Interacting with the Environment the Digital Way

A practical guide for interfacing sensors

What is a sensor?

A sensor is basically a device which detects and converts your signal of interest into a measurable or observable quantity (mostly an electrical signal).

What concepts of Arduino are required?

- **Mostly Basic Digital I/O**

- **Concept of Aanalog To Digital Conversion using Arduino**

The Analog World

- **Microcontrollers are capable of detecting binary signals: is the button pressed or not? These are digital signals.**

- **When a microcontroller is powered from five volts, it understands zero volts (0V) as a binary 0 and a five volts (5V) as a binary 1.**

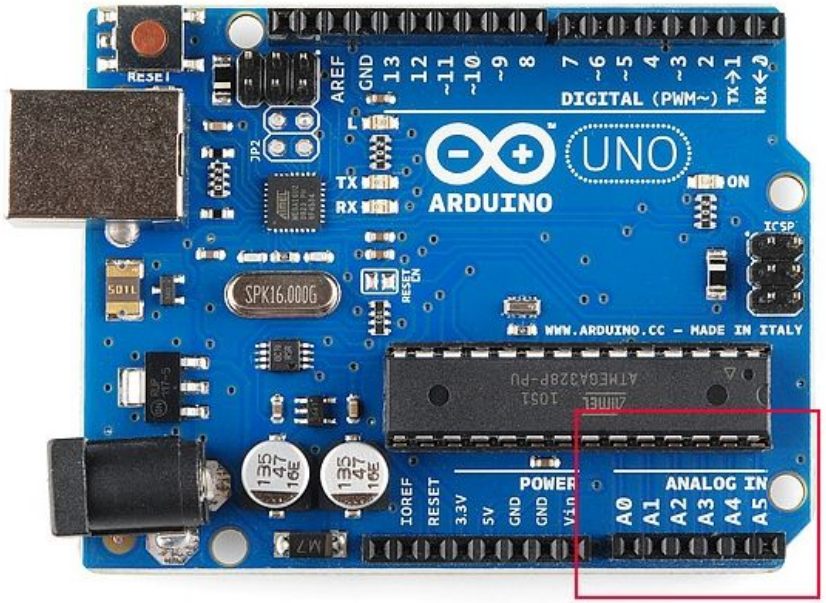
The Analog World : Where Things Get Complex

- **The world however is not so simple and likes to use shades of gray. What if the signal is 2.72V? Is that a zero or a one?**
- **We often need to measure signals that vary; these are called analog signals.**
- **A 5V analog sensor may output 0.01V or 4.99V or anything inbetween.**

What is the ADC?

- **An Analog to Digital Converter (ADC) converts an analog voltage on a pin to a digital number.**
- **By the Analog 2 Digital conversion, we can begin to use electronics to interface to the analog world around us.**

Where do ADCs reside?



- Not every pin on a microcontroller has the ability to do analog to digital conversions.
- On the Arduino board, these pins have an ‘A’ in front of their label (A0 through A5) to indicate these pins can read analog voltages.

Specification of ADC

- ADCs can vary greatly between microcontroller. The ADC on the Arduino is a 10-bit ADC meaning it has the ability to detect 1,024 (2^10) discrete analog levels.
- Some microcontrollers have 8-bit ADCs (28 = 256 discrete levels) and some have 16-bit ADCs (2^16 = 65,536 discrete levels).

Relating ADC Value to Voltage

The ADC reports a ratiometric value. This means that the ADC assumes 5V is 1023 and anything less than 5V will be a ratio between 5V and 1023.

$$\frac{Resolution\ of\ the\ ADC}{System\ Voltage} = \frac{ADC\ Reading}{Analog\ Voltage\ Measured}$$

Relating ADC Value to Voltage (contd..)

- **Analog to digital conversions are dependant on the system voltage.**
- **Because we predominantly use the 10-bit ADC of the Arduino on a 5V system, we can simplify this equation slightly:**

$$\frac{1023}{5} = \frac{ADC\ Reading}{Analog\ Voltage\ Measured}$$

Can you answer?

If the analog voltage is 2.12V what will the ADC report as a value?

$$\frac{1023}{5.00V} = \frac{x}{2.12V}$$

The Answer!

Rearrange things a bit and we get:

$$\frac{1023}{5.00V} * 2.12V = x$$

$$x = 434$$

Ahah! The ADC should report 434.

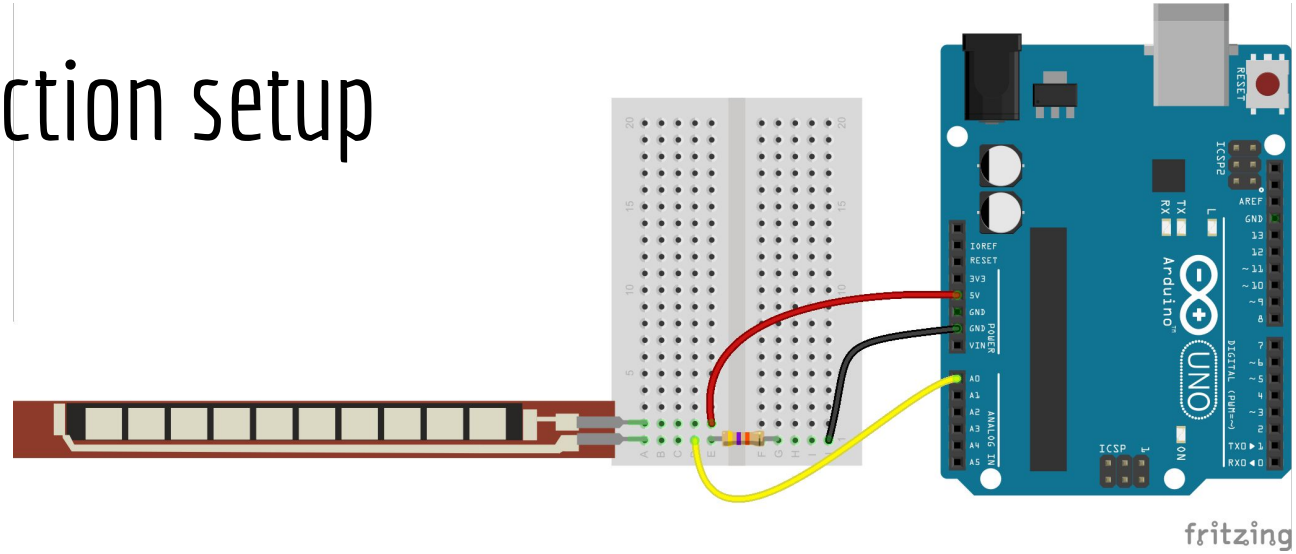
Let's try out Our Knowledge!

