

ME 104
Sensors and Actuators

Laboratory 4
Open Loop Analog Control
of a DC Motor

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California, Santa Barbara

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Introduction

In this laboratory, you will write a *LabVIEW* program that will enable you to drive a DC Motor using an analog voltage signal. You will also learn how to measure and view both angular velocity and angular position feedback signals from the motor. The DC Motor is part of the MS15 DC Motor Control Module (Figure 1). The angular velocity of the motor can be controlled using either an analog voltage signal or a pulse width modulated (P. W. M.) digital signal. In this laboratory, we will use only analog signals.

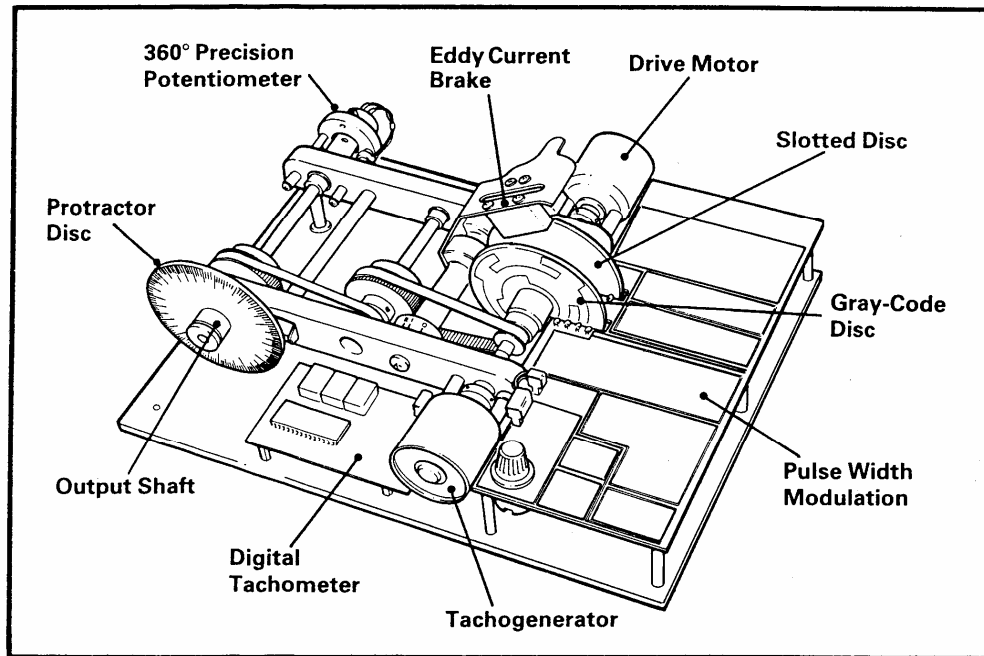


Figure 1: MS15 DC Motor Control Module

Background Reading

Please read the following material prior to this lab:

1. DC Motor Control Module User Manual, Pages 3-7 and 14-16, LJ Technical Systems Inc.

Pre-Lab

Please build the following VIs prior to this lab:

1. `yourname_MotorDrive_Tacho.vi`

Build a VI to generate a DC voltage to drive a motor and read the tachogenerator voltage.

- Open the VI “`DAQ_MotorDrive_Tacho_F08.vi`” located in the melab share drive
- Save this VI as `yourname_MotorDrive_Tacho.vi` to the desktop or your network drive.
- Go to the front panel.
 - Select **Pointer Slide** from the Numeric subpalette and place it on the front panel and change the label to “Motor Drive Input Control”.
- On the block diagram
 - Wire the Pointer Slide to the DAQmx Read.vi.

- Wire the Pointer Slide to the Merge Signal icon that is connected to the Voltage Signal Chart. This displays the Motor Drive Voltage on the Voltage Signal Chart.
- To make the digital display corresponding to the Pointer Slide visible, right-clicking on the Pointer Slide >> Click on Visible Items >> Click on Digital Display. You can now set the the Motor Drive Voltage using the Pointer slide or entering a number in the Digital Display.
- Set the Pointer Slide properties by right-clicking on the Pointer Slide and selecting Properties from the Pop-up menu
 - “Data Range” tab
 - Range: -5.0, +5.0
 - Increment: 0.01
- Save this completed VI as **yourname_MotorDrive_Tacho.vi**. It should look similar to Figure 1 and Figure 2.

