2. LABORATORIES

Topics:

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Objectives:

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2.1 Lab - Lab Safety

2.1.1 Theory

2.1.2 Procedure

1. Mr. Bero will give an overview of the laboratories and cover general safety guidelines

2.2 Lab - Soldering

2.2.1 Theory

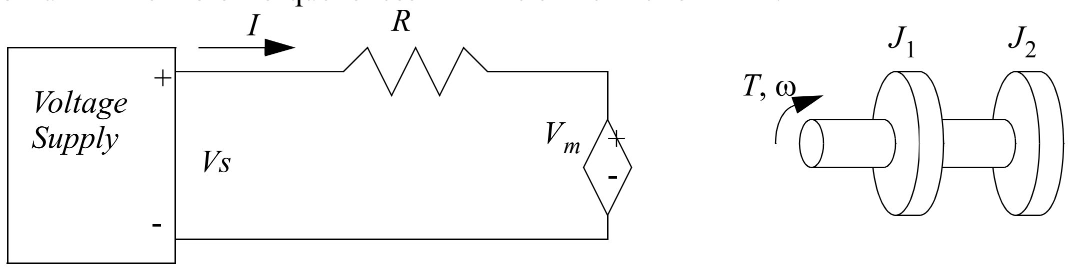
2.2.2 Procedure

1. Prof. Jack will provide circuit boards and simple parts. These should be soldered to the circuit boards and then checked for overall quality.

2.3 Lab - Motors and Tachometers

2.3.1 Theory

The differential equation is derived in Figure 1 and Figure 2 to include a term for friction. In the derivation it is assumed that the motor is turning, and the friction is dynamic. Clearly the motor will not turn if the motor torque is less than the static friction limit.



Because a motor is basically wires in a magnetic field, the electron flow (current) in the wire will push against the magnetic field. The torque (force) generated will be proportional to the current.

$$T_m = KI \qquad \therefore I = \frac{T_m}{K}$$

Next, consider the power in the motor,

$$P = V_m I = T\omega = KI\omega \qquad \therefore V_m = K\omega$$

Consider the dynamics of the rotating masses by summing moments.

$$\sum M = T_m - T_F = J\left(\frac{d}{dt}\right)\omega \qquad \therefore T_m = J\left(\frac{d}{dt}\right)\omega + T_F$$

Figure 1 The torque and inertia in a basic motor model

The coefficients for the differential equation in Figure 2 can be found for the motor in a dynamic case using steady state velocities. The static torque value can be found using the deadband limits.

The current-voltage relationship for the left hand side of the equation can be written and manipulated to relate voltage and angular velocity.

$$I = \frac{V_s - V_m}{R}$$

$$\therefore \frac{T_m}{K} = \frac{V_s - K\omega}{R}$$

$$\therefore \frac{J\left(\frac{d}{dt}\right)\omega + T_F}{K} = \frac{V_s - K\omega}{R}$$

$$\therefore \left(\frac{d}{dt}\right)\omega + \omega\left(\frac{K^2}{JR}\right) = V_s\left(\frac{K}{JR}\right) - \frac{T_F}{J} \qquad \text{if} \quad \omega = 0, |T_F| < T_s$$

$$\text{if} \quad \omega \neq 0, |T_F| < T_k$$

Figure 2 The first-order model of a motor experiencing kinetic friction

Eventually we will use the motors to control systems. In a simple form the motor can be turned on or off with transistors or relays. However we will want to vary the motor speed continuously over the range of operation. To do this we need a power amplifier that will work over a large range, as shown below. In this circuit the two transistors will drive the motor so that the voltage to the motor matches the input voltage. To do this the TIP 31 transistor will will be on when the voltage to the motor is positive, and current will flow left to right. When the TIP 32 transistor is on the voltage to the motor is negative and the current flows right to left. The transistors are controlled by the op-amp. The op-amp is set up as an inverting amplifier with a gain of -1, but it will provide a current amplification. If it was not present and the transistors drew too much current the input voltage would drop.

