

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

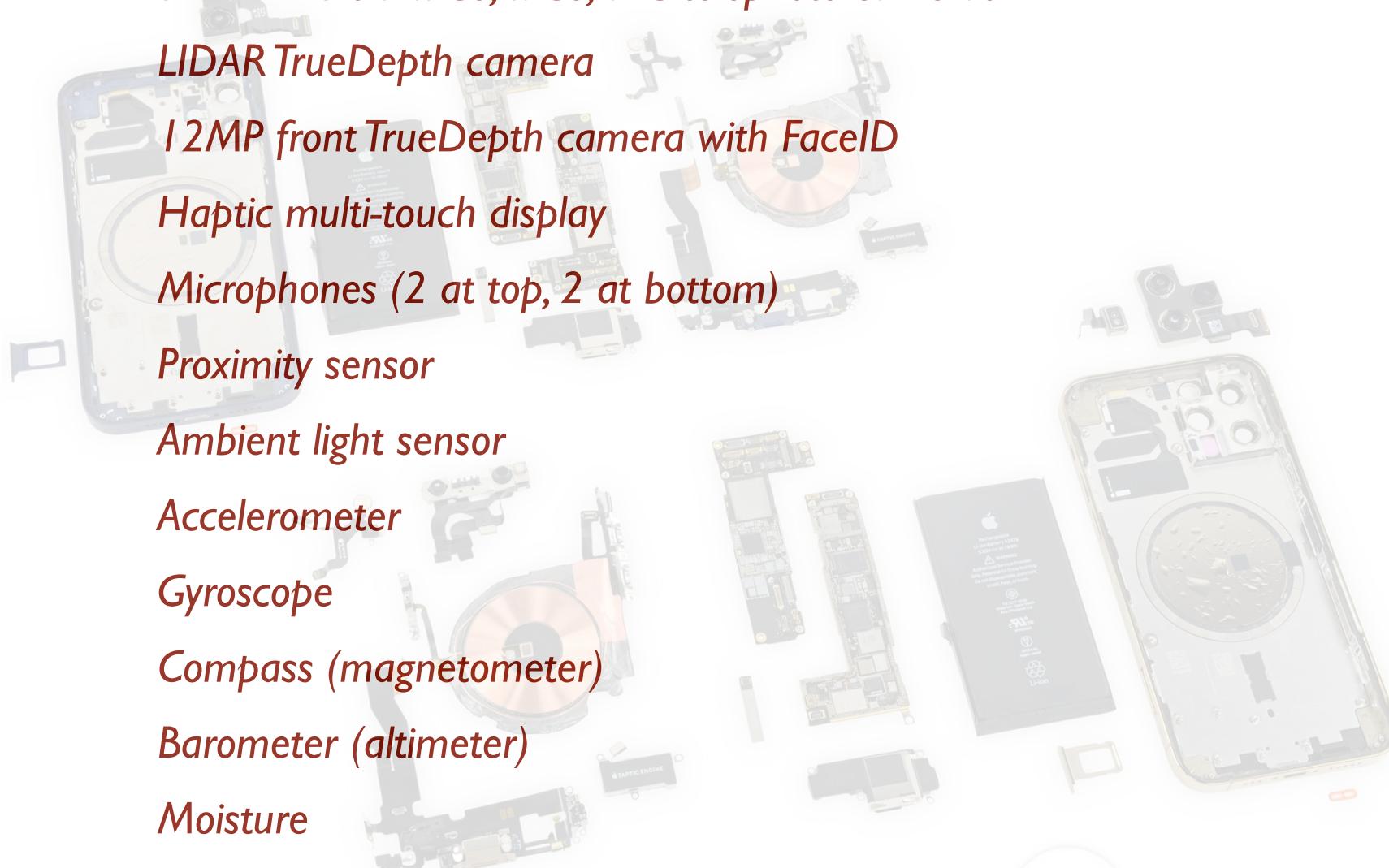
Gyroscope

Compass (magnetometer)

Barometer (altimeter)

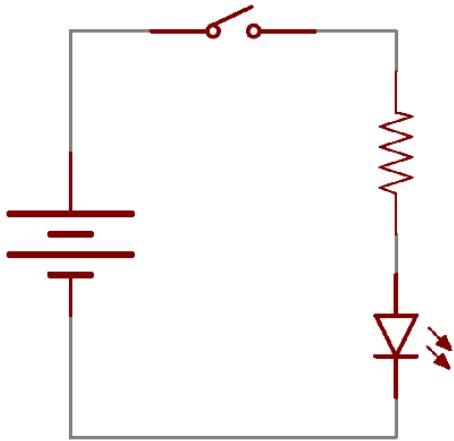
Moisture

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

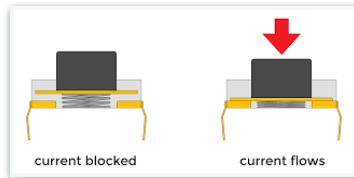


How many sensors?