By Interfacing some sensors!

Flex Sensor

Flex sensors are passive resistive devices that can be used to detect bending or flexing.

Connection setup



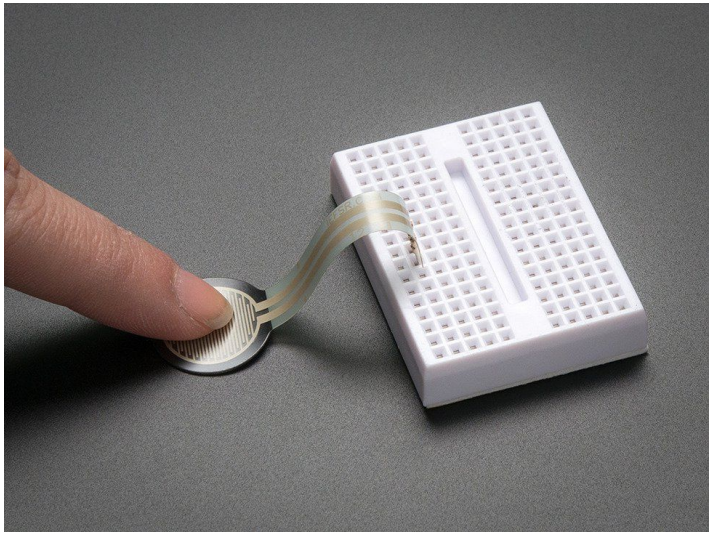
Flex Sensor : Code

```
const int FLEX_PIN = A0;
const float VCC = 4.98;
const float R_DIV = 47500.0;

const float STRAIGHT_RESISTANCE = 37300.0;
const float BEND_RESISTANCE = 90000.0;

void setup()
{
  Serial.begin(9600);
  pinMode(FLEX_PIN, INPUT);
}
```

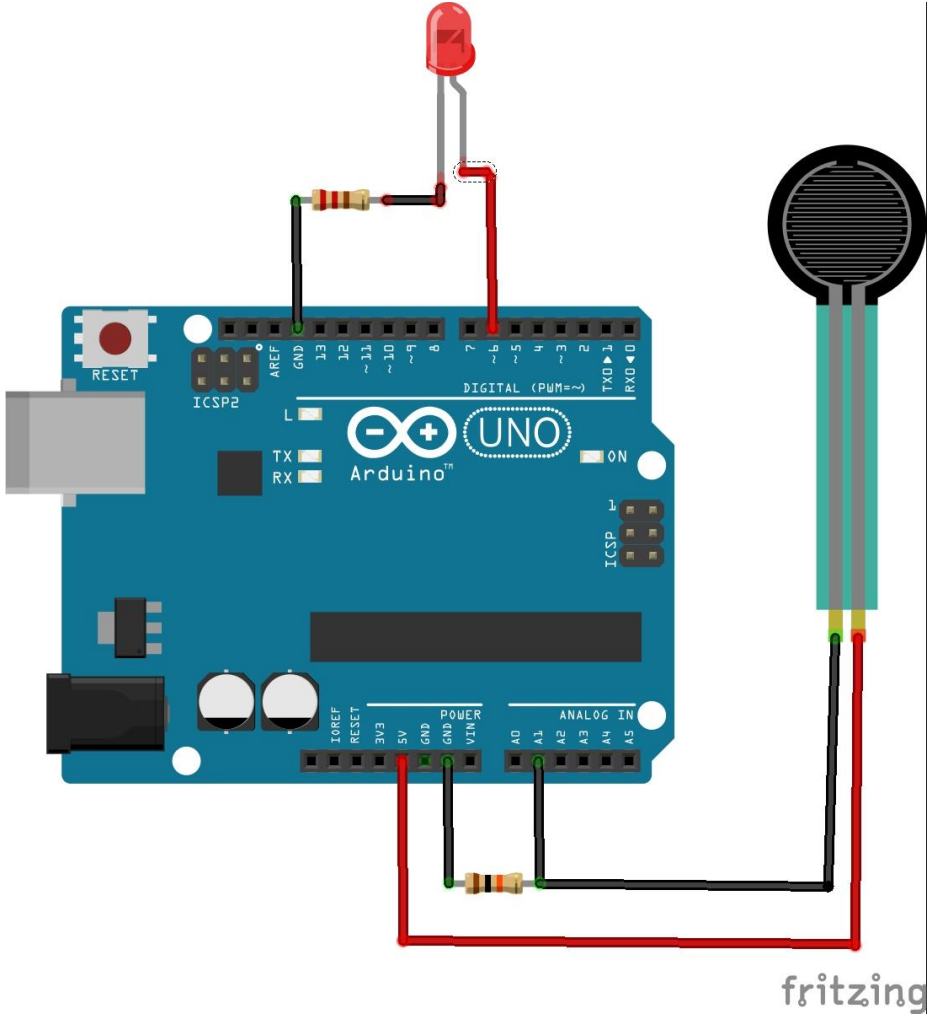
```
void loop()
{
  int flexADC = analogRead(FLEX_PIN);
  float flexV = flexADC * VCC / 1023.0;
  float flexR = R_DIV * (VCC / flexV - 1.0);
  Serial.println("Resistance: " + String(flexR) + " ohms");

  float angle = map(flexR, STRAIGHT_RESISTANCE, BEND_RESISTANCE,
                    0, 90.0);
  Serial.println("Bend: " + String(angle) + " degrees");
  Serial.println();

  delay(500);
}
```

