

Final Projects

Project proposal ideas and hints (<http://cs107e.github.io/project/>)

Form project teams NOW - 1-3 people (2 best)

Google form due 11:59 pm Sun Feb 27

- **Include teammates for shared git repo**
- **Includes short project proposal**

Two labs

- **1st - refine project ideas and solid milestones**
- **2nd - finish milestones and final push**

Class demos (9 am Tue Mar 15)

Final code and writeup submission (due 11:59 pm Wed Mar 17)

\$20 parts budget per person; need to submit receipts

System Bonus

Grading criteria

- A
- P1 and P2 tests pass
- System bonus - final submission uses your own code
- Three extensions
- Excellent project

P1 bug fixes originally due Thu Mar 3rd

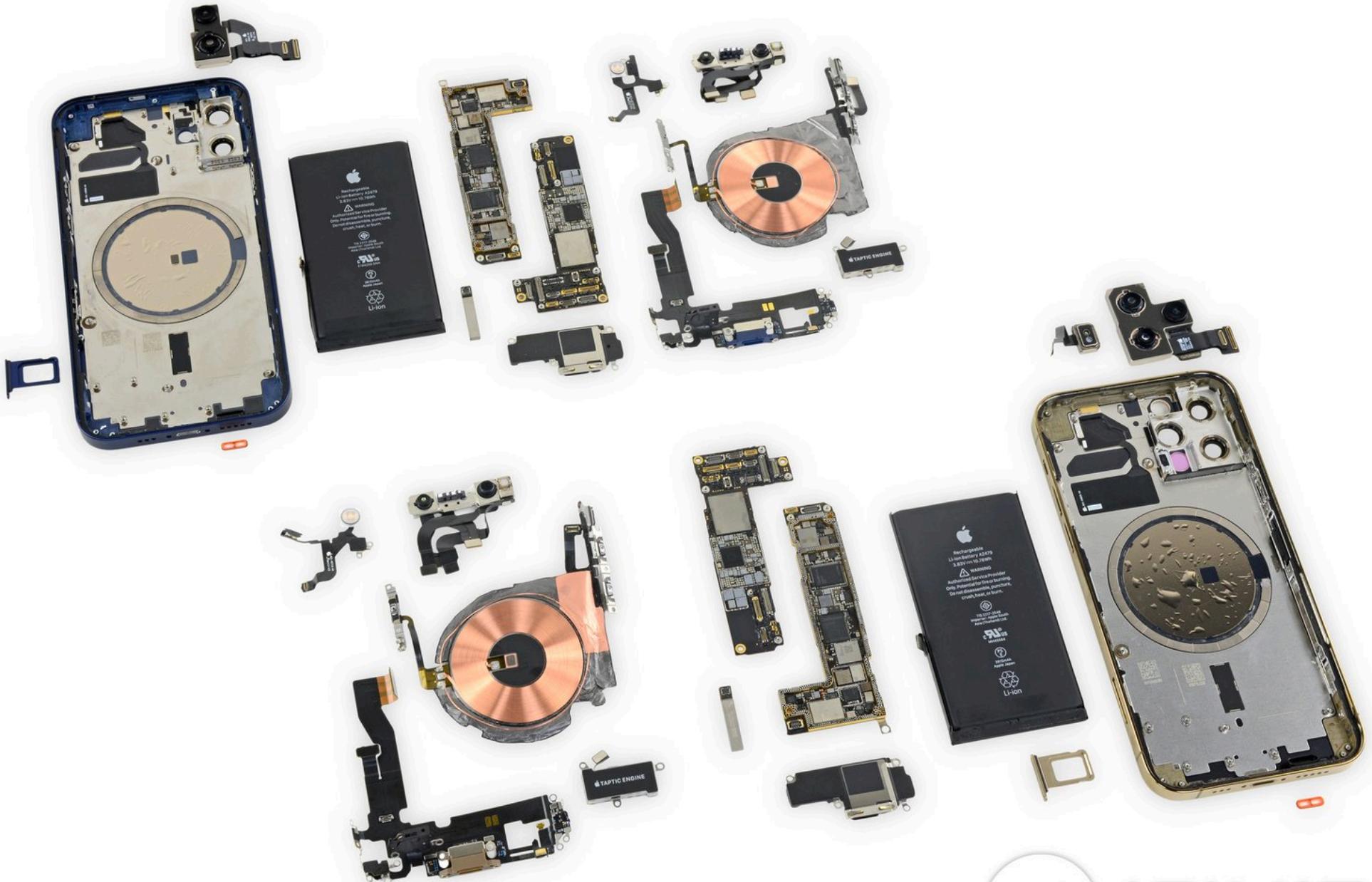
Will accept resubmissions until Sun Mar 6th

Bug fixing party this Sunday!!

CS107e

Sensors

Apple iPhone 12 Teardown



How many sensors?



How many sensors?

3 12MP Ultra wide, wide, and telephoto cameras

LIDAR TrueDepth camera

12MP front TrueDepth camera with FaceID

HapticTouch multi-touch vibrating display

Microphones (2 at top, 2 at bottom)

Proximity sensor

Ambient light sensor

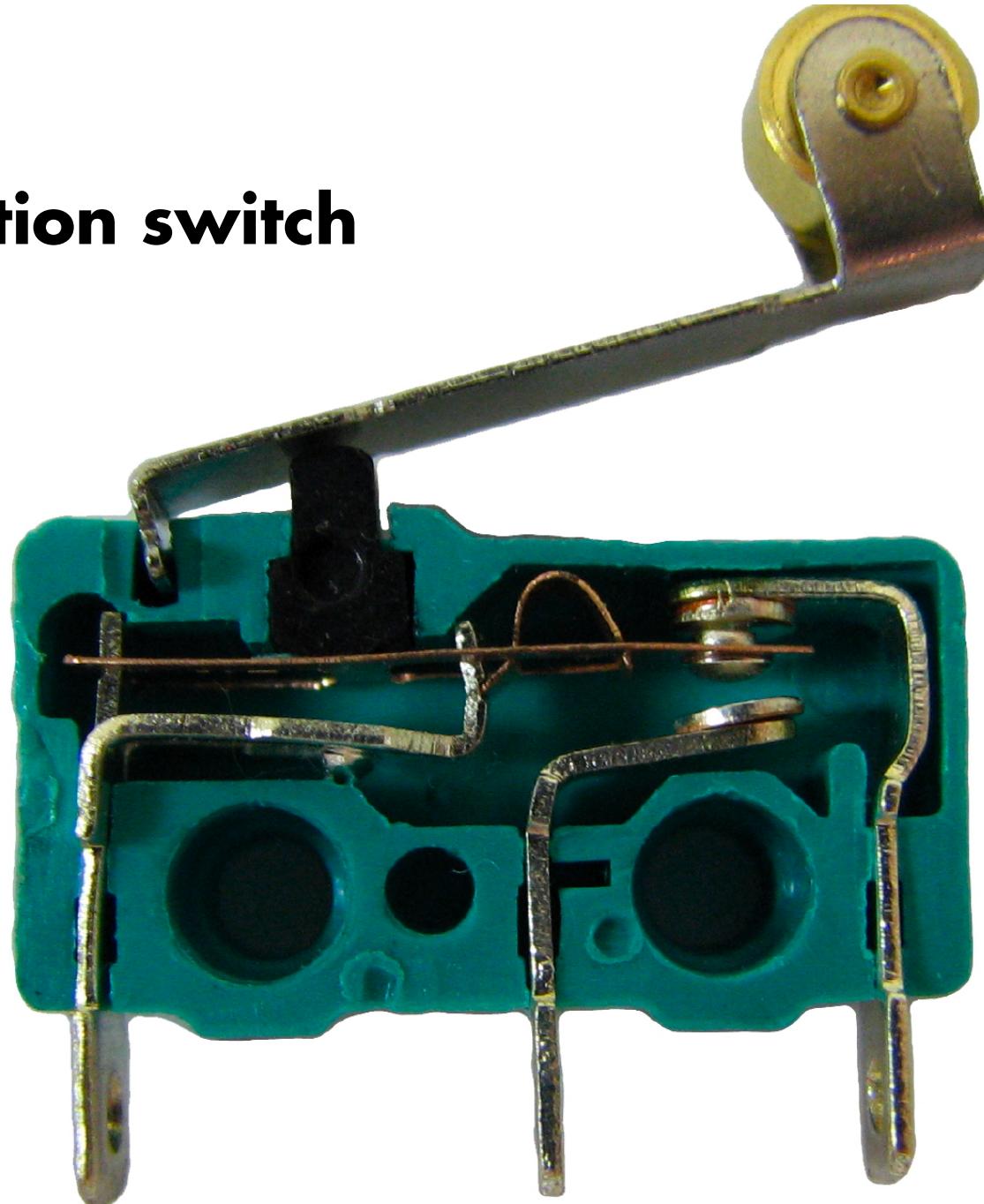
Accelerometer

Gyroscope

Compass (magnetometer)

Barometer (altimeter)

