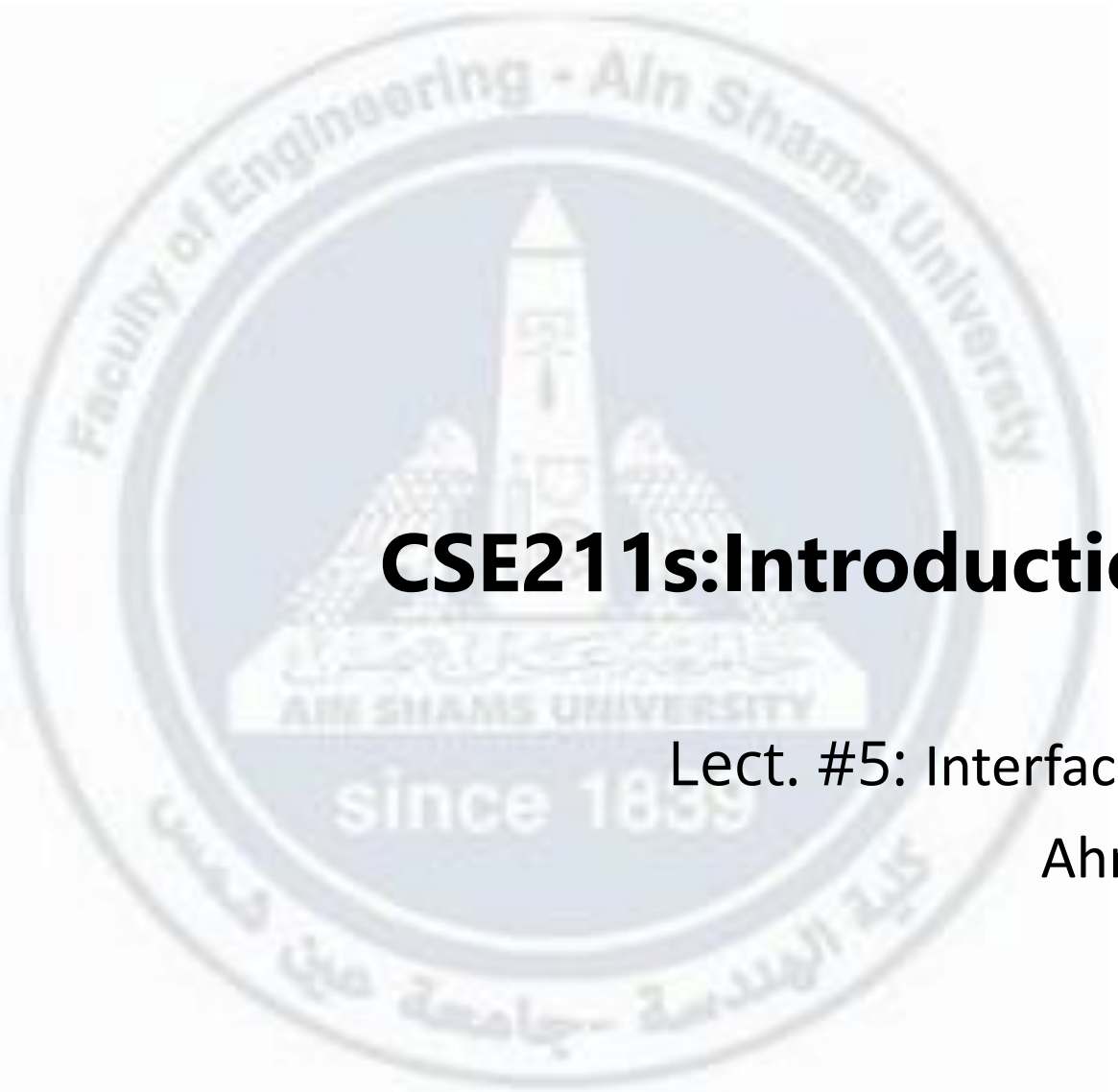


CSE211s:Introduction to Embedded Systems

Lect. #5: Interfacing with Relays and Motors

Ahmed M. Zaki

Agenda

- Realy
- DC-Motors
  - Brushed vs Brushless
  - Control Brushed DC motor Speed
  - H-Bridge
  - Control Brushed DC motor Speed/Direction using H-Bridge
- DC- Servo Motor
- Stepper Motor
  - Unipolar
  - Bipolar

