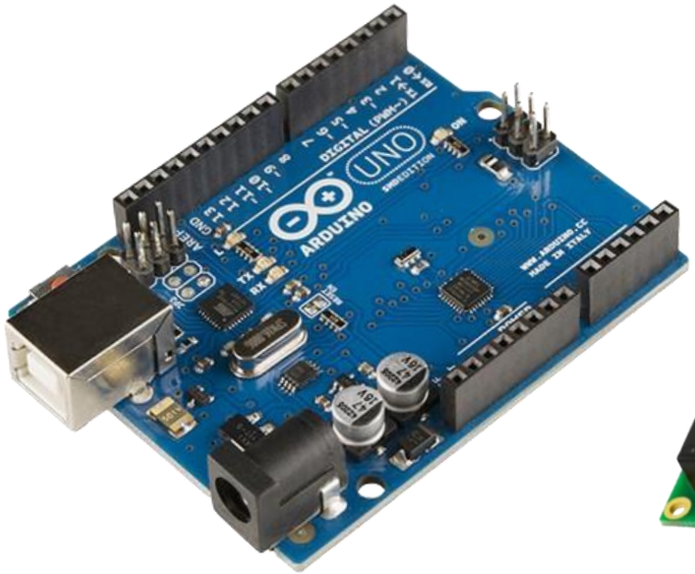
Arduino Course



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BIRZEIT UNIVERSITY

Agenda

Embedded system

ADC & DAC

Arduino environment

Basic electronic component

Interrupts

Sensors

Actuators

Communication

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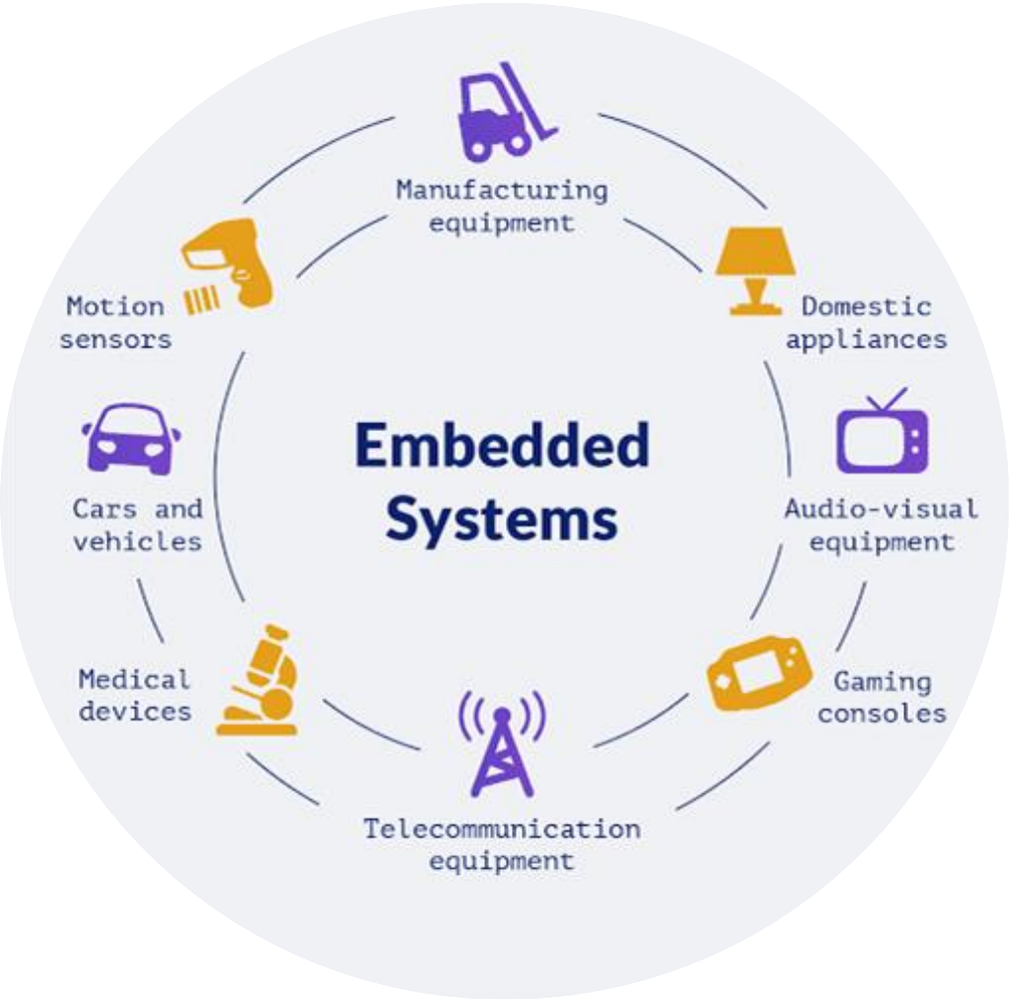
Embedded System



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What is an Embedded System?

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- **Definition**: An embedded system is a specialized computer system that is designed to perform a specific task. Unlike general-purpose computers, which can run a variety of applications, embedded systems are dedicated to one or a few functions.

- **Common Use**: Embedded systems are found in many everyday devices, from household appliances to automobiles, medical equipment, and industrial machines.

Basic Structure of an Embedded System

1- Microcontroller/Microprocessor:

- The brain of the embedded system.
- Executes programmed instructions to perform specific tasks.
- Example: Arduino uses the ATmega328 microcontroller.

2- Memory:

- RAM (Random Access Memory): Temporary storage for data and instructions currently in use.
- ROM (Read-Only Memory): Permanent storage for the system's firmware and operating instructions.

3- Input Devices:

- Collect data from the external environment.
- Examples: Sensors, buttons, keyboards.

4- Output Devices:

- Deliver data or actions to the external environment.
- Examples: Displays, LEDs, motors.

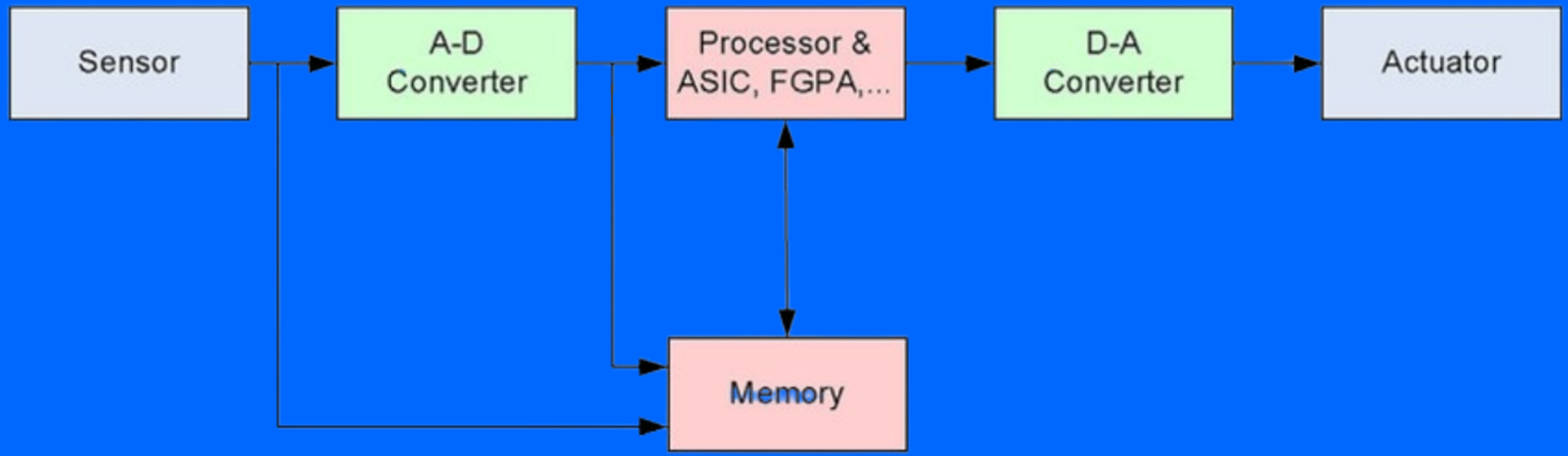
5- Power Supply:

- Provides the necessary power for the system to operate.
- Can be battery-operated or connected to a power source.

6- Communication Interfaces:

- Allow the system to communicate with other systems or devices.
- Examples: Serial ports, USB, Wi-Fi, Bluetooth.

Basic Structure (Symbolic-Based)



Example of an Embedded System: Digital Thermometer

Microcontroller: Reads temperature data from the sensor and processes it.

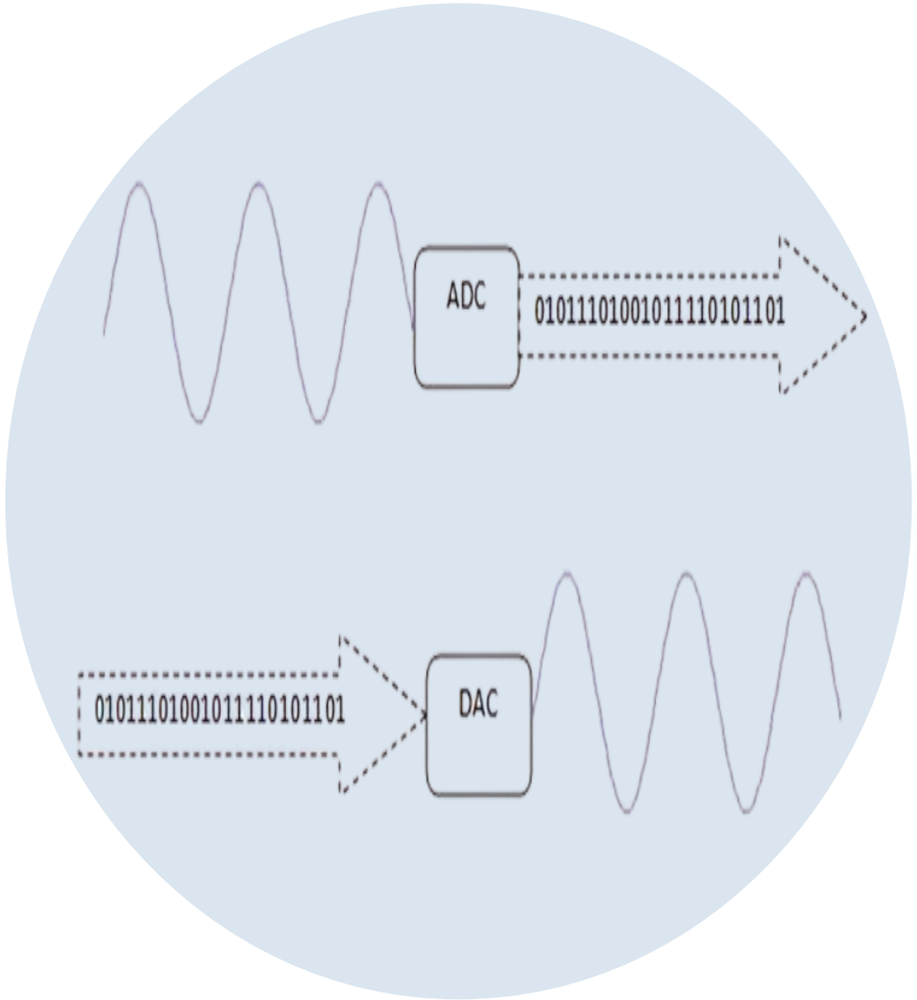
Sensor: Measures the temperature and sends data to the microcontroller.

Display: Shows the temperature reading to the user.

Buttons: Allow users to switch between Celsius and Fahrenheit or reset the device.

Power Supply: Battery that powers the thermometer.

ADC & DAC



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What is an ADC?

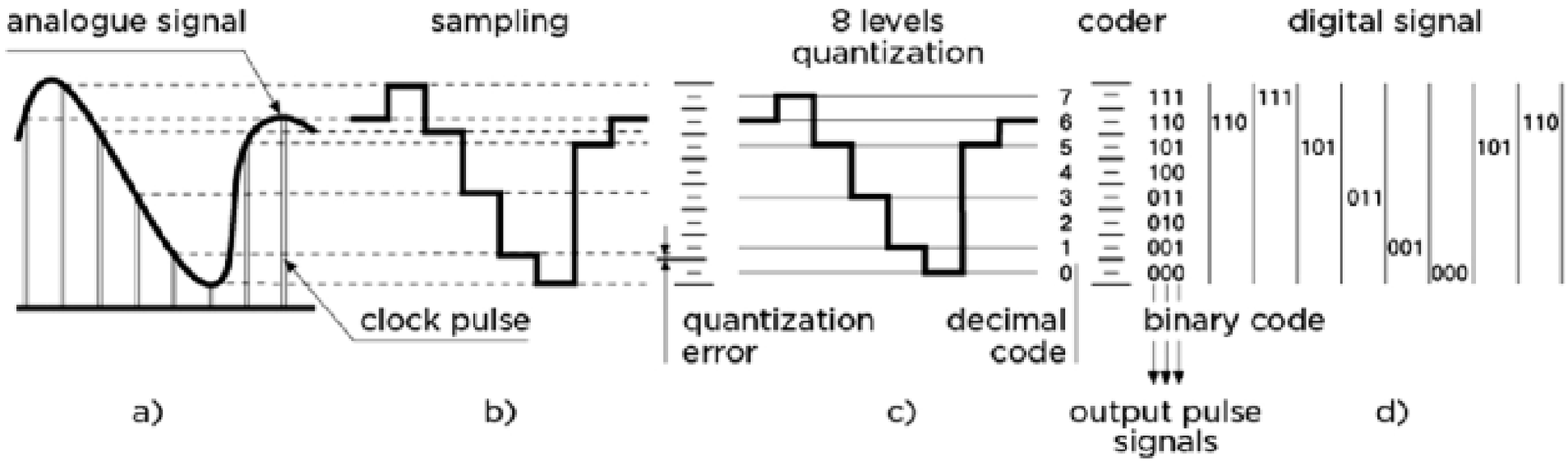
- **Definition**: An Analog-to-Digital Converter (ADC) is a device that converts analog signals (continuous signals) into digital signals (discrete signals) that a microcontroller or computer can process.
- **Purpose**: To allow digital systems to interact with the real world by converting analog inputs (e.g., temperature, sound, light) into a format they can understand and process.

