Experiment 7

Open & Closed Loop Systems

Objectives:

1- Understand the difference between open and closed loop systems.
2- Study motor drives (H-Bridge).
3- Control the position of a motor using DAC & Labview.

Introduction:

A control system has an input, a process, and an output. Control systems can be open-loop or closed-loop.

Open Loop Systems:

An open-loop control system is controlled directly, and only, by an input signal, without the benefit of feedback. A characteristic of the open-loop system is that it does not use feedback to determine if its output has achieved the desired goal of the input. This means that the system does not observe the output of the processes that it is controlling. Consequently, a true open-loop system cannot correct any errors that it could make. It also may not compensate for disturbances in the system.

Examples of open loop systems:

1- Washing machines (the activation of the washing machine is determined simply by a person starting it, not the dryness of the clothes).
2- Cell phones (the cell phone is turned on and off by the person using it, not depending on whether or not it is actually receiving a call).
3- A system consisting of an amplifier and a motor. The amplifier receives a low-level input signal and amplifies it enough to drive the motor to perform the desired job.

![Figure (1): Example of an open loop system](image)
Closed Loop Systems:

A closed-loop system uses feedback to control states or outputs of a dynamical system. A closed loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction. If there is any difference between the two responses, the system drives the plant, via the actuating signal, to make a correction. If there is no difference, the system does not drive the plant, since the plant's response is already the desired response. This means that a closed-loop system is able to regulate itself in the presence of disturbance or variations in its own characteristics.

Examples of closed loop system:

1- System that controls the position and speed of a motor.
2- Systems that control the temperature of a room.
3- Systems that control the level of water in a tank.

![Diagram of a closed loop system]

Figure (2): Example of a closed loop system

Motor Drivers:

Motor drivers are essentially power amplifiers; their function is to take a low-current control signal, and turn it into a proportionally higher-current signal that can drive a motor. Note here that the control signal is likely on the order of 10 mA, and the motor may require 100's of mA to make it turn. An example of a motor driver is an H-Bridge.

An H-bridge is an electronic circuit which 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. H-bridges are available as integrated circuits, or can be built from discrete components.
An H-bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 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.

Note: 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.

**Interpolation method:**

A sensor is used to measure physical quantities such as temperature, speed, position, intensity ....etc. These measurements should be feedback and compared to the desired (input) value and the compensator will correct the error.

In order to relate these physical quantities to values a compensator can understand interpolation is used.

**Interpolation:** is a method of constructing new data points within the range of known data points.
Interpolation formula:

\[ x_{\text{min}} \rightarrow x \]
\[ y_{\text{min}} \rightarrow y \]

\[ \frac{x - x_{\text{min}}}{x_{\text{max}} - x} = \frac{y - y_{\text{min}}}{y_{\text{max}} - y} \]

Lab Work:

The aim of this lab is to control the position of a DC motor by close loop system.

- The shaft of the DC motor is connected to a potentiometer (a sensor).
- The voltage across the variable resistor (0 volt to 5 volt) should be related to the angle of the DC motor rotating from (0° to 360°). This is done using interpolation method.
- Then the measured angle (actual theta) should be compared to a desired value and find the difference between the actual theta and desired theta (error signal).
- This means that the error signal is the difference between the reference input and the output. Finally a comparison is done. There are 3 cases:

1- If the error signal is zero. Then the value applied to the H-bridge (which is connected to the digital output pins of the DAC) is 0 forcing the motor to stop.
2- If the error signal is a positive value (actual value less than desired value) we shall apply logic 1 on one pin of the DAC and logic 0 on the other pin of the DAC forcing the motor to rotate in a direction that will correct the error.
3- If the error signal is a negative value (actual value larger than desired value) we shall apply logic 1 & 0 on the pins of the DAC to force the motor to rotate in reverse direction and correct the error.
**Part (1):**

Connect a potentiometer to the analog input pin of the DAC and convert the voltage values to angle values using interpolation method. Display the converted values on an indicator on the front panel of the Labview.

**Part (2):**

Find the error signal between desired theta and the actual measured theta. Use a control (Knob) to apply the desired theta and an indicator to display the value of the error signal.

**Part (3):**

Built a compensator that will drive the DC motor to its' desired position.

**Final result:**

![Diagram of Labview setup](image-url)