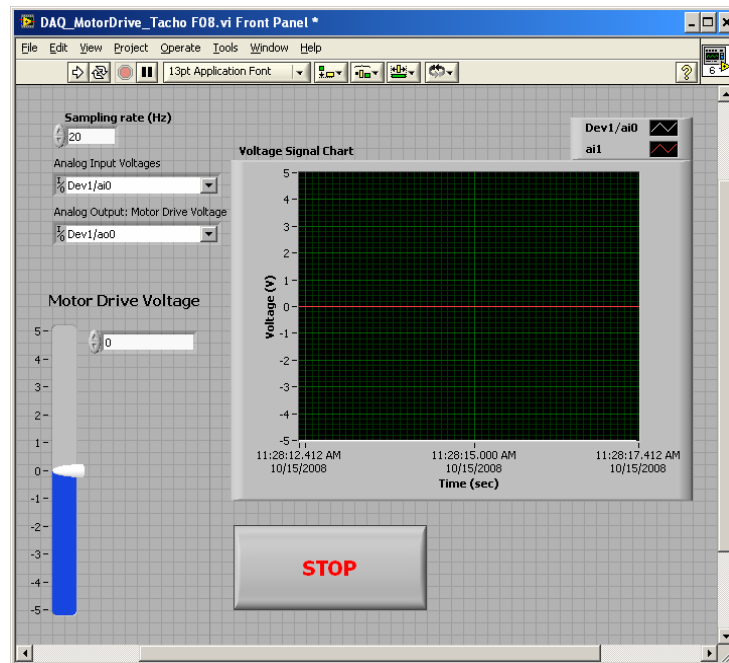


Figure 1. Front Panel for **yourname_MotorDrive_Tacho.vi**

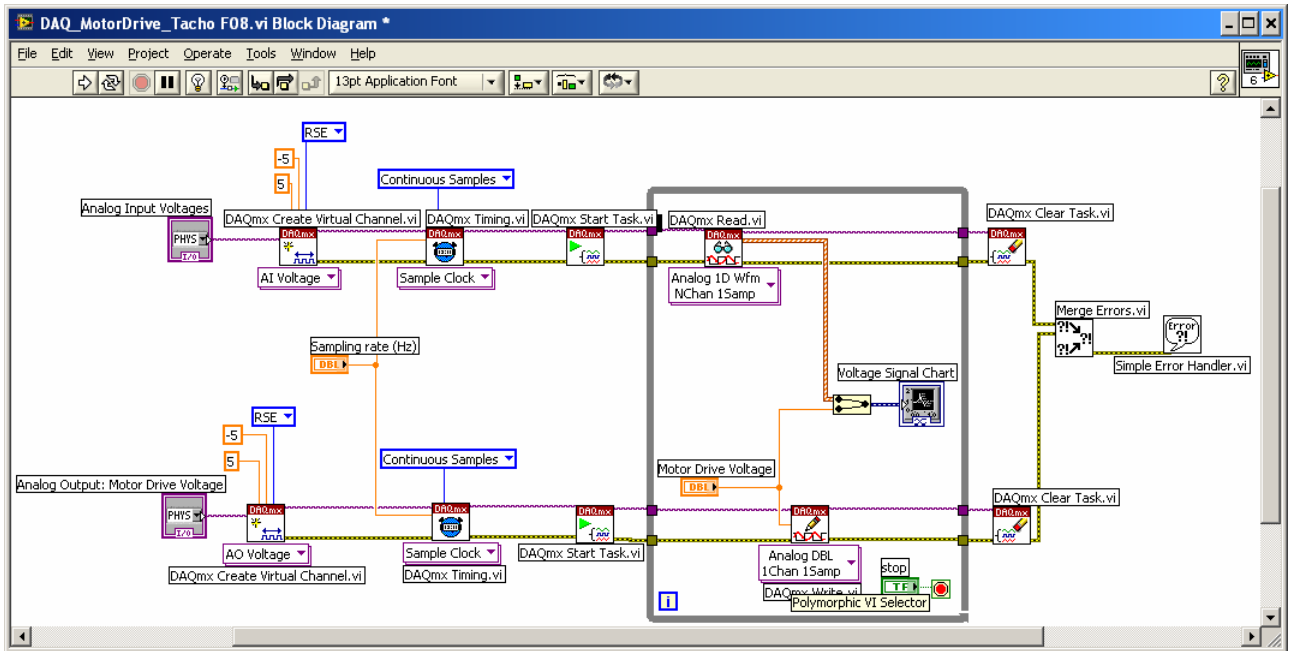


Figure 2. Block Diagram for yourname_MotorDrive_Tacho.vi

Experiment #1: Check the Analog Output Voltage Signal Generated by your Virtual Instrument

In this experiment, you will use a *labVIEW* VI that will enable you to output an analog voltage signal from your DAQ (data acquisition) board. Analog Output Channel 0 (DAC0OUT) on the DAQ board* has already been configured to output voltage signals in the range -5 V to $+5\text{ V}$. You will verify the output voltage signal on the oscilloscope as shown in Figure 2.

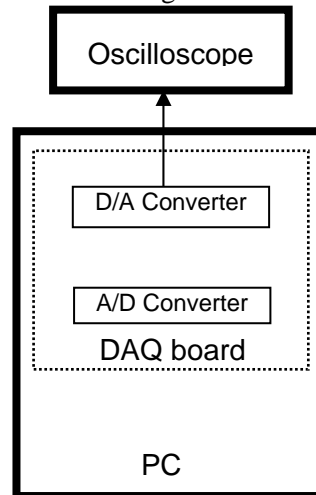


Figure 2. Analog voltage output from DAQ board to oscilloscope.

1. Open yourname_MotorDrive_Tacho.vi

- To view the analog voltage signal from the DAQ board, connect your oscilloscope to the CB-68LP connector block according to Table 1.

