Admin, timeline

Wrap of assignments 🎁

Nightly re-tests

Final deadline for re-test fixes and full system **5pm Sun Nov 24**

Full system bonus 💪 you can do it!!

- Resolve Priority 1 issues
- Console application works correctly using all your modules

Start of project

Fill out team form today

Attend same lab as partner, draft project proposal, submit after lab

Today: Sensor input

Interacting with physical world

Putting the G in GPIO

Today: Input

How to use electrical signals to observe external phenomena

Light, motion, position, temperature, force, pressure, vibration, …

Analog to digital conversion

Friday: Output

How to use electrical signals to drive external outputs

Communication, sound, control servos/motors, …

Digital to analog conversion

Apple iPhone 12 Teardown

3 12MP Ultra wide, wide, and telephoto cameras

LIDAR TrueDepth camera

12MP front TrueDepth camera with FaceID

Haptic multi-touch display

Microphones (2 at top, 2 at bottom)

Proximity sensor

Ambient light sensor

Accelerometer

Gyroscope

Compass (magnetometer)

Barometer (altimeter)

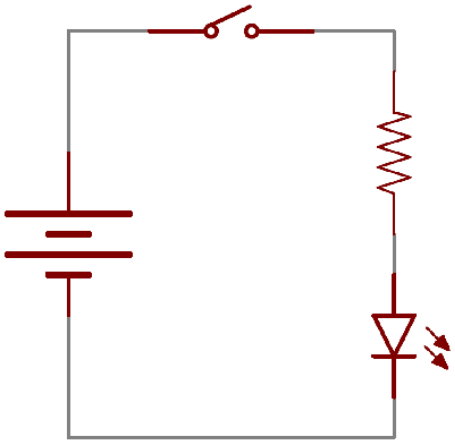
Moisture

Radios (wifi, bluetooth, cellular, gps, NFC)

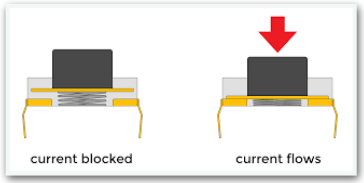
How many sensors?