Force Sensor

FSRs are sensors that allow you to detect physical pressure, squeezing and weight.



Connection Setup



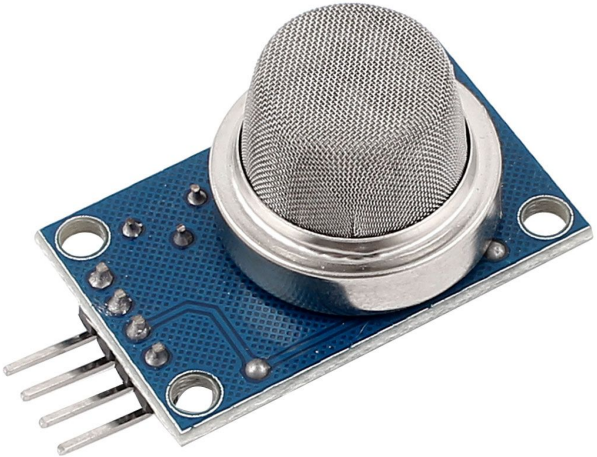
Force Sensor : Code

```
int fsrAnalogPin = A1;
int LEDpin = 6;
int fsrReading;
int LEDbrightness;

void setup(void) {
  Serial.begin(9600);
  pinMode(LEDpin, OUTPUT);
}
```

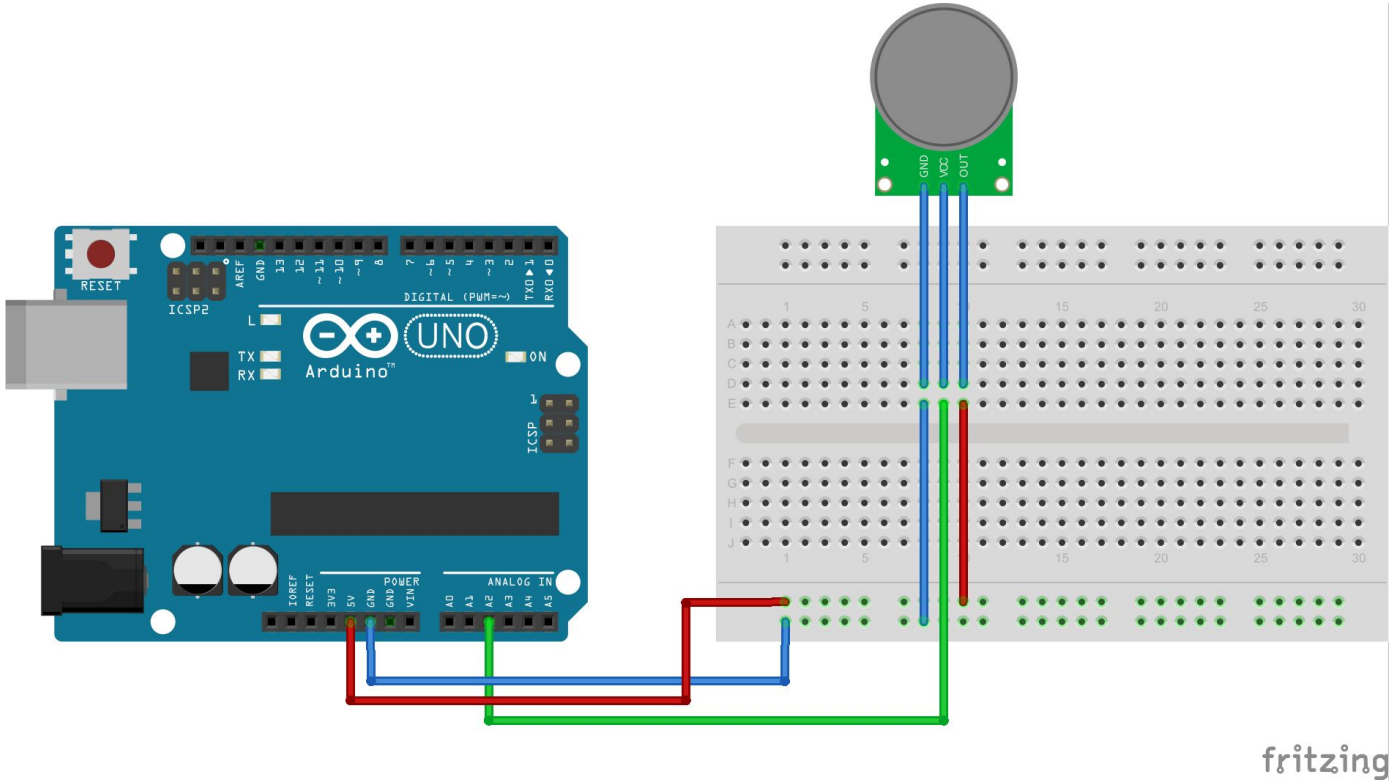
```
void loop(void) {
  fsrReading = analogRead(fsrAnalogPin);
  Serial.print("Analog reading = ");
  Serial.println(fsrReading);
  LEDbrightness = map(fsrReading, 0, 1023, 0,
255);
  analogWrite(LEDpin, LEDbrightness);
  delay(100);
}
```

Gas Sensor

It's used to detect gas leak.



