



LABORATORY ASSIGNMENT NUMBER 3 FOR CMPE 118

Due by 6:00pm on Friday, February 5th, 2010

Pre-Lab Due by January 29th, 2010

Purpose:

This lab is intended to acquaint you with:

- Controlling a DC motor.
- Controlling a stepper motor.
- Controlling an R/C servo.
- Finding information in data sheets.
- Pulse width modulation.
- Phenomena encountered with a DC motor.
- Limitations of techniques implemented purely in software.

Minimum Parts Required:

1 each: DC motor, R/C servo, and stepper motor (provided at each lab station), 1N4744A 15 Volt zener diode, 50K potentiometer. CMPE-118 I/O Board, CMPE-118 Dual H-Bridge, DS3568 High Current Drive, and CMPE-118 Stepper Motor Driver. Ribbon cable connectors and stake headers for the I/O board. See a TA/tutor for any parts you need that are not in your parts kit.

Pre-Lab:

Complete the following exercises AFTER you have read through the lab assignment and BEFORE coming in to complete the lab.

- 0.1) Decide which port and bit(s) you will use to control the motors (all parts of lab).
- 0.2) Decide what, if any, initialization is required for that port.
- 0.3) Describe the mode in which the A/D converter will be operating.
- 0.4) Determine which pins on which cables/connectors you need to hook up.
- 0.5) Determine which ribbon connectors you will need, and how to wire them in.
- 0.6) Draw a fully detailed state diagram for a PWM software driver (this drawing should also be in your lab notebook). Include an example plot of the expected output signal for a given frequency and duty cycle. HINT: using timer events may assist you getting the proper duty cycles for a given frequency.

In the report:

Include a description of which of the port lines on the 9S12C32 you used to implement the control as well as a justification for why you chose to use that (those) particular line(s). Include the answer to question 0.3.

Part 1 Interfacing to a DC Motor and Potentiometer

Reading:

ADS12 and PWMS12 reference documentation, the CMPE118 HC12 IO Board documentation, the CMPE118 DS3658 Module board documentation, the Metrowerks CodeWarrior Quickstart manual.

Assignment:

You are to design the software necessary for the 9S12C32 to drive the supplied DC motor. Motor drive should use Pulse Width Modulation using the provided PWMS12 software module. The speed at which you run the motor should be determined by the setting of an external potentiometer, which your software should read using the A/D converter on the 9S12C32. Your program should

continuously read the voltage set by the potentiometer and set the motor speed directly proportional to the voltage (full scale A/D is full speed). You should be able to exit the program by pressing any key. When you have completed this task, you will be prepared to continue with the laboratory exercises in Part 2. At this point find a tutor or TA and demonstrate Part 1.

Set-Up:

1.1) For this, and the next, part you will be using the CMPE118 DS3658 Module board to drive the DC motor. Since the DS3658 has open collector outputs, you will need to supply the power to the motor separately. To bring the power to your proto-board for connection to the motor, use your banana plug jumpers to bring the power from the positive adjustable outputs to your proto-board.

1.2) Use the +12V voltage source from the power supply for the positive output. Now connect the supply (at the proto-board) to one lead of the DC motor using the connector from the motor assembly. Also, you will need to supply power to the CMPE118 DS3658 Module board, so connect the +12V supply to J4, pin 1 on the DS3658 module, and connect J4, pin 2 to the GND terminal on the power supply.

1.3) Now connect the DS3658's clamp diode for Channels A & B to the motor supply at the proto-board, and the output for Channel A to the remaining lead of the DC motor. The motor should not be rotating at this point, right? If the motor is rotating, this is due to the fact that you haven't hooked up anything to the input of the DS3658, so the state of the input is not guaranteed – it's floating!

1.4) Hook up the 9S12C32 output(s) you selected in the pre-lab to the input of the channel you are using on the DS3658 (use ribbon cable connectors between the IO board and the protoboard).

1.5) Hook the two outer leads from the 50K potentiometer to the **power supply's +5V & GND** terminals. Be **very** careful **NOT** to use the power going to the motor, since that is +12V and will destroy the 9S12C32 once you connect it. After doing this, check to see that the voltage at the wiper (the remaining terminal on the potentiometer) swings between 0 and +5V. You will also use this circuit in Part 5.