https://www.ifixit.com/Teardown/iPhone+12+and+12+Pro+Teardown/137669

Buttons and switches

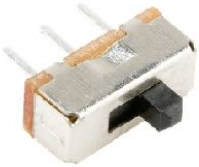


Push button



Button groups

Toggle

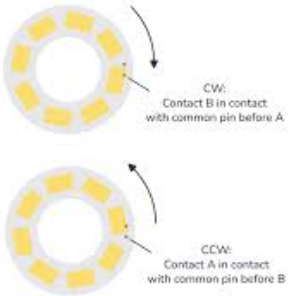


Slide

Microswitch

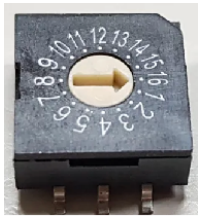
Rocker

Membrane keypad



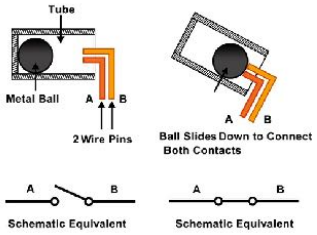
Rotary encoder

Dial wheels

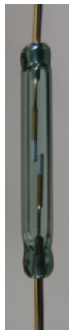


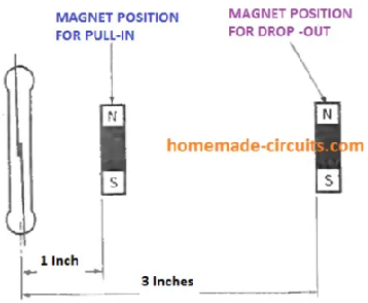
Rotary position

Dip switch

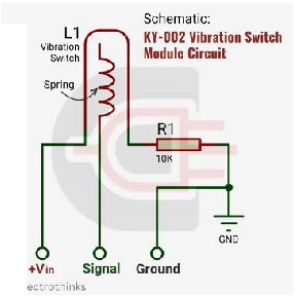


Tilt switch





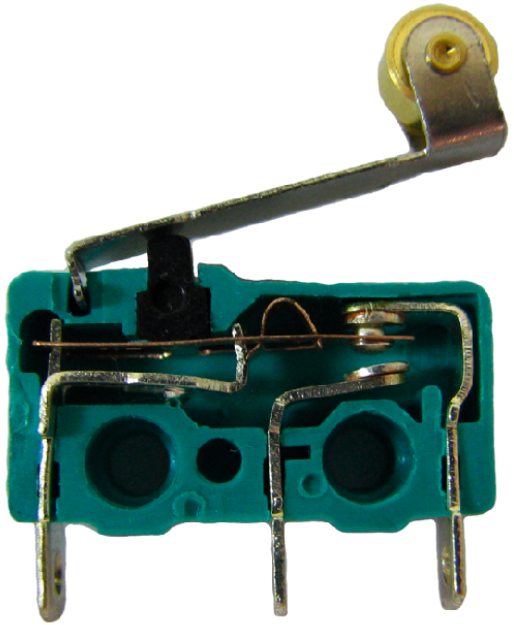
Reed switch



Vibration switch

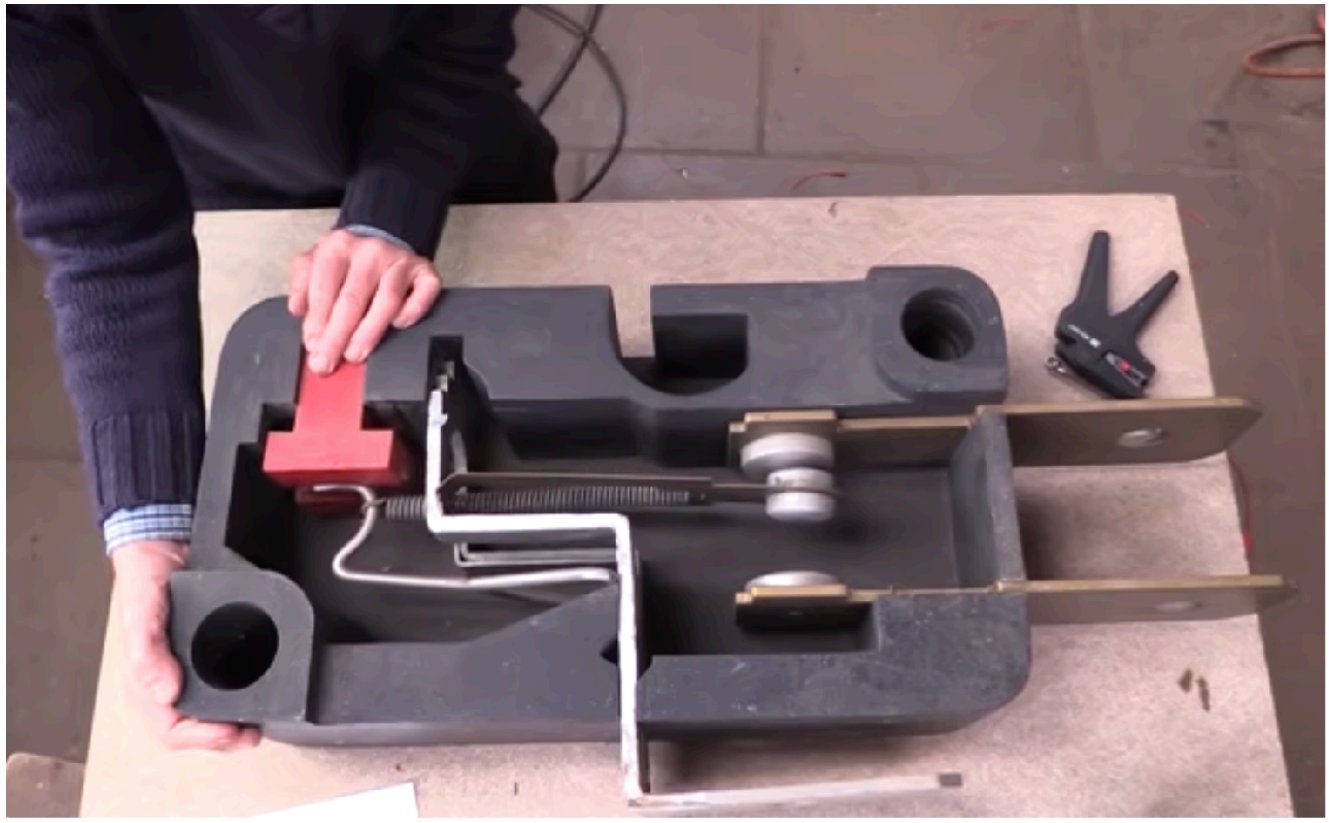
… and many more

Snap-action microswitch



Common NO NC

https://en.wikipedia.org/wiki/Miniature_snap-action_switch



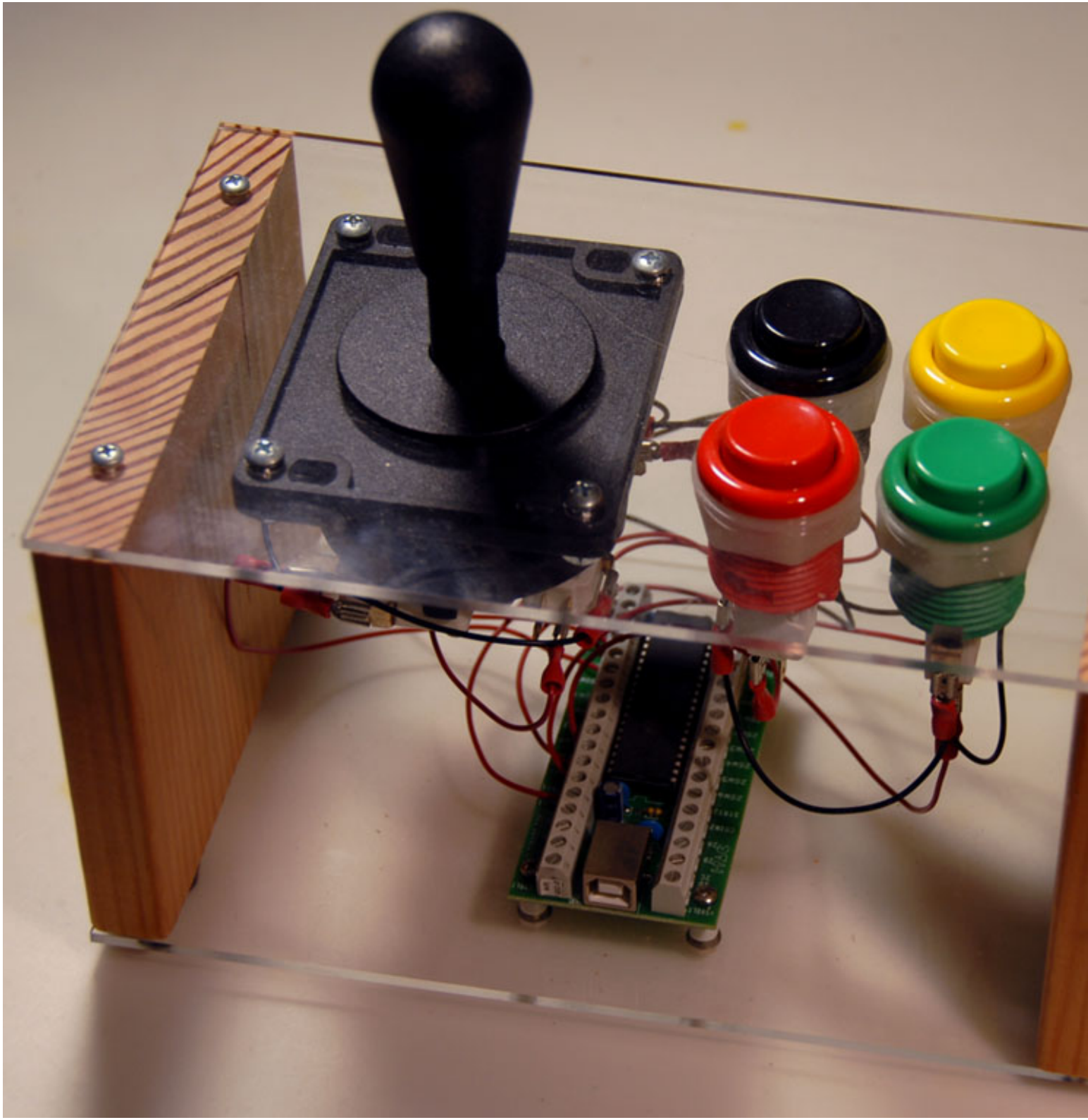
*Patented in **1932!***

Tim Hunkin video: All about Switches

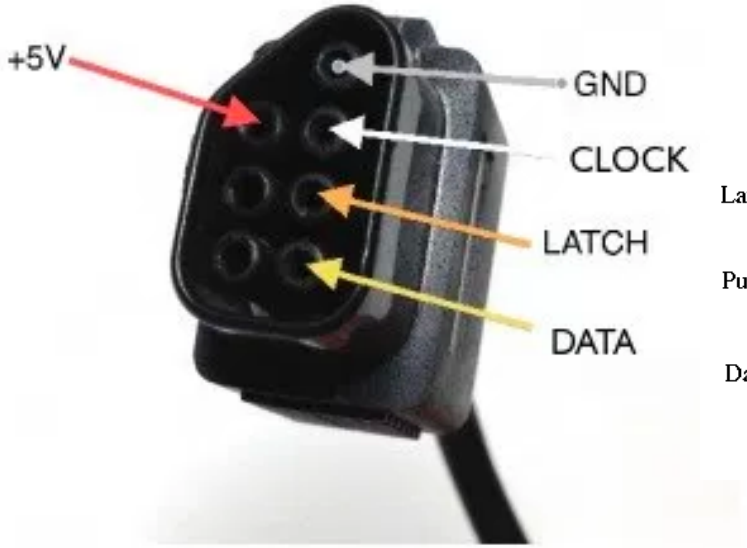
https://www.youtube.com/watch?v=bno0HeQfxrU

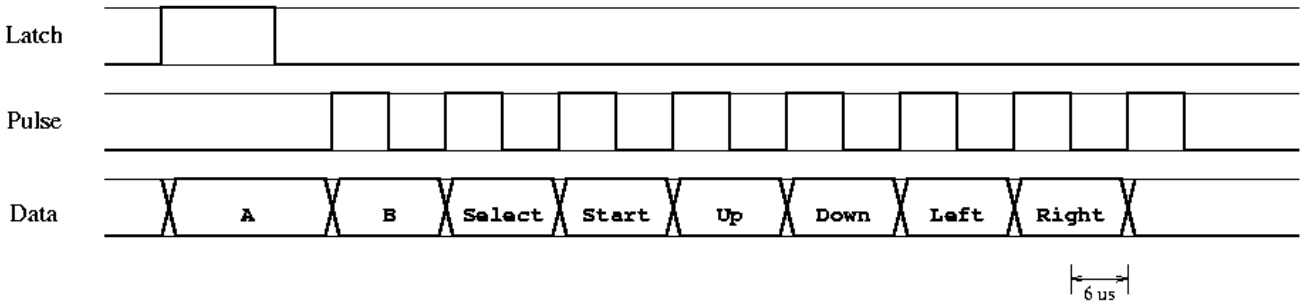
Happ pushbutton

Happ joystick

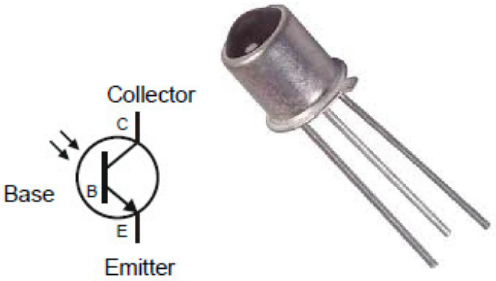


Retro game controllers





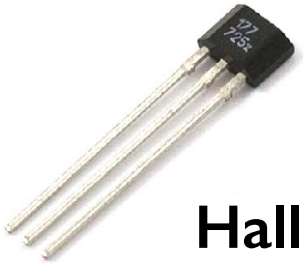
Transistor sensors

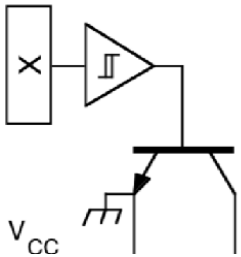


Phototransistor (light)

Capacitance

Gas

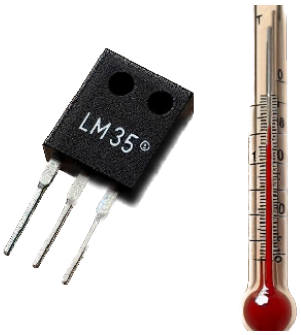




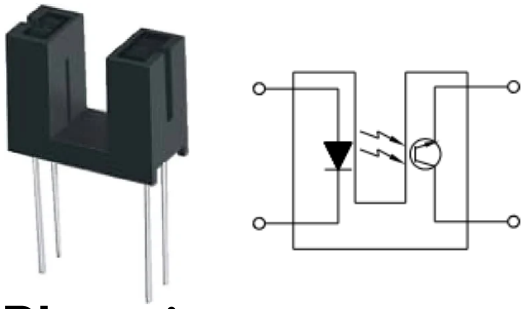
Hall Effect (magnetic field)

IR detector

Passive infrared (PIR)

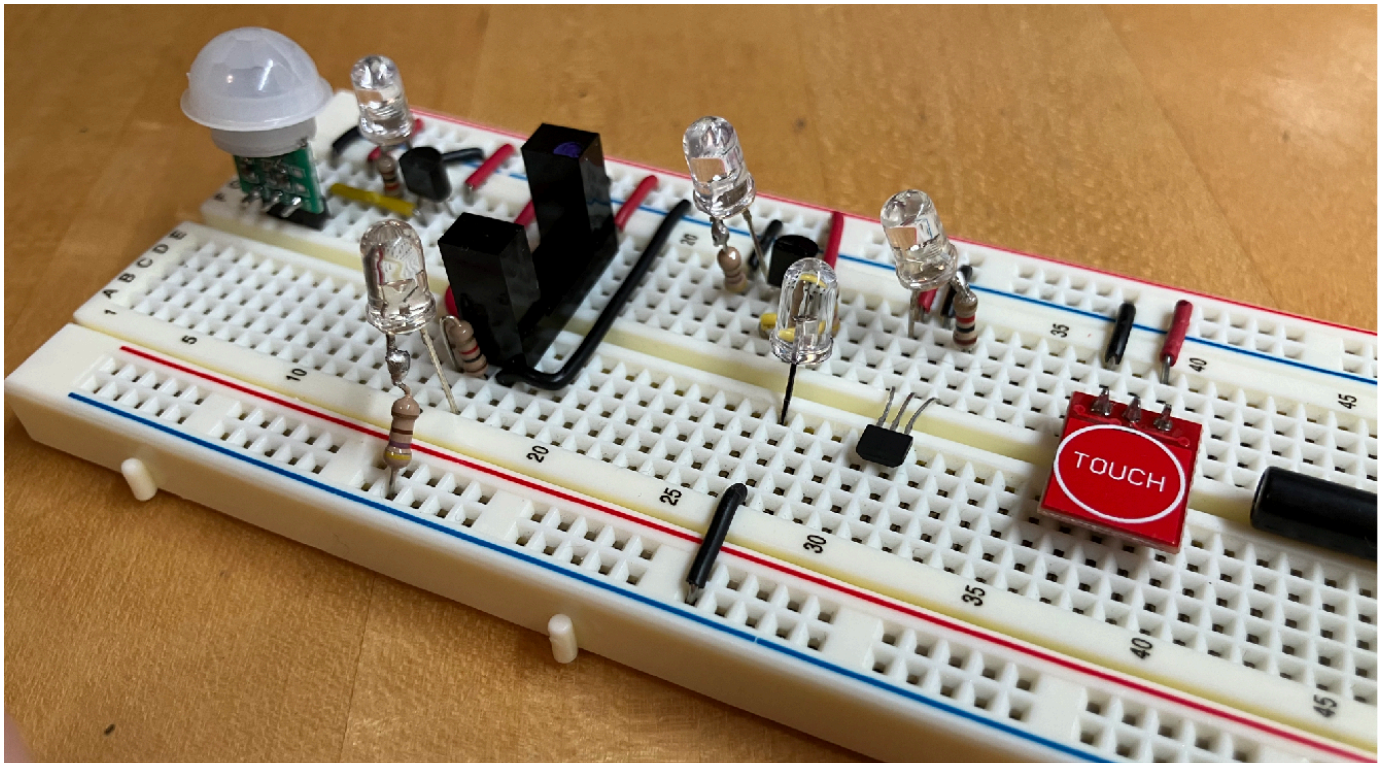


Temperature



Photointerrupter (presence)

Demo: transistor sensors

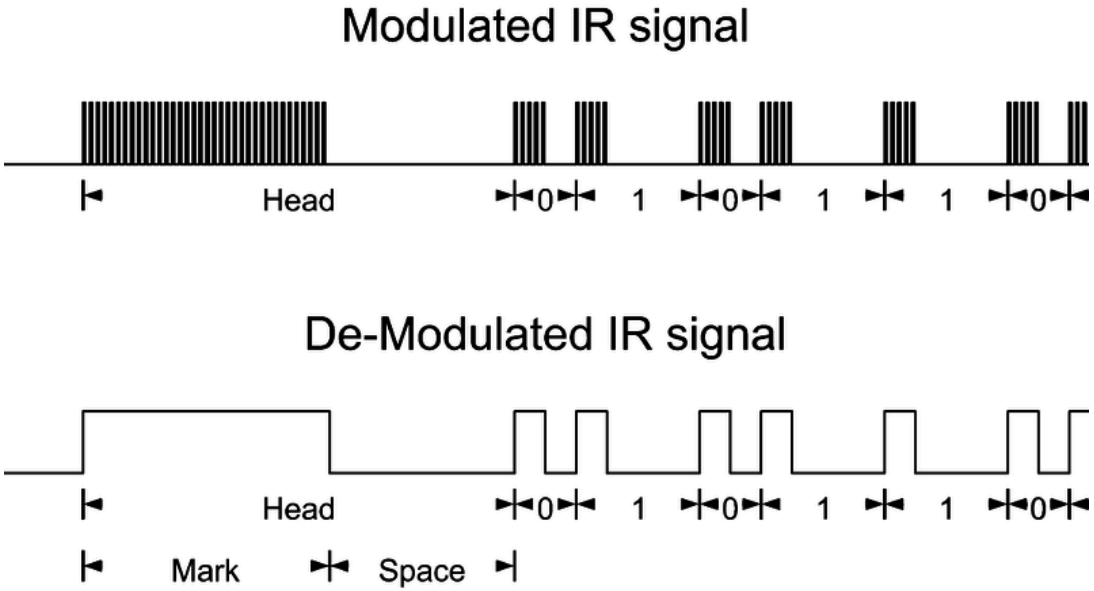


Passive IR, photointerruptor, phototransistor, hall effect, capacitive touch

Demo: IR communication

38 Khz IR Detector

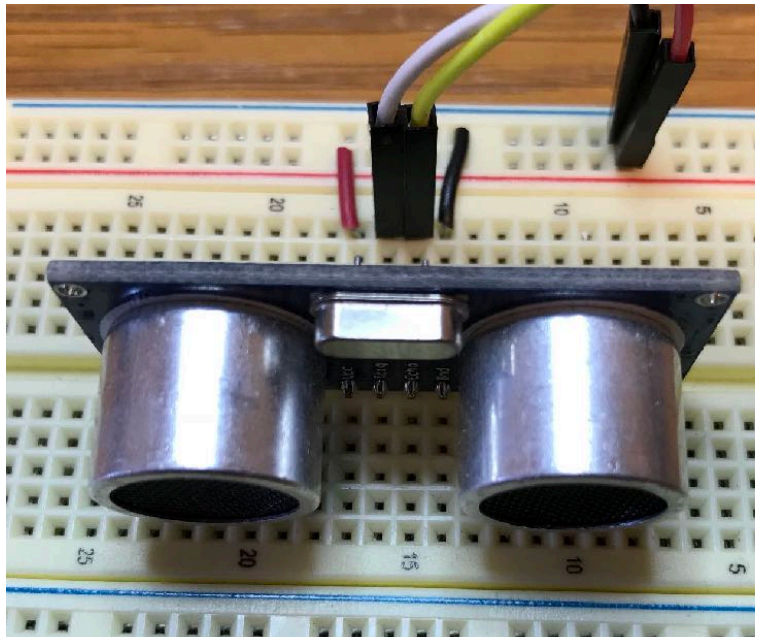
Apple Remote



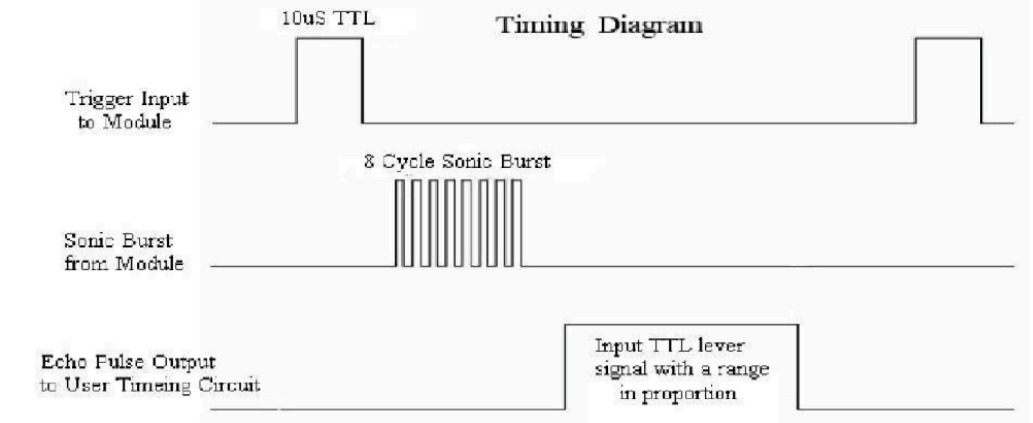
https://hifiduino.wordpress.com/2011/05/11/apple-aluminum-remote-codes/

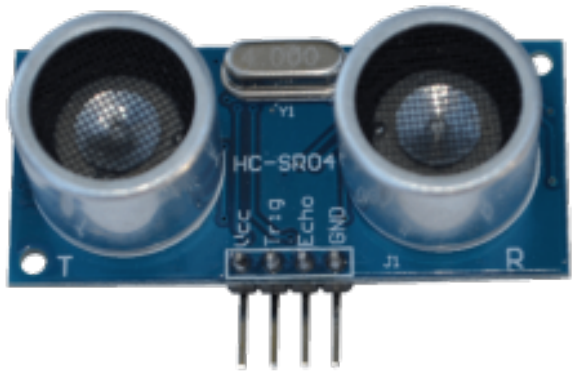
Demo: Proximity detection

Measures time of flight
sound wave to object and return



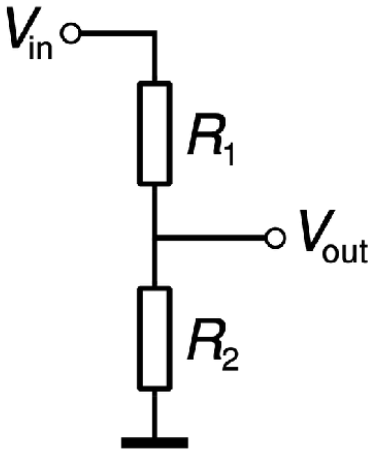
The Timing diagram is shown below. You only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion .You can calculate the range through the time interval between sending trigger signal and receiving echo signal. Formula: uS / 58 = centimeters or uS / 148 =inch; or: the range = high level time * velocity (340M/S) / 2; we suggest to use over 60ms measurement cycle, in order to prevent trigger signal to the echo signal.



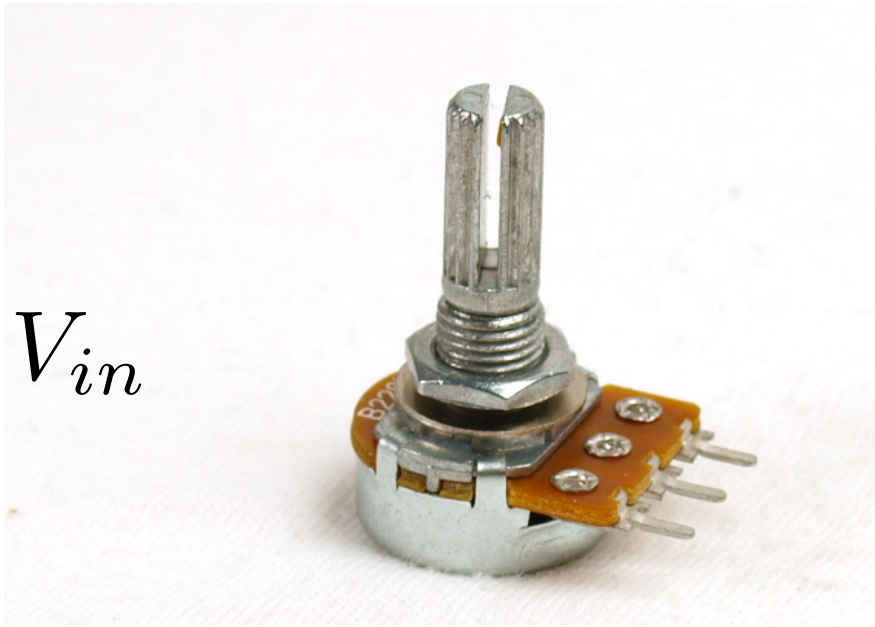


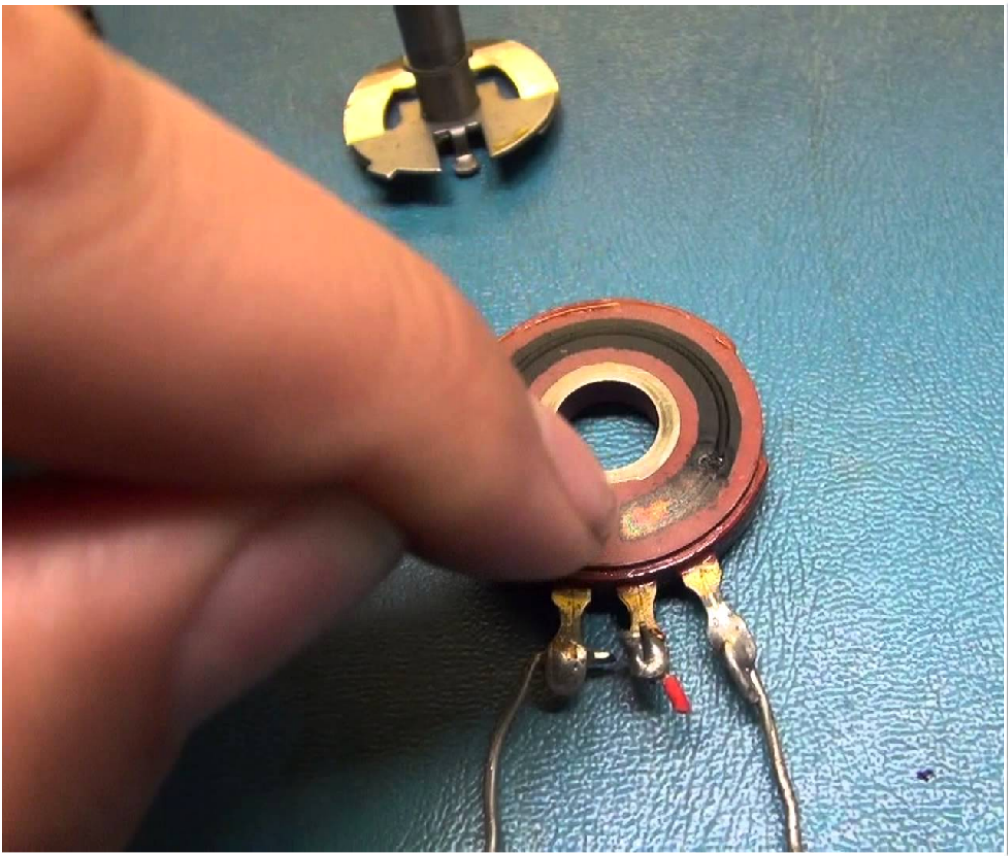
HC-SR04 ultrasonic sensor

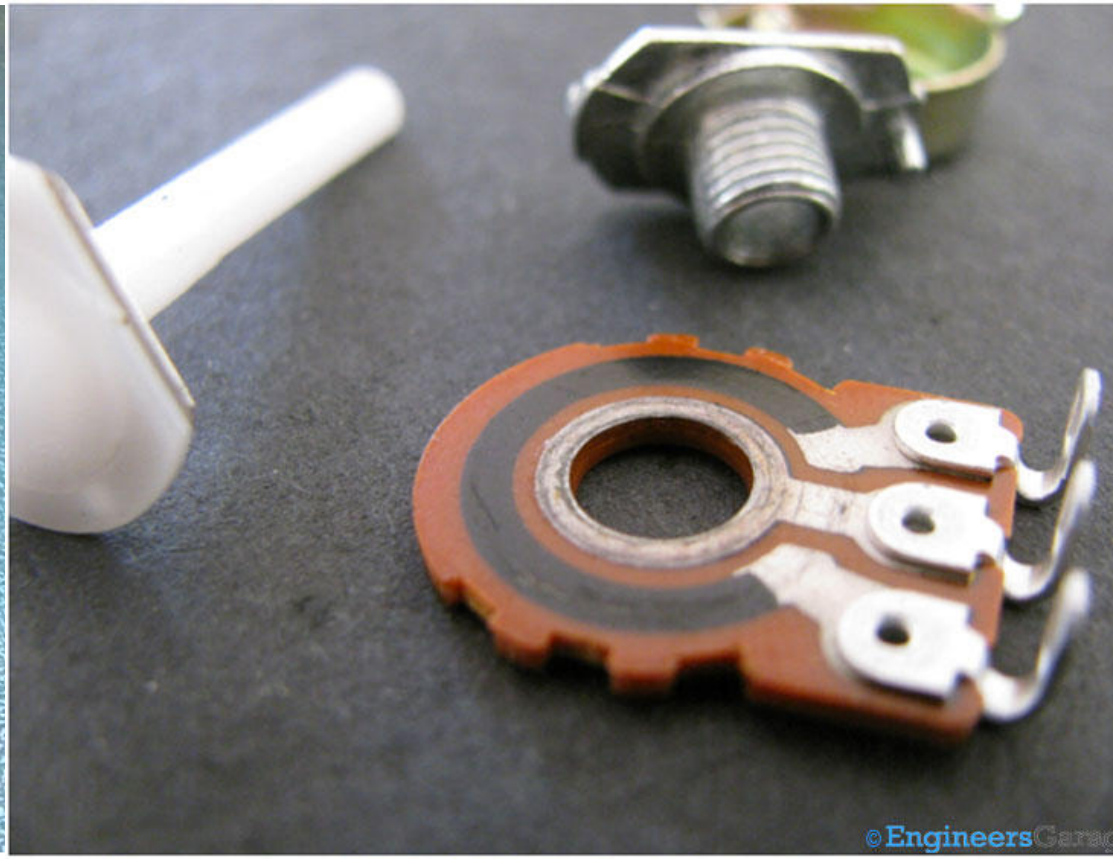
Analog to Digital conversion (ADC)



$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$



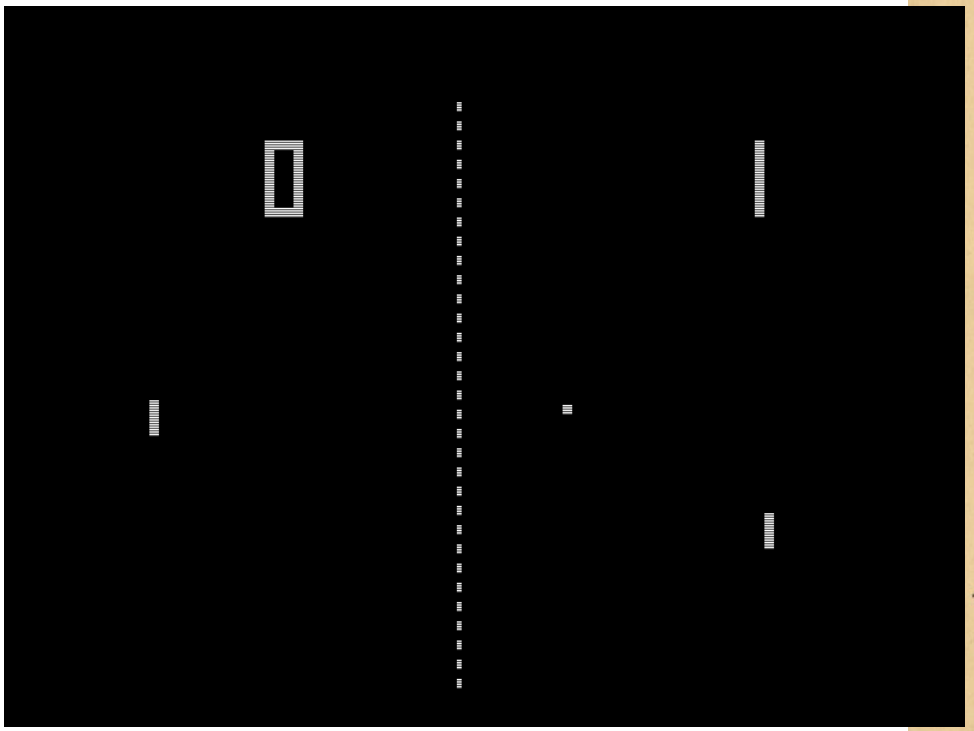




https://allaboutelektronics.wordpress.com/resistors/

How can digital hardware measure analog voltage ?

Atari 2600 Paddle



http://www.pong-story.com/eaus0576.htm

THE NEWEST 2 PLAYER
VIDEO SKILL GAME

PONG

from ATARI CORPORATION
SYZYGY ENGINEERED

The Team That Pioneered Video Technology

FEATURES

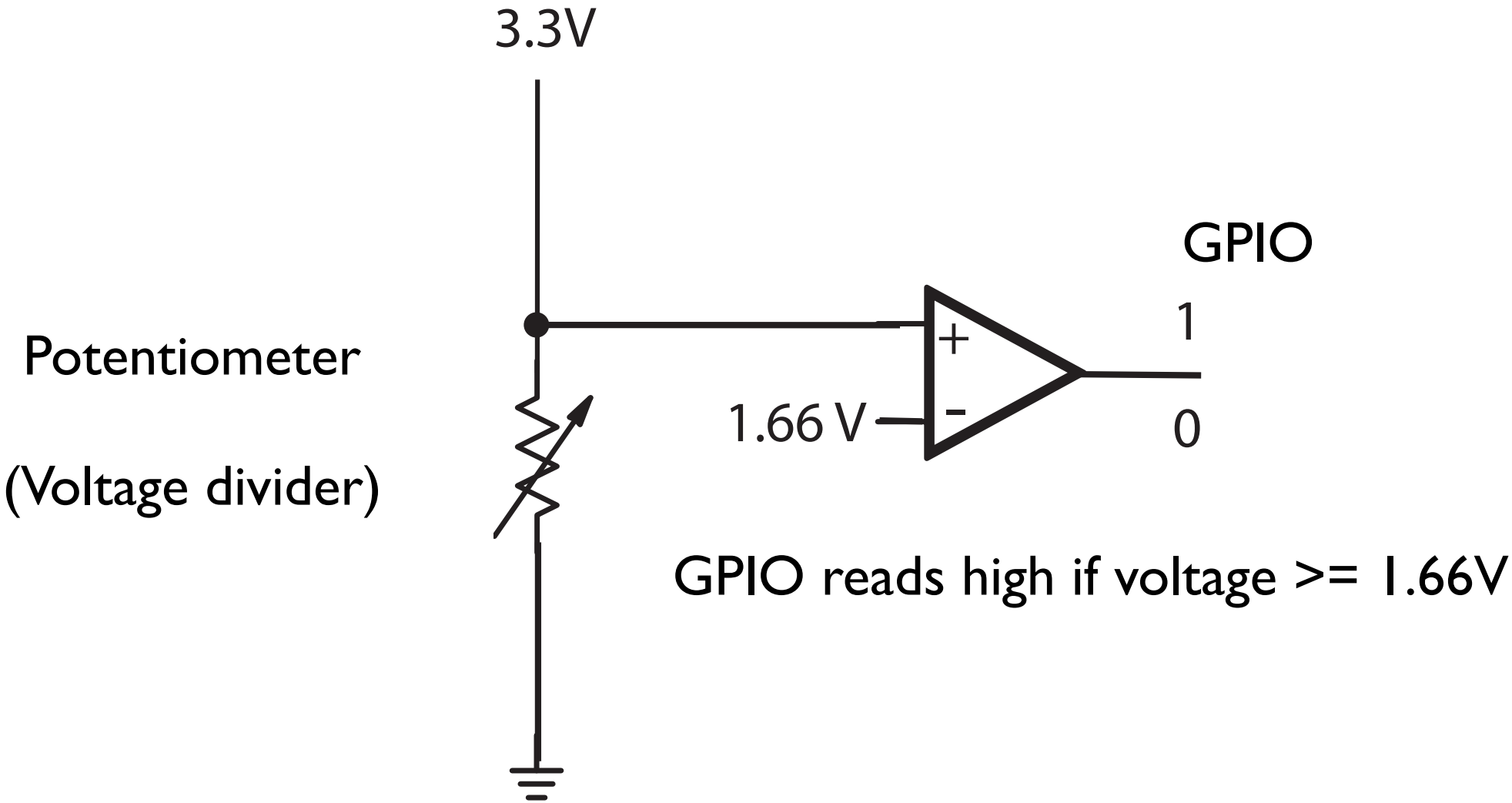
- STRIKING Attract Mode
- Ball Serves Automatically
- Realistic Sounds of Ball Bouncing, Striking Paddle
- Simple to Operate Controls
- ALL SOLID STATE TV and Components for Long, Rugged Life
- ONE YEAR COMPUTER WARRANTY
- Proven HIGH PROFITS in Location After Location
- Low Key Cabinet, Suitable for Sophisticated Locations
- 25¢ per play

THIS GAME IS AVAILABLE FROM YOUR LOCAL DISTRIBUTOR

Manufactured by
ATARI, INC.
2962 SCOTT BLVD.
SANTA CLARA, CA.
95050

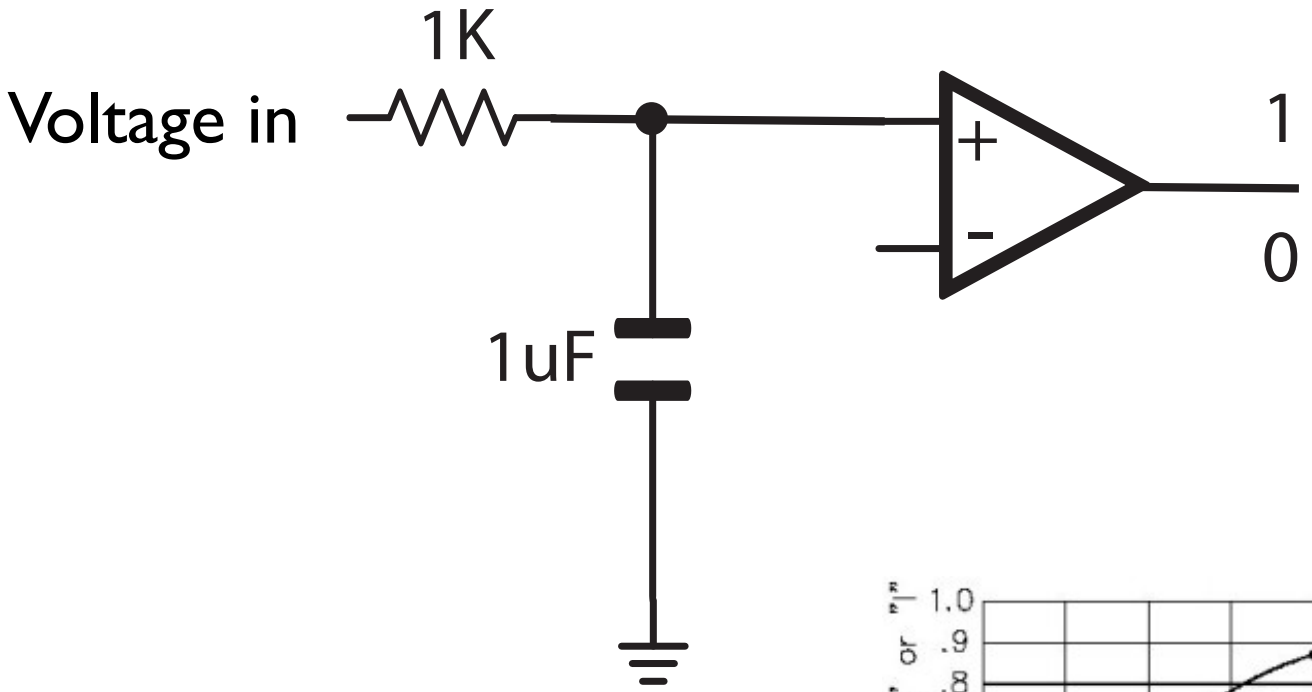
Maximum Dimensions:
WIDTH - 26"
HEIGHT - 50"
DEPTH - 24
SHIPPING WEIGHT:
150 Lb.

GPIO as comparator

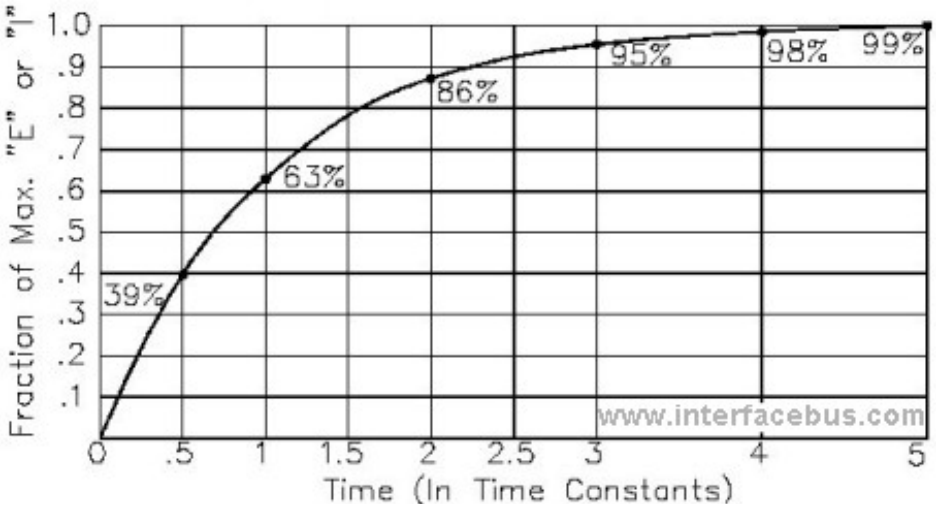


RC Charge circuit

Time to charge depends on voltage of input

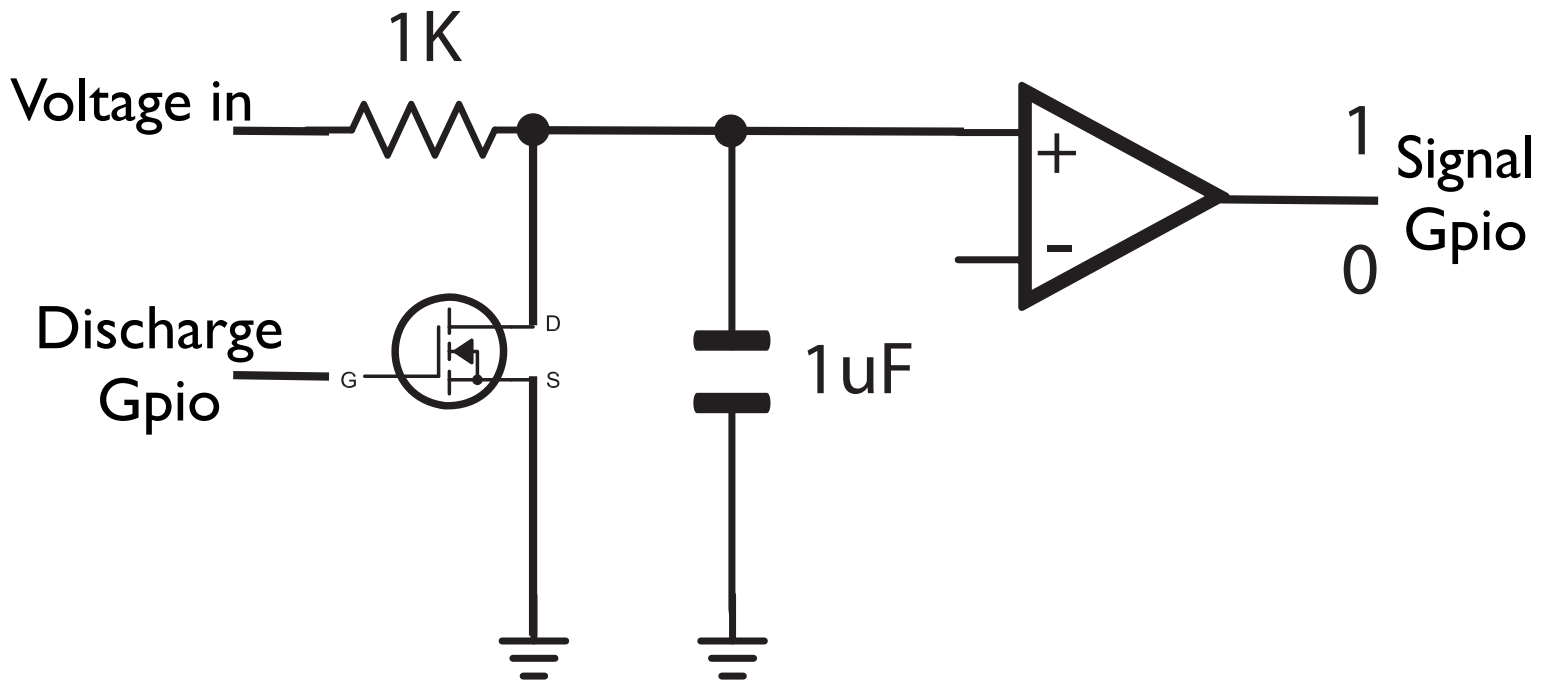


RC = 10^3 x 10^{-6} = 1000 usecs

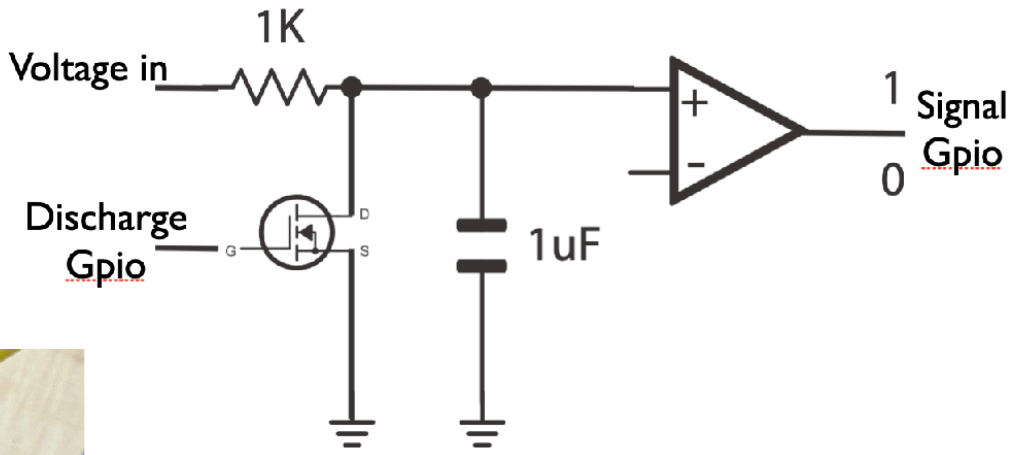


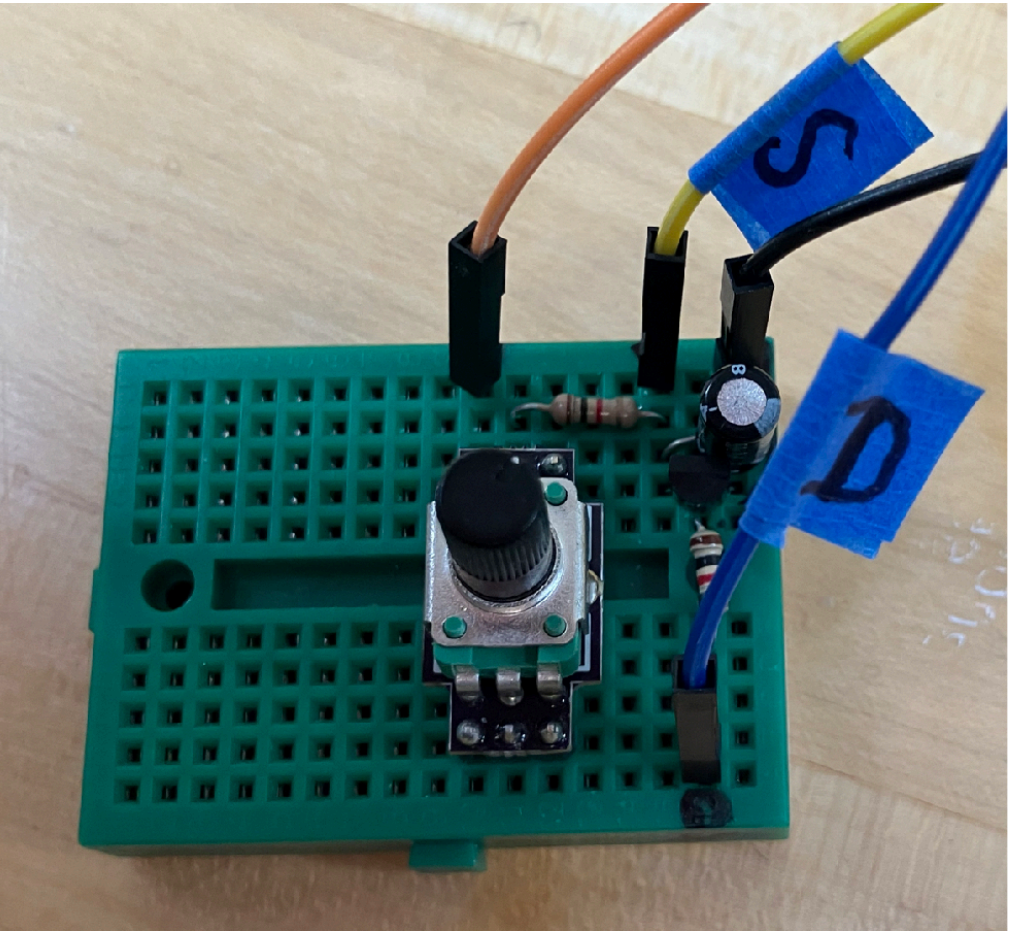
RC circuit ADC

1) Turn on transistor, discharges capacitor
2) Turn off transistor, capacitor will charge
3) Measure time until full, calculate input voltage



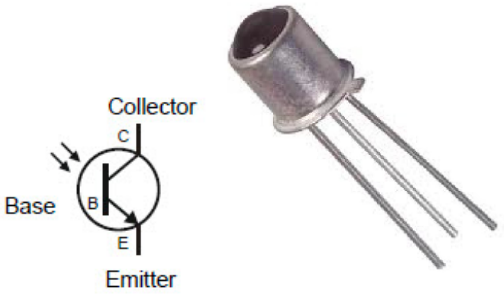
Demo: RC circuit ADC





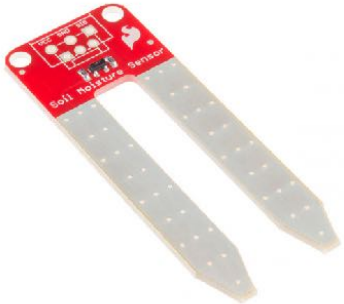

```
unsigned long get_charge_time(void)
{
        // transistor on, will discharge cap
  gpio_write(discharge, 1);
  timer_delay_ms(10);
       // transistor off, cap will recharge
  gpio_write(discharge, 0); //

      // measure time until full
  unsigned long start = timer_get_ticks();
  while (gpio_read(signal) == 0) ;
  return (timer_get_ticks() - start)*TICKS_PER_US;
}
```

Analog inputs



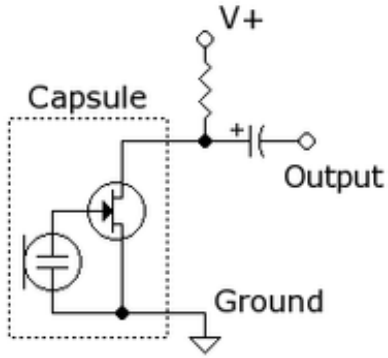
Phototransistor
(light)

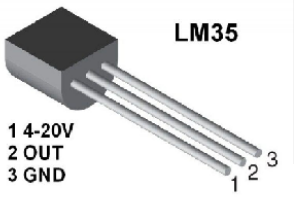
Flex
(deformation)



Moisture
(capacitance)

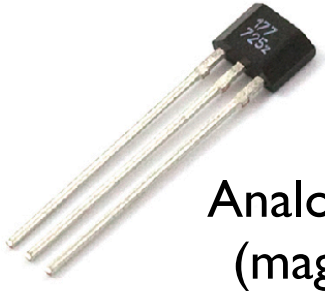
Electret microphone
(pressure)



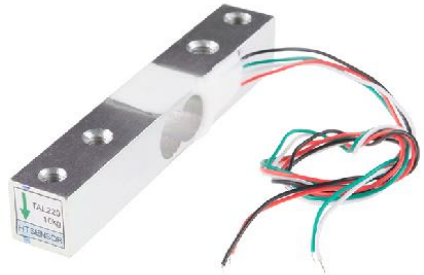


Temperature

Force



Analog Hall effect
(magnetic field)

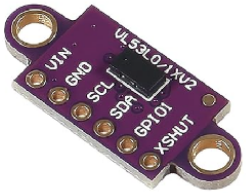


Load cell
(strain/stress)

Smart sensors

Real-time clock
(battery backup power)

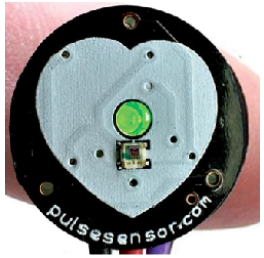
Time of flight range finder
(optical/laser)