Gas Sensor : Connection Setup

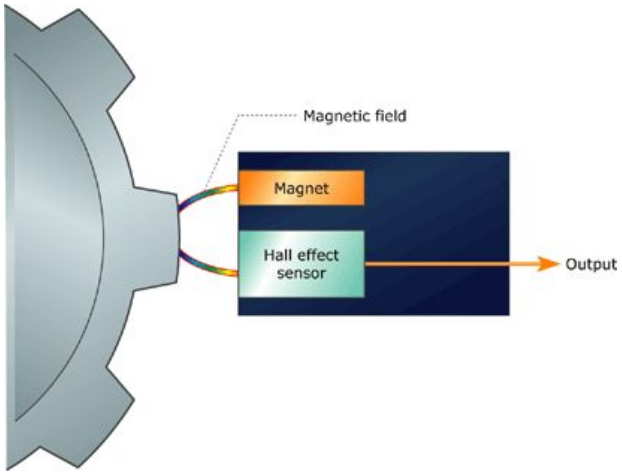


Gas Sensor : Code

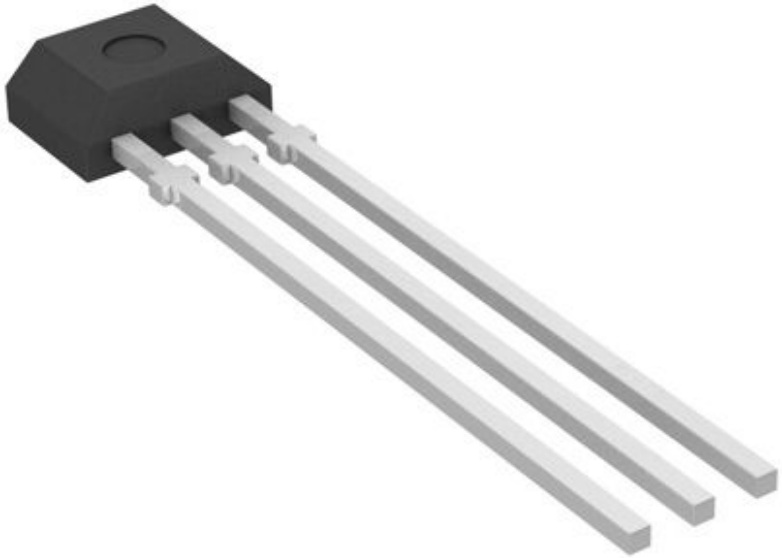
```
int MQ5 = A2;

void setup() {
  pinMode(MQ5, INPUT);
  Serial.begin(9600);
}

void loop() {
  int val = analogRead(MQ5);
  Serial.println(val);
  delay(200);
}
```

Hall Effect Sensor

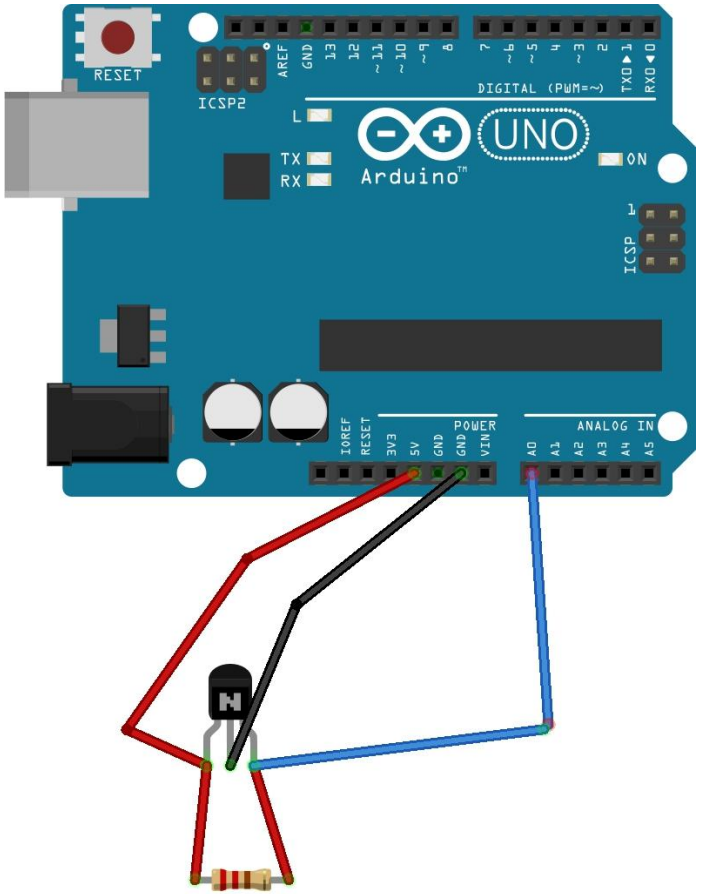
- **It varies its output voltage in response to a magnetic field.**
- **Hall effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications.**



