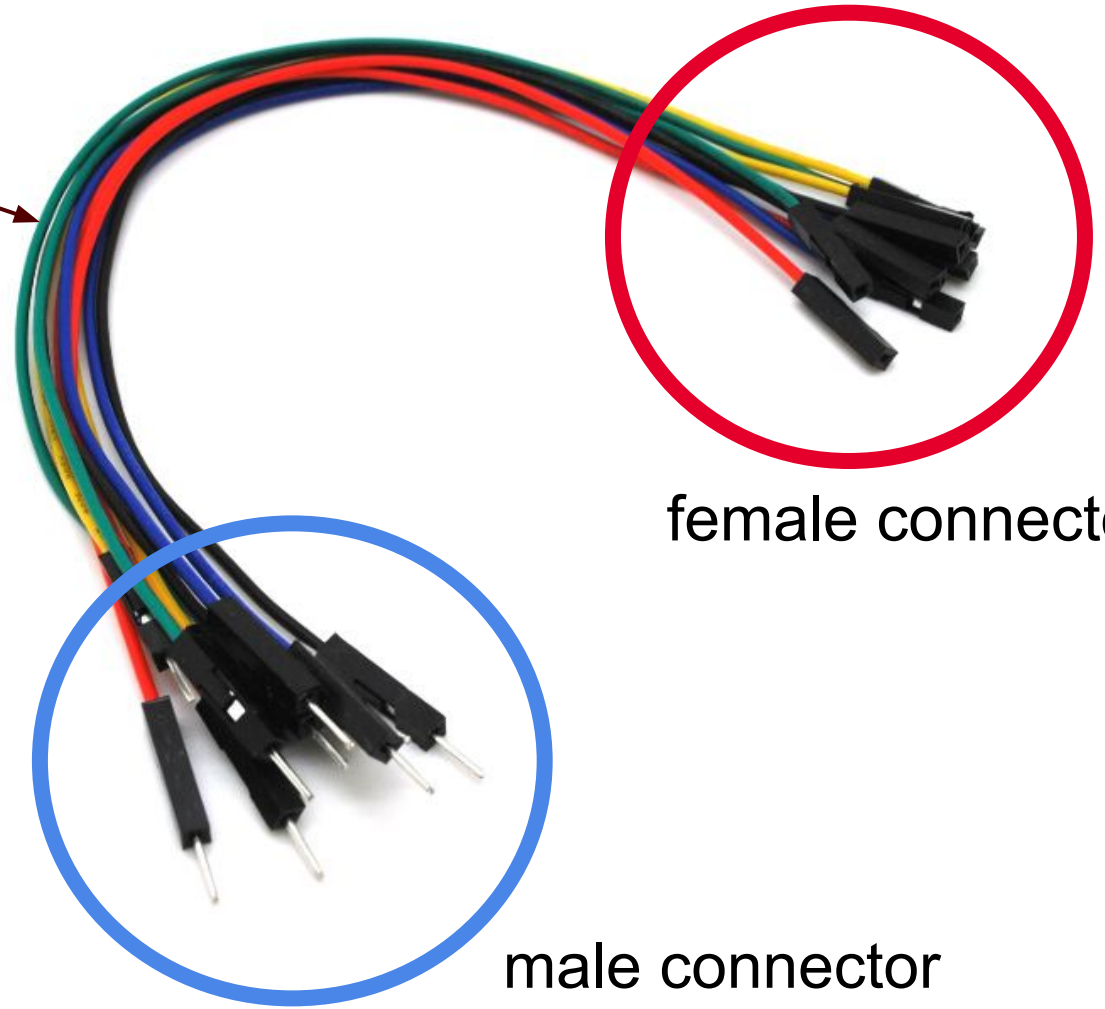
- Cheaper
- Higher Current Capacity
- Effectively male pins

Stranded Core

- More resistant to vibrations
- More flexible

Other Notes

- Jumper Wires
  - Male = protruding pin
  - Female = hole for pin



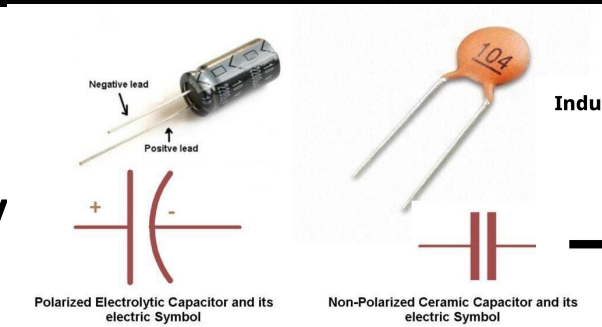
Typical Wire Color Coding

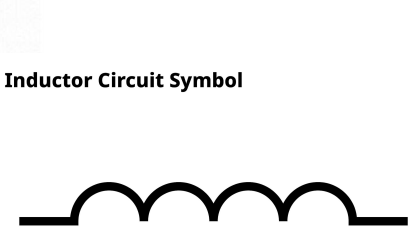
- Black/Brown is GND
- Red is PWR

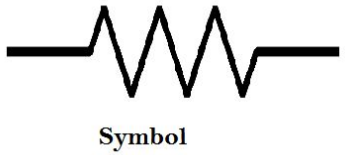
Always check the items documentation about color coding

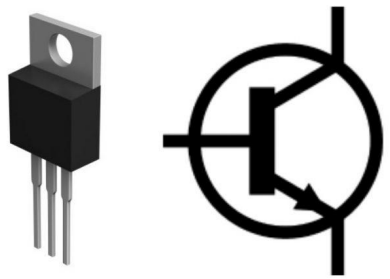
Common Electronic Components

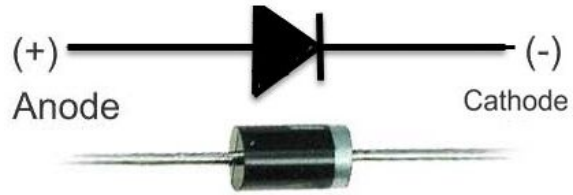
- Capacitors
  - Stores and discharges charge quickly
    - Can be extremely dangerous
- Resistors
  - Impedes the flow of current
- Transistors and MOSFET
  - Amplify signals/digital switch
- Inductor
  - Stores energy in a magnetic field, opposes rapid changes in current.
- Diode
  - Allows current in only one direction







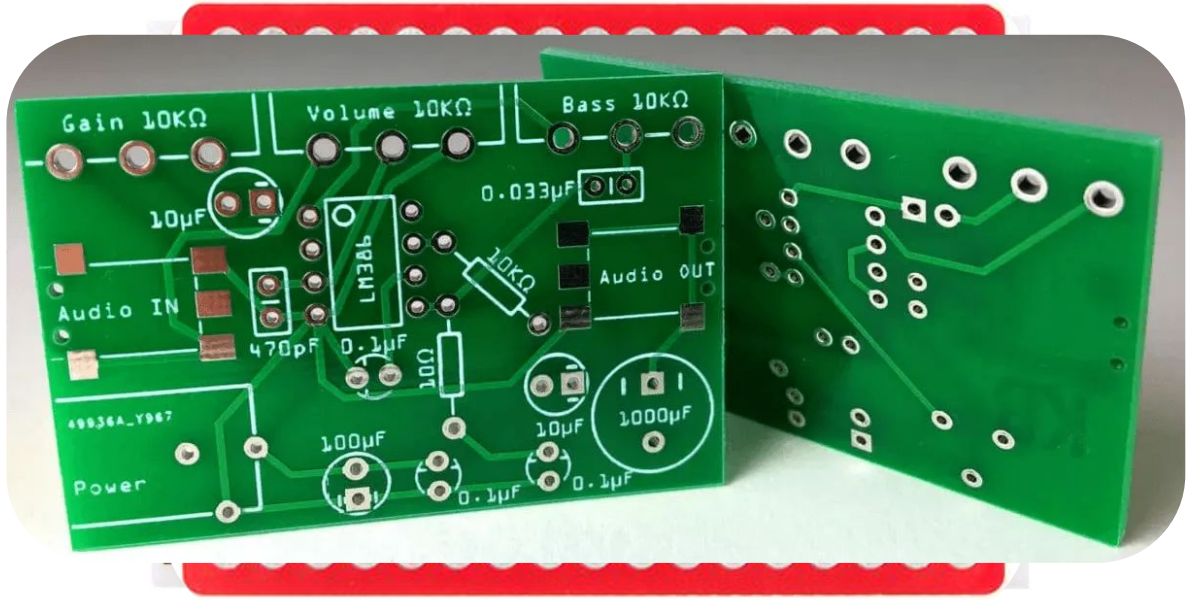




Ways to build circuits

- Solderless breadboard
  - Commonly used for prototyping
  - Inexpensive and easy to change
- Solderable breadboard
  - More permanent than a solderless breadboard
  - Easy to transfer components from a solderless breadboard
- PCBs (printed circuit boards)
  - Permanent connections that are more reliable
  - Expensive

Note: When creating a PCB, it is advisable to test the circuit on both solderless and sordered breadboards before investing in the final PCB.