Buttons and switches



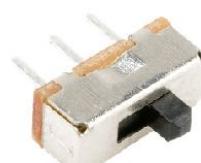
Push button



Button groups



Toggle



Slide



Microswitch



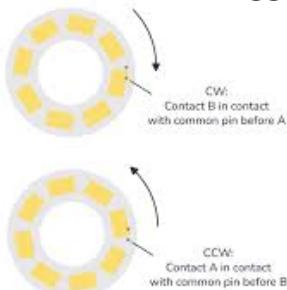
Rocker



Membrane keypad



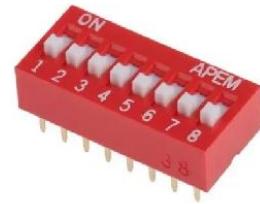
Rotary encoder



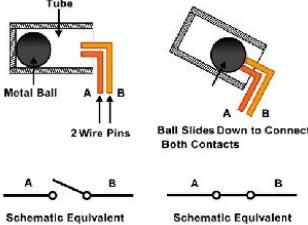
Dial wheels



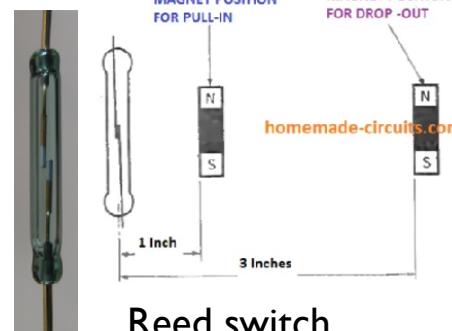
Rotary position



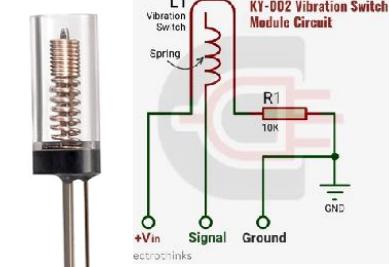
Dip switch



Tilt switch



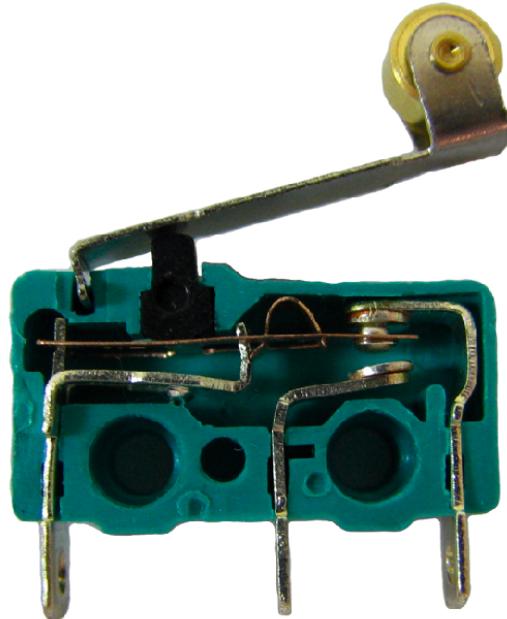
Reed switch



Vibration switch

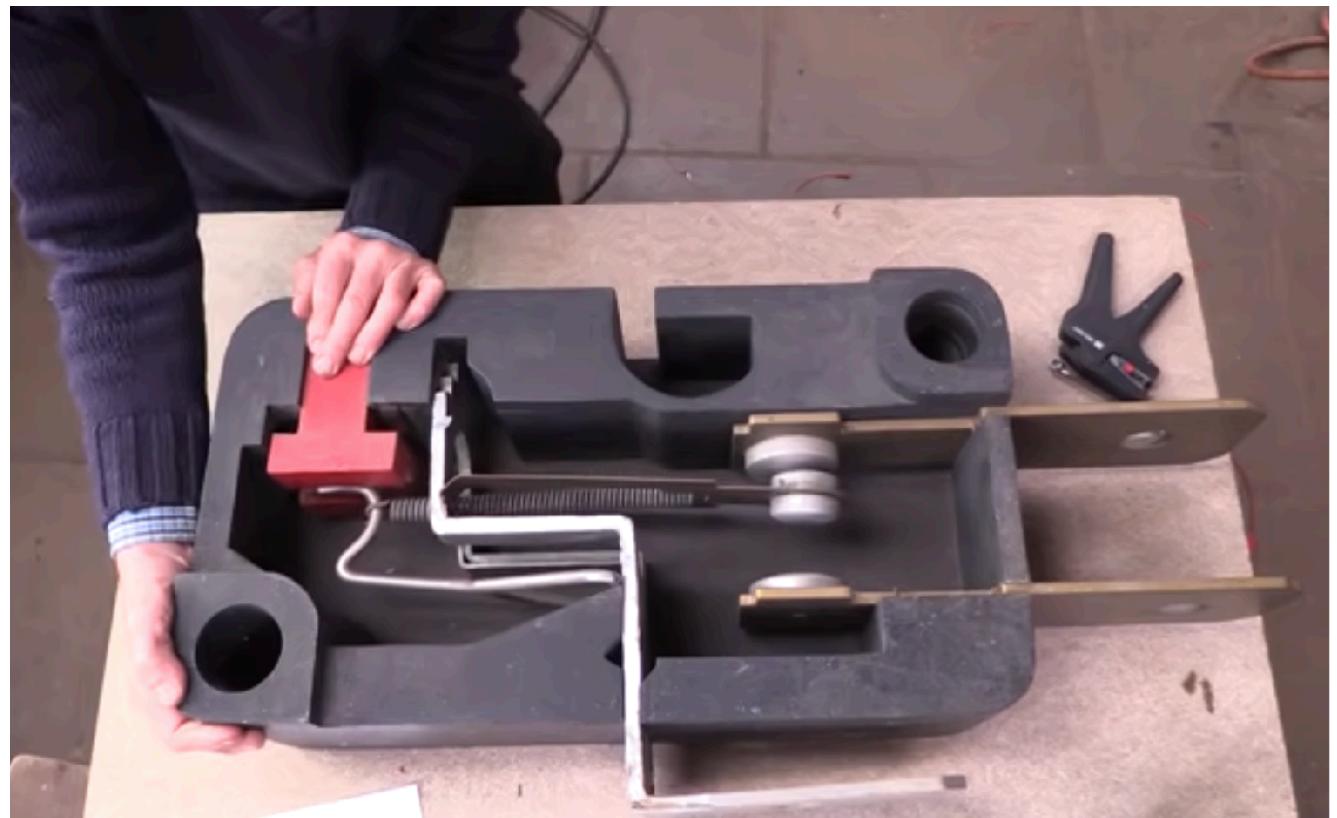
... and many more

Snap-action microswitch



Common NO NC

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



Patented in **1932!**

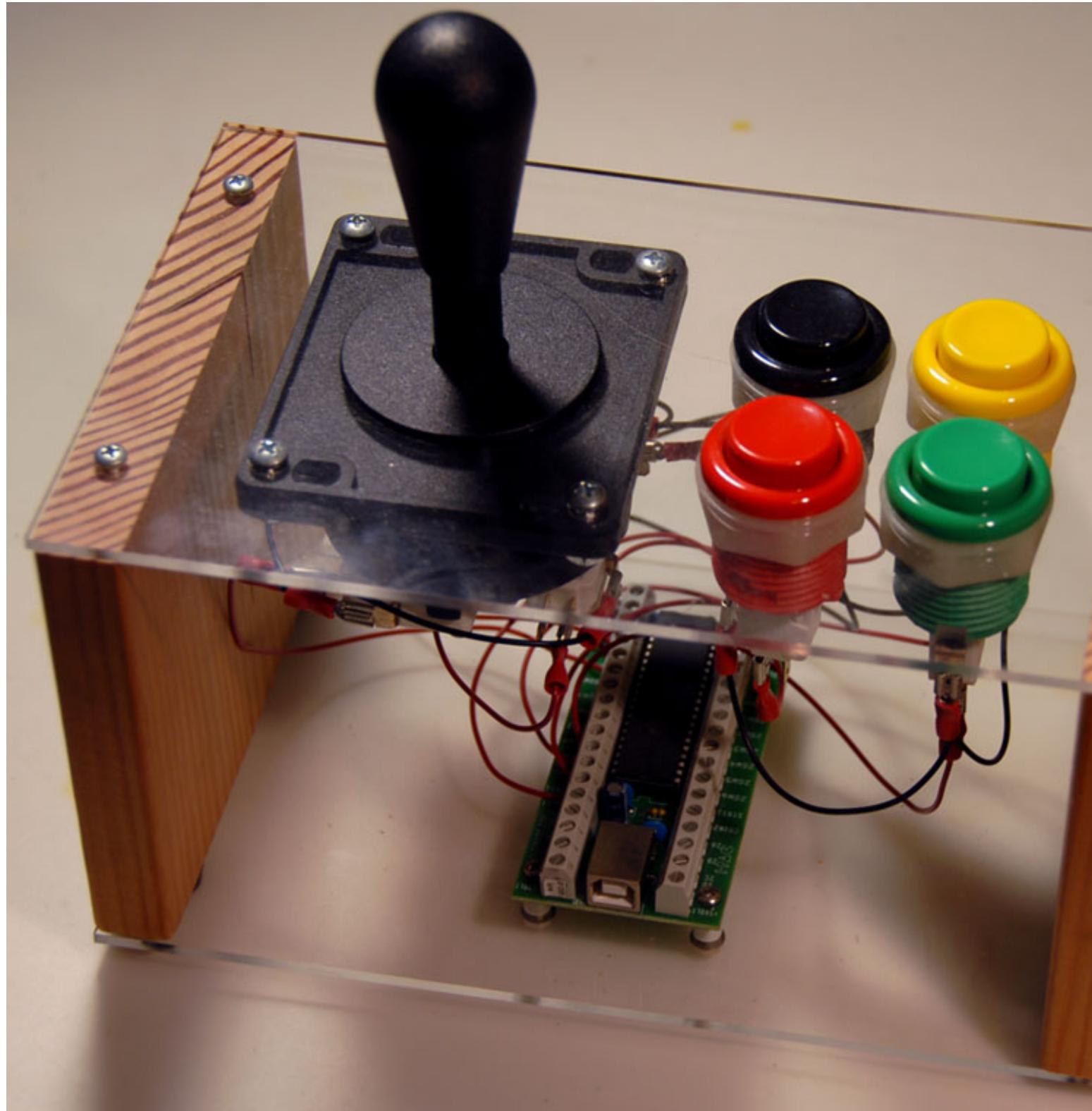
Tim Hunkin video: All about Switches

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

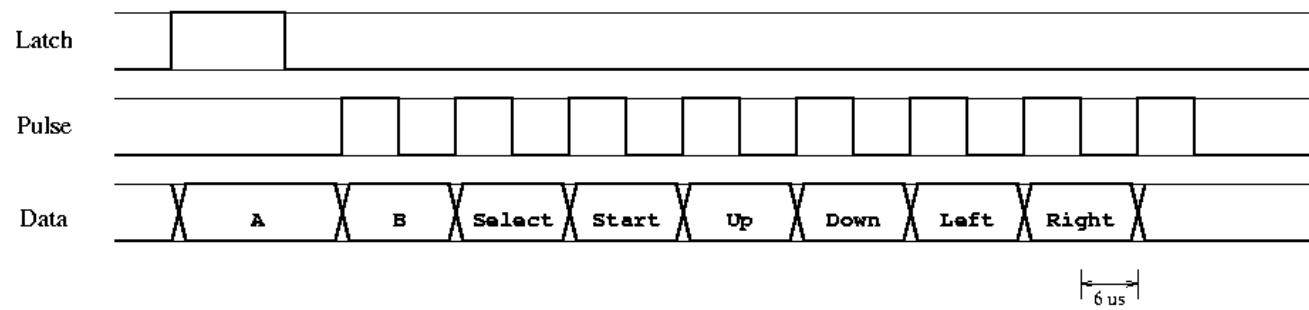
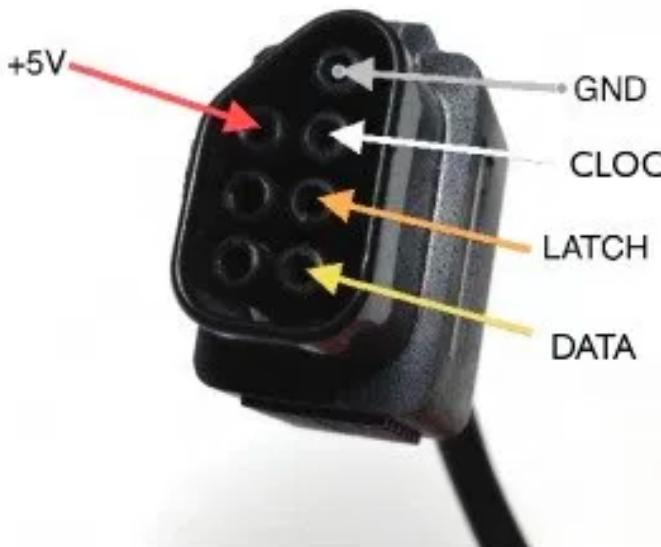
Happ pushbutton