What is a DAC?

- **Definition**: A Digital-to-Analog Converter (DAC) is a device that converts digital signals (discrete signals) into analog signals (continuous signals).
- **Purpose**: To allow digital systems to produce analog outputs (e.g., audio signals, light intensity control) that can be used in the real world.

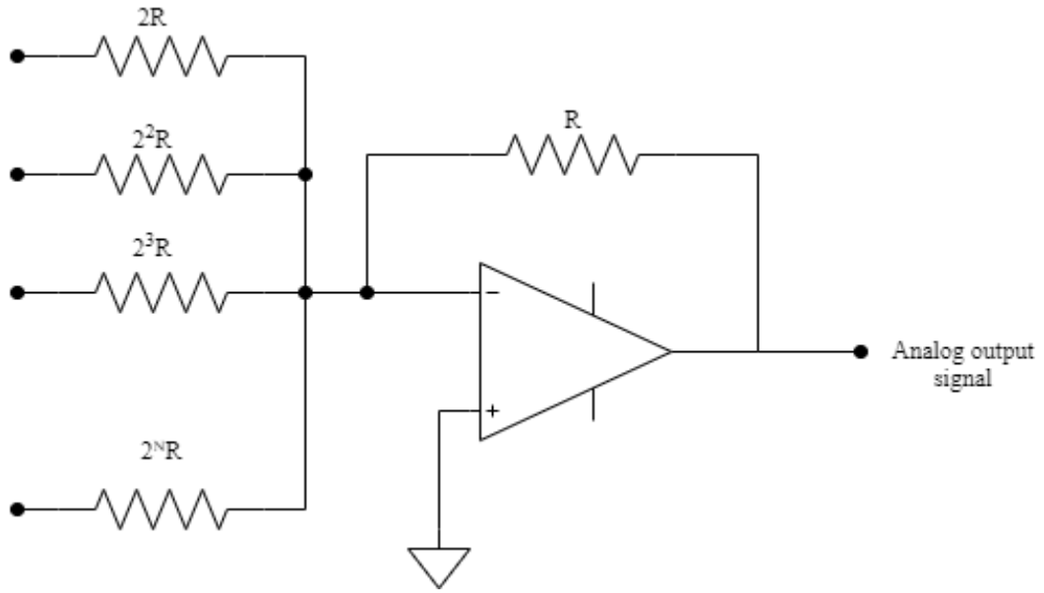
How ADC Works

- **Sampling**: The analog signal is sampled at regular intervals.
- **Quantization**: Each sample is approximated to the nearest value within a range.
- **Encoding**: The quantized values are converted into binary code.



How DAC Works

- **Input:** The digital signal is received from a microcontroller or computer.
- **Conversion:** The digital values are converted to corresponding analog values.
- **Output:** The analog signal is output to drive an analog device.



Arduino Environment

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Arduino Hardware

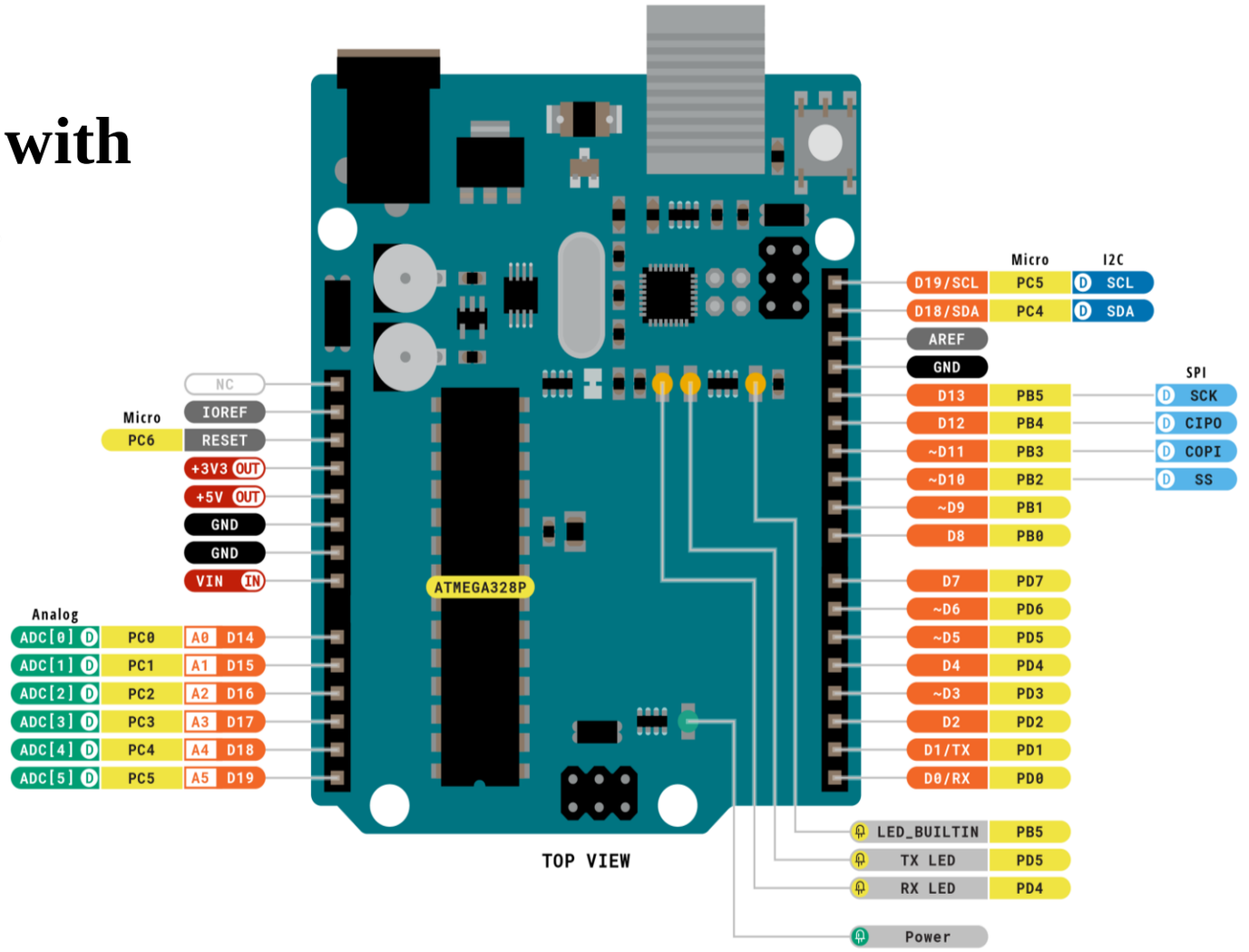
Arduino Boards

- Microcontroller-based boards with various input/output capabilities.
- Examples: Arduino Uno, Arduino Mega, Arduino Nano.

Key Components

- **Microcontroller**: The brain of the board (e.g., ATmega328 on Arduino Uno).
- **Digital Pins**: Used for digital input/output (e.g., LEDs, buttons).
- **Analog Pins**: Used for analog input (e.g., sensors).
- **Power Supply**: Can be powered via USB or external power source.
- **Communication Ports**: Serial, I2C, SPI for interfacing with other devices.

Arduino Uno board with labeled components.



Legend:	Digital	I2C
Power	Analog	SPI
Ground	Main Part	Analog

ARDUINO

ARDUINO UNO REV3
SKU code: A000066
Pinout
Last update: 6 Oct, 2022

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Arduino Software (Arduino IDE)

Arduino IDE

- Integrated Development Environment for writing, compiling, and uploading code to Arduino boards.
- Available for Windows, Mac, and Linux.

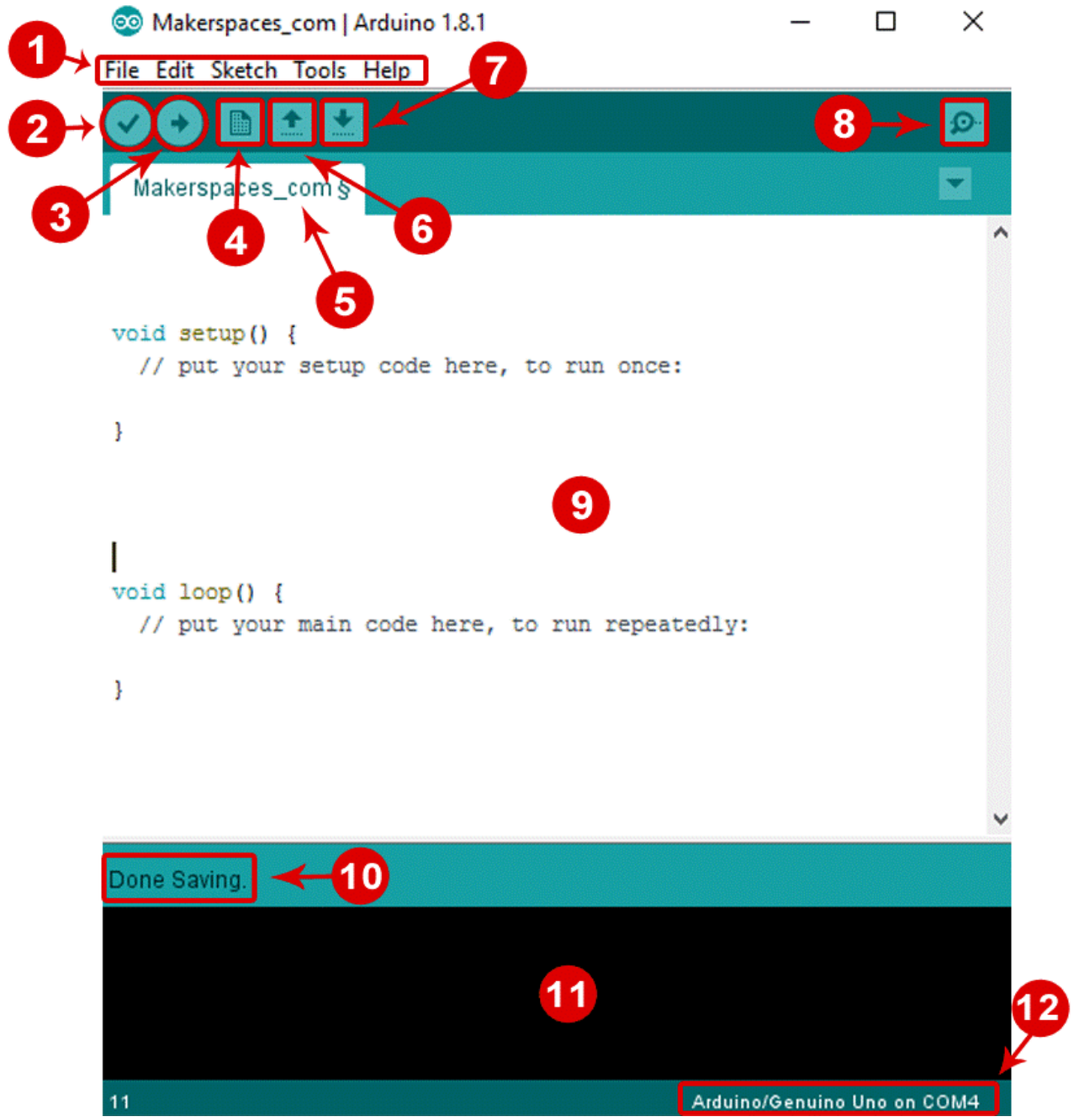
Key Features

- **Code Editor**: Write and edit Arduino sketches (programs).
- **Compiler**: Convert sketches into machine code that the microcontroller can execute.
- **Uploader**: Transfer the compiled code to the Arduino board via USB.
- **Serial Monitor**: Communicate with the board and debug sketches using serial communication.

Programming Language

- Based on C/C++ with simplified syntax and functions.
- Uses libraries to add functionality (e.g., controlling motors, reading sensors).

Arduino IDE simple sketch.



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How to Download the Arduino IDE ?

Visit the Arduino Website:

Open your web browser and go to **arduino.cc**

Navigate to the Software Section:

Hover over "Software" in the main menu.

Click on "Downloads."

Choose Your Operating System:

Select the version for your OS (Windows, Mac, Linux).

Download the Installer:

Click "Just Download" if prompted for a donation.