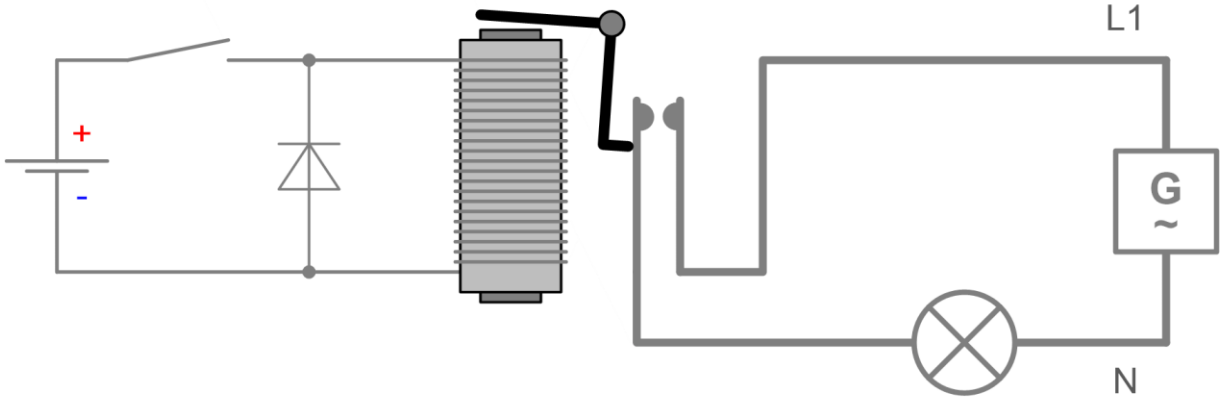
Relay

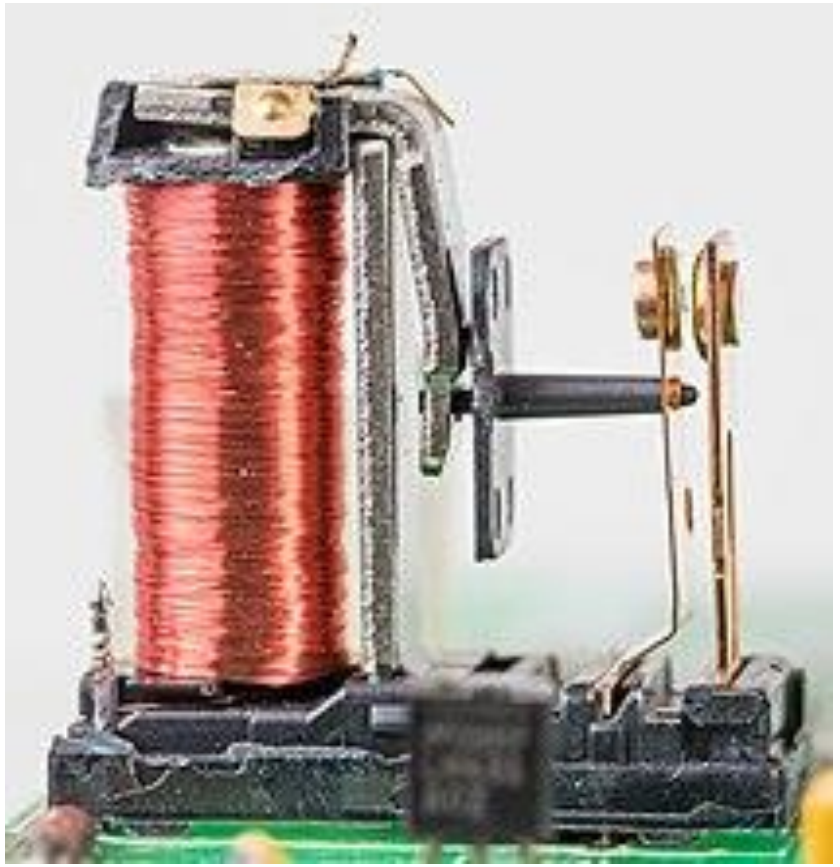
- A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms, such as make contacts, break contacts, or combinations thereof.

- Relays are used where it is necessary to control a circuit by an independent low-power signal, or where several circuits must be controlled by one signal.

Relay(Cont.)

- The traditional form of a relay uses an electromagnet to close or open the contacts, but other operating principles have been invented, such as in **solid-state relays** which use semiconductor properties for control





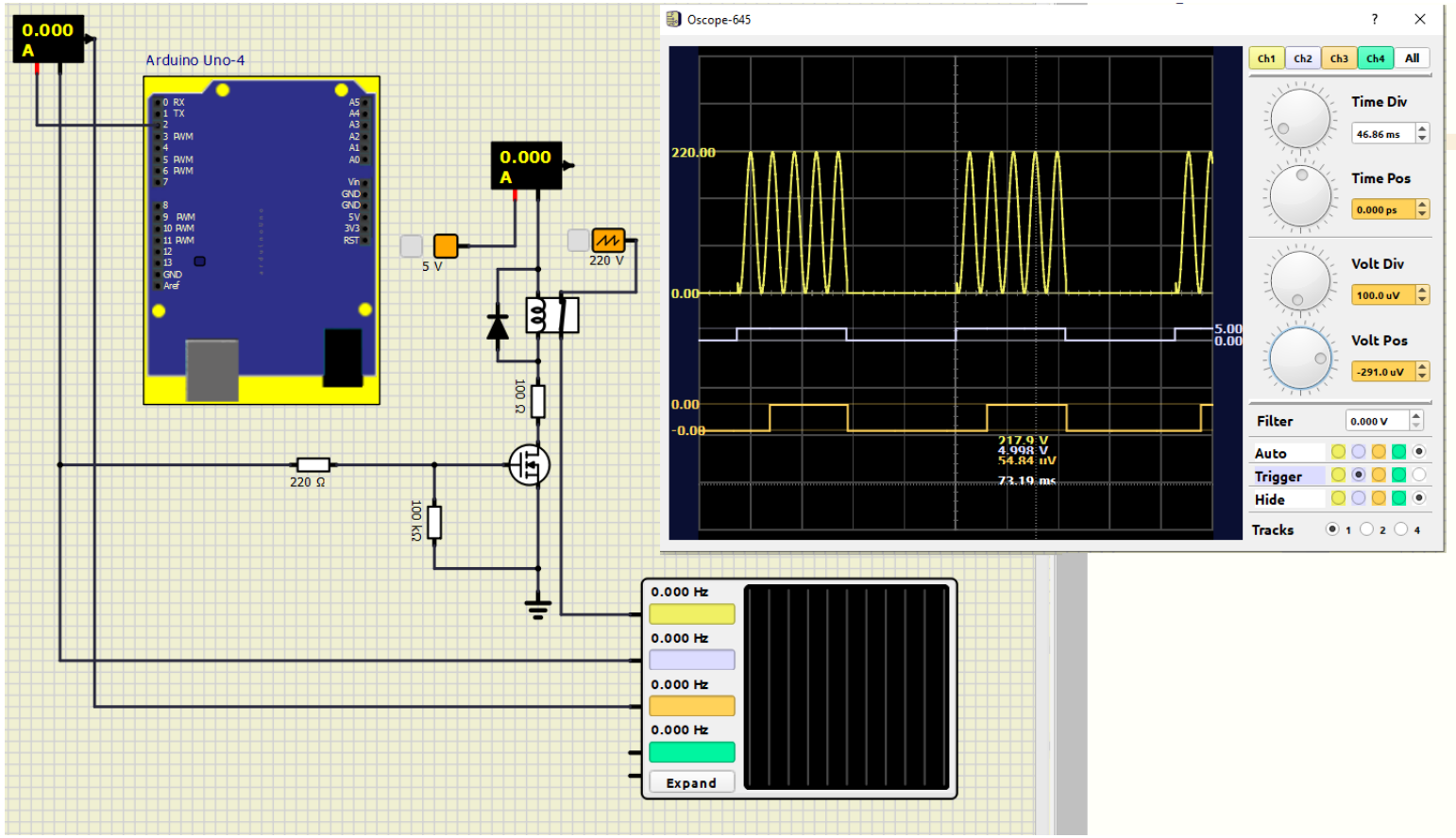
Relay(Cont.)

SEED TECHNOLOGY INC (SEEEDUINO) Electronic brick - 5V Relay module (digital) Model: ELB115E4M

- Relay specifications
  - Working by DC-5V
  - 7A 240VAC
  - 10A 120 VAC
  - 10A 240 VDC

Relay(Ex.)

```
#define  OUT_PIN 2
void setup() {
  pinMode(OUT_PIN,OUTPUT);
  digitalWrite(OUT_PIN,HIGH);
}
void loop() {
  digitalWrite(OUT_PIN,LOW);
  delay(1000);
  digitalWrite(OUT_PIN,HIGH);
  delay(1000);
}
```