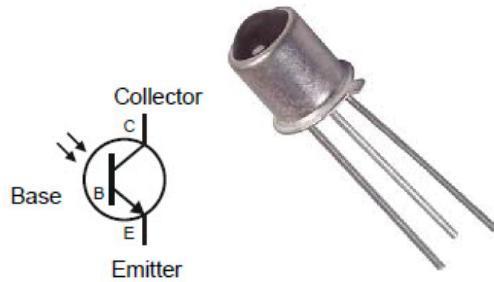
Happ joystick



Retro game controllers



Transistor sensors



Phototransistor
(light)



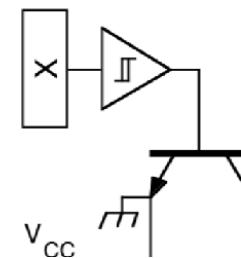
Capacitance



Gas



Hall Effect
(magnetic field)



IR detector



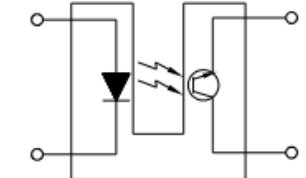
Passive infrared
(PIR)



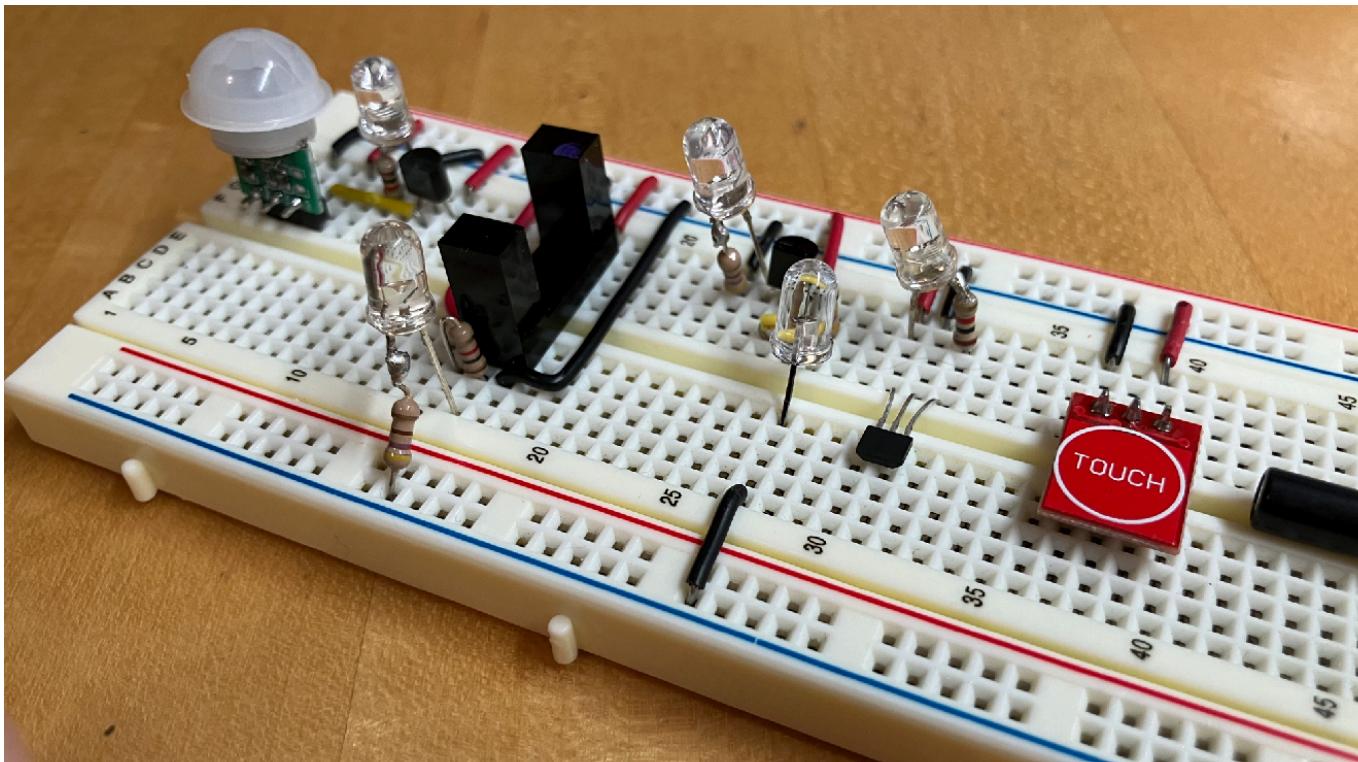
Temperature



Photointerrupter
(presence)



Demo: transistor sensors



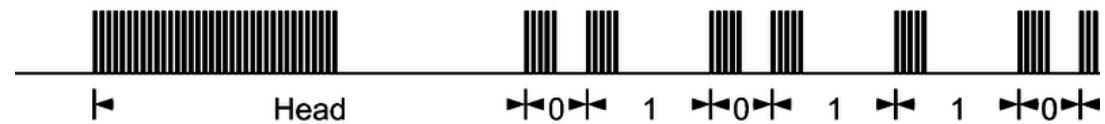
Passive IR, Photointerruptor, Phototransistor, Hall effect, Capacitive touch

Demo: IR communication

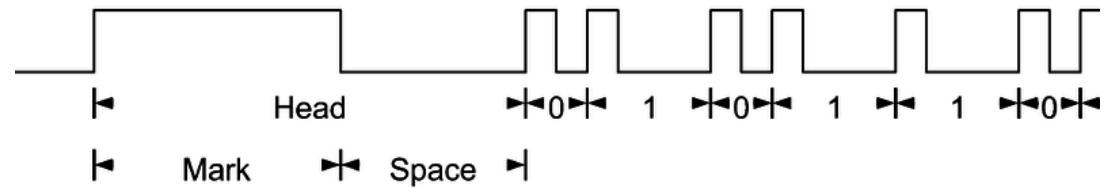


38 Khz IR Detector

Modulated IR signal



De-Modulated IR signal

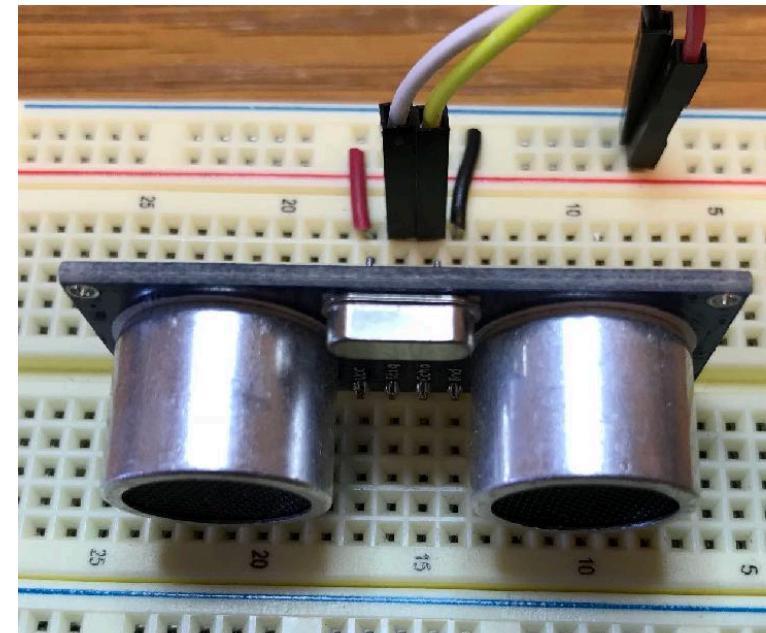
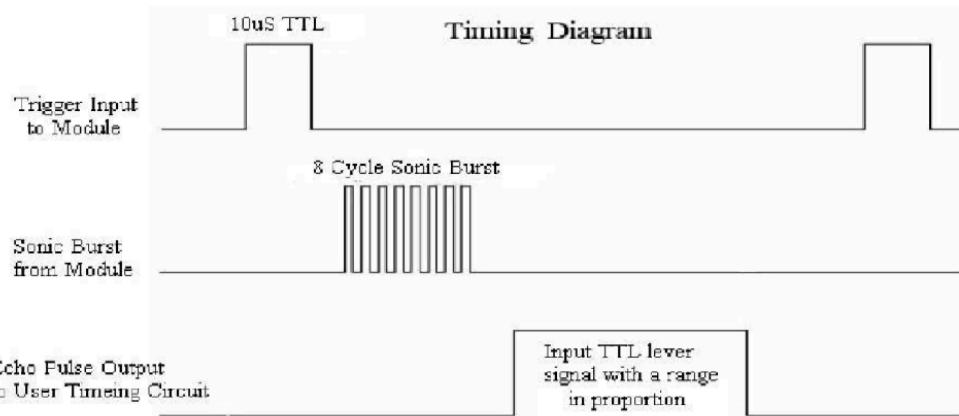


Apple Remote

Demo: Proximity detection

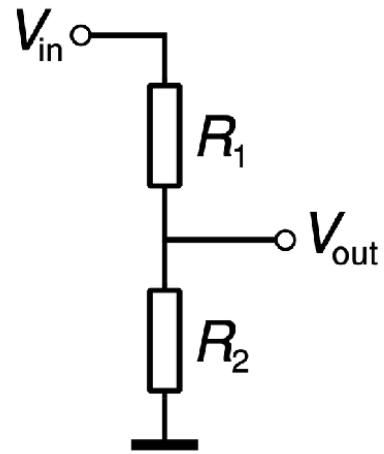
Measures time of flight
sound wave to object and return

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: $uS / 58 = \text{centimeters}$ or $uS / 148 = \text{inch}$; 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.