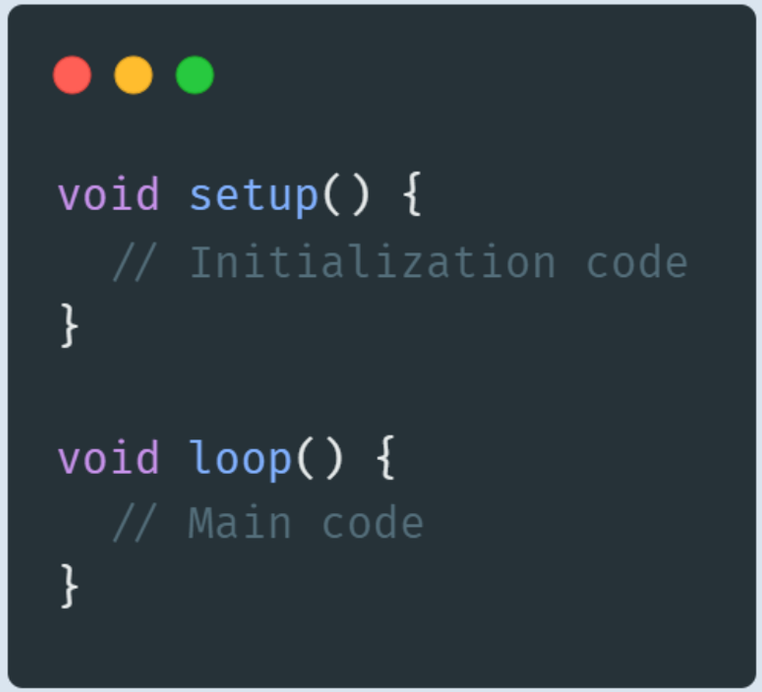
How to Program Arduino and Code Structure

Setup Function:

- **Purpose**: Initializes settings.
- **Runs Once**: This code runs once when the Arduino is powered on or reset.

Loop Function:

- **Purpose**: Contains the main logic of the program.
- **Runs Repeatedly**: This code runs in a loop after the setup function has completed.



```
void setup() {
  // Initialization code
}

void loop() {
  // Main code
}
```

Common Functions Used in Arduino Programming

pinMode():

- **Purpose**: Configures a specified pin to behave either as an input or an output.

digitalWrite():

- **Purpose**: Sets a specified digital pin to HIGH or LOW.

digitalRead():

- **Purpose**: Reads the value from a specified digital pin, either HIGH or LOW.

```
pinMode(pin, mode);

digitalWrite(pin, value);

int value = digitalRead(pin);
```

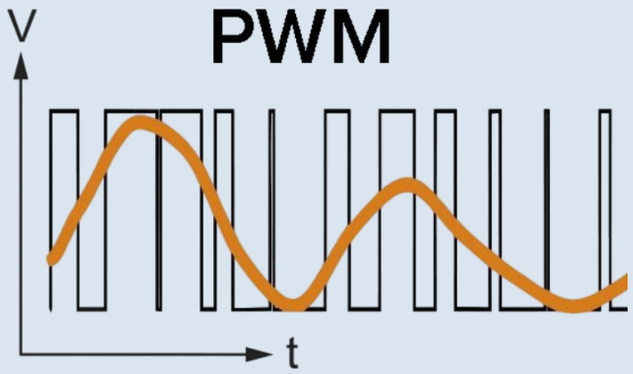
Common Functions Used in Arduino Programming

analogRead():

- **Purpose**: Reads the value from a specified analog pin.

analogWrite():

- **Purpose**: Writes an analog value (PWM wave) to a specified pin.




```
int value = analogRead(pin);

analogWrite(pin, value);
```

Common Functions Used in Arduino Programming

delay():

- **Purpose**: Pauses the program for a specified number of milliseconds.

millis():

- **Purpose**: Returns the number of milliseconds since the Arduino board began running the current program.

```
delay(milliseconds);

unsigned long currentTime = millis();
```

Common Functions Used in Arduino Programming

Serial.begin():

- **Purpose**: Sets the data rate in bits per second (baud) for serial data transmission.

Serial.print():

- **Purpose**: Prints data to the serial port as human-readable ASCII text.

Serial.println():

- **Purpose**: Prints data to the serial port as human-readable ASCII text, followed by a carriage return character.

```
Serial.begin(baudRate);

Serial.print(data);

Serial.println(data);
```

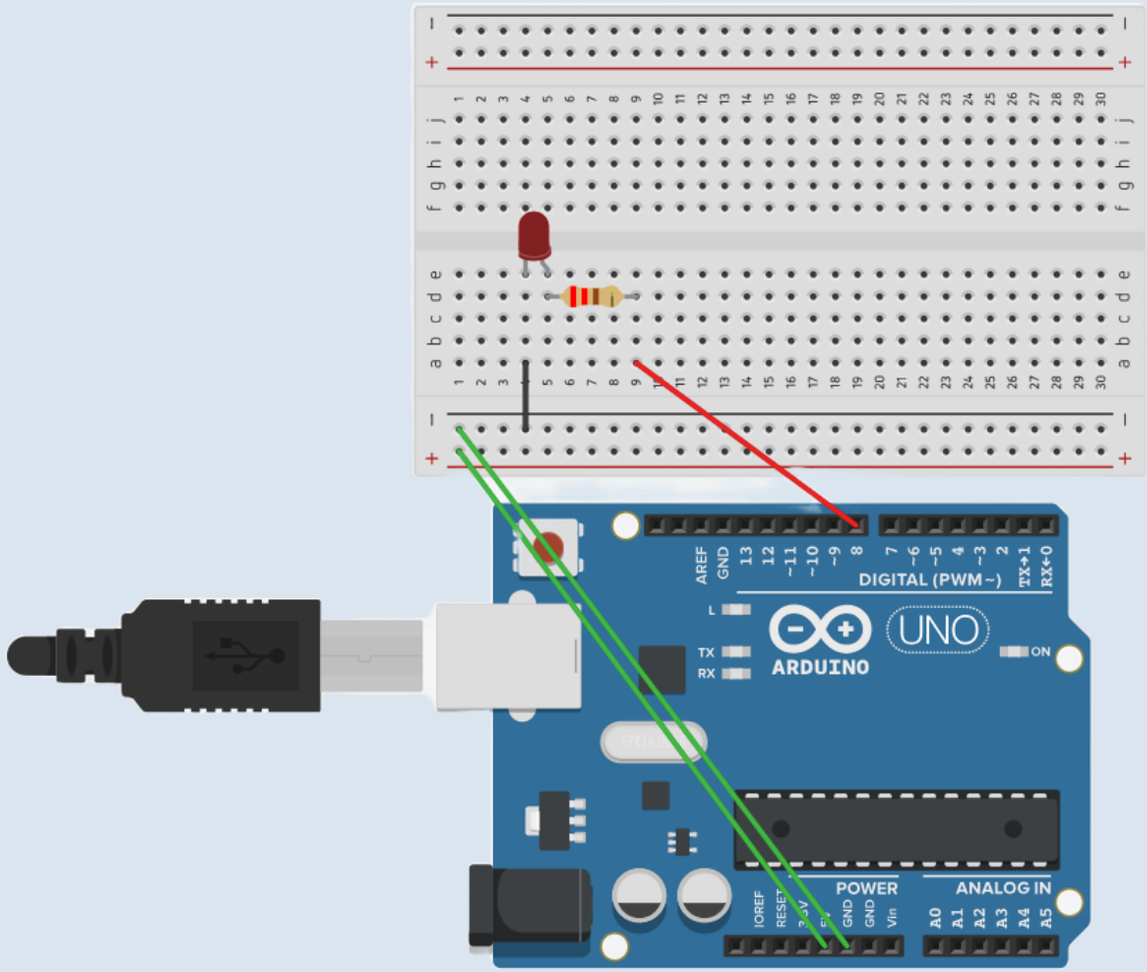
Example 1 => Blinking LED

Blinking LED using Delay function:

```
int ledPin=8;

void setup(){
    pinMode(ledPin,OUTPUT);
}

void loop(){
    digitalWrite(ledPin,HIGH);
    delay(1000);
    digitalWrite(ledPin,LOW);
    delay(1000);
}
```



Example 2 => Blinking LED

Blinking LED using millis function:

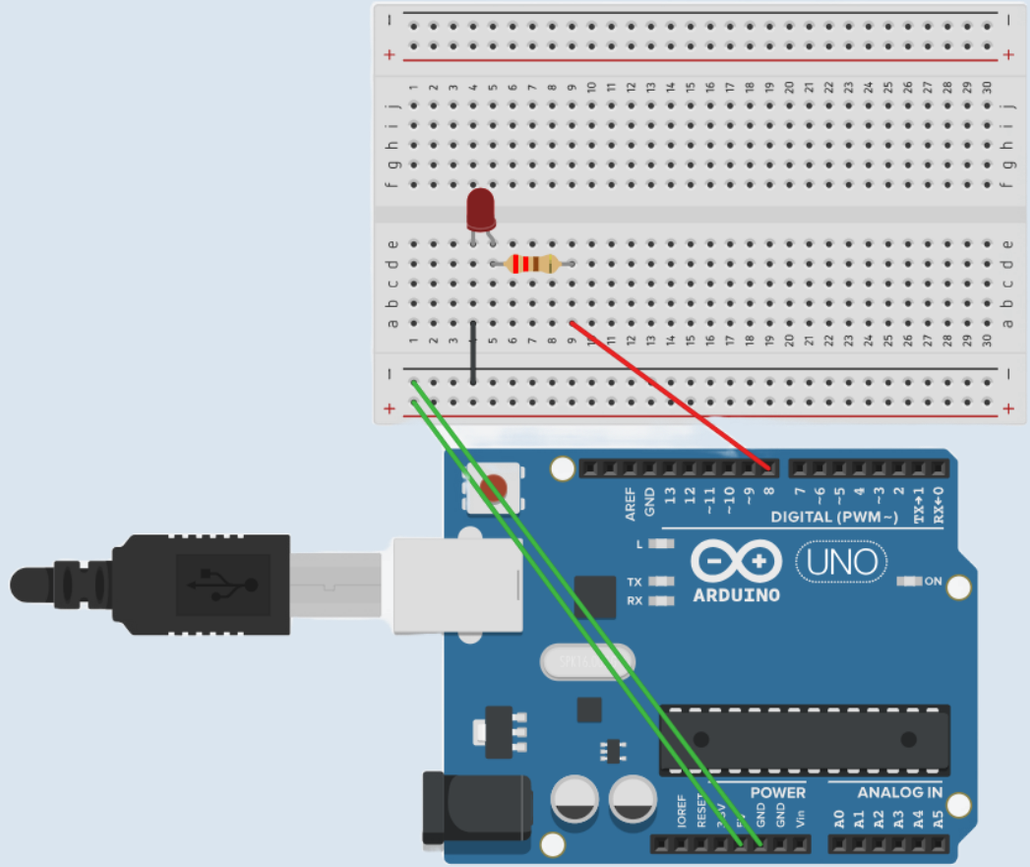
```
int ledPin = 8;
unsigned long previousMillis = 0;
const long interval = 1000;

void setup() {
    pinMode(ledPin, OUTPUT);
}

void loop() {
    unsigned long currentMillis = millis();

    if (currentMillis - previousMillis >= interval) {
        previousMillis = currentMillis;

        if (digitalRead(ledPin) == LOW)
            digitalWrite(ledPin, HIGH);
        else
            digitalWrite(ledPin, LOW);
    }
}
```



Basic Electronic Component

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LED (Light Emitting Diode)

Definition: A semiconductor device that emits light when an electric current passes through it.

Usage: Visual indicators, status lights, displays.

Connection:

- **Anode (+)**: Connected to a positive voltage.
- **Cathode (-)**: Connected to ground, usually through a current-limiting resistor.

Button

Definition: A simple switch used to make or break a connection in an electric circuit.

Usage: User inputs, control signals, event triggers.

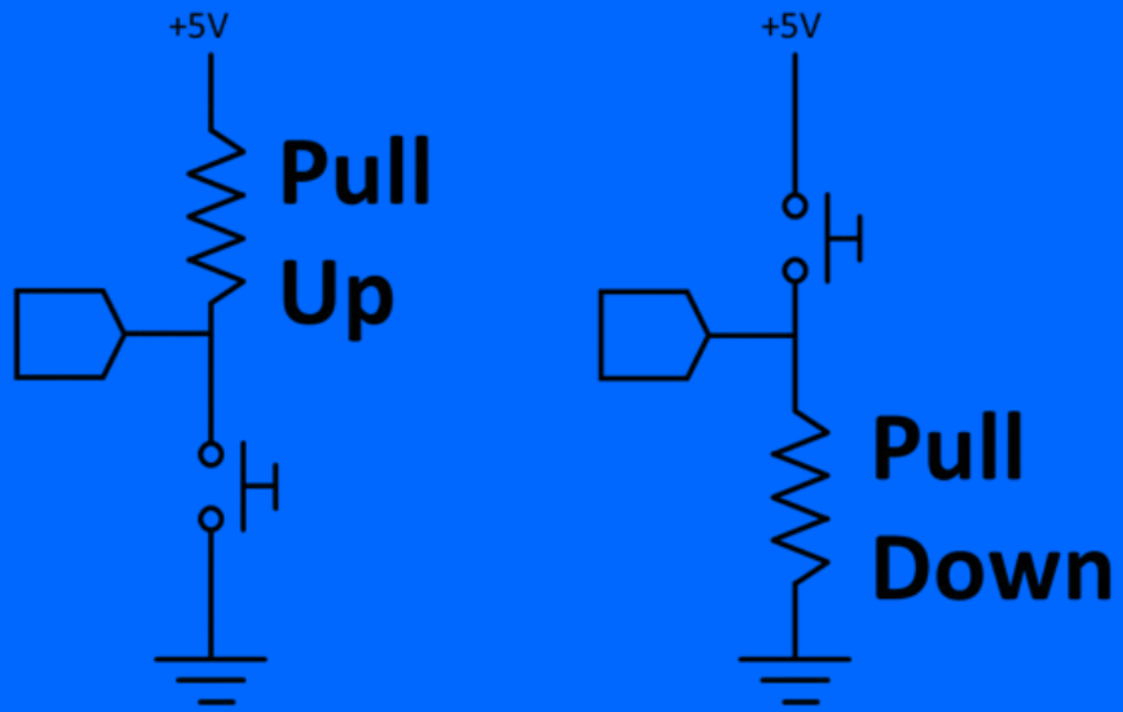
Connection:Typically connected between a digital input pin and ground or VCC.