Made of plastic with metal strips or spring terminals

Made of fiberglass with plated through holes

Two main types:
Surface mount PCB (SMT) - components soldered directly onto the board
Through hole PCB (THT) - components inserted into holes and then soldered

Battery Cells

Stores and generates DC current through a chemical reaction

Many types, but most common are:

- Lead-Acid
  - Cheap, High peak current, Heavy, Large form factor
- Lithium Polymer (LiPo) Note: Only use dedicated LiPo chargers and do NOT use if damaged
  - Highest discharge rate, High care requirements
- Lithium Ion (Li-ion) Note: Typically 18650 or 21700 cells
  - Highest energy density, Long cycle life
- Nickel Metal Hydride (NiMH)
  - Robust, Compared to lithium: Cheaper, lower energy density

Battery Pack Notes

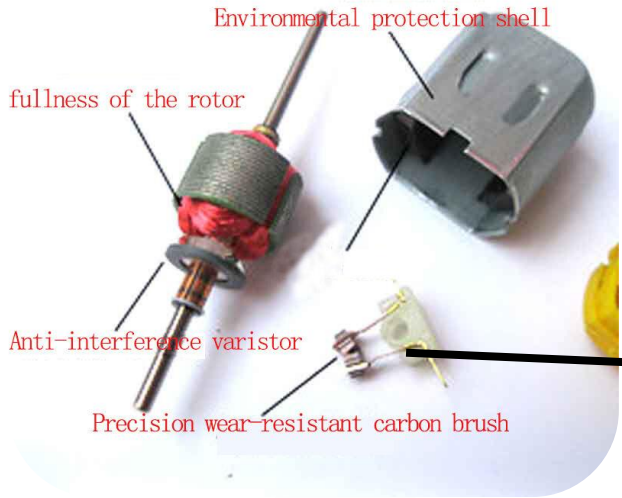
- Convention is #S#P -> Cell count = #S(eries) * #P(arallel)
- Cells in series add voltage, parallel adds capacity
- #C * capacity is the maximum continuous current draw
- Capacity is sustained current for one hour of charge
- To determine the required capacity, add power not current

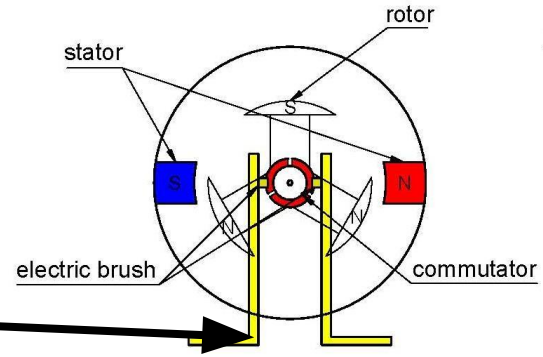
Parallel

Series

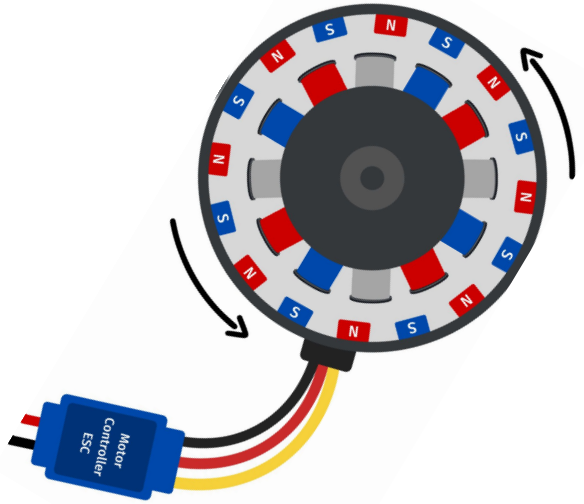
DC Motors- Brushed vs Brushless

- Brushed
  - Spins when power is supplied
  - High starting torque
  - Cheaper



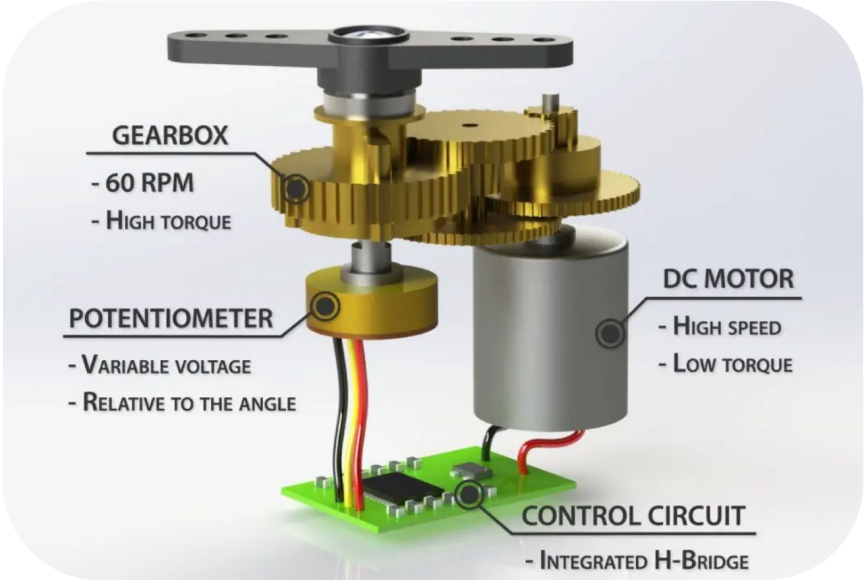


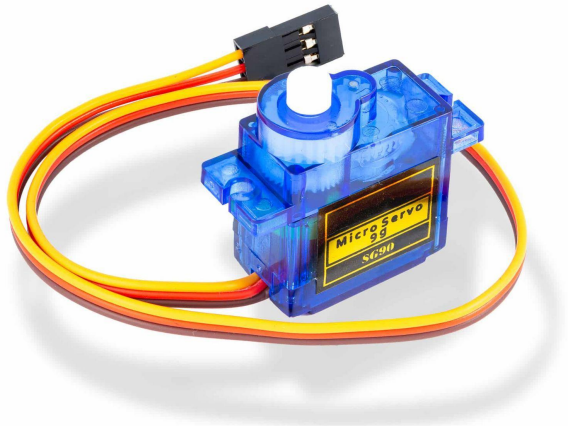
- Brushless
  - Requires specific timing of stator coils to spin
    - Continuously changes the internal magnetic field
  - Consistent torque
  - Higher efficiency %
  - Longer life cycle



DC Motors - Servos

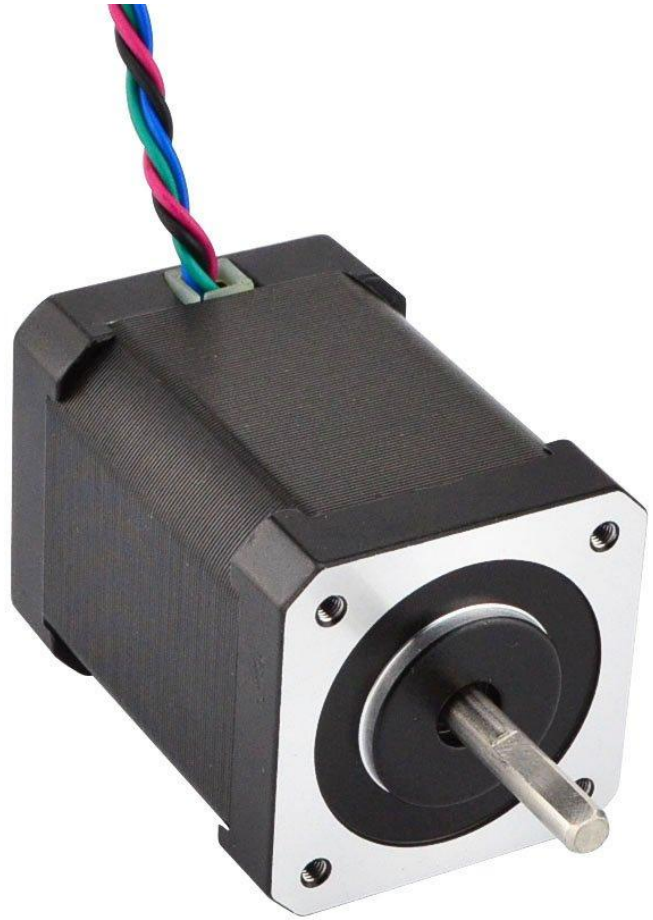
- Servos are DC motors with a gearbox meant for torque.
- Servos typically have limited motion (0 to 180 degrees), this is due to their built in potentiometer.
- Servos have a brushed DC motor and integrated H-bridge. H-bridge controlled by signal wire.
- {Signal,PWR,GND} Wiring
  - The order prevents bad things if a TJC8 connector is plugged in backwards.