Connection Setup



1 Vcc
2 Gnd
3 Vout

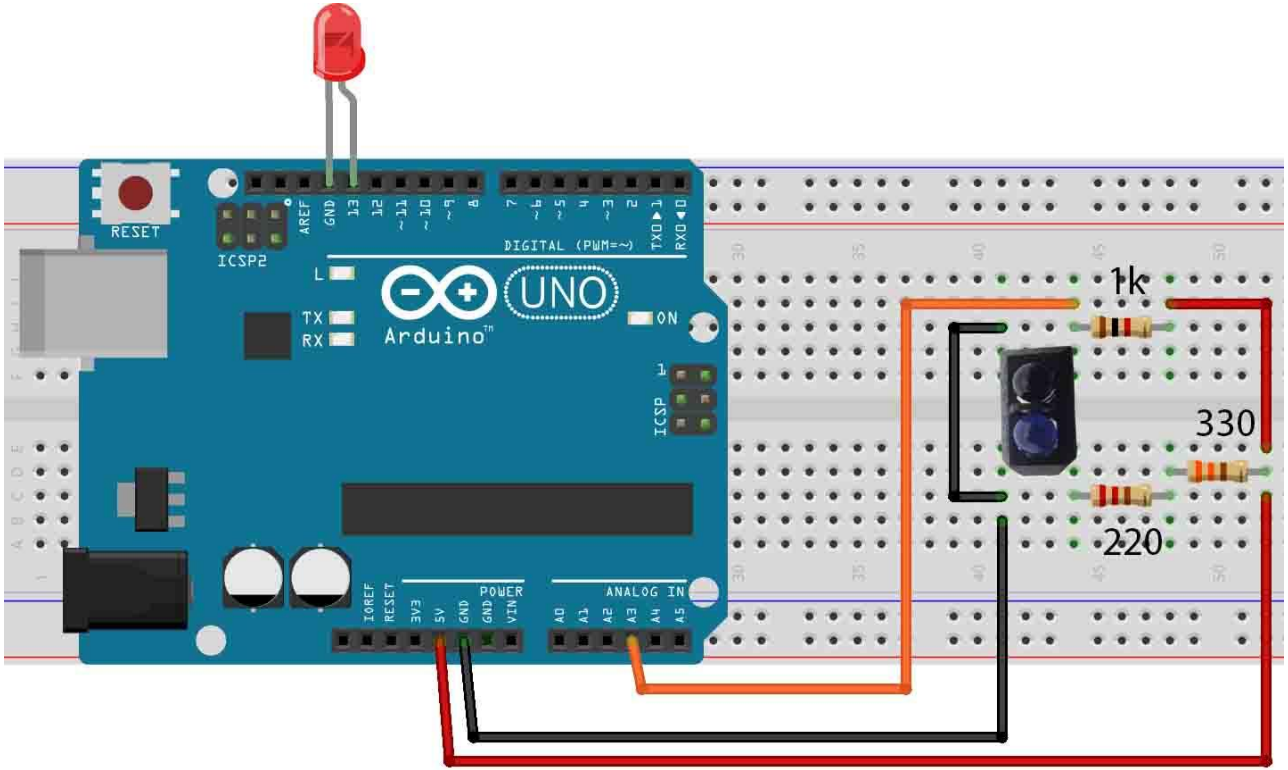


Hall Effect Sensor : Code

IR Sensor : TCRT5000

It's used to sense certain characteristics of its surroundings by either emitting and/or detecting infrared radiation.