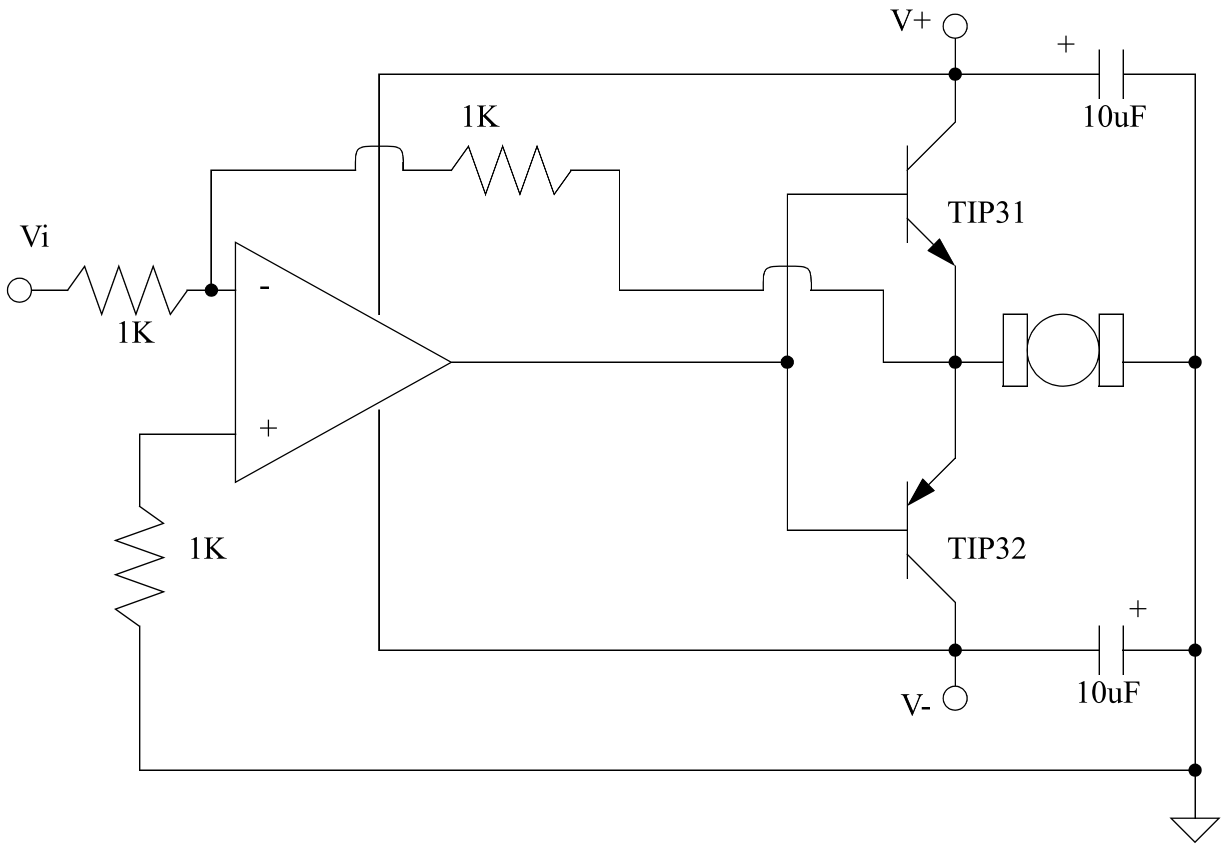