RGB/light

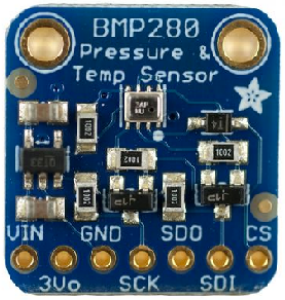
Accelerometer
Gyroscope

Temperature



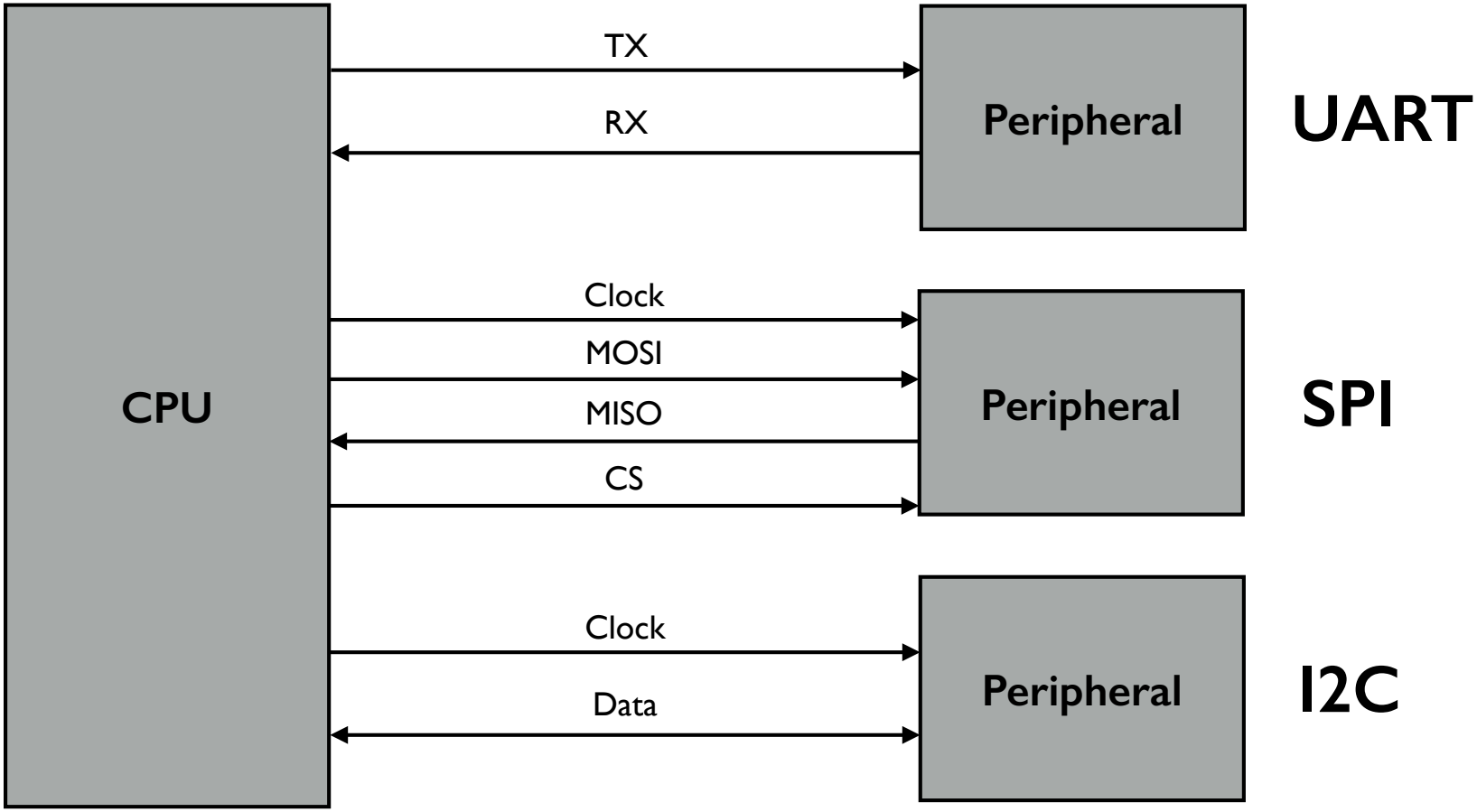
Heart rate
Oxygen saturation

Pressure
Humidity
Temperature



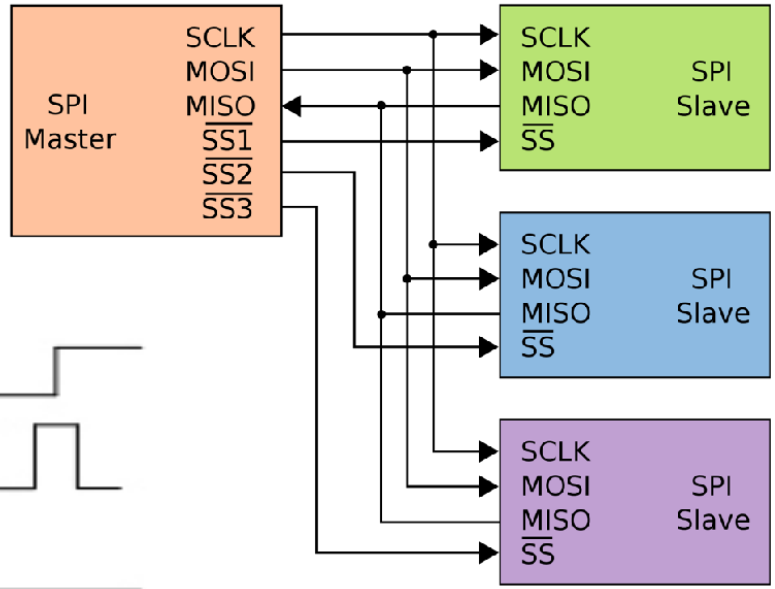
Camera

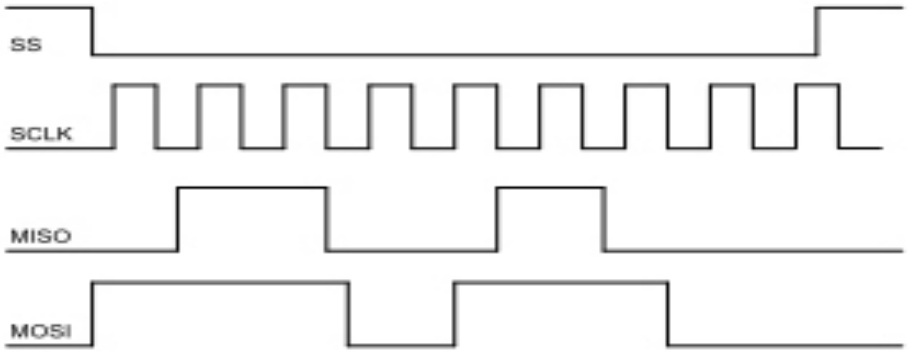
Bus protocols



SPI

- Shared CLK, MOSI, MISO lines
- Select line to indicate which peripheral is active
- Clocked by master

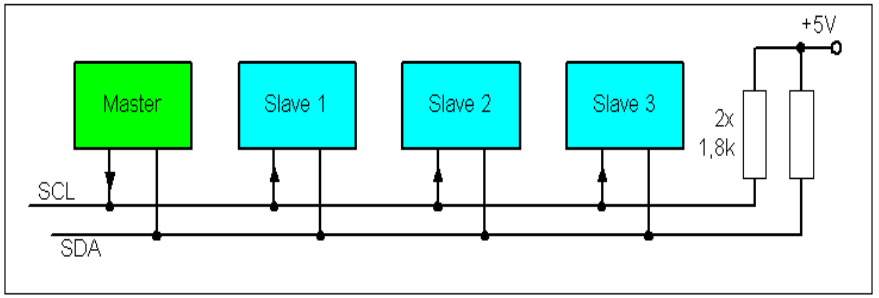


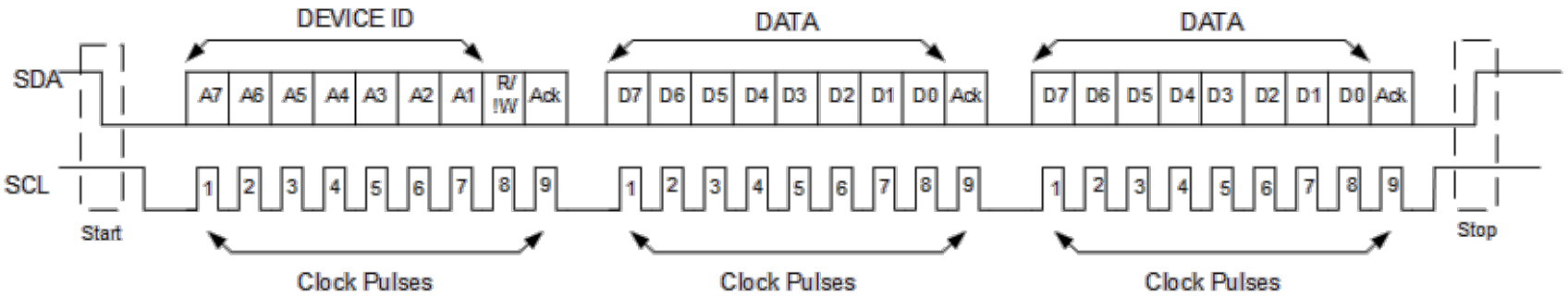


https://upload.wikimedia.org/wikipedia/commons/thumb/f/fc/SPI_three_slaves.svg/2000px-SPI_three_slaves.svg.png (t
http://www.tequipment.net/RigolSD-SPI-DS4.html (bottom)

I2C

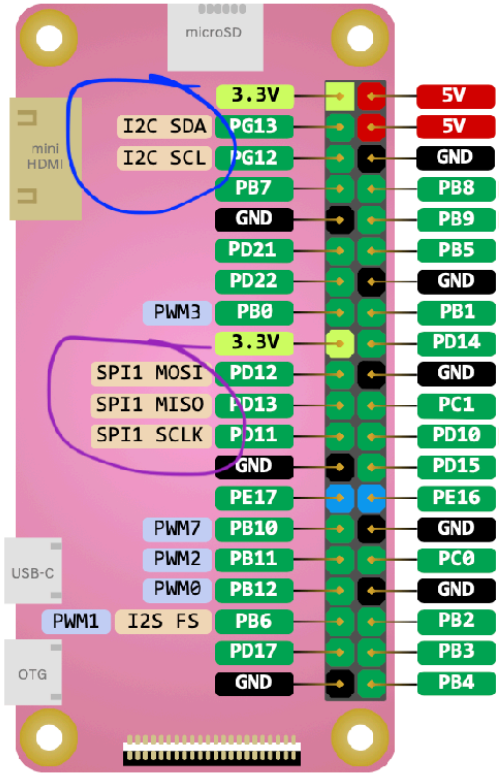
- CLK & DATA lines
- Clocked by main, bi-directional DATA
- Shared bus, target device identified by address





Figures from http://www.cs.fsu.edu/~baker/devices/notes/graphics/i2cbus3.gif (top)
https://learn.digilentinc.com/Documents/chipKIT/chipKITPro/P08/Fig_1_Waveform.png (bottom)

D1 Hardware peripherals



9.1 TWI

9.1.1 Overview

The Two Wire Interface (TWI) provides an interface between a CPU and any TWI-bus-compatible device that connects via the TWI bus. The TWI is designed to be compatible with the standard I2C bus protocol. The communication of the TWI is carried out by a byte-wise mode based on interrupt polled handshaking. Each device on the TWI bus is recognized by a unique address and can operate as either transmitter or receiver, a device connected to the TWI bus can be considered as master or slave when performing data transfers. Note that a master device is a device that initiates a data transfer on the bus and generates the clock signals to permit the transfer. During this transfer, any device addressed by this master is considered a slave.

The TWI has the following features:

- Compliant with I2C bus standard

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9.3 SPI

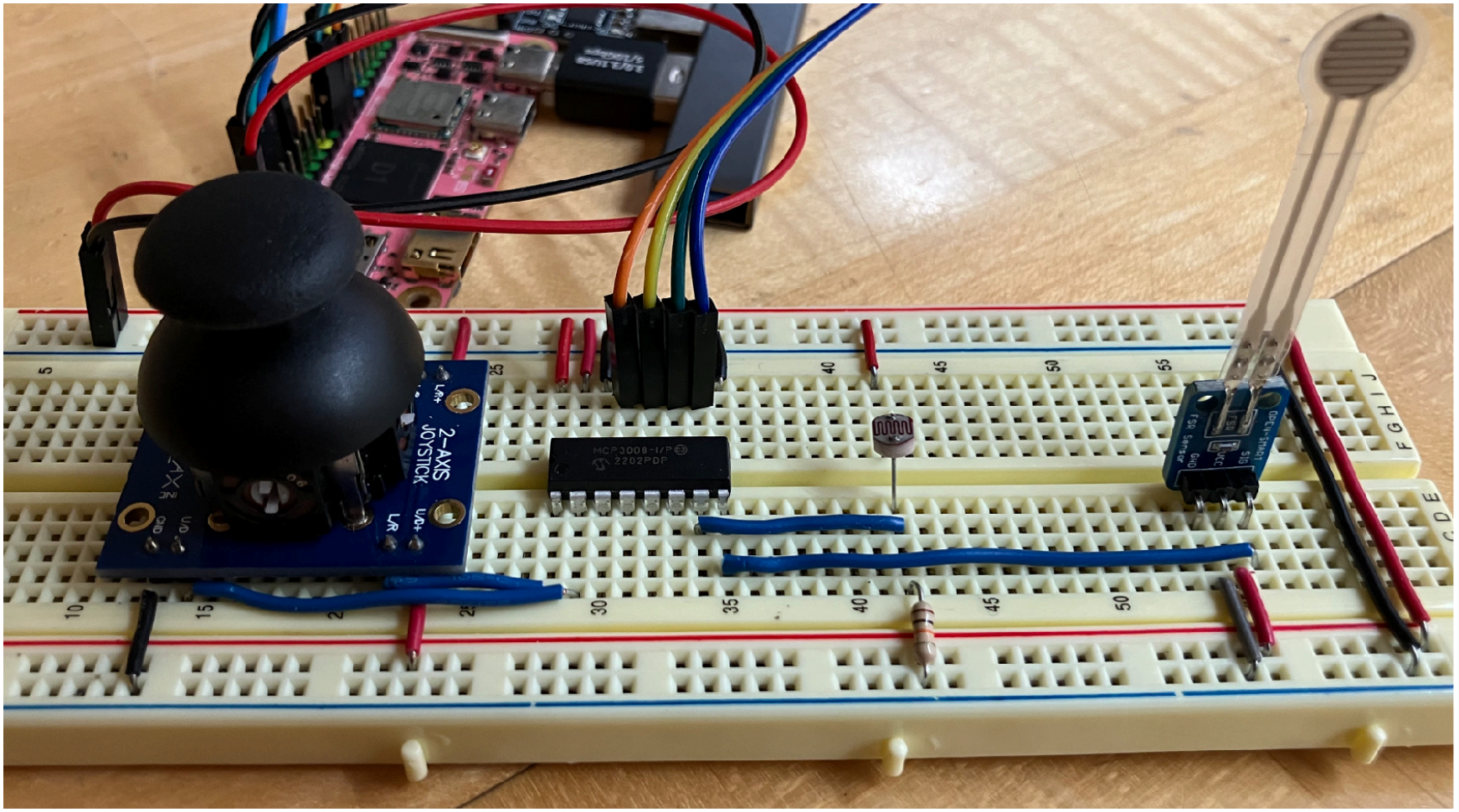
9.3.1 Overview

The Serial Peripheral Interface (SPI) is a full-duplex, synchronous, four-wire serial communication interface between a CPU and SPI-compliant external devices. The SPI controller contains a 64 x 8 bits receiver buffer (RXFIFO) and a 64 x 8 bits transmit buffer (TXFIFO). It can work in master mode and slave mode.

The SPI has the following features:

Sample driver code for SPI and TWI/i2c in `$CS107E/extras`

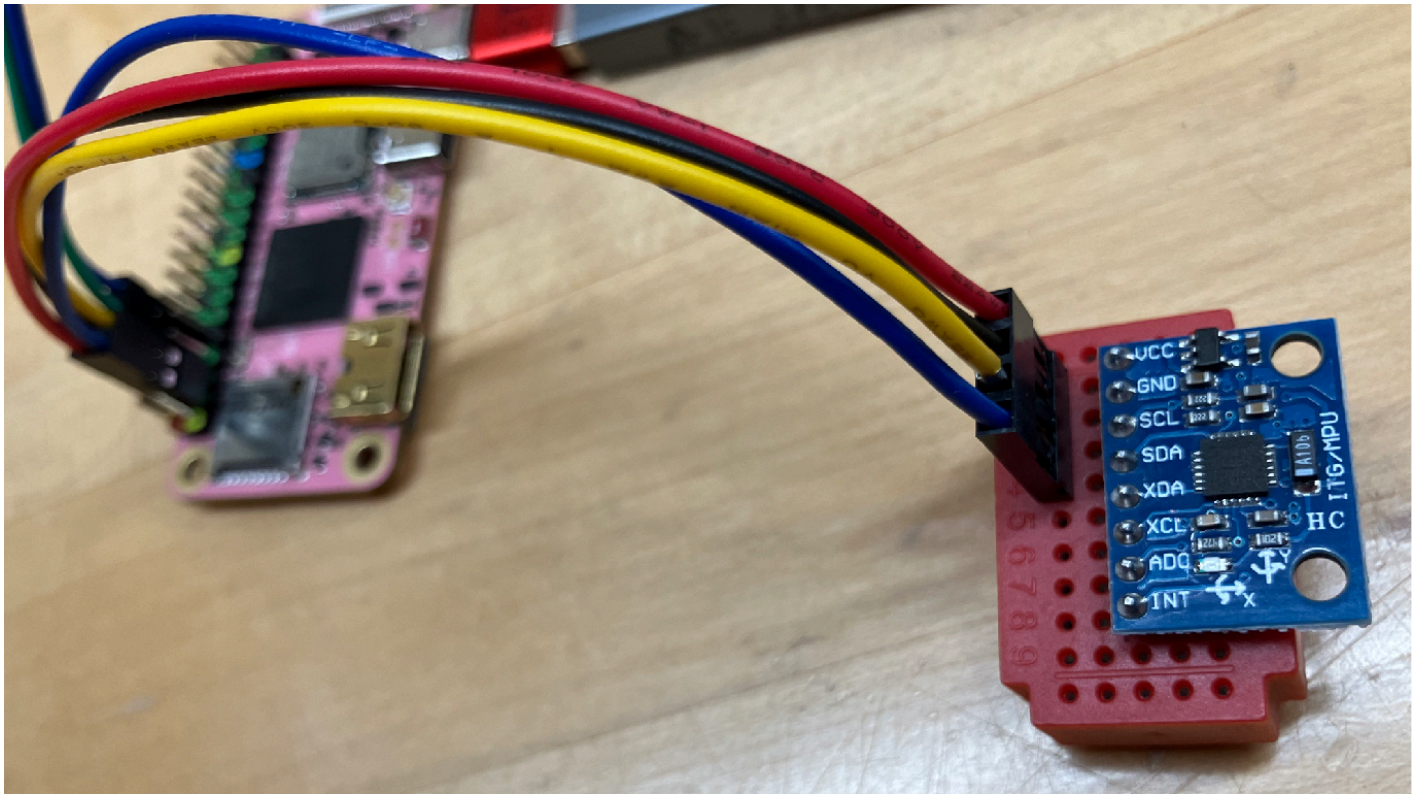
Demo: SPI



MCP3008 SPI 8-channel ADC

Analog readings from joystick, photoresistor, force sensor

Demo: I2C



GY-521 3-axis accelerometer/gyroscope

Sensing an Analog World

Resistance (light dependent resistance, capacitance)

Convert energy to voltage/current

- Light (phototransistor)
- Sound/pressure/deformation (microphone, piezo, electret, strain gauge, force, pressure)
- Temperature (infrared, humidity, barometric)
- Electromagnetic fields (hall effect, compass, coil, antenna)

ADC for raw analog inputs

Smart sensors (digital interface, integrated ADC)

- IMU (accel/gyro/compass), camera, microphone, …