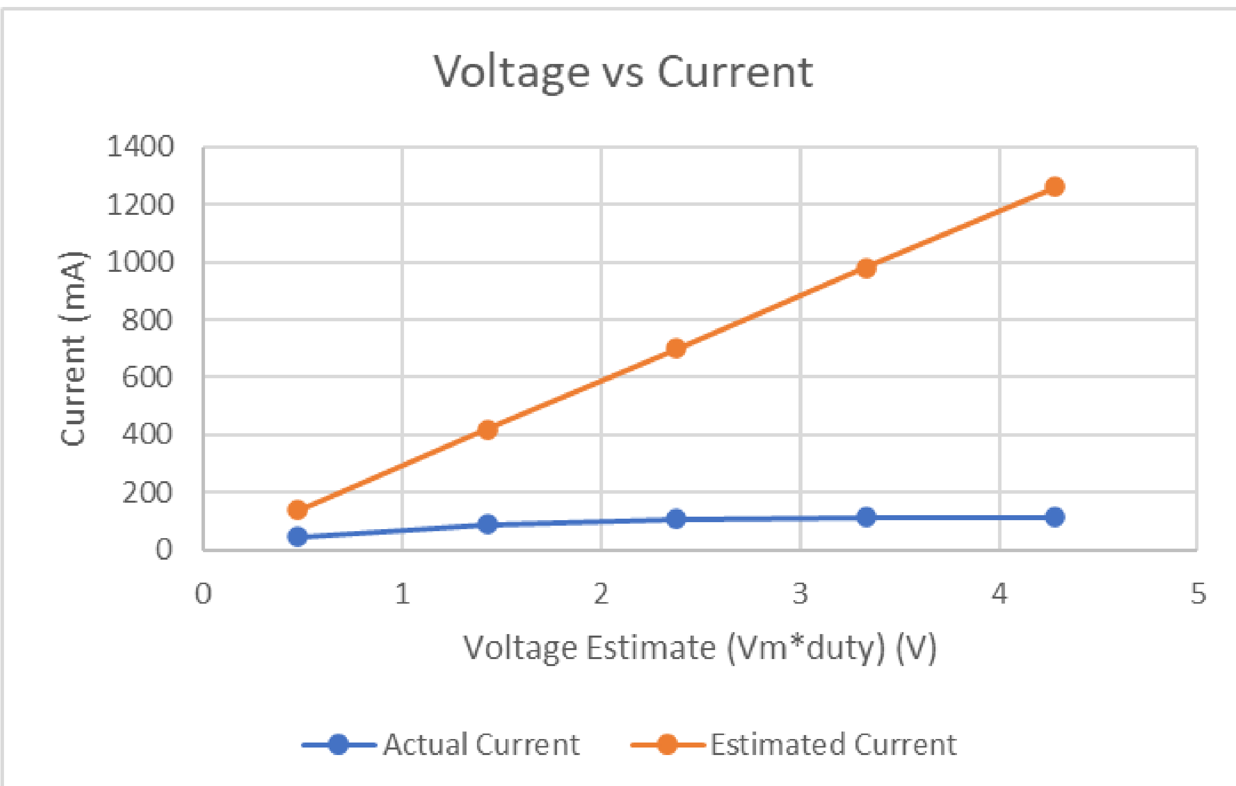
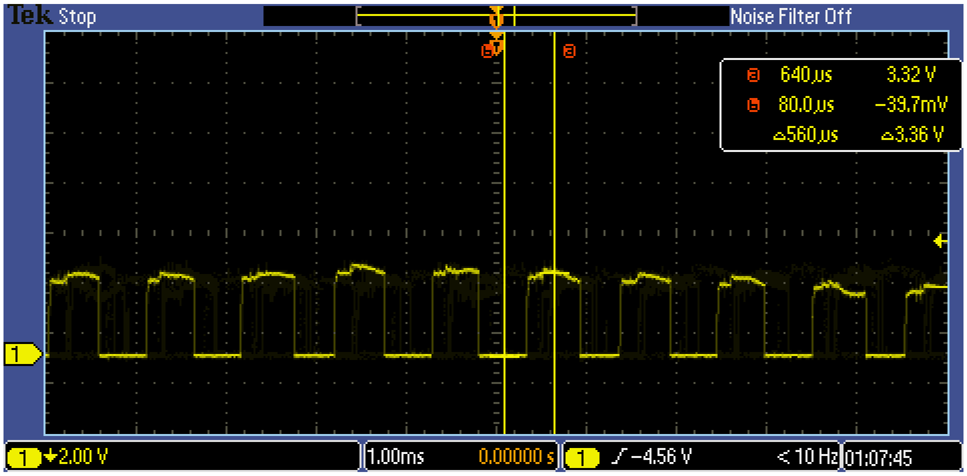
Lab 10 Deliverables

