

CSE 3215 Embedded Systems Laboratory

Lab 4: Stepper Motor Control

Introduction

Stepper motors are electrical motors that rotate in discrete steps. Stepper motors come in two types Unipolar and Bipolar. Unipolar motors are comprised of two coils wound on the same bobbin with a total of four coils per motor. Operating a Unipolar motor is accomplished by energizing each coil sequentially. Bipolar motors have only two windings and require a push-pull driver to operate. Stepper motors are specified with a typical operating voltage, step angle and holding torque. They can be driven/controlled in single step or continuous rotation mode. Other phrases you will hear when dealing with stepper motors are full-step, half-step, and micro-stepping, these refer to the step angle that the motor will rotate at. Full-step rotation is obtained by a four-step switching sequence. Half-step rotation is obtained by an eight-step switching sequence (see Table 1). Half-step rotation is preferable for a smoother continuous rotation. Micro-stepping is more complicated and is a technique used to decrease the motor's step angle by controlling the motor's phase current ratio. The motor's speed of rotation is based on the rate at which the coils are energized, the faster you energize the coils the faster it will rotate. However, there is an upper limit for the speed. The range of smooth speed depends also on the inertial momentum of the load. The rotation direction is determined by the order the coils are energized.

Lab Equipment

1. Dragon 12 board
2. Wiper blade module
3. Power supply PS-3330
4. Test equipment : Oscilloscope and Logic analyzer

Objectives

The objectives of this lab are to provide you with a brief introduction to controlling stepper motors, and to give you a better understanding of how to use interrupts when controlling external hardware. To meet these objectives you will design an interrupt driven stepper motor controller that will operate in a similar fashion to a two speed with variable delay windshield washer wiper blade on a car. The motor you will be using is a unipolar stepper motor with a step angle of 3.0 degrees. The motor supply voltage is listed on the wiper blade module.

Specifications

The motor controller will operate as follows:

Power Up

1. The controller will be turned off and set for 1Hz continuous operation (i.e. one 'wipe' per second) on initial execution of your code.
2. If the wiper blade is somewhere between the Home and End positions at start up the controller must first move the wiper blade to the End position then back to Home and stop.

Control

1. SW5 acts as an ON/OFF switch, actuating SW5 toggles the controller ON and OFF. When turned on the wiper blade will operate according to the previous operating mode and the current speed setting.
2. The controller has two modes of operation, continuous and delay that are selected by SW2. Actuating SW2 toggles the controller between the two modes.
3. The stepper motor has 120 full steps per one revolution (for 3.0°/step or 240 steps for the 1.5°/half-step version). Table 1 shows the stepper motor phase control at half step mode (1.5°/half-step). The lever arm limits the stable operation of the stepper motor between 6.25 ms/halfstep and 12.5 ms/halfstep. This will define the fast and slow speed setting of the wiper. The angle between the HOME and END positions is approximately 130°. The pulse width from the optical sensors for HOME and END at fast speed is about 0.8 ms.
4. Use SW1[8] for switching between slow and fast speed of the wiper.
5. In delay mode the wiper lever stays a predetermined time at the END position. Select a few sections of SW1 for setting of different time intervals for lever at the END position. Range and precision of delay settings are given below

Movement

1. When the controller is turned OFF with the wiper blade somewhere between the HOME and END positions the controller must, depending on the current direction of travel: 1) If on the return to home phase then continue moving to the HOME position and Stop. 2) if on the travel to end phase then continue moving to the END position then move back to the HOME position and stop. Movement should during these homing movements should be at the current set speed but there should be no delay at the end position.
2. If the mode is switched while the wiper blade is between the HOME and END positions the controller must, depending on the current direction of travel: 1) continue moving to the HOME position and then continue with the new mode

setting. 2) Continue moving to the END position then move back to the HOME position and continue with the new mode setting.

3. When the wiper blade is operating in delay mode the wiper blade will move from the home position to the end position once every 1 to 16 seconds at the slowest speed setting. The delay setting is selectable via SW [1..4], which codes the wiping rate in seconds as a binary number.
4. Use the state table given in Table 1 to drive the motor in a half-step configuration. Transition backwards through the table reverses the motor direction.

Home & End Position Sensors

Two Optek OPB804 slotted optical sensors are used to detect the HOME and END positions of the wiper blade. These sensors are comprised of an infrared emitter and detector pair mounted in the same package. The sensor output is at a TTL high when the infrared beam is blocked and is low when the optical path is clear. The HOME position sensor is mounted on the apparatus such that the wiper blade is parallel with the horizontal axis when at rest. The END position is mounted approximately 135° from the HOME position. Note that the optical sensors may provide not steady level but temporally bouncing signals for HOME and END positions.

Hints

The 16-bit timers can be used to generate interrupts from external events. This may be of use when detecting the HOME and END positions.

PreLab

Develop a plan on how you will design your wiper blade controller. Draw a block diagram, state machine and other supporting documents showing the components you will need and describe their function within the overall design.

Develop an HCS12 program that will meet the specifications. ALL INTERFACING WITH THE TIMER PERIPHERALS MUST BE HANDLED UNDER INTERRUPT.

Develop a test plan and test code/scaffolding to help debug various components of your implementation.