Table 1. Pin assignments for viewing voltage from Analog Output Channel 0 on oscilloscope.

Oscilloscope probe	Connect to:
Analog voltage (Red probe)	Pin 22 (AO 0)
Analog ground (Black probe)	Pin 55 (AO GND)

You are now ready to run your VI.

Verify that the voltage viewed on your oscilloscope corresponds to the voltage specified by your Motor Drive Input Control.

- FOR LAB REPORT , Save screenshot of front panel and block diagram
- To stop running the VI, set your Motor Drive Input Control to the 0V position[†] and then click the **STOP** button.

Experiment #2: Drive the DC Motor Using an Analog Signal

In this experiment, you will drive the DC motor using the analog voltage output from your DAQ board. The open loop analog motor control system is shown in Figure 3.

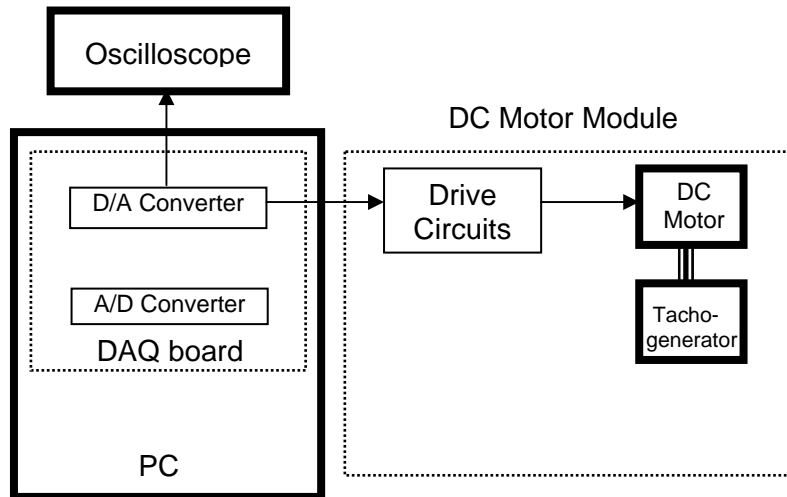


Figure 3. Open loop analog control of DC Motor

The MS15 DC Motor Control Module requires an external power supply that consists of +5V, +12V, and -12V signals with specific currents.

- Make sure the Tektronix PS280 DC Power Supply is off.
- Configure the DC Power Supply to provide: +5V, +12V, -12V, and 0V(ground).
- Wire the DC Power supply to the Motor Control Module.
- Be sure to connect all 0V plugs to ground with a wire.
- ASK YOUR TA TO CHECK THE POWER SUPPLY CONNECTION BEFORE CONTINUING.**

* The PCI-6024E DAQ board has two 12-bit analog output channels, each with a maximum output rate of 10 kS/s.

[†] This is to prevent the motor from turning due to random data after you have turned off your VI.

6. Find the **MOTOR DRIVE** switch on your motor control module. To specify that you are using analog drive input, select the **V_{IN}** position.
7. Find the **TACHO GENERATOR** switch on your motor control module. To enable voltage output reading at the Tacho Generator Output, select the **V_{OUT}** setting.
8. Find the **MOTOR DRIVE INPUT** panel on your motor control module. To enable the selected input (**V_{IN}**) to drive the motor, use a banana connector to connect the **\bar{E} (Enable Input)** socket to the **0V** socket as shown in Figure 5.
9. Turn on your Tektronix PS280 DC Power Supply. This will provide power to the motor control module.
10. Make sure the **Eddy Current Brake** is disengaged. That is, make sure that the Eddy Current Brake Position Indicator (shown in Figure 4) is in the 0 position.

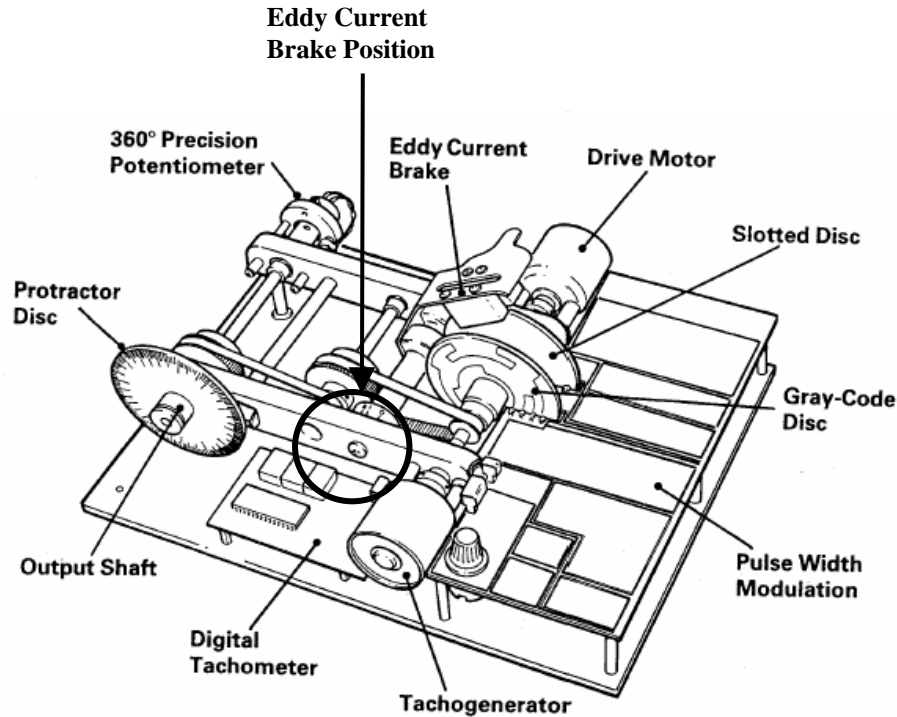


Figure 4. Eddy Current Brake Position Indicator on DC Motor Control Module.

- To drive the motor module with the analog voltage signal generated by your VI, connect the voltage input socket, V_{IN} , on the “**Motor Drive Input**” Panel (shown in Figure 5) of the motor control module to the CB-68LP connector block according to Table 2. Do not remove the connections to the oscilloscope.

Table 2. Pin assignment for using voltage from Analog Output Channel 0 to drive DC Motor.

MOTOR DRIVE INPUT Panel on DC Motor Control Module	Connect to:
V_{IN} socket (Analog voltage)	Pin 22 (AO 0)
$0V$ socket (Analog ground)	Pin 55 (AO GND)

You are now ready to drive your DC Motor.

- Open `yourname_MotorDrive_Tacho.vi`.
- Click the **Run** button to drive the DC Motor using the voltage output from your DAQ board. Verify that a positive voltage from the Motor Drive Input Control results in counterclockwise rotation, while negative voltage from the same Motor Drive Input Control results in clockwise rotation. Observe that the DC Motor does not move for drive voltages very close to 0 V. The small voltage neighborhood within which the motor does not move is known as a “dead zone” and is a result of friction and a few other effects.
- You DON'T need to save the vi for this part of the lab, just verify that it works!
- To stop running the VI, set the Motor Drive Input Control to the 0V position in your VI and then click the **STOP** button.

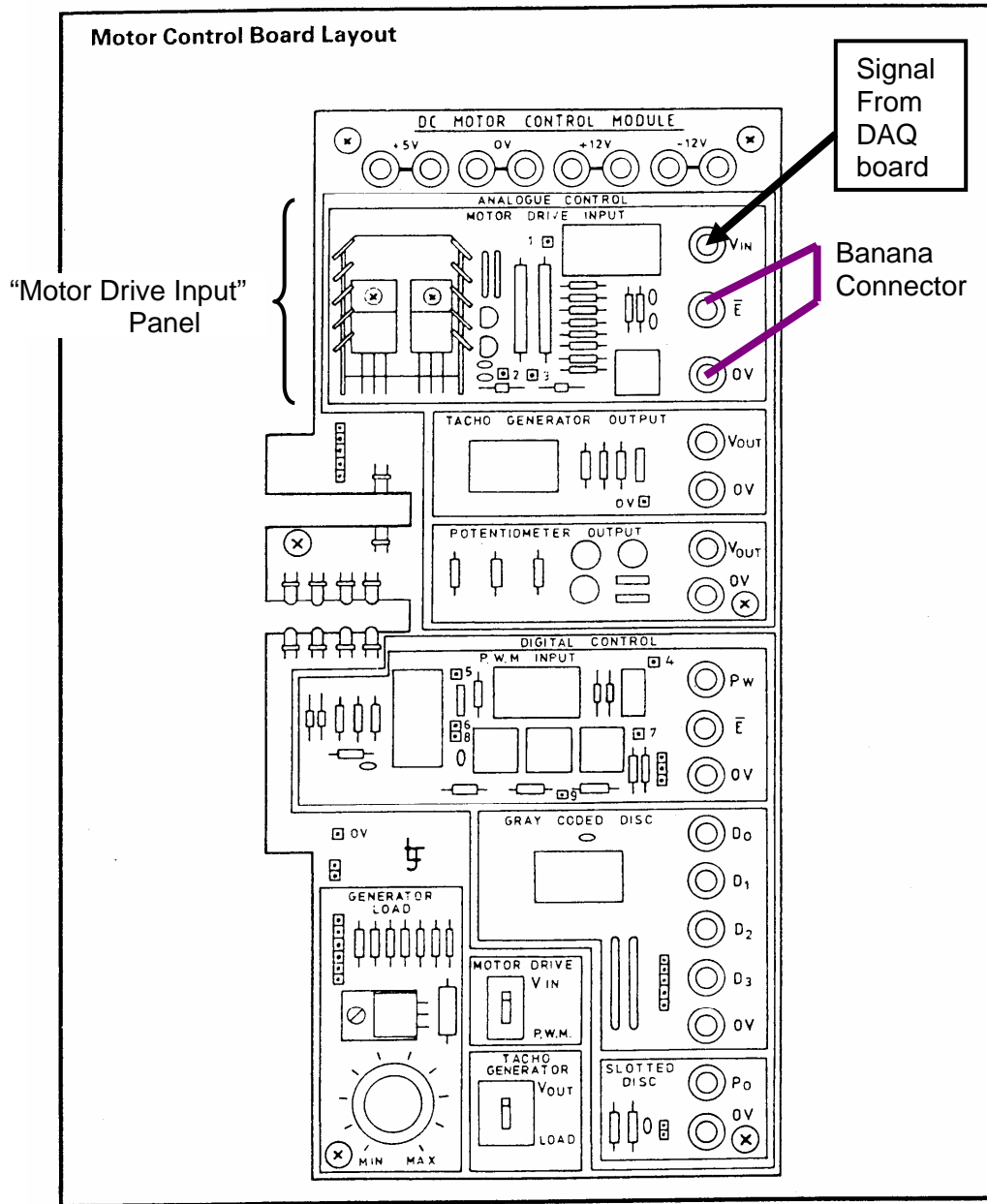


Figure 5. DC Motor Control Module connections for open loop analog control

Experiment #3: Obtain Analog Velocity Feedback from the DC Motor Module

In this experiment, you will use a *LabVIEW* VI to obtain analog velocity feedback from the tacho generator output of your DC motor control module. This system is shown in Figure 6.

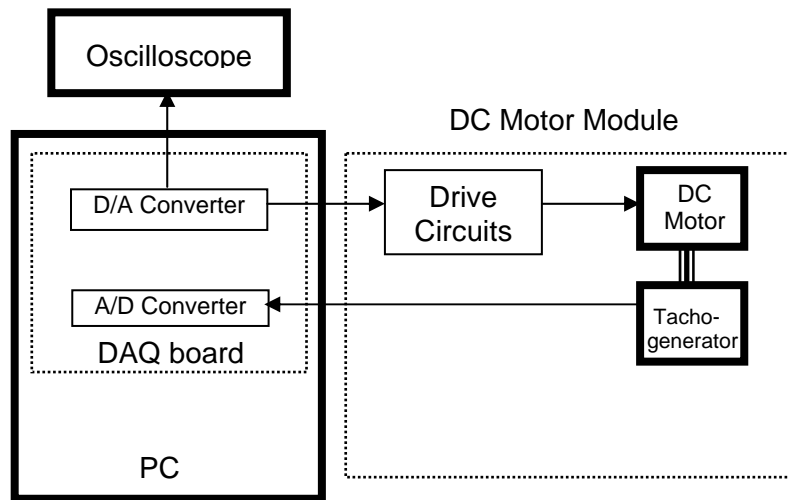


Figure 6. Open loop analog control of DC Motor including velocity feedback.

View Analog Velocity Feedback Signal

- To view the analog velocity feedback signal, use a banana connector to connect the Tacho Generator Output from your motor control module to the CB-68LP connector block according to Table 3. Do not remove the connections you made between the CB-68LP connector block and the motor control module during Experiment #2. Also retain the oscilloscope connections for viewing purposes.

Table 3. Pin assignment for measuring a voltage signal using Analog Input Channel 0.

TACHO GENERATOR OUTPUT Panel on Motor Control Module	Connect to:
V_{OUT} socket (Analog feedback)	Pin 68 (AI 0)
$0V$ socket (Analog ground)*	Pin 67 (AI GND)

Run Your VI

Open `yourname_MotorDrive_Tacho.vi`

- Click the **Run** button. Verify that the voltage viewed on your oscilloscope and Tacho Generator Chart corresponds to the voltage specified by your Motor Drive Input Control. Also observe the

digital **OUTPUT SHAFT R.P.M.** indicator on the **TACHOMETER** panel on your motor control module (Figure 7).

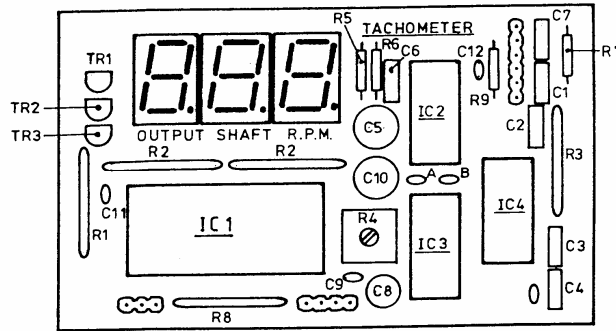


Figure 7. Tachometer panel on DC Motor Control Module

3. FOR LAB REPORT, Save screenshot of front panel and block diagram showing data in the chart.
4. To stop running the VI, set your Motor Drive Input Control to the 0V position and then click the **STOP** button.

Experiment #4: Obtain Analog Position and Velocity Feedback from the DC Motor Module

In this experiment, you will use a *LabVIEW* VI to obtain analog position feedback from the potentiometer output of your DC motor control module. The position feedback will be in addition to the velocity feedback you already have. This system is shown in Figure 8.

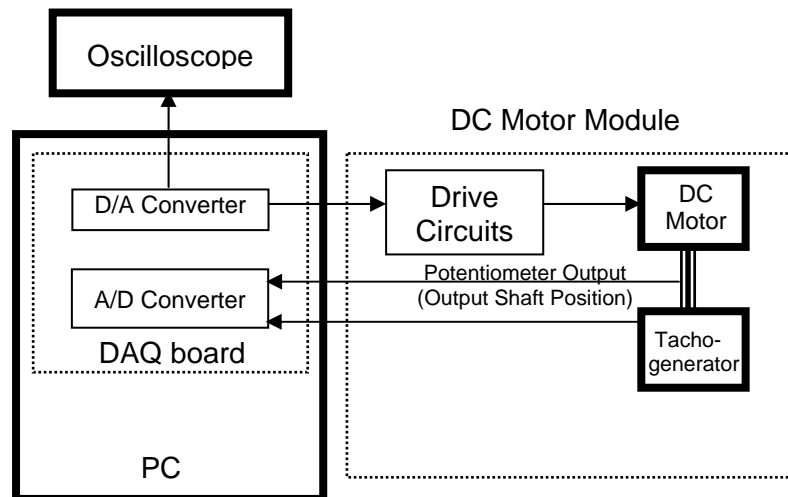


Figure 8. Open loop analog control of DC Motor including position and velocity feedback

View Analog Position Feedback Signal

1. To view the analog position feedback signal, use banana connectors to connect the Potentiometer Output from your motor control module to the CB-68LP connector block according to Table 4. Do not remove the connections you made between the CB-68LP connector block and the motor control module during Experiment #3. Also retain the oscilloscope connections for viewing purposes.

Table 4. Pin assignment for measuring a voltage signal using Analog Input Channel 1.

POTENTIOMETER OUTPUT Panel on Motor Control Module	Connect to:
V_{OUT} socket (Analog feedback)	Pin 33 (AI 1)
OV socket (Analog ground)*	Pin 67 (AI GND)

Run Your VI

Open `yourname_MotorDrive_Tacho.vi`

2. Click the **Run** button. Verify that the voltage viewed on your Potentiometer Chart agrees with the voltage specified by your Tacho Generator Output Chart. That is, the frequency of the signal on your Potentiometer Chart should increase with rotation speed.[†]
3. FOR LAB REPORT, Save screenshot of front panel and block diagram showing data in the chart.
4. To stop running the VI, set your Motor Drive Input Control to the 0V position and then click the **STOP** button.

Experiment #5: Calibrate Velocity of DC Motor Module

In this experiment, you will document the motor drive signal and velocity feedback signal from your motor control module. By plotting this data, you can calibrate the angular velocity versus drive voltage behavior of your open loop system.

1. Retain all the CB-68LP connections and banana plug connections you had at the end of Experiment #4.

Run Your VI

2. Click the **Run** button for `yourname_MotorDrive_Tacho.vi`

Obtain Data

3. Enter -5.00 in the Motor Drive Input Control. FOR LAB REPORT, record the voltage values shown on the Motor Drive Input Control and the Tacho Generator Indicator. Also record the value shown on the **OUTPUT SHAFT R.P.M.** indicator on your motor control module. You will plot this data as part of your lab report. If the indicator values are changing (not steady), observe the changing values for a few seconds and record the lowest value and the highest value.
4. Increase the voltage value on your Motor Drive Input Control by 0.20 V and repeat step 3 above. Do so up to (and including) the maximum Motor Drive Input Control

[†] At high velocities, the signal displayed on your Potentiometer Chart will be distorted due to aliasing and graphical interpolation effects. For better viewing of the potentiometer output signal, you may consider (simultaneously) viewing it using the second (unutilized) channel of your oscilloscope.

value of 5.00 V. For your convenience, you may specify the increment value of your Motor Drive Input Control by right-clicking on it and selecting **Data Range**.