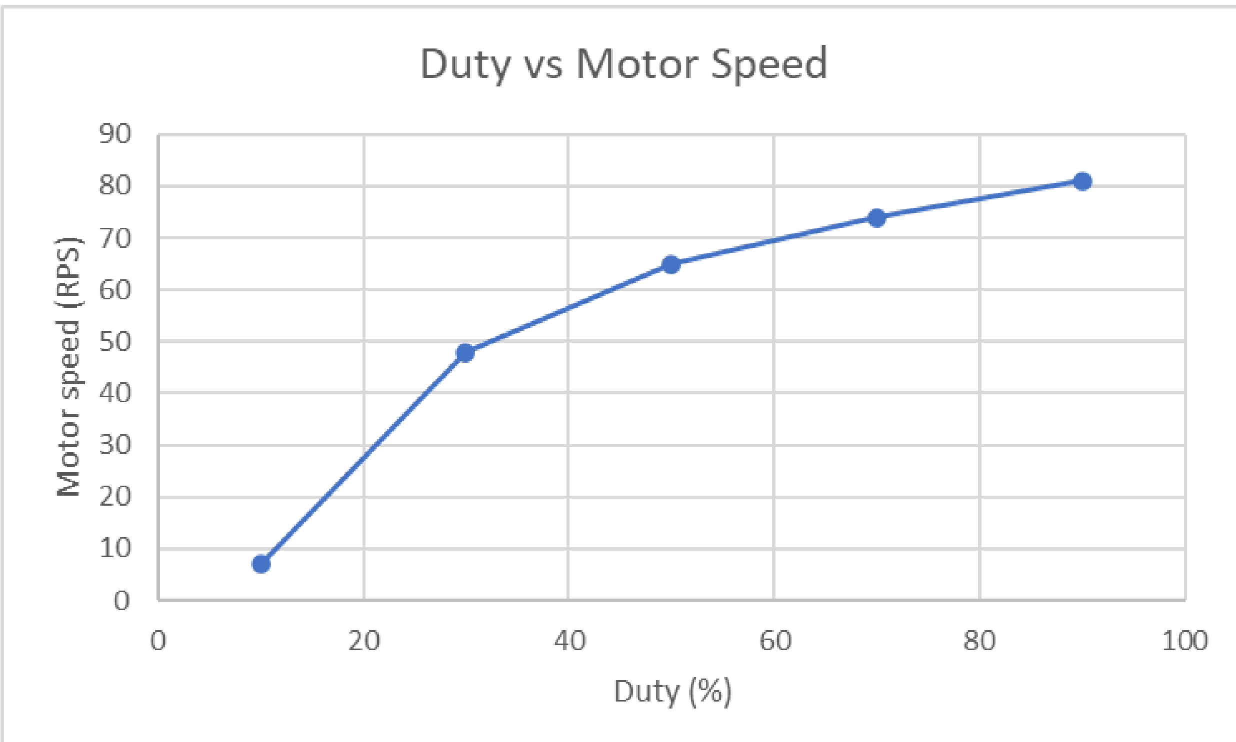
1. Objectives (final requirements document)
2. Hardware design (.sch file)
    i. DC motor and tachometer interfaces, showing all external components
    ii. LCD and switch interfaces, showing all external components
3. Software design
    i. Include units on all software variables
    ii. Clear distinction between variables used for debugging and variables needed in the controller
4. Measurement data
    i. Voltage, current, and resistance measurements of the motor
        a. Voltage (across motor): 4.76V
        b. Voltage (across MOSFET): 11.1mV
        c. Current: 115.5mA
        d. Resistance: 3.4Ω
    ii. Graph of motor current vs duty cycle * Vm



