CMPE 460 Laboratory Exercise 6

Motor Control

Hunter Culverhouse, Gloria MBaka
Performed: 03/06/24
Submitted: 03/27/24

Lab Section: L1
Instructor: Prof. Ketout
TA: Jack Sipley
Andrew Tevebaugh
Colin Vo

Lecture Section: 01
Professor: Prof. Ketout

By submitting this report, you attest that you neither have given nor have received any assistance (including writing, collecting data, plotting figures, tables or graphs, or using previous student reports as a reference), and you further acknowledge that giving or receiving such assistance will result in a failing grade for this course.

Your Signature: ______________________________

1 Lab Description

This exercise explored three different types of motors, a DC motor, stepper motor, and servo motor. First, code was written, enabling the TimerA0 module, to control the motors. Before controlling any motors, a 20% duty cycle signal at 10KHz was generated and displayed using an oscilloscope. The output signal capture can be seen in Figure 4. In order to control the DC motor, an SN754410 H-bridge was connected to the MSP432P and DC motor as seen in Figure 1. The motor was then run going forward and backwards. The stepper motor was then investigated. Code was written to control the stepper motor using four GPIO ports 4.1, 4.2, 4.3, and 4.4. A ULN2068 darlington array was then connected between the MSP432 and the stepper motor as seen in Figure 2. The stepper motor was then run going forward and backward. Finally, the servo motor was investigated. Since stepper motors are PWM controlled, code was written to control the servo motor utilizing the TimerA2 module to create a 50Hz signal, fluctuating the duty cycle to move the mote. An oscilloscope was used to capture the signal generated as seen in Figure 5. As before, the servo motor was connected as seen in Figure 3, and then run, changing the duty cycle to 0.05, 0.075, and 0.1 to move the motor left, center the motor, and move the motor right respectfully. Code was then written to control two DC motors and a servo motor. The 10KHz signal and the 50Hz signal were then captured on an oscilloscope as seen in Figure 6. In the capture, the top (orange) waveform is the 10KHz signal while the bottom (green) waveform is the 50KHz signal. The code was then uploaded to the TI Cup Car and run. All motors functioned as expected.

2 Code Description

In order to created a PWM signal to control the motors, the TimerA0 and TimerA2 modules must be used. These modules were initialized by making functions that took in inputs of period, percent duty cycle, and pin. The period input was an integer input defined as system core clock frequency divided by the frequency of the signal desired. The percent duty cycle input was a decimal percentage, between 0.0-1.0, of the duty cycle desired. Finally, the pin input was an integer from 1-4, this indicated which pin, P2.4-P2.7 respectively, of the MSP432 the TimerA0 module outputted to. The CCR[0] register was set to the period and the CCR register representing the pin desired was set to the period multiplied by the duty cycle. Finally, the CCTL register output mode was set to Reset/Set and CTL register was set to count up, the source clock set to the SMCLK, and then cleared the timer. The TimerA2 module was initialized similarly, except the pin input only took in the value '1' as the only output pin for TimerA2 was P5.6. Functions were then created to change the duty cycle of each TimerA module. The TimerA0 was then used to control the DC motor and the TimerA2 was used to control the servo motor. To control the stepper motor, pins P4.1-P4.4 were set to GPIO. Each pin was then enabled individually to control the motor.