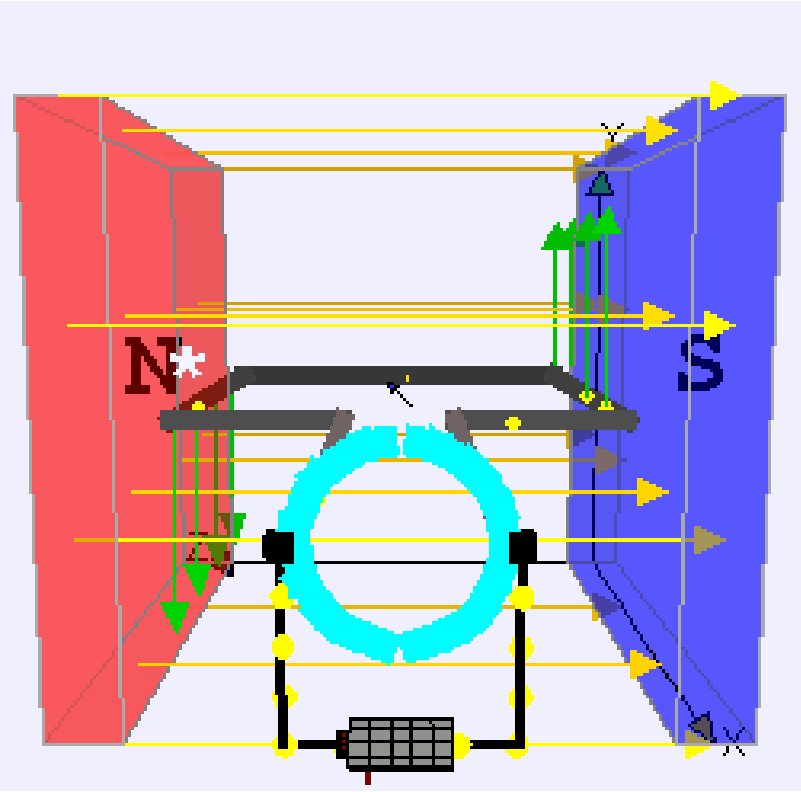
DC- Motors

- A DC motor is any of a class of rotary electrical motors that converts direct current (DC) electrical energy into mechanical energy.
- The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.
- Characteristics
  - Rotate directly when DC voltage is applied
  - As the input current increase as the rotation speed increase
  - There is no way to make a precise rotation angle by applying the power for a certain time.
- Types
  - Brushed
    - Simple to operate, reliable, Available in many sizes and ratings, Easy controls, Good on lower duty cycles
    - Less efficiency. Shorter life span, Requires more maintenance
  - Brushless
    - High efficiency, Longer life, Less maintenance, Better suited to continuous or long-running duty cycles, Precise speed control
    - Requires electronic controller, More expensive, More complex

DC- Motors: (Brushed DC-Motor)

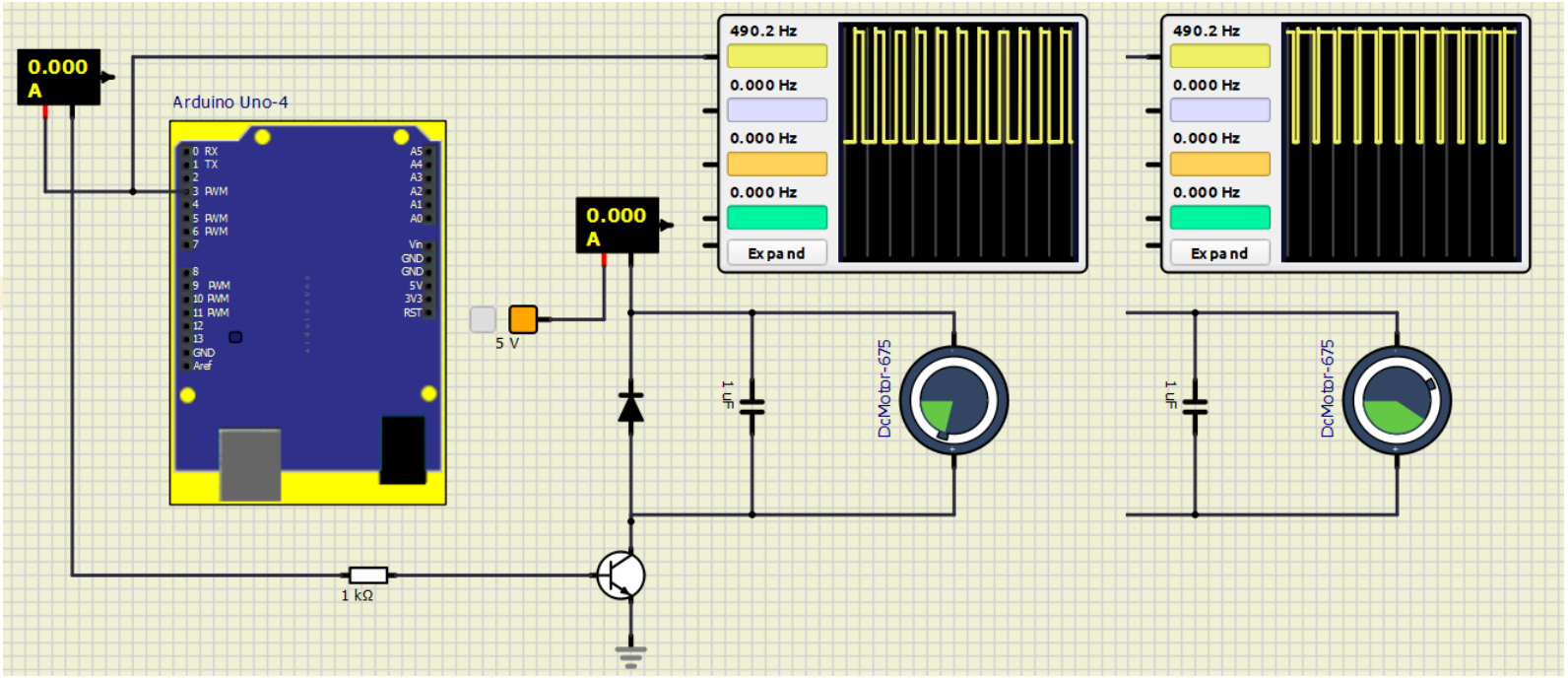
A simple DC motor has a stationary set of magnets in the stator and an armature with one or more windings of insulated wire wrapped around a soft iron core that concentrates the magnetic field. The windings usually have multiple turns around the core, and in large motors there can be several parallel current paths. The ends of the wire winding are connected to a commutator. The commutator allows each armature coil to be energized in turn and connects the rotating coils with the external power supply through brushes.

(Brushless DC motors have electronics that switch the DC current to each coil on and off and have no brushes.)



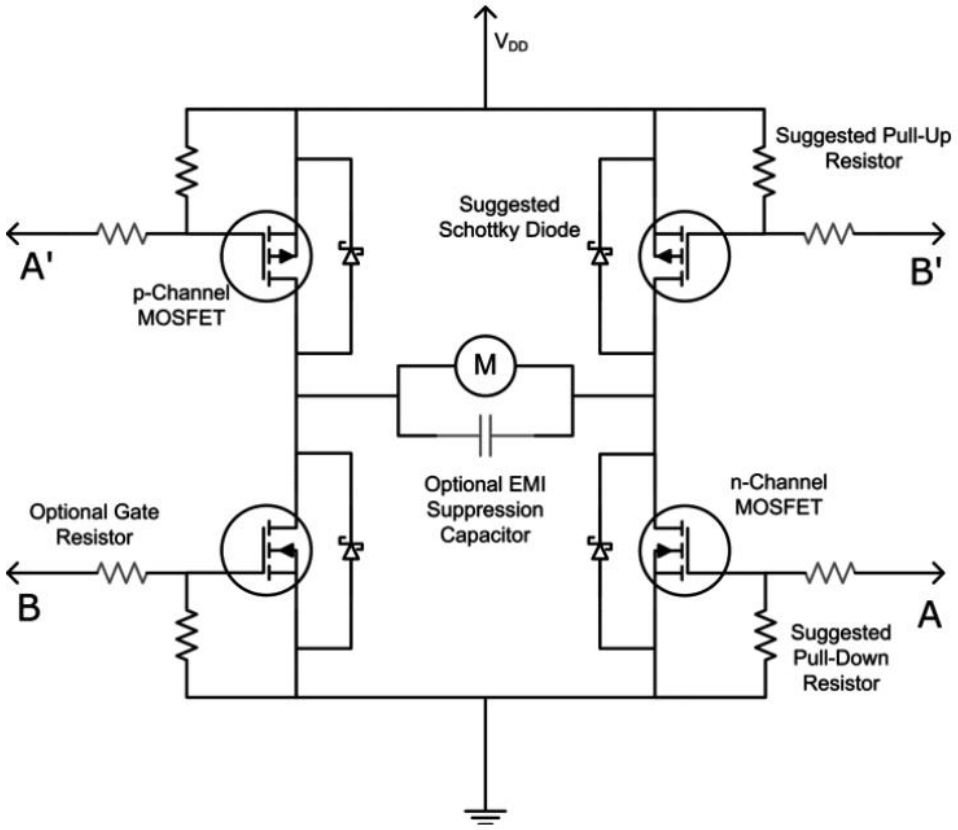
DC-Motor (Speed-Control) Example

```
#define  OUT_PIN 3
void setup() {
  pinMode(OUT_PIN,OUTPUT);
  analogWrite(OUT_PIN,0);
}
void loop() {
      analogWrite(OUT_PIN,100);
      delay(1000);
      analogWrite(OUT_PIN,200);
      delay(1000);
}
```