Pull-Up and Pull-Down Resistors:

Pull-Up: Connects the pin to VCC (high voltage) through a resistor, ensuring a known state when the button is not pressed.

Pull-Down: Connects the pin to ground (low voltage) through a resistor, ensuring a known state when the button is not pressed.

Internal Pull-Up: Use pinMode(pin, INPUT_PULLUP); to enable the internal pull-up resistor.



Potentiometer

Definition: A three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.

Usage: Variable resistors, volume controls, sensor calibration.

- **Connection**:**Wiper**: Connected to an analog input pin.
- **Other Terminals**: Connected to VCC and ground

LED (Light Emitting Diode)

LED (Light Emitting Diode)

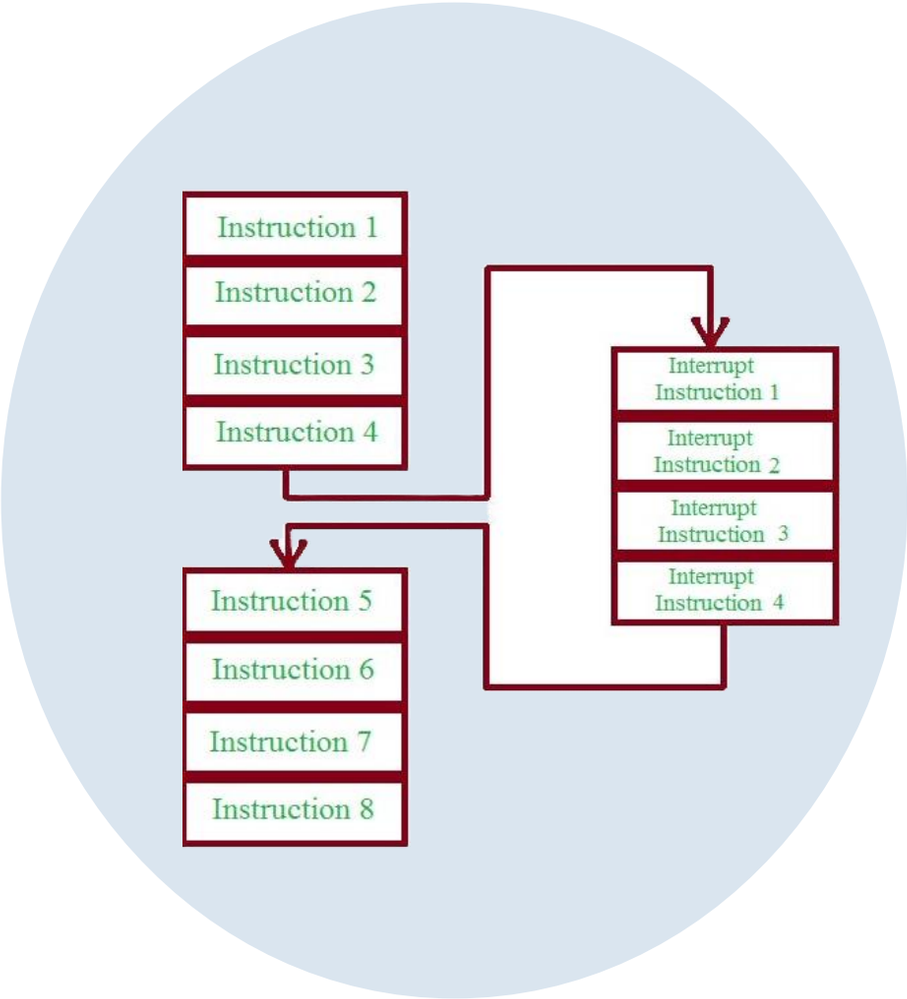
Definition: A semiconductor device that emits light when an electric current passes through it.

Usage: Visual indicators, status lights, displays.

Connection:

- **Anode (+)**: Connected to a positive voltage.
- **Cathode (-)**: Connected to ground, usually through a current-limiting resistor.

Interrupts



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What are Interrupts?

- **Definition**: Interrupts are signals that temporarily halt the main program execution to immediately run a special function called an Interrupt Service Routine (ISR).
- **Purpose**: To handle time-critical tasks, respond to external events, or process real-time signals without delay.
- **Benefits**: Allows for efficient handling of tasks without continuously checking for events within the main loop.

Using Interrupts in Arduino

Attaching an Interrupt:

- Use the attachInterrupt() function to specify which pin and condition will trigger the interrupt, and which ISR to call.

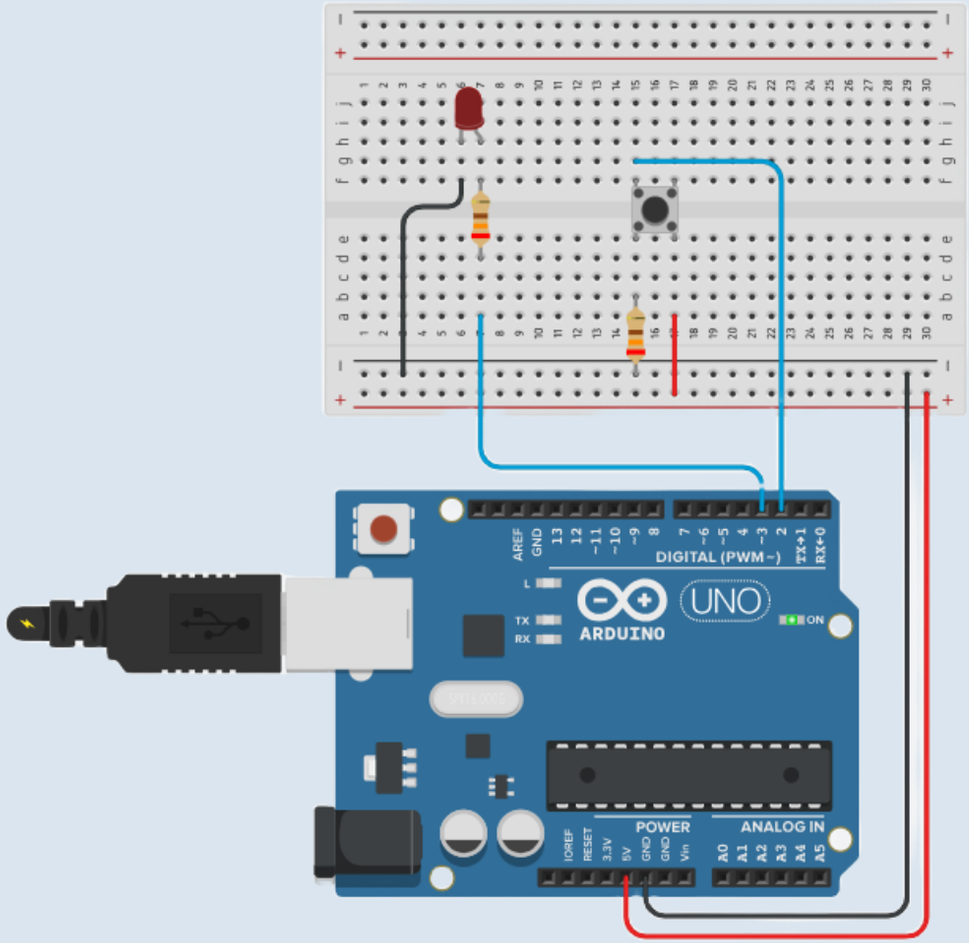
```
attachInterrupt(digitalPinToInterrupt(pin), ISR, mode);
```

- Parameters:
  - pin: The pin number where the interrupt is attached.
  - ISR: The name of the function to call when the interrupt occurs.
  - mode: The condition that triggers the interrupt (LOW, CHANGE, RISING, FALLING).

Example 3 => Toggle LED

Toggle LED without interrupts:

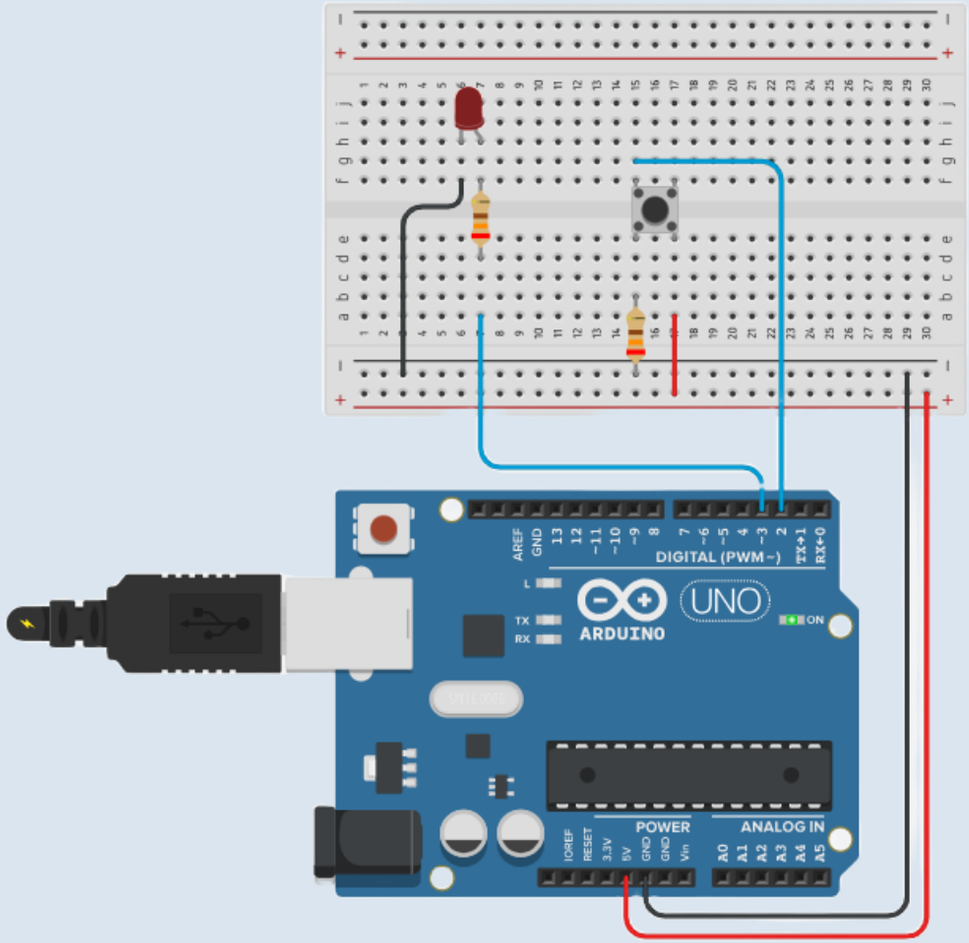
```
const int Switch = 2, LED = 3;
int state = 0, LEDstate=0;

void setup(){
  pinMode(Switch, INPUT);
  pinMode(LED, OUTPUT);
}

void loop(){
  if (state == 0 && digitalRead(Switch) == HIGH) {
    state = 1;
    LEDstate=!LEDstate;
  }
  if (state == 1 && digitalRead(Switch) == LOW) {
    state = 0;
  }
  digitalWrite(LED, LEDstate);
}
```



Example 4 => Toggle LED

Toggle LED with interrupts:

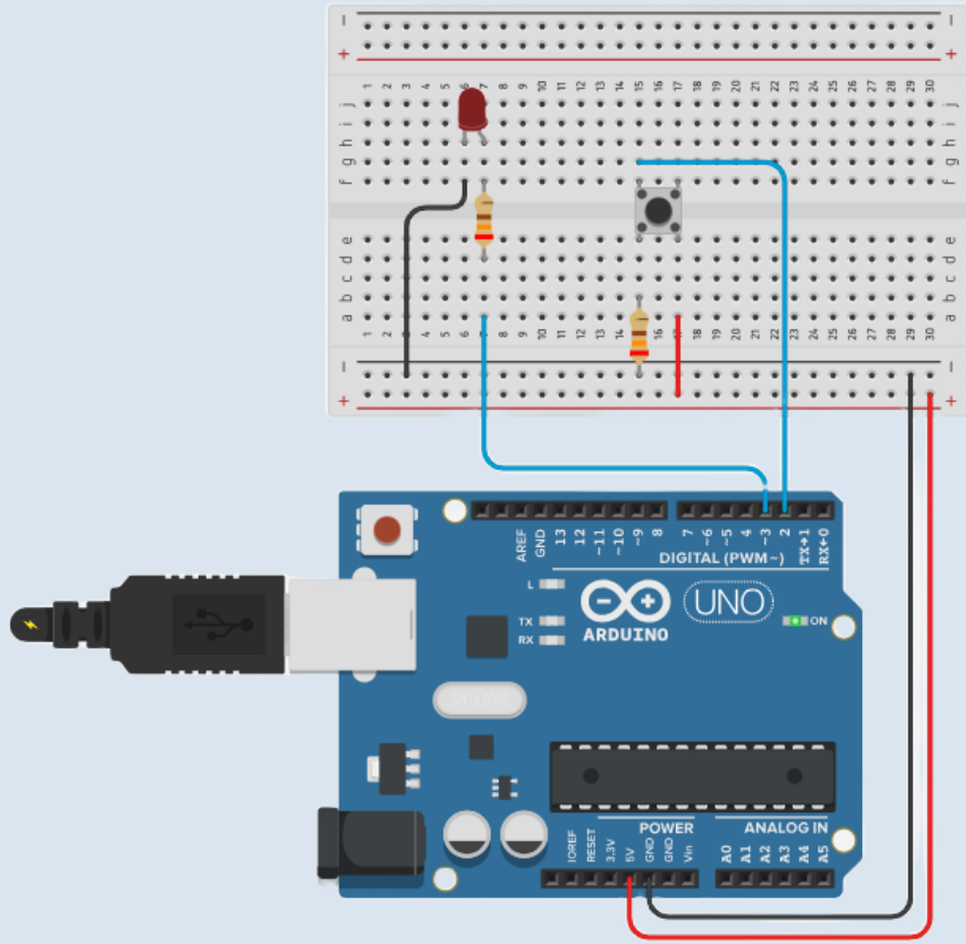
```
const int buttonPin = 2;
const int ledPin = 3;
volatile int LEDstate = LOW;

void setup() {
    pinMode(buttonPin, INPUT);
    pinMode(ledPin, OUTPUT);
    attachInterrupt(digitalPinToInterrupt(buttonPin),
                    toggleLED, RISING);
}

void loop() {
}

void toggleLED() {
    LEDstate = !LEDstate;
    digitalWrite(ledPin, LEDstate);
}
```



