CMPE 460 Laboratory Exercise 6

Motor Control

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Lab Section: 2
Instructor: Professor Beato
TA: Brunon Sztuba
Eri Montano
Connor Henley

Lecture Section: 1
Professor: Professor Beato

Your Signature: ______________________________

Lab Description

The purpose of this lab was to use the K64 to control the speed and direction of both DC motors and stepper motors, using Darlington arrays and H bridges. In addition, the K64 was also used to drive a servo motor. The last objective was to interface the K64 with the NXP car to move the servo motor's position while the rear wheel DC motors were running simultaneously.

Circuit Schematics

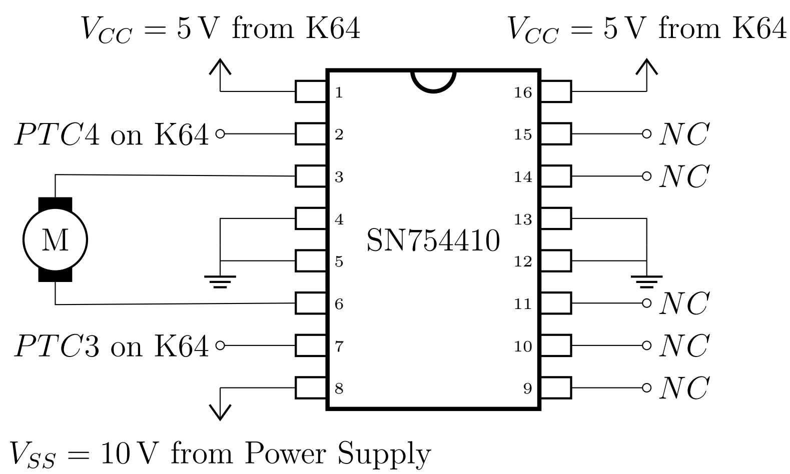

Figure 1: DC Motor Darlington Array Schematic

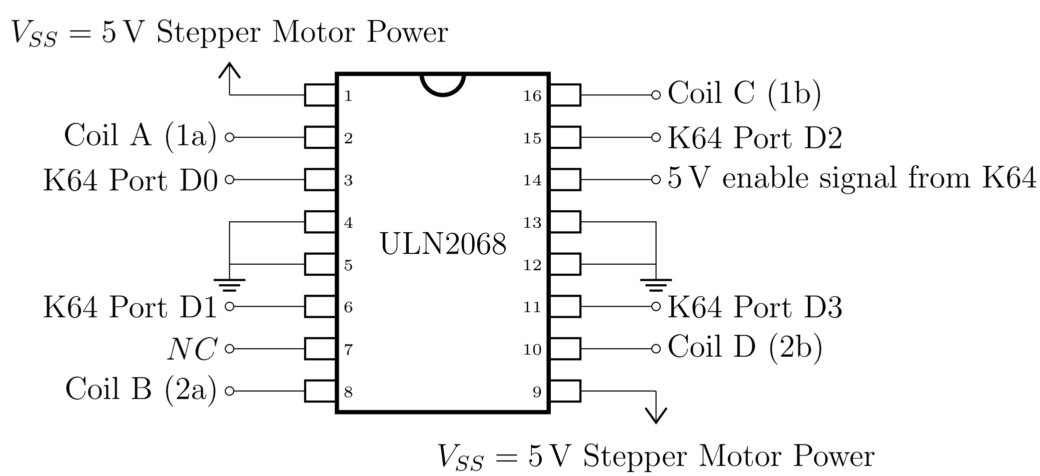

Figure 2: Stepper Motor Darlington Array Schematic

Pre lab Questions

Question 1

a) Torque of the motor = 0.1533 kg-cm, 2.1293 oz-in
b) Maximum current draw = 1.4 A
c) Maximum motor turn speed before gear reduction = 6 krpm
d) Maximum torque after gear reduction = 4.5 kg-cm, 62.49 oz-in
e) Maximum turn speed after gear reduction = 0.20 krpm

Question 2

a) The diodes prevent the kickback current from burning out the transistors.
b) The capacitor provides a smoother input current from the power supply and will absorb any excess current if there is a spike as the motor changes direction.
c) The transistors are in pairs because they must provide a voltage difference across the motor to get it to spin, so they have to provide a path to power and a path to ground, so the motor can spin. In addition, the transistors are in pairs to allow the motor to spin in both directions.
d) The 2N3904/ 2N3906 transistors are small signal transistors. They can only dissipate a max of 625 mW, which is not enough to handle the power signal to the motor. Their purpose is to act as the logic to turn on the higher power rated transistors that handle passing current to the motor. The TIP31/ TIP42 transistors can dissipate a maximum power of 40 W, which is sufficient to pass a high amperage to the motor when the motor is powered. If the 2N3906/2N3906 transistors were used in place of the TIP31/TIP42 transistors, they would either burn out instantly when the normal motor power supply was connected, or the motor would barely spin because the maximum amount of current that could be passed to the motor is close to 200 mA, which is nowhere near the amount of current required to drive the motor (1.4 A).

