Lab 10: DC Motor Control

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Overview

1.1. Objectives: Why are we doing this project? What is the purpose?

The objectives of this project are to design, build and test a brushed DC motor controller. The motor should spin at a constant speed and the operator can specify the desired set point. Educationally, students are learning how to interface a DC motor, how to measure speed using input capture, and how to implement a digital controller running in the background.

1.2. Process: How will the project be developed?

The project will be developed using the LaunchPad. There will be two switches that the operator will use to specify the desired speed of the motor. The system will be built on a solderless breadboard and run on the usual USB power. The system may use the on board switches or off-board switches. A hardware/software interface will be designed that allows software to control the DC motor. There will be at least five hardware/software modules: tachometer input, switch input, motor output, LCD output, and the motor controller. The process will be to design and test each module independently from the other modules. After each module is tested, the system will be built and tested.

1.3. Roles and Responsibilities: Who will do what? Who are the clients?

EE445L students are the engineers and the TA is the client. Student Allen will build and test the sensor system. Student Baris will build the actuator and switch input. Both students will work on the controller.

1.4. Interactions with Existing Systems: How will it fit in?

The system will use the microcontroller board, a solderless breadboard, and the DC motor shown in Figure 10.1. The wiring connector for the DC motor is described in the PCB Artist file Lab10E_Artist.sch. It will be powered using the USB cable.

1.5. Terminology: Define terms used in the document.

integral controller- feedback mechanism used to control the output of a system using the error of the output and the amount of time the error occurs

PWM - pulse width modulation- encoding information as a function of the width and duty cycle of a pulse of voltage

board support package - Code for a hardware device that allows it to run with a certain operating system

back emf- induced electromagnetic force that is acting against the voltage that is spinning the motor

Torque - rotational force. Tendency to rotate about an axis. Calculated as force X distance

time constant - A constant defined in analog circuit as the time required for the output to reach 63.2% of its final output, after an input is suddenly supplied. E.g. In a first-order RC circuit time constant is RC.

Hysteresis - the dependence of a system on its past states.

1.6. Security: How will intellectual property be managed?

The system may include software from TivaWare and from the book. No software written for this project may be transmitted, viewed, or communicated with any other EE445L student past, present, or future (other than the lab partner of course). It is the responsibility of the team to keep its EE445L lab solutions secure.

2. Function Description

2.1. Functionality: What will the system do precisely?

If all buttons are released, then the motor should spin at a constant speed. If switch 1 is pressed and released, the desired speed should increase by 5 rps, up to a maximum of 40 rps. If switch 2 is pressed and released, the desired speed should decrease by 5 rps, down to a minimum of 0 rps. Both the desired and actual speeds should be plotted on the color LCD as a function of time similar to Figure 10.4

2.2. Scope: List the phases and what will be delivered in each phase.

Phase 1 is the preparation; phase 2 is the demonstration; and phase 3 is the lab report. Details can be found in the lab manual.

2.3. Prototypes: How will intermediate progress be demonstrated?

A prototype system running on the LaunchPad and solderless breadboard will be demonstrated. Progress will be judged by the preparation, demonstration and lab report.

2.4. Performance: Define the measures and describe how they will be determined.

The system will be judged by three qualitative measures. First, the software modules must be easy to understand and well-organized. Second, the system must employ an integral controller running in the background. There should be a clear and obvious abstraction, separating the state estimator, user interface, the controller and the actuator output. Backward jumps in the ISR are not allowed. Third, all software will be judged according to style guidelines. Software must follow the style described in Section 3.3 of the book. There are three quantitative measures. First, the average speed error at a desired speed of 20 rps will be measured. The average error should be less than 5 rps. Second, the step response is the time it takes for the new speed to hit 25 rps after the set point is changed from 20 to 25 rps. Third, you will measure power supply current to run the system. There is no particular need to minimize controller error, step response, or system current in this system.

2.5. Usability: Describe the interfaces. Be quantitative if possible.

There will be two switch inputs, one increments the desired RPS by 5, and the other decrements it by 5. The tachometer will be used to measure motor speed. The DC motor will operate under no load conditions. The LCD shows a plot of desired RPS against actual RPS.