3 Wiring Diagrams

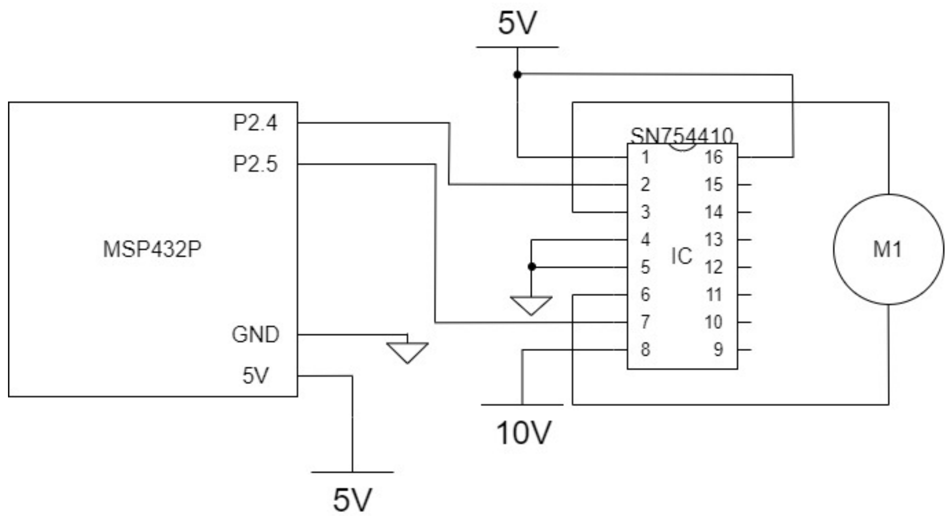

Figure 1: DC Motor Schematic

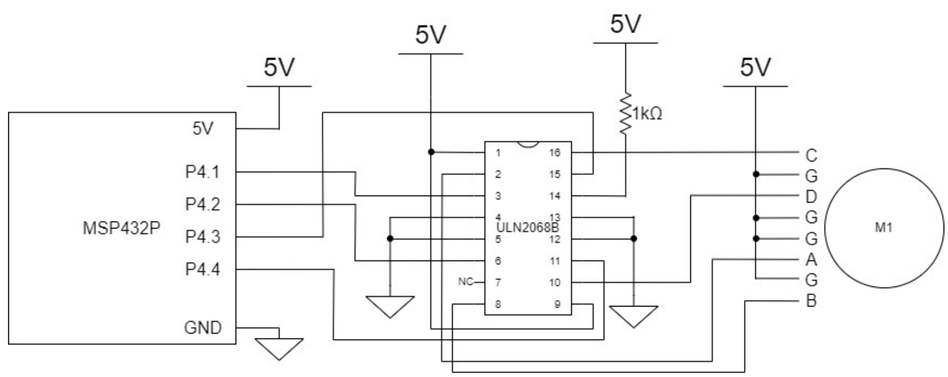

Figure 2: Stepper Motor Schematic

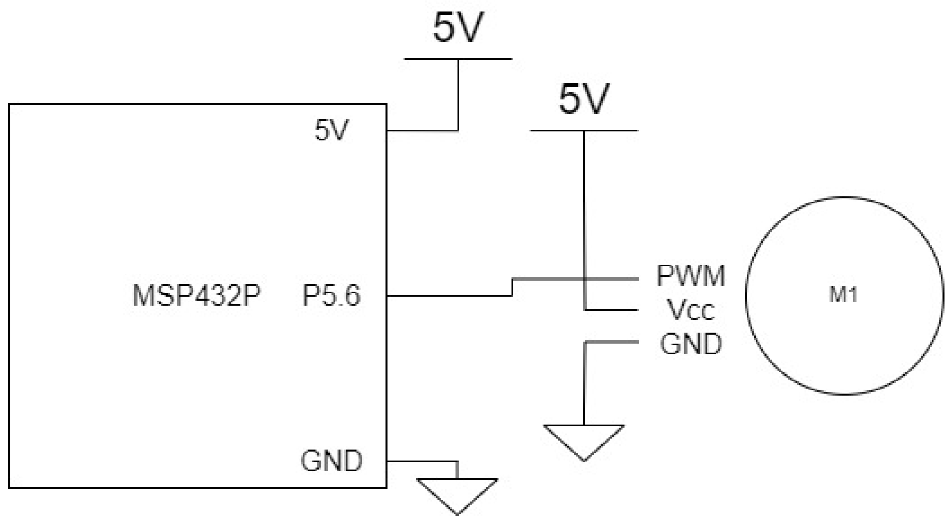

Figure 3: Servo Motor Schematic

4 Oscilloscope Captures

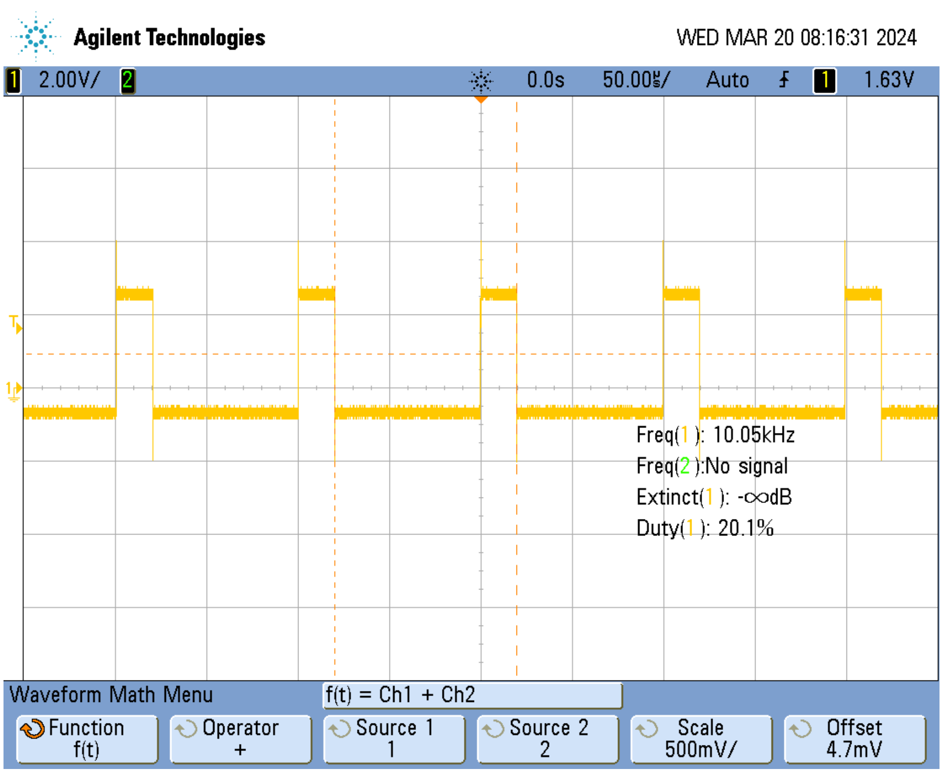