1.6) Using one of the jumpers that goes from a wire to a push-on connector, make the connection from the wiper to the pin labeled AN0 on the HC12 IO Board (it's on J12). Make sure you go through the follower board and not directly to the pin. What are the limitations that this imposes? What does it do for the microcontroller? Why might you not want to do this?

1.7) It's finally time to try out your code. In CW12, build your project into an executable file. Then, with the uBug12 window active, turn on (or reset) the 9S12C32 board and type "CON 1" <ENTER>. You should get the connection message. If not, ensure SW1 is in the boot position. At this point you are ready to download your code. Downloading and testing your code should proceed exactly as it did in Lab 0. Before you can download your code, you need to clear the FLASH, so you must type "fbulk" and press <ENTER>. Now, everything is ready for the new code to be downloaded. You need to tell the Terminal window which file to download, so type "fload ;b" and select your file, which should be named something like MOTORLAB.ABS.S19 (the *.S19 file is compiled code in the proper format for downloading). Once your code is finished downloading, the You are now ready to execute your code. Type "go" or restart the 9S12C32 with SW1 in the "Run" position and connect using Tera Term to use serial IO. The proper settings are at 115.2Kbaud, no flow control, and be sure to init the SCI using `TERMIO_Init()`.

In the report:

You must include the wiring diagrams of the circuits you used, noting which bits were used and what connections were made on the HC12 IO Board and the CMPE118 DS3658 Module board, the sign-off sheet, the answers to the questions in part 1.6, as well as a listing of the software used to control the motor. All wiring diagrams and schematics should be completed using the OrCAD Capture program provided on each workstation.

Part 2 Exploring DC Motors

Reading:

CKO Ch. 19, 20, and 21 (on the website)

Assignment:

Complete the following exercises:

Basic Waveforms

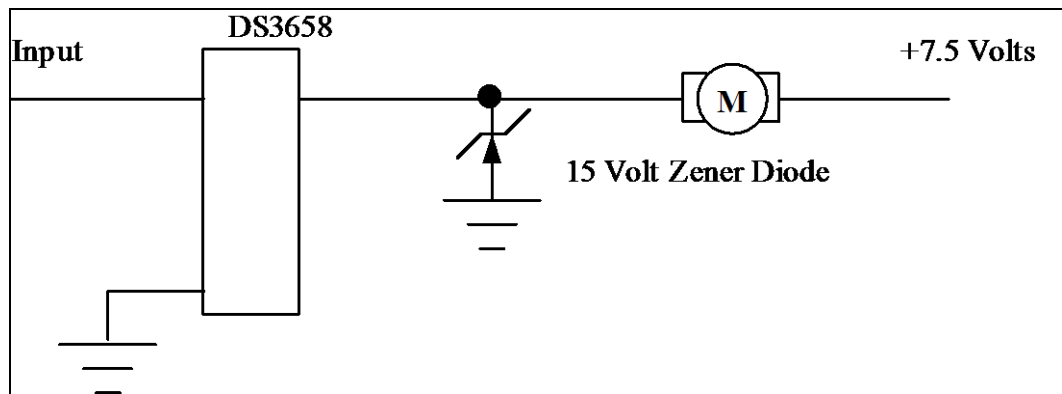


- 2.1) Set the 'scope up for dual trace and examine the waveforms at the input and output of the DS3658. Draw a neat and readable representation of the two wave-forms. Include at least 2 full cycles. Label the parts of the waveform to show the active (driven) portion of the waveform, the decay period as the motor field collapses, the peak of the inductive kickback, and the back-EMF generated by the motor. Do this at 2 duty cycle levels (i.e. 20% and 80%). Make a separate scope face drawing for each. Note the different back-EMF values at the different motor speeds. To best see the back-EMF, you might want to draw a composite of two waveforms, one with the motor stalled (hold the shaft to keep it from turning) and one with the motor turning.

Using a Zener in lieu of the kick-back diode



- 2.2) Disconnect the clamp diode from the circuit and replace it with the 15 volt zener in a configuration like the one shown below. **Note:** the band on the zener diode body corresponds to the horizontal bar in the zener symbol. Repeat the labeled waveform drawing from Part 2.1. Contrast the decay times for the 2 techniques; be specific about durations. To do this you will probably need to use a different time scale on the 'scope. This portion will be most clear if you examine the alternatives at a very low duty cycle (i.e. active for 1 part in 256). This way the effects of back EMF do not obscure the decay time. From this exercise you can see how a zener protects the output transistor by limiting the peak voltage to the zener voltage, and at the same time minimizes the decay time of the collapsing field. It is important to minimize this decay time in order to make the duty cycle response of the motor as linear as possible. At very high duty cycles it would be possible for a long delay time to completely overlap the un-driven portion of the waveform.