2.6. Safety: Explain any safety requirements and how they will be measured.

Figure 10.2 shows that under a no load condition, the motor current will be less than 100 mA. However, under heavy friction this current could be 5 to 10 times higher. Therefore, please run the motors unloaded. Connecting or disconnecting wires on the protoboard while power is applied will damage the microcontroller. Operating the circuit without a snubber diode will also damage the microcontroller.

3. Deliverables

3.1. Reports: How will the system be described?

A lab report described below is due by the due date listed in the syllabus. This report includes the final requirements document.

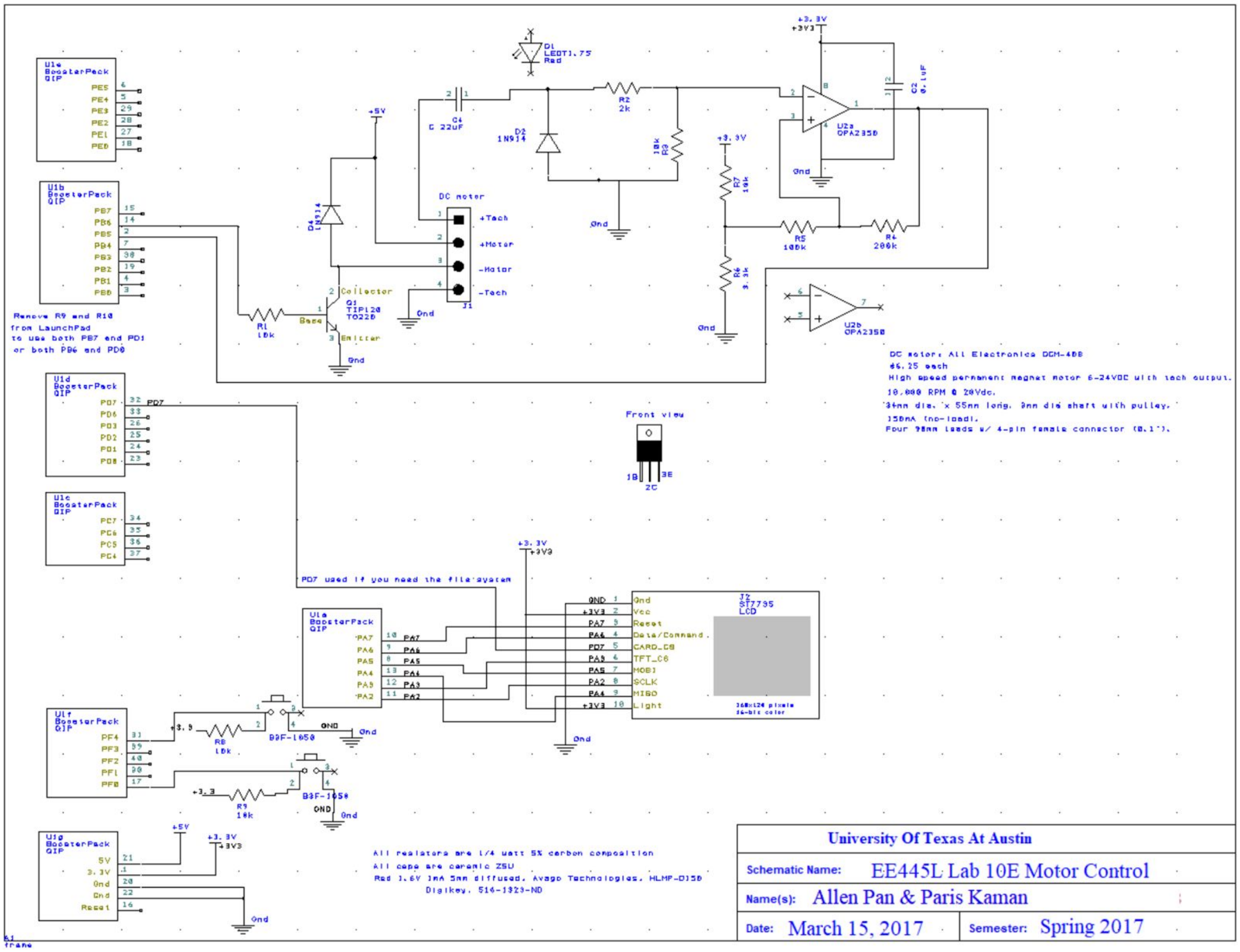
3.2. Audits: How will the clients evaluate progress?

The preparation is due at the beginning of the lab period on the date listed in the syllabus.

3.3. Outcomes: What are the deliverables? How do we know when it is done?

There are three deliverables: preparation, demonstration, and report.

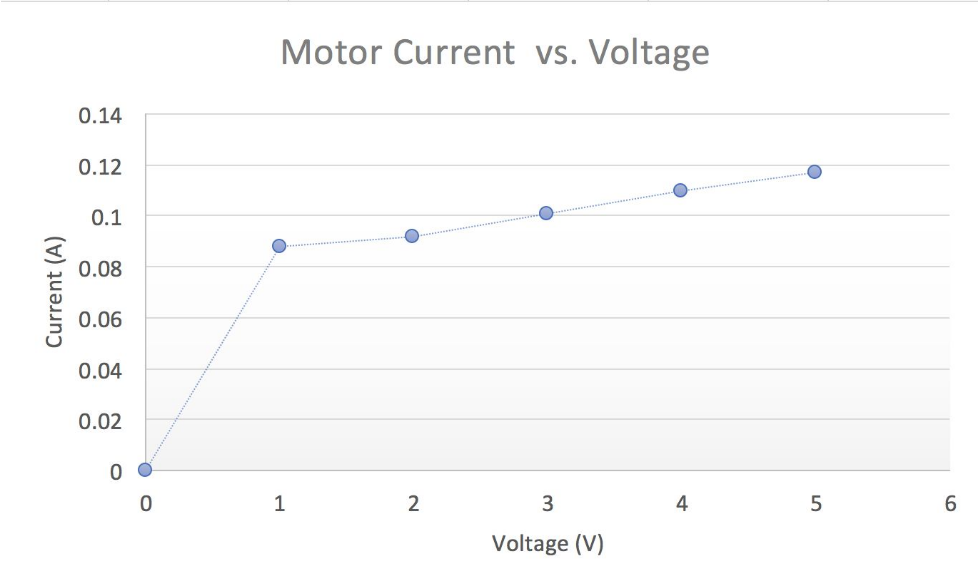
Hardware



Measurement Data

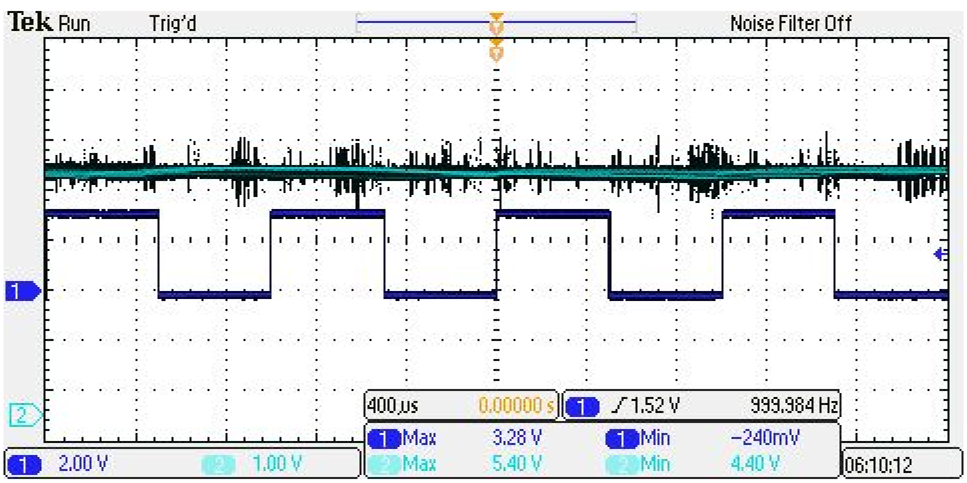
1) Resistance of Coil: 38.4Ω

Voltage (V)	Current (A)
0	0
1	0.088
2	0.092
3	0.101
4	0.11
5	0.117



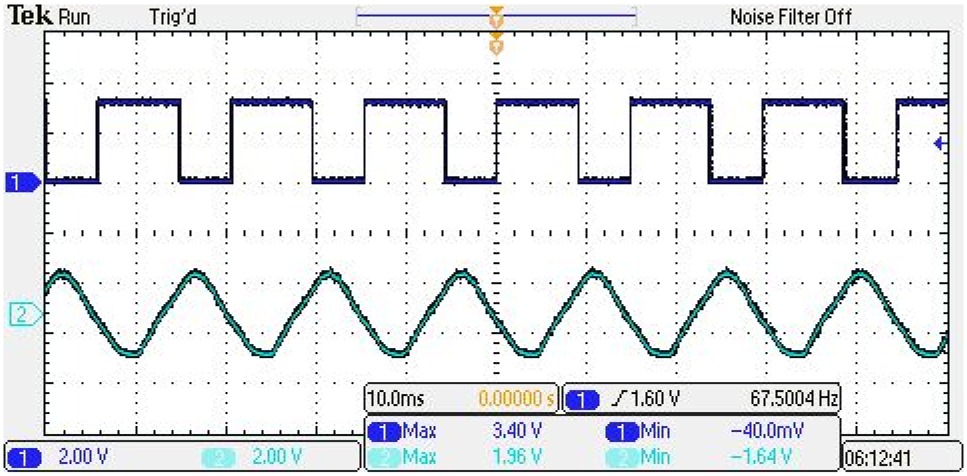
2) Base-Emitter Current 0.18 mA
Collector-Emitter Current 90.9 mA
The equation is $I_{ce} = I_{be} * h_{ef}$.

3)



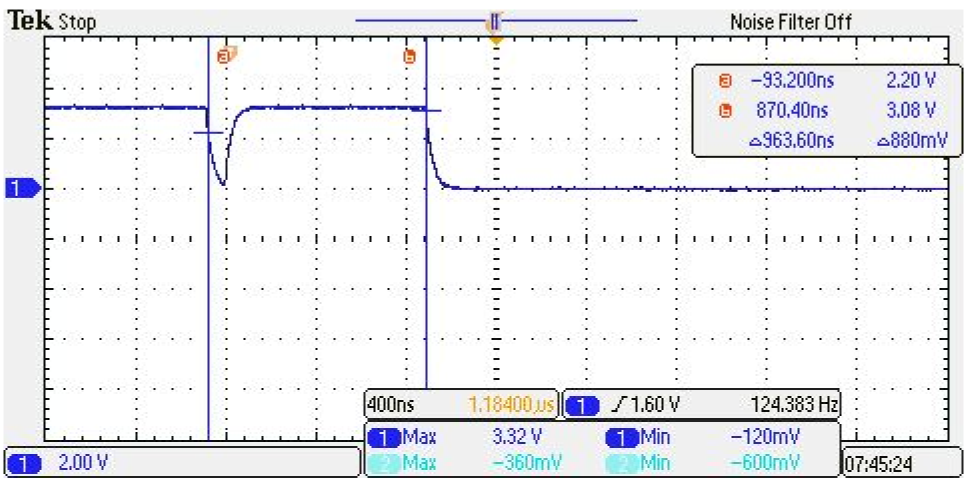
PWM output and motor voltage

The snubber diode is used to suppress the voltage spikes caused by the motor's inductance when voltage is suddenly applied.
(In deliverable it says "two screen shots of the hardware in operation". Don't know what it exactly means but we've only got the scope screenshots.)