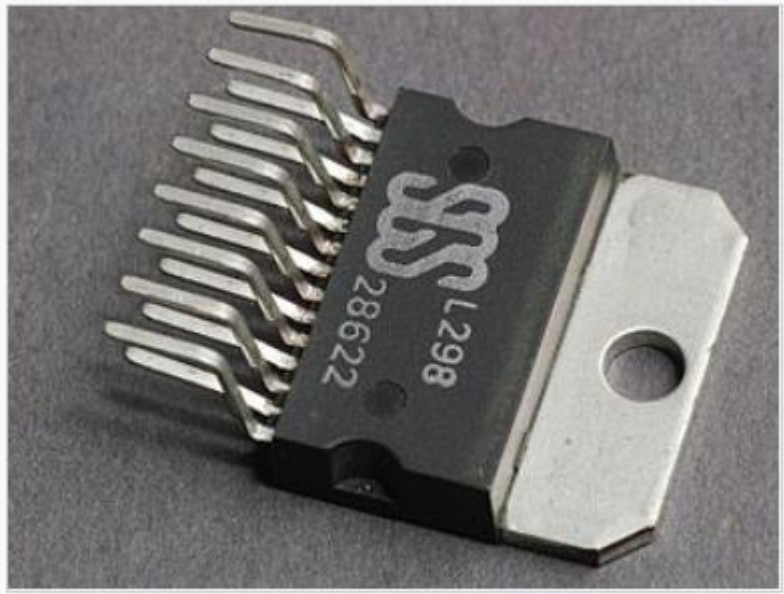
H-Bridge

- A H-bridge is an electronic circuit that switches the polarity of a voltage applied to a load.
- These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards.
- The name is derived from its common schematic diagram representation, with four switching elements configured as the branches of a letter "H" and the load connected as the cross-bar.



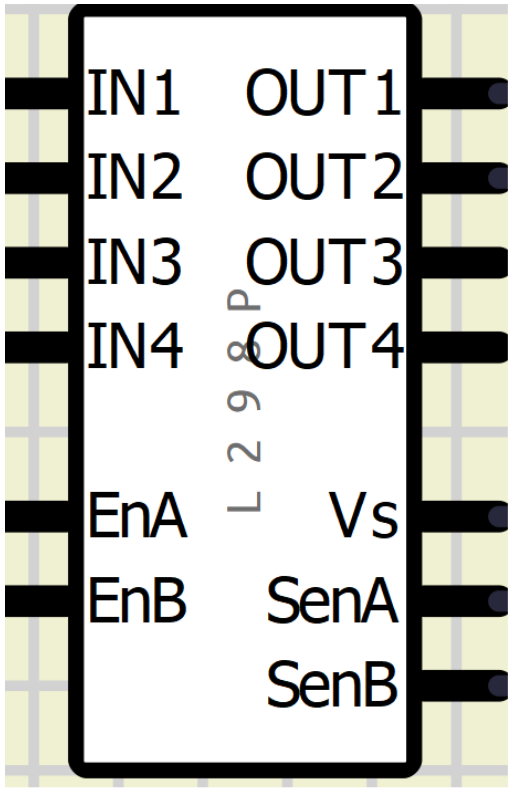
H-Bridge(cont.) construction

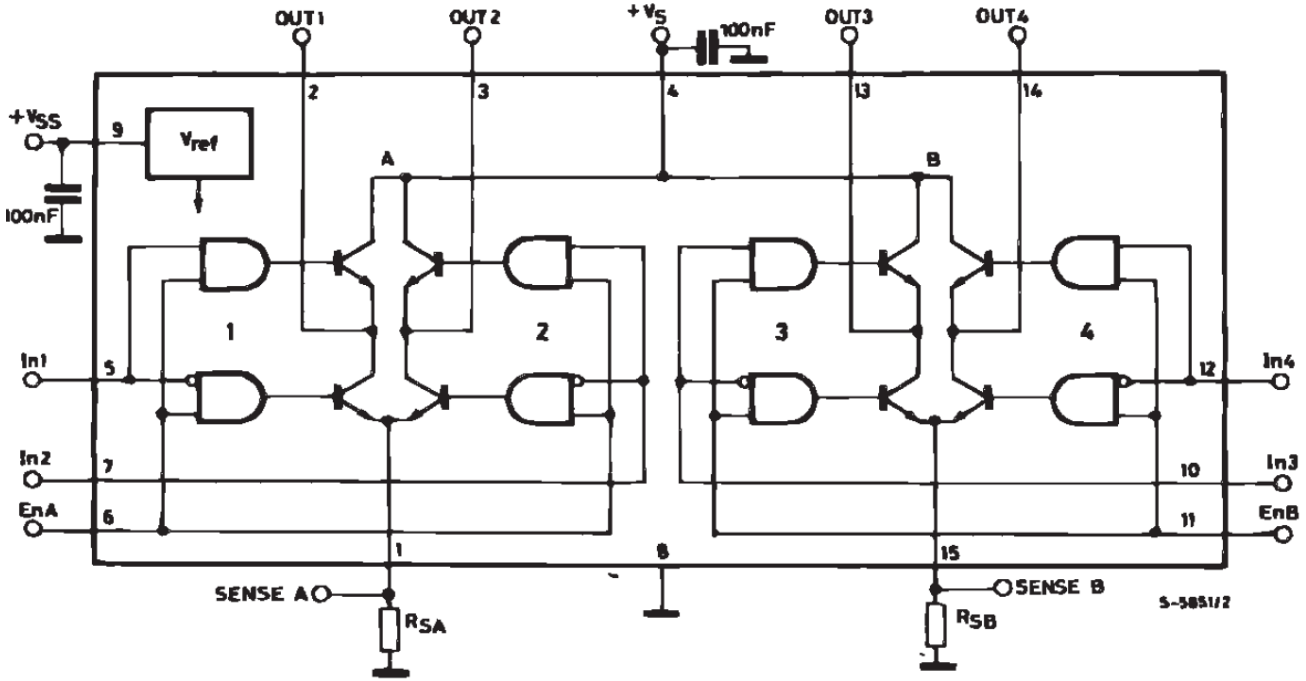
- One way to build an H-bridge is to use an array of relays from a relay board
- A "double pole double throw" (DPDT) relay can generally achieve the same electrical functionality as an H-bridge (considering the usual function of the device). However a semiconductor-based H-bridge would be preferable to the relay where a smaller physical size, **high speed switching**, or low driving voltage (or low driving power) is needed, or where the wearing out of mechanical parts is undesirable.
- L298 is an example for H-Bridge
  - The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input