Figure 4: 10KHz, 20% Duty Cycle Oscilloscope Capture

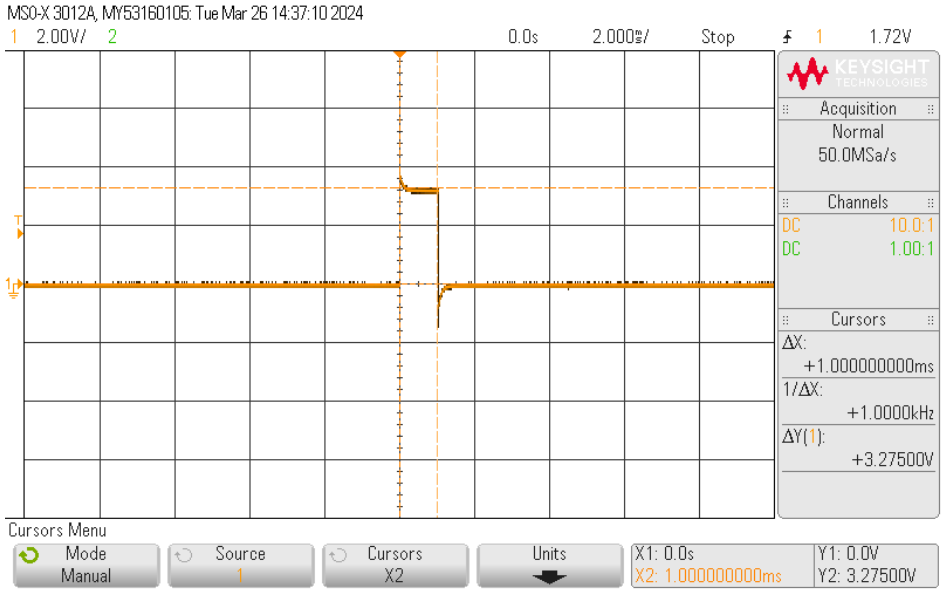

Figure 5: 50Hz, 0.075% Duty Cycle Oscilloscope Capture

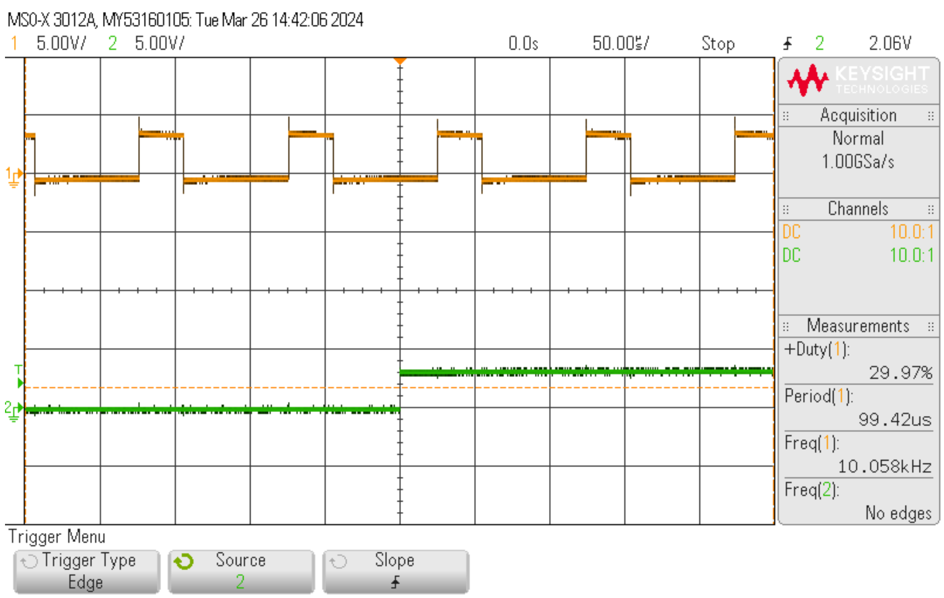

Figure 6: 10KHz, 30% Duty Cycle and 50Hz, 0.075% Duty Cycle Oscilloscope Capture

5 Questions

Pre-lab questions:

1.
(a) Motor Stall torque before reduction: 2.083 Oz-in
(b) Maximum current draw: 1.4A

(c) Maximum motor turn speed before reduction: 6.3kRPM
(d) Maximum torque after reduction: 4.5Kg-cm
(e) Maximum turn speed after reduction: .21kRPM

2.
(a) Purpose of the diodes:
The diodes in the diagram are connected in parallel to each transistor. These are called clamp diodes or recalculating diodes. They serve a critical purpose in motor control circuits. When the motor is turned off or when the direction of current is changed rapidly, the inductive nature of the motor generates a high voltage spike due to the collapsing magnetic field. Adding diodes in this fashion gives the current a safe path to the source., protecting the transistors from being damaged by these potentially high voltages.

(b) Purpose of the capacitor:
The capacitor (0.1 µF) is connected across the power supply lines near the motor. This capacitor helps to smooth out voltage fluctuations and noise on the power supply line. This noise can be generated by the rapid switching of the transistors and by the motor itself due to its inductive properties. When a voltage spike occurs, the capacitor will try to absorb the energy, when a voltage dip occurs, the capacitor will discharge energy. By filtering out this noise, the capacitor helps to protect the motor and the transistors from erratic behavior and provides a more stable operation.

(c) Transistors in pairs:
The transistors are arranged in pairs (2N3904 with TIP31 and 2N3906 with TIP42) to control the motor in both directions. Each pair forms a half-bridge, and together, the two half-bridges make up the full H-Bridge. By activating a diagonal pair of transistors, the motor can be made to run in one direction; by activating the opposite diagonal pair, the motor runs in the other direction. This arrangement allows for both the direction and the speed of the motor to be controlled by applying the appropriate signals to the transistor bases.

(d) Use of different transistors:
The 2N3904 and 2N3906 are general-purpose transistors used for signal processing or low power applications. In this circuit, they are likely used to interface with the control logic, such as a microcontroller, which operates at a lower current. They act as the initial switch to trigger the larger TIP31 and TIP42 transistors, which are power transistors capable of handling the high currents required by the motor. The 1kΩ resistors limit the base current into the transistors, protecting them from damage due to overcurrent.

How to change speed and direction of turn of the DC motor:
To change the speed of a DC motor, the duty cycle must be increased. Due to the motor being DC controlled, a greater duty cycle creates a longer pulse width, supplying the motor with more charge. To change the direction of a motor, the positive and negative terminals must be switches.

Alternative method that only uses 1 PWM line and GPIO line to change DC motor direction:
In order to control the direction of a DC motor utilizing a single PWM line and single GPIO line, you can toggle the GPIO line to change the direction.
Which stepping mode does stepping code use:
A full-step mode was utilized as the motor only completed a single step every time it moved. This was due to only a single GPIO pin being activated at a time.

Exercise 6: Motor Control

<table>
<tr><th colspan="2">Report</th><th>Point Value</th><th>Points Earned</th><th>Comments</th></tr>
<tr><td colspan="2">Exercise Description</td><td>5</td><td></td><td></td></tr>
<tr><td colspan="2">Circuit Schematics/Wiring diagrams</td><td>10</td><td></td><td></td></tr>
<tr><td rowspan="2">Oscilloscope Captures</td><td>20% Duty Cycle</td><td>5</td><td></td><td rowspan="2"></td></tr>
<tr><td>TI Car</td><td>5</td><td></td></tr>
<tr><td colspan="2">Code Explanation</td><td>5</td><td></td><td></td></tr>
<tr><td colspan="2">Questions</td><td>10</td><td></td><td></td></tr>
<tr><td colspan="2">Total for prelab, demo, and report</td><td>100</td><td></td><td></td></tr>
</table>

Exercise 6: Motor Control

Student's Name: Gloria Mbaka / Hunter Culverhouse Section: 01

PreLab		Point Value	Points Earned	Comments
PreLab	Motor Calculations	10	10	AJT 3/6
	H-Bridge Questions	10	10	

Demo		Point Value	Points Earned	Date
Demo	20% Duty Cycle at 10kHz	10	10	JTS 3/20
	DC Motor Functionality	5	5	AJT 3/20
	Stepper Motor Functionality	5	5	RH 3/26
	Servo Motor Functional ity	5	5	MT 3-26
	Simultaneous TI Car Motors-Servo Motor	15	15	MT 3-26

To receive any grading credit students must earn points for both the demonstration and the report.