DC Motor - Stepper Motors

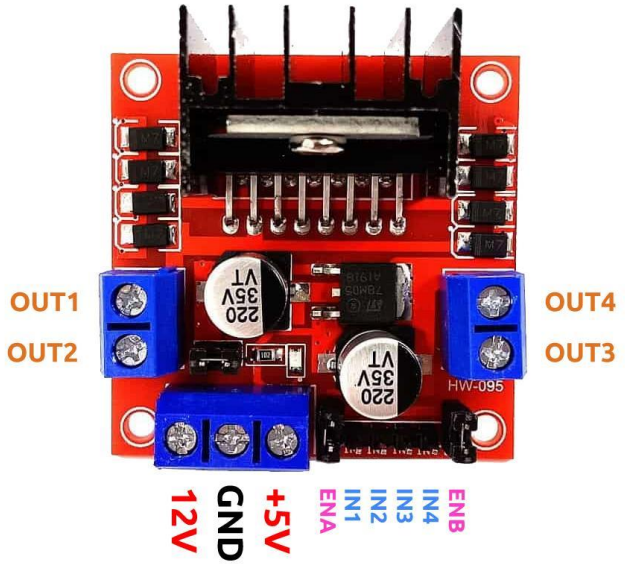
- A type of motor that rotates in a series of precise steps via changing the internal magnetic field sequentially
  - A step is typically 1.8 degrees
- High precision and repeatability
  - Lower speed
- Higher low speed torque
  - Draws full current at all times (Even at rest)

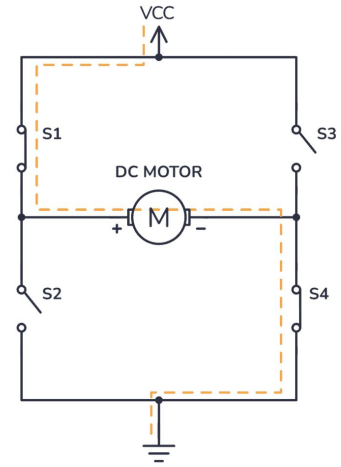


Motor drivers

Brushed Motor Driver

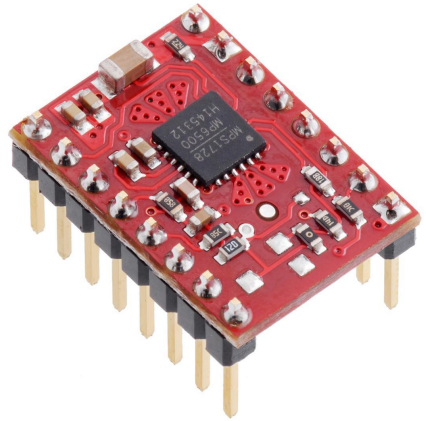
- Controls via an H-Bridge
  - Four switches that control current direction
- Requires external power supply
  - Large heatsink due to inefficiency





Electronic Speed Controllers (ESCs)

- Regulates the timing of stator coils in Brushless DC motors

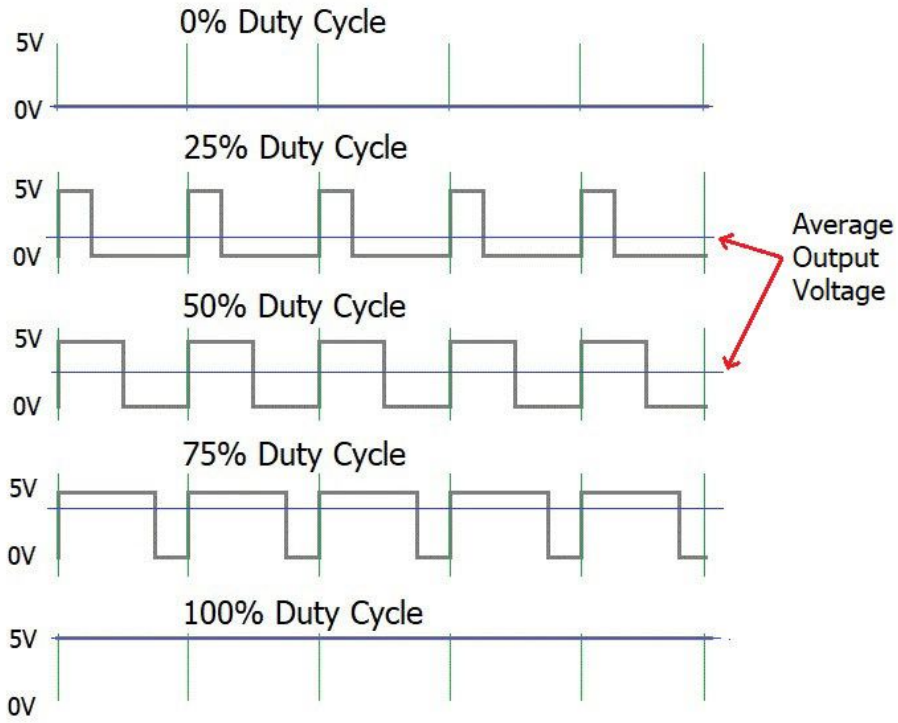


Stepper Motor Driver

- Regulates the timing of stator coils in stepper motors
  - Most capable of microstepping

PWM (Pulse Width Modulation)

- The default way of controlling signals
  - Includes motors, servos, LEDs
- Tri-state Logic [H(igh)-L(ow)-Z(ero)] changing the duty cycle to regulate average voltage
  - Duty Cycle is typically 1 to 2 ms
- Exploits the ability of transistors to operate as fast switches



Common Sensors (Not all)

- Accelerometer
  - measures acceleration

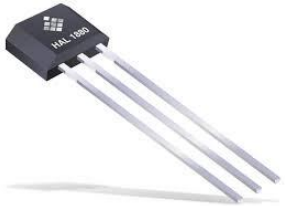
- Gyroscope
  - Measures the change in rotation angle per unit of time

- IMU - Inertial Measurement Units
  - Combines various sensors into one unit

- Ultrasonic Distance
  - Measures distance through ultrasonic waves

- Rotary Encoders
  - Digital device used to measure the rotation of a shaft

- Hall Effect
  - transduce magnetic fields to electrical signals

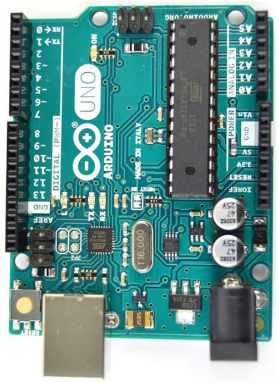


- Torque Sensor
  - Measures torque on a rotating system

Microcontroller (MCU) vs Single-Board Controller (SBC)

Micro Controller

- None or Real Time OS
- Lower power consumption
  - Limited processing
  - Limited memory
- GPIO Peripheral
- Low level languages
  - Single program always running
- Examples:
  - Arduino
  - ESP32/ESP8266
  - STM32



Single-Board Controller

- Full OS (Typically Linux)
- Higher computation ability
- Peripherals
  - GPIO, USB, HDMI, etc
- Higher-level languages
  - Can run multiple programs
- Examples:
  - Raspberry Pi
  - BeagleBoard
  - NVIDIA Jetson Nano