The Limits of Software control



- 2.3) Using the oscilloscope and/or the counter-timer, determine the frequency of the duty cycle waveform that you are generating. What is the frequency?



- 2.4) Can you find a way to increase the operating frequency? (Look at how to shorten your cycle time to the minimum.)



- 2.5) What happens to the upper frequency limit if we only have 7 bits of resolution? How about 10 bits? We are making a trade-off between resolution and frequency of operation.

- 2.6) Given a resolution, what is the key parameter in determining the total period of the PWM signal?
- 2.7) Can your solution achieve a full range of operation? (i.e. What happens if you try to get 0% or 100% duty cycle). If it can't, don't try and fix it, just explain why it won't work.
- 2.8) For a given duty cycle, what are the sources of error in the approach you have chosen? (i.e. if you ask for 50% duty cycle do you get it? ...theoretically, that is, you probably will not be able to measure the error.)

In the report:

Several scope face drawings are requested; please make your drawings legible. Using different colors for different waveforms is helpful. Include the discussion requested in Part 2.2. Be sure also to include in the lab report your answers to the all the questions in Parts 2.3-2.8. **To ease the grading task please quote the question you are answering before your answer. This way the grader can read the question you think you are answering followed by your answer.**

Part 3 Interfacing to a Stepper Motor**Reading:**

CKO Ch. 23 (on website), the CMPE118 A3949 H-Bridge Driver Module documentation, STEPS12 software module documentation.

Assignment:

You are to design the necessary software to run on the 9S12C32 to drive the supplied stepper motor in Full Drive, Wave Drive, and Half-Step Drive modes. After demonstrating this to the TA or tutors, you will use a hardware stepper driver to drive the same motor.

Set-Up:

- 3.1) For this part, you should use the CMPE118 A3949 Dual H-Bridge Driver Module board.
- 3.2) You will need to connect power and ground to J3 of the CMPE118 H-Bridge Module, which will in turn supply current to the stepper motor. Note that you must supply it using the +12V source. J4 of the CMPE-118 H-Bridge Module will need to be interfaced to the PortA on 9SC32 as follows to work properly with the STEPS12 module:

DA (J4.4) connected to PA1, EA (J4.3) to PA0, DB (J4.8) to PA3, and EB (J4.7) to PA2. Note: the motor drive board and I/O board need to have a common ground (back at the power supply).
- 3.3) You will have to probe the motor wires to determine which wires correspond to which coils and then connect those wires to the proper motor outputs on the Drive Module. Use the STEPS12 software module to control the Drive Module and ensure the motor rotates properly with the provided modules. You will need to experiment with the motor coil polarities to get the motor to rotate. If at first you don't succeed, try, try again (there are only a few possibilities)
- 3.4) Now, edit the STEPS12 module to drive the motor using Wave Drive and Half-Step Drive. You will have to edit the state machine outputs and add additional states.
- 3.5) After verifying your motor can be driven all three ways, increase the frequency until it stops stepping. How fast can you go under each mode of operation?
- 3.6) Now run the motor forward a complete revolution then in reverse for a complete revolution—did you lose steps? How fast can you operate the motor without losing steps (for accurate positioning)?
- 3.7) After demonstrating the above code to the TAs/Instructors and getting signed off, get one of the CMPE-118 Stepper Motor Driver boards. These boards have only two control signals, step and direction, and a jumper to select Full or Half-Step Drive, as discussed in the attached description of the module. You will now have to write code to produce these signals.



- 3.8) Repeat parts 3.5 and 3.6 using the stepper driver under both Full and Half-Step operation. How did this compare to your software driver? Demonstrate the working stepper module to a tutor or TA for check off.

In the report:

Include the wiring diagram of the circuit you used, a copy of the code that drives the stepper motor, discussion of the performance differences between hardware and software stepper drivers, and the sign-off sheet from the coach. Be sure to indicate on the diagram which bits of which ports of the 9S12C32 you used.

Part 4 Interfacing to a DC Motor and H-Bridge**Reading:**

The CMPE 118 A3949 Dual 2.8A H-Bridge Module documentation.

