GOAL:
This section will introduce DC motors and motor drivers to control the speed and direction of DC motors.

OBJECTIVES:

- Learn the basics of Arduino Programming
  - Commands:
    - setup()
    - loop()
    - Functions
- Interface with the TB6612FNG motor driver
- Operate a DC motor
- Control various aspects of DC motor operation

OVERVIEW AND REQUIREMENTS:

Brushed DC Motors

A DC motor is an electric motor that runs on direct current (DC) electricity. DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines.

The brushed DC electric motor generates torque directly from DC power supplied to the motor by using internal commutation, stationary magnets (permanent or electromagnets), and rotating electrical magnets.
The inside of a DC Motor

When the coil pictured above is powered, a magnetic field is generated around the armature. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation. The armature will then continue to rotate and when the armature becomes horizontally aligned, the commutator reverses the direction of current through the coil, reversing the magnetic field. This process then repeats, causing the motor rotation.

Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the brushes and springs which carry the electric current, as well as cleaning or replacing the commutator. These components are necessary for transferring electrical power from outside the motor to the spinning wire windings of the rotor inside the motor.

The DC motor used for this lab is a 130-size DC motor and has a recommended operation voltage of 3 to 12V. Its approximate specifications at 6V are a free-run speed of 11,500 RPM, free-run current of 70 mA, and stall current of 800 mA.

**H Bridge**

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards.
An H bridge is built with four switches. When the switches S1 and S4 (in the diagram pictured above) are closed, and S2 and S3 are open, a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor. The switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4.

**TB6612FNG Dual Motor Driver Carrier**

The TB6612FNG motor driver is a dual H Bridge based driver that can control up to two DC motors at a constant current of 1.2A (3.2A peak). Two input signals (IN1 and IN2) can be used to control the motor in one of four function modes - CW, CCW, short-brake, and stop. The two motor outputs (A and B) can be separately controlled, the speed of each motor is controlled via a PWM input signal with a frequency up to 100kHz. The STBY pin should be pulled high to take the motor out of standby mode.

Logic supply voltage (VCC) can be in the range of 2.7-5.5VDC, while the motor supply (VM) is limited to a maximum voltage of 15VDC. The output current is rated up to 1.2A per channel (or up to 3.2A for a short, single pulse).

**COMPONENTS:**

- Arduino Uno
- USB A-B Cable
- TB6612FNG Dual Motor Driver Carrier
- 6V DC Motor
- Breadboard Shield
- Jumper Wire
- Host PC
- Installed Arduino Uno drivers and IDE
**OPERATION:**

This is the layout for the breakout board of the TB6612FNG. Here is a short guide on how to connect the motor driver. The connection guide is given from the left side down, then the right side down.

- **GND** - Connect to the ground terminal on the Arduino board.
- **VCC** - Connect to the 5V VCC on the Arduino board.
- **AO1** - Connect to the negative lead of motor A.
- **AO2** - Connect to the positive lead of motor A.
- **BO2** - Connect to the positive lead of motor B.
- **BO1** - Connect to the negative lead of motor B.
- **VMOT** - Connect to the positive side of the power source you are using to power the motors.
- **GND** - Connect to the negative side of the power source you are using to power the motors.
- **PWMA** - Connect to PWM pin on the Arduino. [Pins 3, 5, 6, 9, 10, 11]
- **AIN2** - Connect to a digital pin on the Arduino.
AIN1 - Connect to a digital pin on the Arduino.
STBY - Connect to a digital pin on the Arduino.
BIN1 - Connect to a digital pin on the Arduino.
BIN2 - Connect to a digital pin on the Arduino.
PWMB - Connect to a PWM pin on the Arduino. [Pins 3, 5, 6, 9, 10, 11]
GND - Connect to the ground of the Arduino.

For this exercise the following wiring was used for the Arduino:

```c
#define PWMA 3
#define AIN1 2
#define AIN2 1
#define BIN1 4
#define BIN2 5
#define PWMB 6
#define STBY 0
```

**Assembling the circuit:**

1. Attach the Breadboard Shield to the Arduino, making sure to properly align the pins. If you are using an R3 revision of the Arduino UNO, there will be 2 pins on each side that will have no corresponding pins on the shield.

2. Wire the circuit as shown in the wiring guide. Your final result should be something similar to the following snapshots.
3. Attach the Arduino UNO to the host PC with the use of the USB cable.

4. Connect the VMOT pin and subsequent GND pin to the power source provided for the lab. This is typically a battery pack of 4x AA batteries in series, but if it is not provided then a laboratory power supply can be used to power the motors. Please refer to the power supply tutorial provided in the lab.

5. Use the power supply to provide 6 volts (4x AA = 1.5V x 4 = 6V) in this situation.
6. Open the Arduino IDE and create a new sketch titled “DCMotor”. Verify that the correct COM port is in use.

7. Upload the following sketch to your Arduino UNO:

```cpp
#include <Servo.h>

#define PWMA 3  // pin 10
#define AIN1 2
#define AIN2 1
#define BIN1 4
#define BIN2 5
#define PWMB 6
#define STBY 0
#define motor_A 0
#define motor_B 1
#define FORWARD 1
#define REVERSE 0
#define RIGHT 1
#define LEFT 0

void setup()
{
  pinMode(PWMA,OUTPUT);
  pinMode(AIN1,OUTPUT);
  pinMode(AIN2,OUTPUT);
  pinMode(PWMB,OUTPUT);
  pinMode(BIN1,OUTPUT);
  pinMode(BIN2,OUTPUT);
  pinMode(STBY,OUTPUT);

  motor_standby(false);        //Must set STBY pin to HIGH in order to move
}

void loop()
{
  motor_drive(FORWARD, 255);
  delay(1000);
  motor_stop();
  delay(1000);
  motor_drive(REVERSE, 255);
  delay(1000);
  motor_stop();
  delay(1000);
}

//Turns off the outputs of the Motor Driver when true
void motor_standby(char standby)
{
  if (standby == true)
  {
    digitalWrite(STBY,LOW);
  }
  else
  {
    digitalWrite(STBY,HIGH);
  }
```
void motor_stop()
{
    digitalWrite(AIN1,1);
    digitalWrite(AIN2,1);
    digitalWrite(PWMA,LOW);
}

void motor_drive(char direction, unsigned char speed)
{
    if (direction == FORWARD)
    {
        motor_control(motor_A, FORWARD, speed);
        //Control motor B Forward here
    }
    else
    {
        motor_control(motor_A, REVERSE, speed);
        //Control motor B Reverse here
    }
}

void motor_control(char motor, char direction, unsigned char speed)
{
    if (motor == motor_A)
    {
        if (direction == FORWARD)
        {
            digitalWrite(AIN1,HIGH);
            digitalWrite(AIN2,LOW);
        }
        else
        {
            digitalWrite(AIN1,LOW);
            digitalWrite(AIN2,HIGH);
        }
        analogWrite(PWMA,speed);
    }

    //Write Motor B code here.
}

8. Verify your results by checking to see that the motor rotates in one direction, then in reverse. When facing the motor, it should rotate counter clockwise, then clockwise.
DEMO AND SCREENSHOTS:

```cpp
if (motor == motor_A)
{
    if (direction == FORWARD)
    {
        digitalWrite(AIN1,HIGH);
        digitalWrite(AIN2,LOW);
    }
    else
    {
        digitalWrite(AIN1,LOW);
        digitalWrite(AIN2,HIGH);
    }
    analogWrite(PWM1,speed);
}

//Write Motor B code here.
```

Binary sketch size: 1,476 bytes (of a 32,256 byte maximum)
PRELAB:

1. What is an H Bridge and why is it used?
2. Why do we have to use an external power supply to power the motors?

EXPERIMENTS:

Experiment 1
1. Wire the circuit and motor as mentioned in “Operation” section
2. Verify the operation of the motor
3. Demonstrate the results to the TA

Experiment 2
1. Extend the circuit:
   a. Modify the code so that the motor operates based on PWMB and rotates clockwise at the full speed, and then counter clockwise at half the speed.
2. Demonstrate the results to the TA

Experiment 3
3. Extend the circuit:
   a. Modify the design so that the DC motors is connected to BO1 and BO2.
   b. Make motors to spin in different directions at the same time
4. Demonstrate the results to the TA

POSTLAB REPORT DELIVERIES

Include the following elements in your postlab report:

1. Theory of operation
   a. List 3 types of electrical motors, with few sentences of explanation how each one works
   b. Provide a circuit that allows to change the direction of DC motor operation without rewiring and changing the direction of source current.
2. Results of the experiments
   For each experiment, include:
   a. The code that you developed for the experiment. Each line that was added must be highlighted and commented with the explanation of what is its meaning.
   b. Brief explanation how the goal of the experiment was reached
   c. Screenshots of the serial monitor with the values, presenting the operation of your code
3. Answer the questions:
   a. What are some advantages and disadvantages of brushed DC motors?
   b. Why DC motor cannot be connected directly to the analog pin of the Arduino?
   c. This lab uses functions in order to interface with the driver and DC motors. Research and write a short explanation what are the functions in programming.
4. Conclusions
a. Write down your conclusions, things learned, problems encountered during the lab and how they were solved, etc.