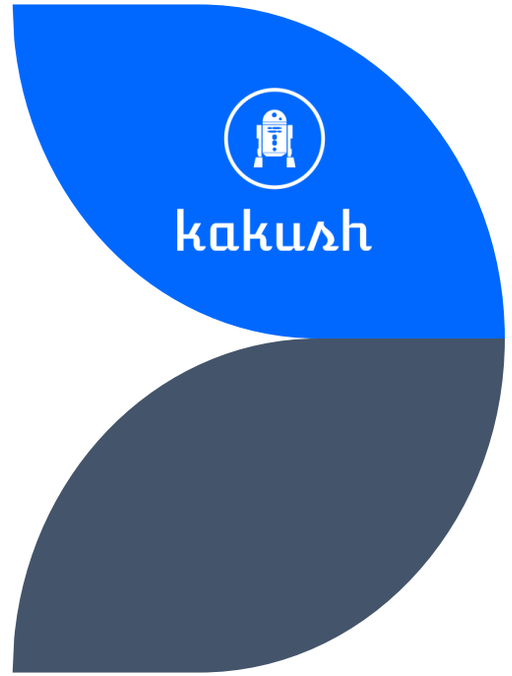
Example 5 => Toggle LED

Toggle LED with interrupts and avoid bouncing effect:

```
const int buttonPin = 2;
const int ledPin = 3;
volatile int LEDstate = LOW;
volatile unsigned long lastDebounceTime = 0;
const unsigned long debounceDelay = 50;

void setup() {
    pinMode(buttonPin, INPUT);
    pinMode(ledPin, OUTPUT);
    attachInterrupt(digitalPinToInterrupt(buttonPin),
                    toggleLED, RISING);
}

void loop() {
}

void toggleLED() {
    unsigned long currentTime = millis();
    if (currentTime - lastDebounceTime
        > debounceDelay) {
        LEDstate = !LEDstate;
        lastDebounceTime = currentTime;
        digitalWrite(ledPin, LEDstate);
    }
}
```



Examples for training



Example 6 => Controlling LED

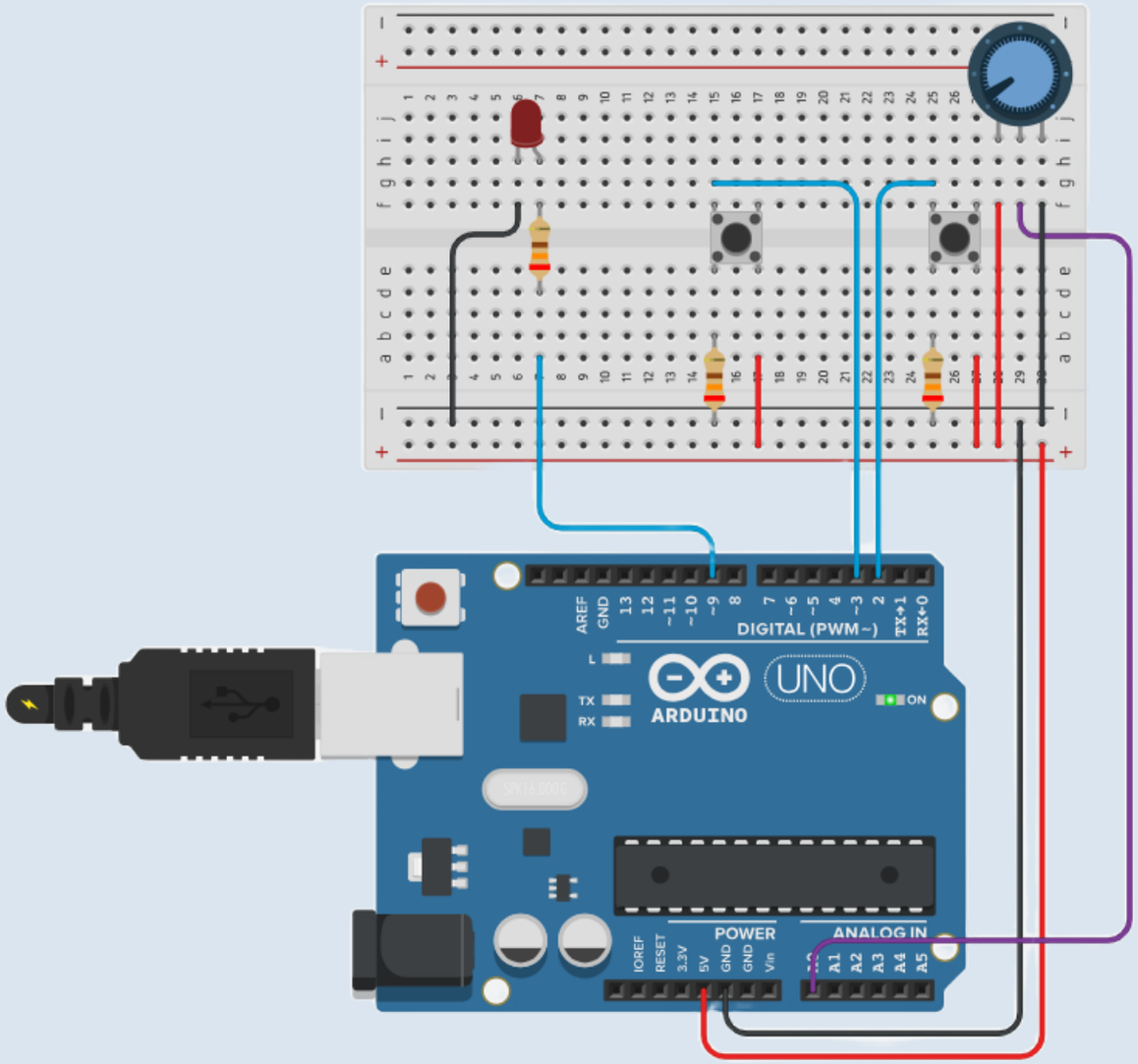
Creating an interactive system using an Arduino that involves the following components:

- A potentiometer
- Two buttons
- An LED

Requirements:

- The potentiometer should control the brightness of the LED.
- Button 1 should toggle the LED on and off.
- Button 2 should reset the brightness of the LED to a default value.
- Use interrupts to handle the button presses efficiently.

Example 6 => Controlling LED



Example 6 => Controlling LED

```
const int potPin = A0;
const int ledPin = 9;
const int button1Pin = 2;
const int button2Pin = 3;
volatile bool ledState = false;
volatile bool resetBrightness = false;
int potValue = 0;
int brightness = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(button1Pin, INPUT);
  pinMode(button2Pin, INPUT);

  attachInterrupt(digitalPinToInterrupt(button1Pin), toggleLED, RISING);
  attachInterrupt(digitalPinToInterrupt(button2Pin), resetLED, RISING);
}

void loop() {
  if (resetBrightness) {
    brightness = 128;
  } else {
    potValue = analogRead(potPin);
    brightness = map(potValue, 0, 1023, 0, 255);
  }

  if (ledState)
    analogWrite(ledPin, brightness);
  else
    analogWrite(ledPin, 0);

  delay(10);
}

void toggleLED() {
  ledState = !ledState;
}

void resetLED() {
  resetBrightness = !resetBrightness;
}
```

Example 7 => Controlling Array of LEDs

Unsolved example

You need to create an Arduino system that controls four LEDs based on the value of a potentiometer.

Requirements:Use a potentiometer to determine how many LEDs should be turned on.

The system should work as follows:

- If the potentiometer value is between 0 and 255, turn on 1 LED.
- If the potentiometer value is between 256 and 511, turn on 2 LEDs.
- If the potentiometer value is between 512 and 767, turn on 3 LEDs.
- If the potentiometer value is between 768 and 1023, turn on all 4 LEDs.

Example 8 => LED Reaction Game

Unsolved example

Design an Arduino-based reaction game that uses LEDs, a potentiometer, and a button. The goal of the game is to test the player's reaction time.

Requirements:

- Use a potentiometer to set the difficulty level of the game.
- An LED should light up randomly after a delay.
- The player must press a button as quickly as possible when the LED lights up.
- The system should display the player's reaction time using LEDs.
- The game should reset automatically after displaying the reaction time.

LCD liquid crystal display

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Introduction to 16x2 LCD

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- **Definition:** A 16x2 LCD is a display module that can show 16 characters per line and there are 2 such lines.
- **Uses:** Commonly used in various electronic projects for displaying data, such as temperature, humidity, sensor readings, etc.

Pin Configuration

VSS: Ground

VDD: +5V Power Supply

VO: Contrast Adjustment

RS: Register Select

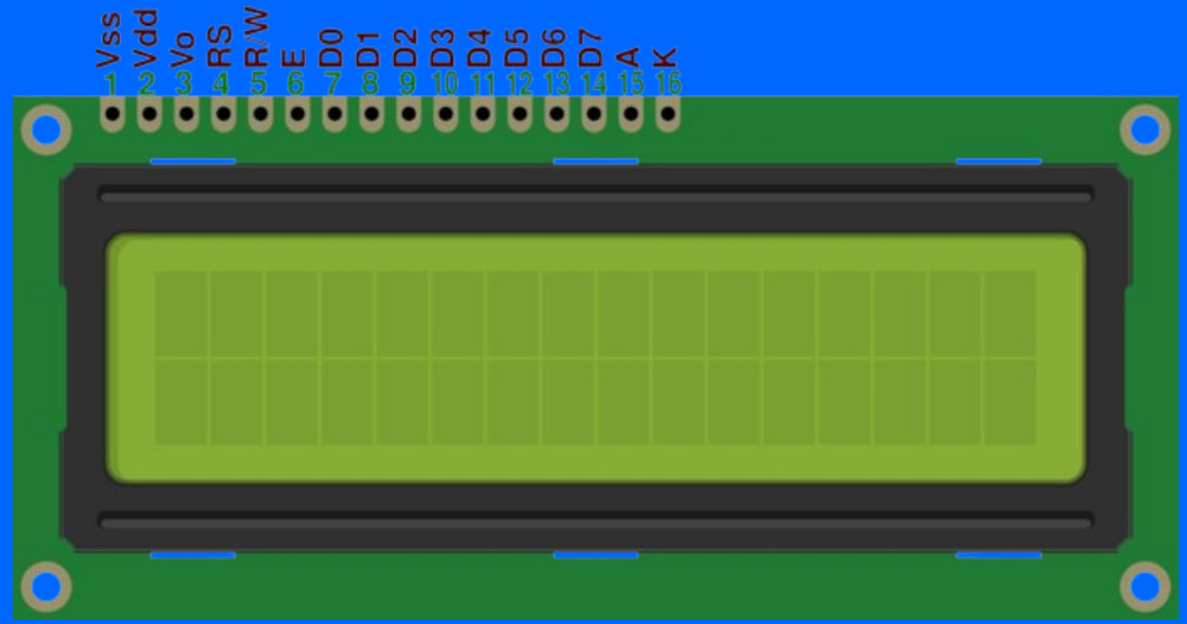
RW: Read (High) / Write (Low)

