Activity Sheet - Week 8 Studio 2

Start	Duration	Activity
0:00	30 mins	Briefing
0:30	60 mins	Activity #1: DC motor characterization
1:30	60 mins	Activity #2: DC motor speed control

Group activity: 2 members per group

Learning outcome

At the end of this session, you will be able to

1. explain basic operation of a PMDC motor
2. get the speed versus applied voltage graph and to determine the speed constant
3. get the speed versus current graph of a PMDC motor (alternative to the speed-torque graph) and to determine motor resistance R_a and motor constants K_e and K_t
4. control (bidirectional) the speed of a PMDC motor

Equipment and Components

1. DC motor test setup
2. Desktop power supply
3. Signal generator
4. Ammeter
5. Tachometer
6. Motor controller IC L293D
7. Breadboard, wires etc.

DC motor test setup

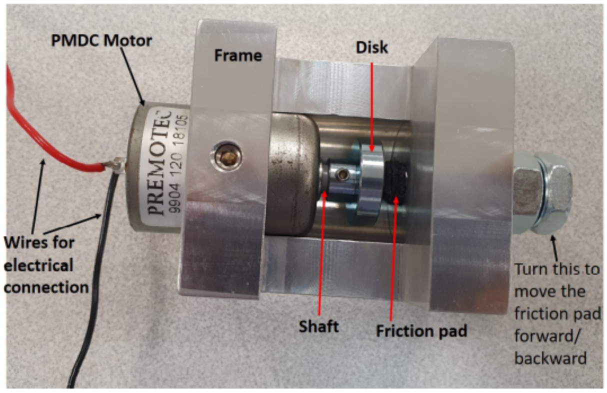


Figure 1: The test setup used for the activities in this session.

- A PMDC motor is rigidly attached to the frame.
- A metal disk is attached to the motor shaft.
- A friction pad is attached to a screw. The pad can be moved forward and backward by turning the screw.
- The friction pad is used to vary the friction load on the motor.

The rotor bearing adds a friction load, but that cannot be varied by the user.

Tachometer

Figure 2: A tachometer is used to measure the steady state speed of a rotating shaft.

When you press the button, the tachometer emits a red visible ray. To measure the RPM, aim the ray at the reflective mark pasted on the motor shaft. Measured RPM is displayed on the LCD screen.

Activity #1: DC motor characterization

Activity #1(a): Speed versus motor voltage

Activity #1(a) is to be carried out with NO external load applied. Make sure that the friction pad is not touching the disk. If required, slowly turn the screw to move the friction pad away from the disk.

1. Set the DC power supply output to **8 V**.
2. Apply the voltage to the motor, measure the RPM and record it.
3. Repeat the measurement for a few other voltages in the range $8\ V < V_a \leq 12\ V$.
4. Use EXCEL or any other software to plot RPM versus motor voltage, and determine the **speed constant** ($\frac{RPM}{Volt}$) of the motor.

Activity #1(b): Speed versus motor current

Speed-torque graph is an important characteristic plot of any motor. As the laboratory setup used does not have the provision to measure torque, you will do an alternative characterization, *i.e.*, speed versus motor current. Note that the electromagnetic torque is directly proportional to the armature current:

$$T_{em} = K_t I_a.$$

1. Make sure that the friction pad is not in contact with the disk.
2. For this activity, use a fixed voltage, *e.g.*, $V_a = 10\ V$.
   - Set the DC power supply accordingly, and use the same throughout this activity.
3. Connect the motor to the DC voltage source with an ammeter in series.
4. Turn the power supply ON. Record the values of the RPM and the armature (rotor) current I_a.
5. Move the friction pad slowly towards the disk by turning the screw until it softly touches the disk. Record the values of RPM and I_a.
   - Friction torque can be varied by varying the contact pressure between the friction pad and the disk.

As the pressure exerted by the pad on the disk is increased, you will notice increased magnitude of I_a and decrease in RPM. Why so?

6. Record the values of RPM and I_a for a few different positions of the friction pad.
7. When the motor is stalled (not spinning), quickly record the data and release the friction pad. **Keeping the motor in stall condition for long is harmful to the motor.**

8. Plot RPM versus I_a.
   - Speed versus I_a graphs should be a straight-line described by the equation
   $$\omega = \frac{V_a}{K_e} - \frac{R_a}{K_e} I_a,$$
   $$2\pi \frac{RPM}{60} = \frac{V_a}{K_e} - \frac{R_a}{K_e} I_a.$$
9. Determine, from the graph, the values of motor parameters K_e and R_a. What is the value of the torque constant K_t?

E-logbook for Activity #1

- Include the following graphs:
  (i) Speed versus motor voltage (Activity #1(a))
  (ii) Speed versus motor current (Activity #1(b))
- Answer to the following questions:
  (a) What is the speed constant $\frac{RPM}{Volt}$ of the motor used?
  (b) What are the back emf constant (K_e), armature (rotor) resistance R_a, and torque constant K_t?
  (c) What are the no-load speed (express as RPM and rad/s) and the no-load current at the operating voltage? Can you use this information to determine the torque resulting from the bearing friction? If so, what is the friction torque magnitude?
  (d) What is the stall current (I_{stall}) for the operating voltage used?
  (e) What is the maximum torque this motor can produce at the operating voltage used?
  (f) What is the maximum mechanical power the motor can produce?

Activity #2: DC motor speed control

You will use pulse width modulation (PWM) to vary the speed of a PMDC motor.

Activity #2(a): Generate PWM signal

1. Use the signal generator to generate TTL signal (binary signal with voltage levels of 0 V and 5 V) and observe the waveform on the oscilloscope.
2. Learn how to vary the duty cycle from the function generator.
3. Learn how to measure the duty cycle.
4. Set the frequency to 1 kHz and duty cycle to 50%. Later, you will use this signal in Activity #2 (c).

Activity #2(b): Construct motor driver circuit on breadboard

Motor driver IC L293D is used in this activity to drive the PMDC motor.

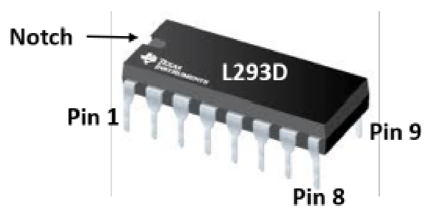


Figure 3: L293D Motor driver IC

L293D given to you comes in a dual-in-line (DIP) package. Familiarize yourself with the pin numbering convention for this package as shown in Figure 3.

- L293D contains four high current (600 mA per channel) half-H drivers.
- For bidirectional control of motor, we need one H-bridge. So, L293D can drive two motors simultaneously. You will use only half of its functional capability.
- Connections of different pins of L293D are shown in Figure 4.
- Explanations are given in this activity sheet for connecting the motor between pin #3 and pin #6 (Output 1 and Output 2, respectively, in Figure 4).
  - Relevant output pins and control pins are all on the left side of the diagram in Figure 4
  - If someone wants to use the other driver circuit, he/she should identify the corresponding output pins and control pins from the other side.

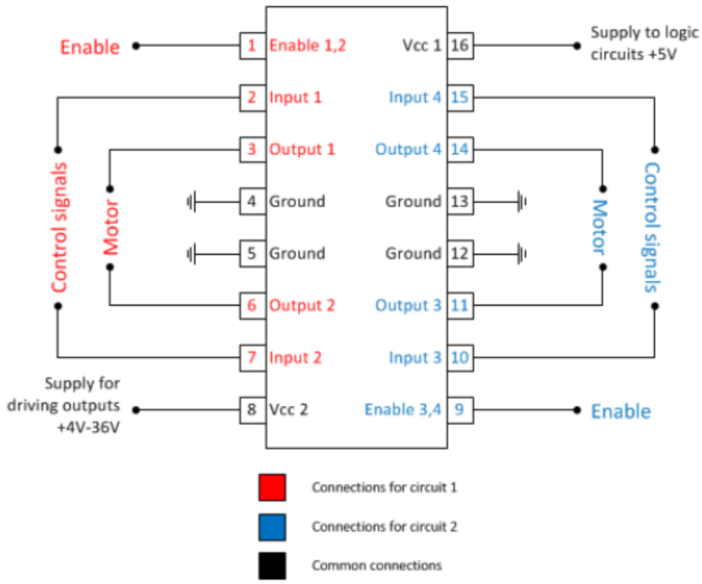
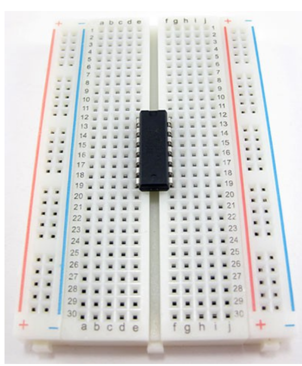


Figure 4: Functional descriptions of L293D pins

Step 1: Placing DIP IC on the breadboard

Insert the L293D IC on the breadboard as shown in the figure below, *i.e.*, pins #1 to #8 on one side of the ravine of the breadboard and pins #9 to #16 on the other side.



Step 2: Connecting Power and GND pins

1. Connect pin #16 to 5V DC supply. This voltage provides power to the logic circuits in the IC. You can use the fixed 5V output of the DC power supply for this purpose.

2. Connect GND of the power supply to pins #4, #5, #12, and #13.

3. Connect the power supply required to drive the motor to pin #8.

   (a) L293D supports any voltage from 4 V to 36 V for this pin. As you will control a 12 V, 3 W DC motor, connect a voltage **<12 V** DC to this pin. Use one of the two variable voltage outputs of the DC power supply.

Step 3: Connecting the control pins

Three pins are needed to control motor speed and the direction of its rotation. The logic signals (TTL) for these control pins are given in the Table below for the driver circuit 1 shown in Figure 4.

Driver circuit 1			
Enable (Pin #1)	Input 1 (Pin #2)	Input 2 (Pin #7)	
HIGH	LOW	HIGH	Spin forward
HIGH	HIGH	LOW	Spin backward
HIGH	LOW	LOW	Stop
HIGH	HIGH	HIGH	Stop
LOW	X	X	Not enabled

- Logic HIGH is 5 V, Logic LOW is 0 V.
- Enable pin must be logic HIGH to make the driver circuit to work.
- If Enable pin is at logic LOW, the driver circuit **will not work** regardless of the logic status of Input 1 and Input 2 (indicated by X in the table).
- Input 1 and Input 2 must be complementary to one another (one HIGH, one LOW) to make the motor spin.
- If Input 1 and Input 2 are at the same logic level, the motor will stop.
- We can use PWM signal to control power flow to the motor and thus to control the speed.

- Make appropriate connections to the control pins.

How will you connect the PWM signal generated by the function generator to these control pins?

Step 4: Connecting the motor

Connect the motor terminals to Output 1 (Pin #3) and Output 2 (Pin #6).

Activity #2(c): Speed control

- Apply the 1 kHz, 50% duty cycle signal from the function generator to the appropriate input pin of L293D.
- Switch the motor power supply ON. Motor should start spinning.
- Measure the RPM and record it.
- Change the PWM duty cycle to a few other values and measure the corresponding RPM.
- Plot Speed versus duty cycle graph.
- (*Optional*) Try different PWM frequencies (both higher and lower than 1 kHz).

E-logbook for Activity #2

- Include a photo of the breadboard circuit
- Include speed versus duty cycle graph
- If you have used different PWM frequencies (optional activity), write your comments on the effect you observed when the PWM frequency was changed.