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School of Mechanical Engineering
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# Mechatronics Lab Manual


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## SESSION #8

DC Motor & Encoder (Part 3 – Closed-loop Control)

# Mechatronics

Lab Manual
Session #8 – DC Motor & Encoder (Part 3 – Closed-loop Control)

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**Session Objectives**

- Speed closed-loop control of a DC motor.

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**Introduction to TA**

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**Thanks to:**

- Amin Mirzaee, Mahdi Robati

## 1. System Transfer function

To design a controller that meet our desired specifications, we need to identify the system. For the DC motor the system transfer function can be assumed to be a first order, so we can identify the system just using the step response. You have sampled the step response of the system in the previous session so you can estimate the TF now. TF of the system can be either in continuous (s) or discretized (z) form. If you use the continuous form of the system to design a controller, the controller should be then z-transformed so we can employ the difference equation to Arduino. For this TF, the **input is PWM** and **the output is speed**.

We suggest that you discretize the plant before the controller design step, using the methods discussed in the lectures. The continuous plant has the form shown below.

$$T(s) = \frac{Speed(s)}{PWM(s)} = \frac{k}{\tau s + 1}$$

### 1.1. Task 1

Use Matlab to estimate a first-order transfer function for the system.

## 2. Closed-loop Controller Design

As we have the plant, we can now design controllers. In this lab session, you have to design three PI controllers to meet the specifications below.

| Specifications | $\omega_n \left(\frac{Rad}{s}\right)$ | $\zeta$ |
|---|---|---|
| Controller 1 | 33 | 0.4 |
| Controller 2 | 42 | 0.75 |
| Controller 3 | 99 | 0.24 |

You can design the controller analytically (as in lectures) or by using Matlab “Control System Designer.” If you have used the continuous plant, you may now discretize the controller TF. The discretized TF of the PI controller has the form shown below.

$$D(z) = \alpha \frac{(z - \beta)}{z - 1}$$

### 2.1. Task 2

Design the Controllers and specify the parameters in your report.

**Control Using Arduino**

Now that you have the discretized controller, the difference equation should be calculated to be then used in the Arduino Code. The equation has the form below.

$$u_0 = u_1 + \alpha e_0 - \alpha\beta e_1;$$

### 2.2. Task 3

Implement the controllers to the system and sample the step response of the system as you did in the previous session. Note that you just need to add the equation to the ISR, after calculation of the current speed, and analogWrite the control effort.

**Important reminder:** To control the motor, Timer1 is used to run the ISR. As such, we cannot use other functions of the microcontroller that depends on Timer1 such as PWM signal generation on pins 9 and 10.

Timer0: Used for **millis** and delay; **analogWrite** on pins 5 and 6

Timer1: **analogWrite** functions on pins 9 and 10; driving servos using the **Servo library**

Timer2: **analogWrite** functions on pins 3 and 11; **tone** function