Common Board Pins

#V# - Power output of #.# Volts

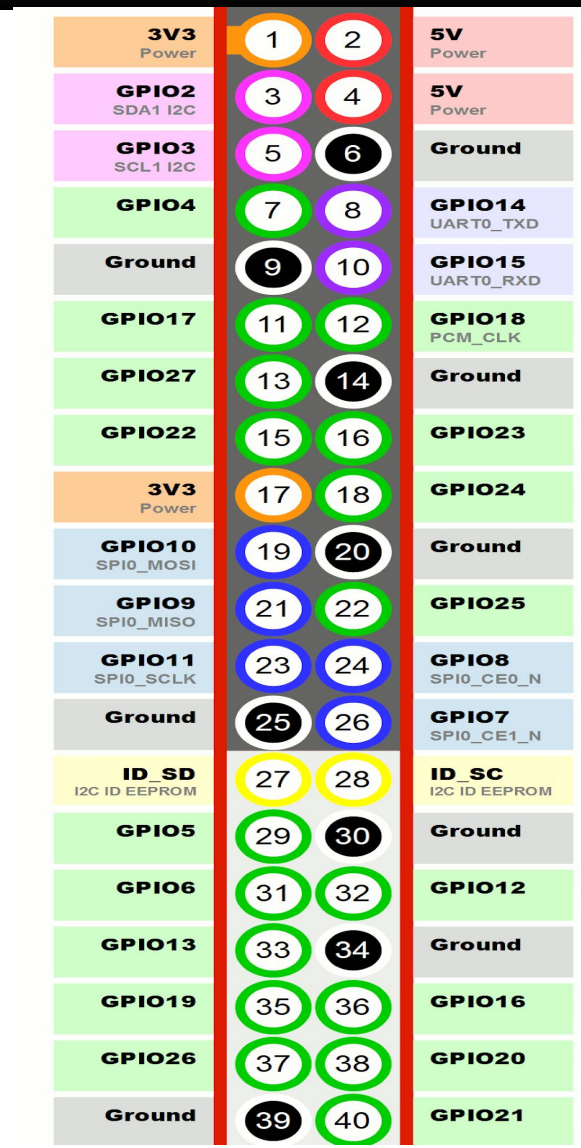
GND- Ground

GPIO# - General Purpose Input/Output

I2C/UART/SPI - Communication Protocols

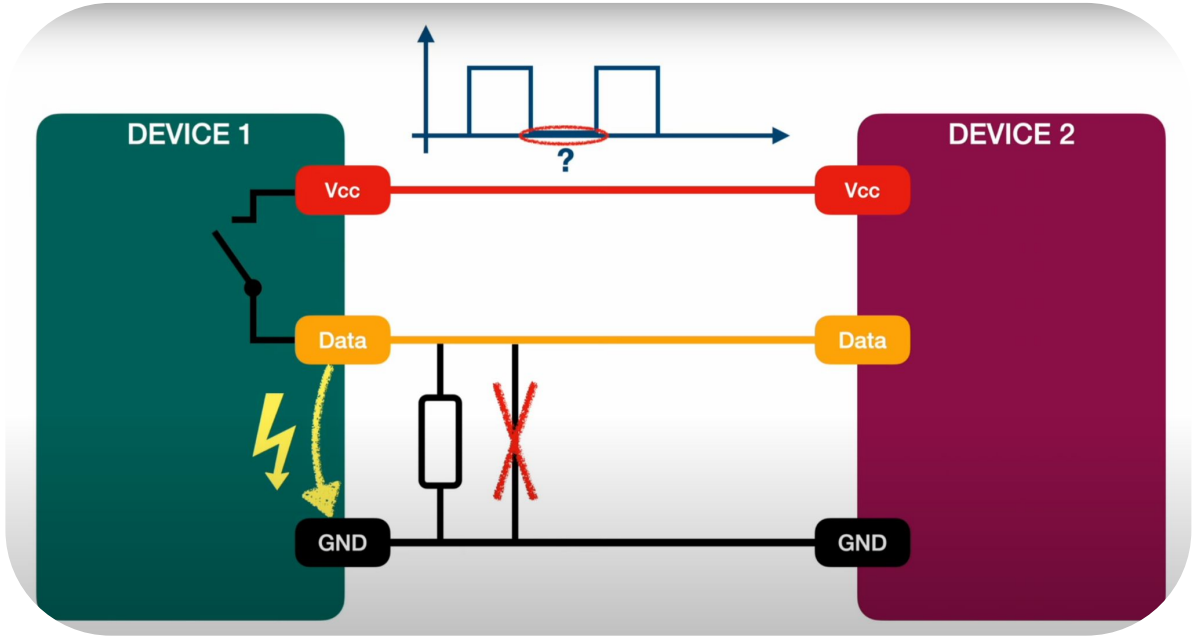
PWM/PCM - Pulse Width/Code Modulation

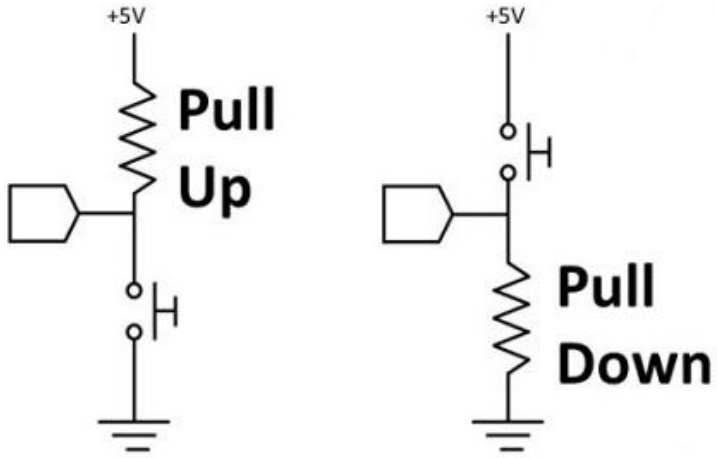
PCM is an audio transmission protocol



*RPi Zero

Pull up / Pull Down Resistors



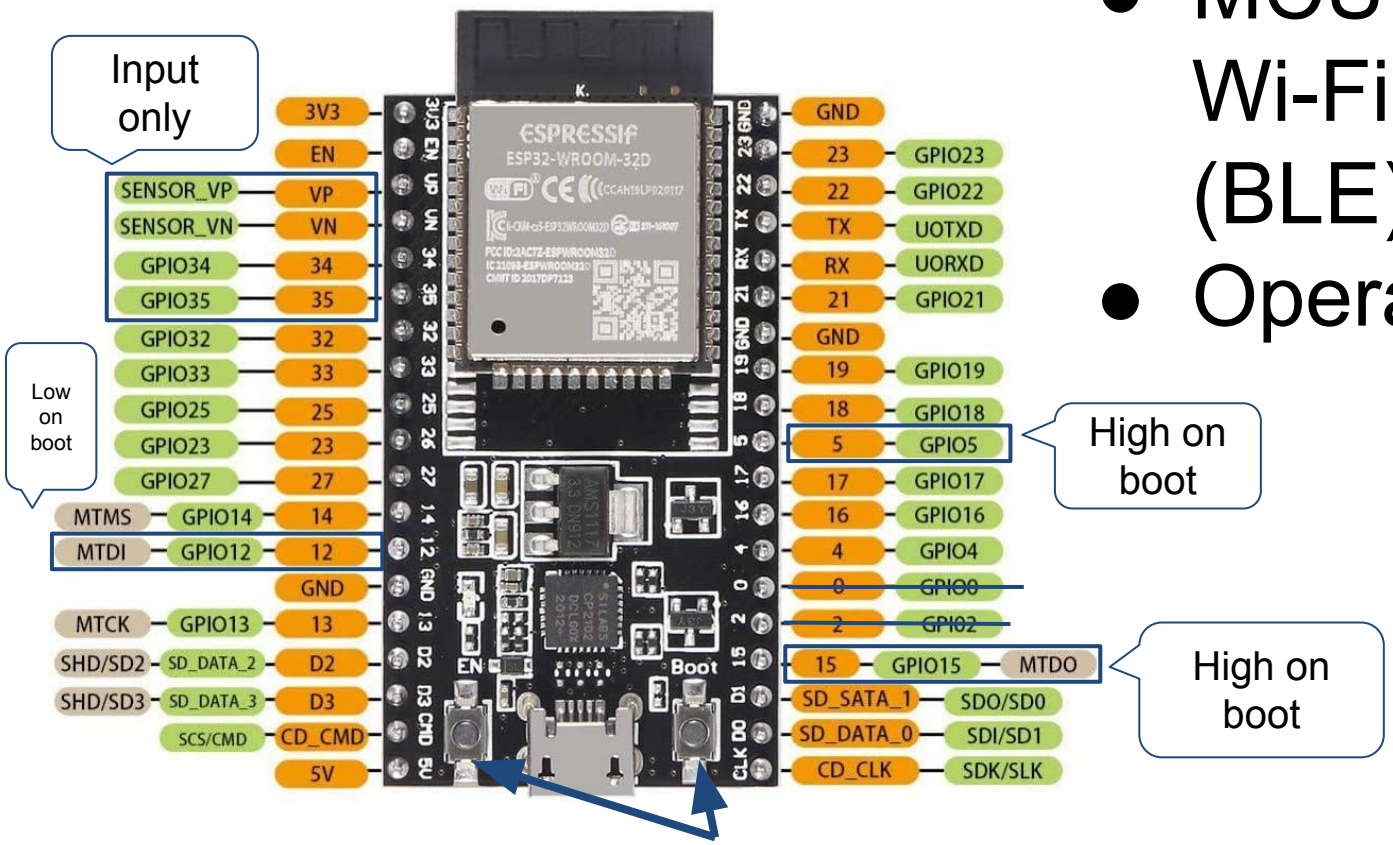


Use:

- Device 1 will change the switch depending on the bit it wants to send
- Without resistor
  - Short
  - Pin would float
    - When it does not ground properly giving the pin unreliable readings

Note: Most chips have embedded pull up and down resistors

ESP32-DevkitC Development Board



- MCU ESP32 Chips have built in Wi-Fi and Bluetooth low energy (BLE) ment for IOT
- Operates on 3.3V logic

Note: Do NOT power ANY board by the GPIO and USB Port at the same time

"EN" Button: Press to soft reset

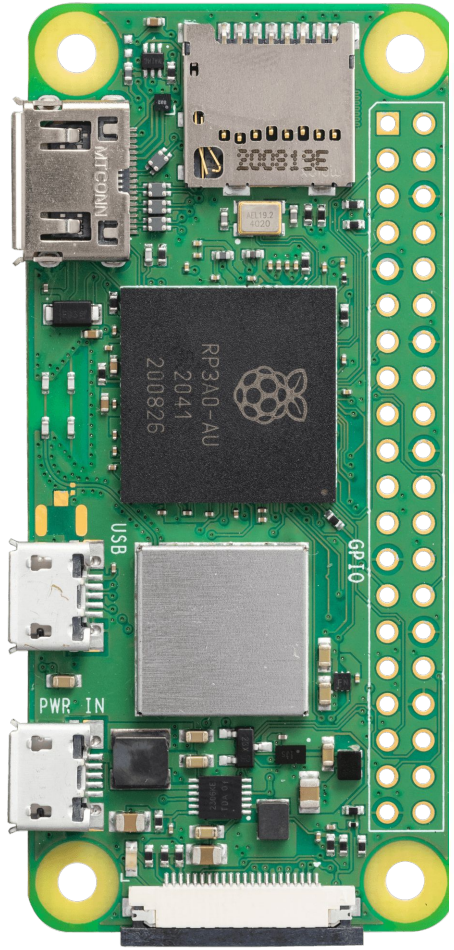
"Boot" Button: Hold on code upload if failing

Raspberry Pi

Small form factor, low cost computer (SBC) used for digital/hardware projects

Features:

- Operates on 3.3V logic
- Bluetooth, WIFI, and *Ethernet
- HDMI, GPIO, and USB
- Can run High-level languages like Python
- Requires micro-SD card to boot OS



RPi Zero

RPi 4b

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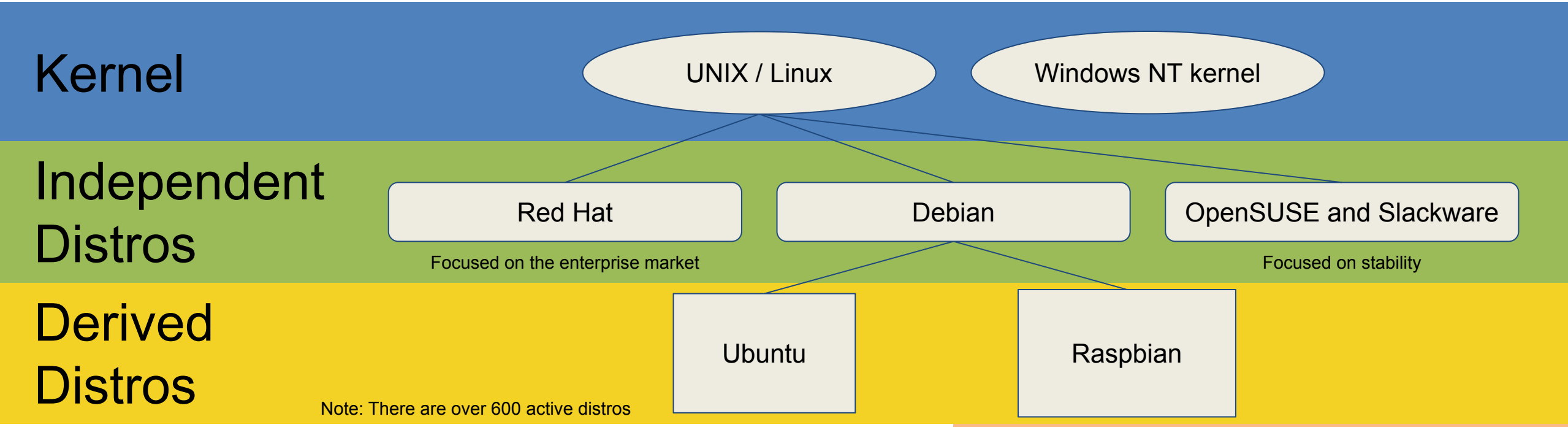
Very Brief Linux

Simplified OS Tree



Kernel - Program bridging the hardware and software
Distros - Full OS, short for distribution
Shells - Command Line Interpreter

Common Shells

- Bash (Bourne Again Shell) - Default for Linux
- Zsh (Z-Shell) - Default for Mac
- Fish (Friendly interactive shell) - Uses different syntax

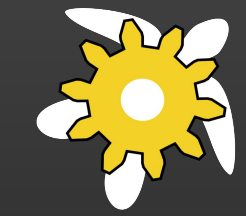
Common Bash and Zsh Commands

`ping 192.168.8.1`	measure speed of connection to machine with IP number `192.168.8.1`
`ssh 192.168.8.1`	securely open a shell on `192.168.8.1`
`echo $0`	show what kind of shell you are currently in
`uname -a`	show info about processor architecture, system hostname, and kernel version
`zsh` or `bash` ; `exit`	spawn & enter a new `zsh` or `bash` shell (inside current shell); exit this shell
`chsh -s /bin/zsh`	change your default shell to `zsh` (recommended, if it isn't already)
`pwd`	print the name of the current working directory
`ls -lah`	list all files in current directory, including ownership, privileges, and size
`mkdir foo`	make a new directory named `foo`
`cd foo` ; `cd ..`	change directory to `foo`; change back to parent directory
`touch bar`	create a new file named `bar` (or, just update its timestamp)
`echo 'hello' > bar`	create (or, erase and create) the file `bar`, and write "`hello`" to this file
`echo 'world' >> bar`	append "`world`" to the file `bar` (or, create and write to this file)
`man echo` ; (space) ; `q`	display detailed manual page (alternative to Google) for the command `echo`
`cat bar`	show contents of the file `bar` (all at once)
`less bar` ; (space) ; `q`	show contents of the file `bar` (pausing after each screenfull)
`head bar` ; `tail bar`	show the 10 lines at the head (or, the tail) of the file `bar`
(up arrow) ; (down arrow)	scroll up to recently executed commands; scroll down
`history`	show a list of recently executed commands
`hist` (tab)	complete (as far as possible) name of command(s) starting with "`hist`"
`rm bar`	remove (warning: permanently!) the file named `bar`
`rmdir foo`	remove directory `foo`, but only if it is empty
`rm -rf foo`	remove recursively the directory `foo` and all files contained in it (danger!!!)
`cp foo/bar* foo1/.`	copy all files starting with the letters `bar` in `foo` into the directory `foo1`
`cp -r foo foo1`	copy recursively everything in `foo` to the directory `foo1`
`mv bar foo/bar1`	move and rename the file `bar` as `bar1` inside the directory `foo`
`chmod 644 bar`	change mode (§2.2.3.2) of `bar` to read/write for owner, read for group & world
`chown foo1:foo bar`	change ownership of file `bar` to user `foo1` and group `foo`
`sudo rm bar`	do the command `rm bar` as superuser (danger!)
`su` ; `exit`	enter superuser mode for subsequent commands (danger!!!); exit su mode
`df -h`	report disk free space on the available filesystems
`du -sh foo`	report significant disk use within directory `foo`
`grep psfrag *.tex`	search files ending in `.tex` (in current directory) for the string "`psfrag`"
`top`	periodically report a list of all running threads, sorted by top CPU usage
`ps -ef`	report all running processes (once)
`ps -ef |grep kernel`	pipe output of `ps` to `grep`, to extract the lines with "`kernel`" in them
`file bar`	test `bar` to determine what type of file it is
`find bar`	scan current directory and all its children for filenames containing `bar`
`tar cvfz fb.tgz fb`	compress all contents of `fb` into a (compact) gzipped tarball `fb.tgz`
`scp fb.tgz bar:.`	securely copy `fb.tgz` to machine with name `bar` on local network
`tar xvf fb.tgz`	extract contents of `fb.tgz`, retaining its original directory structure
`alias l='ls -lah'`	use "`l`" as a shorthand alias for the command "`ls -lah`" in this shell
`env`	list all aliases and other environmental variables defined in this shell
`vim` ; `nano`	command-line text editors (see §2.4.1.2) available in all linux distros
`~/.bashrc`	initial run commands executed when a `bash` or `zsh` shell is spawned
`make foo`	run commands in Makefile (see §2.2.3.3) to make an executable `boo`

Commands follow:
<command> -<options> <arguments>

Note: Commands are often shortened versions of words/phrases

Taken directly from Renaissance Robotics



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Communication Protocols

SSH - Secure Shell

Secure remote access and communication protocol. Allows you to work on the RPi from your laptop.

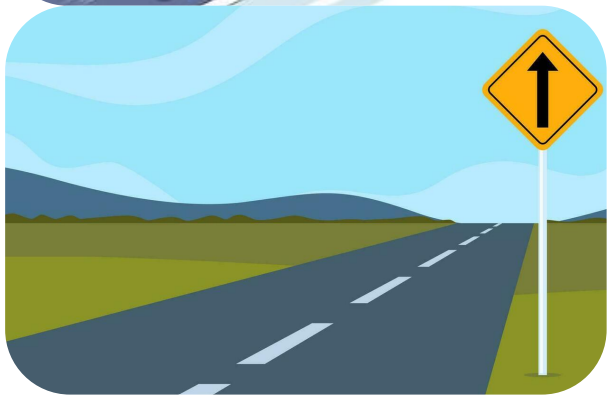
How to do it via command line:

1. Connect RPi and computer to same network
   a. Make sure RPi has SSH enabled in settings or `sudo raspi-config`
2. Find RPi IP address with `hostname -I`
3. On computer, type `ssh <RPi username>@<ip address>`
   a. Type your RPi password when prompted

Duplex

Think of it like roads

- Full (Two way road)
  - Data can be sent and received at the same time
- Half (Single wide road)
  - Data can be sent and received but **NOT** at the same time
- Simplex (One way road)
  - Data can be sent or received but **NOT** both



Short-Range Wired Communication Protocols

SPI - Serial Peripheral Interface (~Max of 10 meters)

- A Master-Slave architecture using wires to identify between slaves
- Full-duplex

I2C/I3C - Integrated Circuit (~Max of 5 meters)