Snap-action switch



Common

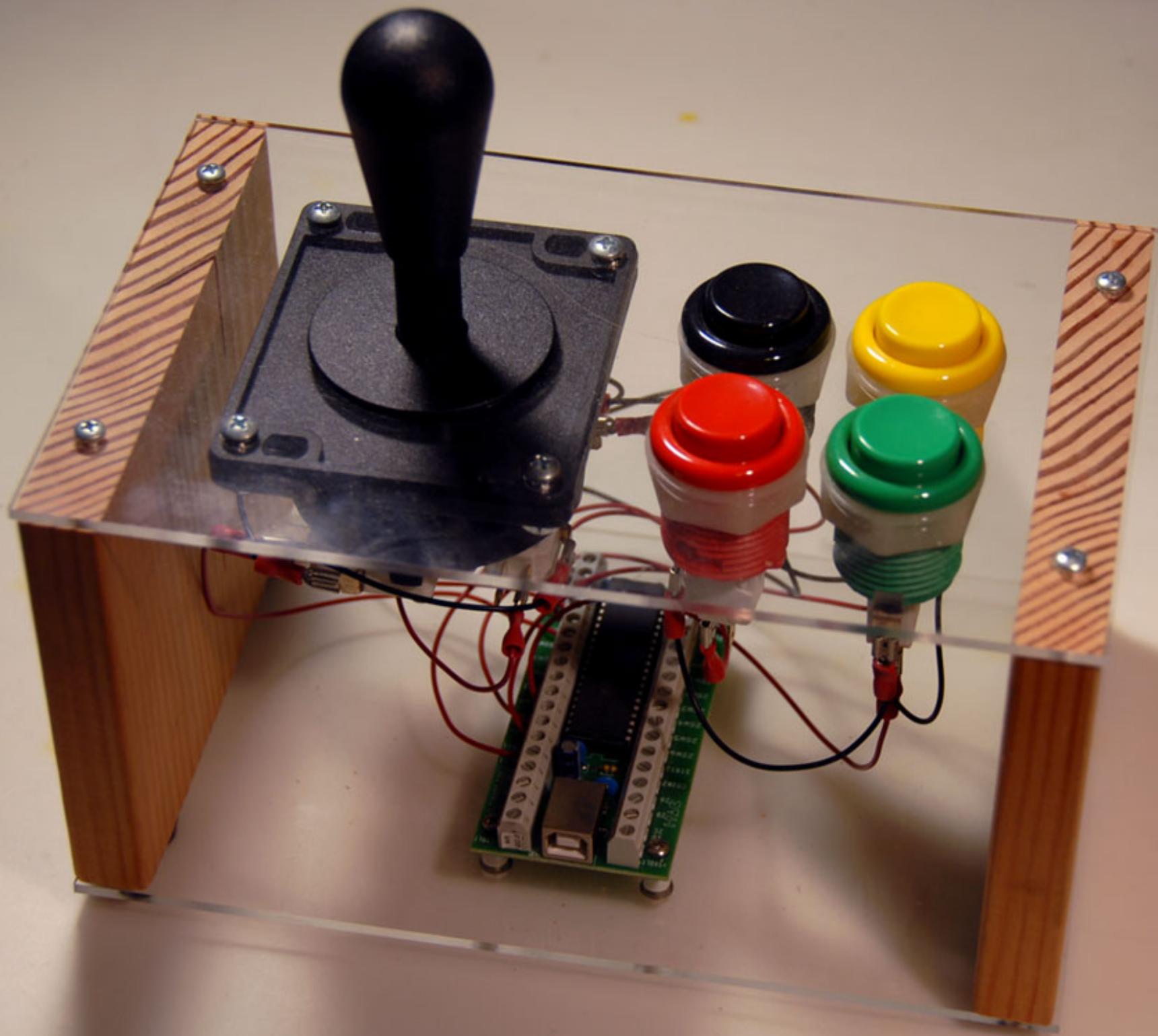
NO

NC

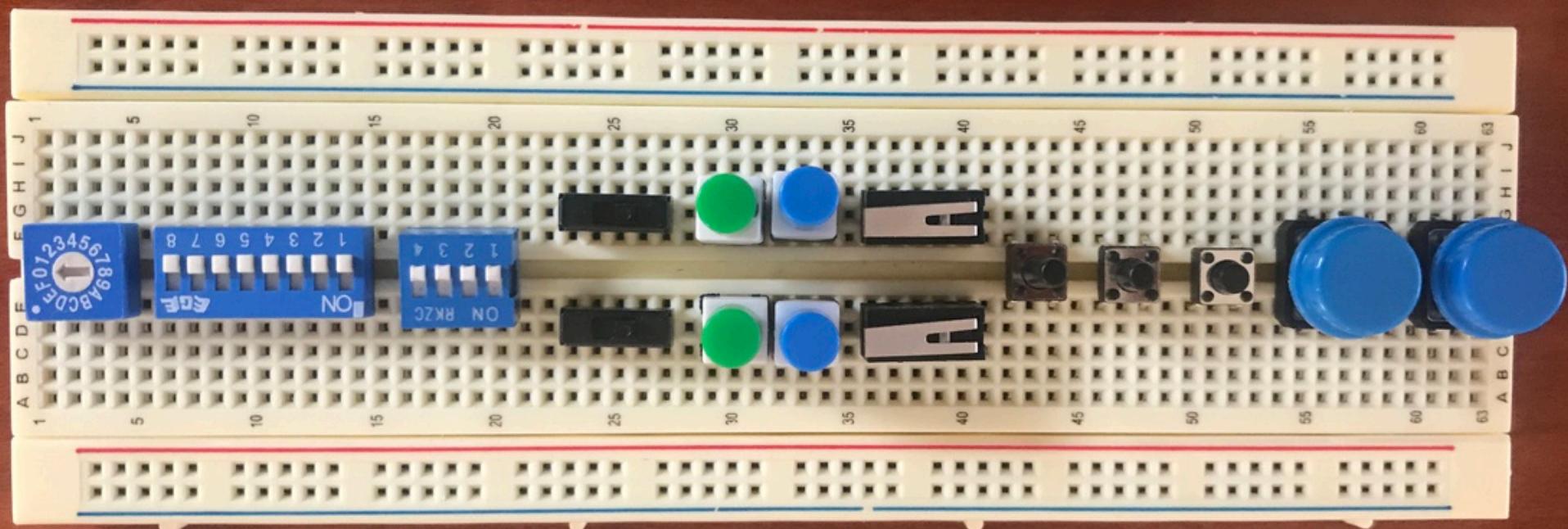
Happ Pushbutton



Happ Joystick



Buttons and Switches

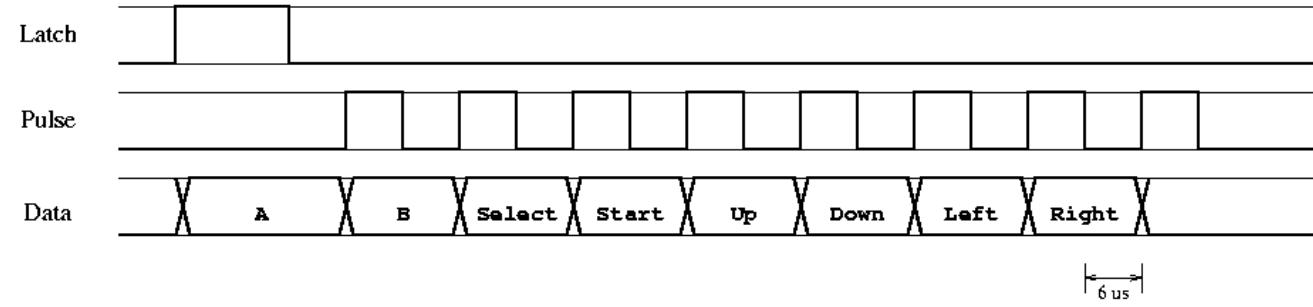
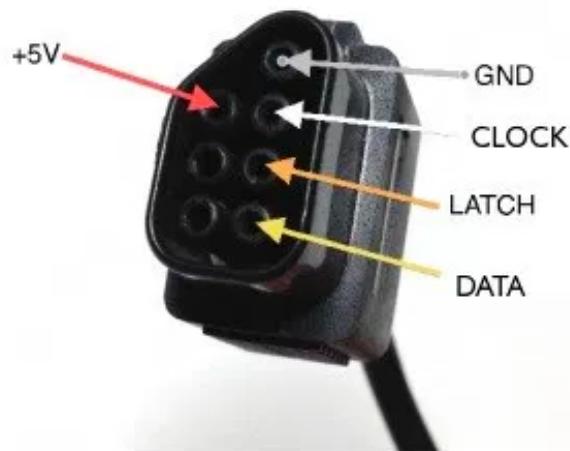


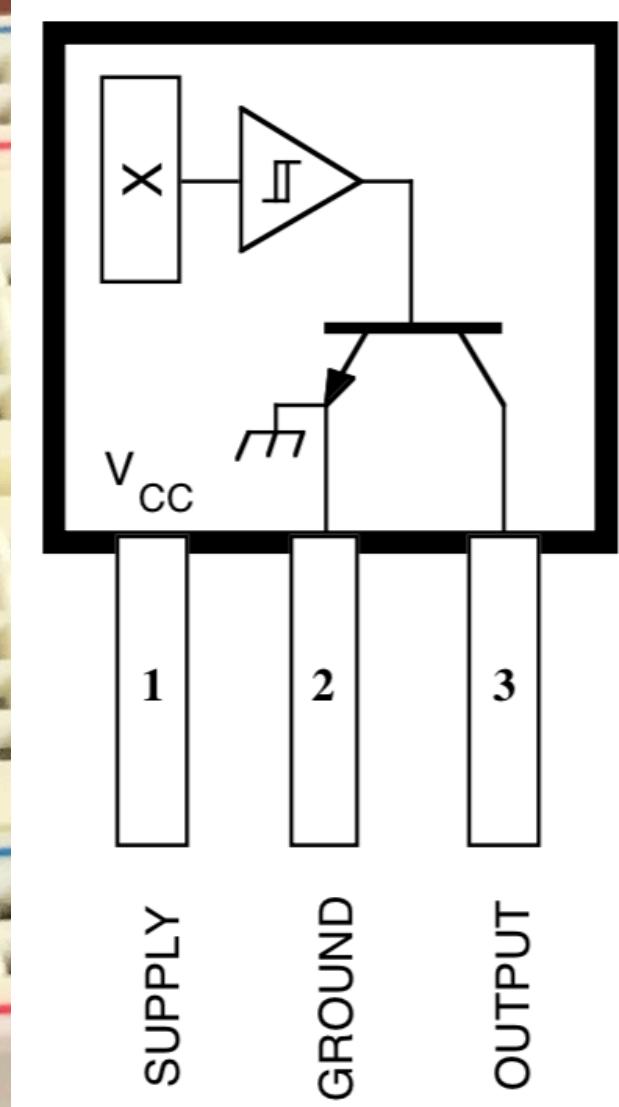
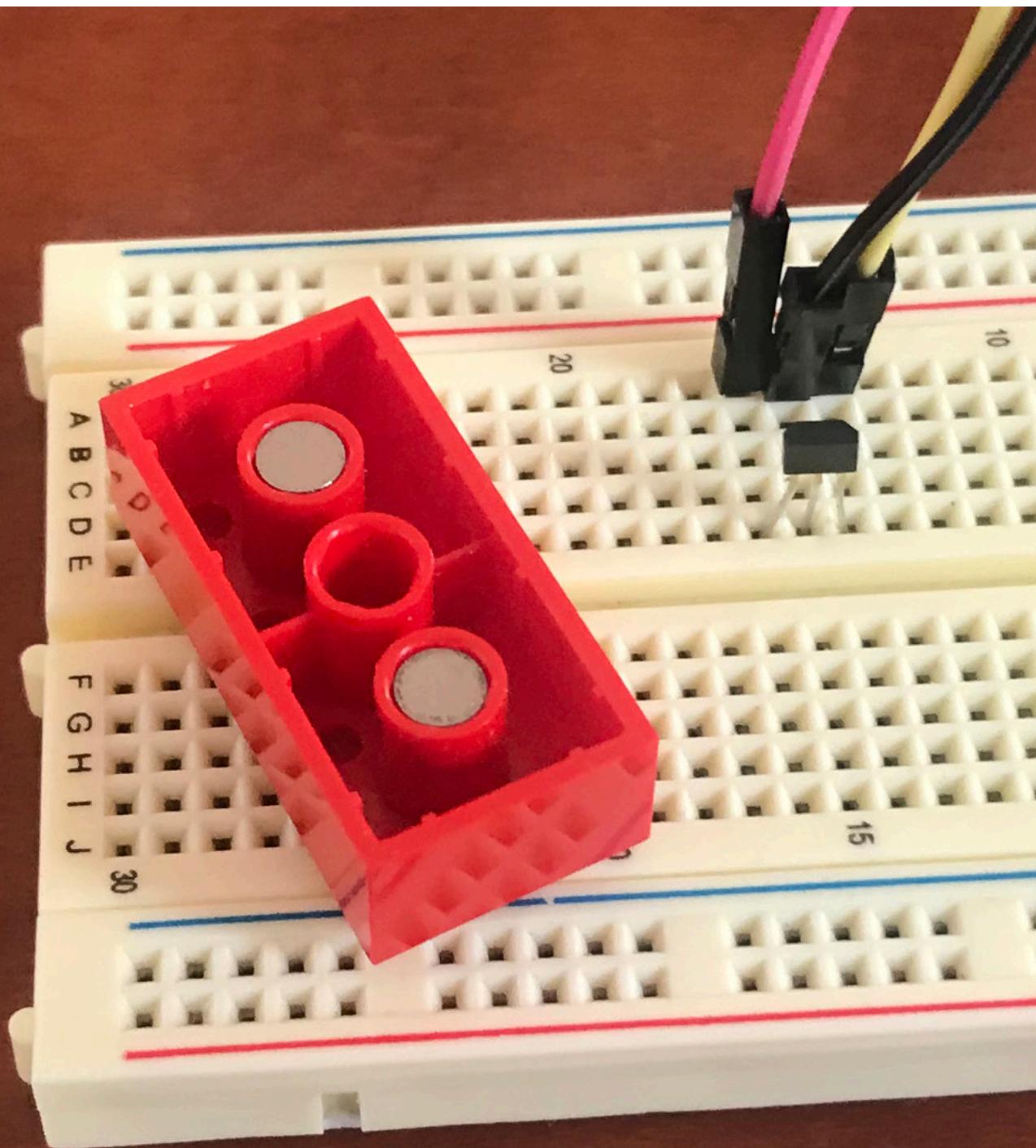


