ROB - Motors laboratory

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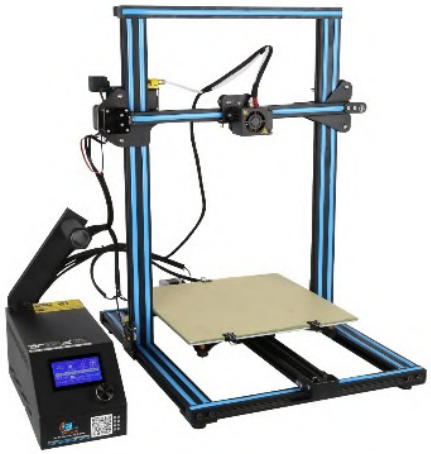
Today's lab will be focused on motors.

What are motors used for

Motors are electrical actuators that perform mechanical movement.



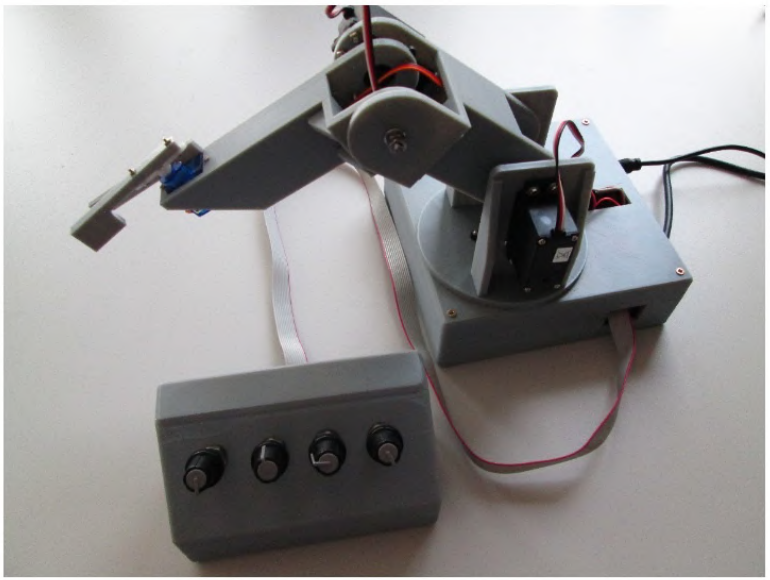
Types of motors used in this laboratory

Types of motors used in this laboratory:

- Servo motor
- Stepper motor
- DC motor

Used for precise control of angular position.

Servo motors can be used in robotic arms or as a steering in RC cars.



Servo motor - working principle

Working principle of a servo motor:

- Contains small DC motor which performs the movement
- At the output shaft is a small potentiometer, which value is fed to the controlling circuit
- Controlling circuit, based on the feedback from potentiometer, controls the DC motor
- Controlling circuit is given PWM by user to control output angle

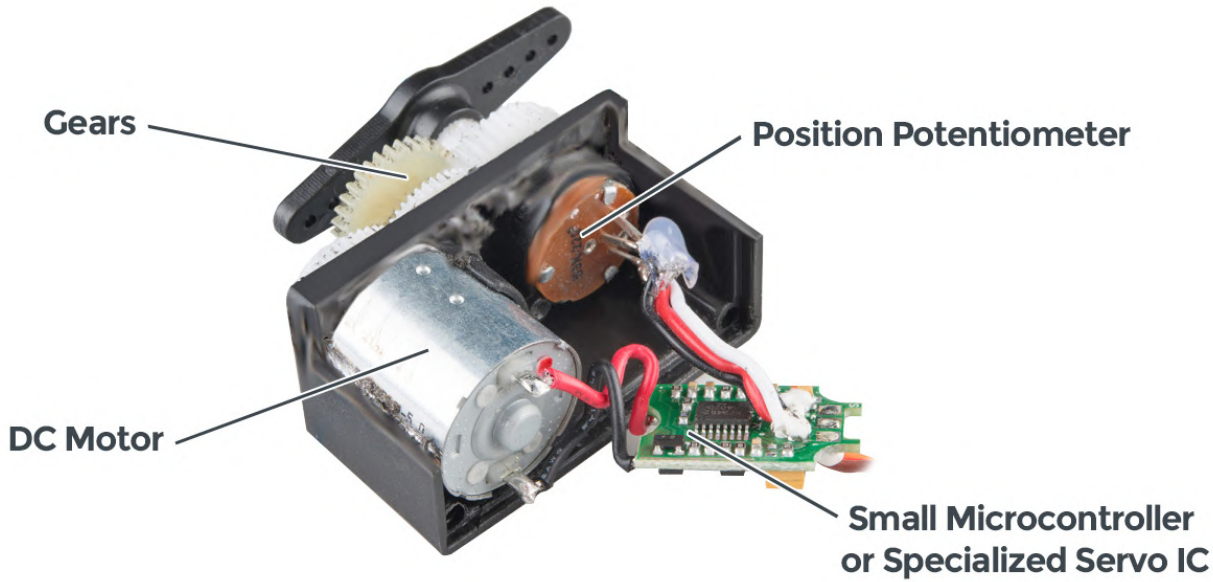
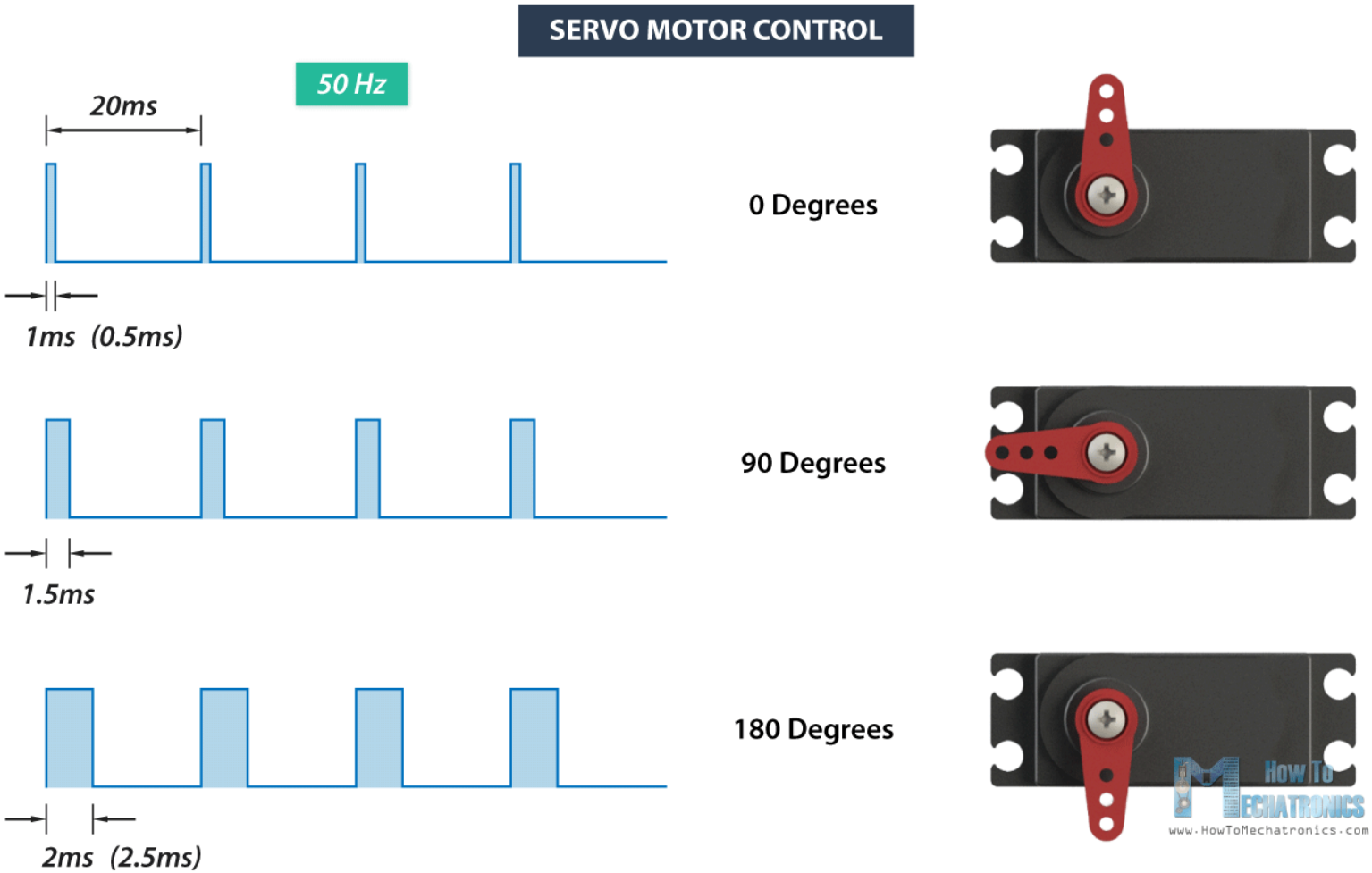
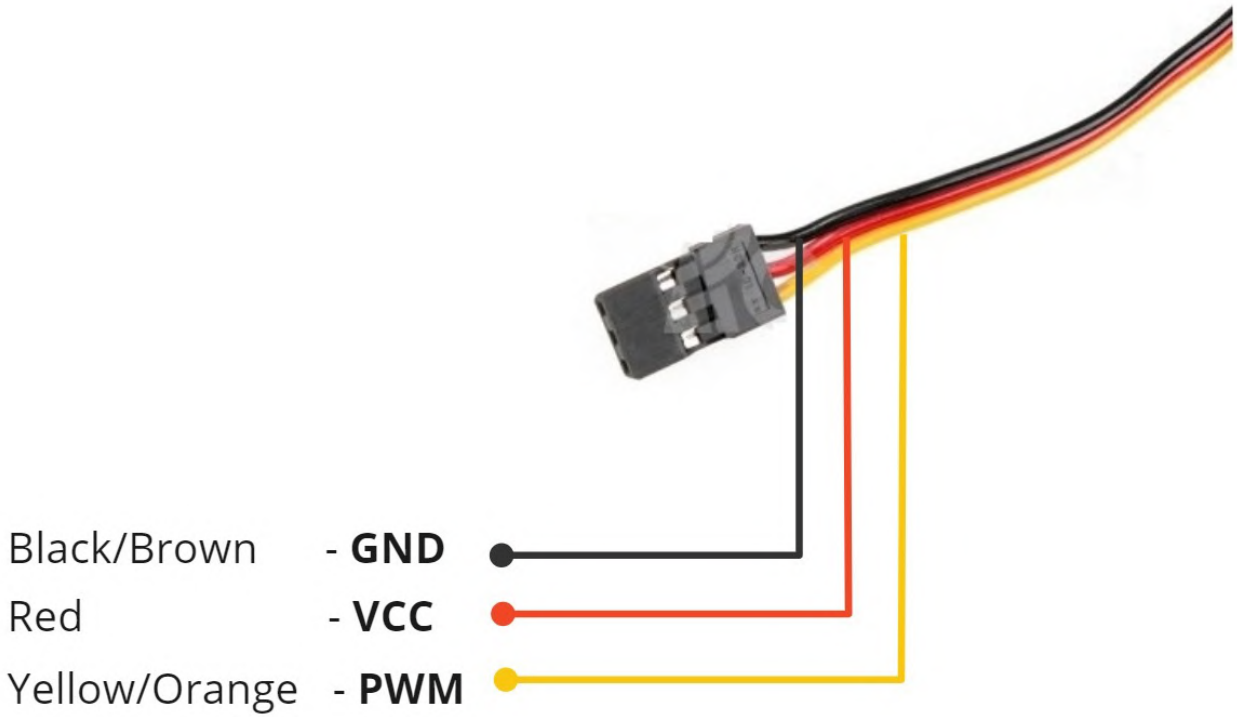