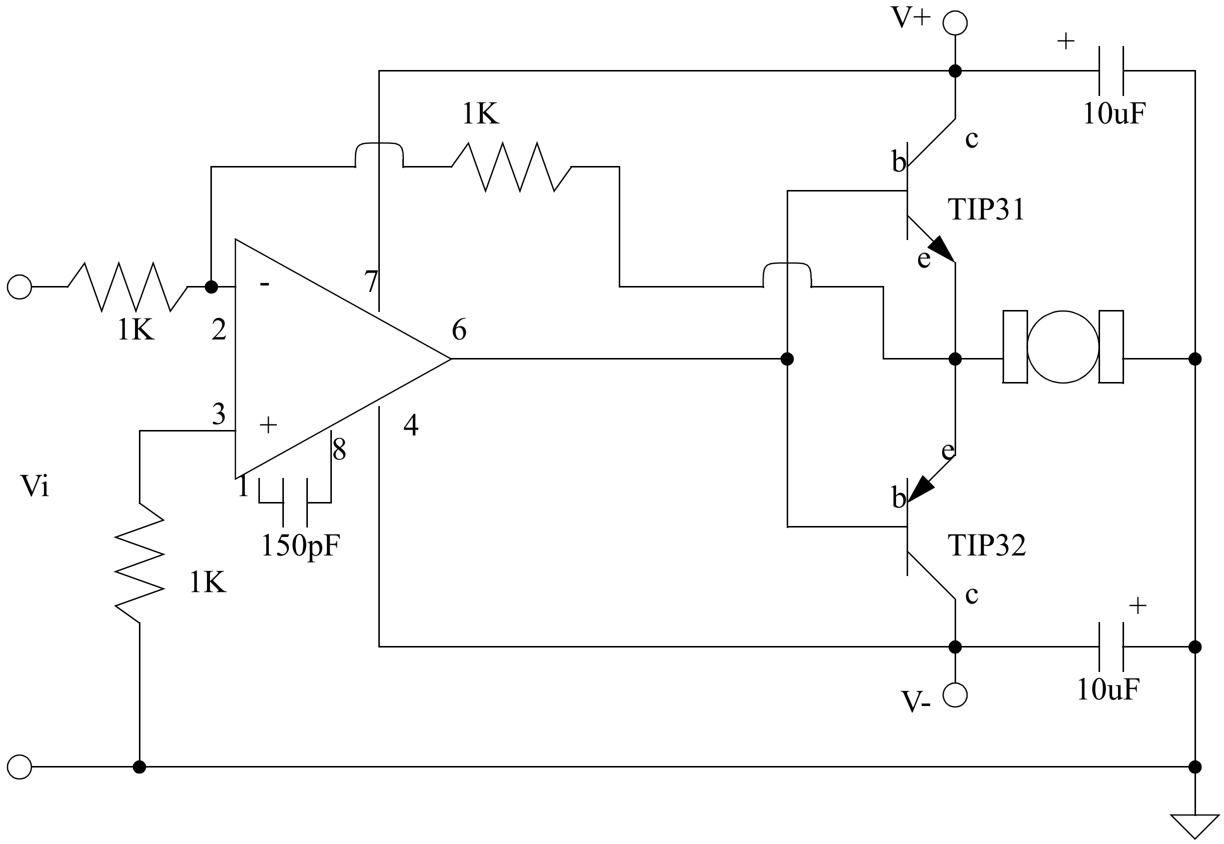