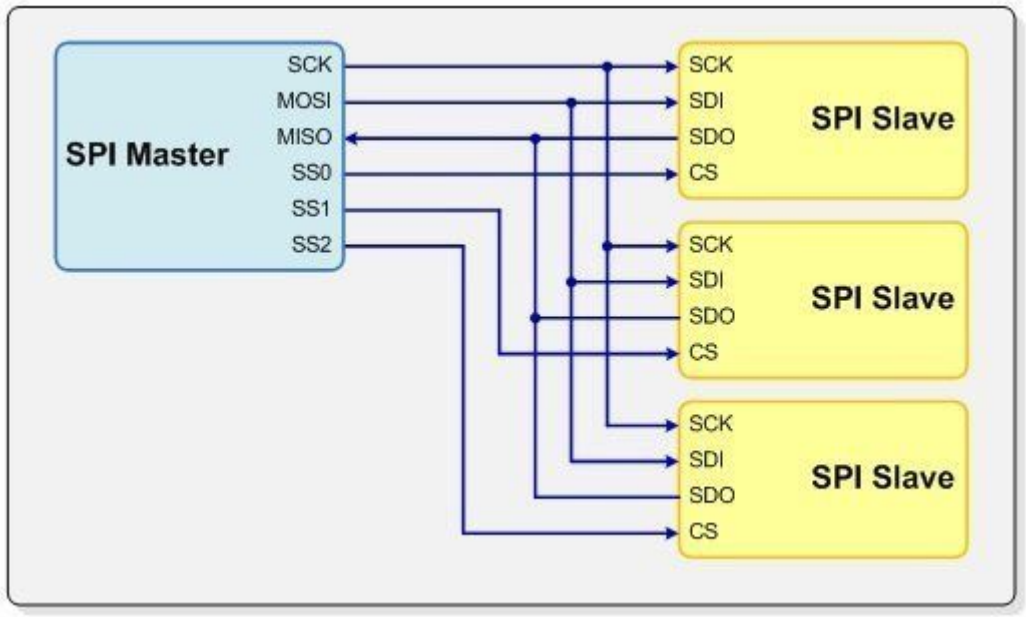
- A Master-Slave architecture using a unique addresses on a shared-bus
- Half-duplex

UART - Universal Asynchronous Receiver Transmitter (~Max of 15 meters)

- A point-to-point architecture where both devices can initiate transmissions
- Simplex/Half/Full-duplex

Note: Master-Slave convention is becoming outdated.
Typically renamed Master-<Peripheral>

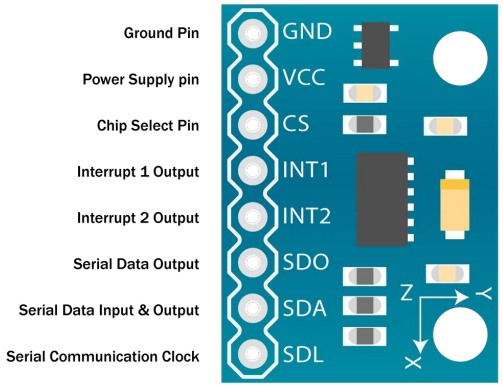
SPI



Four Wires Full Duplex:

- SCLK: Clock that controls bit upload speed
- MOSI: Data from Master to Slave
- MISO: Data from Slave to Master
- CS: Selects which Slave it is communicating to

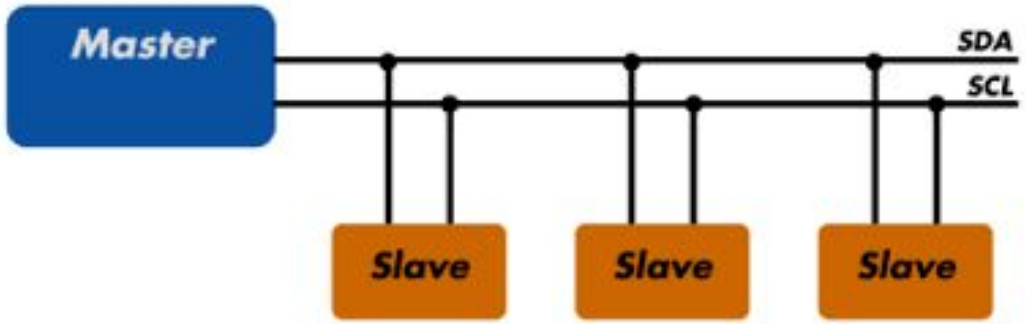
ADIY ADXL345 Triple Axis Accelerometer Module



Connecting Using SPI Accelerometer:

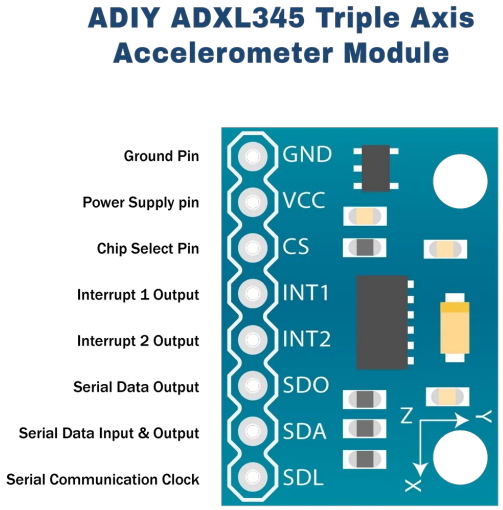
- Find GPIO compatible with SPI (able to do I/O and Clk)
- MISO(SDA) & MOSI(SDO): Most GPIO Pins will do as long as it isn't reserved for other comm. protocols.
- SCLK(SDL): Look for SCLK compatibility
- SS(CS): Most GPIO will work

I2C



Two Wires Half Duplex:

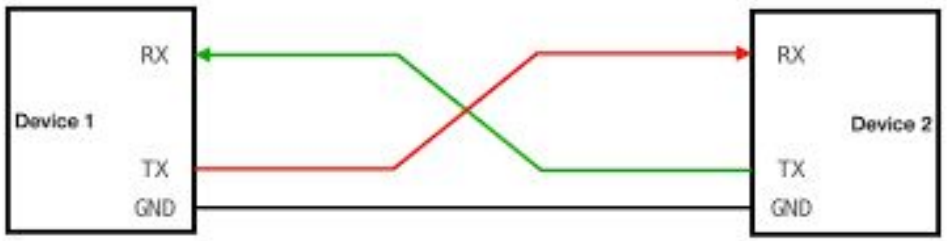
- SCL: Clock that controls bit upload speed
- SDA: Line for data
- Note: No need for chip select b/c address is sent to active Slave before data transmission



Connecting Using I2C Accelerometer:

- Find GPIO compatible with I2C (able to do I/O and Clk)
- SDA (SDA): Most GPIO Pins will do as long as it isn't reserved for other comm. protocols.
- SCL(SDL): Look for SCL compatibility
- Note: Some parts are compatible with multiple protocols

UART



Two Wires Full Duplex:

- Tx: Transmits data
- Rx: Receives data
- Note: No need for Clk b/c it has a set baud rate which is the speed it will transfer data

Connecting Using UART IMU (NOT COMMON WITH IMU):

- Find GPIO compatible with UART (UART has dedicated Tx and Rx pins most of the time)
- Note: This the protocol used for uploading code into arduino boards

Long-Range Wired Communication Protocols

RS485/Modbus RTU (~Max of 1200 meters)

- A Master-Slave architecture using hardware addresses
- Half-duplex

CAN - Controller Area Network (~Max of 40 meters)

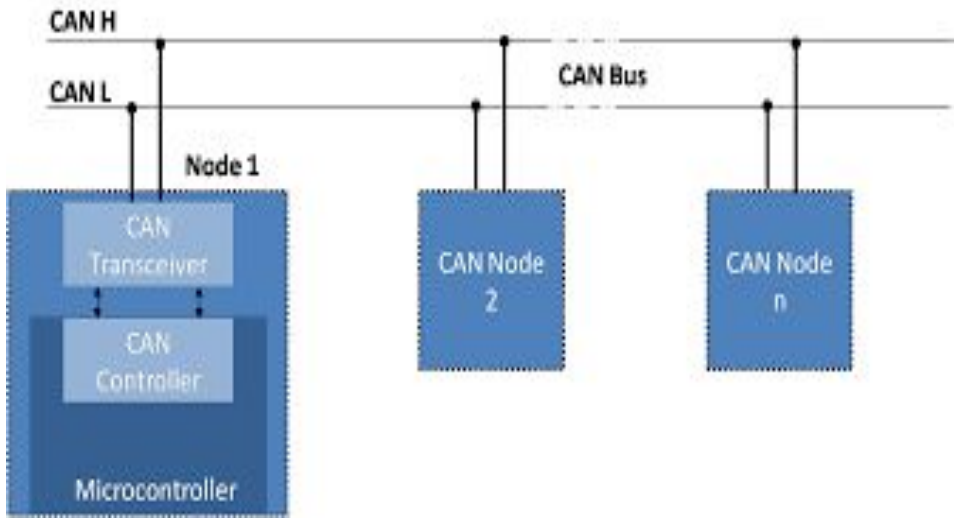
- A real-time multimaster architecture using message frames
- Half-duplex