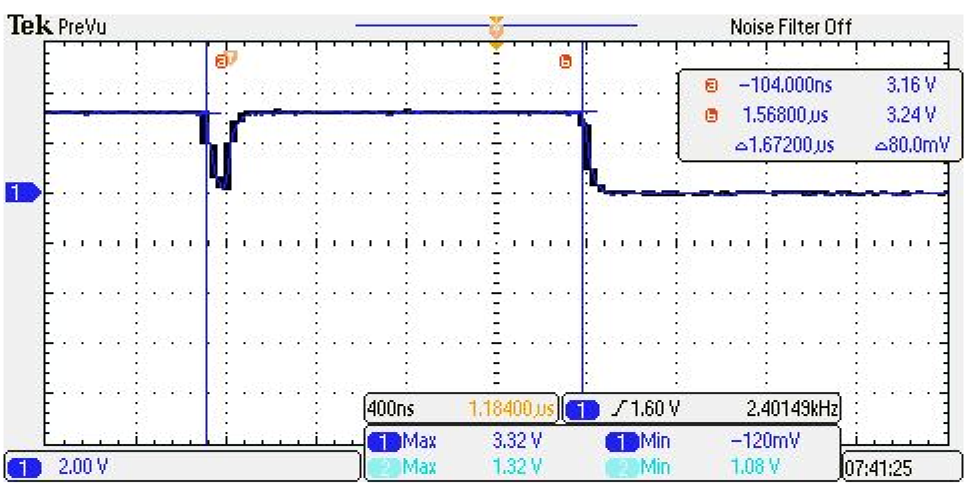


tachometer signal and the amplified tach signal

4)



Period Measurement ISR execution time: 963.60ns



Integral Controller ISR execution time: 1.672 µs

We took 10 samples (not consecutive) with desired RPS being 20. The average error is about 0.3.

Sample	Desired rps	Actual rps	Error	Average Error
1	20	19.4	0.6	0.3
2	20	19.7	0.3	
3	20	19.8	0.2	
4	20	20.1	0.1	
5	20	19.7	0.3	
6	20	19.4	0.6	
7	20	20.2	0.2	
8	20	20.4	0.4	
9	20	20.1	0.1	
10	20	19.8	0.2	

What is the approximate time it takes the speed to stabilize after the set point is increased from 20 to 25 rps?
It is really quick, so it is difficult to eye-ball. Approximately 0.2 seconds.

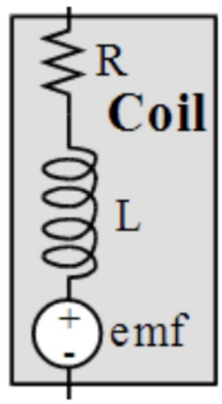
5) With motor running: 183mA
Without motor running: 85mA
(didn't ask us to take a screenshot for this part)

Analysis and Discussion

1) What is torque? What are its units?

Torque is rotational force. It's measured in Newton-meters because it is created by a an applied force at a certain distance from the point of rotation.

2) Draw an electrical circuit model for the DC motor coil, and explain the components. Use this circuit model to explain why the current goes up when friction is applied to the shaft.



This model shows the equivalent resistance within the coil that the current flows through, the inductor that represents the inductive property of the coils, and the back emf induced that acts against the applied voltage that's causing the motor to spin.
When the friction is high, the force to overcome in order for the rotor to rotate gets larger. Therefore, higher current (hence higher power) is required to drive the load.

3) Explain what parameters were important for choosing a motor drive interface chip (e.g., TIP120 or 2N2222). How does your circuit satisfy these parameters?

It is important to make sure you choose an interface chip that can handle the amount of current that your circuit is going to need. The parameters to consider includes current gain, supply voltage/current, maximum current. The TIP120 can handle more current, so it is used for projects that include higher power devices like DC motors and solenoids

4) You implemented an integral controller because it is simple and stable. What other controllers could you have used? For one other type of controller how would it have been superior to your integral controller.

We could have used a PID controller, which would look at the rate of change of error of the system (derivative) and attempt to reduce this down to zero. This method would improve the amount of time it would take to settle on a specific value as well as improve the stability of the system by reducing the rate of change.

5) It the motor is spinning at a constant rate, give a definition of electrical power in terms of parameters of this lab? Research the term “mechanical power”. Give a definition of mechanical power. Are the electrical power and mechanical power related?

If the motor is spinning at a constant rate, it will be using a constant amount of power, which will be a function of the pulse width. Mechanical power refers to the rate at which work is done, which can be calculated with either work/time or the integral over a curve of force*velocity. Electrical power is the rate at which energy (J) is transferred. Both forms of power are referring to the amount of energy transfer per second.