NES D-pad



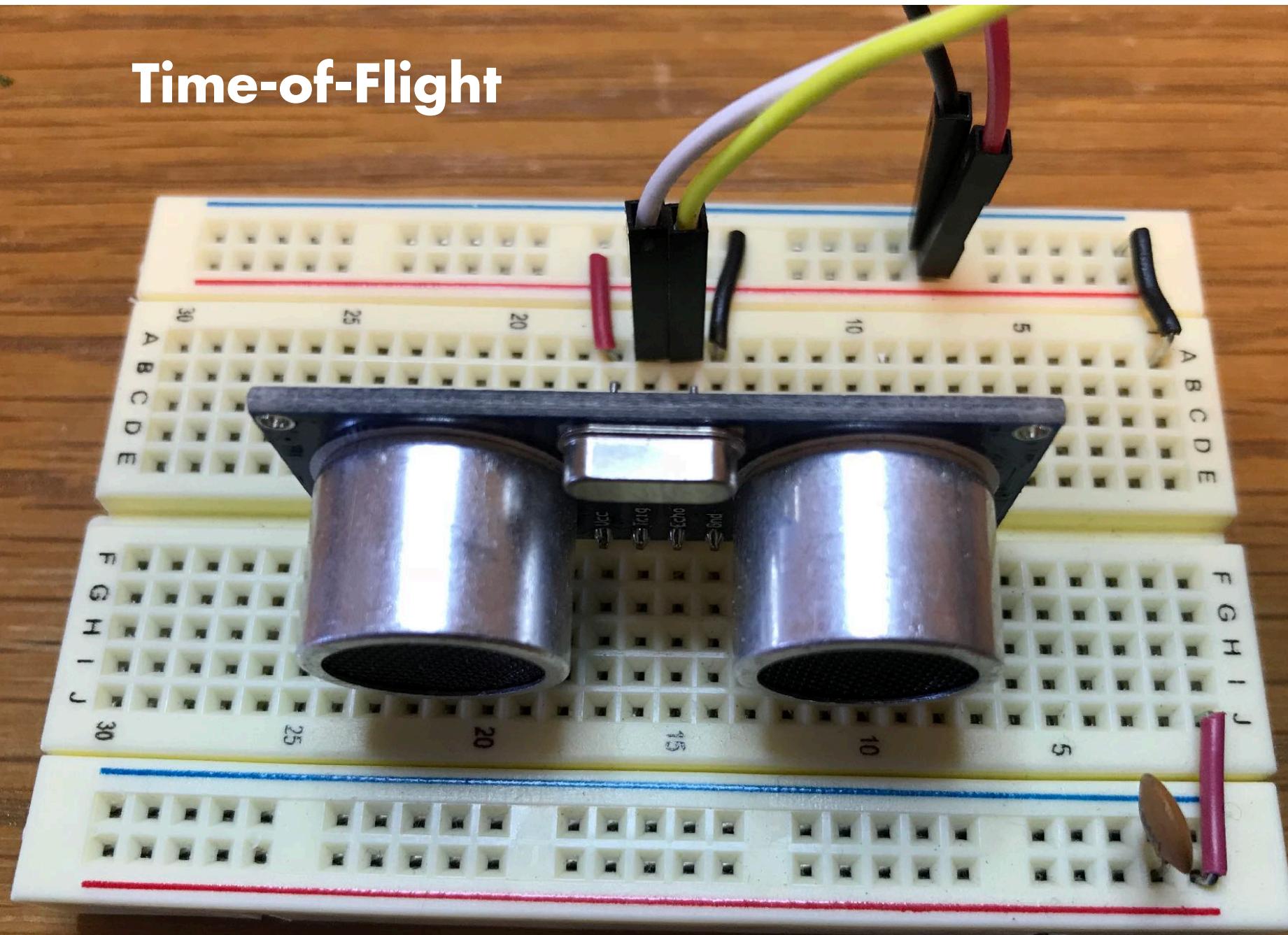
Famicom D-pad





3144 Hall Effect Sensor and Magnet

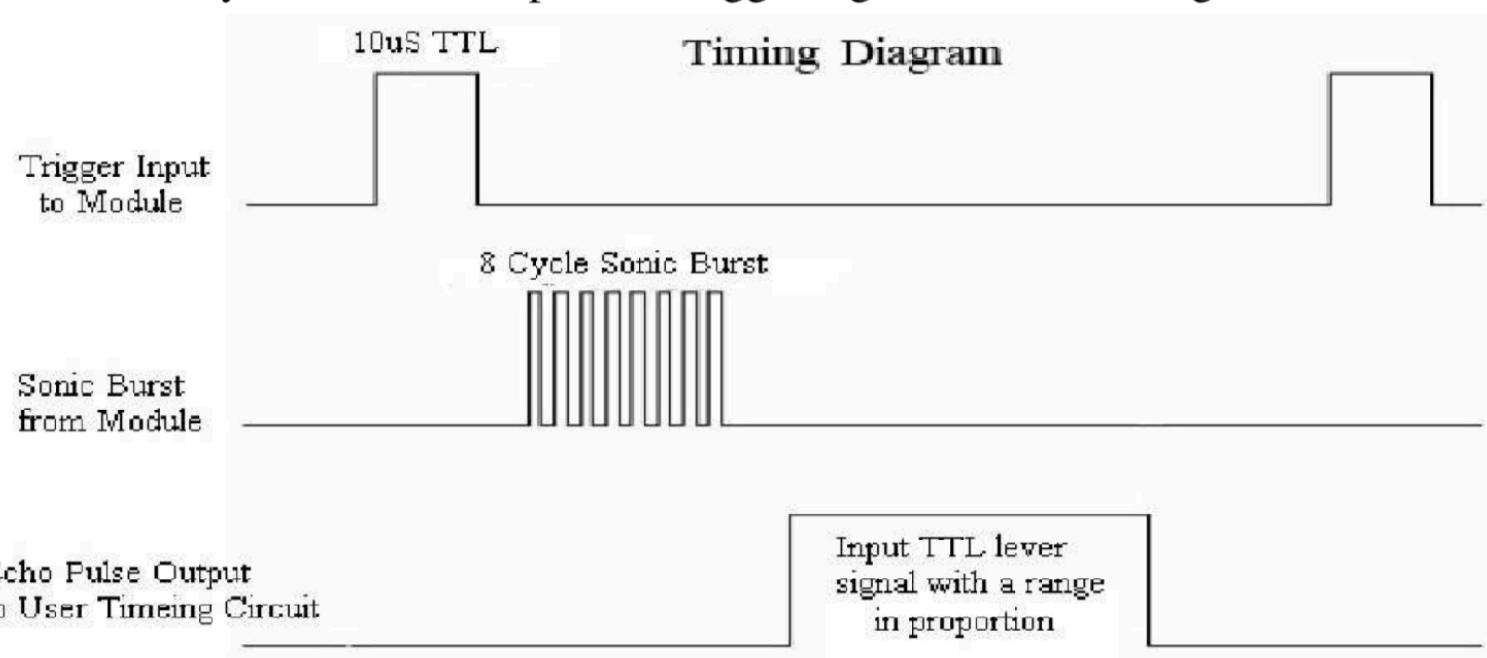
Time-of-Flight



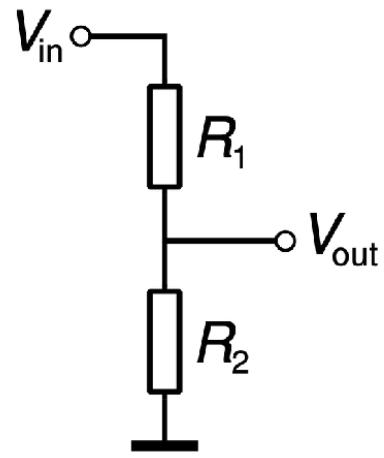
HC04 Ultrasonic Sonar



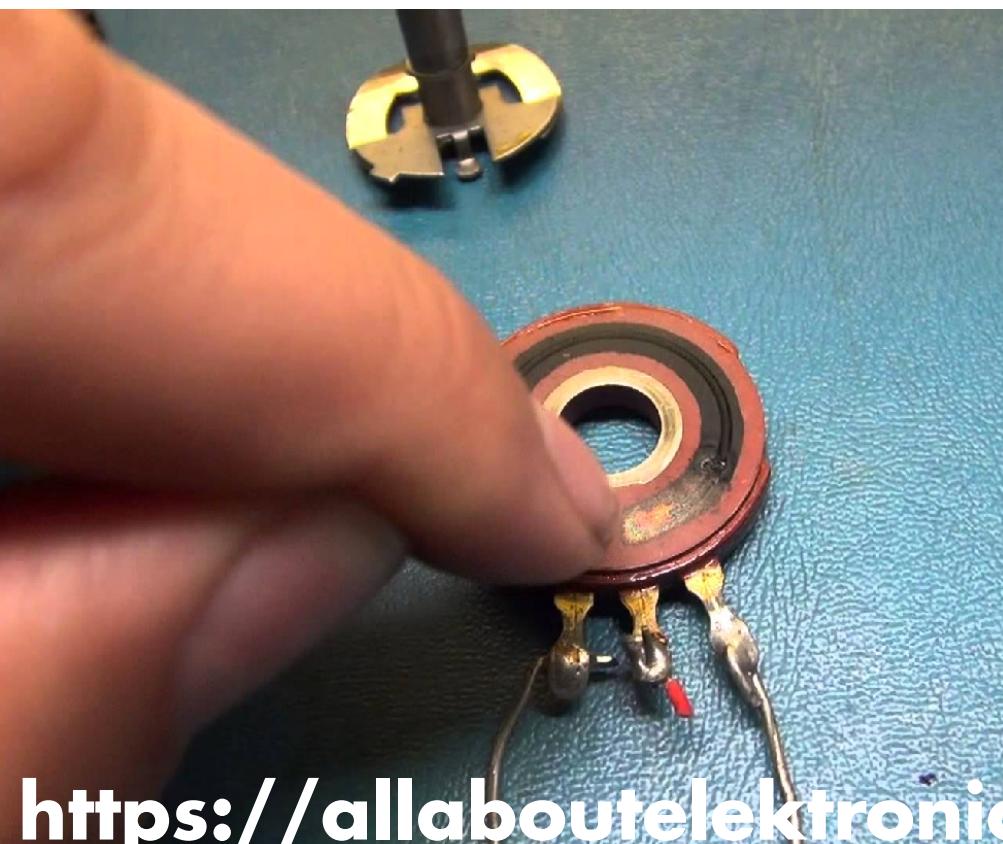
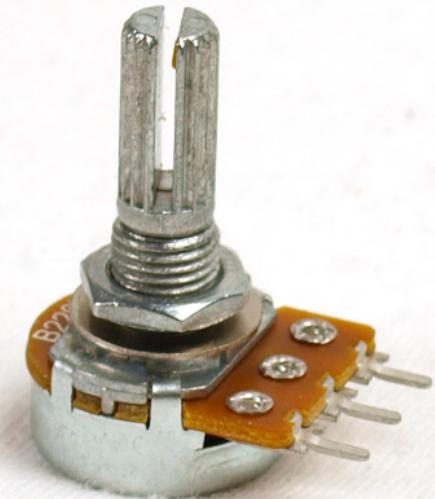
The Timing diagram is shown below. You only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion .You can 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.



Analog to Digital (ADC)



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



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

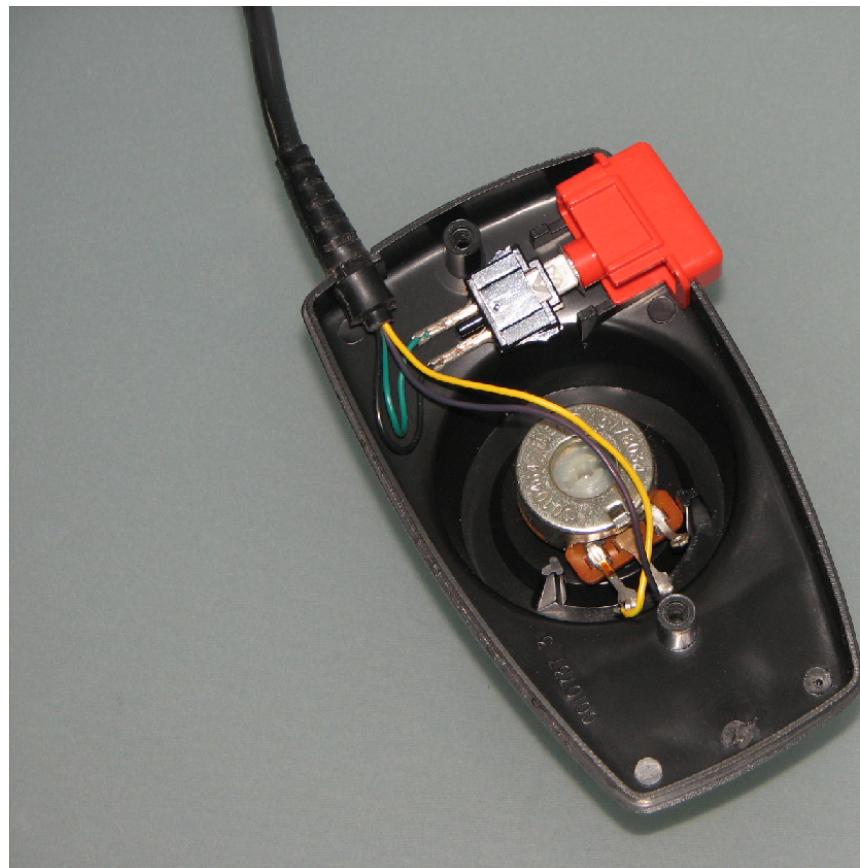


Image © Avon Fox
www.the-liberace.net
Image may be used in accordance
with this watermark

Atari 2600 Paddle

How would you measure the voltage?