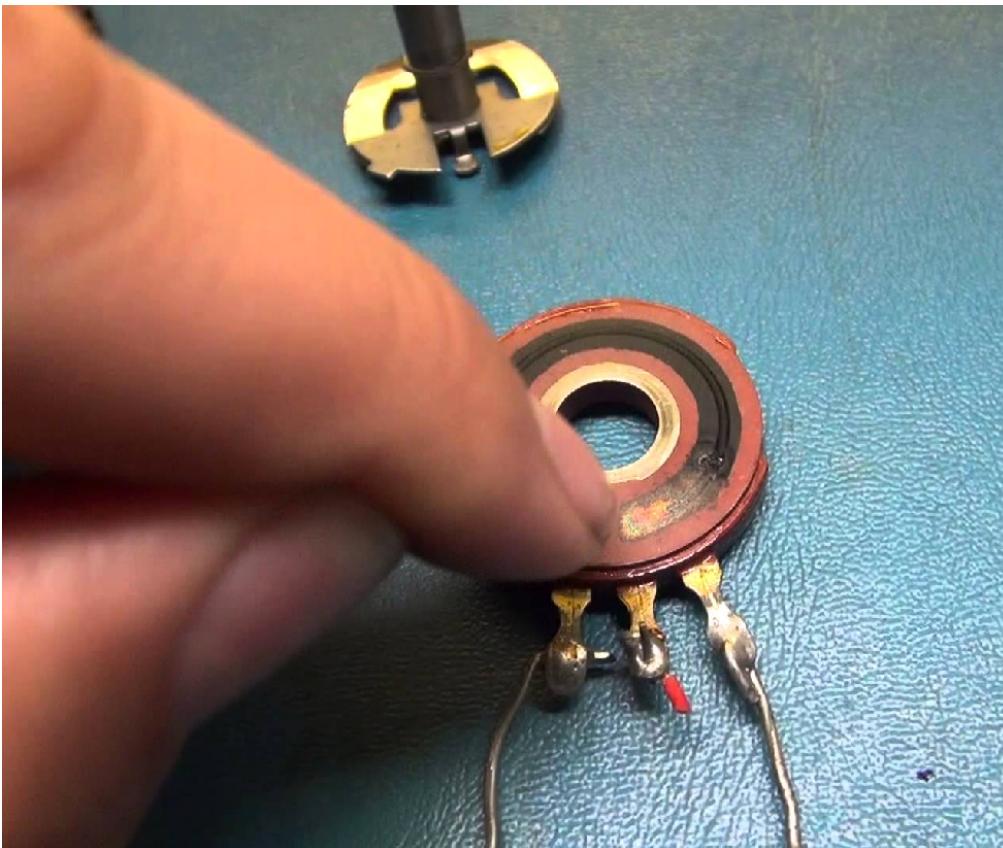
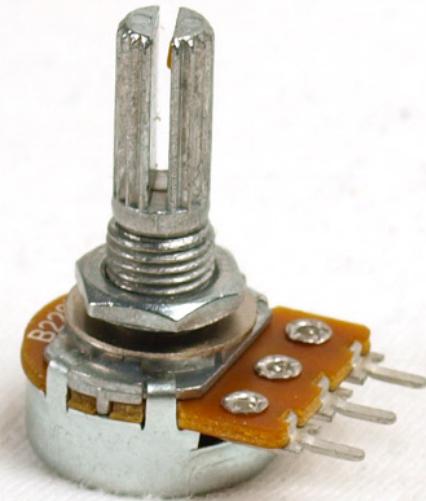


HC-SR04 ultrasonic sensor

Analog to Digital conversion (ADC)



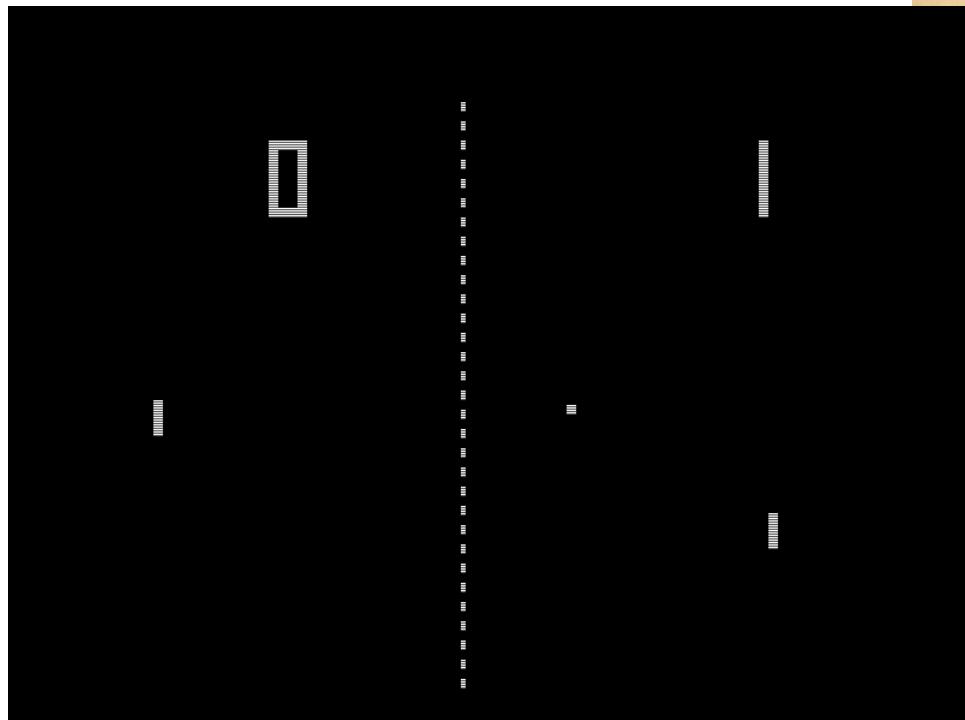
$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$