Assignment:

You are to duplicate the functionality of Part 1, this time using the H-Bridge to drive the motor. You will also need to add a little complexity. You should include a provision to change the direction of rotation of the motor. When you have completed this task, get a tutor or TA to sign off on its function. For this section of the lab, you should use the supplied libraries providing PWM output.

Set-Up:

- 4.1) You will need to add a power connector to supply power to the H-bridge on the A3949 Dual 2.8A H-Bridge Module. Connect power and ground to J3 of the module.



- 4.2) You will need to supply enable and direction inputs to the module. Remember to bring ground back to the power supply for both the module and I/O board.



- 4.3) Experiment and determine the maximum and minimum frequencies you can use to properly drive your motor at a given duty cycle.

In the report:

Include the wiring diagram of the circuit you used, a copy of the code that drives the DC motor and the sign-off sheet from the coach. Be sure to indicate on the diagram which bits of which ports of the 9SC32 you used.

Part 5 Driving an R/C Servo Motor**Reading:**

CKO Ch. 24 (especially section 24.3)

http://www.societyofrobots.com/actuators_servos.shtml

Assignment:

You are going to drive an R/C servo with position feedback. By adjusting the duty cycle of a fairly slow PWM signal to the servo, you command a position for the head to go to and hold. Just as you read an analog value of 0-5V and adjusted the speed of the DC motor, you will now read that same voltage and position the servo motor to correspond to the voltage. When reading 2.5V on the A/D, the servo should be in the neutral position, with 0V positioning it at one end of the range and 5V positioning it at the other.

Set-Up:

- 5.1) **Important note:** the R/C servos can only take +5V, so DO NOT connect them to a higher power supply, you will kill them. Power the servos off of +5V from the power supplies, again making sure NEVER TO EXCEED THIS—you will break the feedback circuitry around the motor. Eventually (like in your final project) you may need to use a linear regulator to get +5V from your batteries, but you will be wasting lots of power as heat—you will need a heatsink.



- 5.2) Connect the servo on the motor drive lab board to +5 on the RED wire, and GND on the BROWN wire. Connect a wire from your I/O board to the ORANGE signal wire (your I/O board and the servo need to have a common ground connection back to the power supply).



- 5.3) The servo is a position feedback device. That is, it will go to and hold a specific position that ranges from about +90 degrees to -90 degrees, with a 1.5ms pulse being CENTER. We will

provide a routine to produce this signal, and it will be up to you modify it further to produce a range of duty cycles.

- 5.4) Experiment and determine the minimum change of the pulse high time that results in motion of the servo head.
- 5.5) Experiment and determine the minimum and maximum duty cycles that the servo is able to respond to. How do these limits and the neutral duty cycle correspond to head position?
- 5.6) Use the potentiometer from Part 1, after first checking that it stays within the range 0-5V, to command a position of the servo. When sweeping from 0-5V the servo head should follow from -90 degrees to +90 degrees. If the servo introduces noise on your power and this is affecting your A/D readings, bypass your potentiometer with a capacitor to smooth it out.
- 5.7) Show the completed servo control to the tutors or TA for your final checkoff.

In the report:

Include the wiring diagram of the circuit you used, a copy of the code that drives the servo motor, a discussion of the behavior of the servo as relating to questions 5.4 and 5.5, and the sign-off sheet from the coach. Be sure to indicate on the diagram which bits of which ports of the 9SC32 you used.

Hints on working this assignment

When you go into the lab, follow a well thought-out and systematic approach to testing both the hardware and the software. It is a good idea to get into the habit of testing your software, as much as possible, separately from testing your hardware.

If you really did your preparation properly, you should come into the lab ready to build and test the hardware in Part 1. **If you have spent more than one hour on any single task, after coming in prepared as described above, something is wrong! STOP and ask a TA or your neighbor to take a look at what you are doing.** Often a new look will spot simple problems that you've missed.

Lab #3**Time Summary**

Be sure to turn this in with your lab report

This information is being gathered solely to produce statistical information to help improve the lab assignments.

Pre-Lab	Preparing Outside of the lab _____	In the lab working this part _____
Part 1	Preparing Outside of the lab _____	In the lab working this part _____
Part 2	Preparing Outside of the lab _____	In the lab working this part _____
Part 3	Preparing Outside of the lab _____	In the lab working this part _____
Part 4	Preparing Outside of the lab _____	In the lab working this part _____
Part 5	Preparing Outside of the lab _____	In the lab working this part _____
Report	Preparing the Lab Report _____	