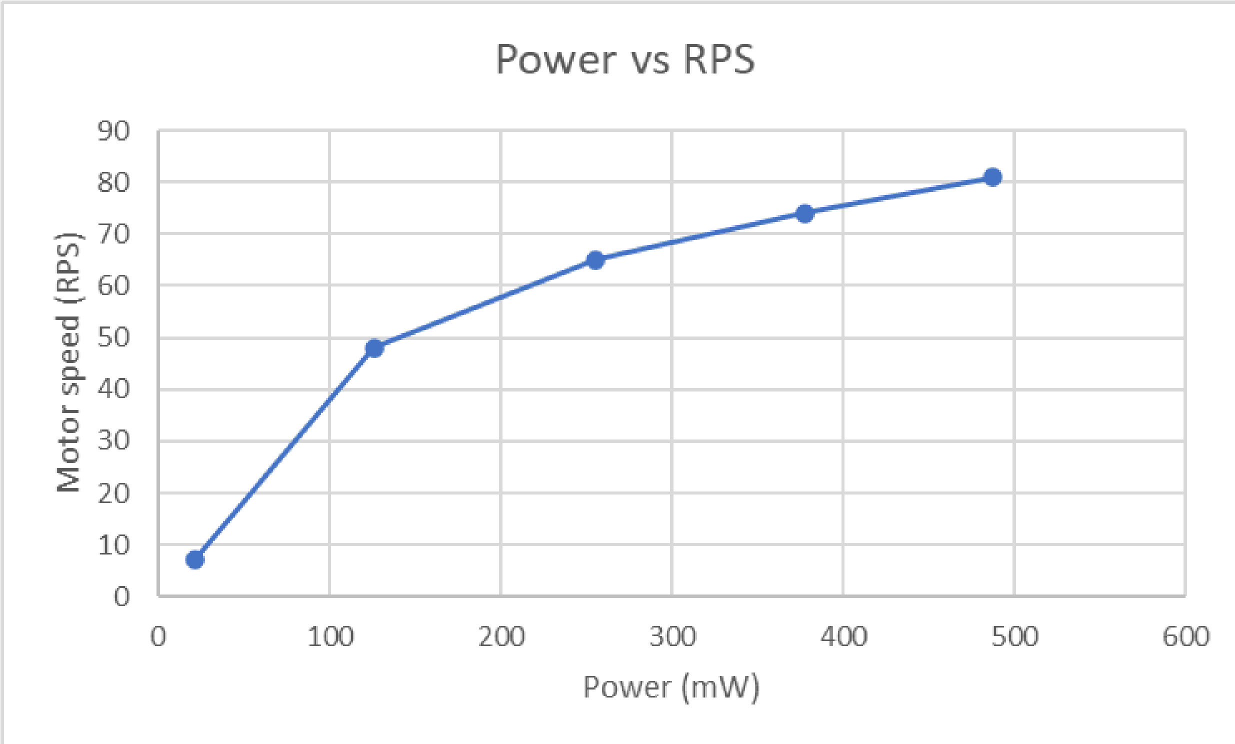
    iii. Plot of the typical tachometer output:



iv. Graph of motor speed vs PWM

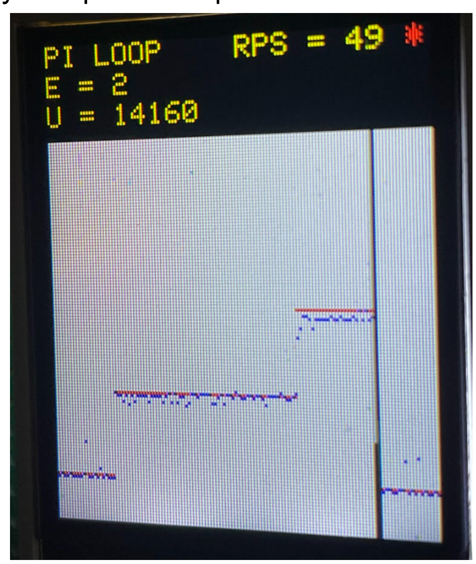


v. Graph of motor speed vs power

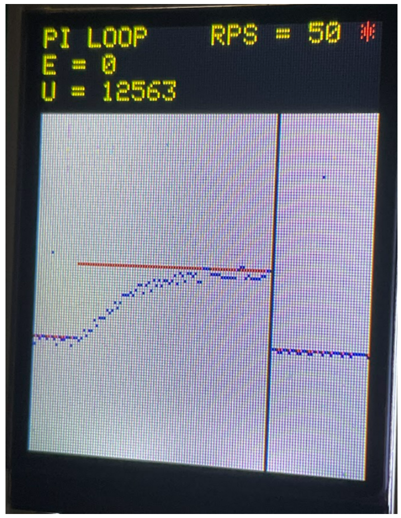


vi. Graphs of 4 dampings:

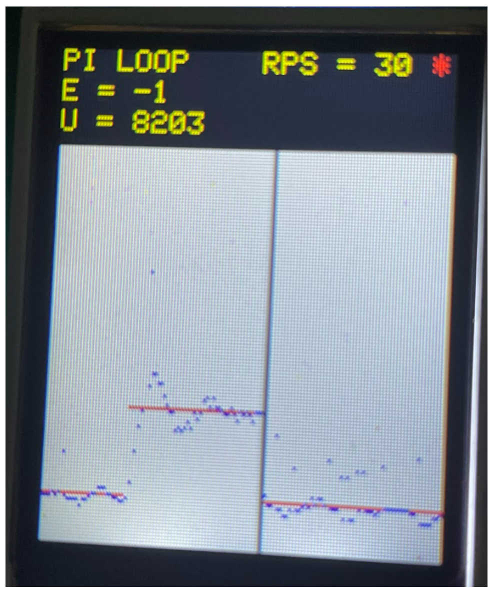
a. Critically-damped PI loop



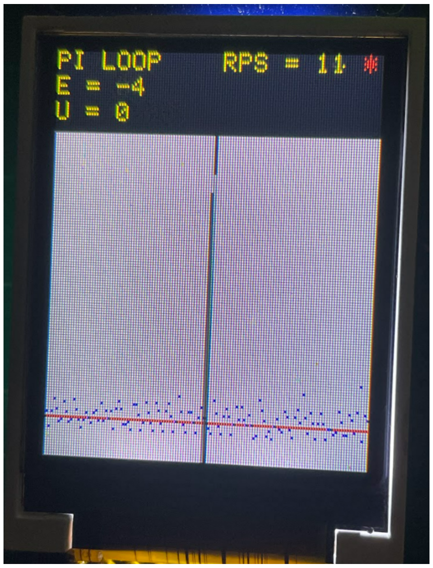
b. Over-damped PI loop



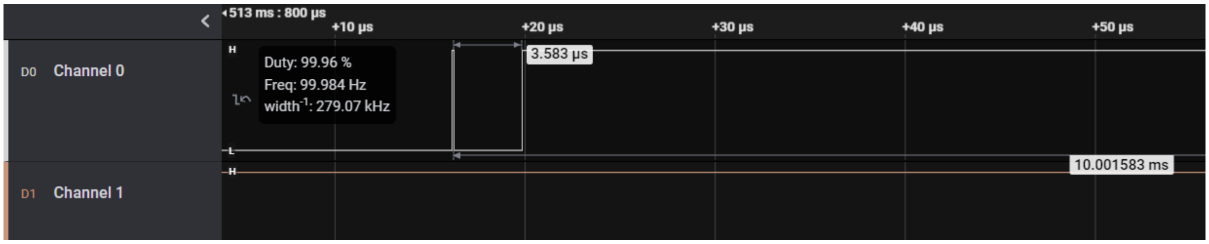
c. Under-damped PI loop



d. Unstable PI loop



vii. Specify maximum time to execute one instance of the ISR
Max time = 3.58 us based on the logic analyzer output below.



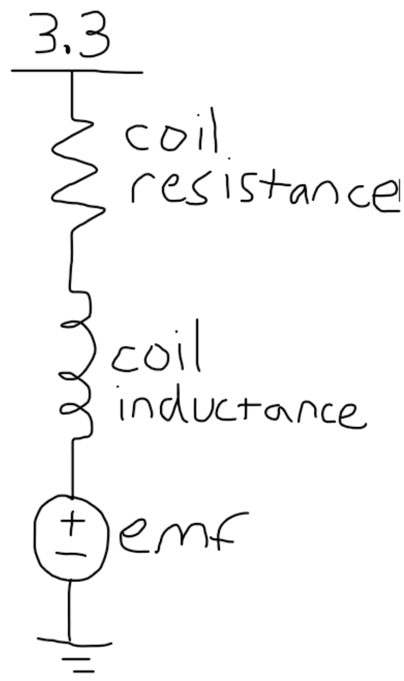
viii. Determine percentage time required to run all ISRs
% time = 100*2.583us/10.002ms = 0.026%

ix. Specify average controller error for different controllers:
   a. P controller
      Taking the average of 128 consecutive error values for only P (kpn = 9000, kpd = 1) gives RPS error = 2
   b. I controller
      Taking the average of 128 consecutive error values for only I (kin = 7, kid = 1) gives RPS error = 0
   c. PI controller
      Taking the average of 128 consecutive error values for only I (kpn = 1200, kpd = 1, kin = 11, kid = 1) gives RPS error = 0

x. Specify response time for different controllers:
   a. P controller (kpn = 9000, kpd = 1)
      190 ms rise time from 10 to 70 RPS, 450ms fall time from 70 to 10 PRS.
   b. I controller (kin = 7, kid = 1
      917 ms rise time from 10 to 70 RPS, 2.313s fall time from 70 to 10 RPS.
   c. PI controller (kpn = 1200, kpd = 1, kin = 11, kid = 1)
      1.31s rise time from 10 to 70 RPS. 1.2s fall time from 70 to 10 RPS.

5.2 Analysis and Discussion Questions

1. What is torque? What are its units?
   Torque is the force that makes an object move about an axis. Its units are Newton-meters.
2. Draw an electrical circuit model for the DC motor coil and explain the components. Use the circuit model to explain why the current goes up when friction is applied to the shaft.

   The current increases because when there is no load, there is back EMF. In this no-load scenario, the back EMF is applied opposite to the source voltage. However, as friction increases, the back EMF decreases and this causes an increase in the actual current needed to drive the system.
3. Explain what parameters were important for choosing a motor drive interface chip (eg. IRLD024 or IRLD120). How does your circuit satisfy these parameters?
   Some parameters that are important in selecting the driver chip include the current gain and the max current that can be sourced.
4. You implemented an integral controller because it is simple and stable. What other controllers could you have used? How would another type of controller been superior to your integral controller?
   A derivative controller can also be used in addition to the proportional and integral terms. This type of controller can have a faster rise time to the desired speed and can also reduce any overshoot of the system.
5. If the motor is spinning at a constant rate, give a definition of electrical power in terms of parameters of this lab.
   P=I_motor * V_motor * duty cycle
6. Research the term mechanical power. Give a definition of mechanical power.

Mechanical power is defined as the product between the torque and the RPM, while electrical power is the product of the voltage and current.

7. Are electrical power and mechanical power related.
   Both mechanical and electrical power measure power in Watts (W). While mechanical power is measured by the rate at which work is done, electrical power is measured as the rate at which energy is transformed. In lab 10, efficiency can be measured as mechanical power/electrical power. Thus, they are related by the motor's efficiency.