5. To stop running the VI, set the Motor Drive Input Control to 0 and click the **STOP** button.
6. Repeat steps 1 through 5, but this time, use 1.00 V as your starting voltage and decrement the voltage by 0.20 V until you reach -1.00 V.
7. Set your digital control to the 0V position and stop running the VI.

Determine “Dead Zone”

If you look at your data, you will notice the drive voltage “dead zone” in which the motor does not turn even though the drive voltage is not zero. To determine the exact location of the dead-zone you can repeat the procedure outlined in Steps 3 through 7, but with a more convenient starting point and a smaller increment (or decrement) such as 0.01V.

8. Turn off your Tektronix PS280 DC Power Supply.

Experiment #6: Calibrate Velocity of DC Motor Module under External Load Conditions

In Experiment #5, you calibrated your DC Motor while the **Eddy Current Brake** was disengaged (in the 0 setting). In this exercise you will calibrate your motor with the Eddy Current Brake engaged (in the 1 setting).

1. Retain all the CB-68LP connections and banana plug connections you had at the end of Experiment #4.
2. Open `yourname_MotorDrive_Tacho.vi`
3. Set the **Eddy Current Brake** to the 1 position and repeat the calibration you performed in Experiment #5 (Steps 2 through 8).

Saving Files

Before you leave, remember to save all of your files to your ECI account (for later use and backup purposes). For this laboratory, you should save the following files from the Desktop:

`yourname_MotorDrive_Tacho.vi`

Laboratory Report

1. For the VI's you wrote in this laboratory (listed in the preceding section), provide a printout that shows the front panel and block diagram with working data.
2. Provide four tables that contain the data you collected in Experiment #5 and #6. The first and second tables should be for the (upward) calibration from -5V to +5V for the motor w/out brake and w/brake, and the third and fourth tables should be for the (downward) calibration from 1V to -1V for the motor w/out brake and motor w/ brake. Each table should have separate columns for the Motor Drive Input data, the Tacho Generator Output data and the Tachometer Output Shaft RPM data.
3. Using the data you tabulated in question 2 above, plot Tacho Generator Output voltage versus Motor Drive Input voltage for the No Brake case and Brake case. Plot separately the upward calibration curve and the downward calibration curve and clearly indicate which is which. Label the dead zone(s) in your plots. Define V_{IN+} as the minimum positive (smallest magnitude) drive voltage that

causes the shaft to turn and define V_{IN-} as the maximum negative (smallest magnitude) drive voltage that causes the shaft to turn. Clearly label all values of V_{IN+} and V_{IN-} on your calibration graph.

4. Provide a piecewise linear description of the calibration curve you obtained in Question 3 above. Make sure your description covers the entire drive voltage range (-5V to +5V). In particular, what are the equations for the linear region(s) of your calibration curve? What would the equations be if you plotted Motor Output Shaft Angular Velocity versus Motor Drive Input voltage? Explain and clearly specify units.
5. Was the dead zone for your upward calibration equal to the dead zone for your downward calibration? Justify your observation from a physical point of view. (Hint: Why does a dead zone occur?).
6. Compare and comment on the calibration curves for the two different Eddy Current Brake settings (0 and 1). Do the differences between the calibration curves for the two different settings make sense from a physical point of view? Explain.

Your Lab Report should clearly state your name, Lab Report number, Lab date, and your laboratory partner's name (if any). Your lab report should be thorough, but concise. You will be graded on quality, not quantity. **Lab Report #4 is due at the beginning of Laboratory #5.**

Additional Reading

Feel free to read the following material to learn more about *LabVIEW*'s analog output features.

1. ***LabVIEW Data Acquisition Basics Manual***, Chapter 10 (*Things You Should Know About Analog Output*) and Page 11-1. Available online at www.ni.com/pdf/manuals/320997e.pdf.