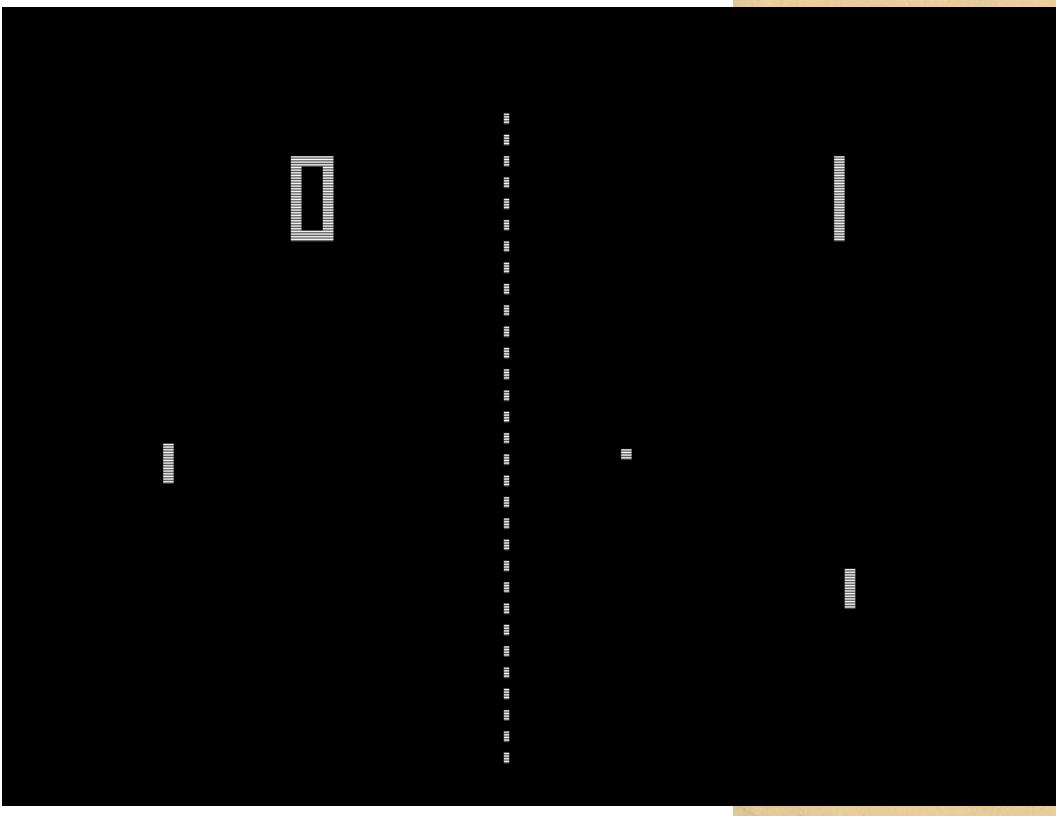


THE NEWEST 2 PLAYER
VIDEO SKILL GAME

PONG

from ATARI CORPORATION
SYZYGY ENGINEERED

The Team That Pioneered Video Technology



TRACT MODE
AUTOMATICALLY
MOVES POSITION
OF BALL
BASIC PADDLE
CONTROLS
FOR HOME TV AND
COMMERCIAL USE.
LONG,

COMPUTER

PROFITS
- Location
- Suitable
- Locations

FROM YOUR LOCAL DISTRIBUTOR

Maximum Dimensions:

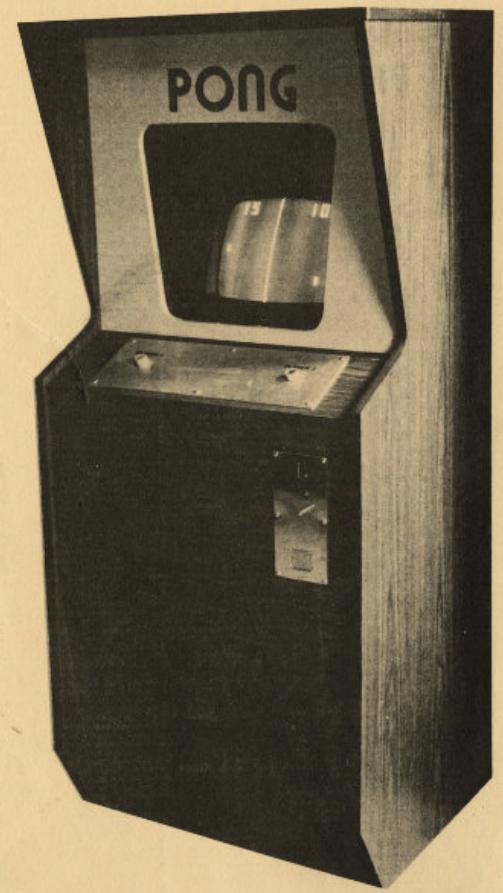
WIDTH - 26"

HEIGHT - 50"

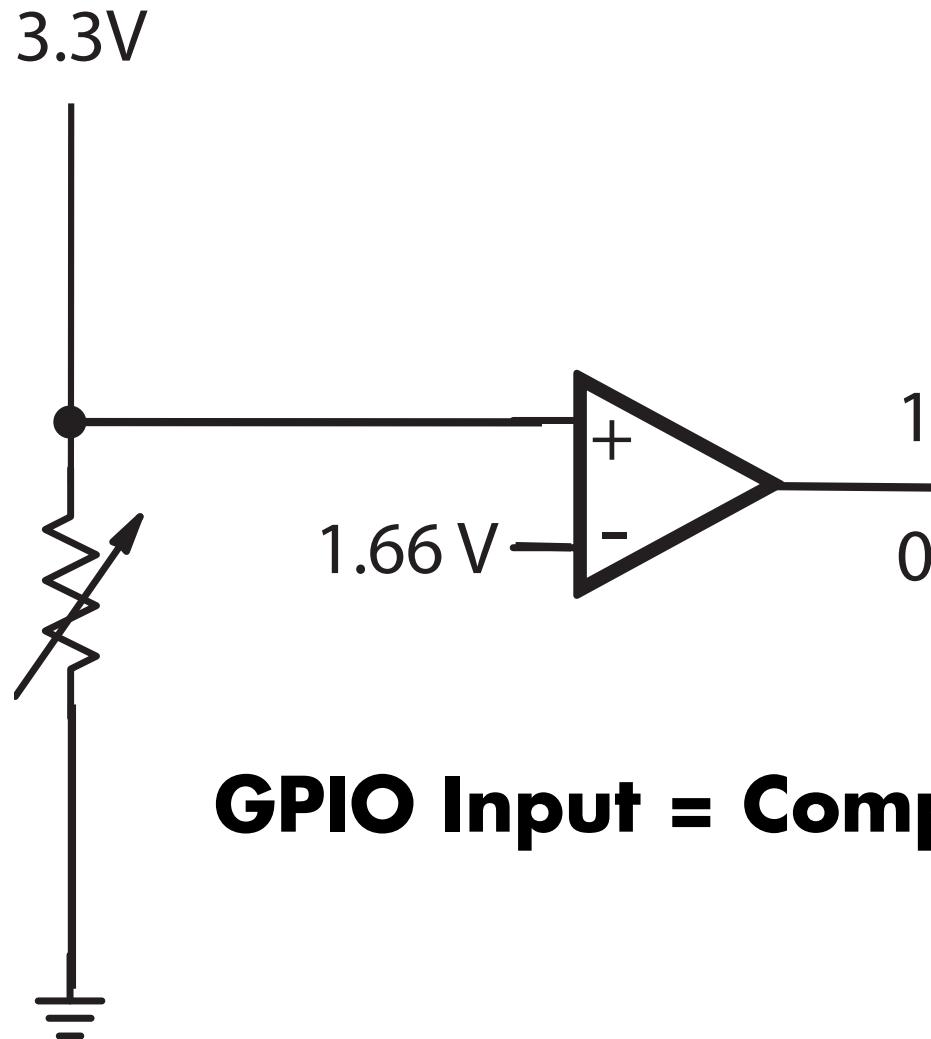
DEPTH - 24"

SHIPPING WEIGHT:

150 Lb.



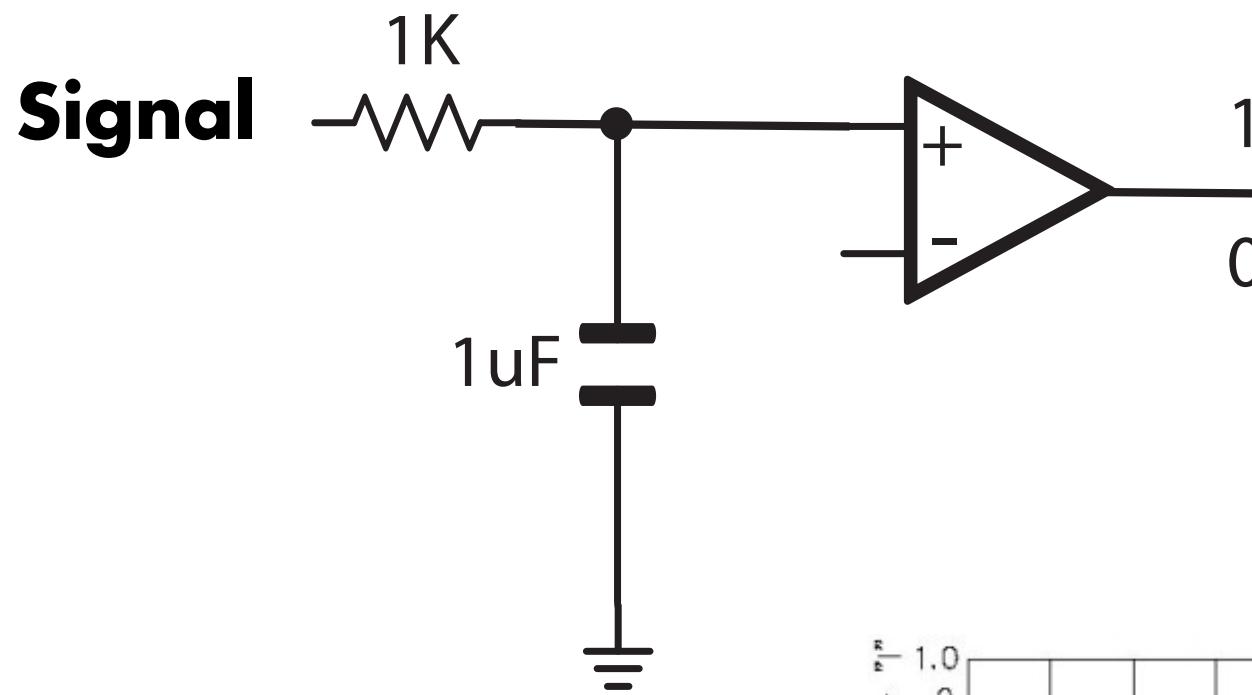
**Potentiometer
(Voltage divider)**



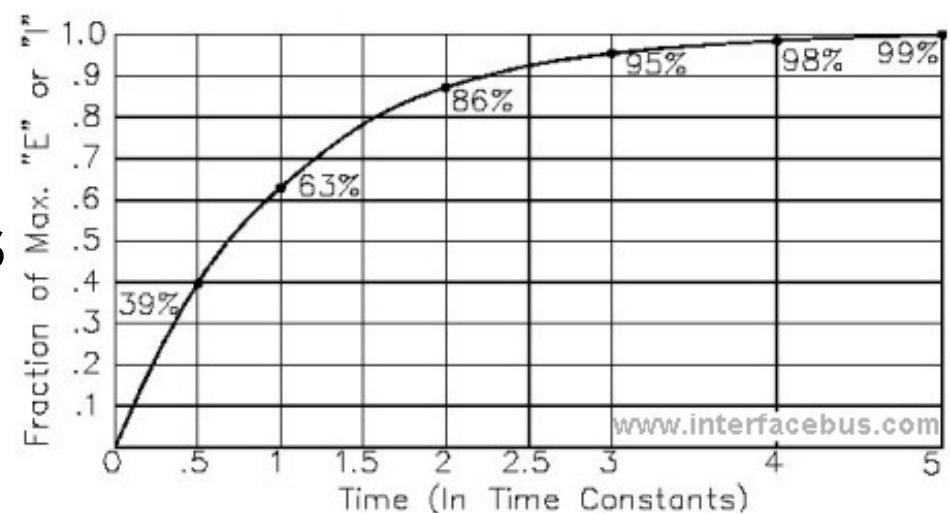
GPIO Input = Comparator

Charging Circuit

The time to fire depends on the input signal voltage

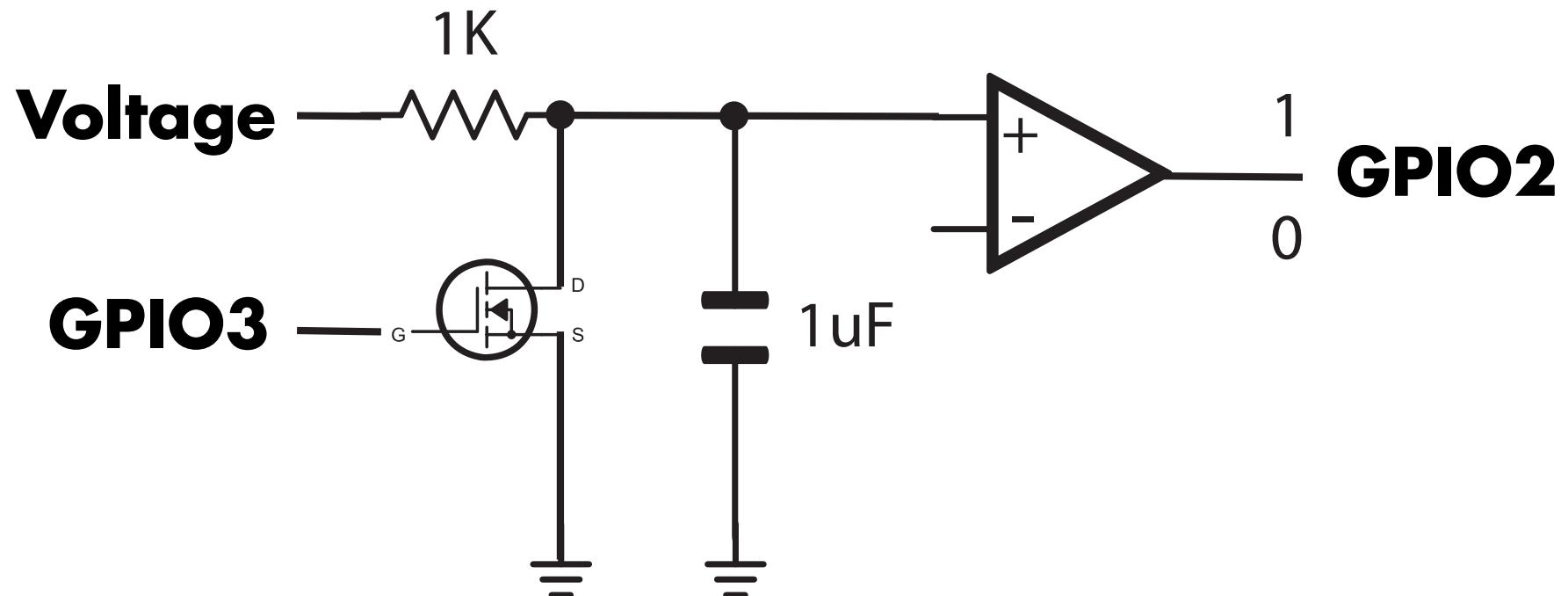


$$RC = 10^3 \times 10^{-6} = 1000 \text{usecs}$$

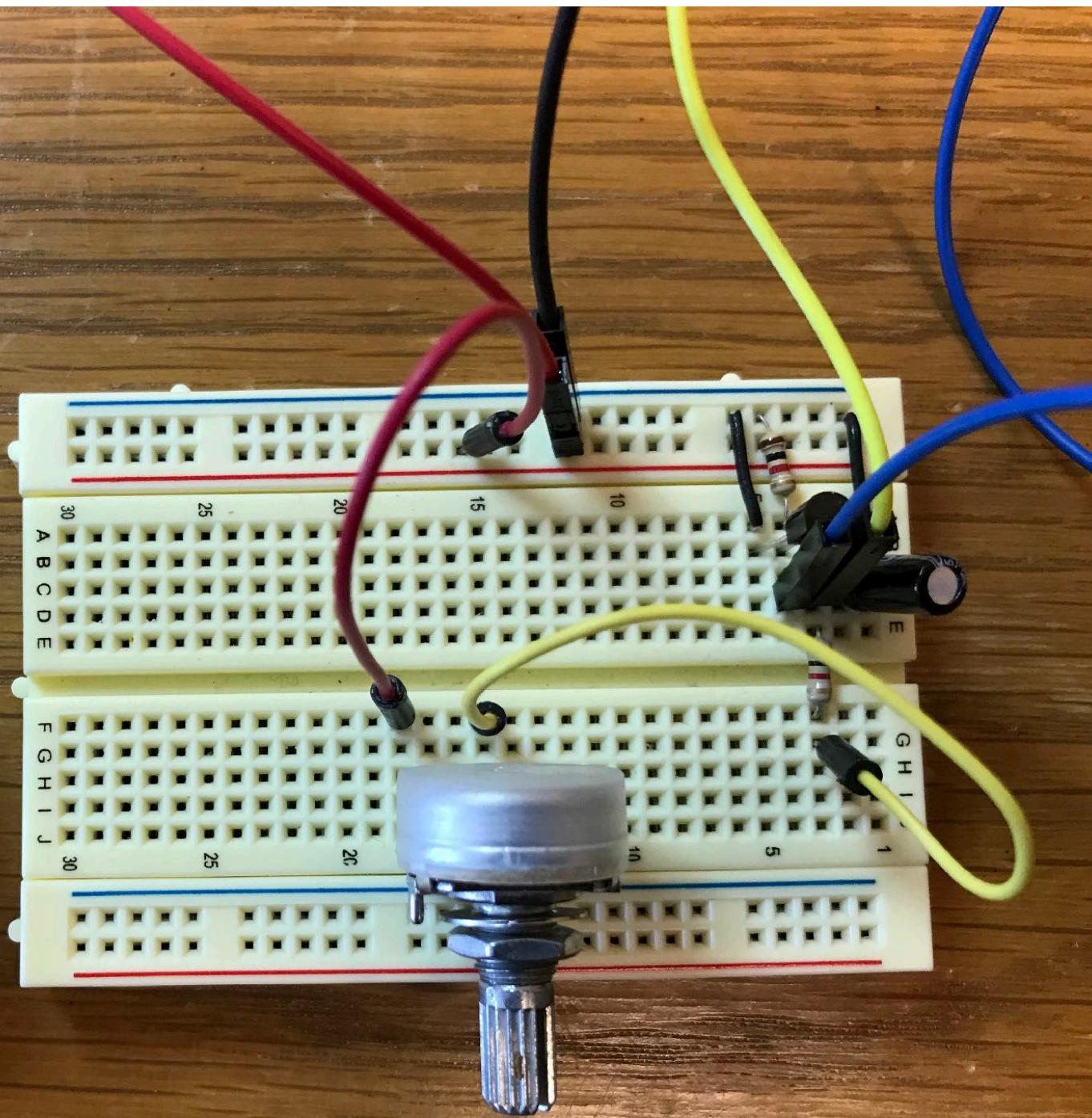


ADC

- 1. Turn on transistor, discharge capacitor**
- 2. Turn off transistor, charge capacitor**



RC = 1000 usecs



```
unsigned int get_charge_time(void)
{
    // discharge the capacitor
    gpio_write(discharge, 1);
    timer_delay_ms(10);
    gpio_write(discharge, 0);

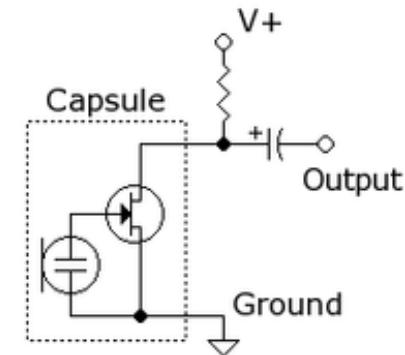
    // time the capacitor charging
    unsigned int start = timer_get_ticks();
    while(!gpio_read(signal))
        ;
    unsigned int end = timer_get_time();

    return (end - start);
}
```

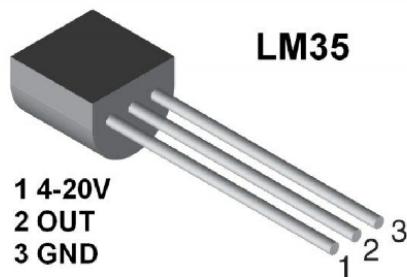
Analog Sensors



**Phototransistor
(light)**



**Electret Microphone
(pressure)**



(temperature)



**Analog Hall Effect
(magnetic field)**

Digital to Analog (DAC)

Pulse-Width Modulation (PWM)

50% duty cycle



75% duty cycle

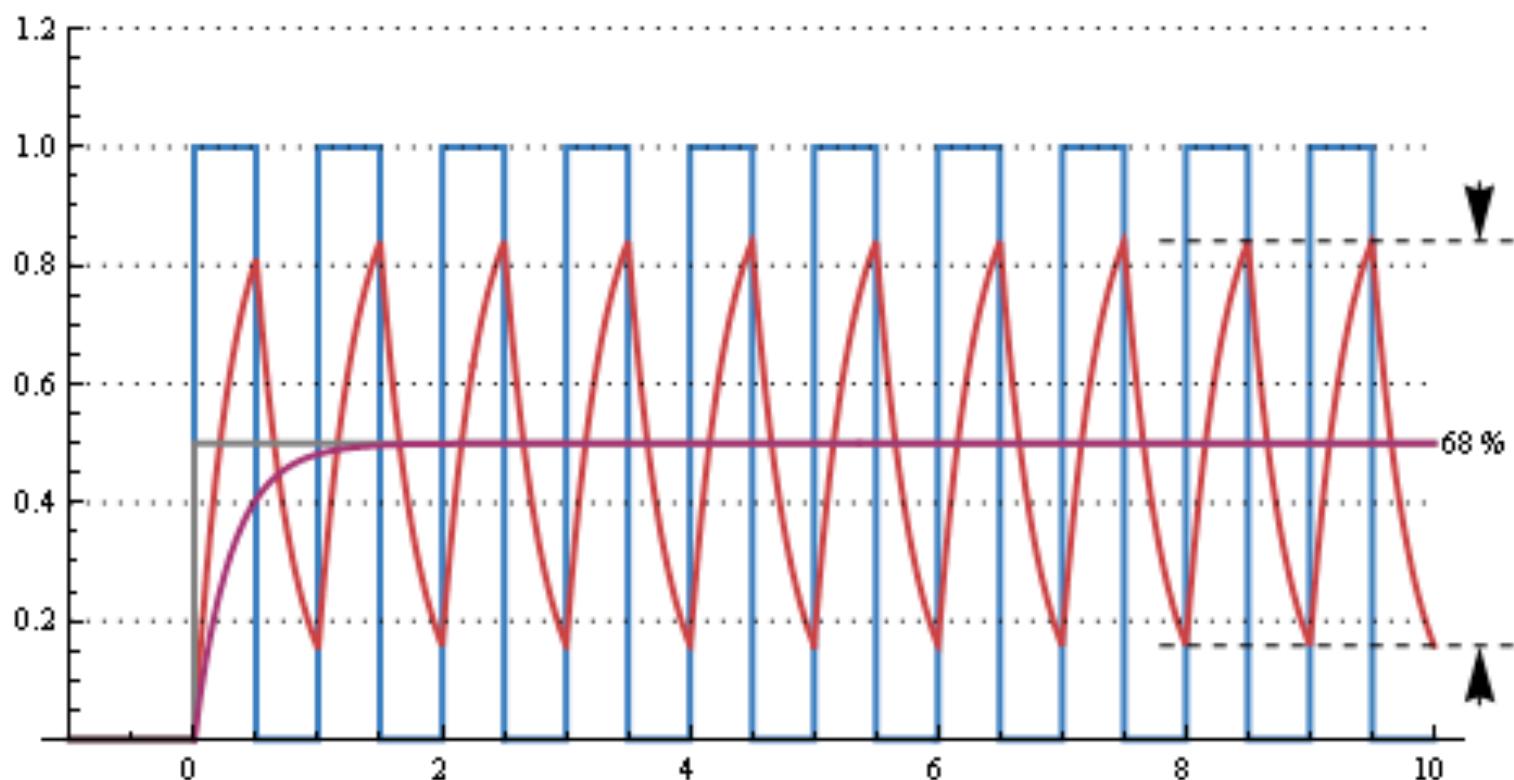
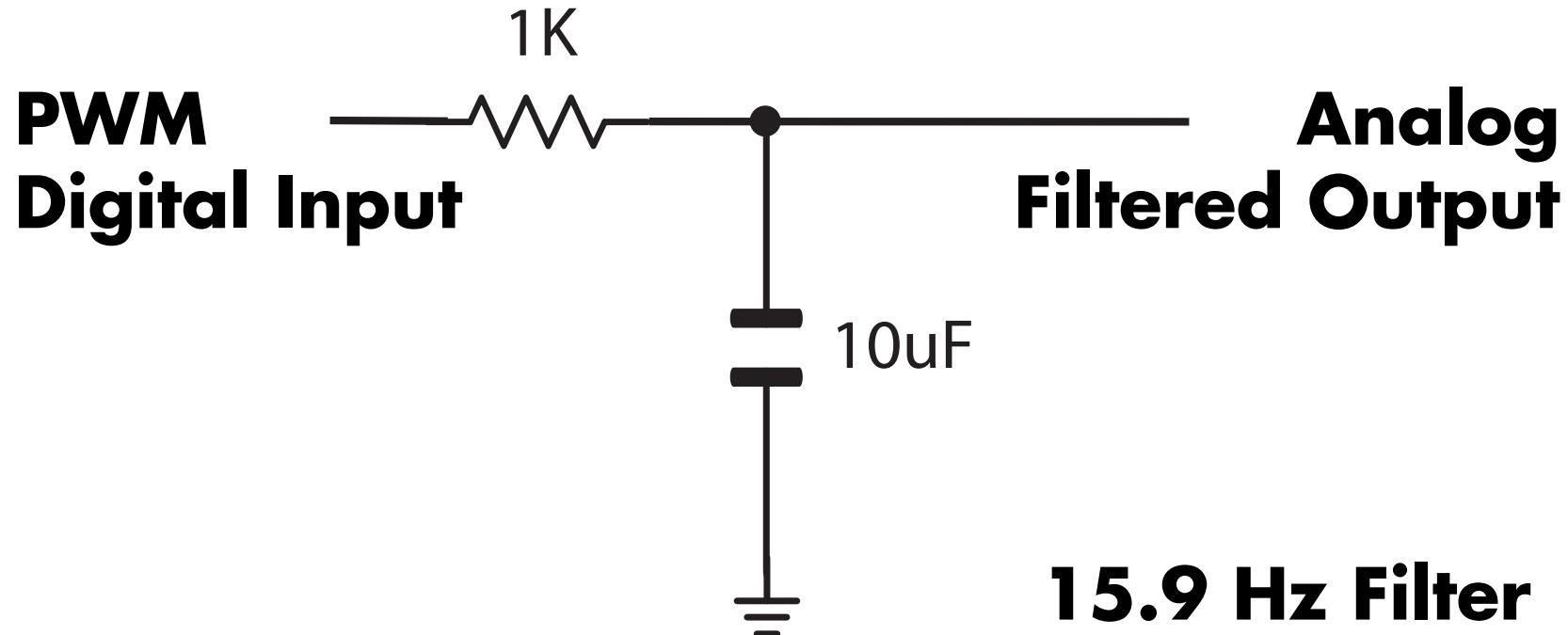