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

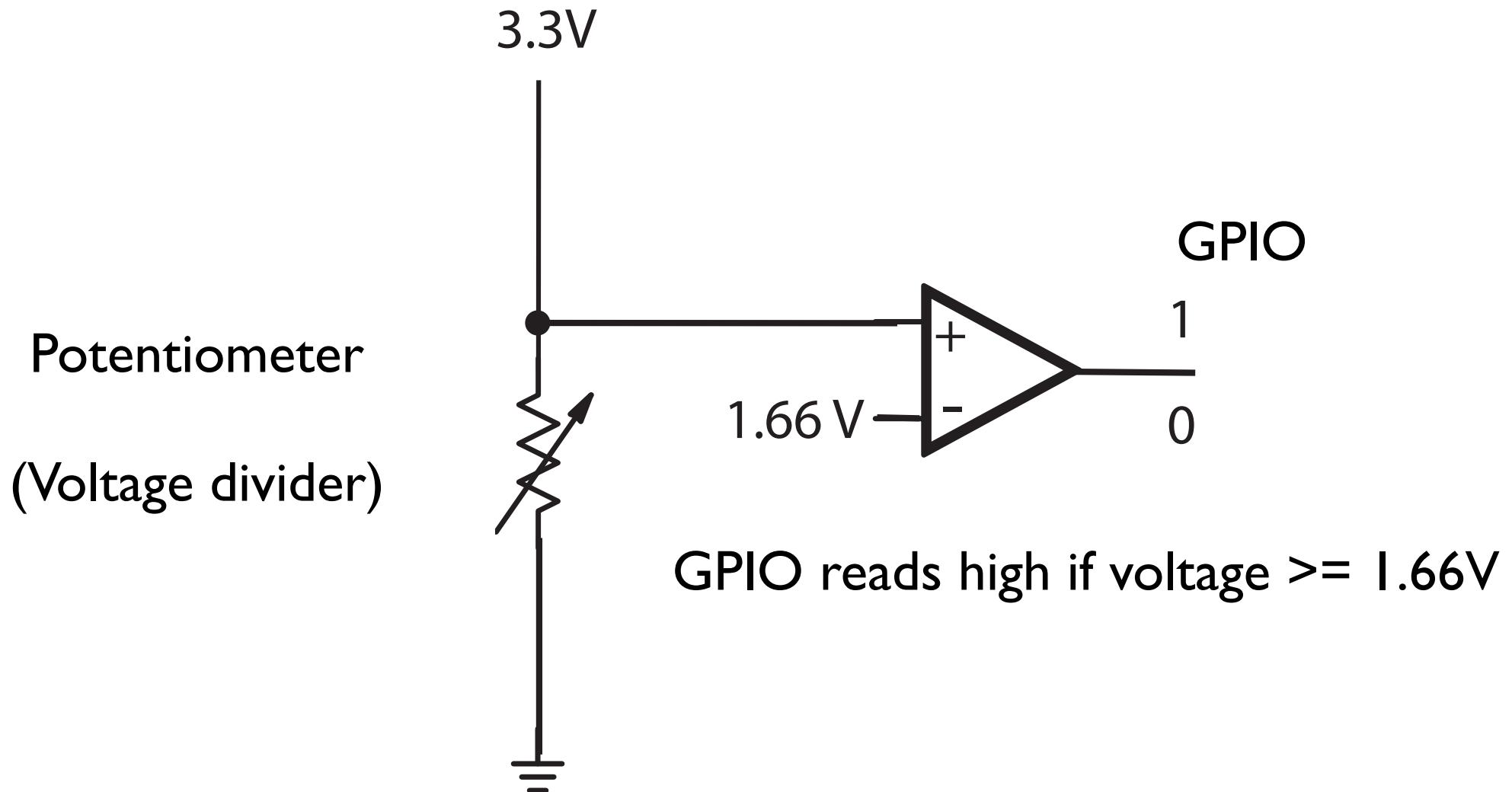
THIS GAME IS AVAILABLE FROM YOUR LOCAL DISTRIBUTOR

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

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

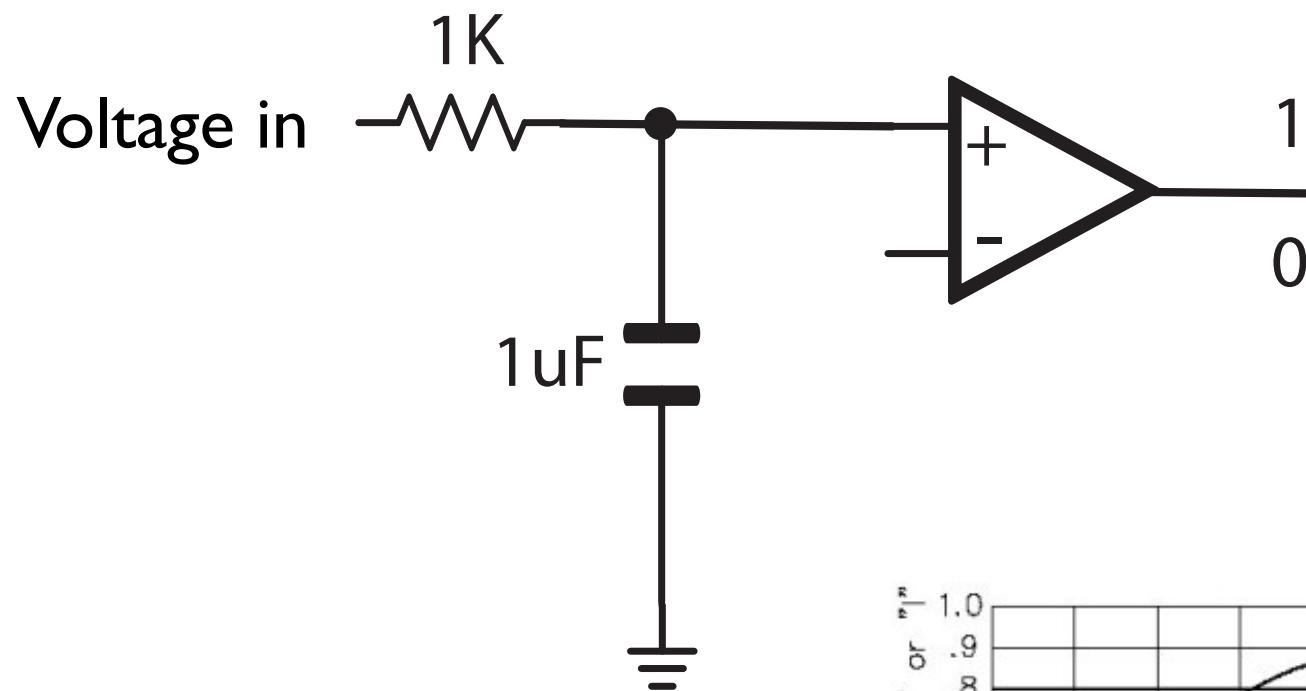