E: Enable

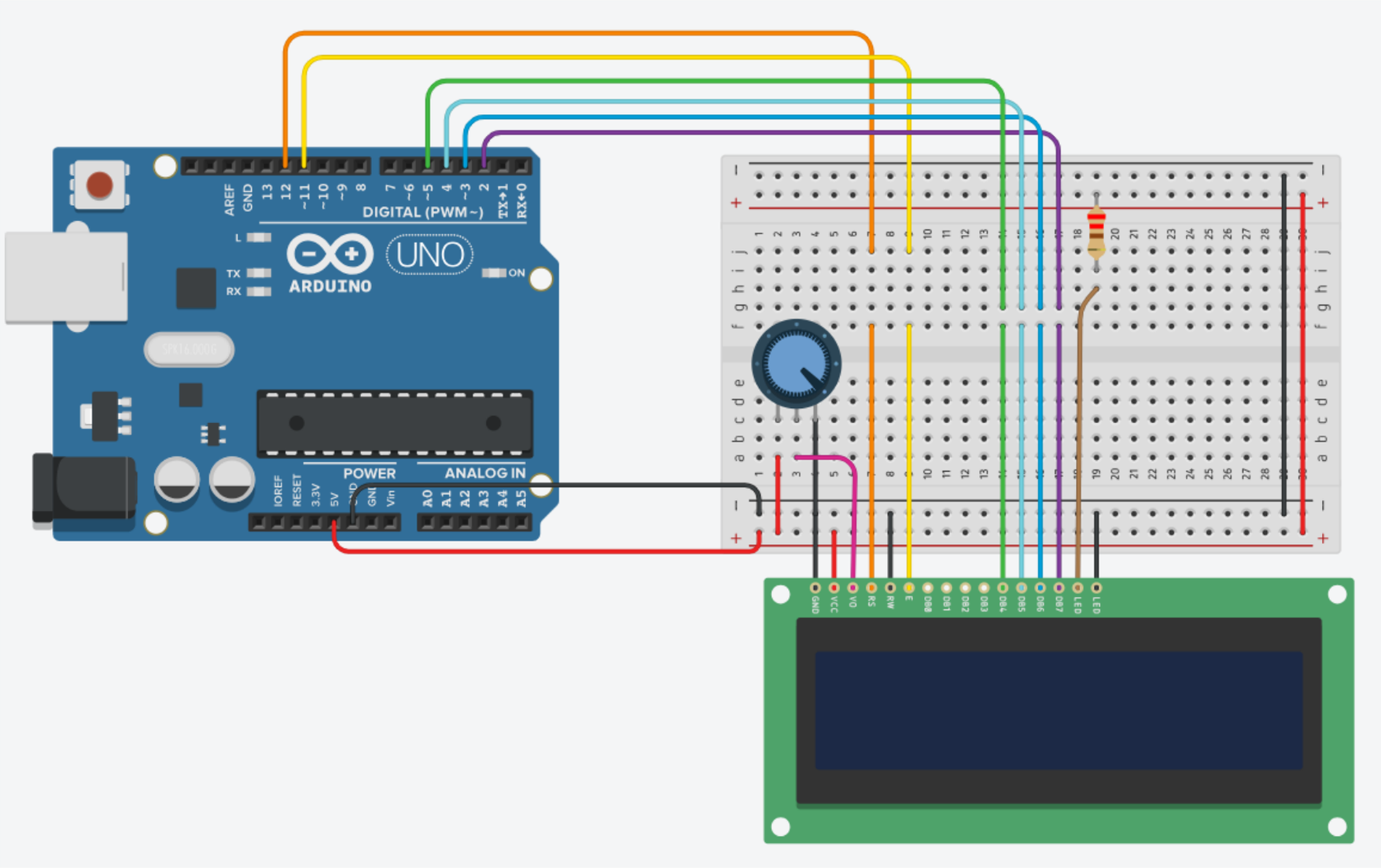
D0 to D7: Data Pins

A (LED+): LED Positive

K (LED-): LED Negative



Example 9 => Print Your Name



Example 9 => Print Your Name

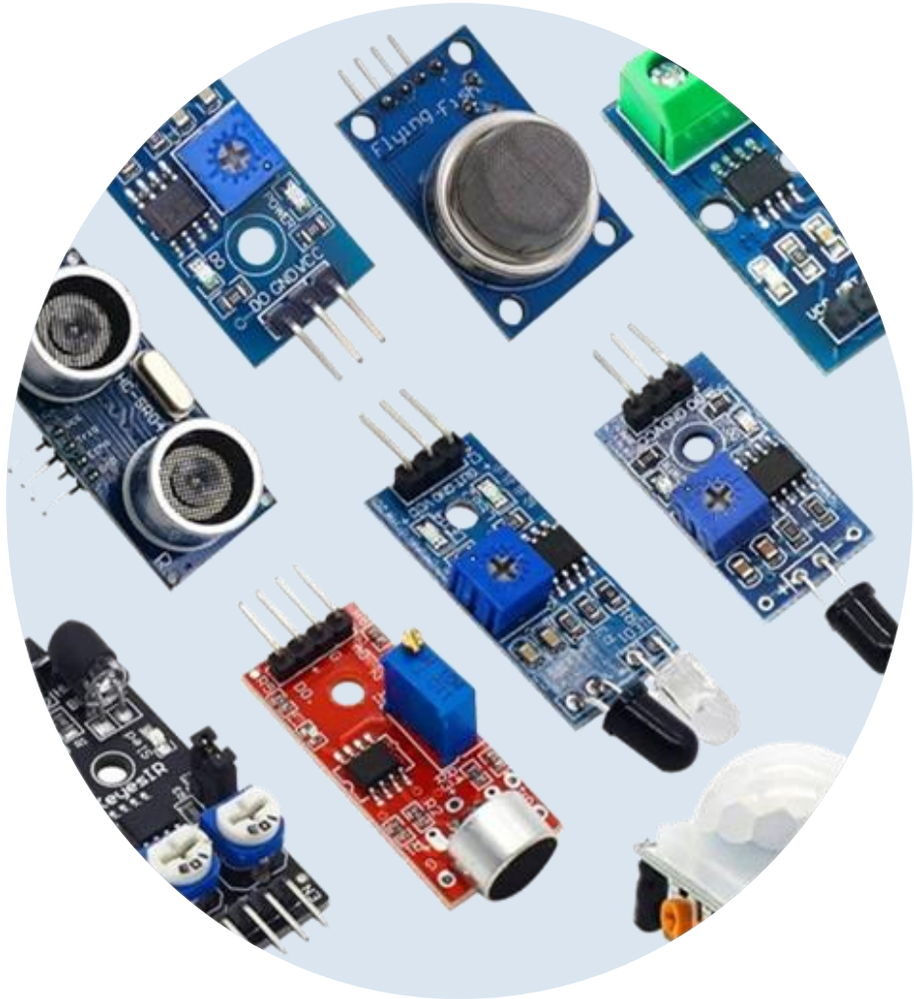
```
#include <LiquidCrystal.h>

// LiquidCrystal(rs, enable, d4, d5, d6, d7)
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup()
{
  lcd.begin(16, 2);

  lcd.setCursor(0, 0);
  lcd.print("Qossay Abu Rida");
}

void loop(){
}
```



Sensors

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Ultrasonic Sensor

Introduction:

- **Definition:** Ultrasonic sensors use sound waves to measure the distance between the sensor and an object.
- **Common Model:** HC-SR04.

Working Principle:

- **Sound Waves:** Sends out an ultrasonic wave and measures the time it takes for the echo to return.
- **Distance Calculation:** Uses the speed of sound to calculate distance based on the time it took for the echo to return.

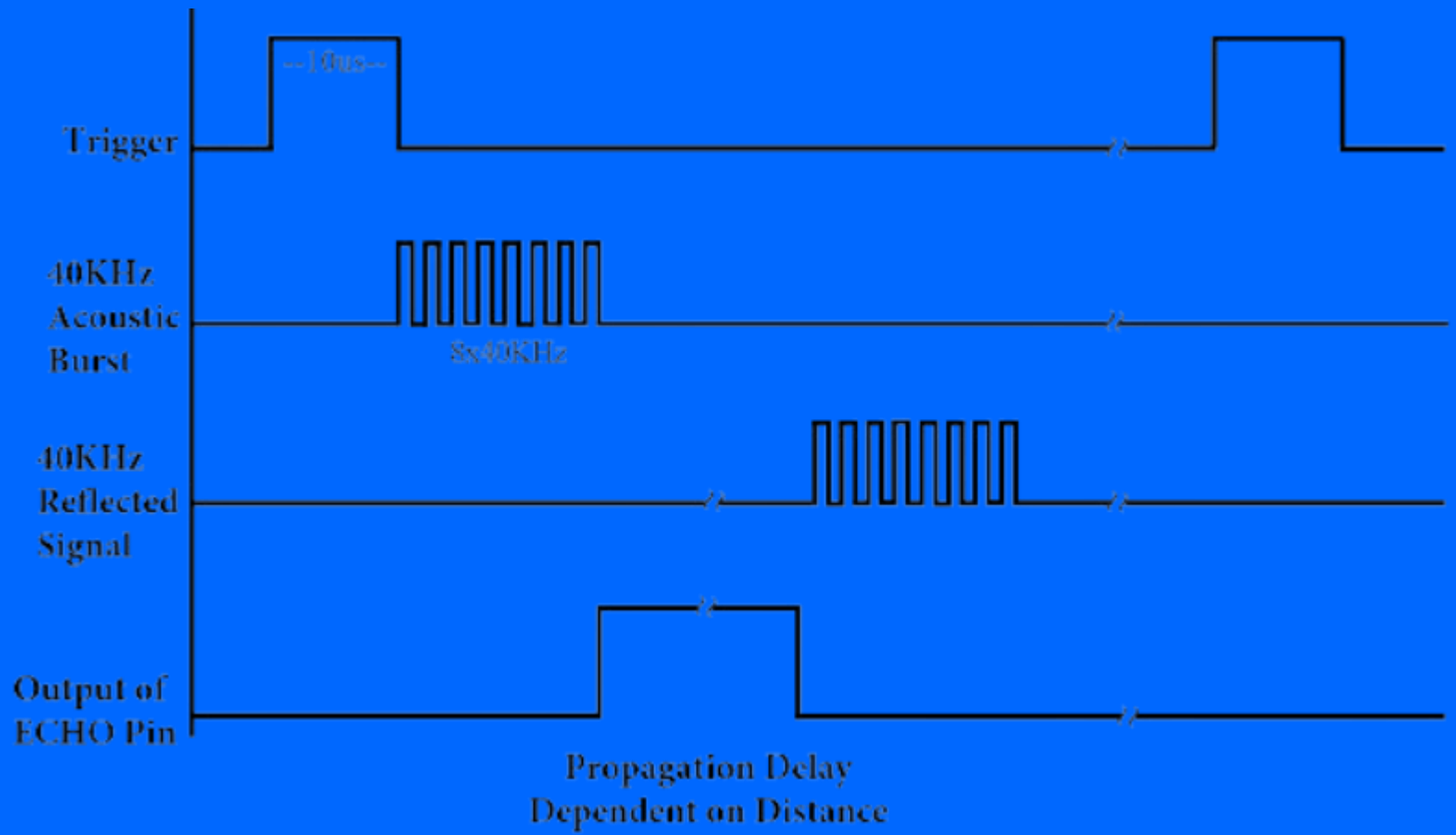
Pin Configuration

VCC: +5V Power Supply

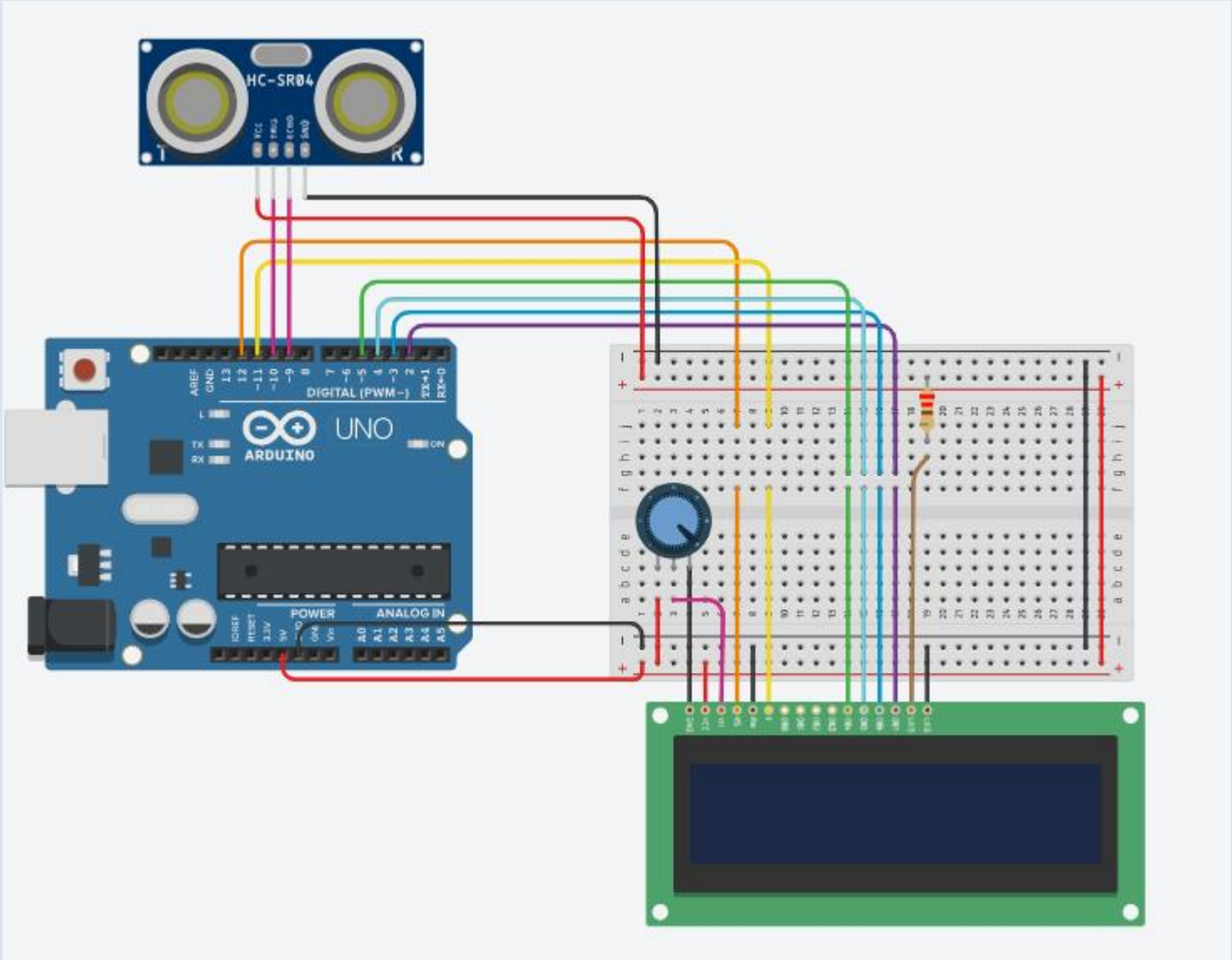
GND: Ground

Trig: Trigger Pin

Echo: Echo Pin



Example 10 => Distance Measurement



Example 10 => Distance Measurement

```
#include <LiquidCrystal.h>

LiquidCrystal lcd_1(12, 11, 5, 4, 3, 2);
const int trigPin = 10;
const int echoPin = 9;

void setup() {
  lcd_1.begin(16, 2);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  lcd_1.print("Distance: ");
}

void loop() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  long duration = pulseIn(echoPin, HIGH);
  float distance = duration * 0.034 / 2;

  lcd_1.setCursor(0, 1);
  lcd_1.print("                "); // Clear previous reading
  lcd_1.setCursor(0, 1);
  lcd_1.print(distance);
  lcd_1.print(" cm");

  delay(500);
}
```

The speed of sound in air is approximately 343 meters per second or 0.0343 centimeters per microsecond.