Oscilloscope Captures

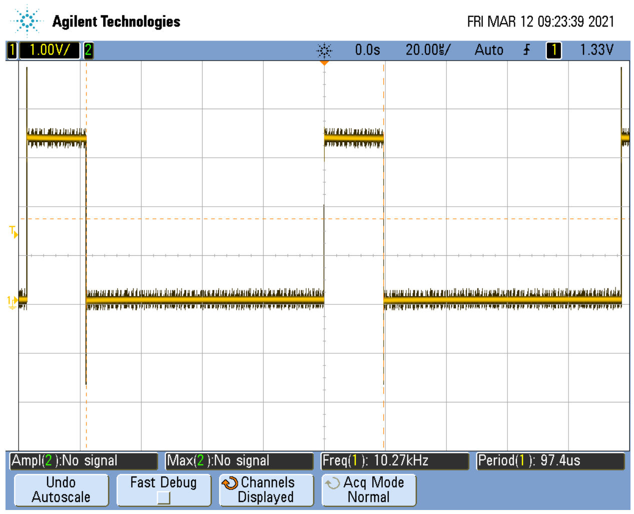

Figure 3: Oscilloscope Capture for DC Motor at 10 kHz and 20% Duty Cycle

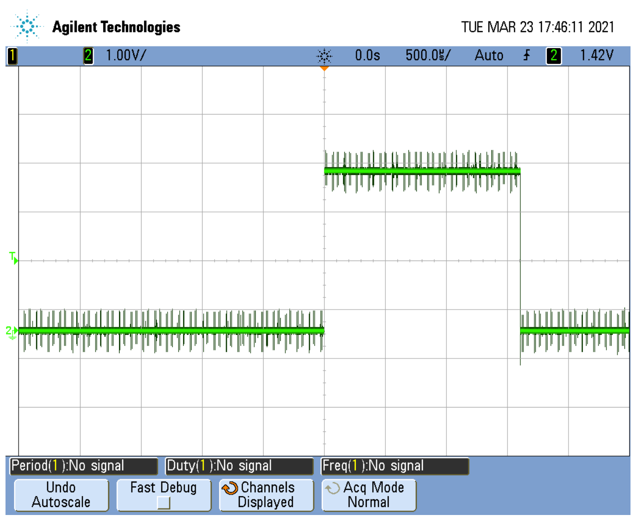

Figure 4: Servo Oscilloscope Capture for NXP Car Cup

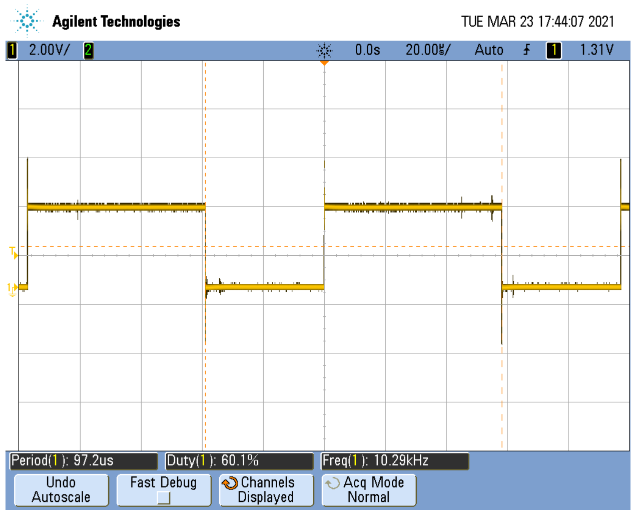

Figure 5: DC Motor Oscilloscope Capture for NXP Car Cup

High Level Code Overview

The provided code enabled the FlexTimer Module to drive a DC motor. The initialization first enabled the module clock and the Port C clock. Each FTM has multiple channels to utilize.Two different channels, channel two and channel three, were routed to PTC3 and PTC4. Next, write protection was disabled to allow for more changes to be made to the module. The counter was then initialized to 0 and the modulo register was set. Each channel being used was then configured to generate an edge-aligned PWM. One channel was configured to generate high true-pulses and the other low. This is because the DC motor is able to be driven based on the difference between the channels. Lastly, the prescaler was set to 1 and the Timer Overflow Interrupt Enable bit was set.