Figure 3 Class AB Amplifier

2.3.2 Procedure

1. Lookup the datasheets for the LM101, TIP31, and TIP32. Review these and make notes to identify the function of the devices. Look on the internet for information on Class A, B and AB amplifiers and make notes.

2. Build the circuit redrawn below. Note: do not turn on the power at this point.



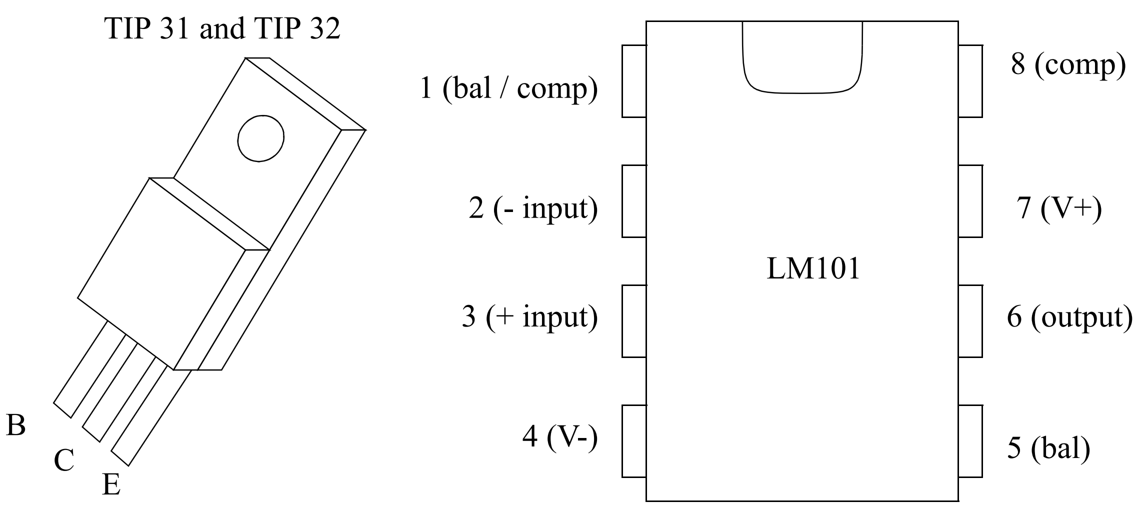


Figure 4 Motor Driver Circuit

3. Connect the input Vi to the power supply on the cadet trainer. This will act as the speed control. Set it to zero to start.

4. Turn the voltage setting on the power supply to zero, and then turn on the cadet trainer and power supply. Use a DMM to monitor the power supply voltage to the circuit and increase it to 5V.

5. Set the input voltage (Vi) to different values and verify that the motor speed varies in both directions. If this is the case the basic motor power amplifier is complete.

6. Connect a similar motor by coupling the shafts of the motors together. The new motor will act as a tachometer.

7. Vary the input voltage Vi and measure the output voltage from the tachometer. Also use a strobe tachometer to measure the speed. Record these in a table and draw these in a graph.

8. Compare the graph to the theoretical predictions.

9. Calculate the motor speed constant. Is it constant?

2.4 Lab - Machining

2.4.1 Theory

2.4.2 Procedure

1. Acquire a piece of round and rectangular stock from Mr. Bero. Drawings will be prepared based upon these pieces.

2. Prepare mechanical drawings for these pieces as directed below. Ideally both will be prepared on A4 paper, but other sizes will be accomodated by permission. Various CAD packages and sketching packages are available. In general drawings should,
    - include a title block and borders
    - be laid out appropriately
    - indicate materials
    - tolerances are expected for ECE students and GD&T for ME/MO/PDM

Note: ME / PDM, and MO students are expected to hold a tolerance of +/- 0.005".

3. The turned (round) part drawing should have the following features,
    - the part should be faced or cutoff
    - the part should be center drilled, or drilled
    - the outside should be turned for a length of at least 1"

4. The rectangular part drawing should have the following features,
    - there should be one face with a slot cut
    - the width of the slot must be a non-standard size.

5. Speeds and feeds should be selected for machining.

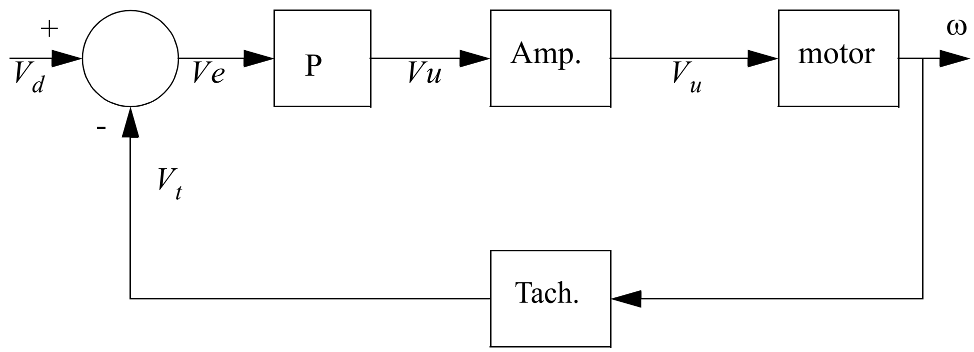
6. After approval the drawings will be manufactured in the machine shop under the supervision of Mr. Bero.