L298 dual H-bridge motor driver

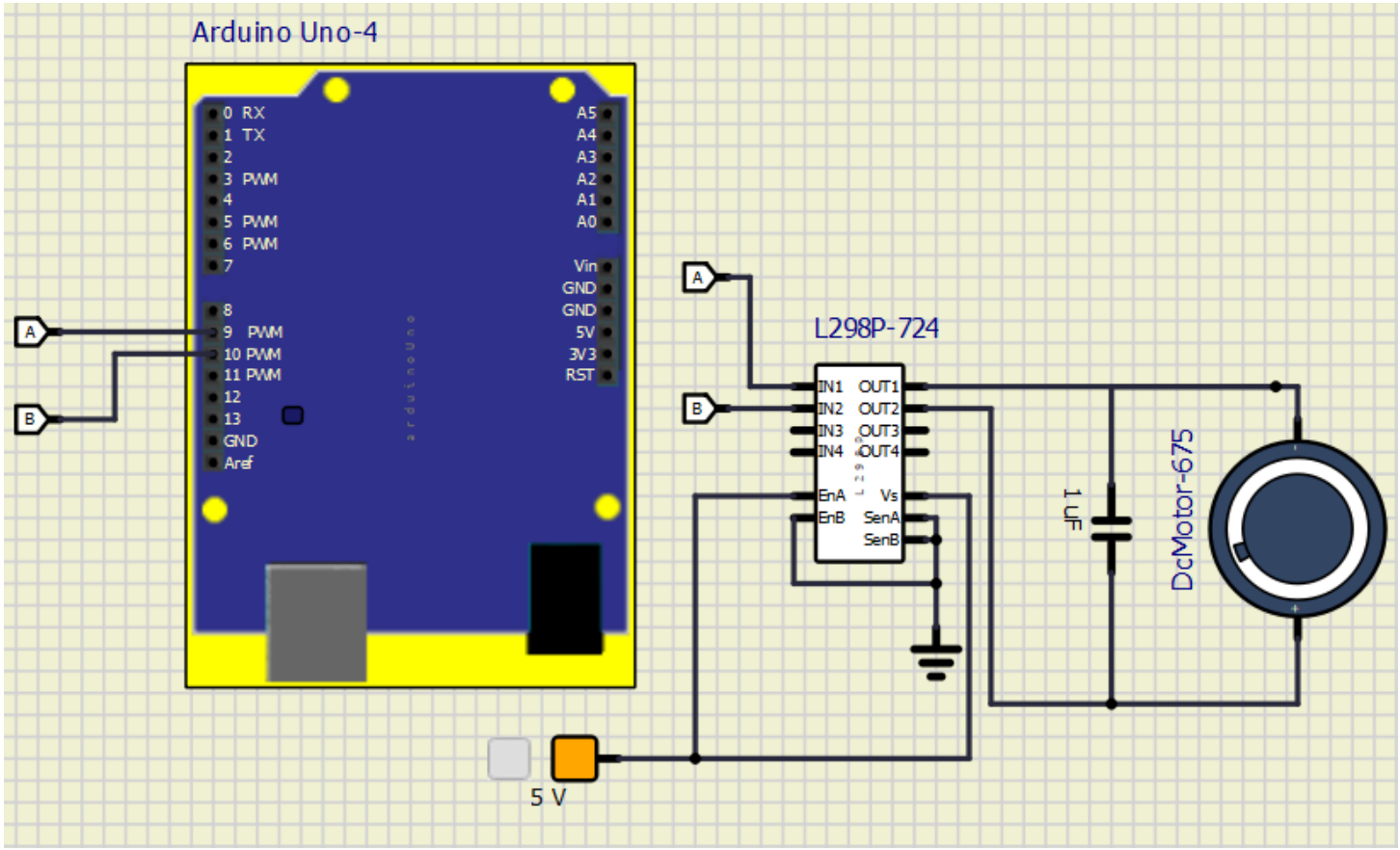
H-Bridge(cont.) construction- L298





DC-Motor (Speed-Control/Direction) Example

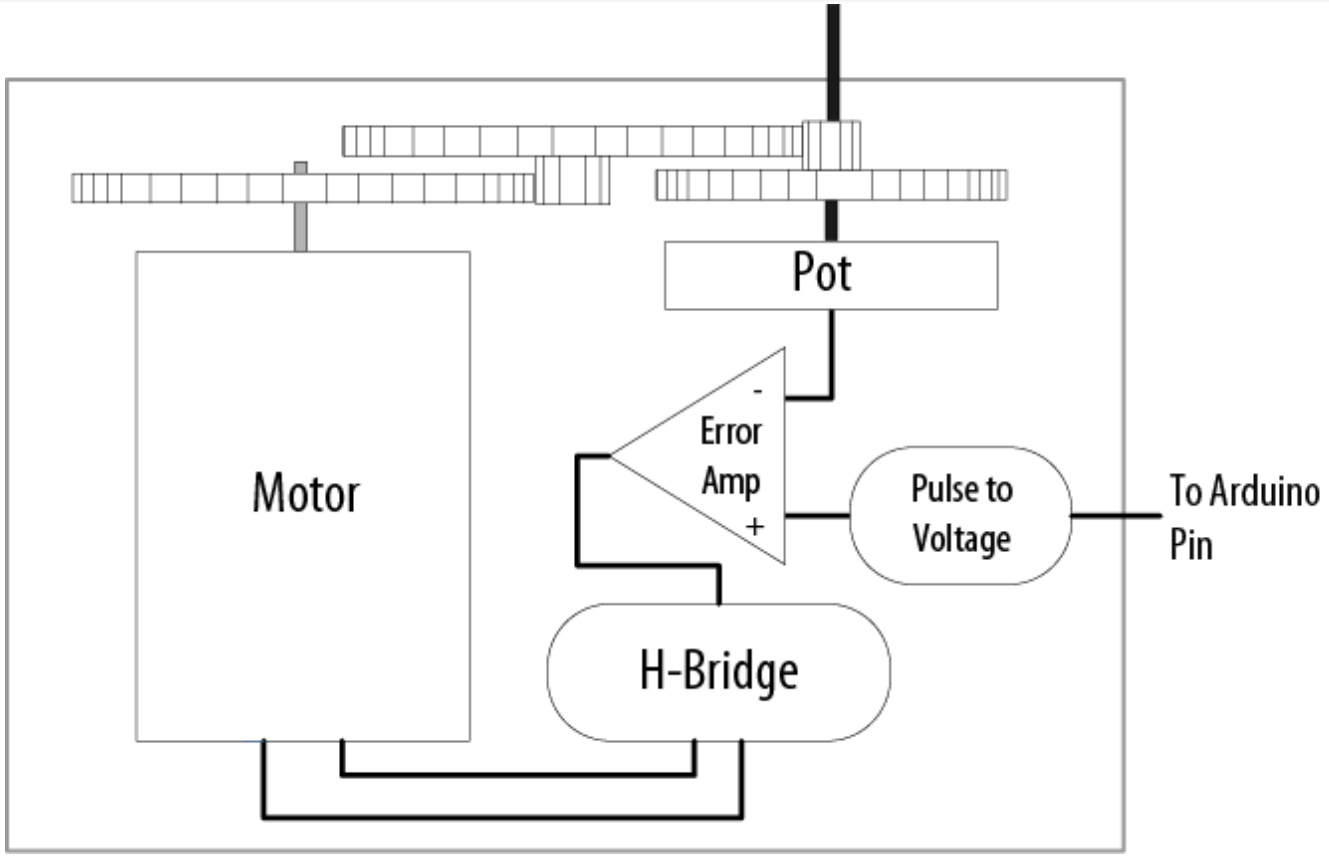
```
#define  A_OUT_PIN 9
#define  B_OUT_PIN 10

void setup() {
  pinMode(A_OUT_PIN,OUTPUT);
  pinMode(B_OUT_PIN,OUTPUT);
  analogWrite(A_OUT_PIN,0);
  analogWrite(B_OUT_PIN,0);
}

void loop() {
      analogWrite(A_OUT_PIN,200);
      digitalWrite(B_OUT_PIN,LOW);
      delay(3000);
      digitalWrite(A_OUT_PIN,LOW);
      analogWrite(B_OUT_PIN,200);
      delay(3000);
      analogWrite(A_OUT_PIN,100);
      digitalWrite(B_OUT_PIN,0);
      delay(3000);
      digitalWrite(A_OUT_PIN,0);
      analogWrite(B_OUT_PIN,100);
      delay(3000);
}
```