Connection Setup



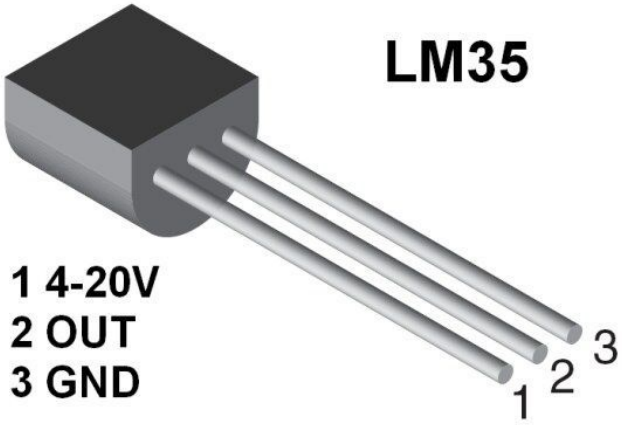
IR Sensor : Code

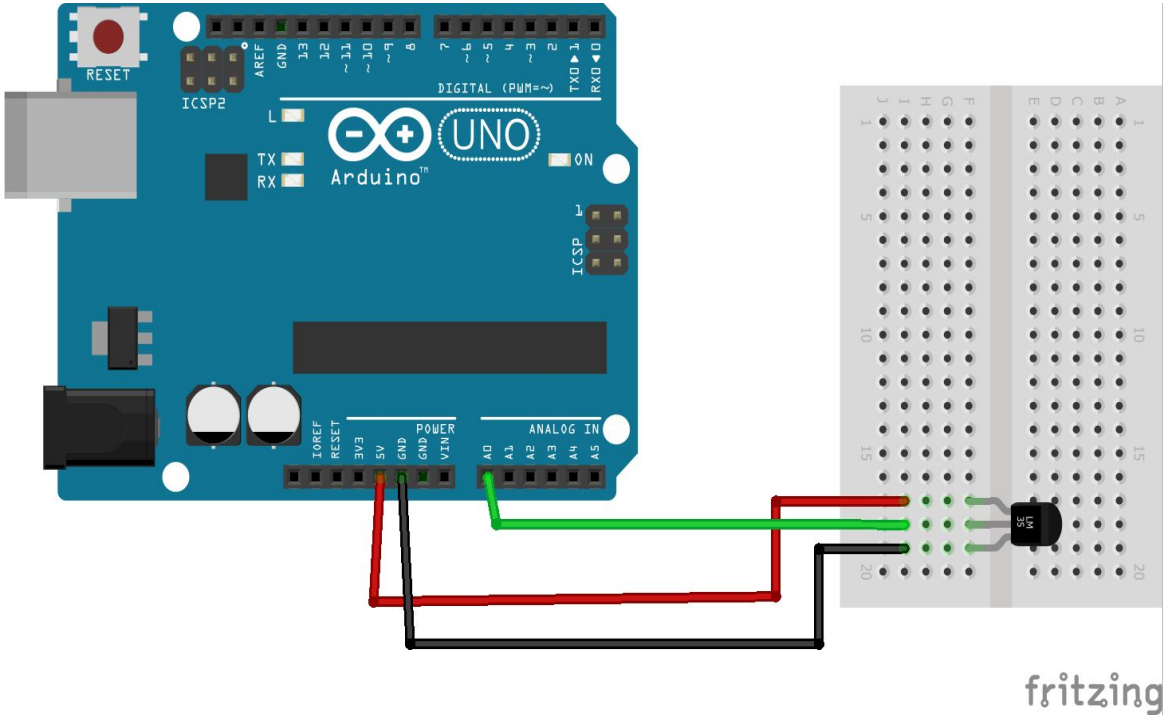
```
int ir = A3;

void setup() {
  pinMode(ir,INPUT);
  Serial.begin(9600);
}

void loop() {
  int val = analogRead(ir);
  Serial.println(val);
  delay(200);
}
```

Temperature Sensor : LM35

You know what it does!

Connection Setup



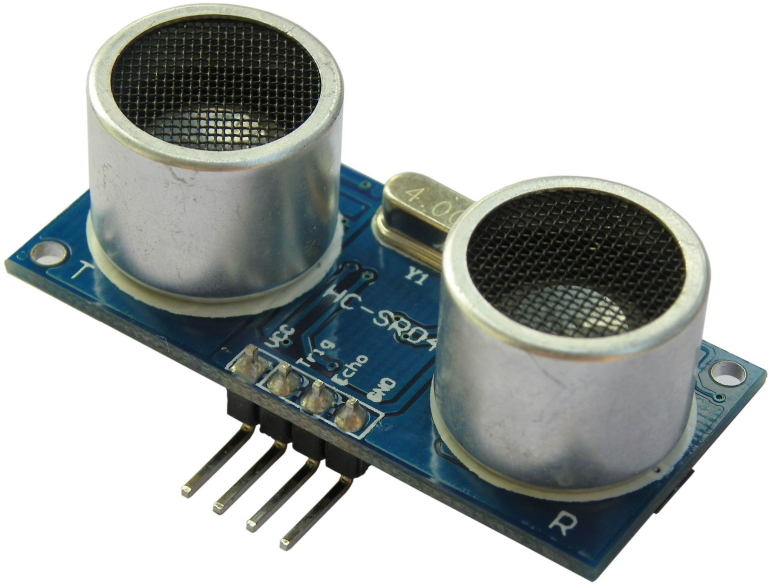


Temperature Sensor : Code

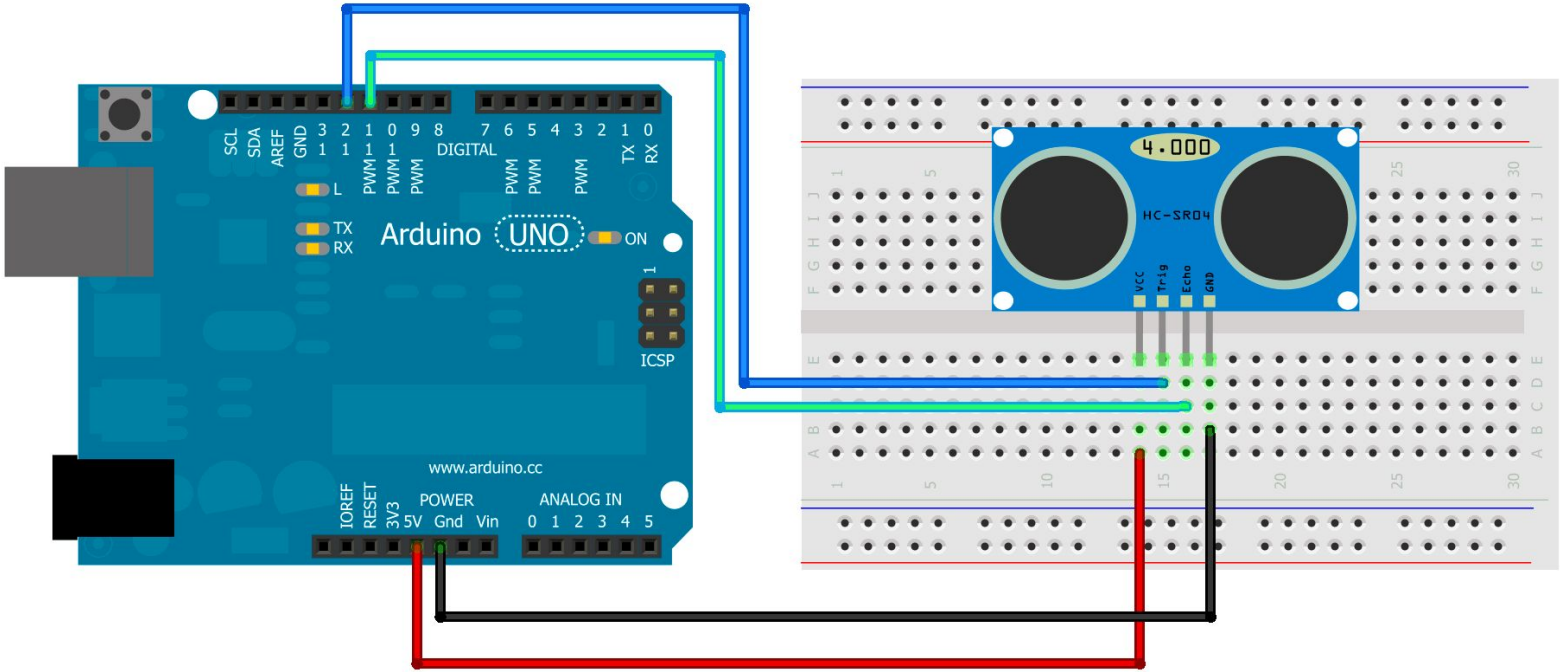
```
int temp_sensor = A0;
float reading = 0;
void setup()
{
    Serial.begin(9600);
}
void loop()
{
    reading = analogRead(temp_sensor)*0.48875855;
    Serial.print("Current Temperature: ");
    Serial.println(reading);
    delay(300);
}
```