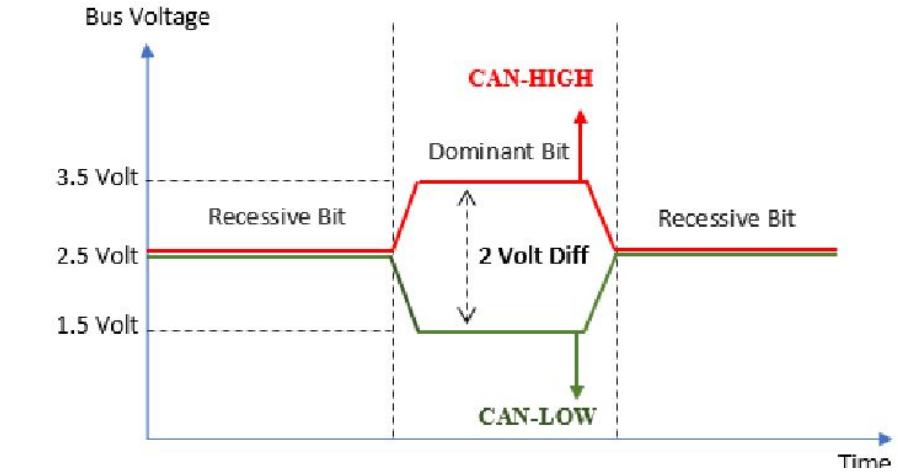
Ethernet/EtherCAT (~Max of 100 meters)

- A real time Master-Slave architecture using message frames
- Full-duplex

Note: Ethernet is peer-to-peer and not real time

CAN





(DIFFERENTIAL VOLTAGE)

Reliant and fault tolerant:

- CAN_H & CAN_L: Data transmission
- Bits are transmitted using differential voltage
- Uses IDs (11bit) for each node which also denotes the nodes “importance” in the network
  - If node 1&100 wants to signal node 1 takes priority (non-destructive arbitration)
- Uses baud rate like UART

- Shared bus should terminate with a 120 Ω resistor and use twisted pair cables for maximum signal integrity
  - Resistor blocks the signal from being reflected (cable impedance matching)
  - Twisted pair cables minimize electromagnetic interference

Wireless Communication Protocols

RFID - Radio-Frequency IDentification (Distance Varies)

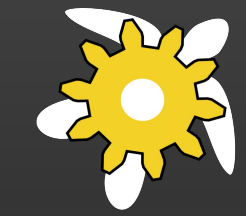
- Reader emits radio waves, activating a tag to return its stored data
- Half-duplex

WIFI - Wireless Fidelity (Distance Varies)

- Router transmits information packets through radio waves (2.4, 5, 6 GHz)
- Half-duplex

Bluetooth/BLE (Distance Varies)

- A 2.4 GHz Master-Slave architecture using packets
- Half-duplex



TEXAS A&M UNIVERSITY

ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Soldering

Soldering Tools

Soldering Iron

Easy to transport

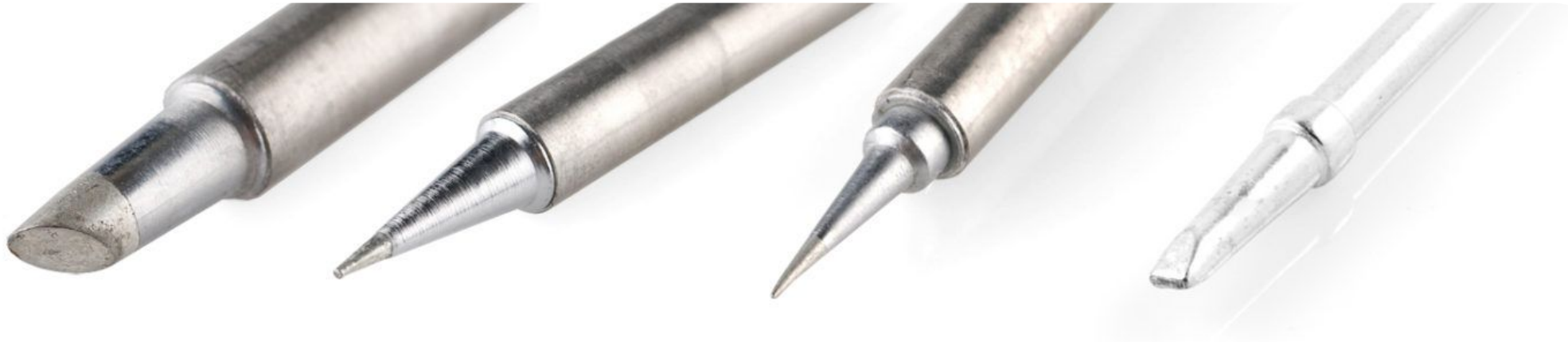
Soldering Station

Allows for more precise temperature control and may have additional features

Soldering Tools

Soldering Iron Tips

- The tip at the end of most soldering irons are interchangeable.
- Each tip has a specific purpose. The most common ones are
  - Conical Tip – Used in precision electronics soldering because of the fine tip.
  - Chisel Tip – Well-suited to soldering wires or other larger components because of its broad flat tip.



Soldering Tools

Sponge

- Using a sponge will help to keep the soldering iron tip clean by removing the oxidation that forms
- Tips with oxidation will tend to turn black and not accept solder as it did when it was new.

Copper Sponge

Solder

- Solder comes in a different diameters
  - Thicker diameter solder is good for soldering larger joints quickly
  - Thinner solder is useful for precision projects

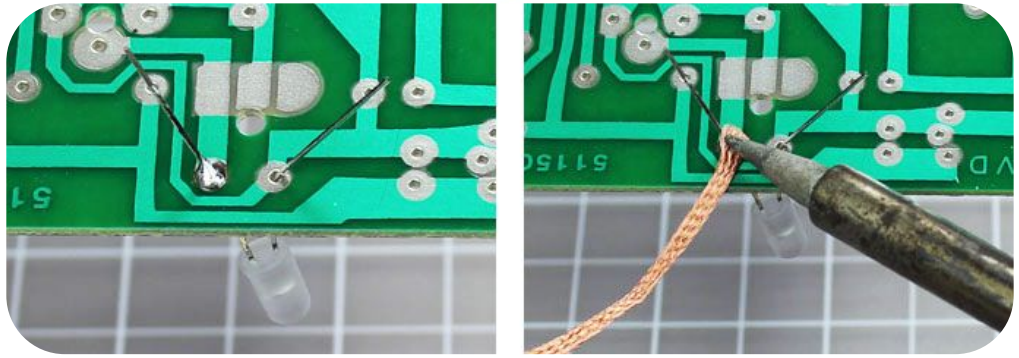
Tinning the tip

- This process will help improve the heat transfer from the iron to your project as well as helping to protect the tip and reduce wear. You should tin the tip of your iron **before and after each soldering session**.

1. Make sure the tip is attached to the iron and screwed tightly in place.
2. Turn on your soldering iron and let it heat up. Set it to 400°C
3. Wipe the tip of the soldering iron on a damp wet sponge to clean it. Wait a few seconds to let the tip heat up again before proceeding to step 4.
4. Hold the soldering iron in one hand and solder in the other. Touch the solder to the tip of the iron and make sure the solder flows evenly around the tip.

Desoldering

1. Place a piece of desoldering braid on top of the joint/solder
2. Heat your soldering iron and touch the tip to the top of the braid.



1. Press the plunger down at the end of the solder pump
2. Heat the joint with your soldering iron and place the tip of the solder pump over the hot solder
3. Press the release button to suck up the liquid solder
4. Press down on the plunger to empty the solder pump

Example

Tips

- Ensure your iron is set to the correct temperature
  - Solder sticking to the tip? Too hot
  - Solder is not free flowing? Too cold
  - Typically *600°- 650°F (316°- 343°C)* for lead-based solder and *650°- 700°F (343°- 371°C)* for lead-free solder
- Plan the order you will solder components
- Hold your iron to the contact point for a few seconds before applying solder
- Tin your iron every time
- Use flux
- Trim components after soldering
- Use the least amount of solder possible

https://www.techspray.com/ultimate-guide-to-electronic-soldering

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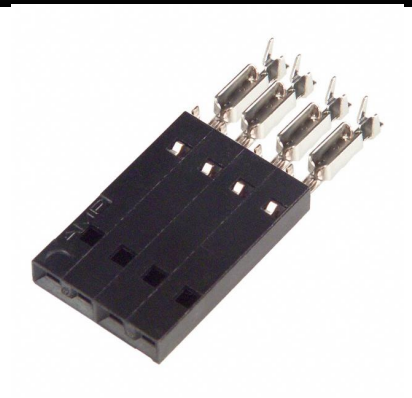
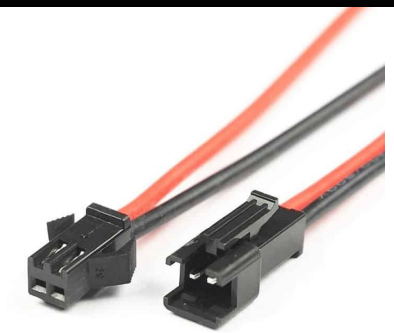
Wire Crimping