A function was then created to set the duty cycle for the FTM. Given a duty cycle, a frequency, and a direction, the different channels were given mod values. With one channel having a PWM signal and the other being 0, the difference was able to successfully drive the DC motor. By varying the duty cycle of the PWM signal, the speed of the motor was changed. In addition, by varying which pin the PWM signal was sent out on (PTC3 vs PTC4), the motor direction was changed.

The stepper motor used GPIO signals to power each coil in a circular fashion. The Port D clock was enabled and four different GPIO pins were each set to outputs. After each was initialized as a 0, a loop was used to cycle through and turn each one on in order. Based on a directional flag, the motor was able to be driven either clockwise or counter-clockwise.
There are several different FlexTimer Modules, each having several different channels available. Both DC motors on the car should be driven independently and were therefore given independent channels. The previous discussion on the DC motor was applied to the car's motors. While both wheels were using FTM0, the left wheel used channels two and three while the right wheel used channels zero and one. For this exercise, the wheels were driven

using the same signal.

The servo motor on the car also used one of the FlexTimer Modules. FTM3 channel 4 was used. A similar setup process was used for the servo module as was used for the DC motor module. The clocks were enabled for both the module and the output pin. In this case, PTC8 was used as the output. The mux was configured to enable the FTM3 output. Write protection was disabled and the counters were initialized to zeros. The modulo register was initialized and the output PWM signal was configured to be edge-aligned with high-true pulses. The prescaler value was set to 128 to allow for the clock to be divided down enough to run the servo at 50 Hz, and the Timer Overflow Interrupt Enable bit was set. Finally, the IRQ was enabled. A function was created that took in a duty cycle. A value was calculated and the output was set based on the provided duty cycle. The duty cycle determined the position that the servo would rotate to.

In Lab Questions

The speed of the DC motor is controlled by the duty cycle of the PWM signal. Sending a 0% duty cycle will have a speed of 0, and the motor won't turn. Sending a 100% duty cycle will spin the motor at its maximum speed. The direction is controlled through the Darlington array or H bridge used, depending on which lead to the motor has the PWM signal, and which lead is sent low to GND. Switching the terminals either in software or hardware will spin the motor in the opposite direction.

An alternative to using 2 PWM lines is to use one PWM line and 1 GPIO line from the K64. The PWM line is fed into the ENABLE pin on the Darlington array, rather than one of the terminals that is directly connected to the motor. Then, the GPIO line sends out a digital signal indicating the direction. That line is connected to one of the motor control input pins on the H bridge, and then the other motor control input pin is fed the direction signal after it gets sent through a 7404 inverter. This way, the direction pins are opposite, and will drive the motor when the ENABLE is high. Because the ENABLE is driven by the PWM signal, it will alternate being on and off, which will control the speed of the motor.

The stepper motor used in lab is a unipolar stepper motor.

The stepper motor used in lab uses full step low torque mode.

Signoffs

Exercise 6: Motor Control

Student's Name: Jacob Meyerson Section: 2

PreLab		Point Value	Points Earned	Comments
PreLab	Motor Calculations	10	10	GL 3-12-21
	H-Bridge Questions	10	10	GL 3-12-21

Demo		Point Value	Points Earned	Date
Demo	20% Duty Cycle at 10kHz	10	10	XB 3/12/21
	DC Motor Functionality	5	5	XB 3/12/21
	Stepper Motor Functionality	5	5	XB 3/18/21
	NXP Cup Signal Generation	5	5	BJS 3/19/21
	Simultaneous NXP Car Motors	15	15	BJS 3/19/21

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

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Exercise 6: Motor Control

Student's Name: Charlie Poliwoda Section: 02

PreLab		Point Value	Points Earned	Comments
PreLab	Motor Calculations	10	10	CH 3-12-21
	H-Bridge Questions	10	10	CH 3-12-21

Demo		Point Value	Points Earned	Date
Demo	20% Duty Cycle at 10kHz	10	10	XB 3/12/21
	DC Motor Functionality	5	5	XB 3/12/21
	Stepper Motor Functionality	5	5	XB 3/18/21
	NXP Cup Signal Generation	5	5	BD 3/19/21
	Simultaneous NXP Car Motors	15	15	BD 3/19/21

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