GPIO as comparator

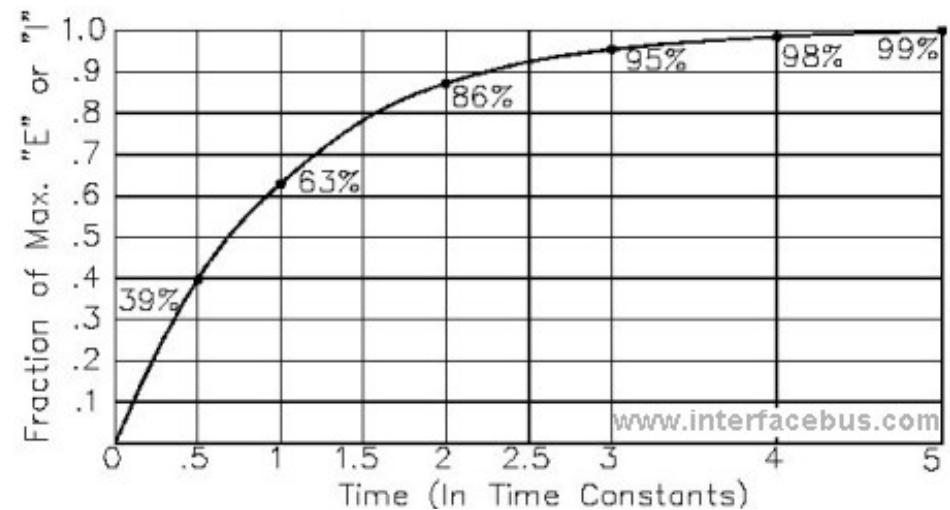


RC Charge circuit

Time to charge depends on voltage of input

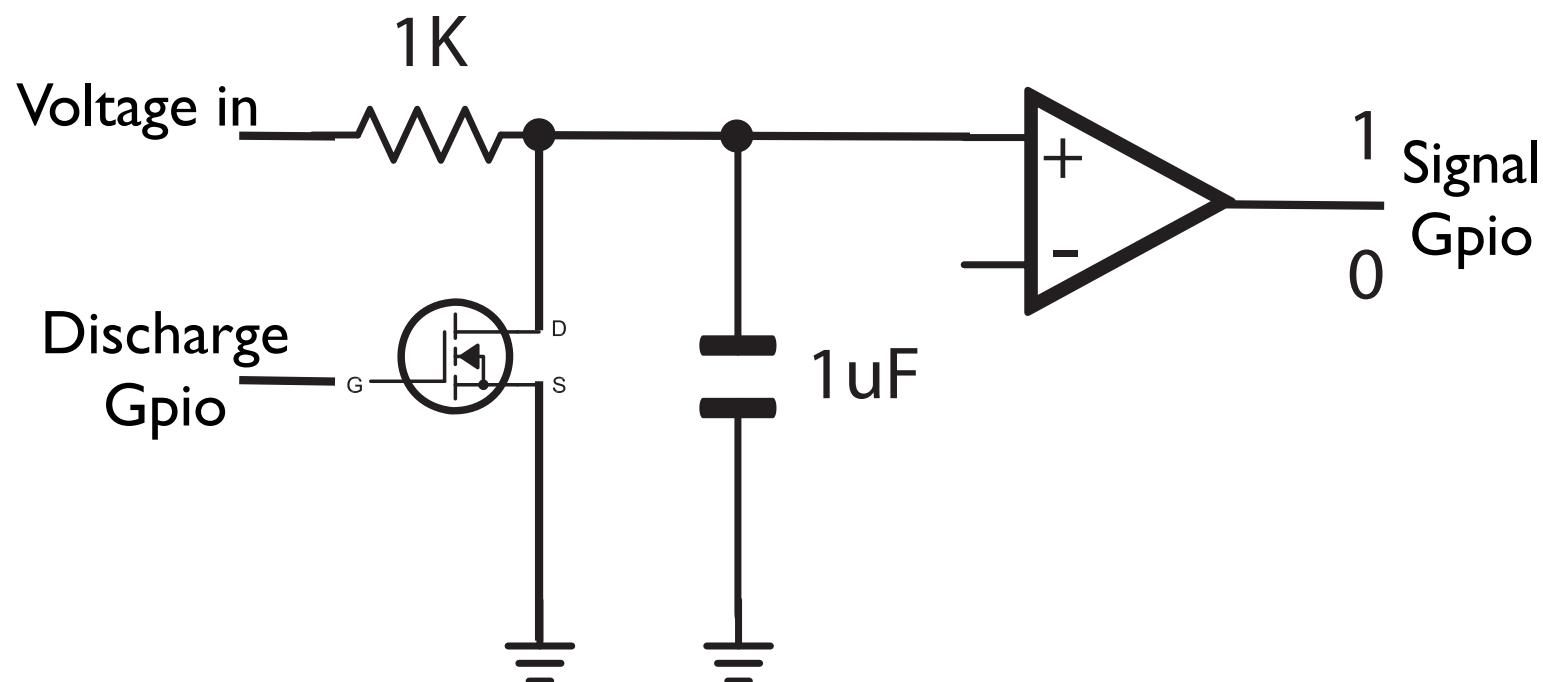


$$RC = 10^3 \times 10^{-6} = 1000 \text{ usecs}$$

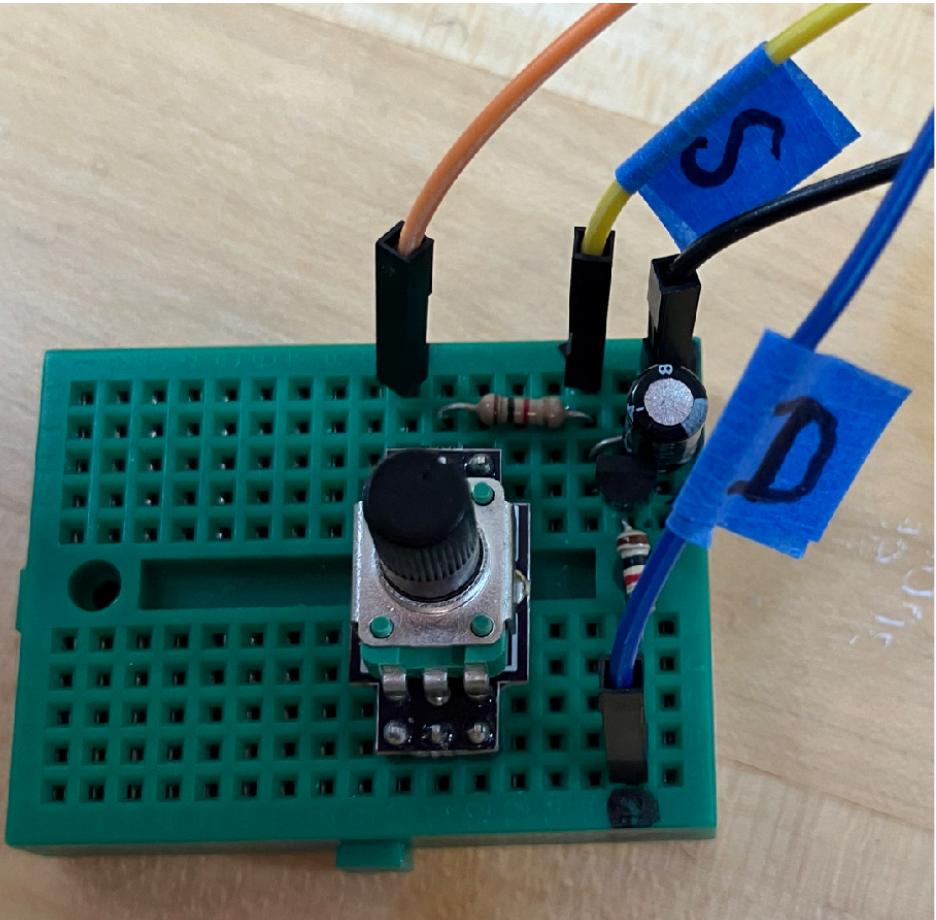
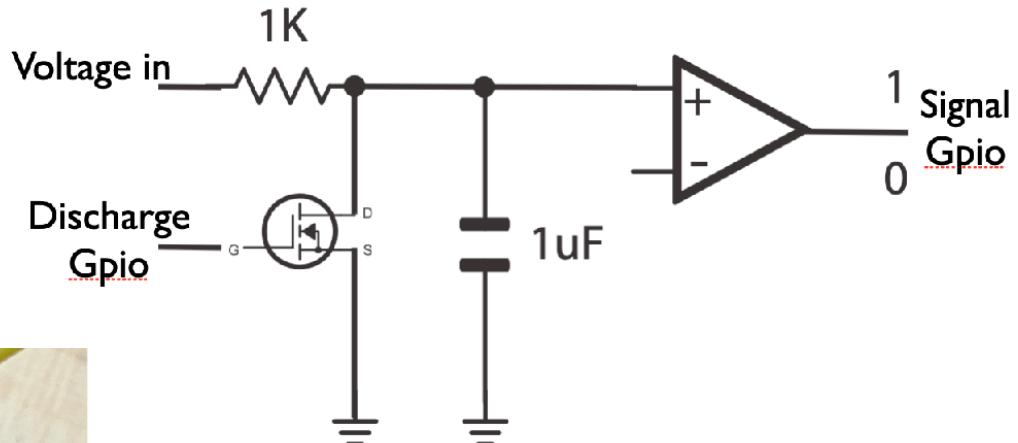