PIR (Passive Infrared) Sensor

Introduction:

- **Definition:** PIR sensors detect motion by measuring infrared radiation from objects in their field of view.
- **Common Usage:** Security systems, automatic lighting.

Working Principle:

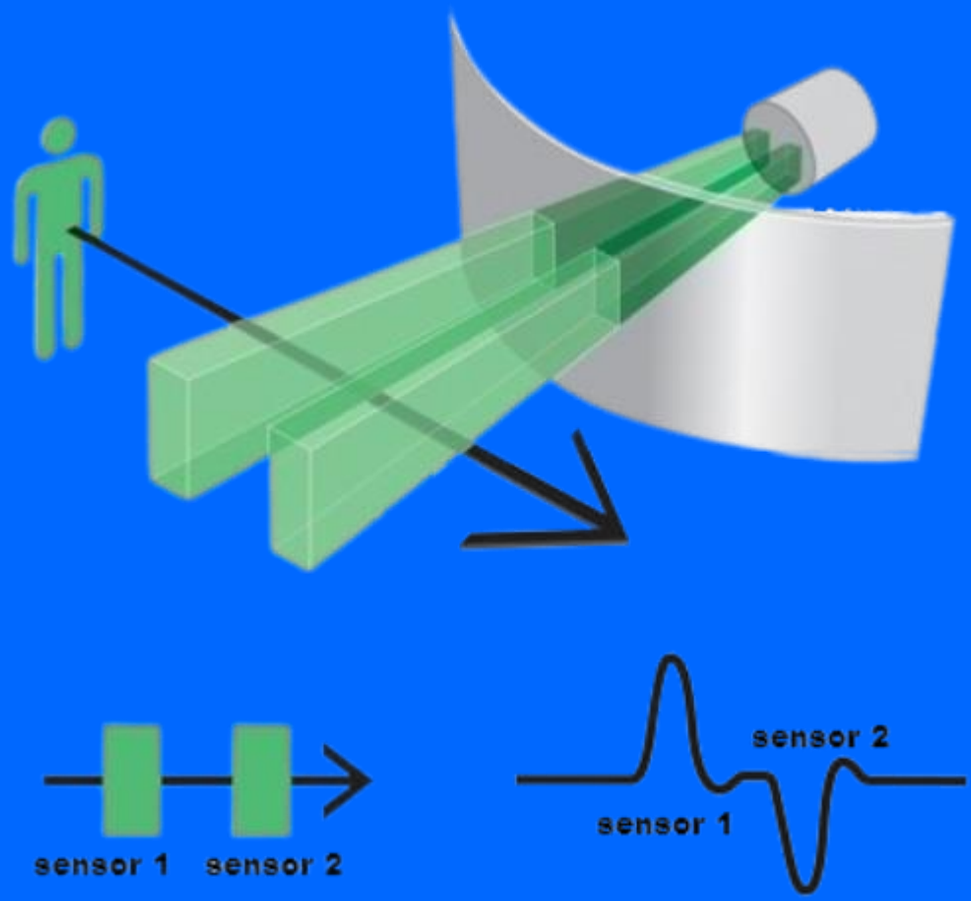
- **Infrared Detection:** Detects changes in infrared radiation, indicating movement of people or animals.

Pin Configuration

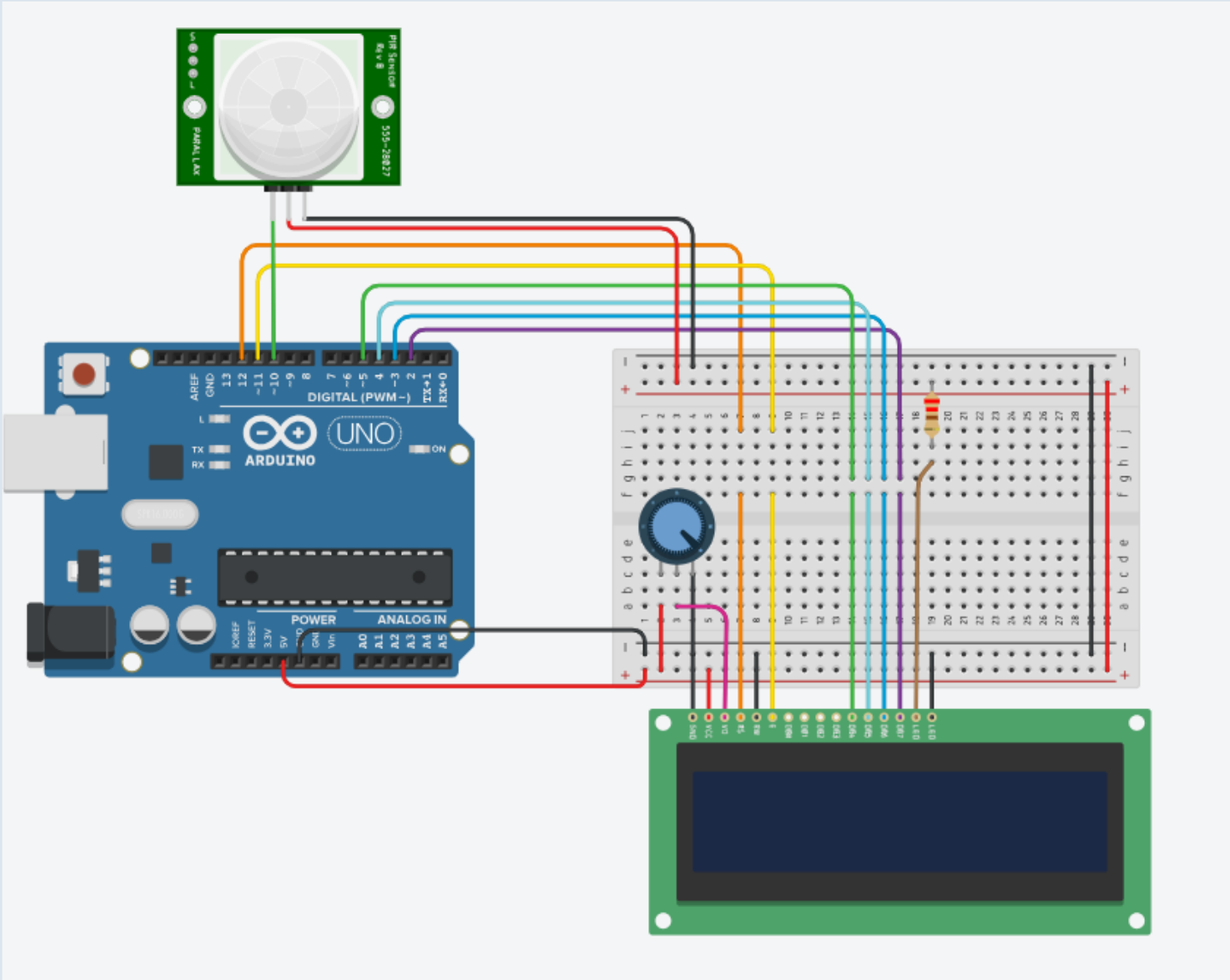
VCC: +5V Power Supply

GND: Ground

OUT: Output Signal



Example 11 => Motion detection



Example 11 => Motion detection

```
#include <LiquidCrystal.h>

LiquidCrystal lcd_1(12, 11, 5, 4, 3, 2);
const int pirPin = 10;

void setup() {
  lcd_1.begin(16, 2);
  pinMode(pirPin, INPUT);
  lcd_1.print("PIR Sensor:");
}

void loop() {
  int pirState = digitalRead(pirPin);

  lcd_1.setCursor(0, 1);
  if (pirState == HIGH)
    lcd_1.print("Motion detected");
  else
    lcd_1.print("No motion      ");

  delay(500);
}
```

Actuators

Actuators

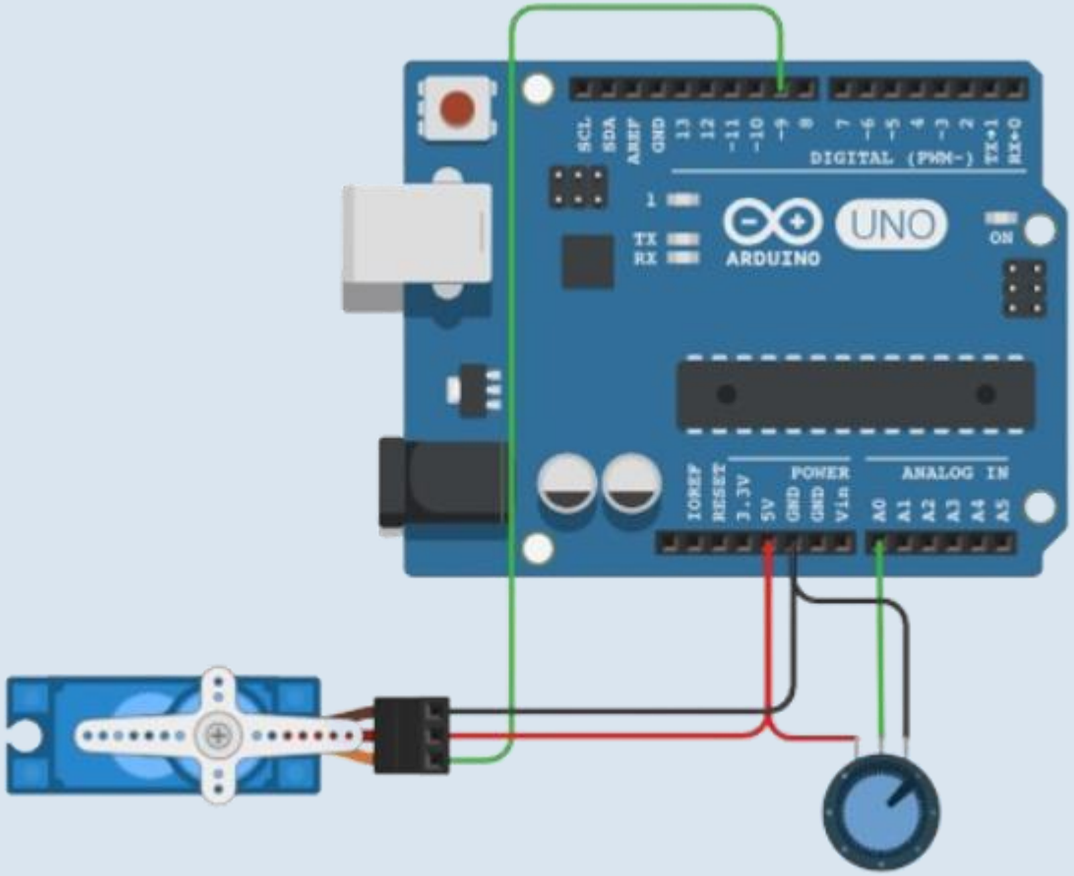
- **Definition:** Actuators are devices that convert electrical energy into physical motion. They are used to move or control mechanisms or systems.
- **Common Types:** Servos, DC motors, stepper motors.

Servo Motors

Definition: Servo motors are precise control motors that use a feedback loop to control position, speed, and acceleration.

Common Use: Robotics, RC cars, controlled positioning systems.