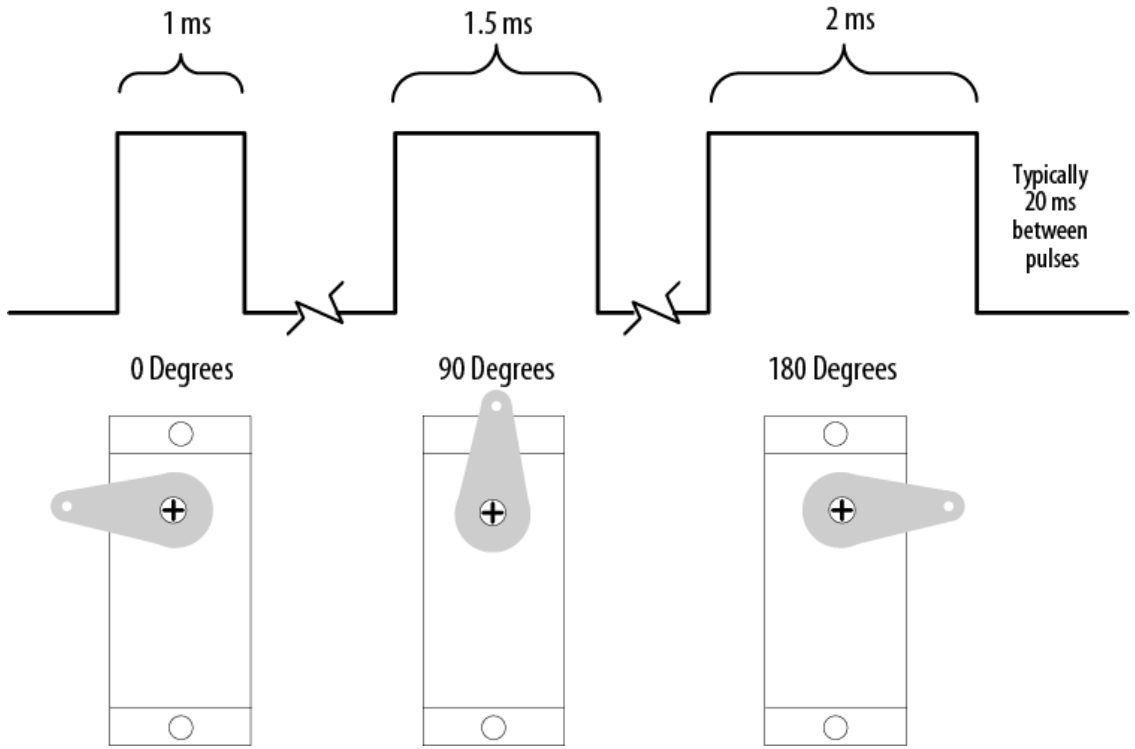
Servo Motors

- Servo Motors uses internal feedback system to go directly to the required angle.
- Servo Motors controlled by a PWM input.
- The input pulse width may vary between minimum and maximum pulse width to produce minimum and maximum deviation angle.
- Typical values
  - Min Pulse width: 1ms → 0 degree
  - Max Pulse width: 2ms → 180 degree
  - PWM duty cycle: 20ms
- Models:
  - ROB12745M from www.fut-electronics.com and http://www.seeedstudio.com
  - HS-311 from http://www.hitecrcd.com
  - SM-S3317S from www.sparkfun.com