Sonar Sensor : HC-SR04

This economical sensor provides 2cm to 400cm of non-contact measurement functionality.



Connection Setup



Code

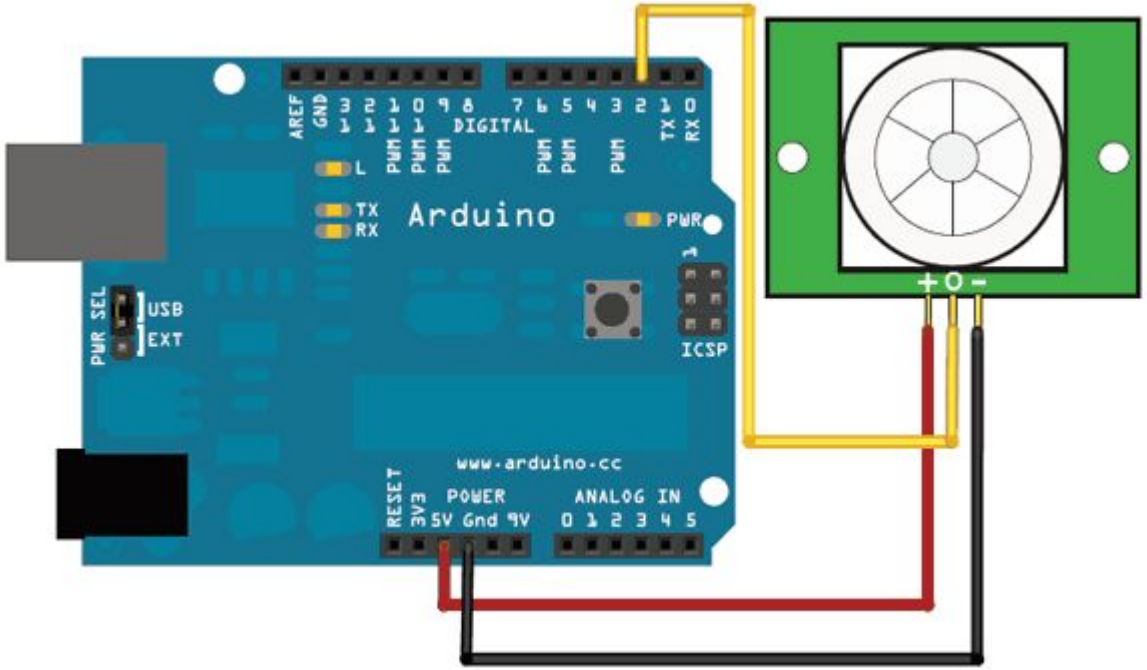
```
#define trig 12
#define echo 11

void setup() {
  Serial.begin(9600);
  pinMode(trig, OUTPUT);
  pinMode(echo, INPUT);
}
```

```
void loop() {
   int distance, duaration;
   digitalWrite(trig, HIGH);
   delayMicroseconds(1000);
   digitalWrite(trig, LOW);
   duaration = pulseIn(echo, HIGH);
   distance = (duaration / 2) / 29.1;
   Serial.print(distance);
   Serial.println(" cm");
   delay (100);
}
```

PIR (Passive Infrared) Sensor : Motion Detector

- **A passive infrared sensor (PIR sensor) is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view.**
- **They are most often used in PIR-based motion detectors.**

Connection Setup



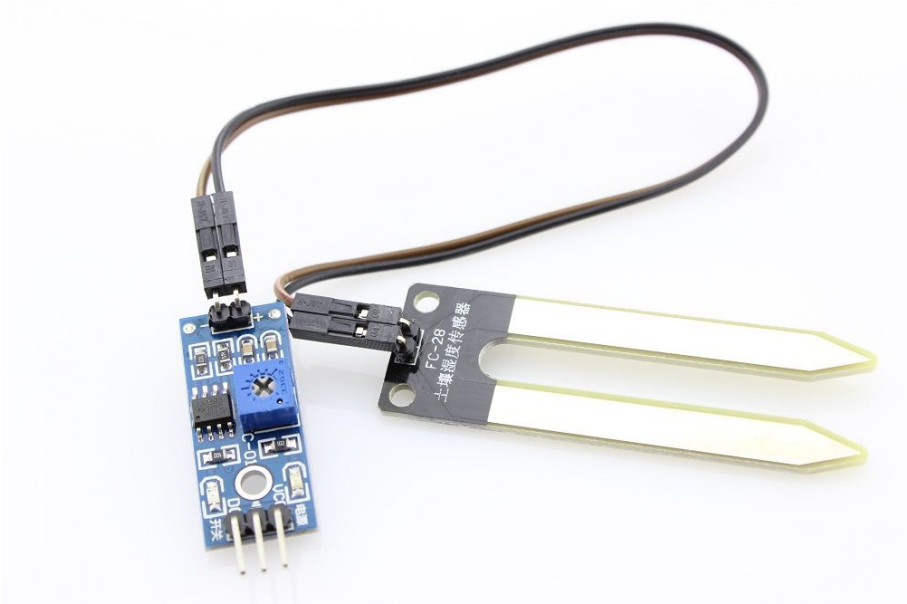
Code

```
int ledPin = 13;
int inputPin = 2;
int pirState = LOW;
int val = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(inputPin, INPUT);

  Serial.begin(9600);
}
```

```
void loop(){
  val = digitalRead(inputPin);
  if (val == HIGH) {
    digitalWrite(ledPin, HIGH);
    if (pirState == LOW) {
      Serial.println("Motion detected!");
      pirState = HIGH;
    }
  } else {
    digitalWrite(ledPin, LOW);
    if (pirState == HIGH){
      Serial.println("Motion ended!");
      pirState = LOW;
    }
  }
}
```

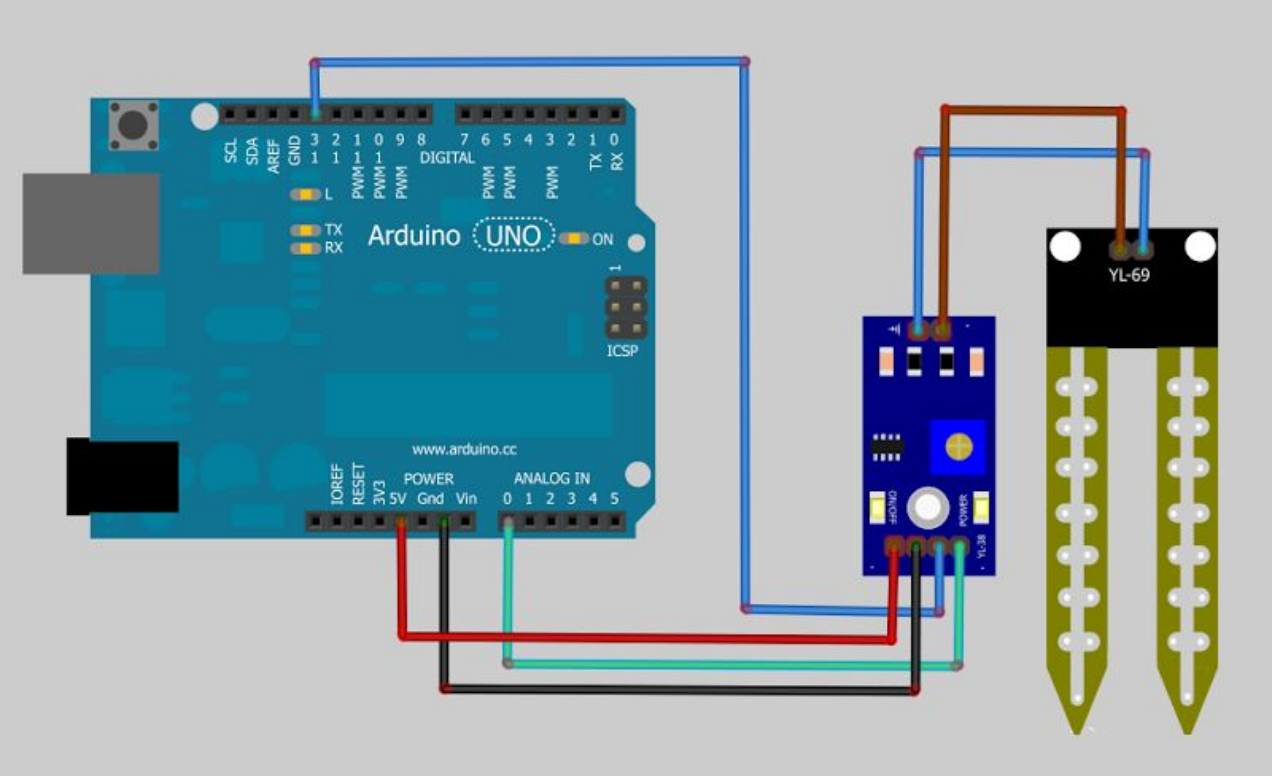
Soil Moisture Sensor

- **Soil moisture sensor can detect moisture of soil further control the pipe valve to water plants.**



- **This sensor comes in 2 parts, sensor probes and module board. The sensor is basically two probes to be inserted into soil. This sensor uses the two probes to pass current through the soil, and then it reads that resistance to get the moisture level.**

Connection Setup



Code

```
int sensorpin=A0;
int outputpin=13;
int moisture;

void setup(){
  Serial.begin(9600);
  pinMode(sensorpin,INPUT);
  pinMode(outputpin,OUTPUT);
}

void loop(){
  moisture=analogRead(sensorpin);
  Serial.println(moisture);

  if(moisture<=600)
    digitalWrite(outputpin,LOW);
  else
    digitalWrite(outputpin,HIGH);
}
```

F.A.Q

1. If sensors are all about Analog World, why are using Digital Pins of Arduino sometimes?

ANSWERS

Some sensors may have feature built in to convert analog signals into digital, that's why no further conversion is needed.