25% duty cycle

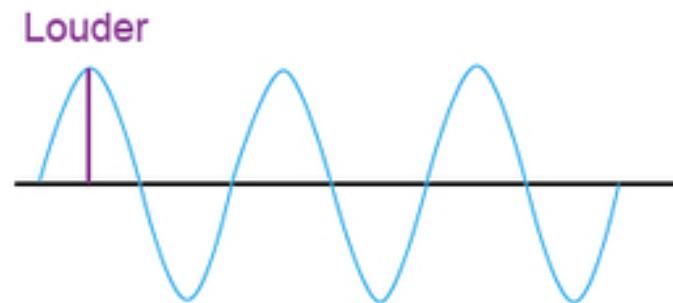
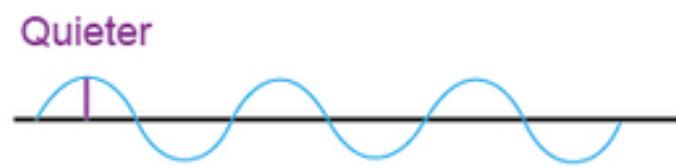
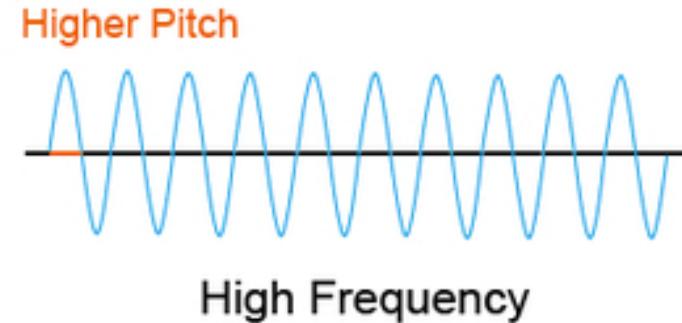
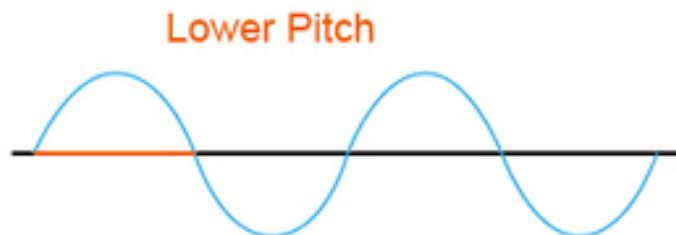


`pwm_clock, pwm_range, pwm_width`

`pwm.c`

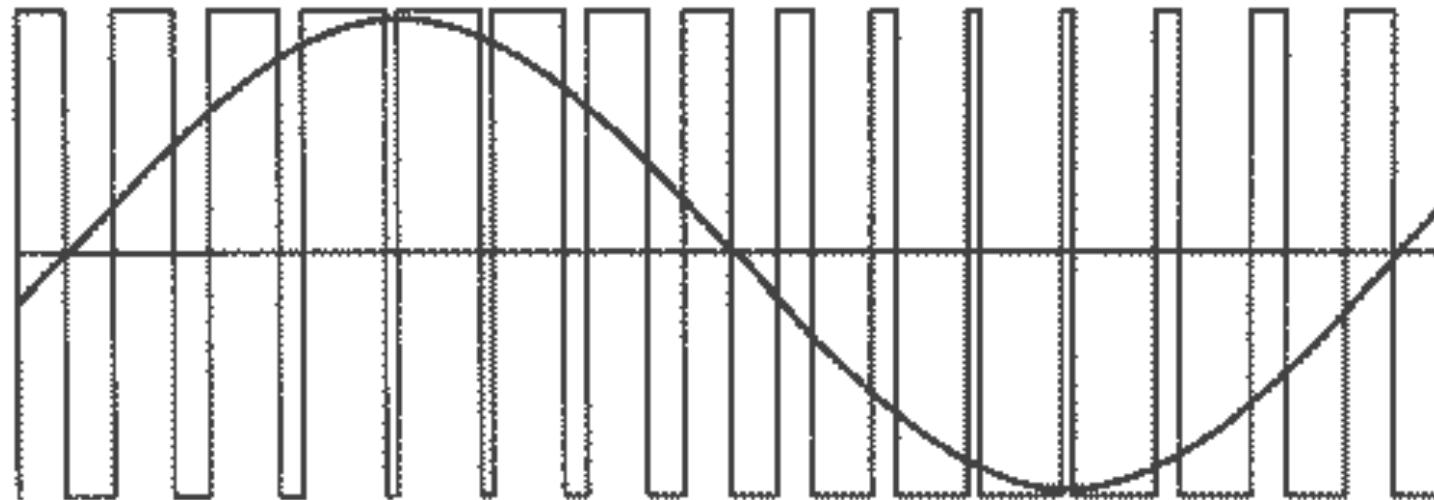


Sound Waves



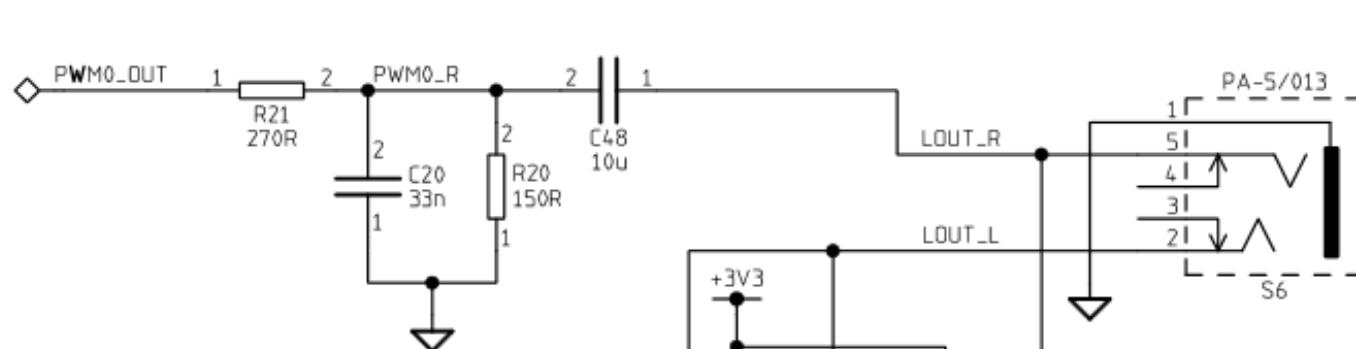
Continuous Values

Can produce continuous values by filtering out the high frequencies in the PWM signal

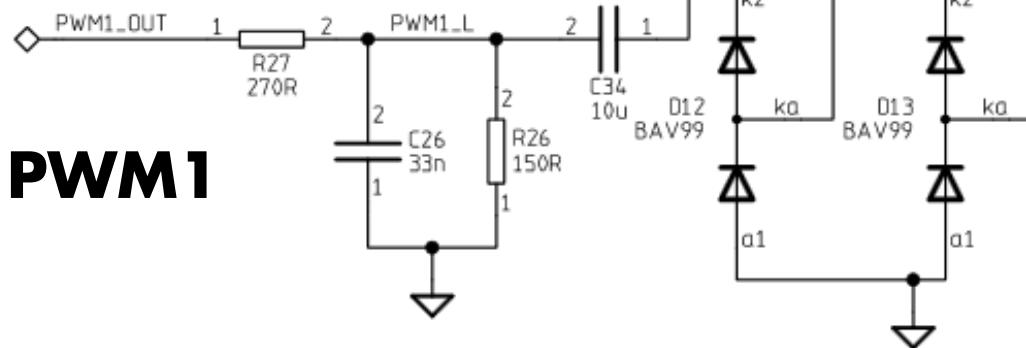


Raspberry Pi Sound

PWMO



PWM1



3.5mm Stereo Jack

Raspberry Pi

Project Code:
RP100021

Title:
Raspberry Pi
HDMI, SD Card,

Scale: NTS	Sheet: 02 of 05	File Name:
	Drawn By: PBL	Issue/PMF

Low-pass Filter

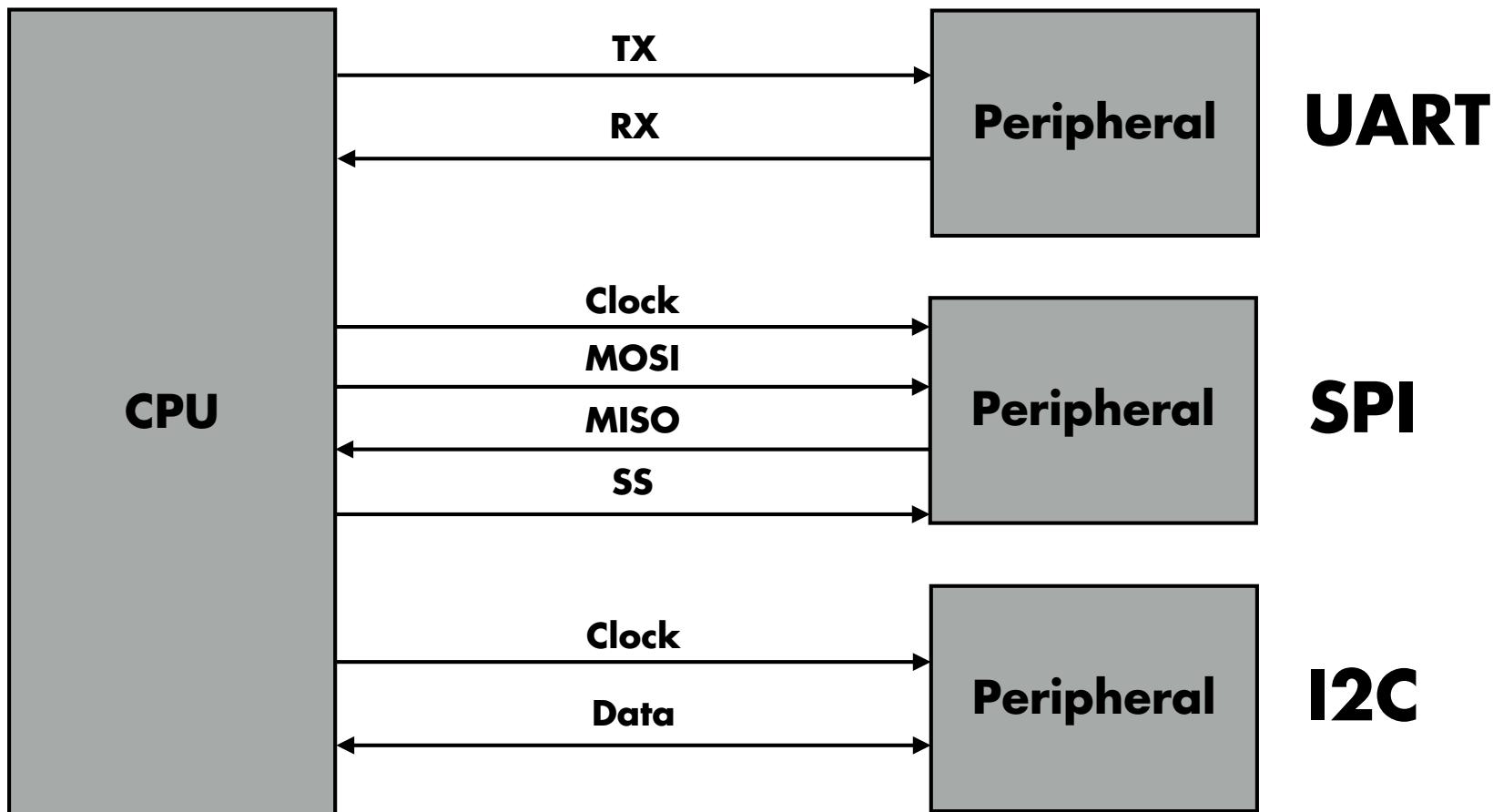
	PWM0	PWM1
GPIO 12	Alt Fun 0	-
GPIO 13	-	Alt Fun 0
GPIO 18	Alt Fun 5	-
GPIO 19	-	Alt Fun 5
GPIO 40	Alt Fun 0	-
GPIO 41	-	Alt Fun 0
GPIO 45	-	Alt Fun 0
GPIO 52	Alt Fun 1	-
GPIO 53	-	Alt Fun 1

**Stereo Jack connected to
GPIO_PIN40 and GPIO_PIN45**

tone.c
melody.c
audio.c

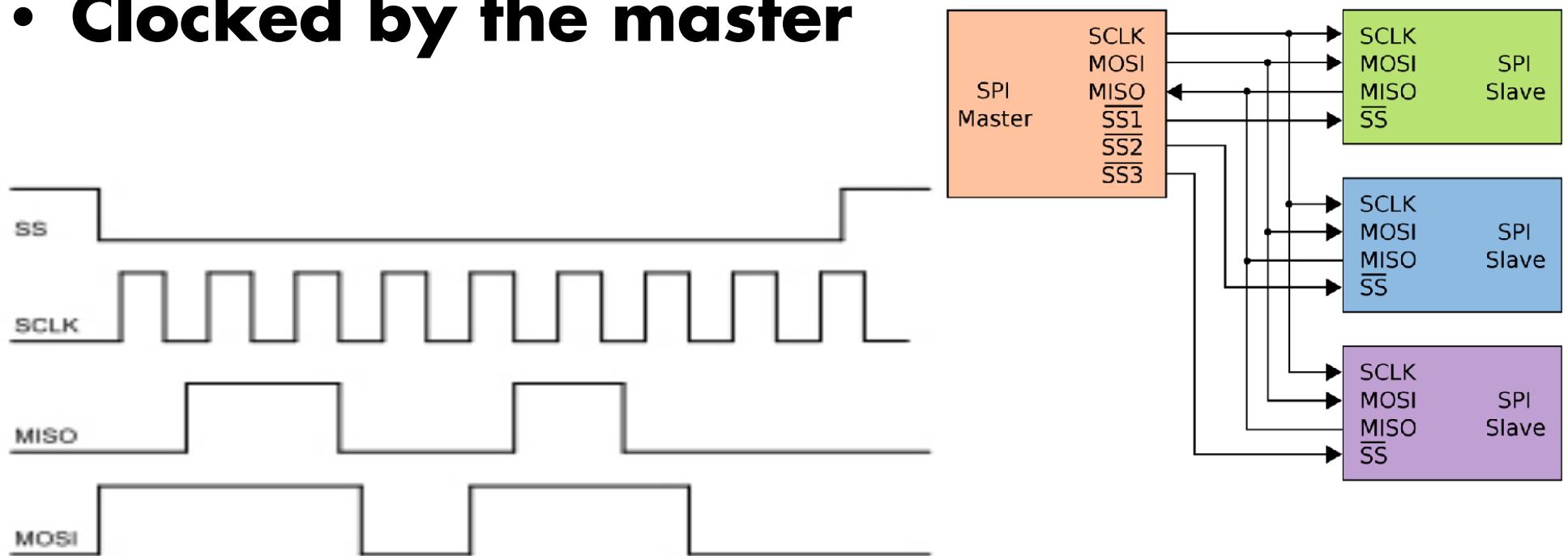
Smart Sensors

Bus Protocols

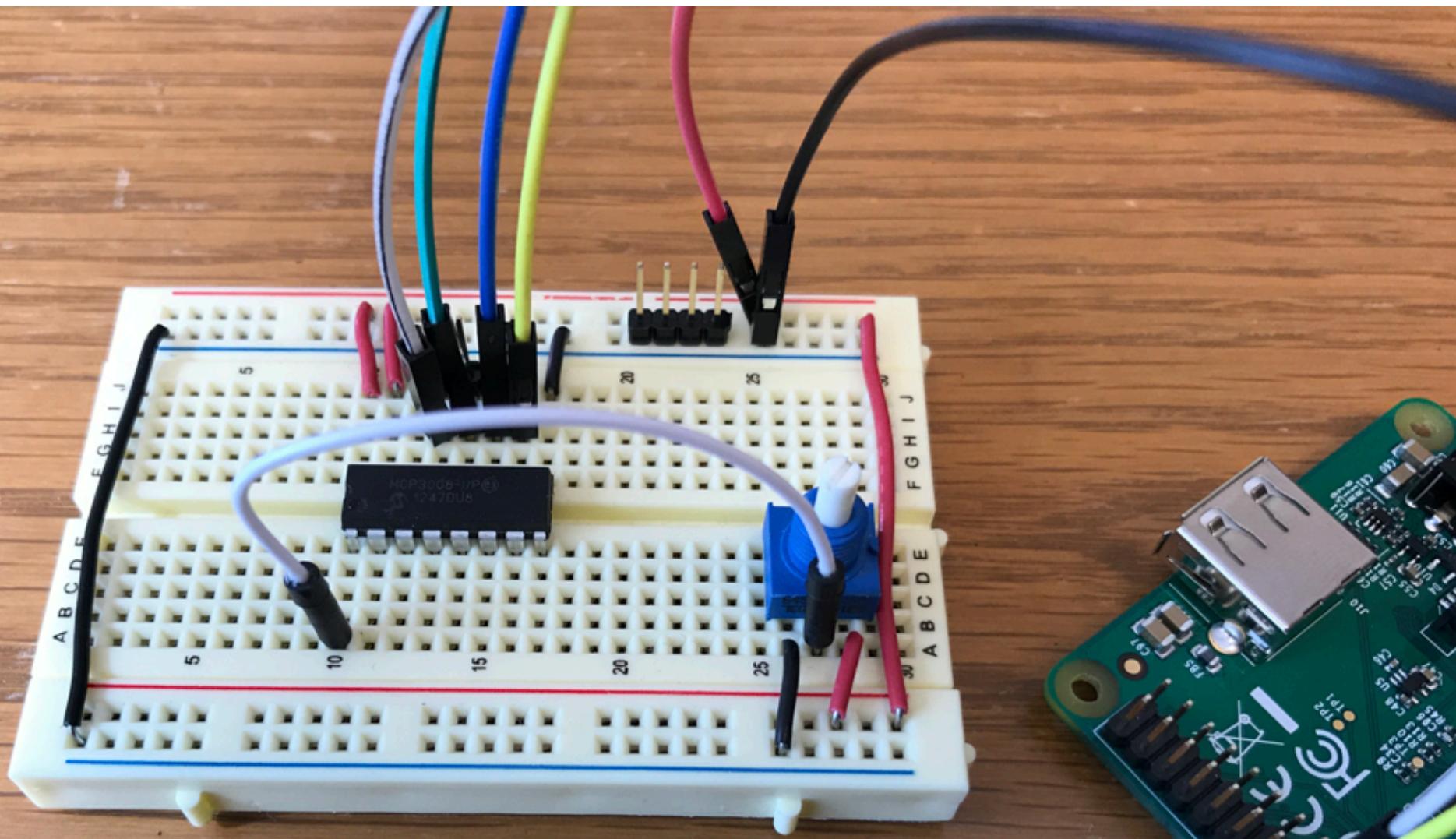


SPI

- **Shared CLK, MOSI, MISO lines**
- **Active low slave select (SS) lines to specify which peripheral is active**
- **Clocked by the master**

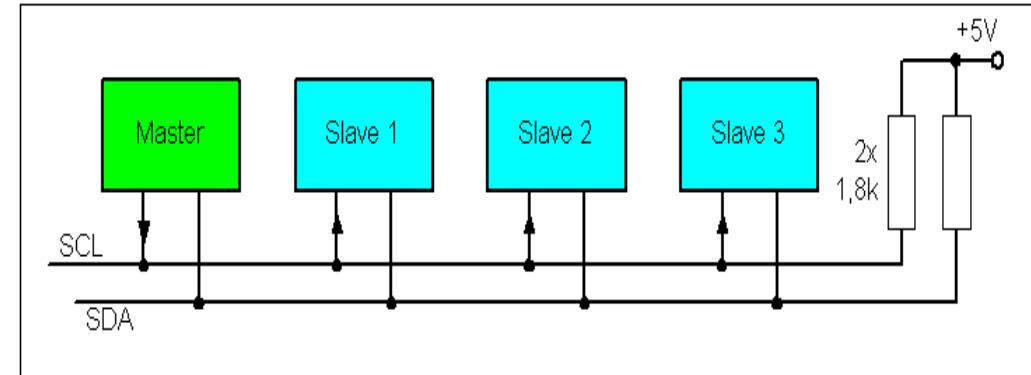


Figures from https://upload.wikimedia.org/wikipedia/commons/thumb/f/fc/SPI_three_slaves.svg/2000px-SPI_three_slaves.svg.png (top), <http://www.tequipment.net/RigolSD-SPI-DS4.html> (bottom)

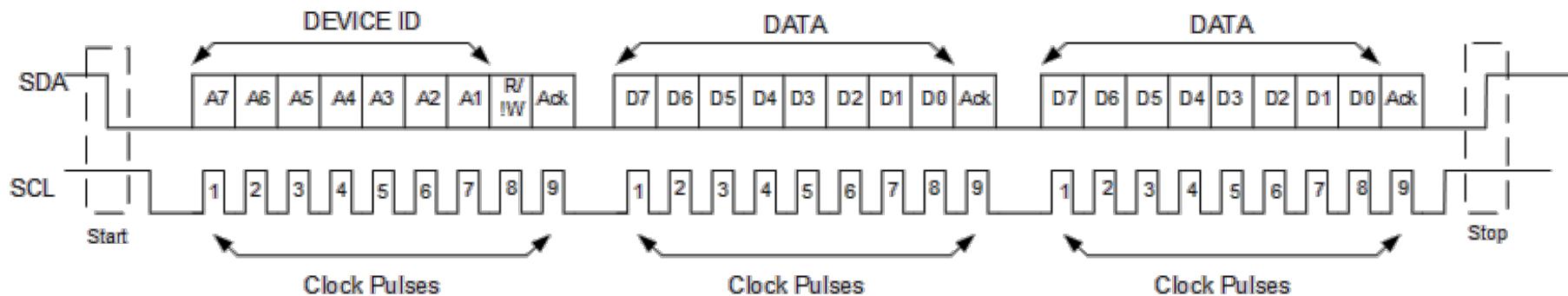


MCP3008 SPI 8-channel ADC

I2C

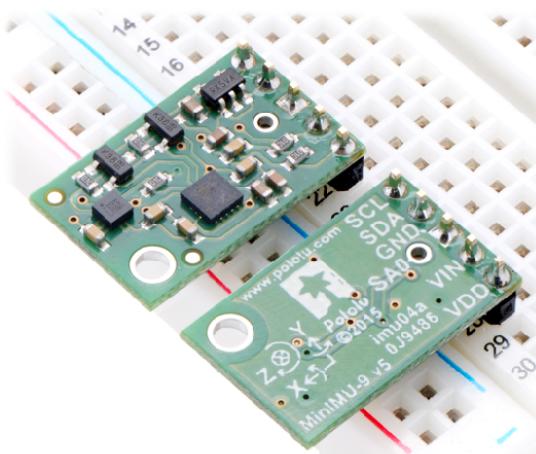


- **CLK & DATA lines (with pull-ups)**
- **Clocked by master, both master and slave and send data**
- **Shared bus, slave identified by 7 (or 10) bit address**

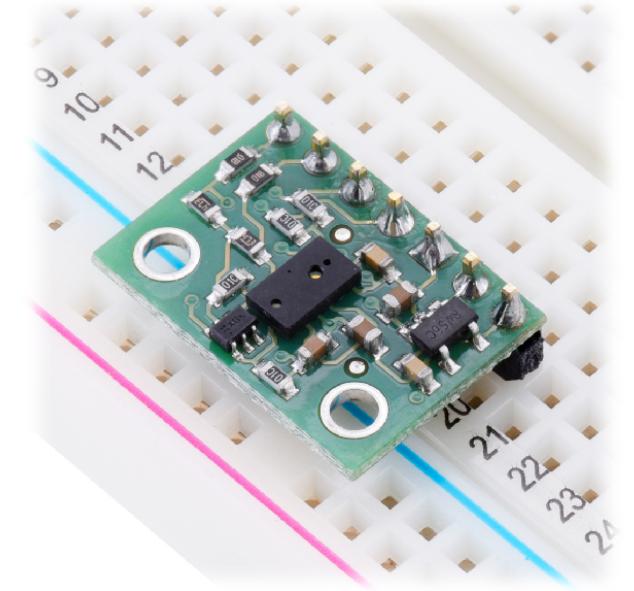


Figures from <http://www.cs.fsu.edu/~baker/devices/notes/graphics/i2cbus3.gif> (top)
https://learn.digilentinc.com/Documents/chipKIT/chipKITPro/P08/Fig_1_Waveform.png (bottom)

I2C Sensors



**Accelerometer
Gyroscope
Magnetometer**



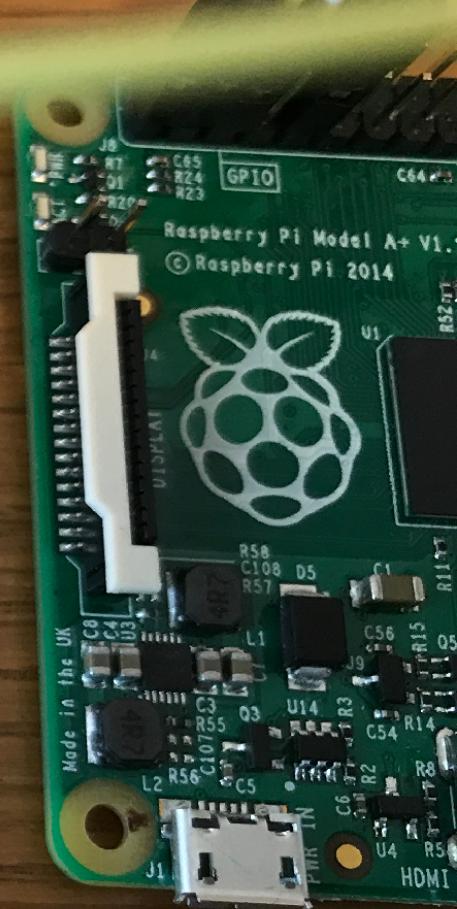
VCSEL Time of Flight



**Temperature,
Humidity,
Pressure**



Arducam (SPI and I2C)

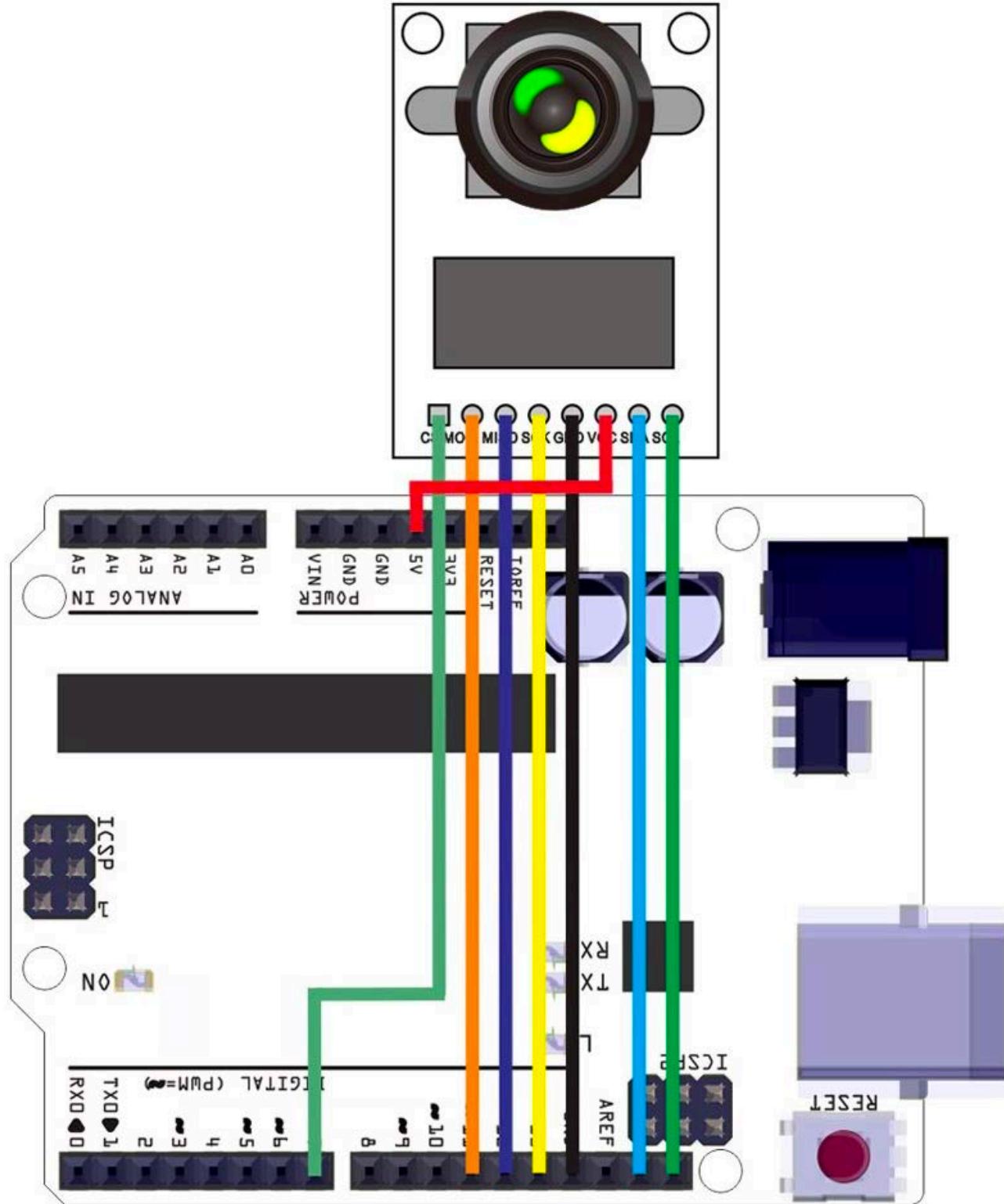


I2C IMU (accelerometer, gyroscope, compass)

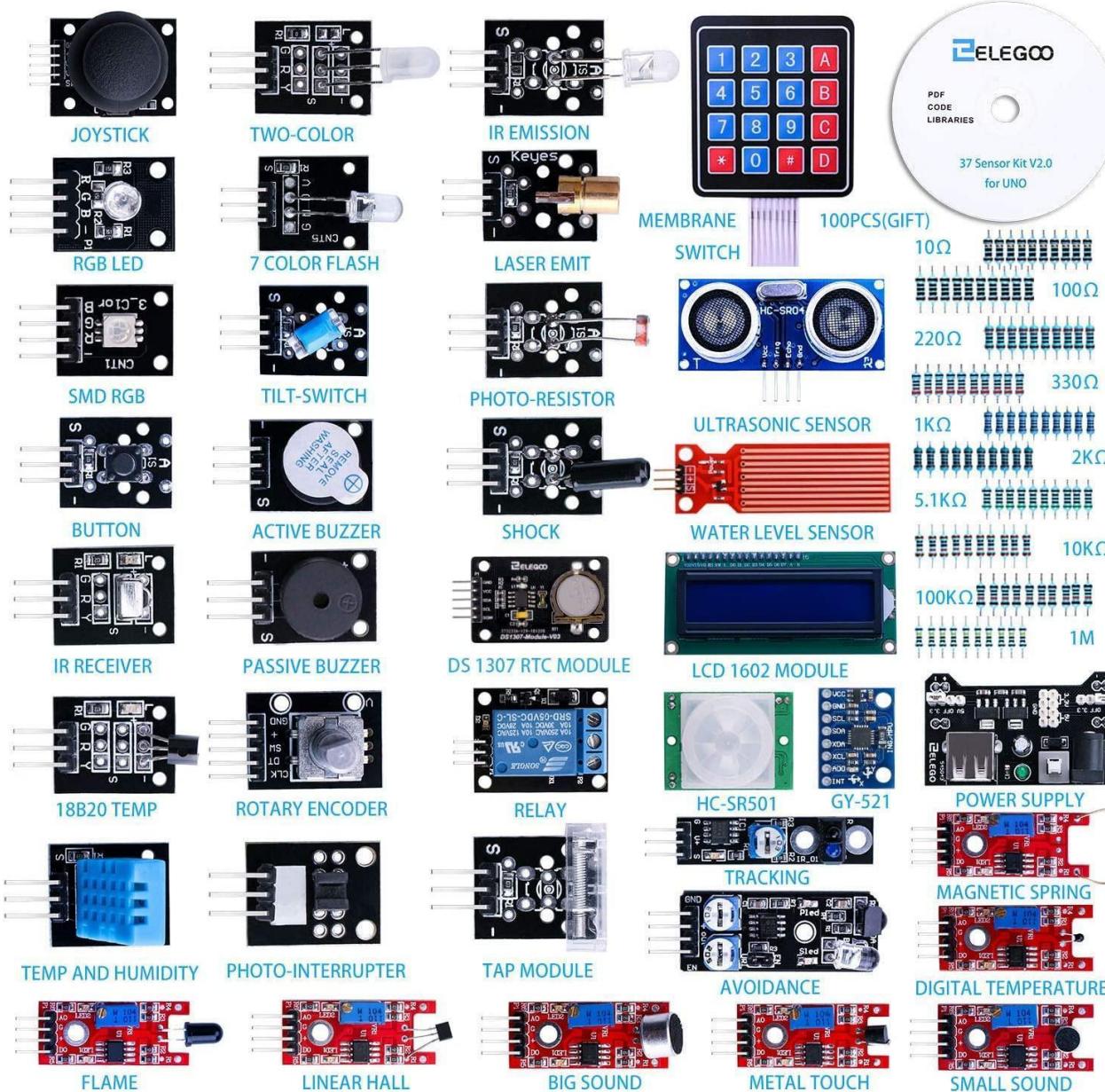


Arducam

SPI + I2C



ELEGOO Sensor Kit



Download code: <https://www.elegoo.com/blogs/arduino-projects/elegoo-37-in-1-sensor-modules-kit-tutorial>

Sensing the World

Resistance (conduction, capacitance)-

Convert energy to voltage/current

- **Light (phototransistor)**
- **Sound/pressure/deformation (piezo, electret, strain gauge)**
- **Temperature (heat), humidity, pressure**
- **Electromagnetic fields (hall effect, compass, antenna)**

Smart sensors (sensor with a digital interface)

- **Acceleration/Orientation/Magnetic (force direction)**
- **Camera, IMU (inertial management unit), ...**