Example 12 => Servo Motors



Example 12 => Servo Motors

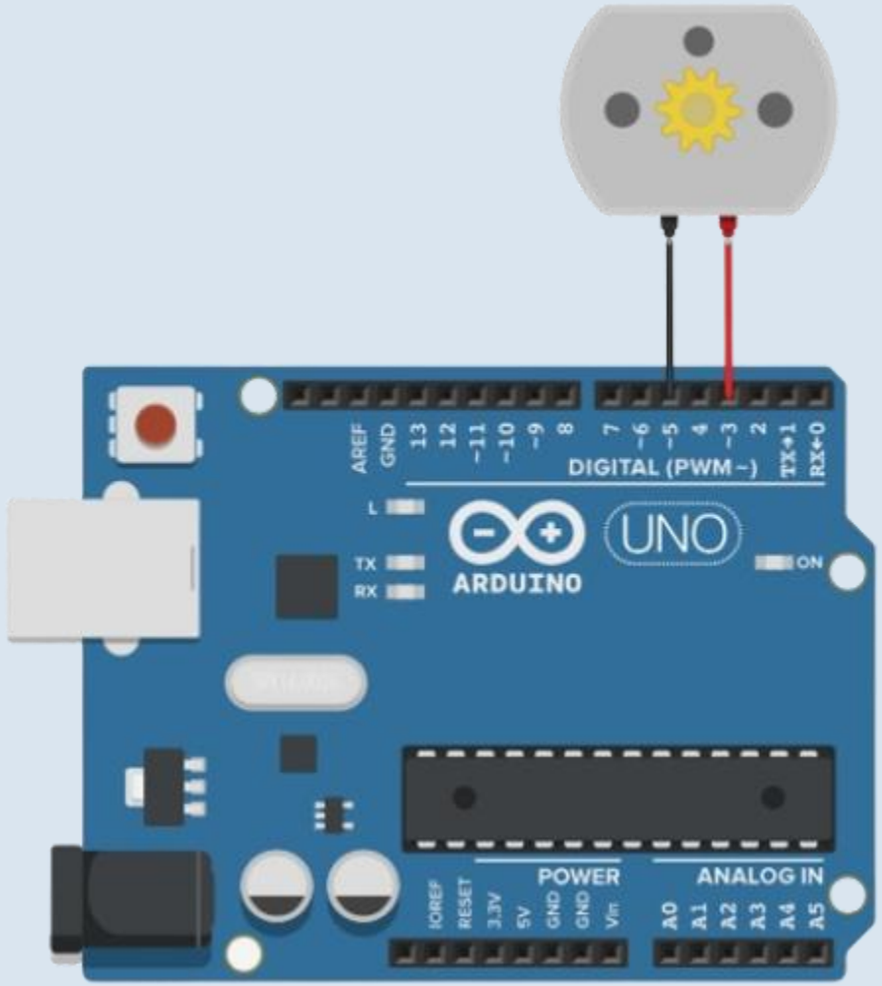
```
#include <Servo.h>

Servo myservo;
int value;
double angle;

void setup()
{
  Serial.begin(9600);
  myservo.attach(9);
}

void loop()
{
  value = analogRead(A0);
  angle = map(value, 0, 1023, 0, 180);
  Serial.println(angle);
  myservo.write(angle);
  delay(15);
}
```

DC Motors

Definition: DC motors convert direct current electrical energy into mechanical motion.

Common Use: Fans, wheels in robots, small appliances.

Example 13 => DC Motors



Example 13 => DC Motors

```
int motorPin1 = 3;
int motorPin2 = 5;

void setup() {
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
}

void loop() {
  digitalWrite(motorPin1, HIGH);
  digitalWrite(motorPin2, LOW);
  delay(2000);
  digitalWrite(motorPin1, LOW);
  digitalWrite(motorPin2, HIGH);
  delay(2000);
}
```

Stepper Motors

Definition: Stepper motors move in discrete steps, offering precise control over movement.

Common Use: 3D printers, CNC machines, camera platforms.

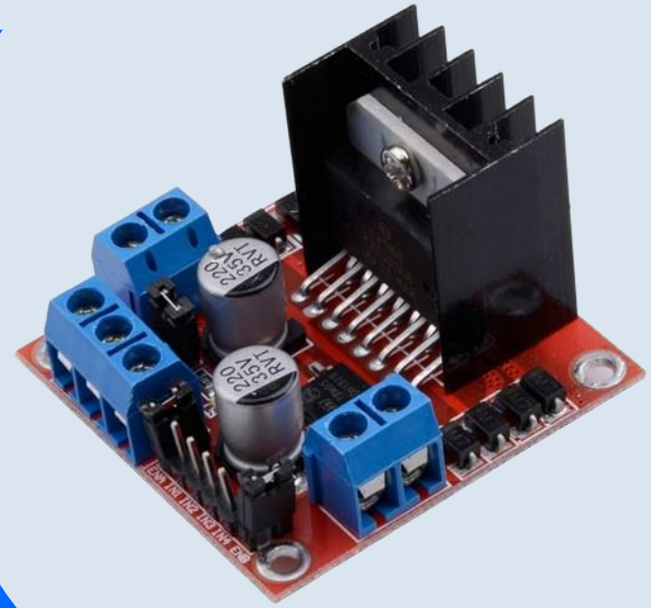
H-Bridge

Introduction:

- **Definition:** An H-Bridge is an electronic circuit that enables a voltage to be applied across a load in either direction.
- **Common Use:** Motor control, allowing motors to run forward or backward.

Working Principle:

- **Configuration:** Consists of four switches (transistors or MOSFETs) that control the direction of current flow.
- **Direction Control:** By closing different pairs of switches, the direction of the current and thus the motor's direction can be controlled.



Pin Configuration

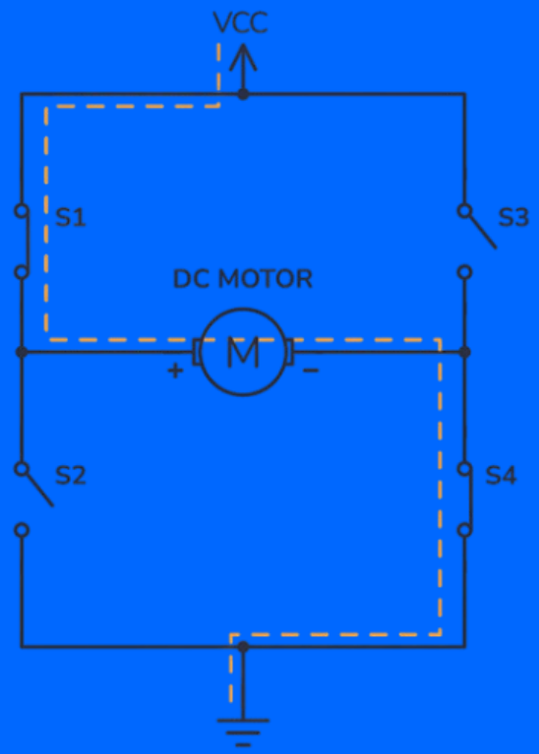
IN1, IN2, IN3, IN4: Input pins to control the switches.

ENA, ENB: Enable pins to activate the H-Bridge channels.

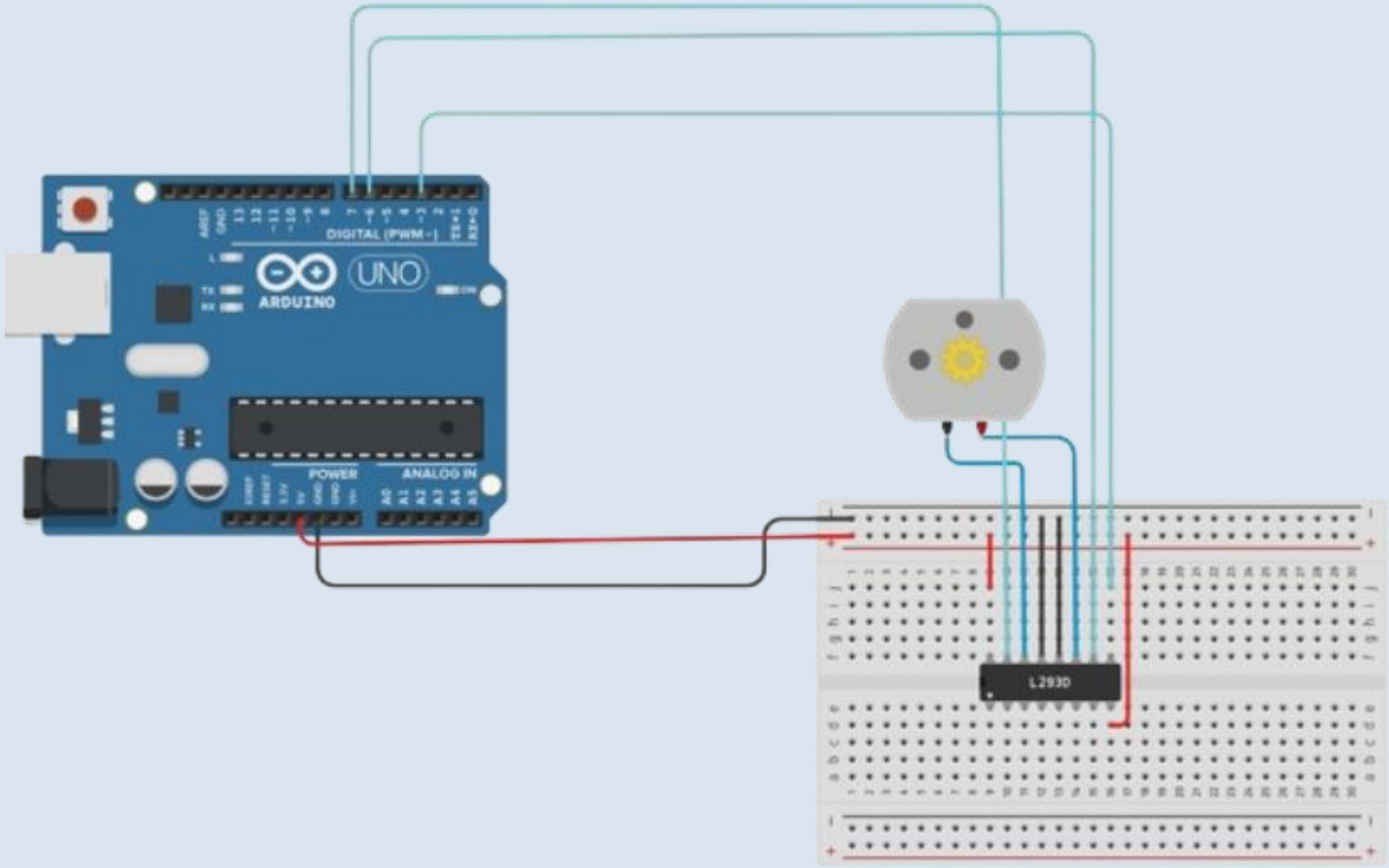
OUT1, OUT2, OUT3, OUT4: Output pins connected to the motor.

VCC: Voltage supply for the H-Bridge.

GND: Ground.12V: Power supply for the motors.



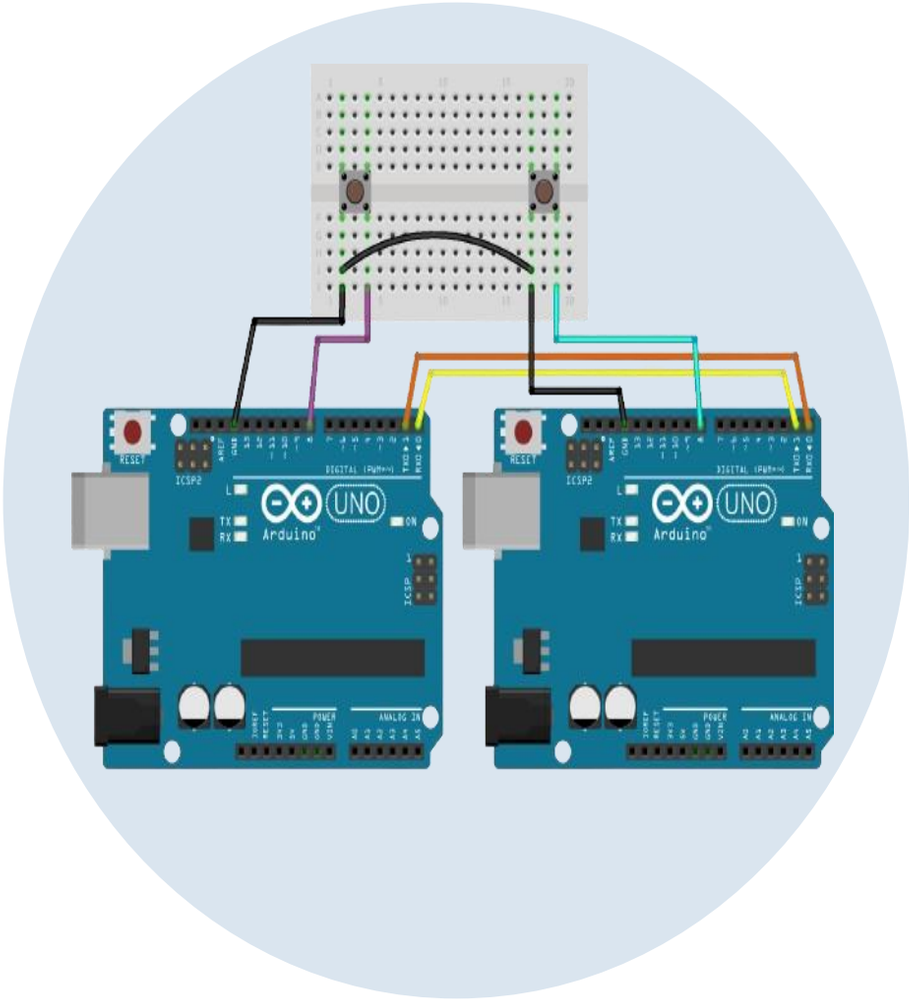
Example 14 => H-Bridge



Example 14 => H-Bridge

```
int enA = 3;
int in1 = 6;
int in2 = 7;

void setup() {
  pinMode(enA, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
}

void loop() {
  digitalWrite(in1, HIGH);
  digitalWrite(in2, LOW);
  analogWrite(enA, 255);
  delay(2000);
  digitalWrite(in1, LOW);
  digitalWrite(in2, HIGH);
  delay(2000);
}
```

Communication



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