Diagram of Servo control using PWM

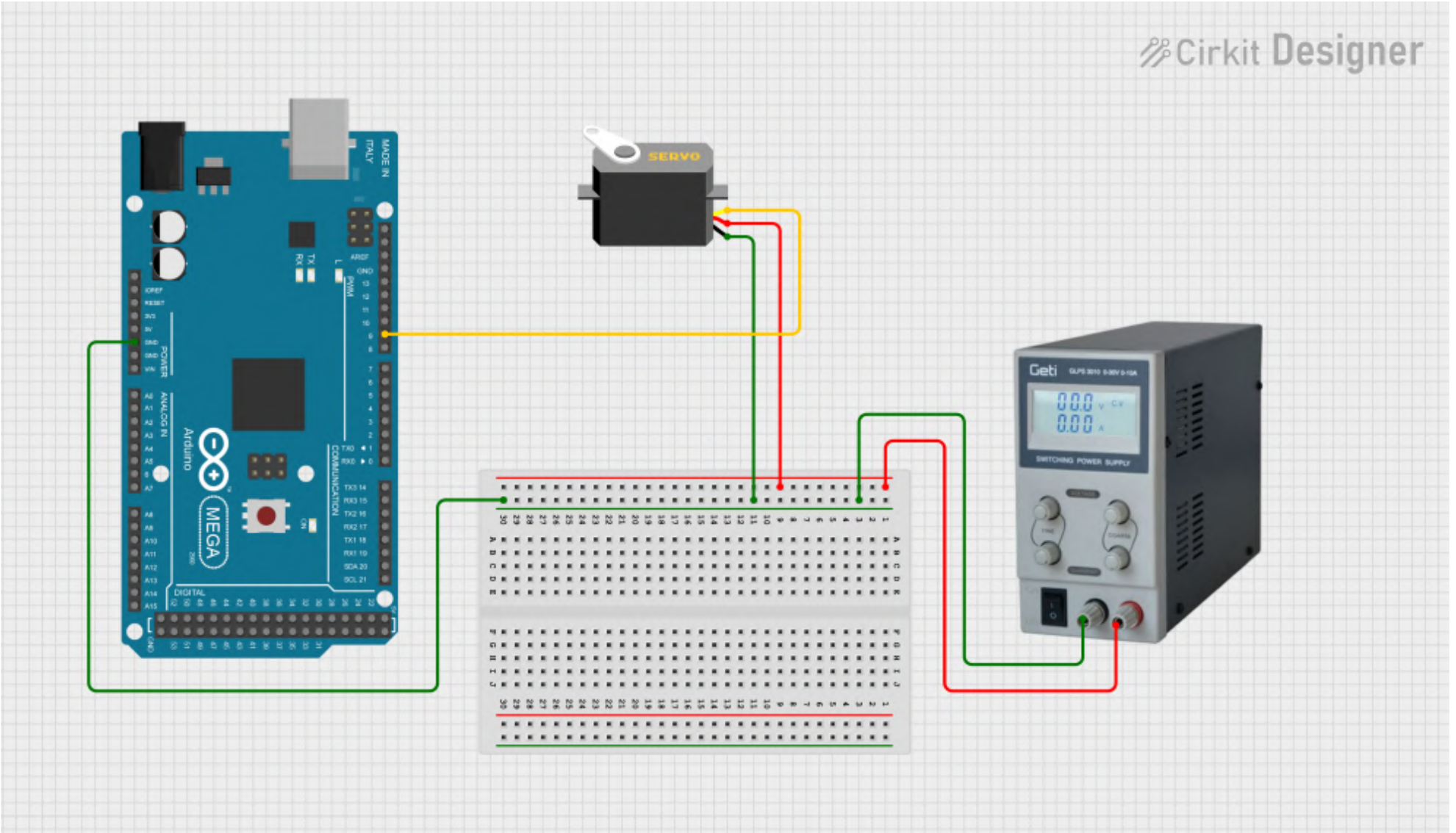


Servo motor - Parameters

- Operating voltage: 5 Volts
- Range: 0 - 180 degrees
- Has 3 Pins - GND, VCC, PWM/Signal



Servo motor - Scheme



There are 2 ways of controlling servo using Arduino:

- Writing custom PWM implementation
  - Great for learning
  - Might use active waiting (not so great)
  - Prone to mistakes
- Using library <Servo.h>
  - Higher level of abstraction (classes)
  - Implementation is all set
  - Need to read documentation

Functions for custom PWM:

```
digitalWrite(pin, HIGH/LOW);   // Set pin to HIGH or LOW level
delayMicroseconds(x);          // Wait for x Microseconds
```

Methods from Servo.h library:

```
#include <Servo.h>       // Import built-in library

Servo myservo;           // Create Servo object to control a servo
myservo.attach(pin);     // Attaches the servo on given pin to the servo object

myservo.write(angle);    // Set angle to servo
```

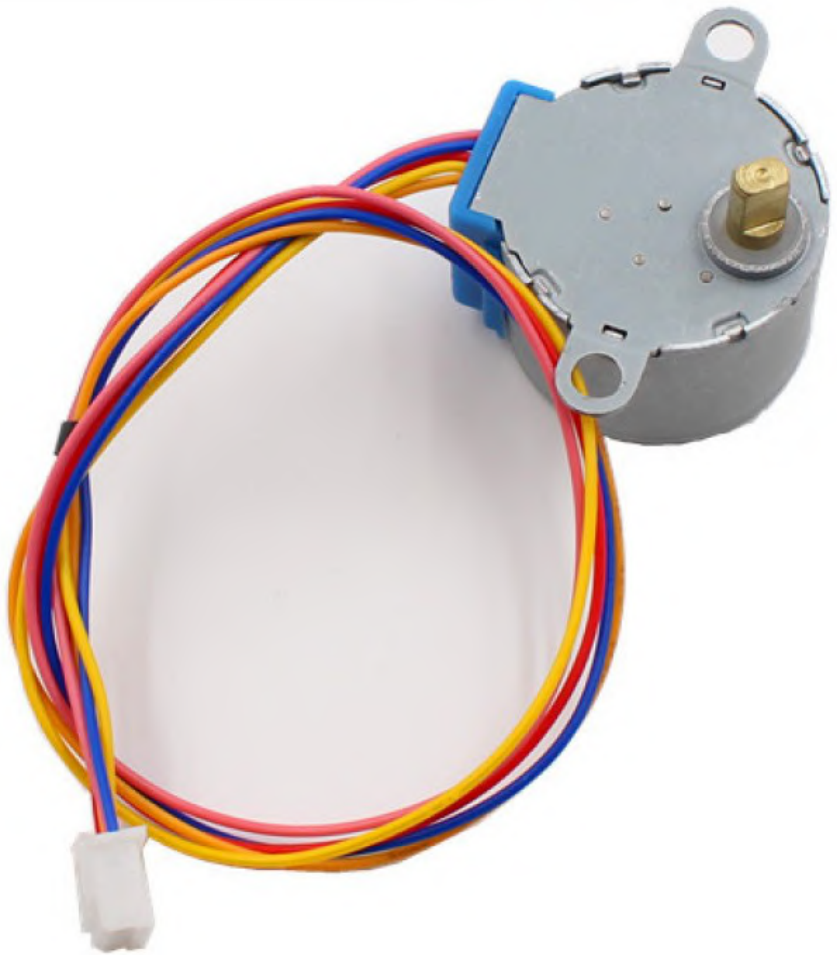
Write your own implementation of PWM that controls servo.

- Open file Servo_custom_PWM.ino
- Take a look at scheme Servo_scheme.png and create circuit as it shown at the image
- Follow the instructions and implement servo control
- Upload the code
- Test your implementation by uploading your code and observing servo movement

Write servo controller using <Servo.h> library.

- Open file Servo_library.ino
- Reuse scheme from previous exercise
- Follow the instructions and implement servo control
- Upload the code
- Test your implementation by uploading your code and observing servo movement

Used for precise control of angular position.



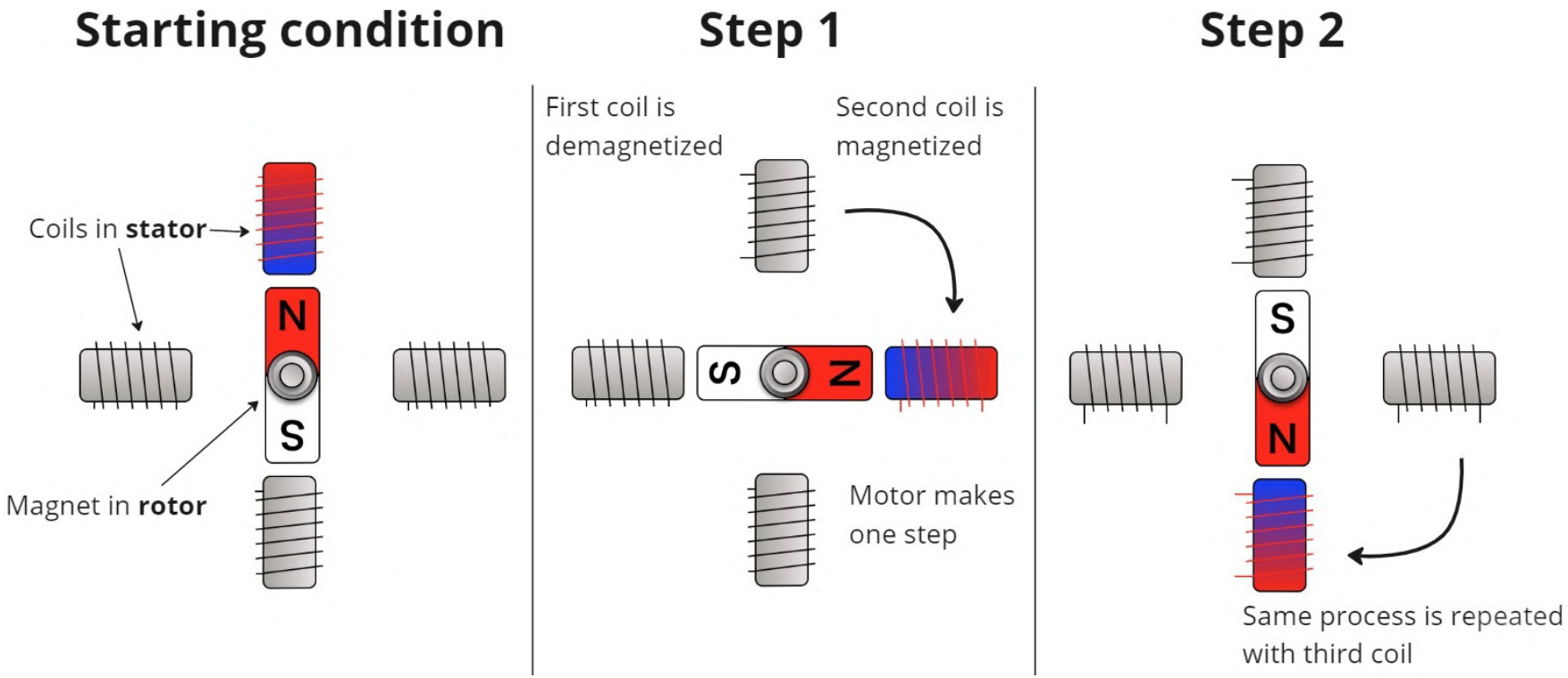
Stepper - What it is used for

Stepper motors can be found in machines like 3D printers or CNC milling machines

Stepper motor - working principle

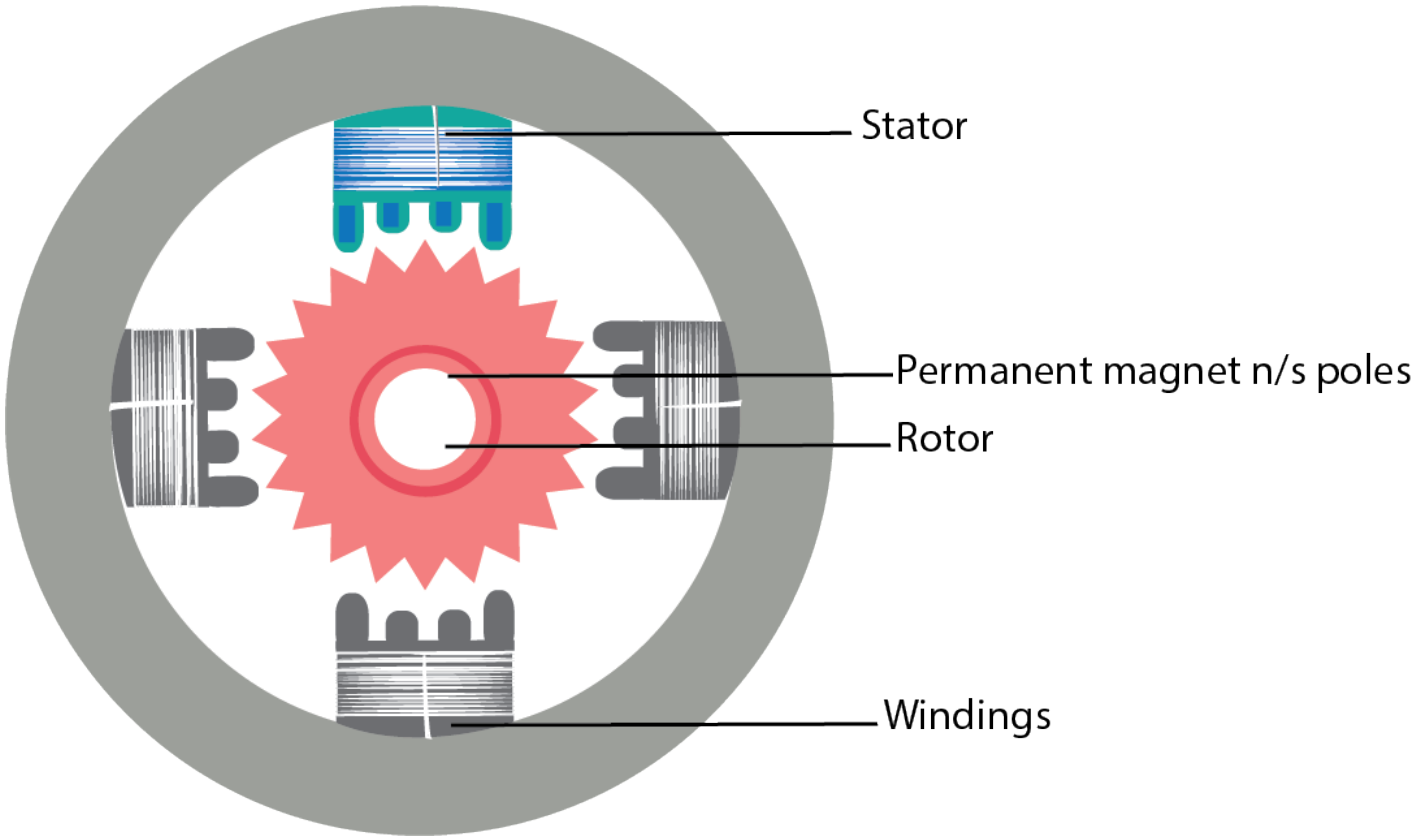
The basic concept goes as follows:

- Rotor is magnet that has south and north pole
- Stator consists of 4 coils that can be magnetized separately, one by one
- As those coils are magnetized in correct order, it "drags" rotor in circular motion



Stepper motor - real

- Stepper motor in this lab has 2048 steps (it has 64:1 gear ratio)
- This number of steps is achieved by "toothed" electromagnets



Coils need to be magnetized in order as shown in tables

Full step sequences

Lower torque method

Step Number	Coil 1	Coil 2	Coil 3	Coil 4
1	HIGH	LOW	LOW	LOW
2	LOW	HIGH	LOW	LOW
3	LOW	LOW	HIGH	LOW
4	LOW	LOW	LOW	HIGH

Higher torque method

Step Number	Coil 1	Coil 2	Coil 3	Coil 4
1	HIGH	LOW	LOW	HIGH
2	HIGH	HIGH	LOW	LOW
3	LOW	HIGH	HIGH	LOW
4	LOW	LOW	HIGH	HIGH

Half-step method offers more steps per rotation

Half step sequence

Step Number	Coil 1	Coil 2	Coil 3	Coil 4
1	HIGH	LOW	LOW	LOW
2	HIGH	HIGH	LOW	LOW
3	LOW	HIGH	LOW	LOW
4	LOW	HIGH	HIGH	LOW
5	LOW	LOW	HIGH	LOW
6	LOW	LOW	HIGH	HIGH
7	LOW	LOW	LOW	HIGH
8	HIGH	LOW	LOW	HIGH

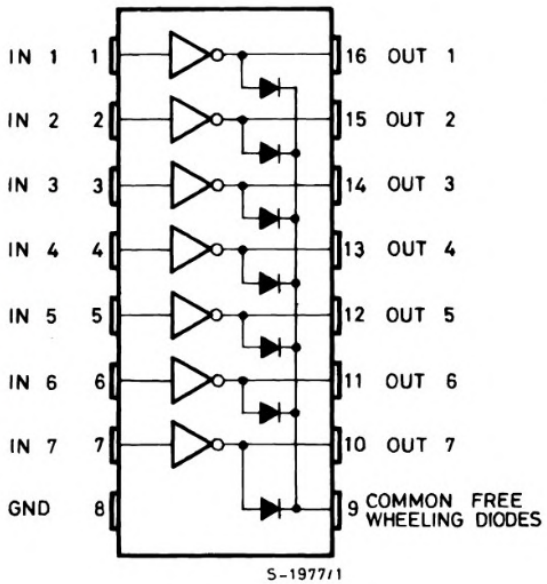
Stepper motor - Driver

Since stepper motors can drain more current than microcontroller can provide, there is need for drivers.

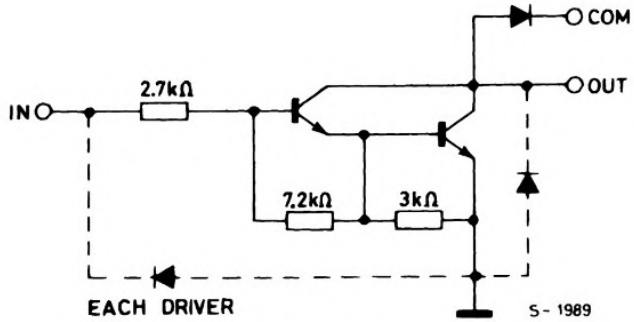
- Drivers can be simple electrical circuits
- They amplify current
- Driver used in this laboratory - ULN2003
  - Consists of Darlington transistors

PCB with driver

Pinout

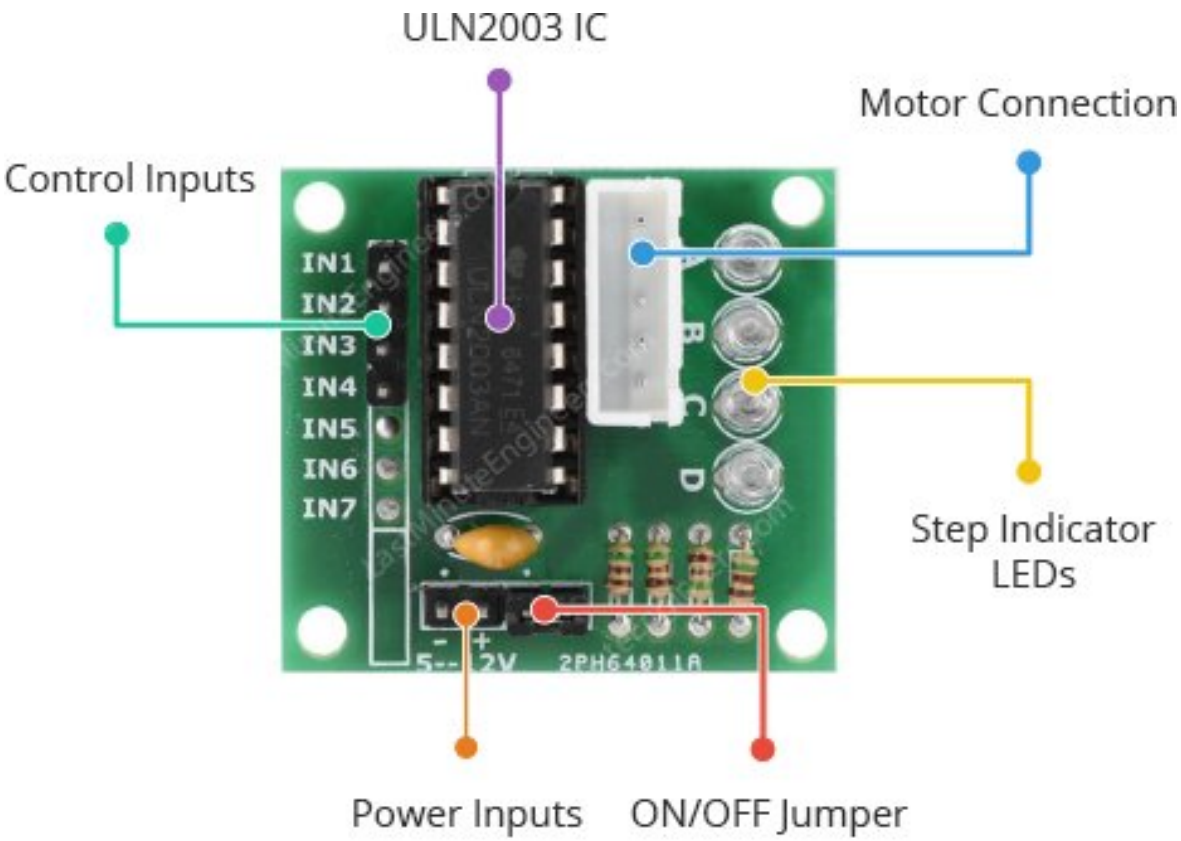


Schematic diagram

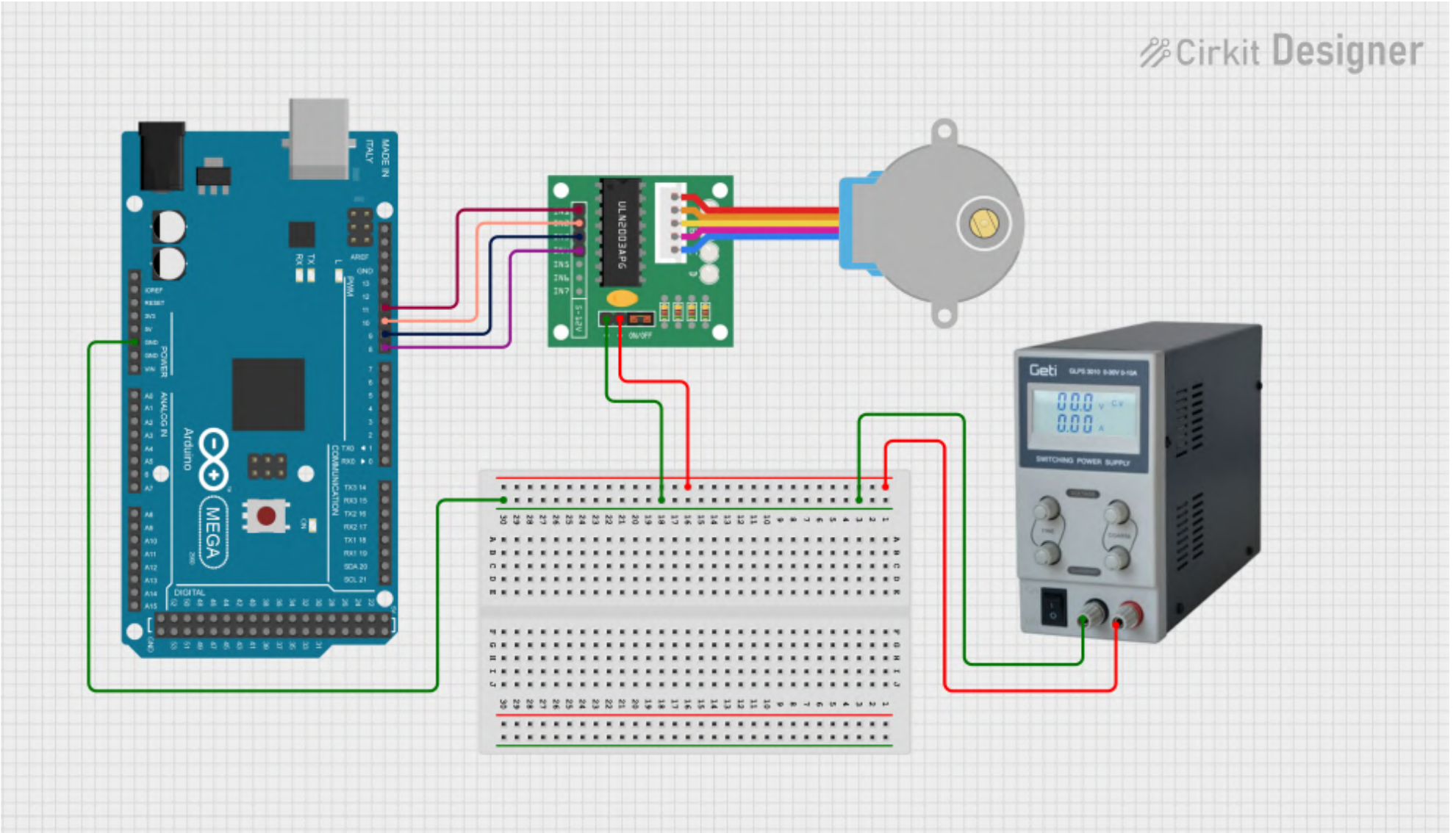


ULN2003 (each driver)

Stepper motor - Pinout



Stepper motor - Scheme



There are 2 ways of controlling stepper using Arduino:

- Writing custom implementation
  - Great for learning
  - Might use active waiting (not so great)
  - Can be modified
- Using library <Stepper.h>
  - Easier to use
  - Does not use active waiting
  - Cannot change step type (full/half)

Function for custom stepper control:

```
digitalWrite(pin, HIGH/LOW);  // Set pin to HIGH or LOW level
```

Methods from Stepper.h library:

```
#include <Stepper.h>    // Import built-in library

// Create Stepper object with given pins
// Need to know steps per revolution
Stepper myStepper = Stepper(stepsPerRevolution, p1,p2,p3,p4);

myStepper.setSpeed(x);  // Set speed for x RPM
myStepper.step(y);      // Make y steps
```

Write your own implementation that controls the stepper motor.

- Open file Stepper_custom.ino
- Take a look at scheme Stepper_scheme.png and create circuit as it shown at the image
- Follow the instructions and implement stepper motor control
- Upload the code
- Test your implementation by uploading your code and observing stepper motor movement

Stepper motor - library function

Write stepper motor controller using <Stepper.h> library.

- Open file Stepper_library.ino
- Reuse scheme from previous exercise
- Follow the instructions and implement stepper motor control
- Upload the code
- Test your implementation by uploading your code and observing stepper motor movement

Converts electrical energy into continuous rotary motion

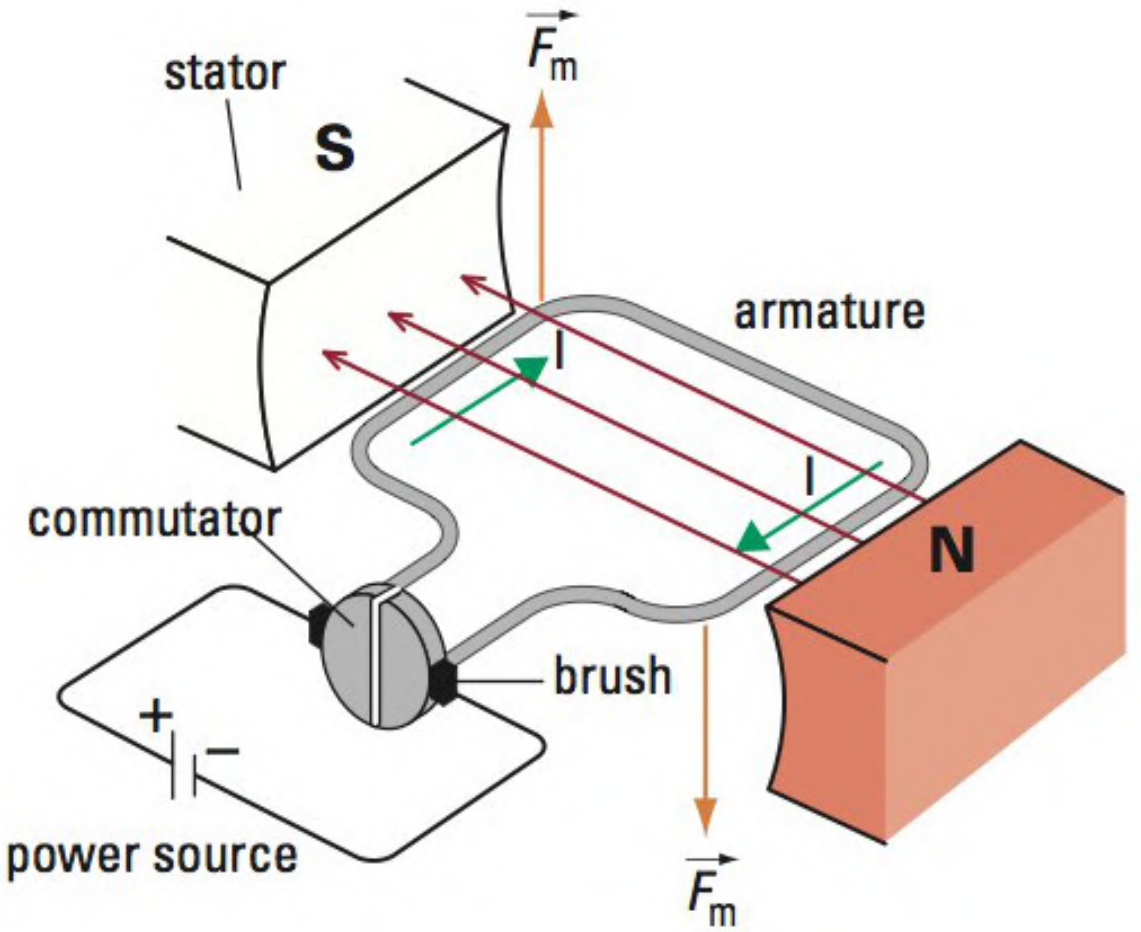
DC - What it is used for

DC motors can be found in fans, RC cars, Electric cars, Trains....

DC motor - working principle

Working principle:

- Works based on Lorentz Law
- The current carrying conductor placed in a magnetic and electric field experience a force

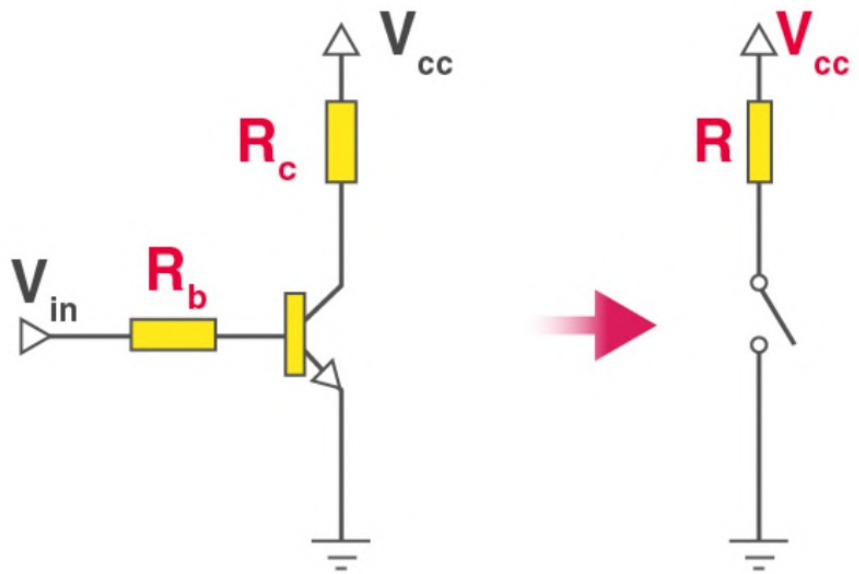


The motor itself is controlled by PWM. But this signal might be weak for power-hungry motor, therefore, it needs amplification. This lab focuses on 3 ways:

- Transistor
- H-Bridge
- Motor driver L293D

Transistor, is a semiconductor electrical part

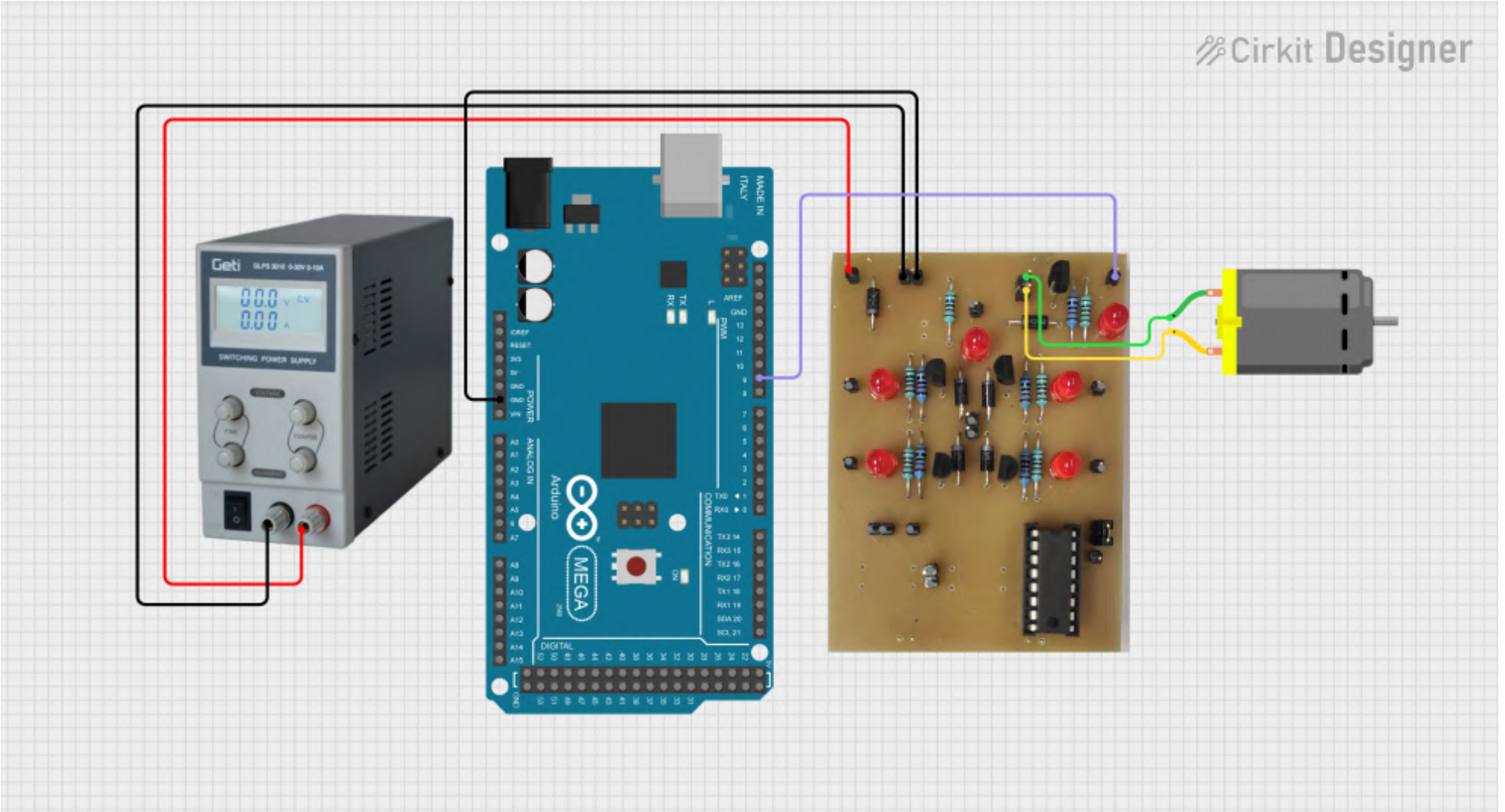
- In this application acts as a switch.
- Has 3 pins - Collector, Emitter and Base
- Can be switched on/off by applying or removing voltage at the Base
- Allows controlling motor's speed but not direction



Function for custom DC motor control using transistor:

```
// Sets PWM to given pin
// val should be from range <0,255>
analogWrite(pin, val);
```

DC motor - Transistor - scheme



Write a program that will control speed of rotation of a DC motor.

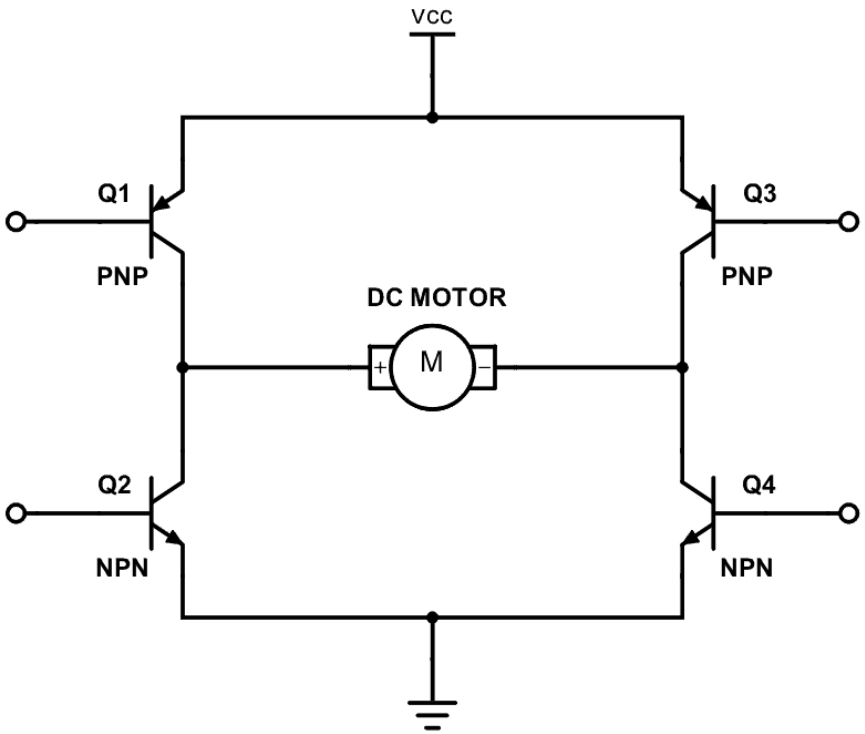
- Open file DC_transistor.ino
- Take a look at scheme DC_transistor_scheme.png and create circuit as it shown at the image
- Follow the instructions and implement DC motor control
- Upload the code
- Test your implementation by uploading your code and observing DC motor movement

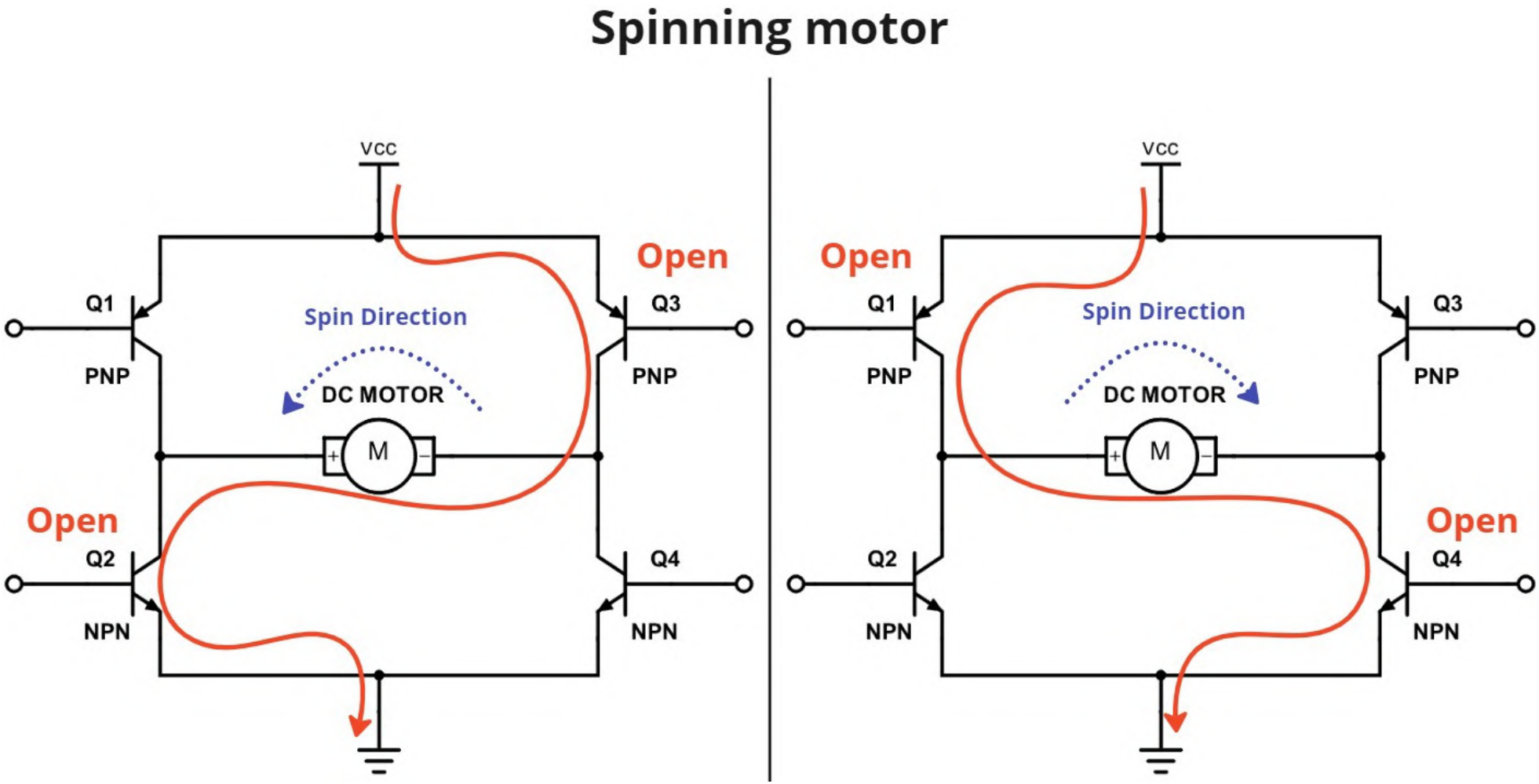
Bonus: Try and change rotation of the DC motor

DC motor - H-Bridge

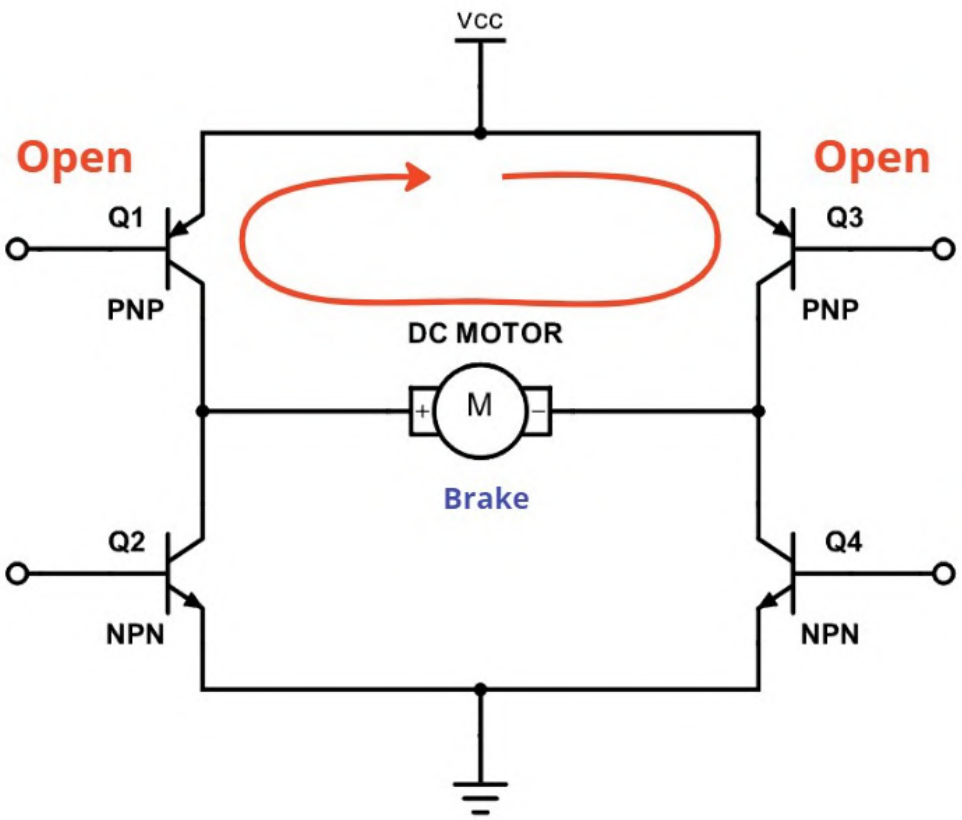
A H-Bridge is an electrical circuit that consists of 4 transistors.

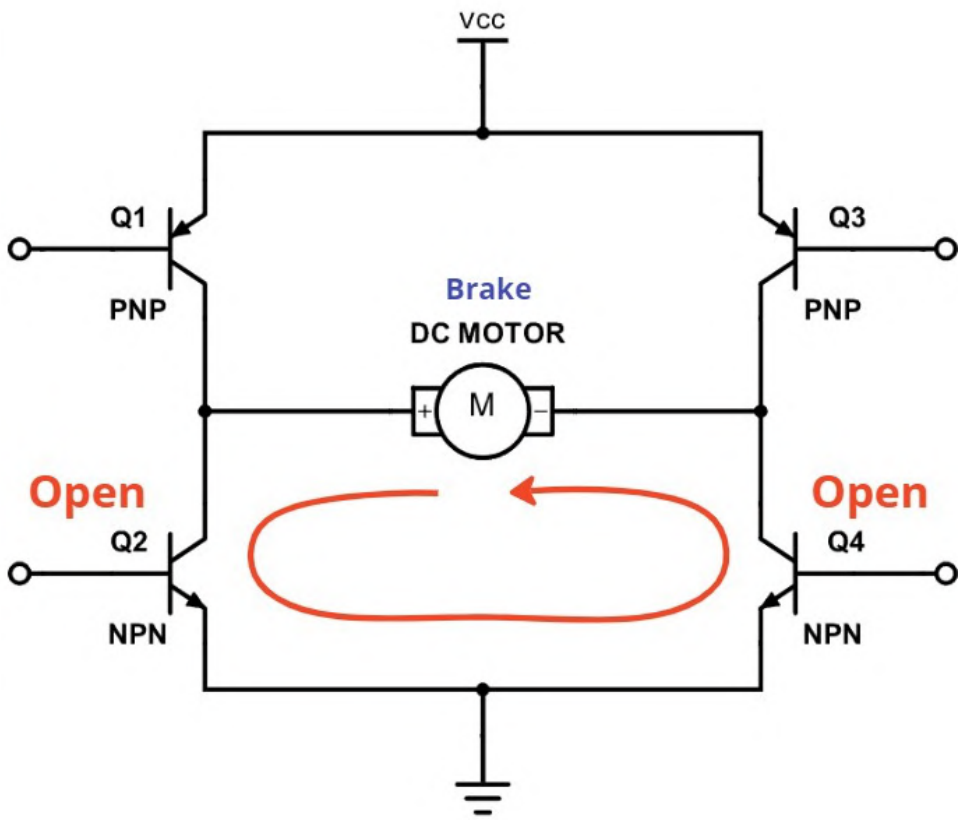
- General scheme looks like a letter H - therefore the name is H-bridge
- Allows controlling motor's speed as well as direction
- Can spin or stop the motor
- In order to spin the motor, one pair of diagonally opposite transistors need to be opened




Spinning motor
VCC
Q1
PNP
Q3
PNP
Open
Spin Direction
DC MOTOR
M
Open
Q2
NPN
Q4
NPN
VCC
Open
Q1
PNP
Q3
PNP
Spin Direction
DC MOTOR
M
Q2
NPN
Open
Q4
NPN

Stopping motor





Shorted power supply - BAD

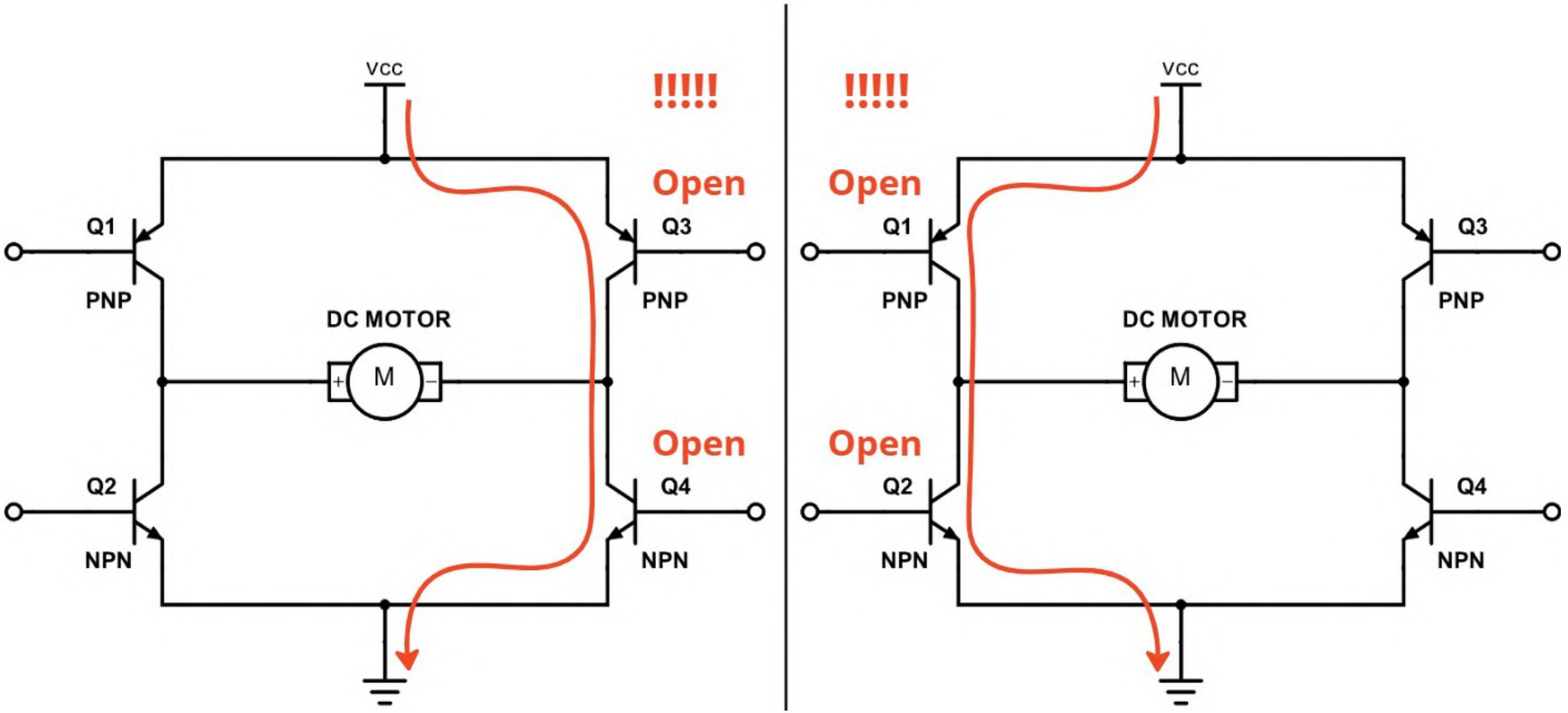


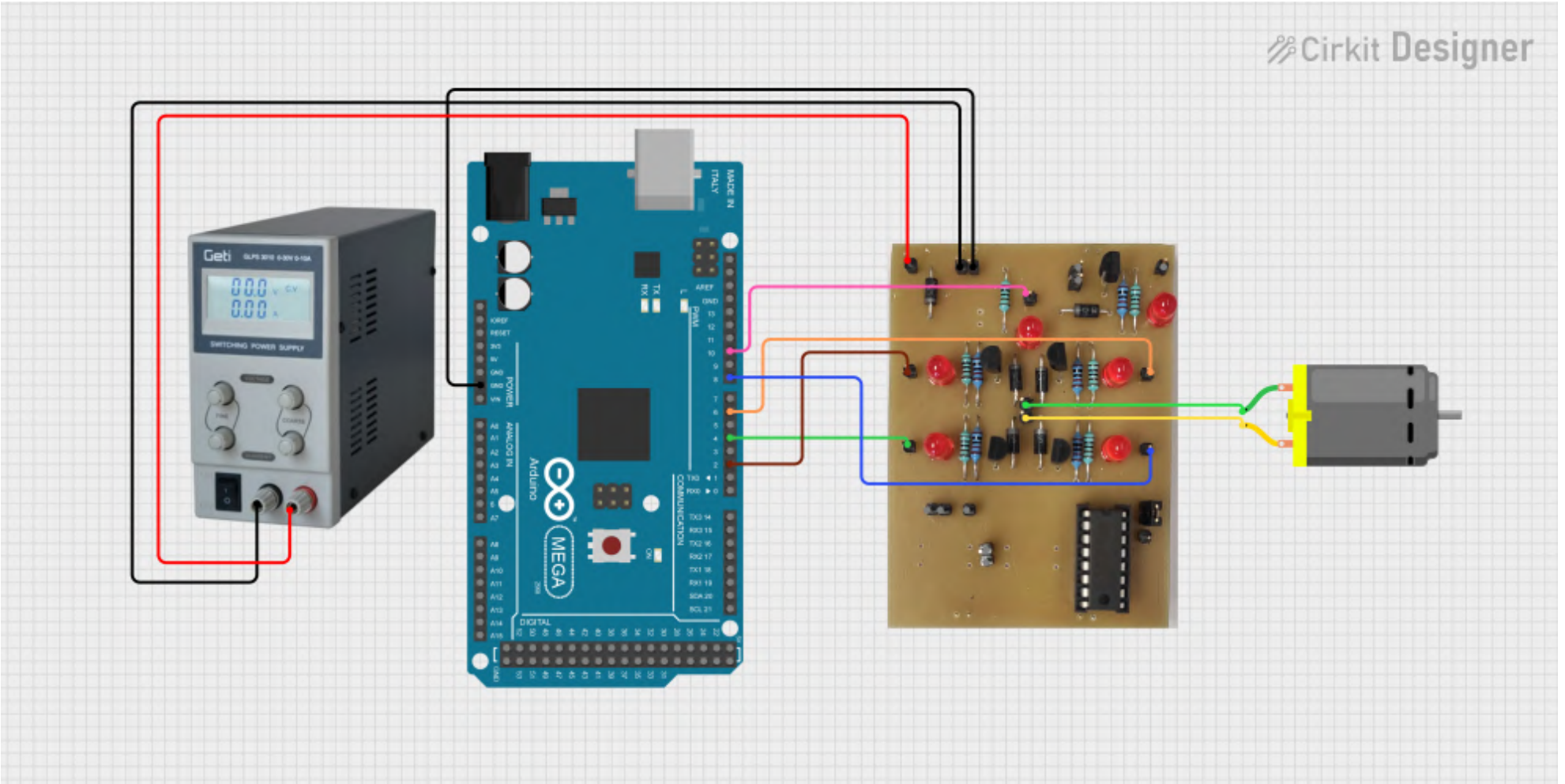
Table of H-Bridge states:

Sw1	Sw2	Sw3	Sw4	Operation
1	0	0	1	Moves Right Side
0	1	1	0	Moves Left Side
1	0	1	0	Motor Brakes
0	1	0	1	Motor Brakes
1	1	0	0	Short Circuit
0	0	1	1	Short Circuit
1	1	1	1	Short Circuit

Function for custom DC motor control using H-Bridge:

```
// Custom function made for this exercise
// Sets transistors T1, T2, T3, T4 to given value
// Values: 1/true  - transistor opened
//         0/false - transistor closed
set_H_Bridge(t1,t2,t3,t4);
```

DC motor - H-Bridge - scheme



Write program that will control speed and direction of rotation of a DC motor.

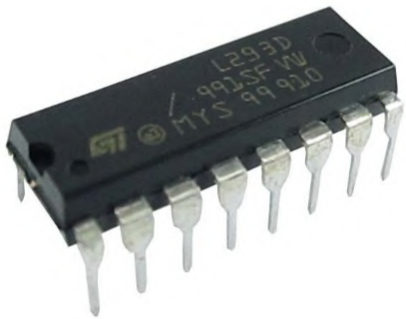
- Open file DC_H_Bridge.ino
- Take a look at scheme DC_H_Bridge_scheme.png and create circuit as it shown at the image
- Follow the instructions and implement DC motor control
- Upload the code
- Test your implementation by uploading your code and observing DC motor movement

DC motor - Driver L293D

Motor driver L293D contains 4 Half-H Drivers

- Allows controlling motor's speed as well as direction
- Can support up to 2 motors
- Has 1 Enable pin and 2 Input pins
- Speed is controlled by PWM at Enable Pin
- Can not be shorted by wrong combination

L293D



L293D - diagram

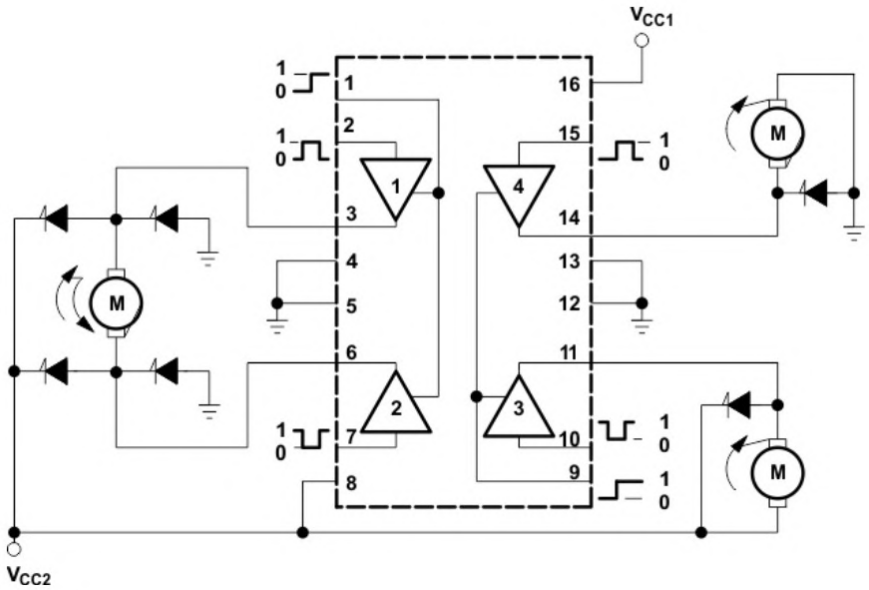


Table of possible input/output states:

Enable	Input 1	Input2	Output
HIGH	HIGH	LOW	Turn right
HIGH	LOW	HIGH	Turn left
HIGH	HIGH	HIGH	Fast motor stop
HIGH	LOW	LOW	Fast motor stop
LOW	X	X	Free-running motor stop

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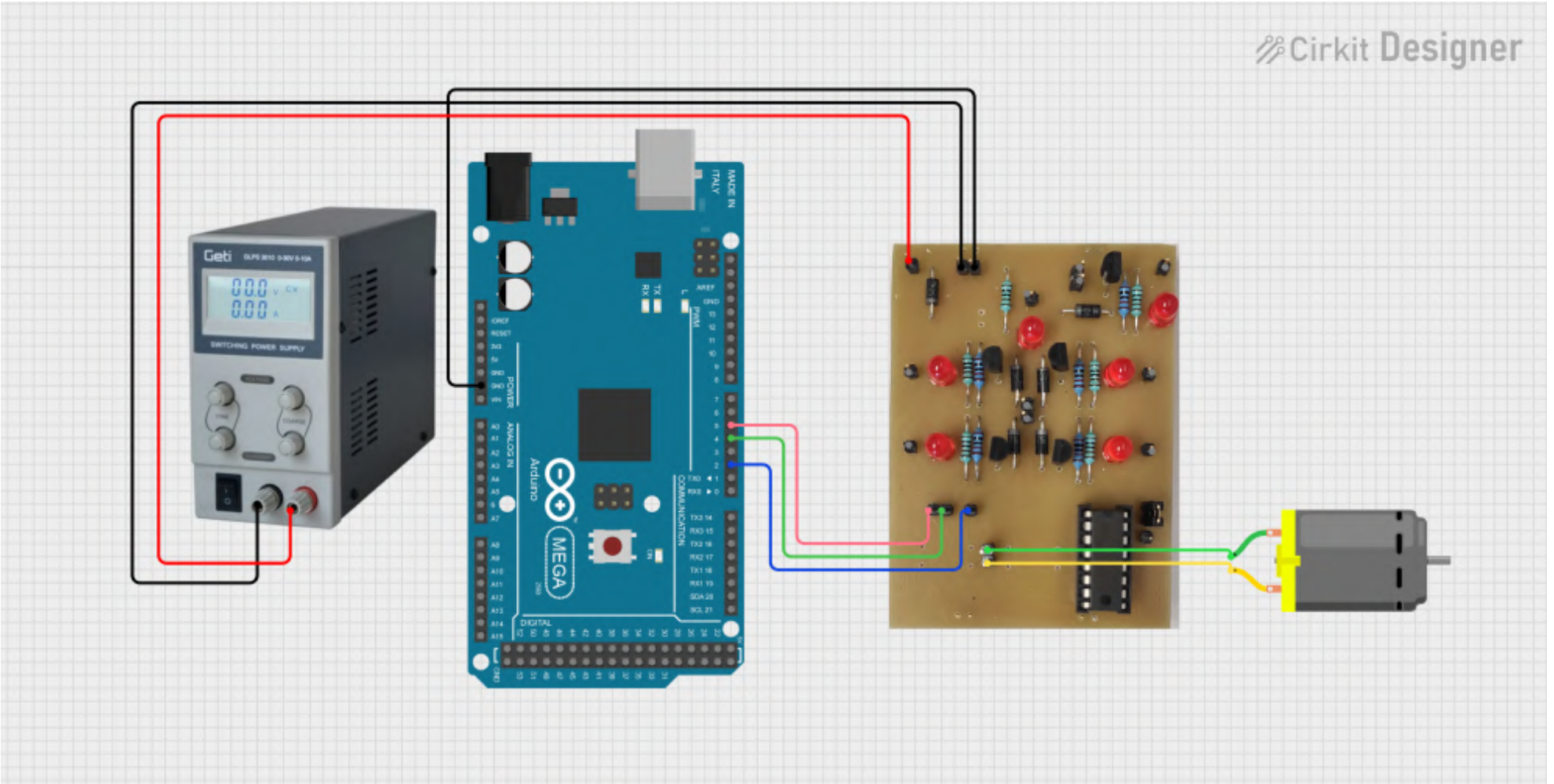
Functions for custom DC motor control using L293D:

```
// Set pin to HIGH or LOW level
// Used for Input pins
digitalWrite(pin, HIGH/LOW);

// Sets PWM to given pin
// val should be from range <0,255>
// Used for Enable pin
analogWrite(pin, val);
```

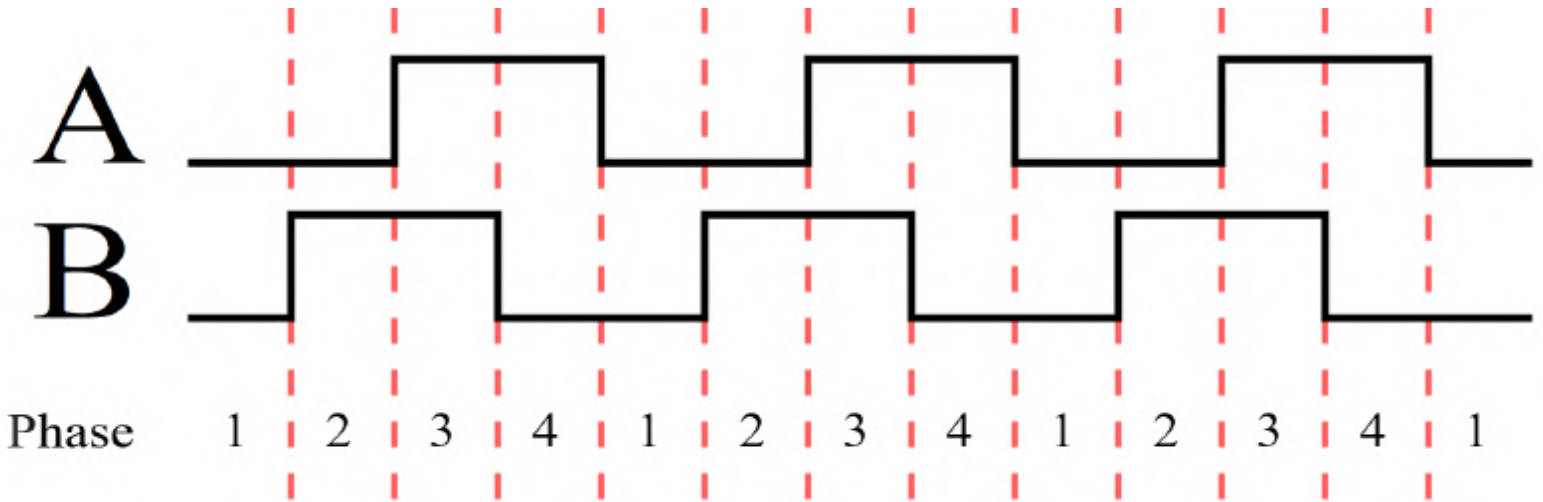
DC motor - Driver L293D - scheme



Write program that will control speed and direction of rotation of a DC motor.

- Open file DC_L293D.ino
- Take a look at scheme DC_L293D_scheme.png and create circuit as it shown at the image
- Follow the instructions and implement DC motor control
- Upload the code
- Test your implementation by uploading your code and observing DC motor movement

- Encoder is an electro-mechanical device that converts the angular position or motion of a shaft to digital output signals.
- DC motors used in this laboratory have 2 channel encoder built-in.



Take a look at output from encoders at an oscilloscope

- Reuse any code that controls motor
- Take a look at scheme DC_Encoder_scheme.png and create circuit as it shown at the image
- Run the motor and look at the oscilloscope

Thank You For Your Attention !