7. Verify the conformance of the parts to the drawings using metrology tools.

2.5 Lab - Feedback Control

2.5.1 Theory

A basic feedback control system is shown in the figure below. In this system the controller will read a velocity signal from a feedback controller and compare it to a desired speed voltage. In this system the desired speed is specified using an input voltage. The deired voltage (Vd) is compared to the feedback voltage (Vt) from the tachometer. The result is the error (Ve = Vd - Vt). This is then passed through a simple proportional controller that amplifies the error by a gain (P) to produce a control output (Vu = P Ve). This output is then used to drive the amplifier produced in last weeks laboratory.



$$V_u = P(V_e) = P(V_d - V_t)$$

Figure 1.1 The complete feedback loop

In the previous lab the Amplifier, motor and tachometer were expolored. This week we will add a proportional feedback controller. A simple circuit based on an op-amp using the inverting op-amp configuration is shown below. This circuit can be manipulated to replace the subtraction and multiplication operations.

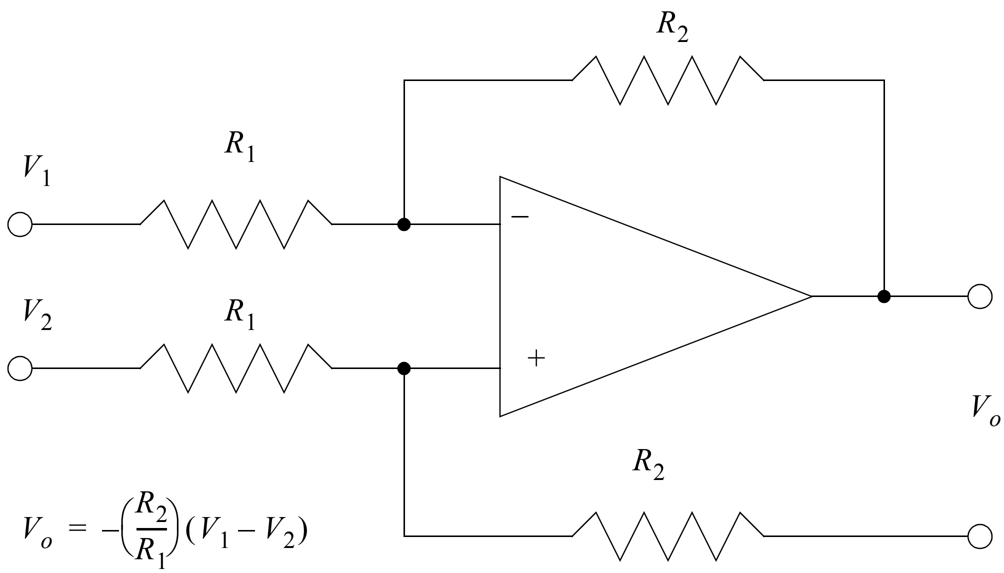


Figure X - A differential Amplifier

2.5.2 Procedure

1. Draw a circuit diagram for the complete control circuit. Select component values. If necessary check with the instructor.

2. Build the class AB amplifier from the previous laboratory and verify the operation.

3. Connect the oscilloscope CH1 (or A) to the function generator on the Cadet Trainer. Verify that the oscilloscope can display the signal.

4. Connect CH2 (or B) to the tachometer and verify that the displayed signal is correct.

5. Connect the input of the amplifier to the signal generator on the Cadet Trainer. Use a sine wave set to a low frequency and observe the results on the oscilloscope. Over a range of frequencies determine the phase shift of the signals.

6. Build the differntial amplifier and verify that it is working properly. Note: For the differential amplifier select components that have very similar values; verify the values with a multimeter.