RC circuit ADC

- 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

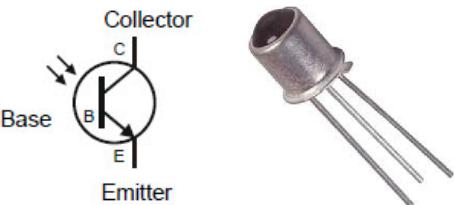


```
unsigned long get_charge_time(void)
{
    // transistor on, will discharge cap
    gpio_write(discharge, 1);
    timer_delay_ms(10);
    // transistor off, cap will recharge
    gpio_write(discharge, 0); //

    // 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

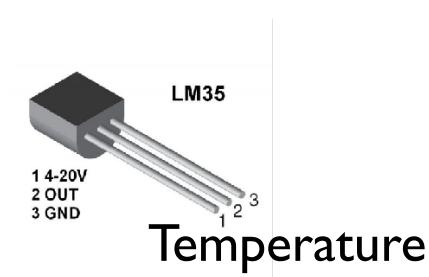
Use with comparator for digital switch or ADC to read analog value



Phototransistor
(light)



Flex
(deformation)



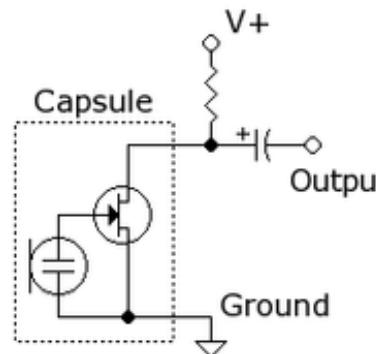
Temperature



Force



Potentiometers



Electret microphone
(pressure)



Load cell
(strain/stress)

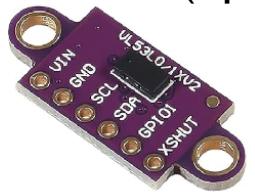


Joystick

Smart sensors

ICs (on-board conversion, communication via I2C/SPI/One-wire)

Time of flight range finder
(optical/laser)