Common Wire Connector Types

Note: Pin count may vary



Dupont
GPIO



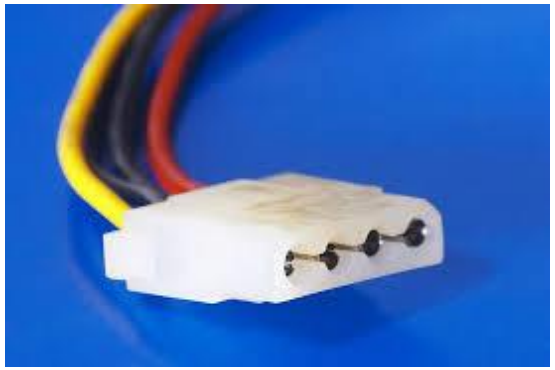
JST
Consumer electronics

Soldered

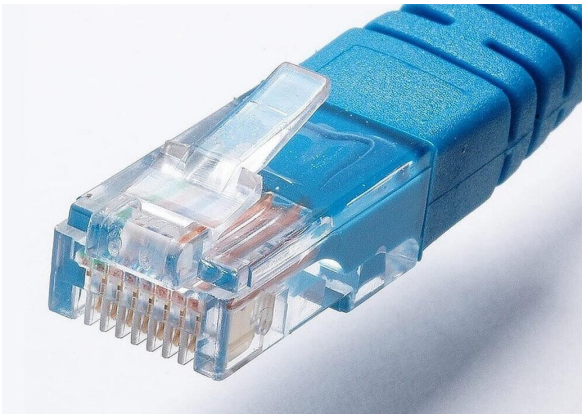
Dean/T-Plug
RC power connections

XT Family
High-current power connections

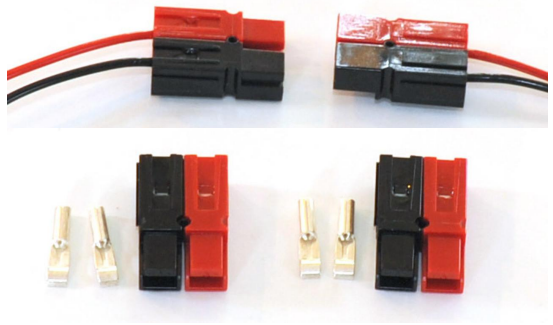
Spade/Ring Terminal
Terminating Screw Terminal



Molex
Power and Signal



RJ Family
Telecommunications



Anderson Powerpole
High-current DC power connections

Crimping

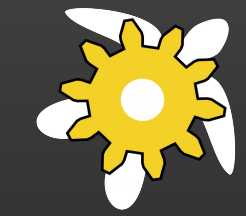
Depends on the type of connector

Generally:

1. Strip wire
2. Grab metallic connection in grove
3. Insert stripped wire
4. Fully clamp crimping tool on wire arms
5. Fully clamp crimping tool on insulation arms

(6) Push metallic connection into the connector housing

Example



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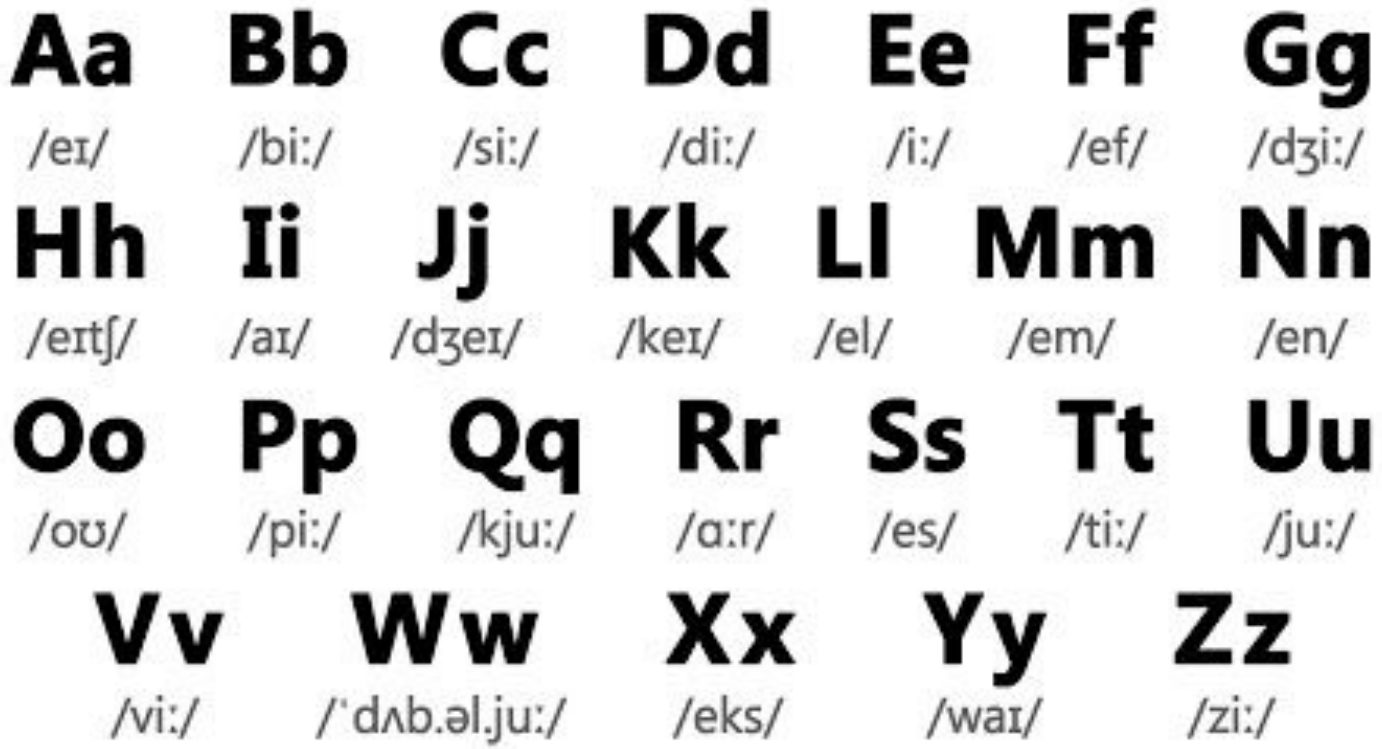
Documentation Navigation

How to Read


Aa /eɪ/
Bb /biː/
Cc /siː/
Dd /diː/
Ee /iː/
Ff /ef/
Gg /dʒiː/
Hh /eɪtʃ/
Ii /aɪ/
Jj /dʒeɪ/
Kk /keɪ/
Ll /el/
Mm /em/
Nn /en/
Oo /oʊ/
Pp /piː/
Qq /kjuː/
Rr /ɑːr/
Ss /es/
Tt /tiː/
Uu /juː/
Vv /viː/
Ww /ˈdʌb.əl.juː/
Xx /eks/
Yy /waɪ/
Zz /ziː/

Understanding technical documentation is an important skill

Most datasheets contain the same information in a similar format. These sheets convey important information such as:

- Physical dimensions and possible manufacturing tolerances
- Pin configurations
- Absolute maximum ratings and recommended operating conditions
- Truth tables and timing diagrams

Data Sheets

T200 Thruster Specifications

Performance		
Full Throttle FWD/REV Thrust @ 12 V	3.71 / 2.92 kg f	8.2 / 6.4 lb f
Full Throttle FWD/REV Thrust @ Nominal (16 V)	5.25 / 4.1 kg f	11.6 / 9.0 lb f
Full Throttle FWD/REV Thrust @ Maximum (20 V)	6.7 / 5.05 kg f	14.8 / 11.1 lb f
Minimum Thrust	0.02 kg f*	0.05 lb f*
Electrical		
Operating Voltage	7–20 volts	
Full Throttle Current (Power) @ 12 V	17 Amps (205 Watts)	
Full Throttle Current (Power) @ Nominal (16 V)	24 Amps (390 Watts)	
Full Throttle Current (Power) @ Maximum (20 V)	32 Amps (645 Watts)	

- With most PCB having the pinout of the GPIO’s will give you most of the information you need
- With other electrical components (Special motors, sensors, etc) Looking at the data sheet will be useful to understanding the communication protocols and the voltage/current needed for each input/output (IMPORTANT AS TO NOT DAMAGE HARDWARE AND BEWARE OF UNITS).

Important Things to Check

- Ensure that the part numbers the document covers matches your part
- Keep an eye on the units
- Make sure that you are supplying the correct voltage and current
  - Avoid damaging hardware

…Kahoot Time!

ESP32 Documentation

Datasheet

That's all for our lectures

Let's build robots

All future meetings will be in your home organizations lab

SOMTECH - HRBB 320 | TAMUDBF - HRBB 024
TURTLE - HEB 023

Let’s work

Lab typically opens at ~10am on weekdays. Feel free to come work on your robot anytime an officer is present.

There are a few rules:

1) Clean up after yourself. Leave the lab nicer than you found it

2) Be respectful of Advanced Project meetings. APs are working hard to prepare for project showcase. Please listen to requests by the project lead.

3) 3D printing priority goes to APs during their meeting time. If your print will overlap any AP meeting times, please ask the project lead if the printer is available.

Next Milestone

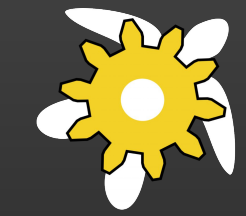
Milestone: Prototype Review

Date: Week 9 - Prototype (1 week from today)

Expectation: Have a CAD assembly of a drive system. Have a finished electronics wiring diagram.

Exceed Expectation: Have a CAD of the entire robot and started prototyping. Began programming the robot.

Impact: We will review design viability and suggest improvements. Potential to prototype your mechanism.



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Prototype Week

Next Week

“Why can’t I ever invent something that does what it’s supposed to do?”

~ Dr. Doofenshmirtz

Hatchling