7. Integrate the amplifier and differential amplifier into the complete control system and verify the operation. Repeat step 5.

2.6 Lab - Basic AVR Board

2.6.1 Theory

2.6.2 Procedure

1. Reach Chapter 1 in the Pardue book for background.

2. Follow Chapter 2 and build the program with the ’Blinky Lights’ program. Include the circuits and program in your notebook. DO NOT TAKE THE CIRCUIT APART YET.

3. Review Chapter 3 and change the blinky lights program to add your own creative twist. The modified program should appear in your notebook.

2.7 Lab - ASCII I/O

2.7.1 Theory

2.7.2 Procedure

1. Review Pardue chapters 4-6. Enter the sample programs and ensure that they operate as expected.

2. Write a program that will interact with a user using a serial data ports. Bits 0-3 of the port will be outputs to LEDs and bits 4-7 will be input bits. The program should allow users to set output bits using 'Sn', where n is the output bit. The user should be able to read input bits using 'Rn' where n is the input bit.

2.8 Lab - Welding Qualification

2.8.1 Theory

2.8.2 Procedure

1. Mr. Bero will provide a demonstration of basic welding technology.

2. Students will be expected to prepare two pieces of materials for a weld and then weld the pieces.

3. The weld should be inspected for final acceptance.

4. The strength of the weld should be predicted and then tested using the tensile test machine.

2.9 Lab - Microcontroller Based Feedback Control

2.9.1 Theory

2.9.2 Procedure

1. Review and do the lab work as outline in Pardue ch. 7.

2. Modify the program to store speed/position data.

3. Put a step input into the control system and measure the step response. Include this in the notebook as a graph and a time constant.

2.10 Lab - Music (or Stepper Motor)

2.10.1 Theory

2.10.2 Procedure

1. Review Pardue ch. 8 and follow the examples.

2(basic). Modify the examples to add a new song.

2(challenge). Connect the board to an H-bridge driven stepper motor. Write a simple program to rotate the motor using ASCII commands.

2.11 Lab - Part Production

2.11.1 Theory

2.11.2 Procedure - ECE

1. Download and install the Eagle PCB layout software (link on the course page)

2. Follow the tutorial (link on the course page).

3. Layout the op-amp schematics, then design a circuit board based upon the feedback controller. Prepare a Gerber file.

4. (With the instructor) mill a circuit board.

5. Add components and test the circuit board.

2.11.3 Procedure - PDM / MO / ME

1. Follow the tutorial on the course home page.

2. Design and mill a tensile test specimen.

3. Calculate the strength of the specimen for yield and failure.

4. Pull the specimen and verify the results.

2.12 Lab - Pneumatics and Sensors

2.12.1 Theory

2.12.2 Procedure

1. There will be a brief demonstration of sensors and pneumatic components.

2. Build a basic pneumatics system, test it using a 3V signal for the inputs.

3. Connect the circuit to the AVR board and write a simple program to control the pneumatics

4. Use a voltage divider to reduce a sensor voltage, verify the range is approx. 3V.

5. Connect it to the AVR board and verify that the inputs can be read.

6. Write a program that reads the inputs from the sensors and controls the pneumatics.

2.13 Lab - Analog I/O

2.13.1 Theory

2.13.2 Procedure

1. Review and test the programs from ch. 9.

2. Create a feedback control program that will monitor the analog temperature input. It should then adjust a PWM output to control a temperature.

3. Build the circuit shown below.

4. Cool the test chamber to room temperature.

5. Set the controller temperature to a new setpoint. Take temperature readings each minute and record these in a table.

2.14 Lab - Structured Programming

2.14.1 Theory

2.14.2 Procedure

1. Review Pardue ch. 10.

2. Modify the Butterfly code to add a new function. XXXXXXXXXXXXXX

2.15 Lab - LCD Control

2.15.1 Theory

2.15.2 Procedure

1. Review Pardue ch. 11.

2. Modify the Butterfly code XXXXXXXXXXXXXXXXXX

2.16 Lab - Mechanical Component Demos

2.16.1 Theory

2.16.2 Procedure

1. Examine a set of bearings. Review spec sheets XXXXXXXXXXXX

2. xxxxxxxxxxxxxxx

3. Projects

Objective: To develop a patentable idea.