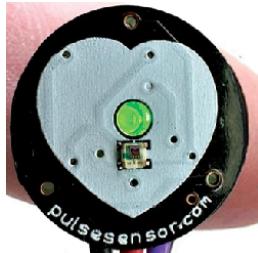
Accelerometer
Gyroscope



RGB/light



Temperature



Heart rate
Oxygen saturation



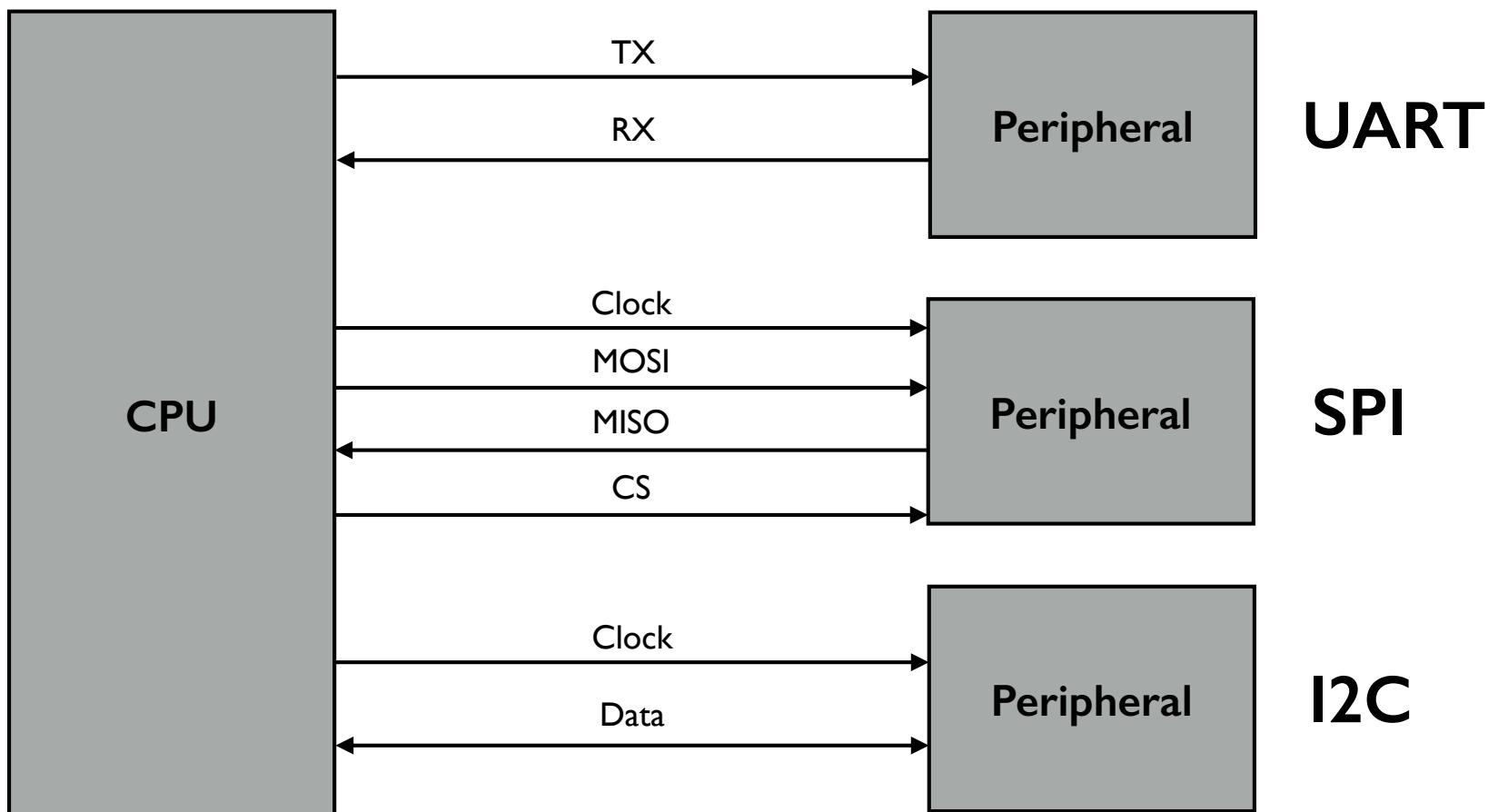
Real-time clock
(battery backup power)

Pressure
Humidity
Temp



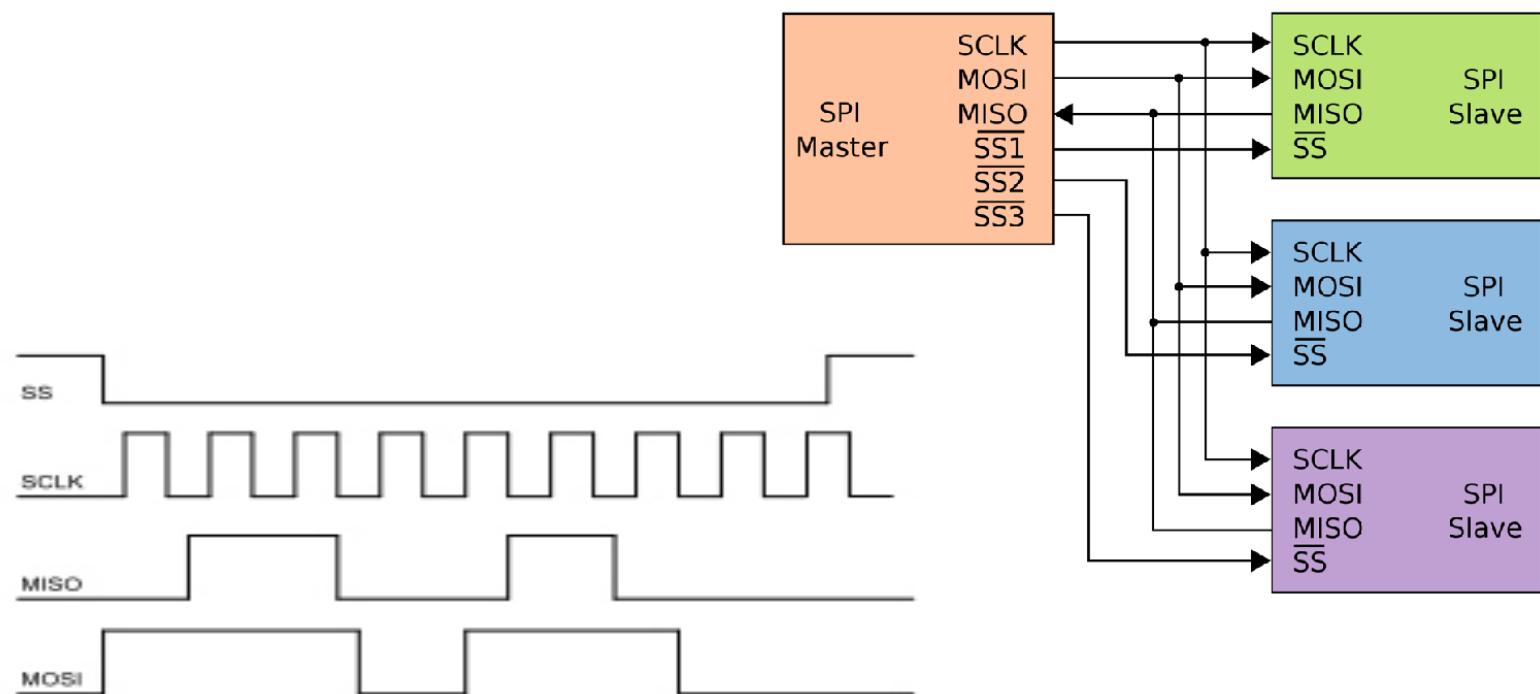
Camera

Bus protocols



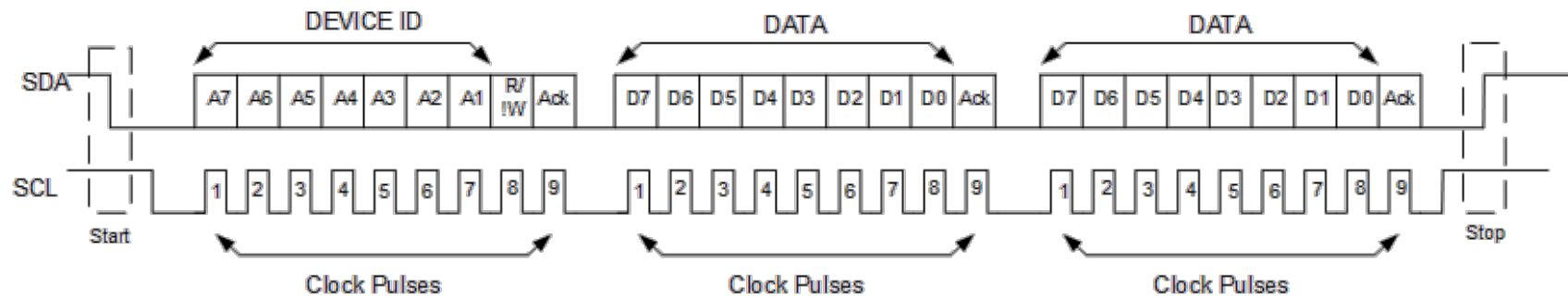
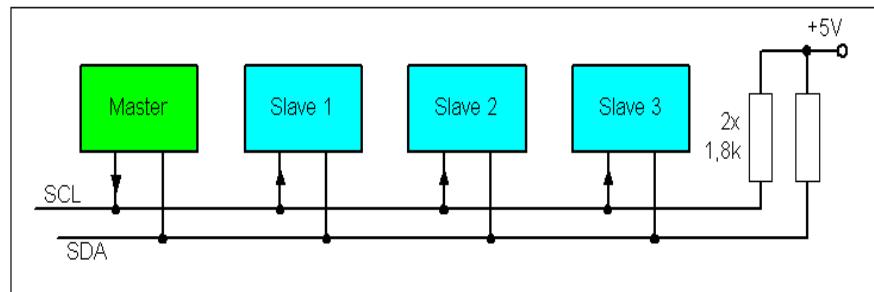
SPI

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



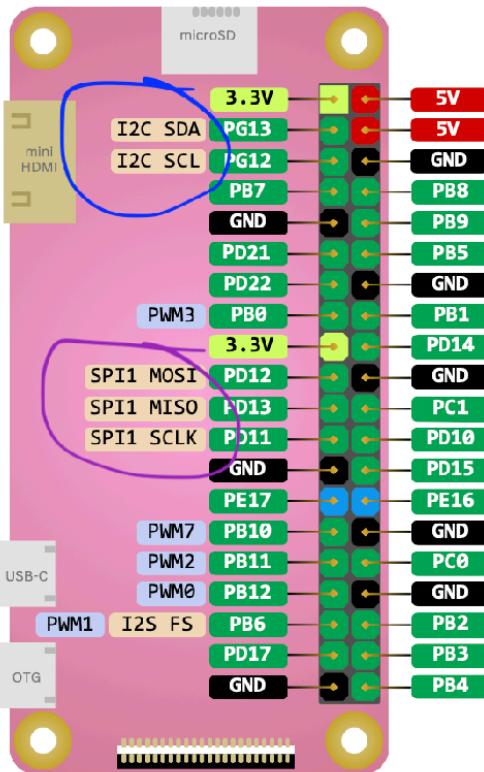
I2C

- 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_I_Waveform.png (bottom)

DI 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

Confidential

9.3 SPI

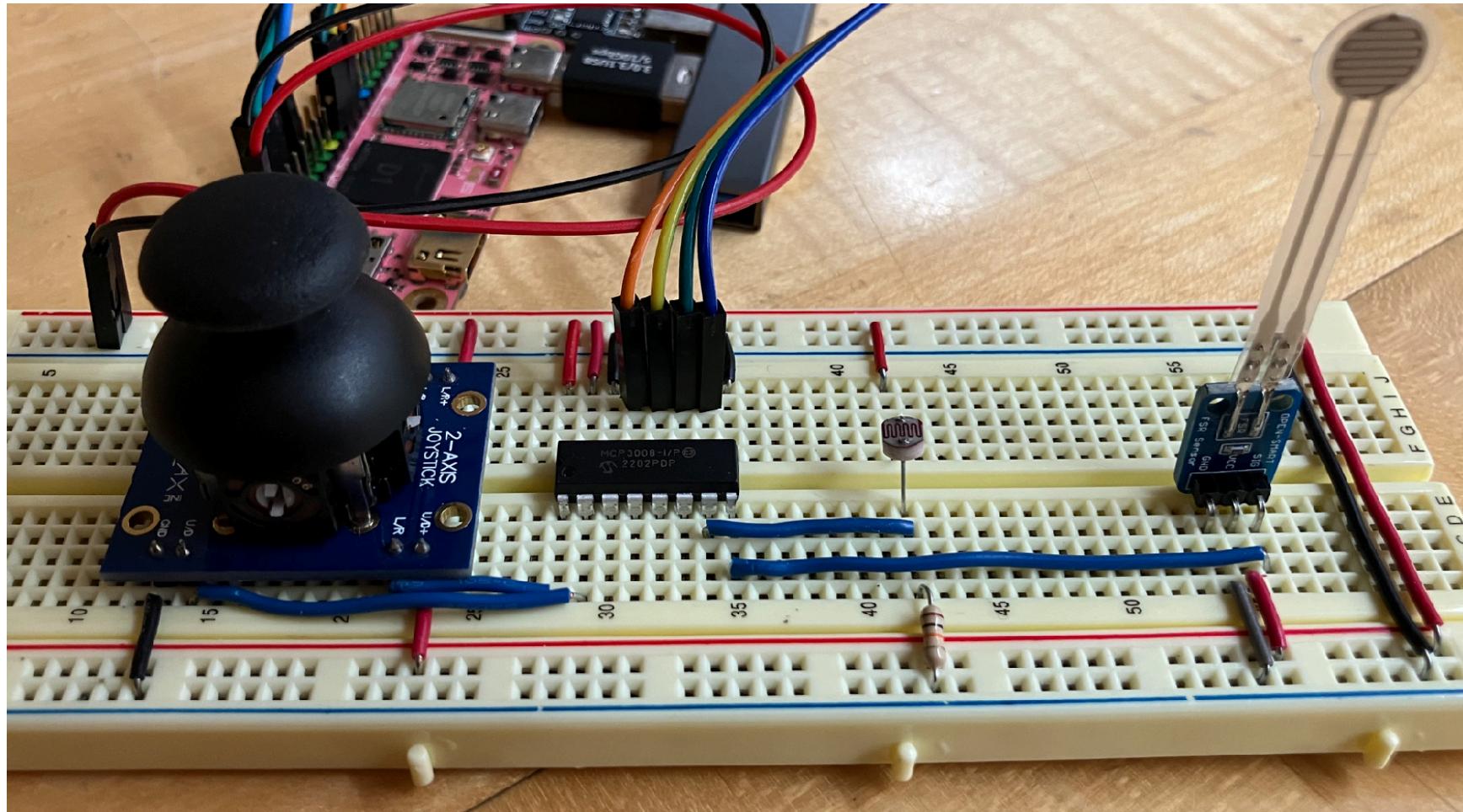
9.3.1 Overview

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**

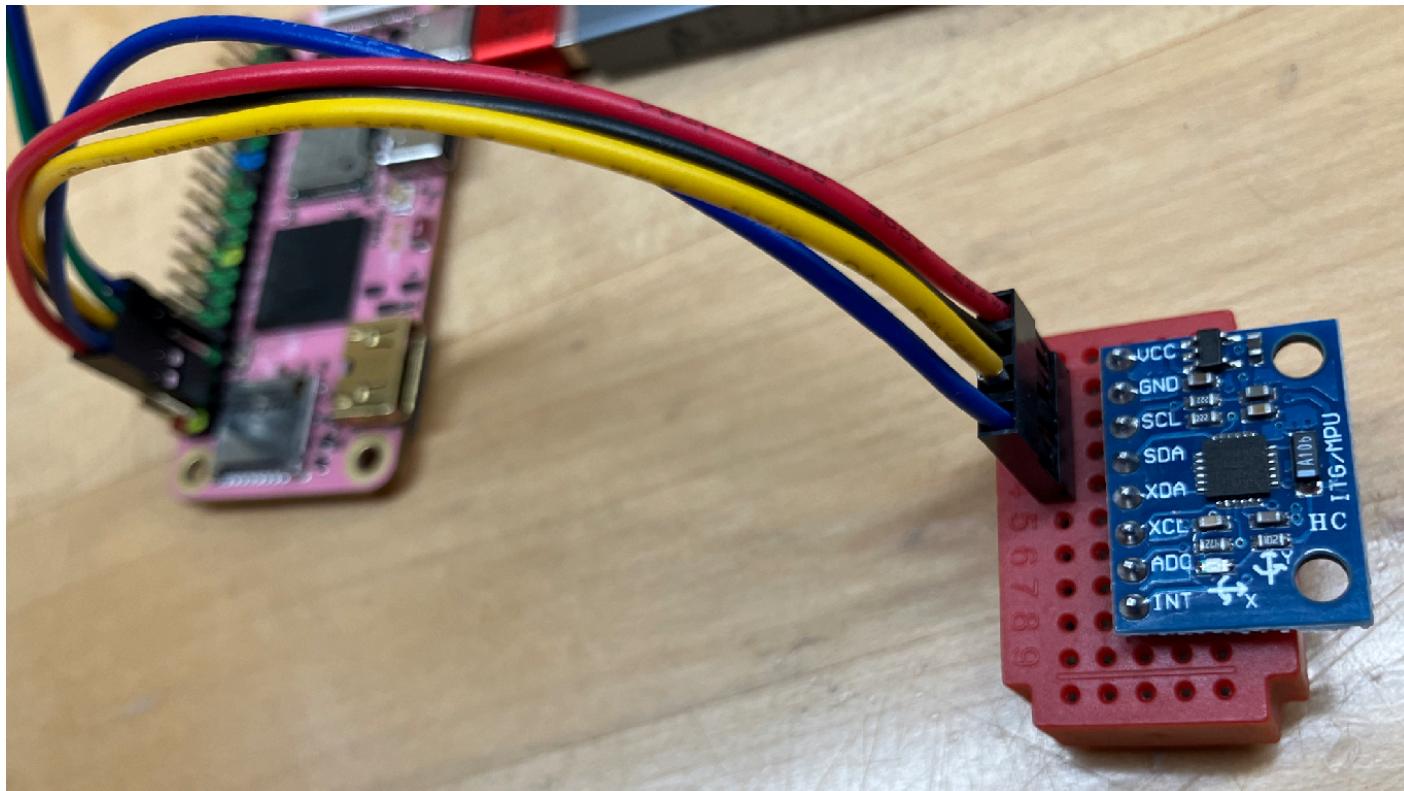
Demo: SPI



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, ...