Servo Motors (cont.)
Internal Feedback Control

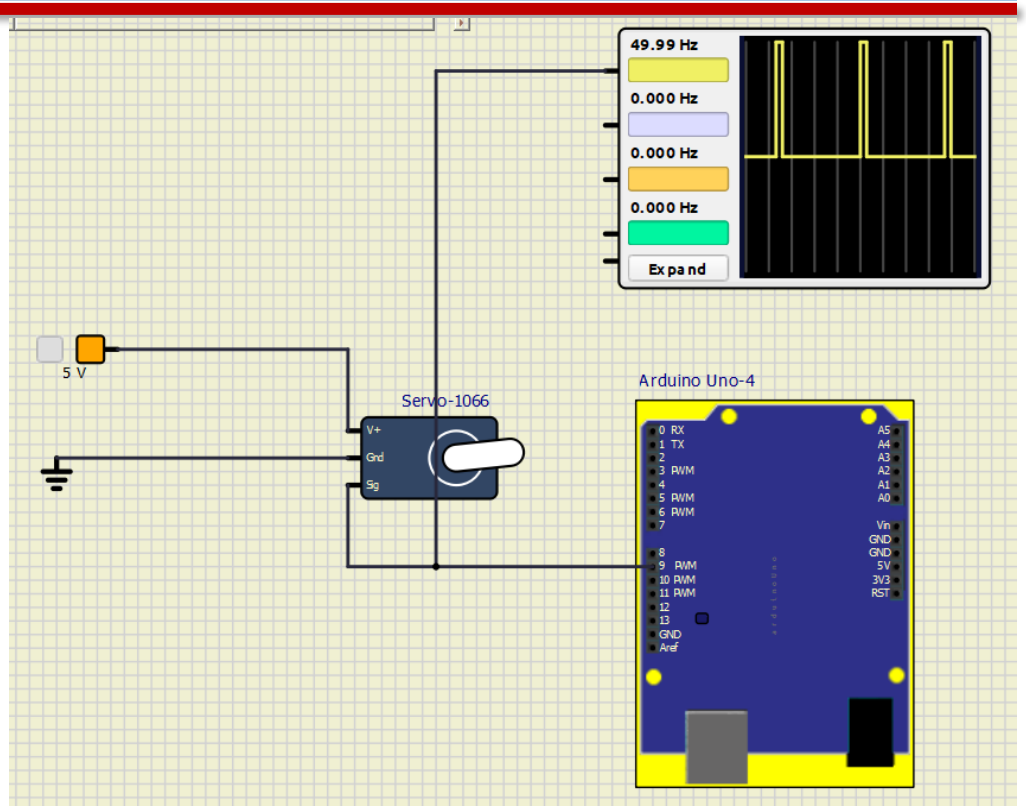


Servo Motors (cont.)
PWM Angle Control



Servo Motors (Example)

```ino
#include <Servo.h>

Servo myservo;
// create servo object to control a servo
// twelve servo objects can be created on most boards

int pos = 0;    // variable to store the servo position

void setup() {
  myservo.attach(9);  // attaches the servo on pin 9 to the servo object
}

void loop() {
  for (pos = 0; pos <= 180; pos += 1) { // goes from 0 degrees to 180 degrees
    // in steps of 1 degree
    myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
  for (pos = 180; pos >= 0; pos -= 1) { // goes from 180 degrees to 0 degrees
    myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
}
```

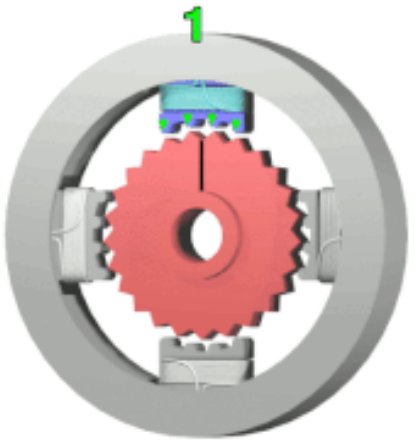


Stepper Motors

- Provide precise angular steps with fixed value.
- Uni-Polar Model
  - Motor: MOT106A3B from www.fut-electronics.com and http://www.seeedstudio.com
  - Driver Chip: L298 from www.mouser.com
  - Driver Board: L298 from www.fut-electronics.com and http://www.seeedstudio.com
- Bi-Polar Model
  - Motor: SM-42BYG011-25 from www.sparksun.com
  - Driver Chip: L293 from www.mouser.com

Stepper Motor (idea)

Animation of a simplified stepper motor (unipolar)



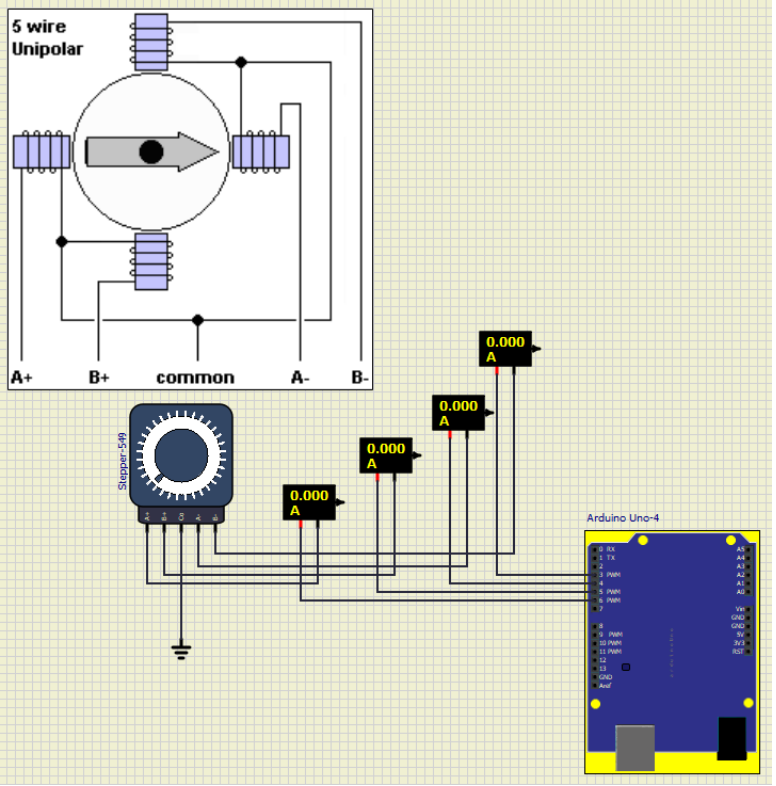
Frame 1: The top electromagnet (1) is turned on, attracting the nearest teeth of the gear-shaped iron rotor. With the teeth aligned to electromagnet 1, they will be slightly offset from right electromagnet (2).

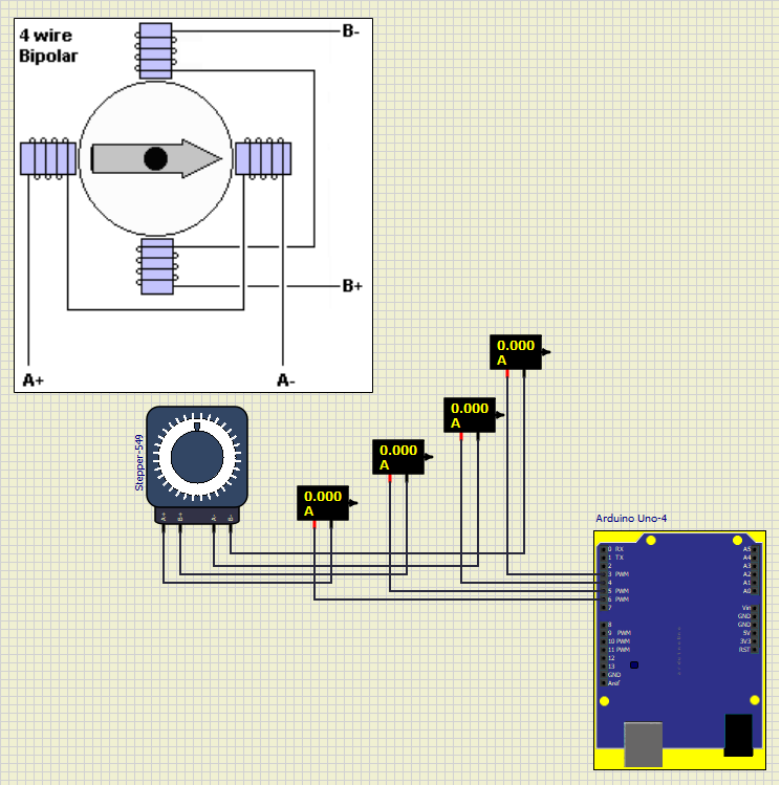
Frame 2: The top electromagnet (1) is turned off, and the right electromagnet (2) is energized, pulling the teeth into alignment with it. This results in a rotation of 3.6° in this example.

Frame 3: The bottom electromagnet (3) is energized; another 3.6° rotation occurs.

Frame 4: The left electromagnet (4) is energized, rotating again by 3.6°. When the top electromagnet (1) is again enabled, the rotor will have rotated by one tooth position; since there are 25 teeth, it will take 100 steps to make a full rotation in this example.

Stepper Motor (unipolar/bipolar Example) (non-practical diagram)





Unipolar pattern

1000
0100
0010
0001

bipolar pattern

1100
0110
0011
1001

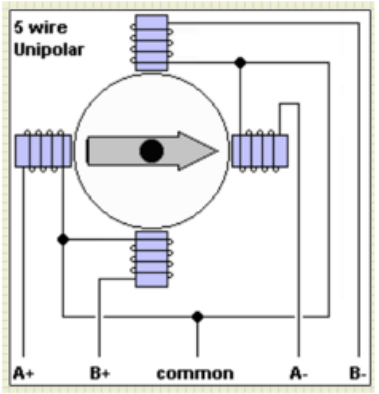
This method is used to obtain the highest possible torque from the motor

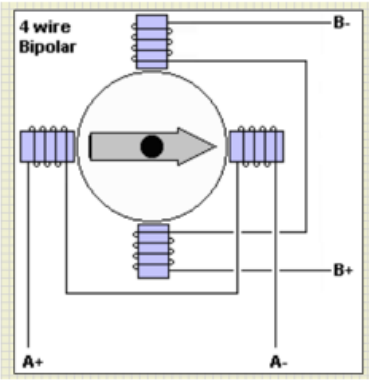
Stepper Motor (unipolar/bipolar Example) (non-practical diagram)

```
#include <stdio.h>
#include <stdlib.h>

#define  INP_PIN 2

#define  Bn_OUT_PIN 3
#define  An_OUT_PIN 4
#define  Bp_OUT_PIN 5
#define  Ap_OUT_PIN 6

#define  A_OUT_PIN 3
#define  B_OUT_PIN 4
#define  C_OUT_PIN 5
#define  D_OUT_PIN 6

#define  DELAY 1000

#define V1 HIGH
#define V2 LOW

//#define V1 LOW
//#define V2 HIGH

void setup() {
  pinMode(INP_PIN,INPUT_PULLUP);
  pinMode(A_OUT_PIN,OUTPUT);
  pinMode(B_OUT_PIN,OUTPUT);
  pinMode(C_OUT_PIN,OUTPUT);
  pinMode(D_OUT_PIN,OUTPUT);

  digitalWrite(A_OUT_PIN,V1);
  digitalWrite(B_OUT_PIN,V1);
  digitalWrite(C_OUT_PIN,V2);
  digitalWrite(D_OUT_PIN,V2);
}
```

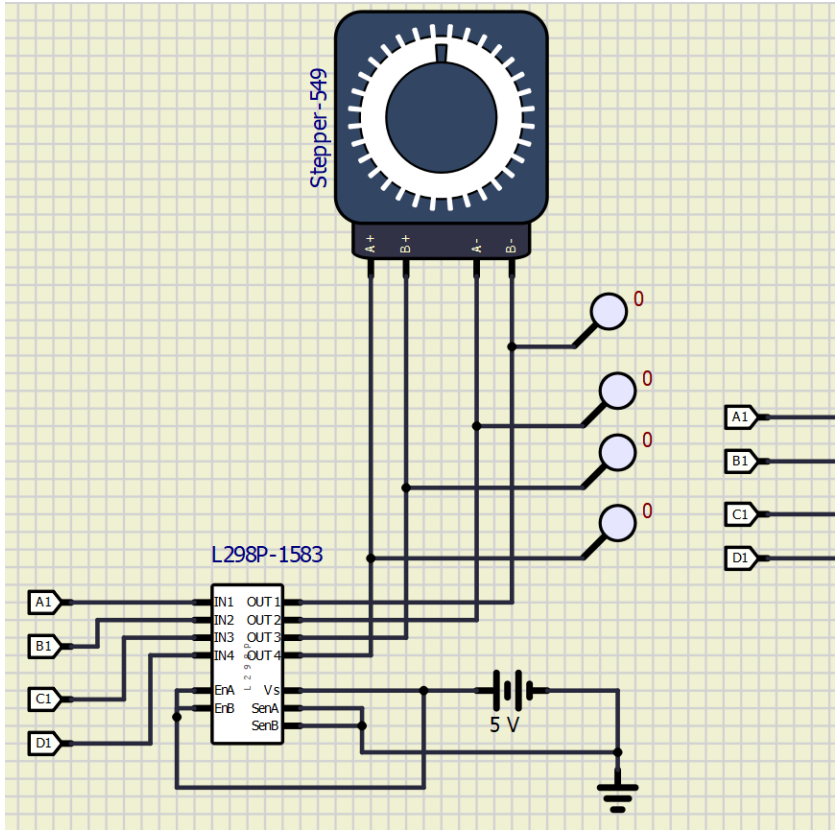
```

void unipolar_driver()
{
     digitalWrite(A_OUT_PIN,V1);
     delay(DELAY);

     digitalWrite(A_OUT_PIN,V2);
     digitalWrite(B_OUT_PIN,V1);

     delay(DELAY);

     digitalWrite(B_OUT_PIN,V2);
     digitalWrite(C_OUT_PIN,V1);

     delay(DELAY);

     digitalWrite(C_OUT_PIN,V2);
     digitalWrite(D_OUT_PIN,V1);

     delay(DELAY);

     digitalWrite(D_OUT_PIN,V2);
}

```

```


void bipolar_driver()
{

     digitalWrite(A_OUT_PIN,V1);
     digitalWrite(B_OUT_PIN,V1);

     delay(DELAY);

     digitalWrite(A_OUT_PIN,V2);
     digitalWrite(C_OUT_PIN,V1);

     delay(DELAY);

     digitalWrite(B_OUT_PIN,V2);
     digitalWrite(D_OUT_PIN,V1);

     delay(DELAY);

     digitalWrite(C_OUT_PIN,V2);
     digitalWrite(A_OUT_PIN,V1);

     delay(DELAY);
     digitalWrite(D_OUT_PIN,V2);

}

void loop() {

unipolar_driver();
//bipolar_driver();

}
```





Stepper motor with H-Bridge



Ready made library for stepper
https://www.arduino.cc/reference/en/libraries/stepper/

References

1) https://en.wikipedia.org/wiki/Relay
2) https://data.electronshik.ru/z/Datasheet/E/ELB115E4M.pdf
3) https://en.wikipedia.org/wiki/DC_motor
4) https://www.powerelectric.com/motor-resources/motors101/what-is-the-difference-between-a-brushless-and-a-brushed-motor
5) https://en.wikipedia.org/wiki/H-bridge
6) https://www.precisionmicrodrives.com/discrete-h-bridge-circuit-enhanced-vibration-motor-control
7) https://en.wikipedia.org/wiki/Stepper_motor