Process:

1. Self evaluations will be used to create project groups.

2. Each group will identify a set of 15 problems not solved by current products. The 15 will then be assigned rankings of novelty, easy of development, size of market, and technical complexity. The summary and a spreadsheet will be submitted.

3. The team will select one problem to solve in consultation with the instructor. Current solutions to the problem will be investigated. This will include identifying currently available products and patents. Note: If necessary another problem can be selected. The results will be submitted.

4. A brainstorming session will be used to generate design concepts to solve the problem. At least 5 concepts will be considered and one will be chosen. These will be submitted with a recommended choice. Note: a tool such as a decision matrix can be helpful in making a decision.

5. A detailed design will be prepared including mechanical drawings, circuitry, and source code. These will be submitted.

6. The design will be built and tested.

7. The final results will be documented in patent format.

EGR 604 Project Peer Evaluation

Your Name: ______________________________

Team Number: ______________________

Person Being Evaluated: _______________________

	good				poor
Communicates well:	1	2	3	4	5

Did the teammate return e-mails and other forms of communication promptly? Could the teammate understand, explain and evaluate the technical aspects of the project in a clear concise manner?

Works in team environment:	1	2	3	4	5

Did your teammate come to meetings on time? Did the teammate participate in all aspects of the project? How much did the teammate's efforts contribute to the overall success of the project?

Meets deadlines:	1	2	3	4	5

Did you teammate complete individual tasks on time? Did the teammate keep the project progressing forward in a timely manner with a consistent effort throughout the project or was the teammate only available when the team was in trouble?

Quality of work:	1	2	3	4	5

Was you r teammate willing to accept and carry out individual tasks on time? How well were these individual tasks carried out? Did your teammate do his or her fair share of the work?

Overall:	1	2	3	4	5

Would you be happy working with the person again? Would you give this person a job reference?

Would you hire this person: yes / no

Other Comments:

3.1 NOTEBOOK ENTRIES

Lab - Soldering
Lab - Motors and Tachometers
Lab - Machining
Lab - Feedback Control
Lab - Basic AVR Board
Lab - ASCII I/O
Lab - Welding Qualification
Lab - Microcontroller Based Feedback Control
Lab - Music (or Stepper Motor)
Lab - Part Production (PCB / CNC)

Project - Problems
Project - Concepts
Project - Details
Project - Final Design / Patent

Notes - Jack, Ch. 2 – Drafting
Notes - Jack, Ch. 3 - Metrology
Notes - Jack, Ch. 4 - Cutting
Notes - Jack, Ch. 5 - Joining
Notes - Jack, Ch. 6 - Rotations
Notes - Jack, Ch. 7 – Feedback Control
Notes - Jack, Ch. 8 – Mechanical Transmissions
Notes - Jack, Ch. 9 – Mechanical Issues
Notes - CPFM Ch. 1 - Introduction
Notes - CPFM Ch. 2 – Quick Start Guide
Notes - CPFM Ch. 3 – A Brief Introduction to C
Notes - Jack, Ch. 10 - Sensors
Notes - Jack, Ch. 11 - Actuators
Notes - CPFM Ch. 4 – C Types, Operators, and Expressions
Notes - CPFM Ch. 5 – C Control Flow
Notes - CPFM Ch. 6 – C Functions and Program Structures
Notes - Jack, Ch. 12 – Project Management
Notes - CPFM Ch. 7 – Microcontroller Interrupts and Timers
Notes - Jack, Ch. 13 – Motion Control
Notes - CPFM Ch. 8 – C Pointers and Arrays

Grade for materials submitted Nov 14:

Final Grade: