CS107e

Sensors

Apple iPhone 12 Teardown

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

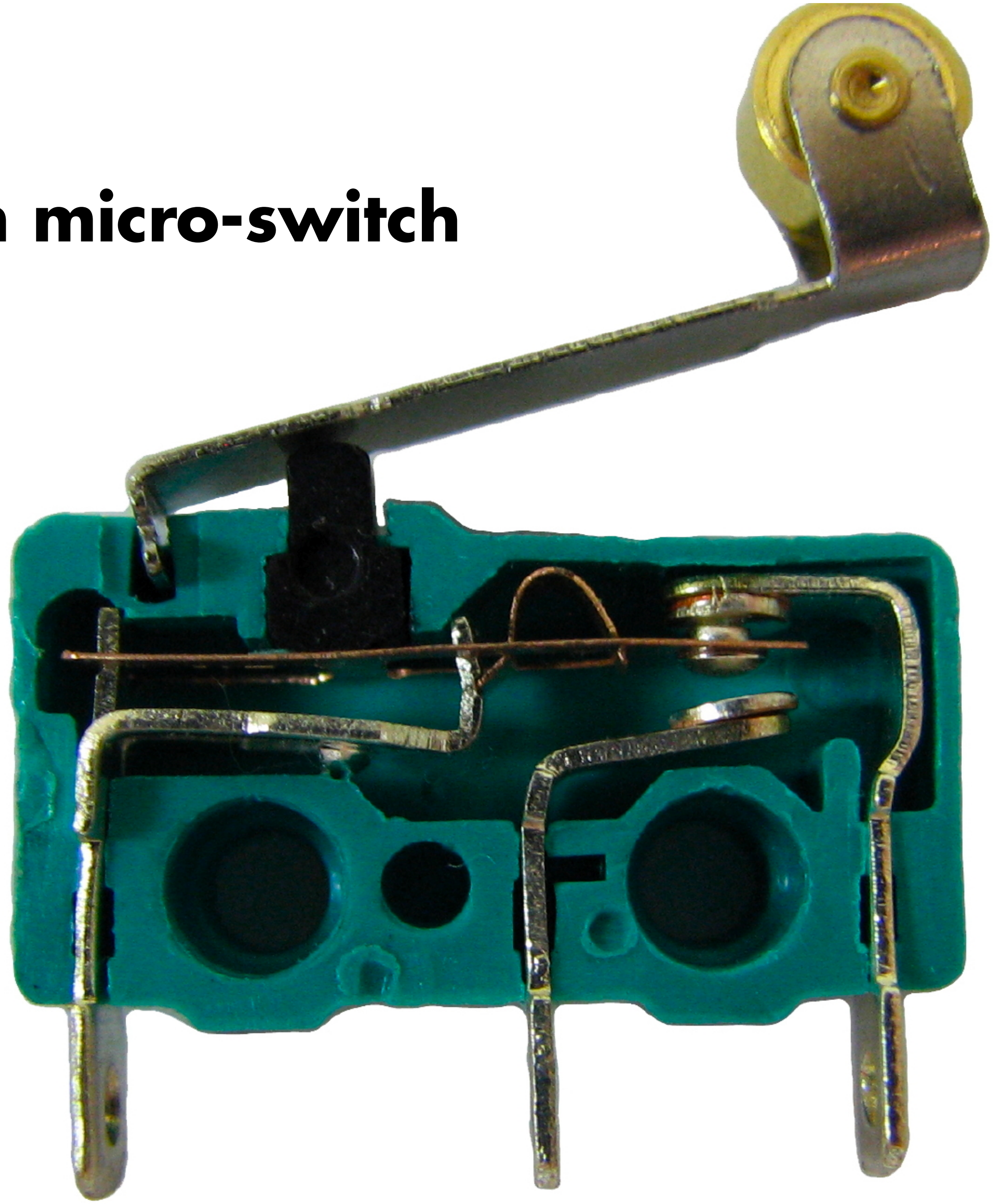
Compass (magnetometer)

Barometer (altimeter)

Moisture

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

Snap-action micro-switch

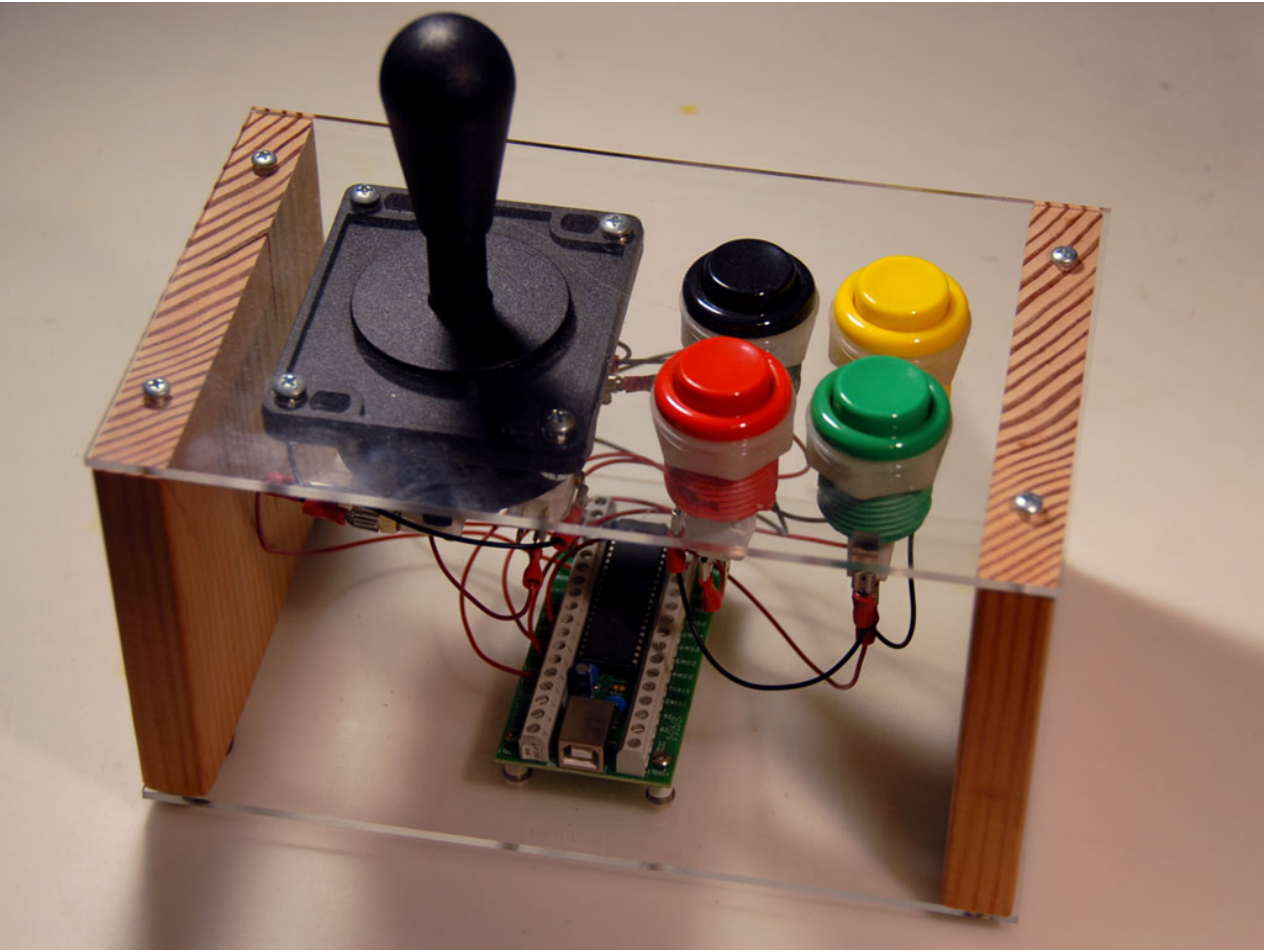


https://en.wikipedia.org/wiki/Miniature_snap-action_switch

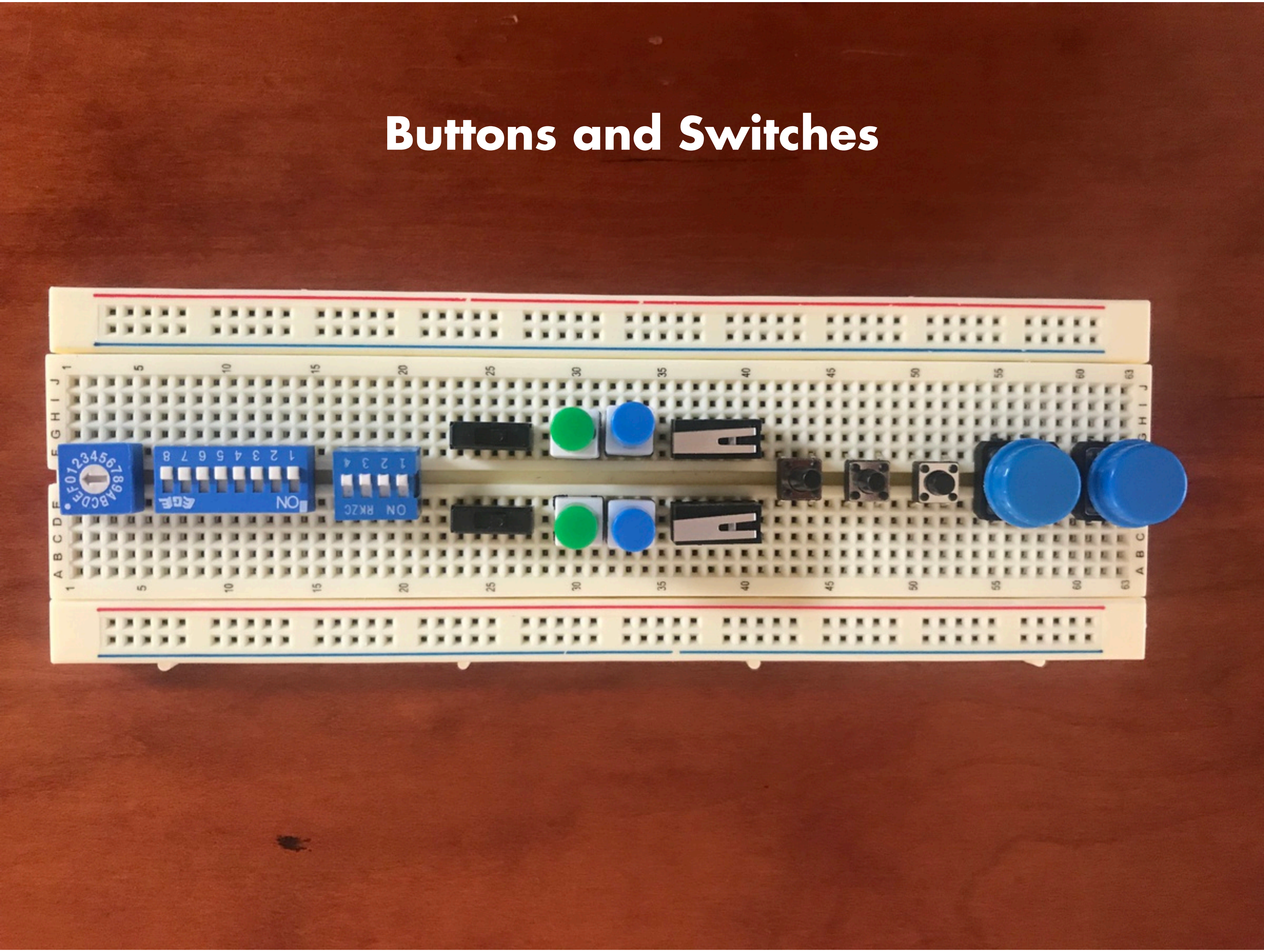
Tim Hunkin's Secret Life of Components - Switches

Happ Pushbutton

Happ Joystick

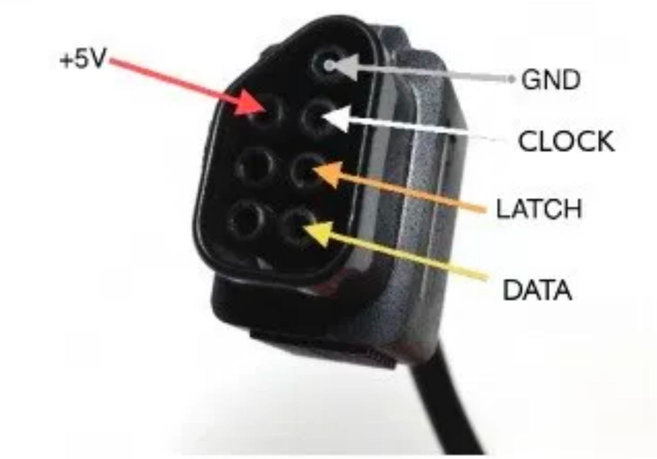


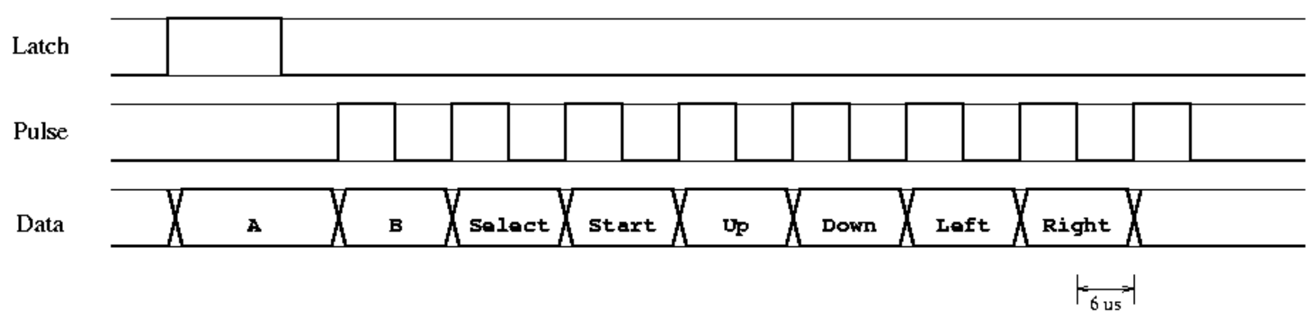
Buttons and Switches



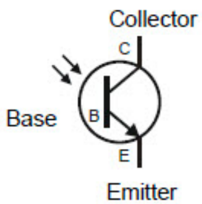
Famicon D-pad

NES D-pad

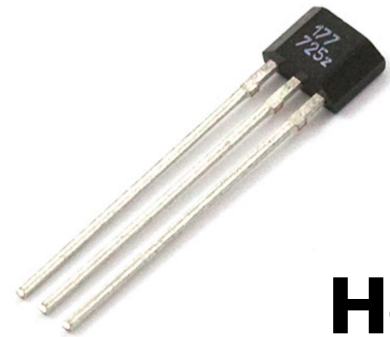




Transistor Sensors



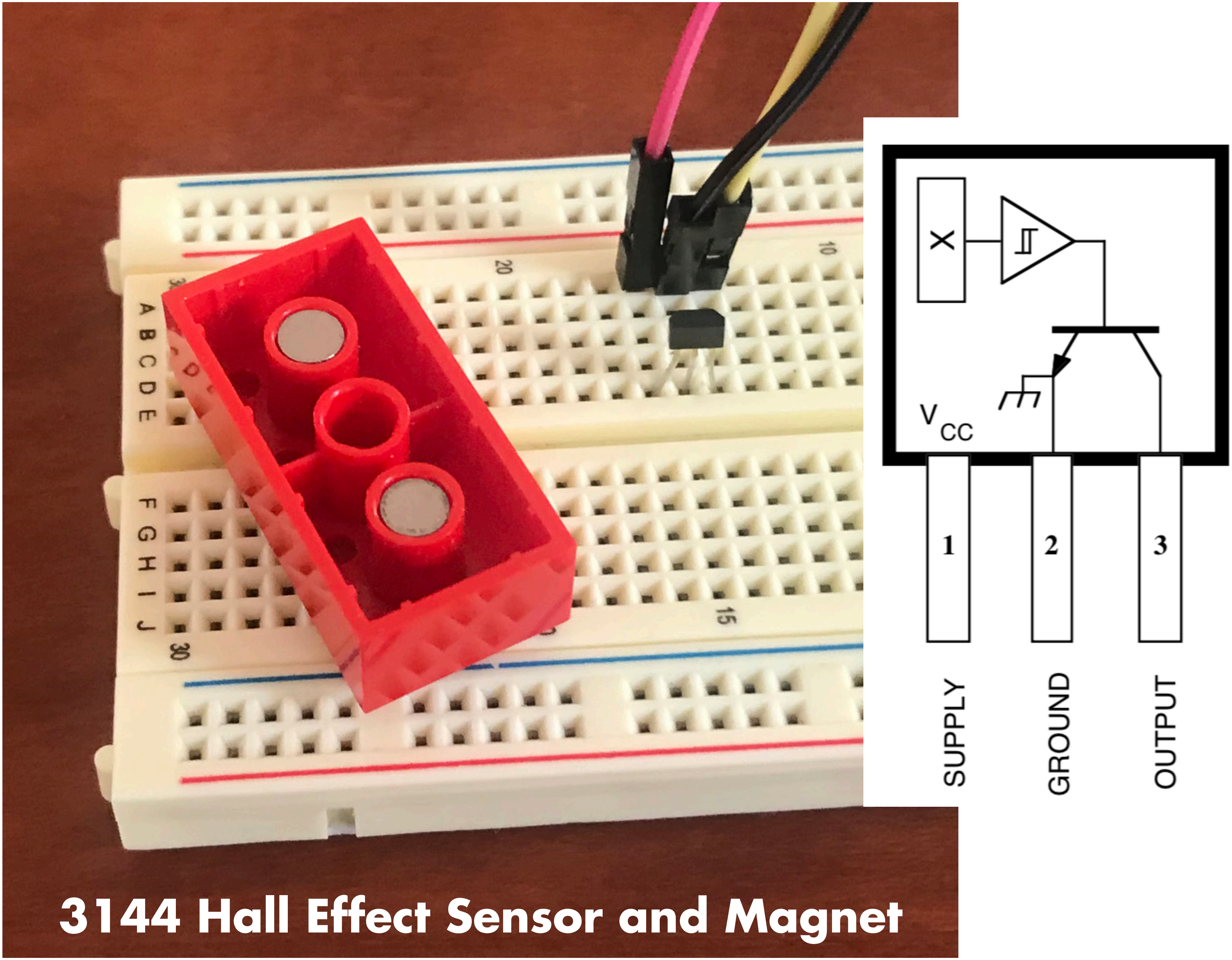
Phototransistor (light)



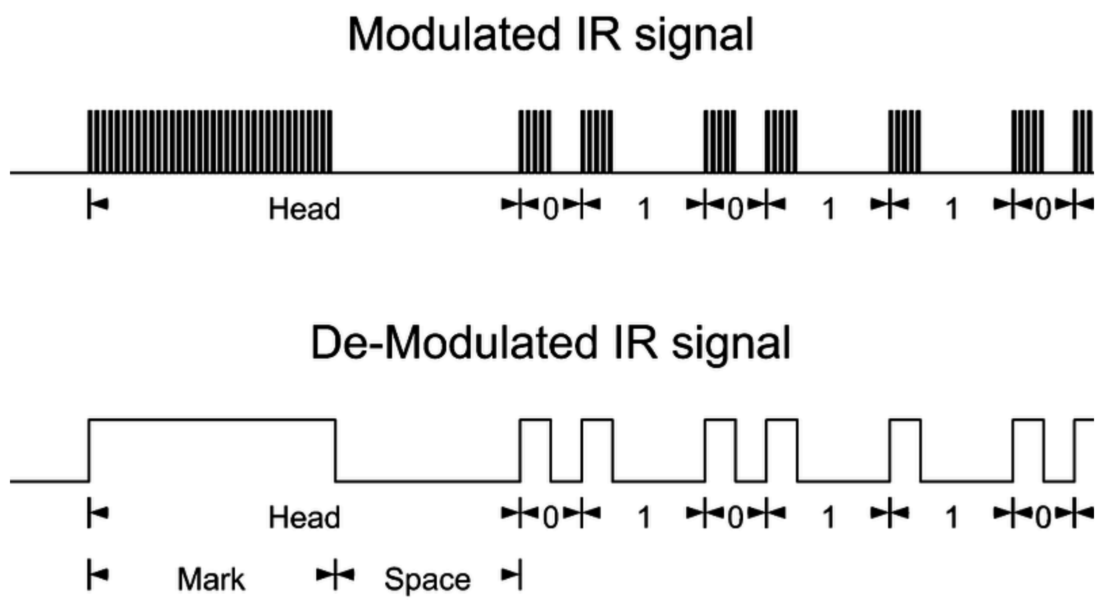
Hall Effect (magnetic field)

38 Khz IR Receiver

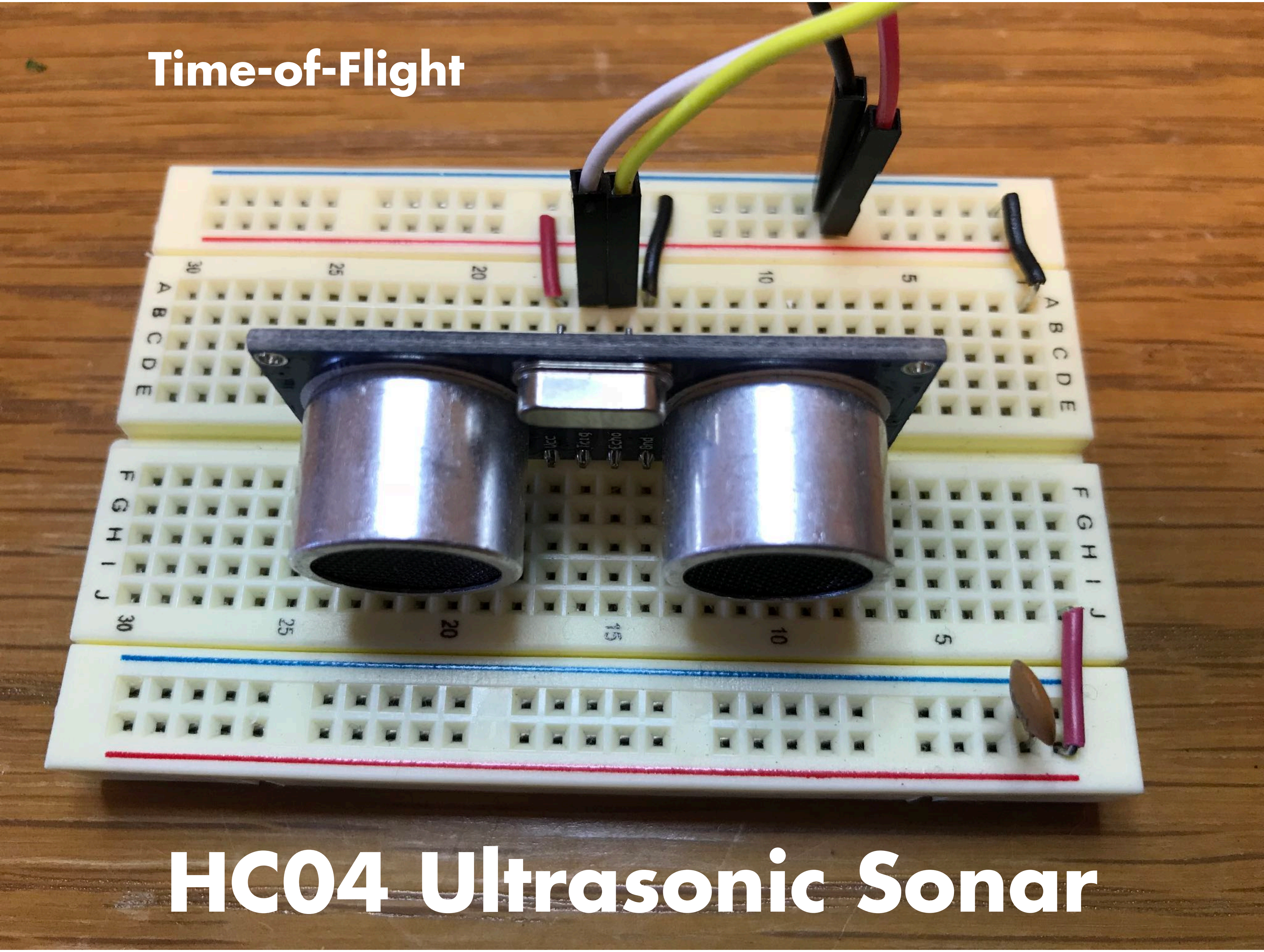
Passive infrared (PIR)


3144 Hall Effect Sensor and Magnet
X
VCC
1
2
3
SUPPLY
GROUND
OUTPUT

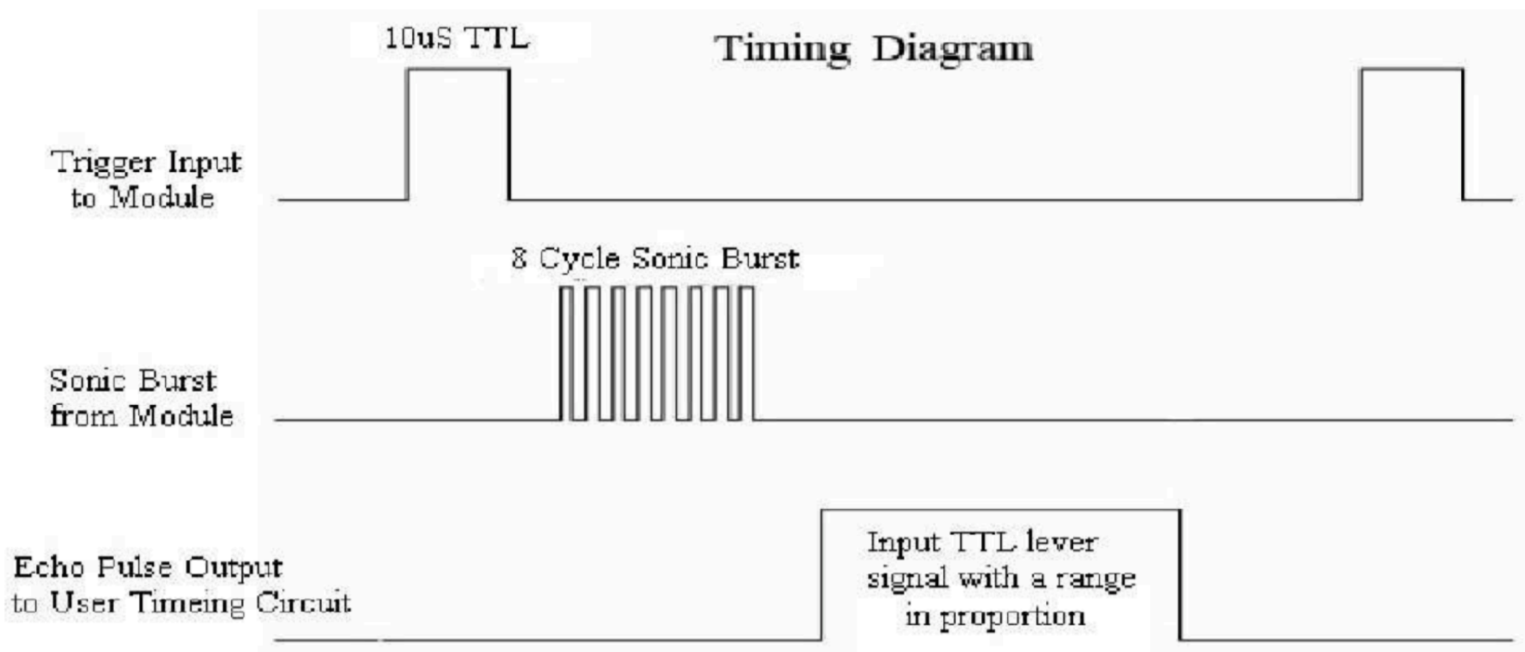
38 Khz IR Receiver



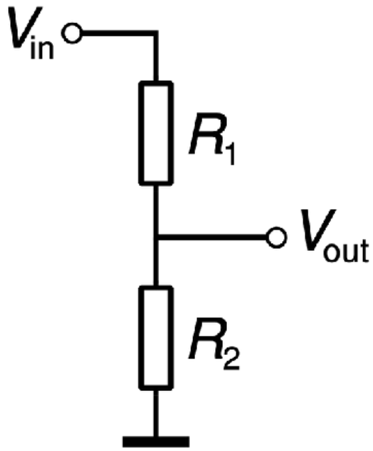
Apple Remote Protocol


Time-of-Flight
HC04 Ultrasonic Sonar

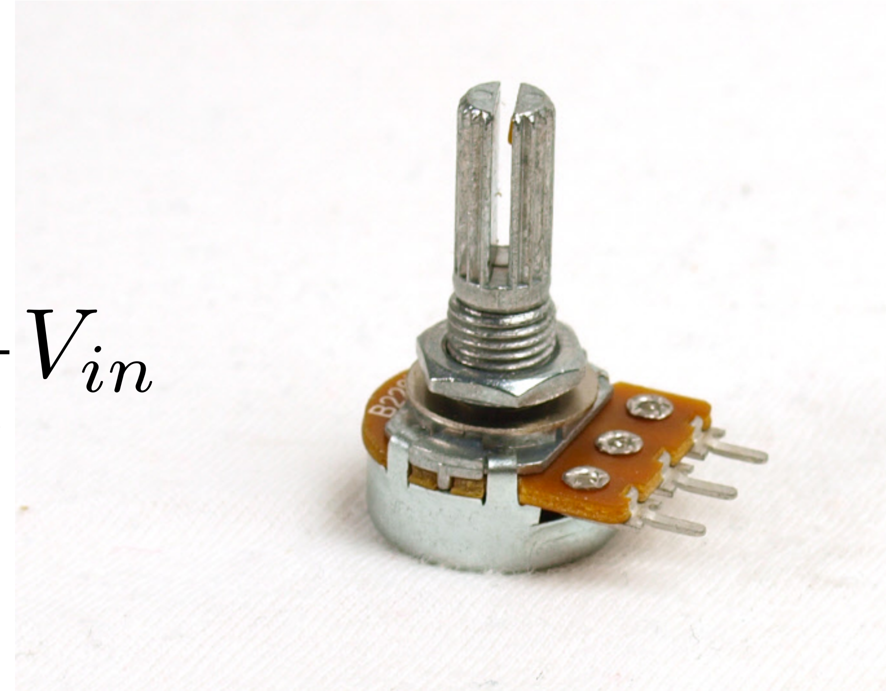
The Timing diagram is shown below. You only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion .You can calculate the range through the time interval between sending trigger signal and receiving echo signal. Formula: uS / 58 = 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.

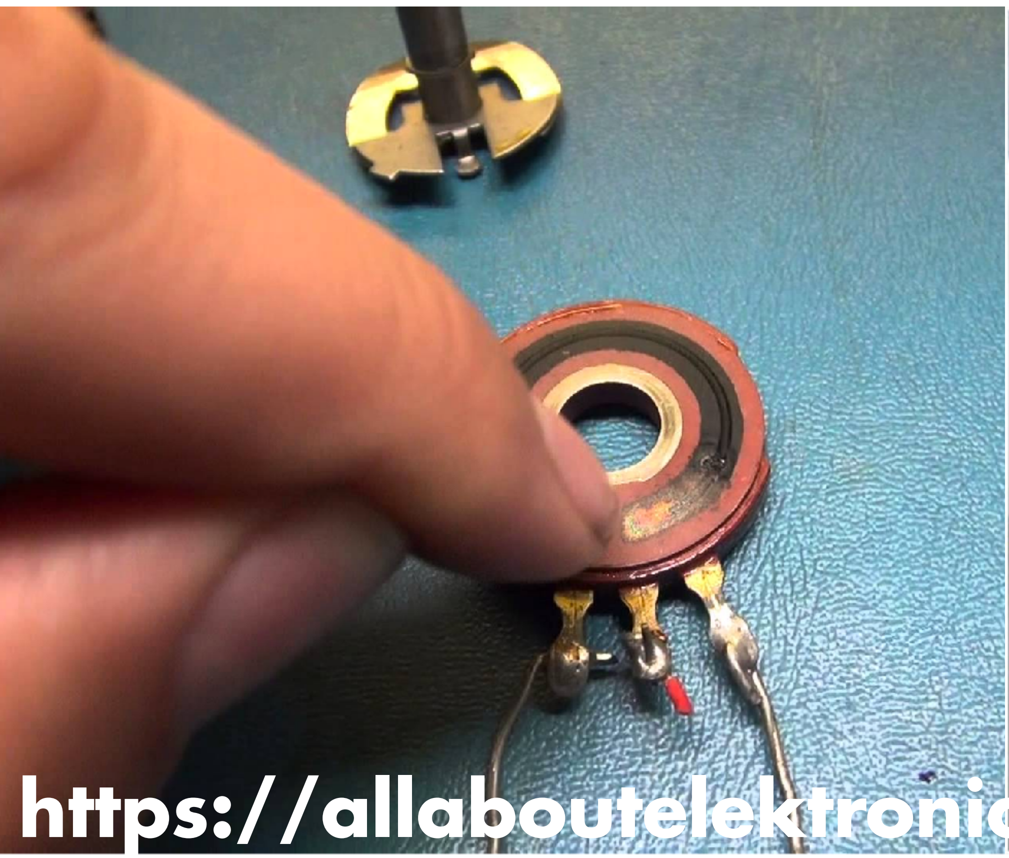


Analog to Digital (ADC)

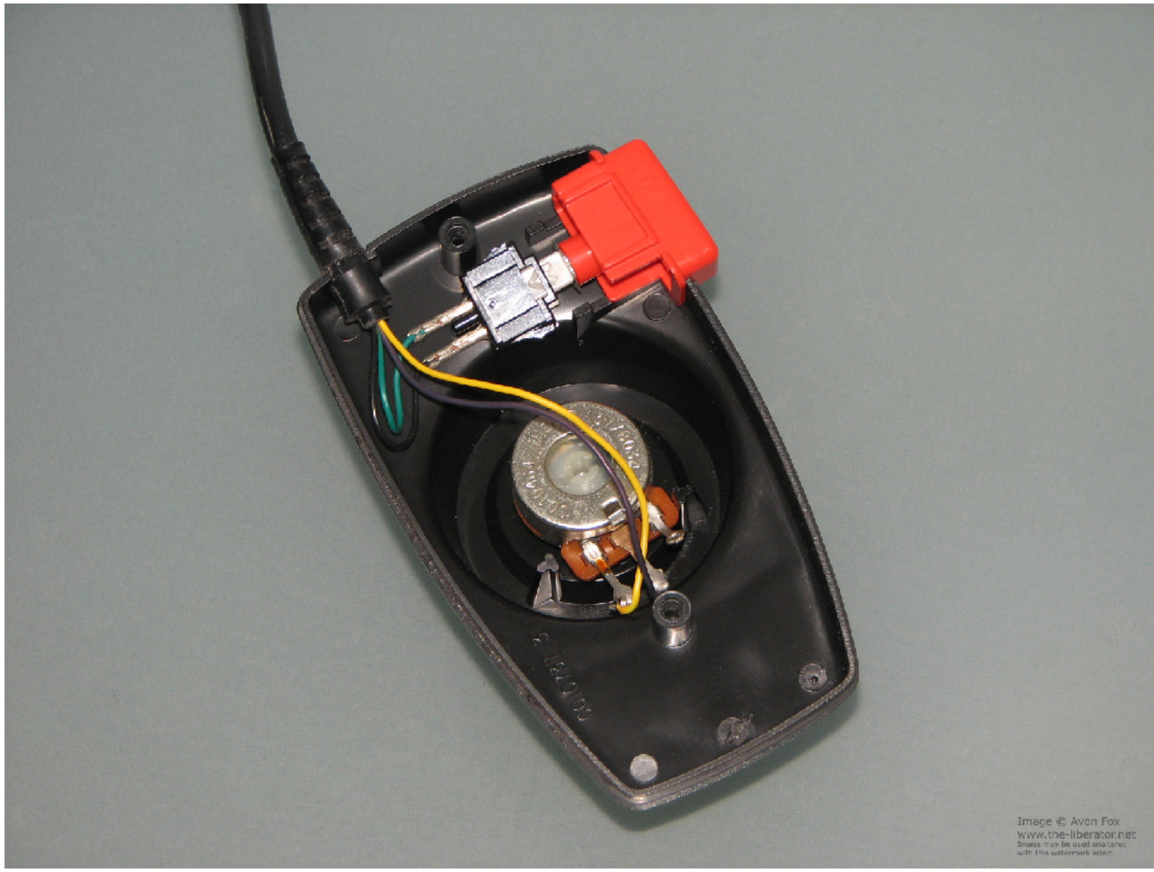


$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$





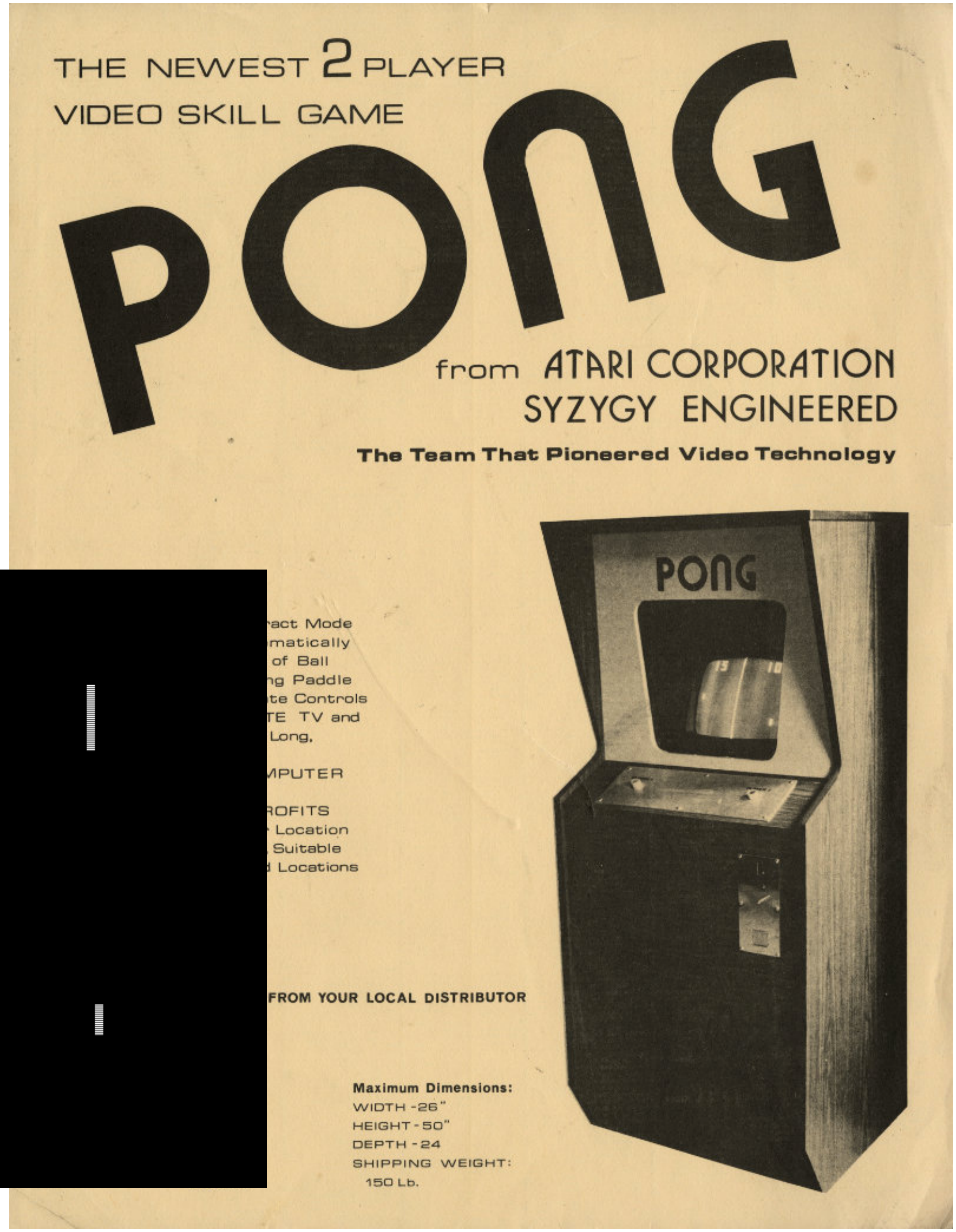
https://allaboutelektronics.wordpress.com/resistors/

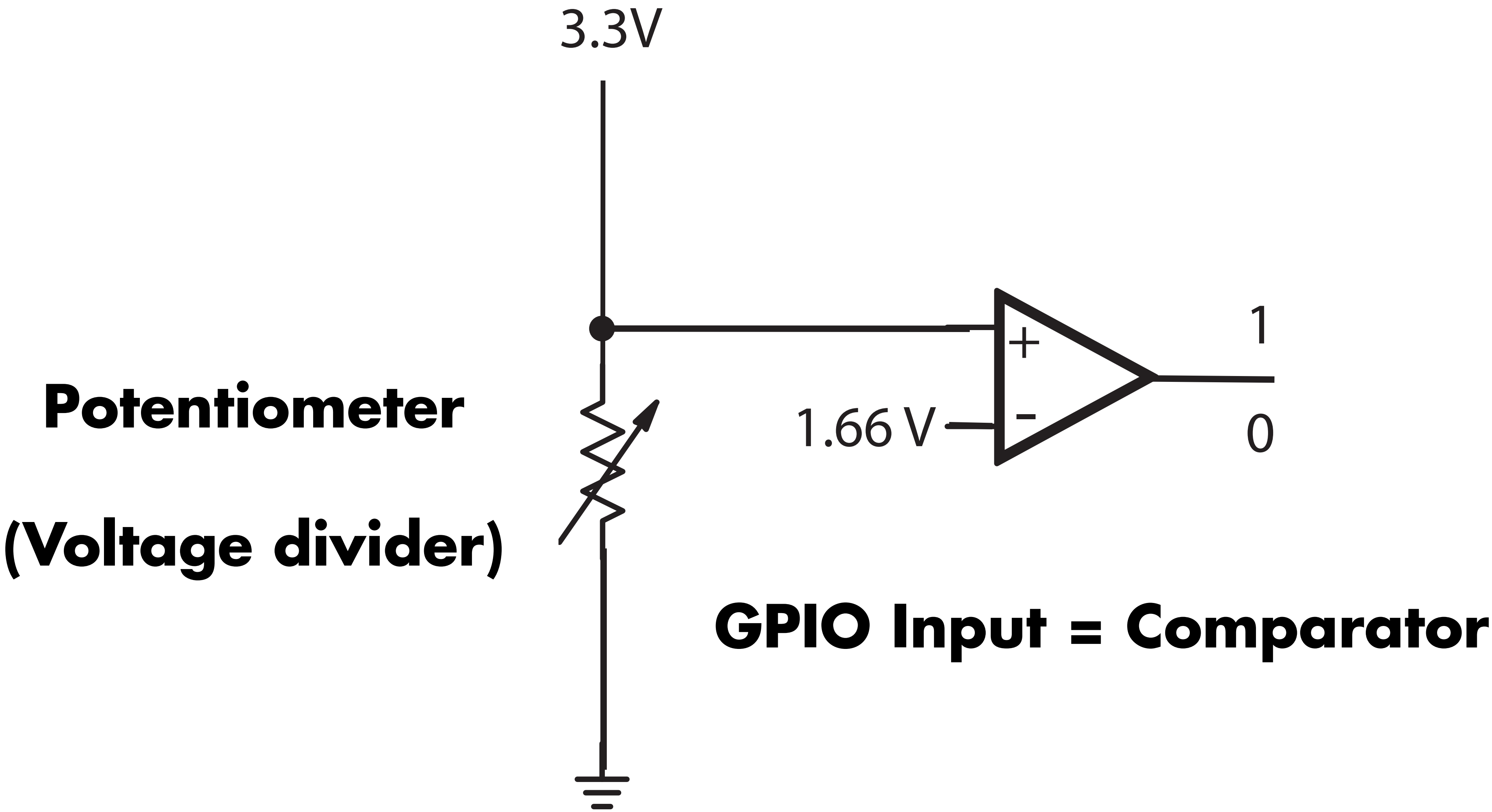


Atari 2600 Paddle

How would you measure the voltage?

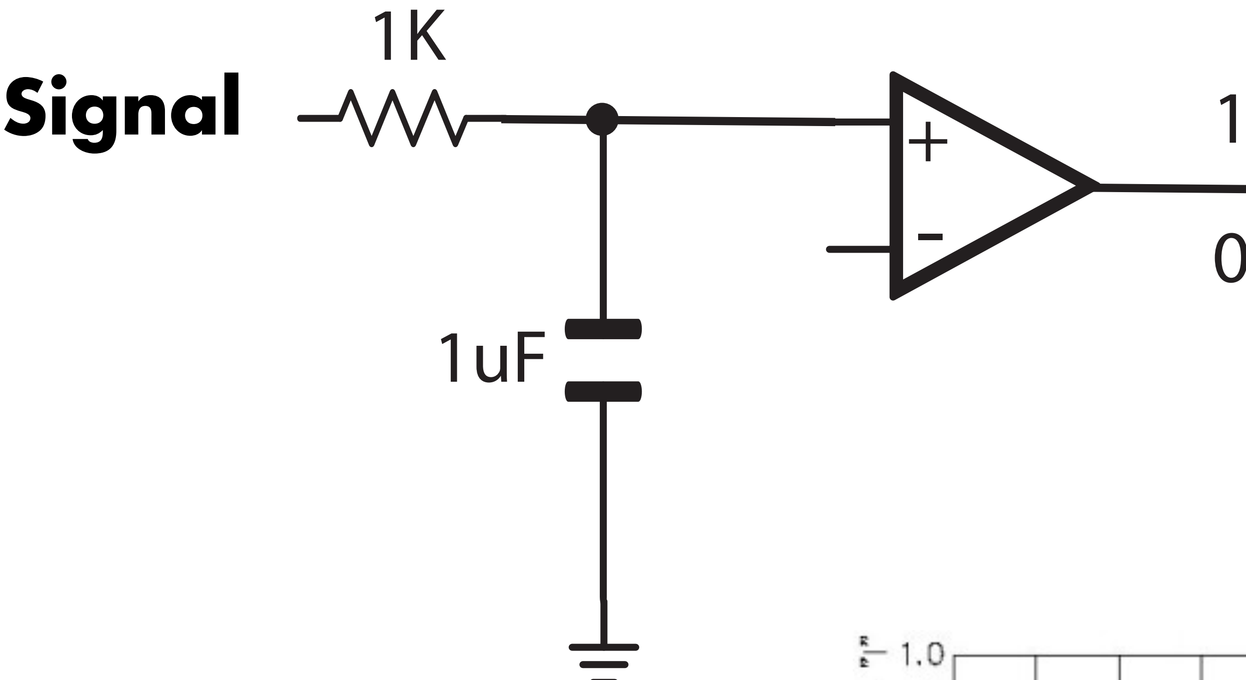

PLAYER 1


THE NEWEST 2 PLAYER
VIDEO SKILL GAME
PONG
from ATARI CORPORATION
SYZYGY ENGINEERED
The Team That Pioneered Video Technology
PONG
ract Mode
matically
of Ball
ng Paddle
te Controls
TE TV and
Long.
MPUTER
ROFITS
Location
Suitable
Locations
FROM YOUR LOCAL DISTRIBUTOR
Maximum Dimensions:
WIDTH -26"
HEIGHT-50"
DEPTH -24
SHIPPING WEIGHT:
150 Lb.

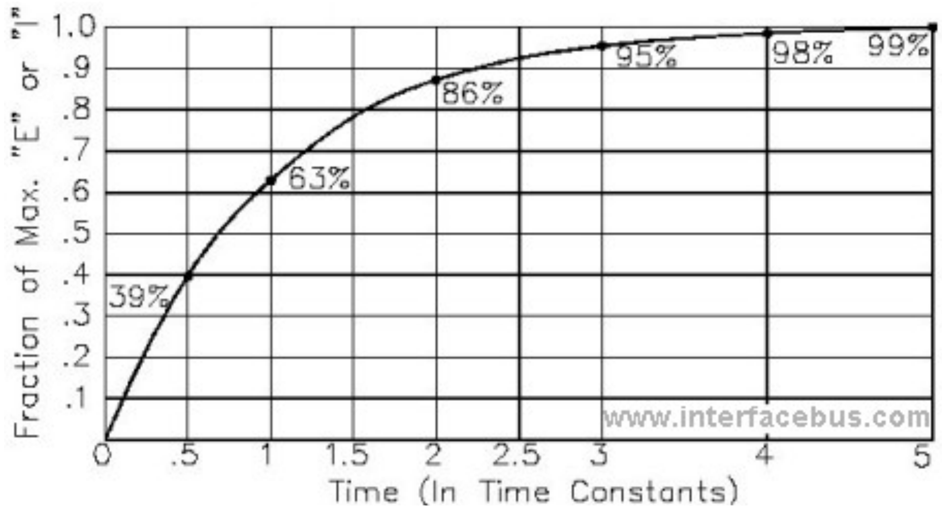

3.3V
Potentiometer
(Voltage divider)
+
-
1.66 V
1
0
GPIO Input = Comparator

Charging Circuit

The time to fire depends on the input signal voltage

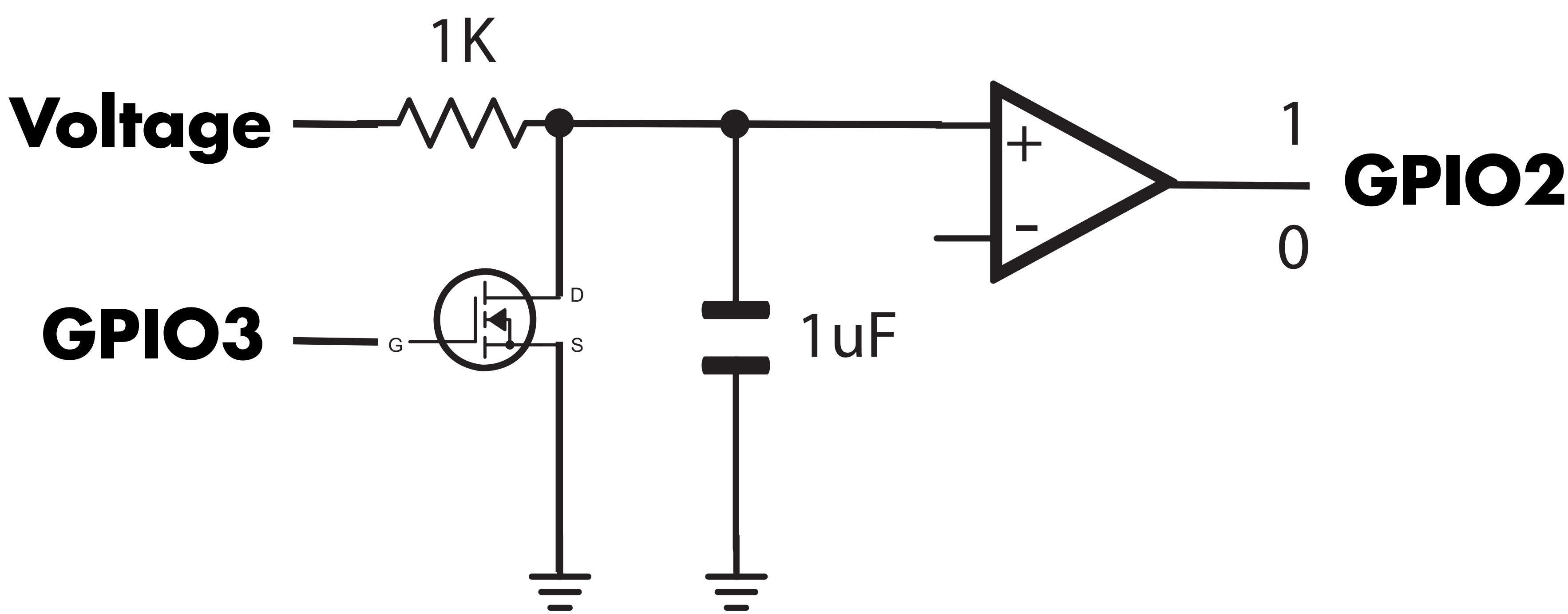


RC = 10^3 x 10^{-6} = 1000usecs

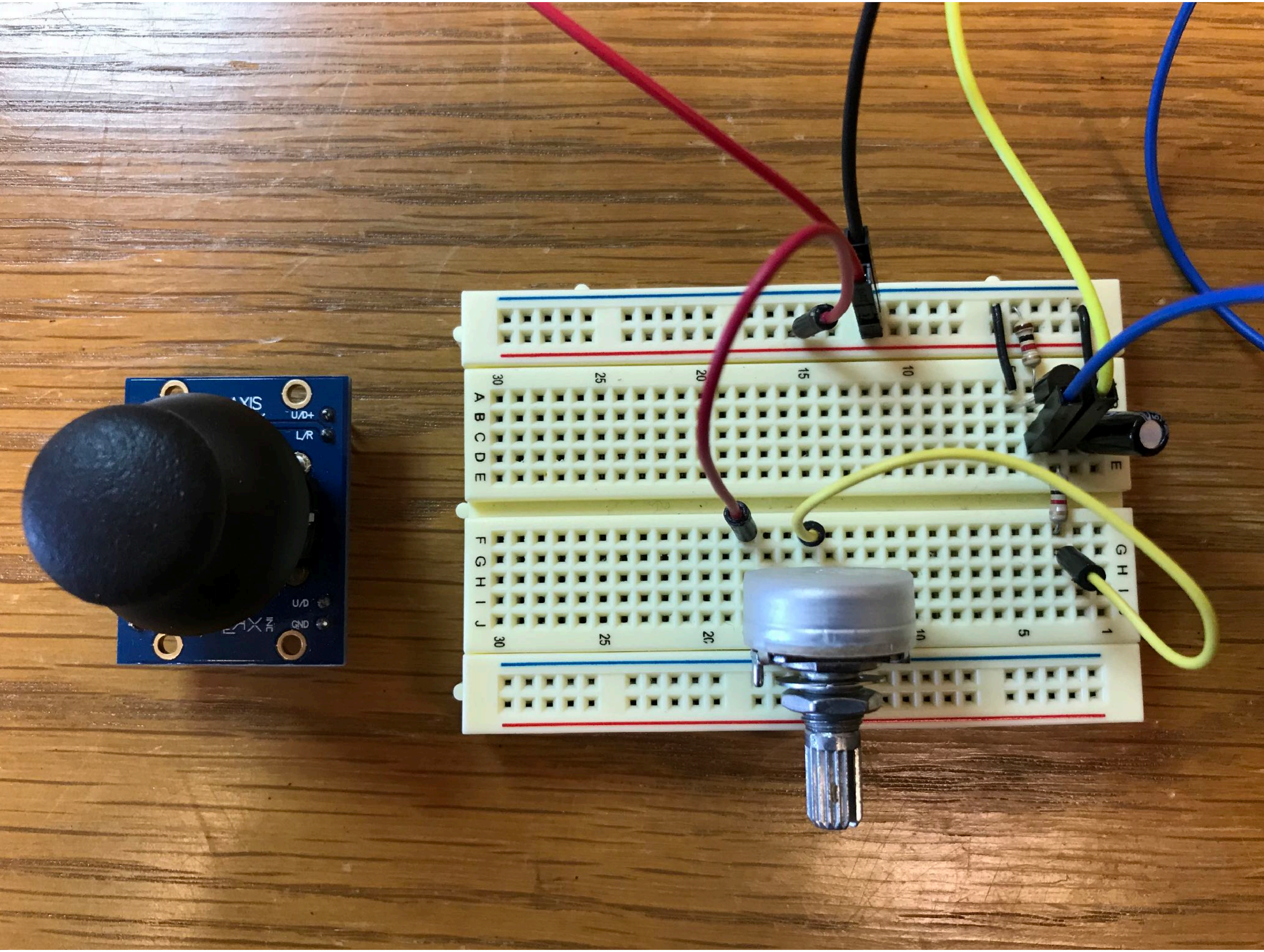


ADC

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



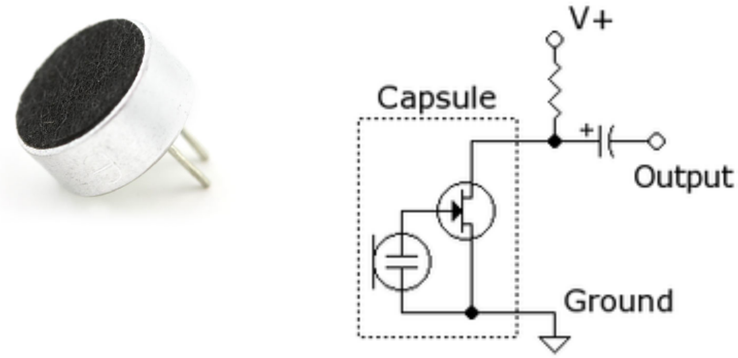
RC = 1000 usecs


U/D+
L/R
U/D
GND

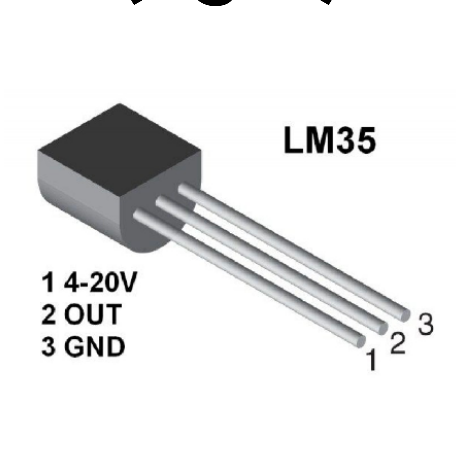
```
unsigned int get_charge_time(void)
{
  // discharge the capacitor
  gpio_write(discharge, 1);
  timer_delay_ms(10);
  gpio_write(discharge, 0);

  // 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

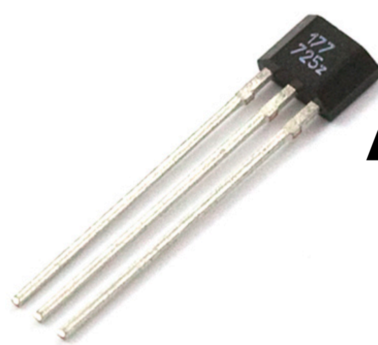
Phototransistor (light)



Electret Microphone (pressure)



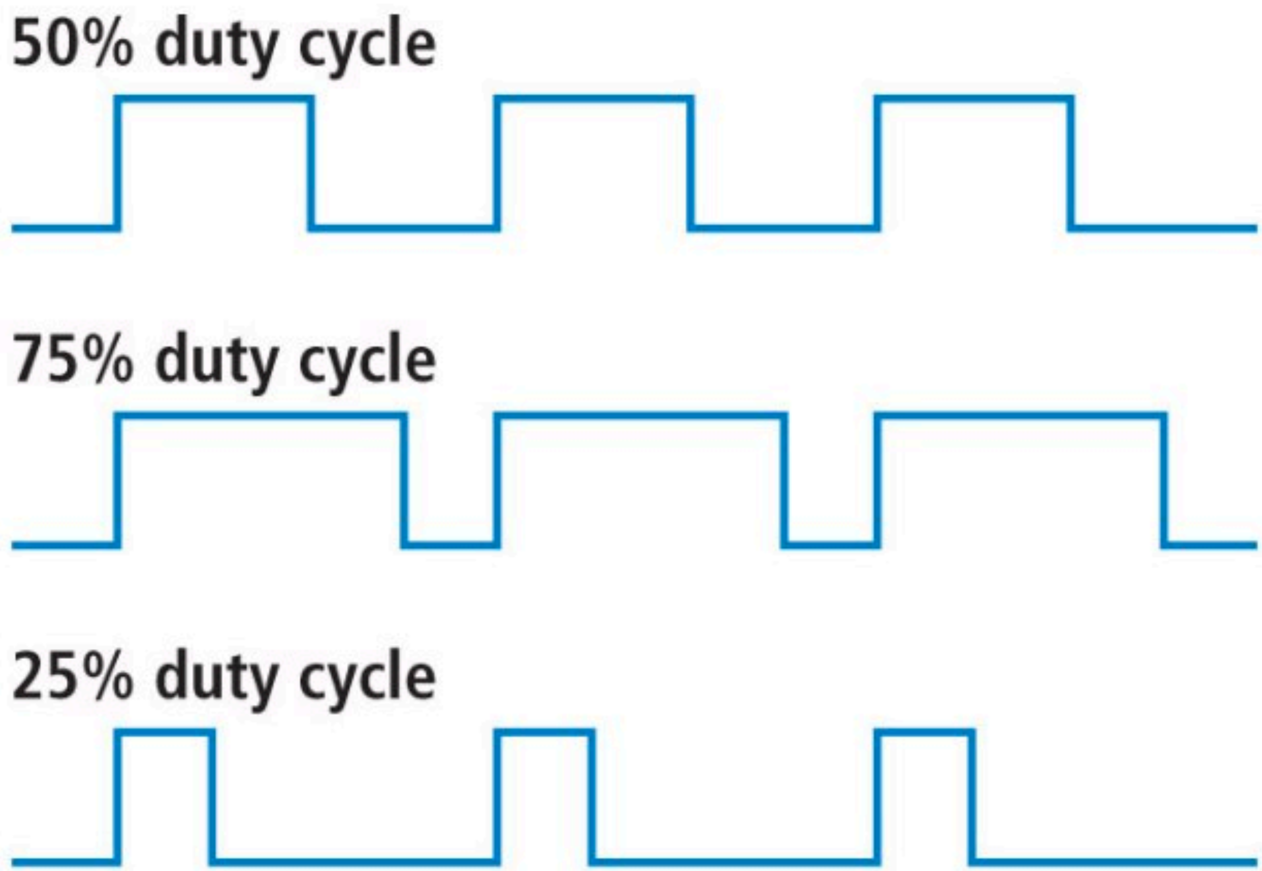
(temperature)



Analog Hall Effect (magnetic field)

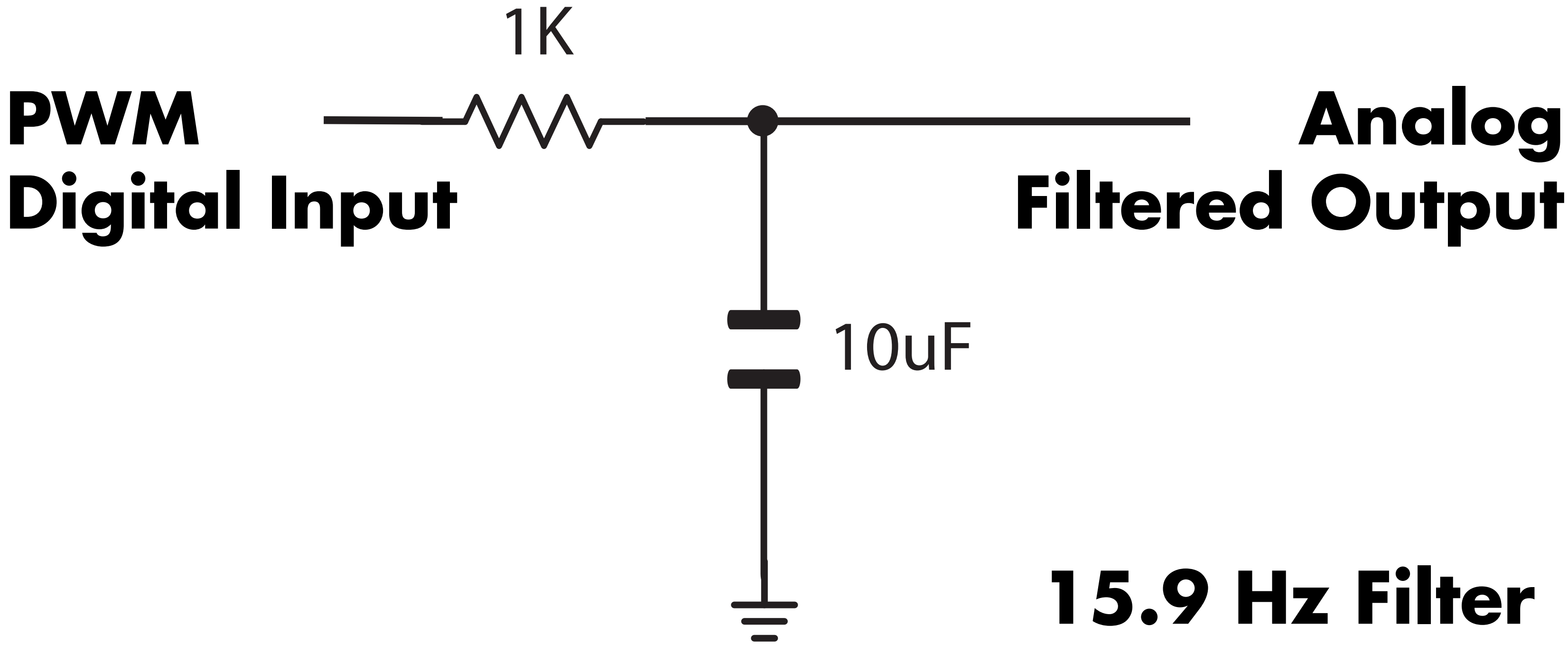
Digital to Analog (DAC)

Pulse-Width Modulation (PWM)

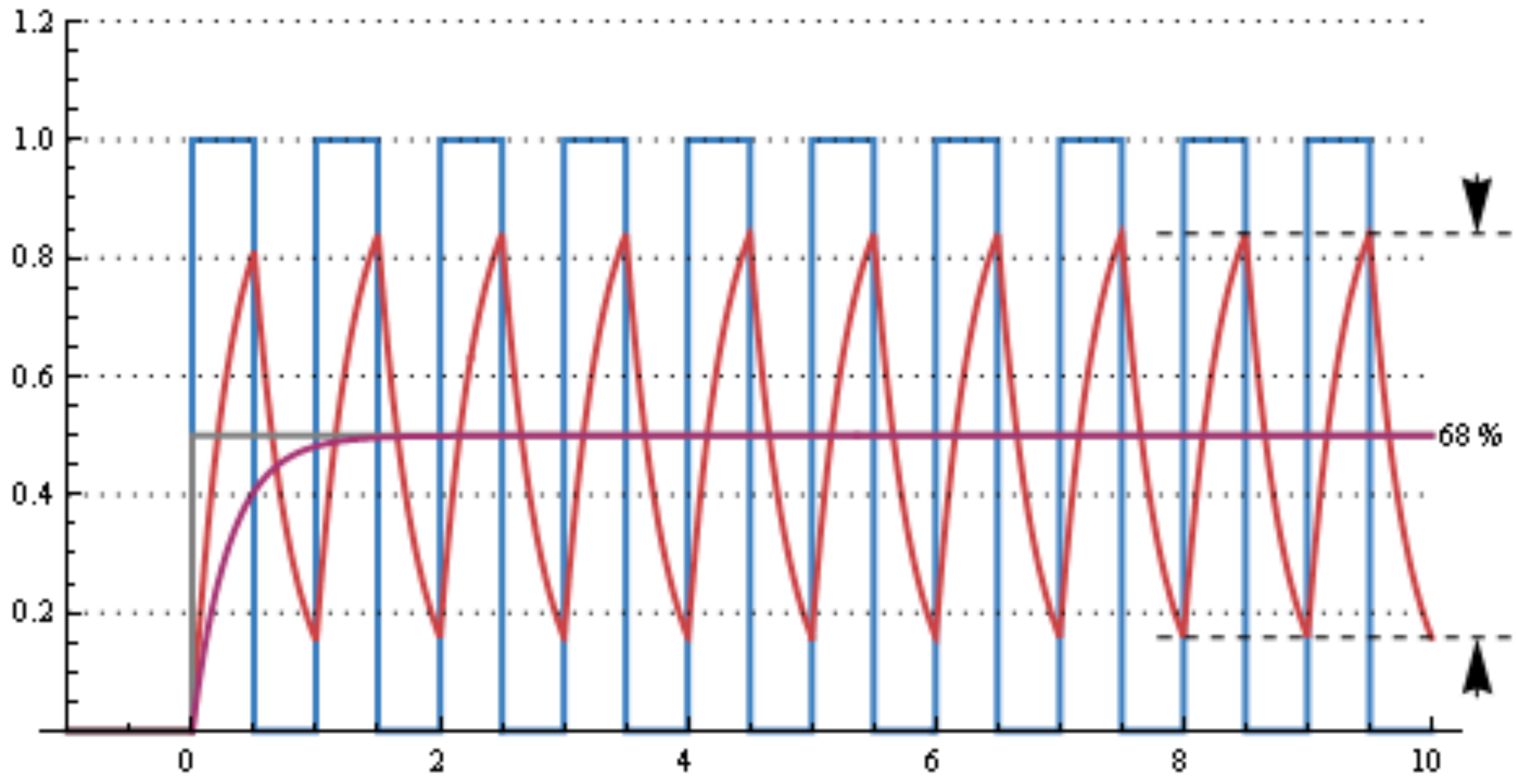


`pwm_clock, pwm_range, pwm_width`

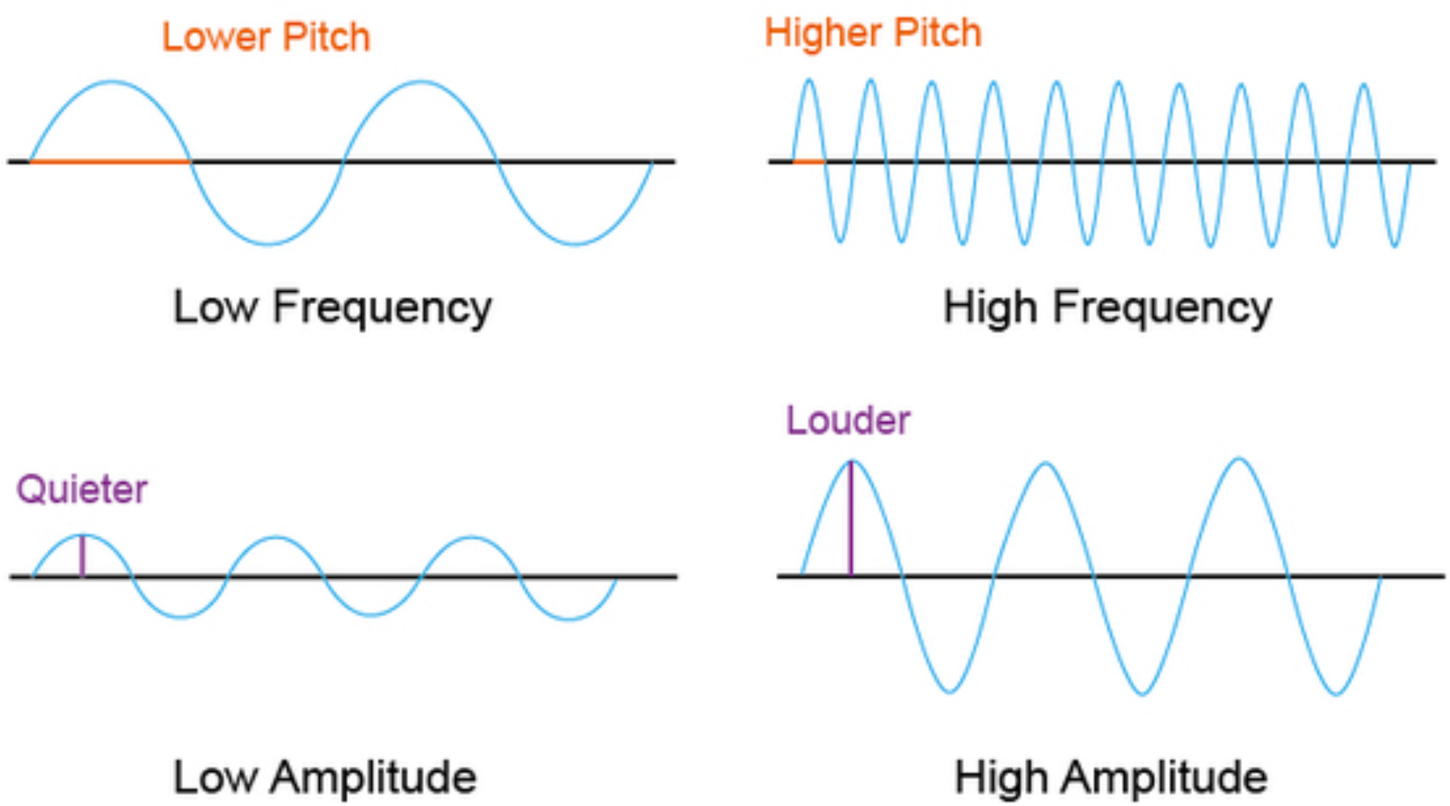
`pwm.c`



15.9 Hz Filter



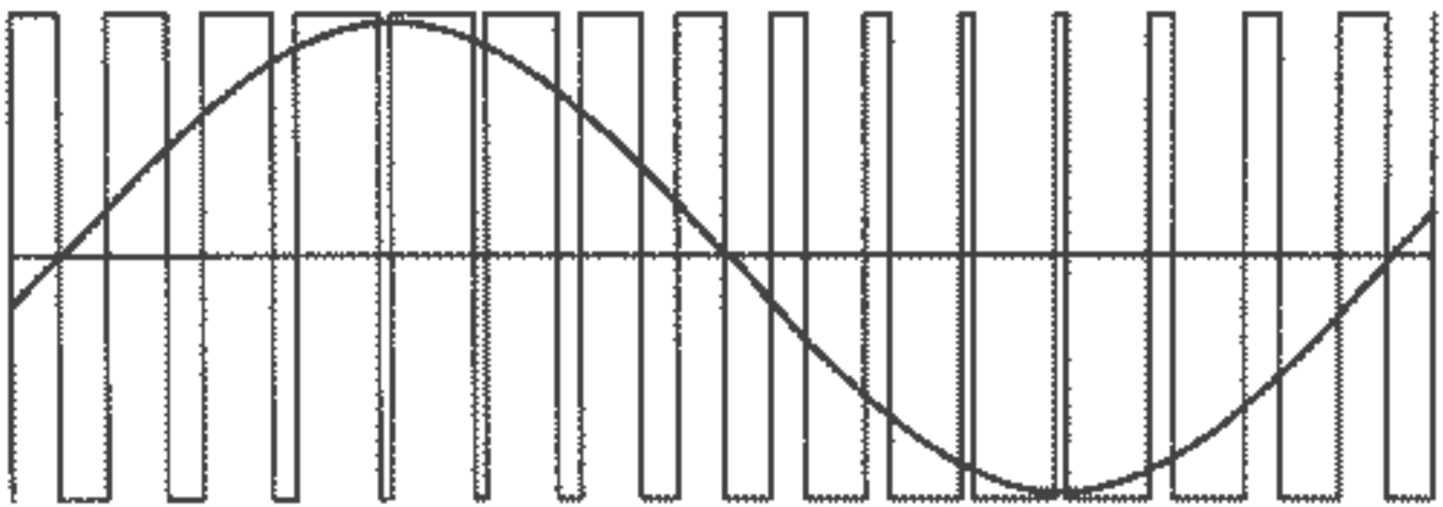
Sound Waves



(c) teachwithict.weebly.com

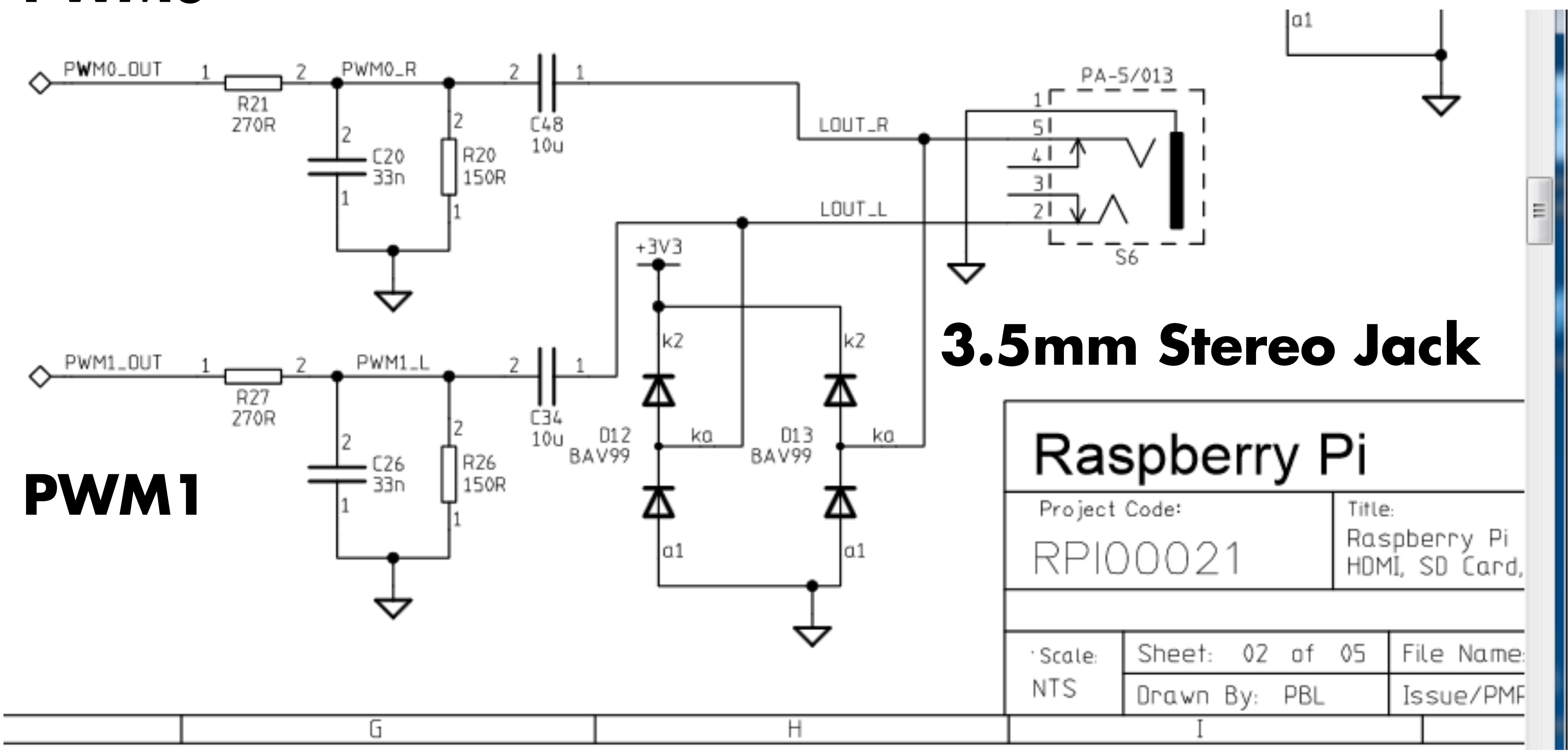
Continuous Values

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



Raspberry Pi Sound

PWM0



3.5mm Stereo Jack

PWM1

Low-pass Filter

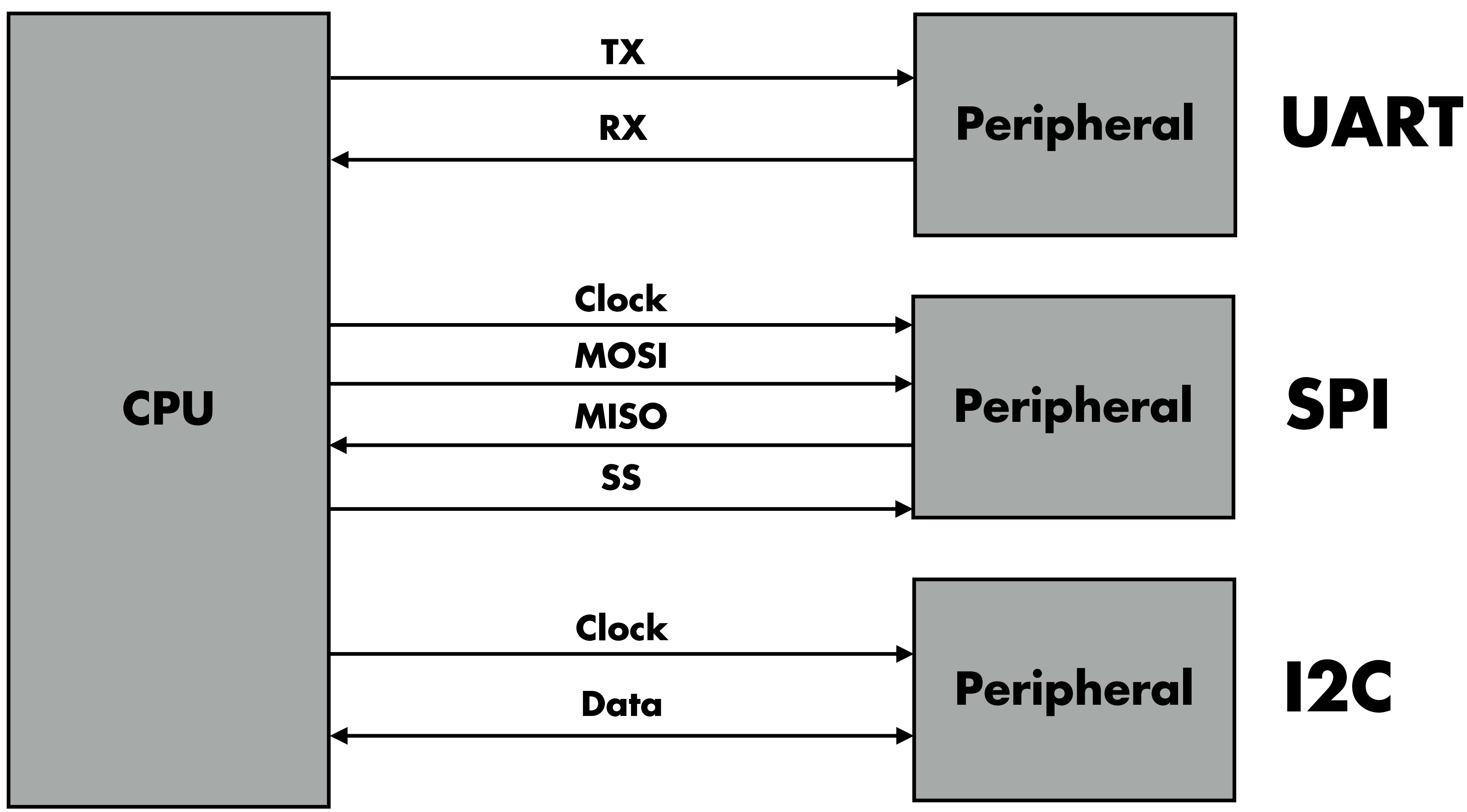
	PWM0	PWM1
GPIO 12	Alt Fun 0	-
GPIO 13	-	Alt Fun 0
GPIO 18	Alt Fun 5	-
GPIO 19	-	Alt Fun 5
GPIO 40	Alt Fun 0	-
GPIO 41	-	Alt Fun 0
GPIO 45	-	Alt Fun 0
GPIO 52	Alt Fun 1	-
GPIO 53	-	Alt Fun 1

Stereo Jack connected to GPIO_PIN40 and GPIO_PIN45

tone.c
melody.c
audio.c

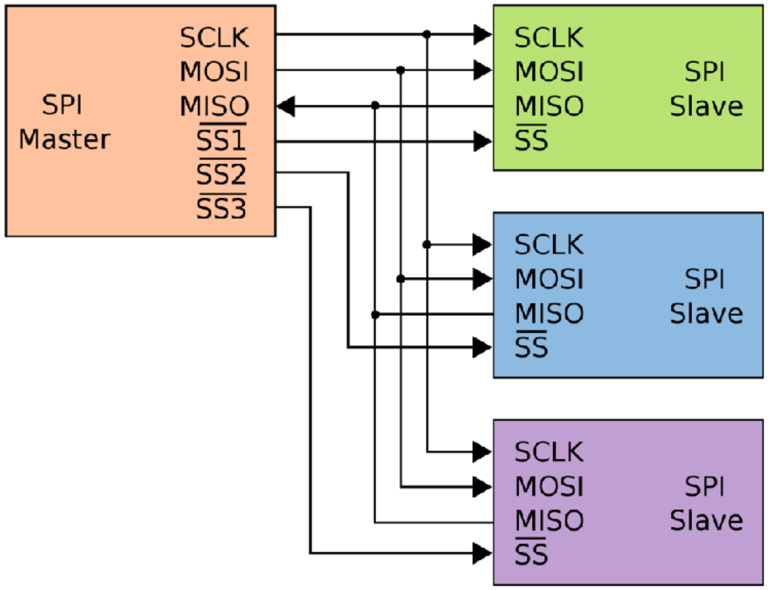
Smart Sensors

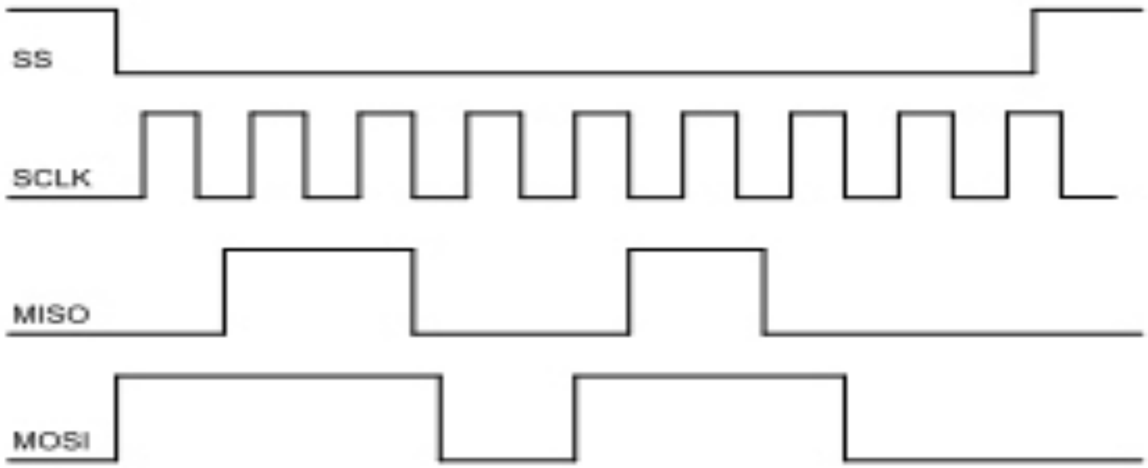
Bus Protocols



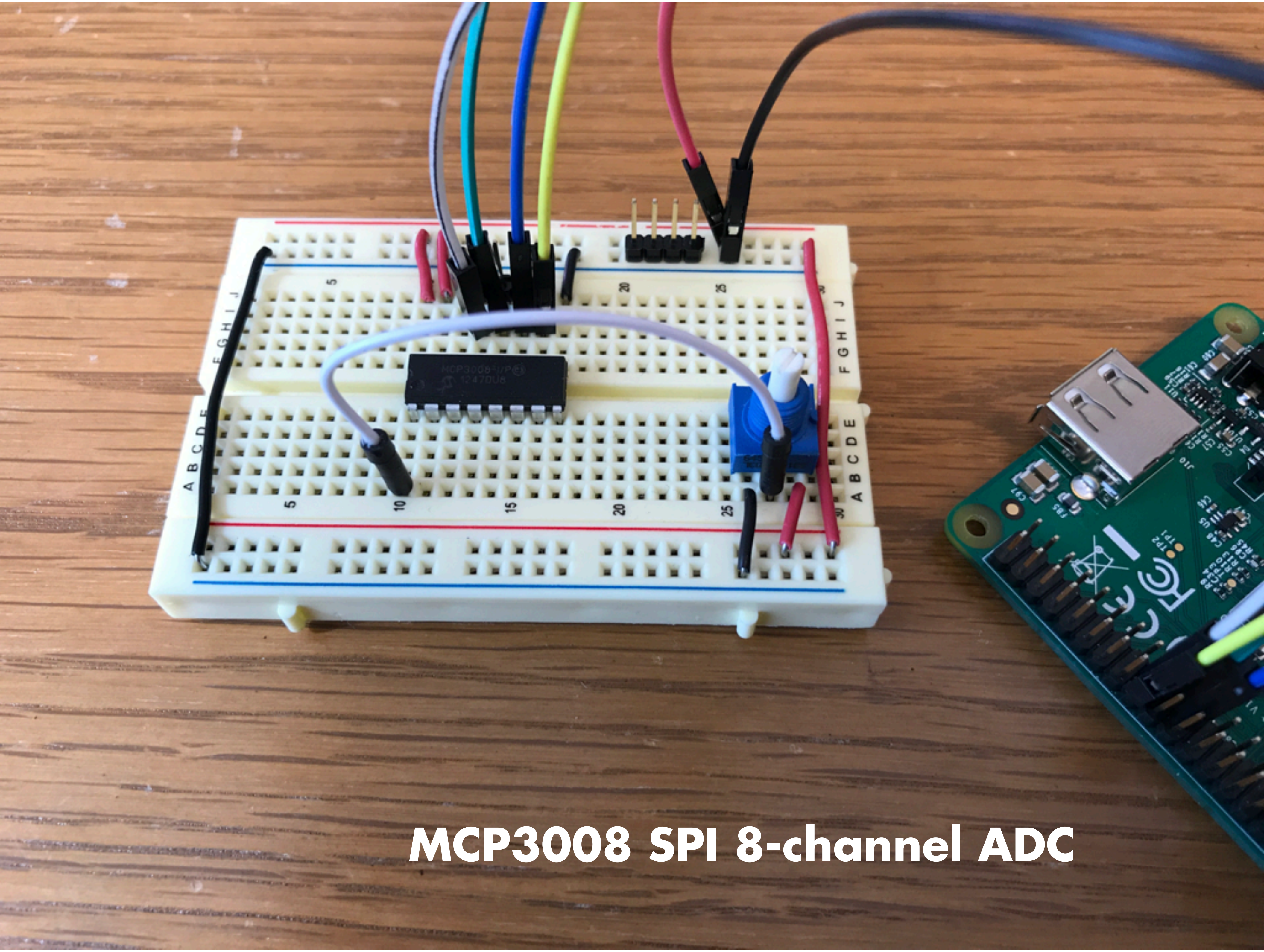
SPI

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

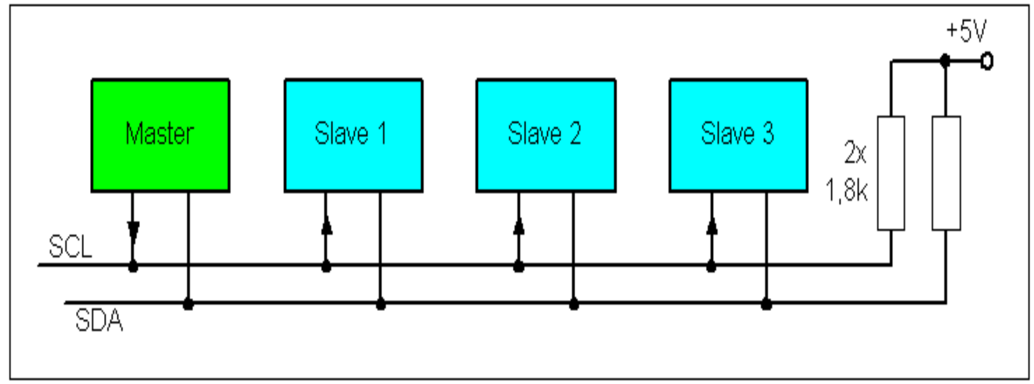




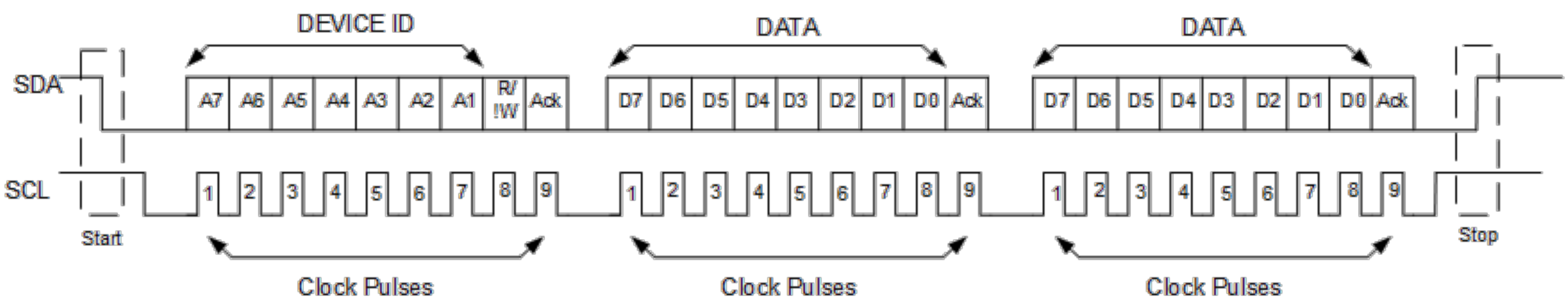
Figures from https://upload.wikimedia.org/wikipedia/commons/thumb/f/fc/SPI_three_slaves.svg/2000px-SPI_three_slaves.svg.png (top), http://www.tequipment.net/RigolSD-SPI-DS4.html (bottom)


MCP3008 SPI 8-channel ADC

I2C

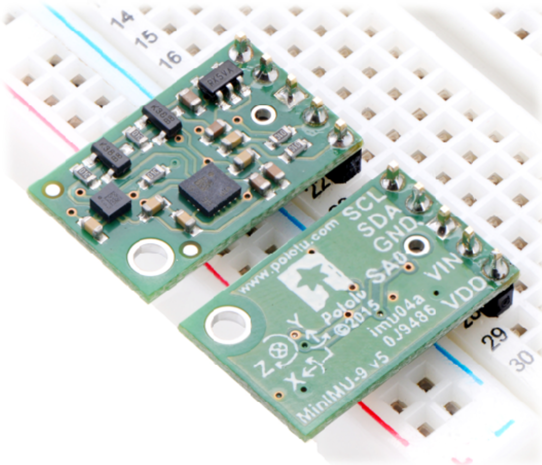


- CLK & DATA lines (with pull-ups)
- Clocked by master, both master and slave and send data
- Shared bus, slave identified by 7 (or 10) bit address

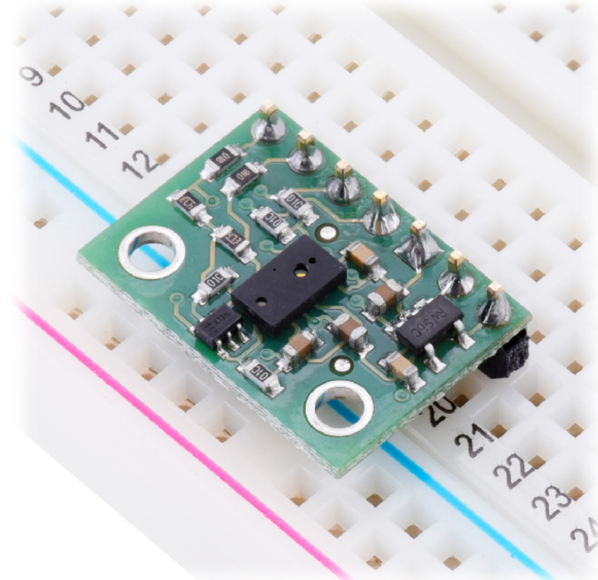


Figures from http://www.cs.fsu.edu/~baker/devices/notes/graphics/i2cbus3.gif (top) https://learn.digilentinc.com/Documents/chipKIT/chipKITPro/P08/Fig_1_Waveform.png (bottom)

I2C Sensors



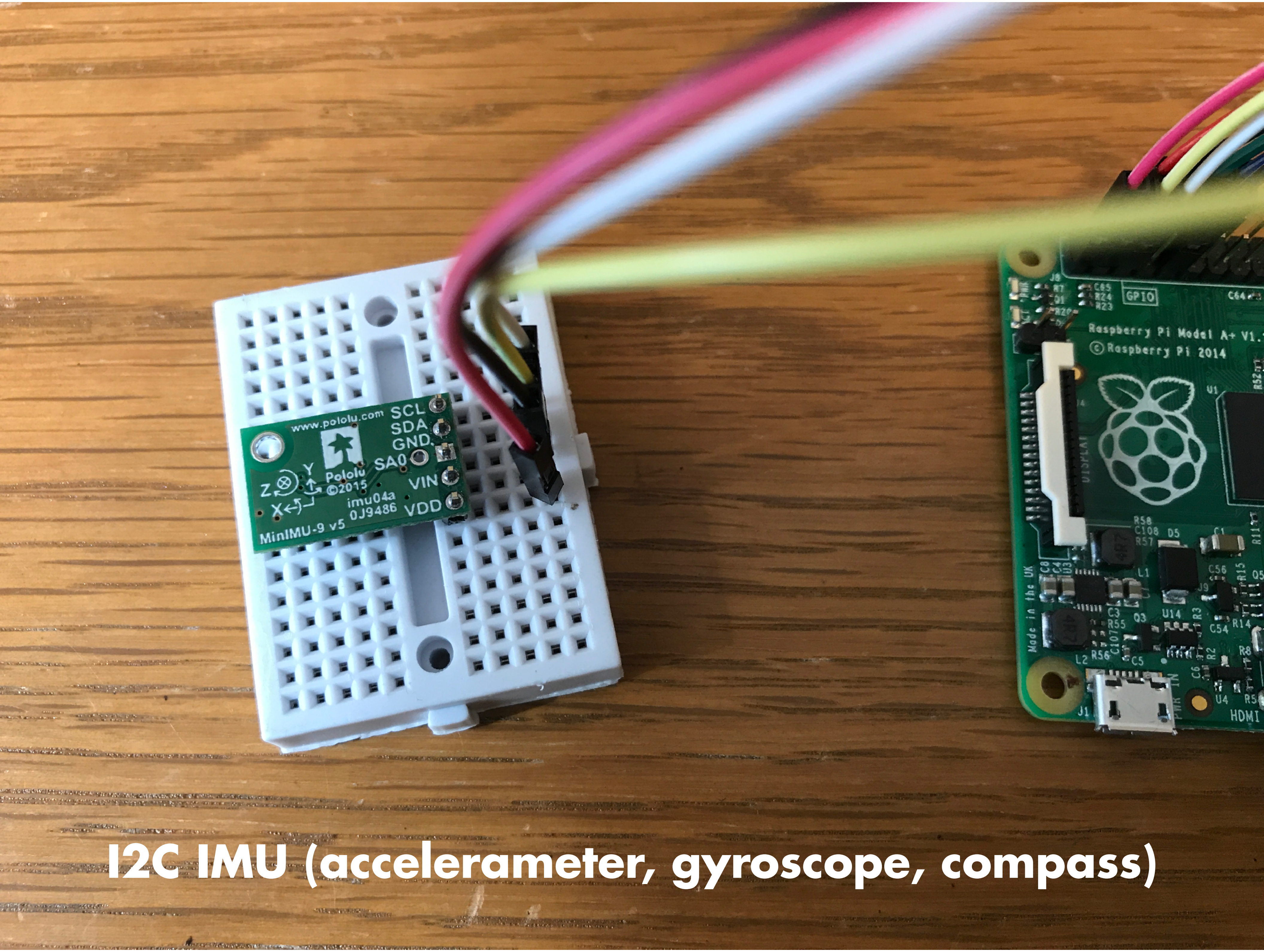
Accelerometer
Gyroscope
Magnetometer



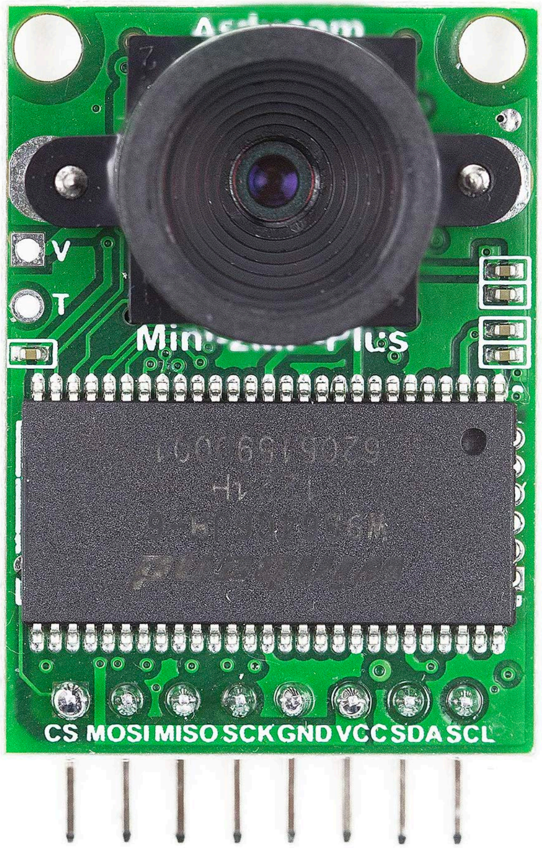
VCSEL Time of Flight

Temperature,
Humidity,
Pressure

Arducam (SPI and I2C)

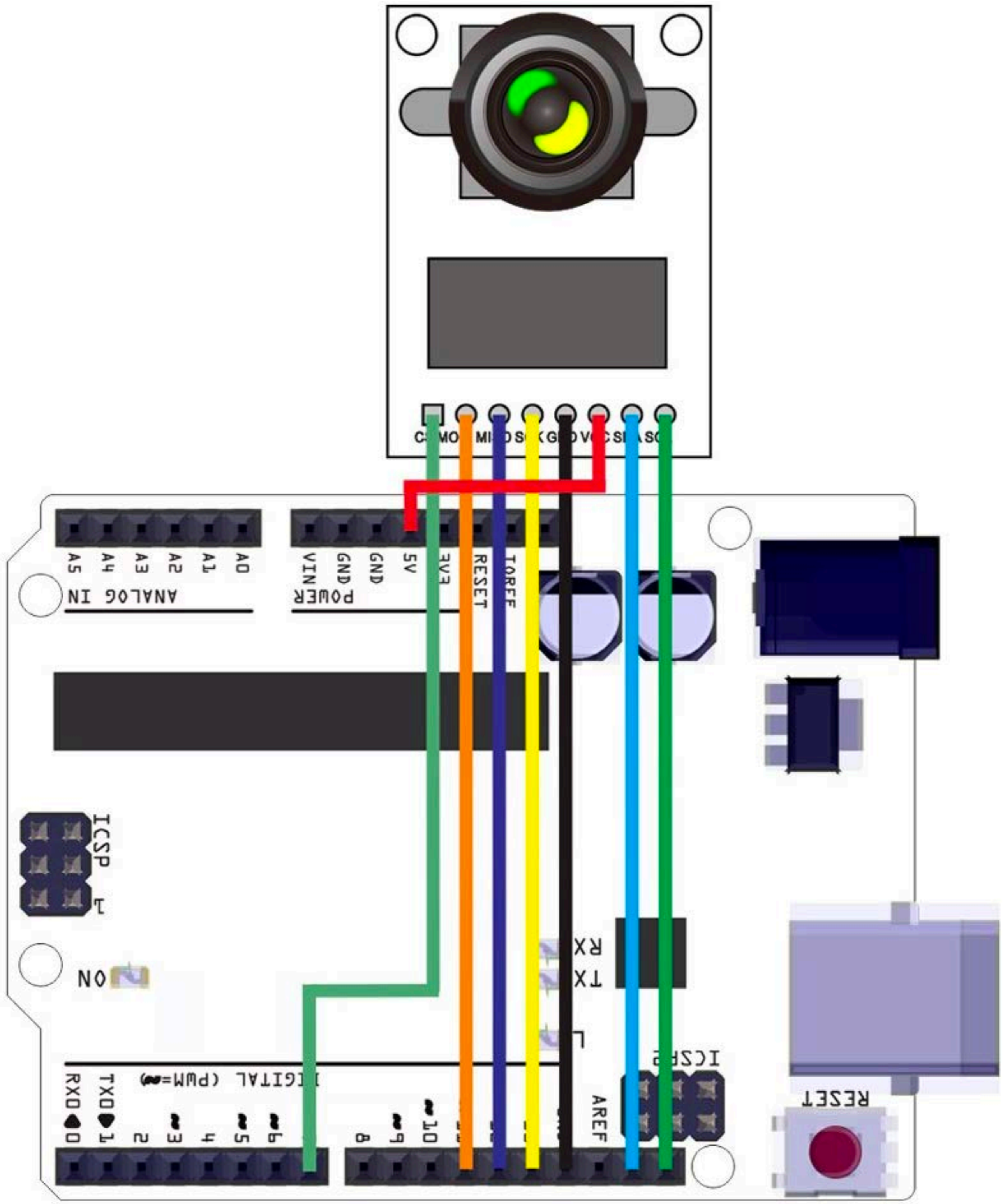


I2C IMU (accelerameter, gyroscope, compass)

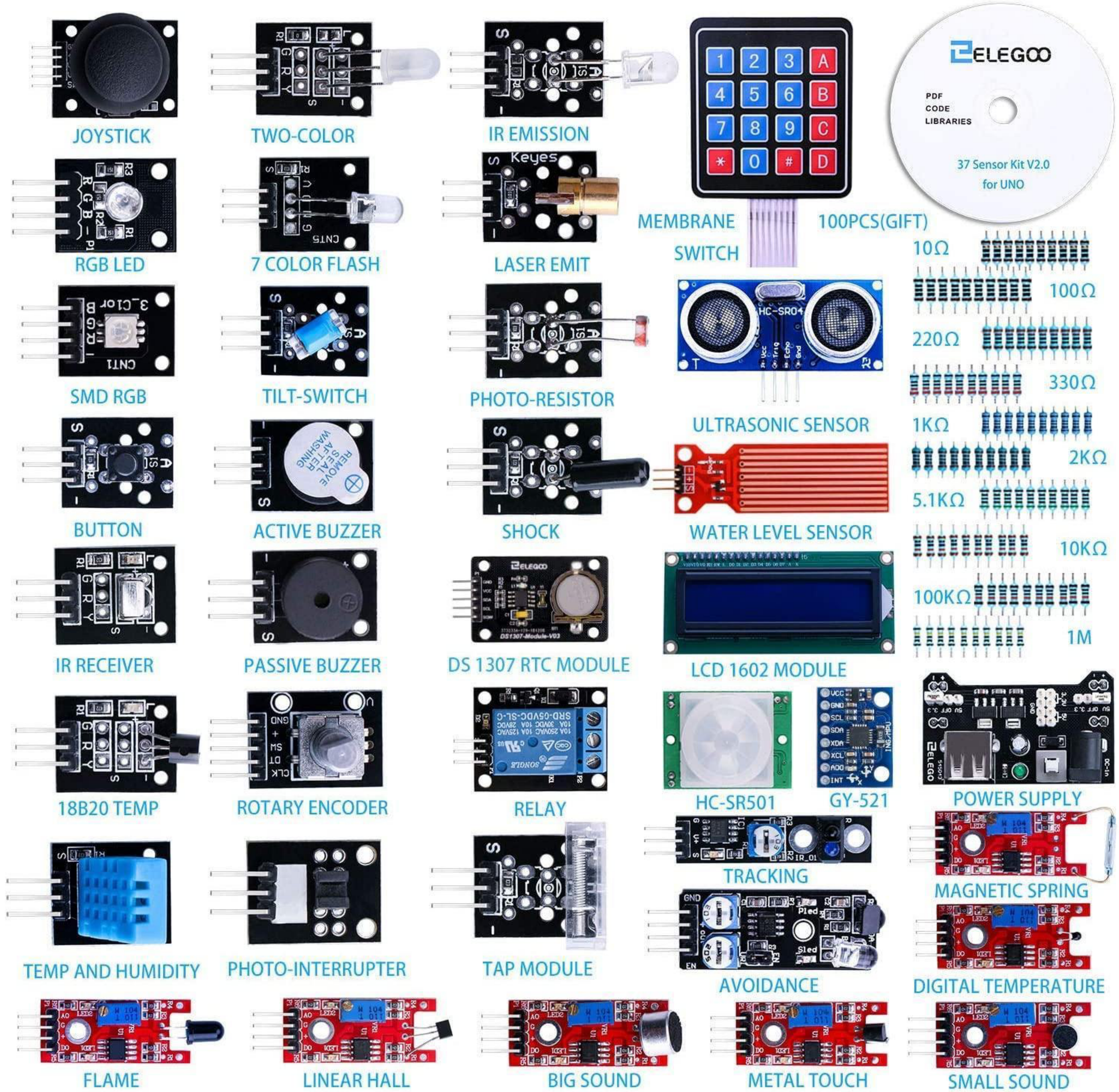


Arducam

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 (light dependent resistance, capacitance)-

Convert energy to voltage/current

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

Smart sensors (sensor with a digital interface)

- Acceleration/Gyroscope/Magnetic
- Camera, IMU (inertial management unit), ...