In Lab Procedure

1. Show the T.A. the design and code you developed for the prelab and describe the approach you have taken to implement your wiper blade controller.
2. After receiving permission to proceed from the T.A., connect the Wiper blade module to the DRAGON12 according to the Table 2 and connect the supply

voltage of the stepper motor. The schematic of the wiper blade module is attached at the end of this document.

3. Download your program onto the DRAGON12 and get it to work. Use the appropriate test equipment to verify any I/O signals involved. BE SURE YOU ARE CORRECTLY GENERATING AND RESPONDING TO THE APPROPRIATE SIGNALS BEFORE CONNECTING THE MOTOR MODULE.
4. Provide 5VDC supply for the optical sensors (see Table 2) of the wiper blade module from PS-3330 power supply.
5. Connect the DC supply of the stepper motor (2-pin connector of the wiper blade module) to the left section of the PS-3330 power supply. The PS-3330 should be in *independent* mode. Adjust the supply voltage according to the label U_{SM} shown on the wiper blade module.
6. Connect the wires from the 10 pin connector (Table 2) of the Wiper blade module to proper selected ports of the microcontroller in Dragon 12 board.
7. Verify that your program functions as per the design specifications.

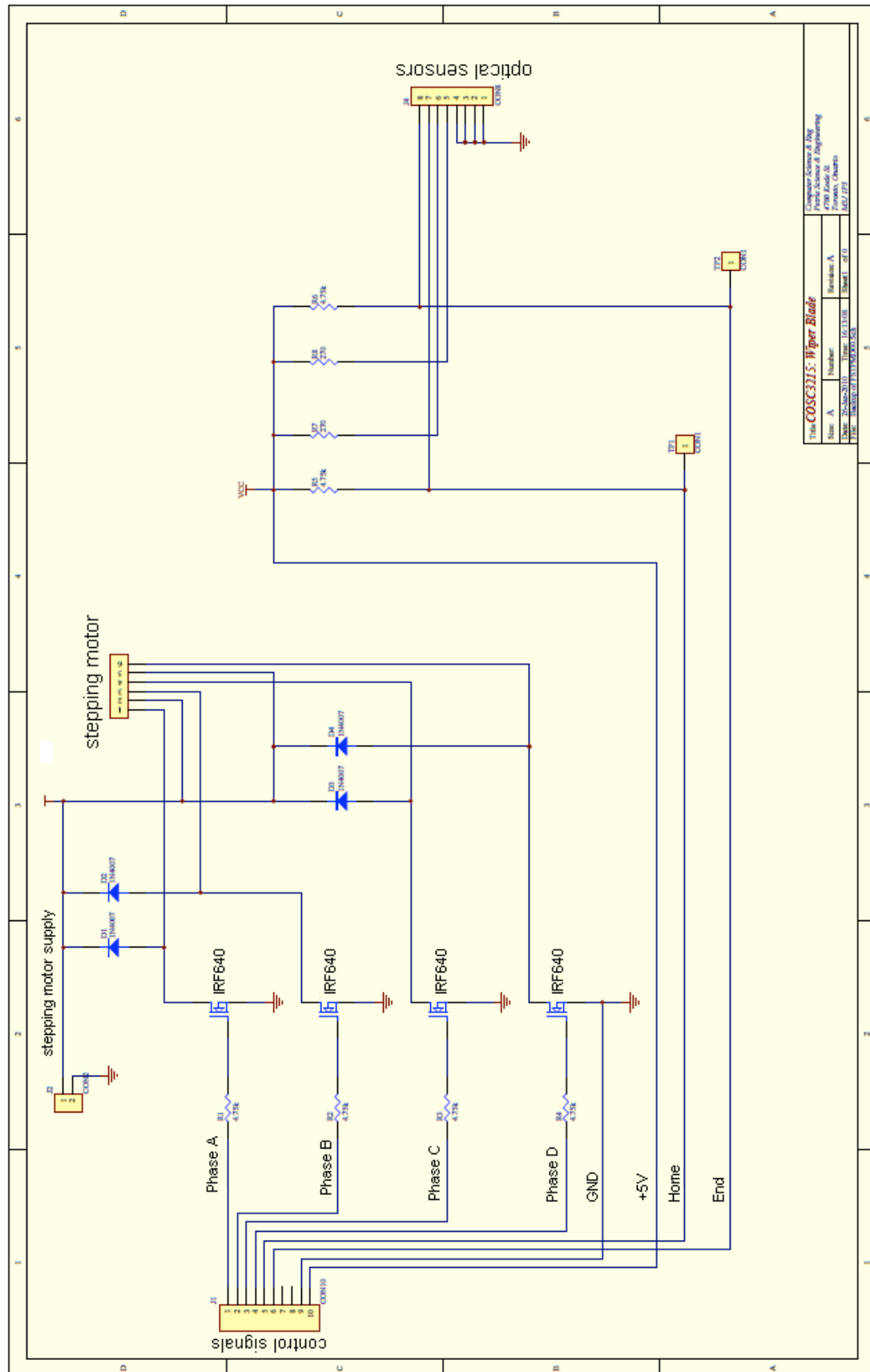
Lab Evaluation

You must demonstrate that your wiper blade motor controller is functioning properly to the lab TA (note this means you must show convincing evidence that it works and meets the specifications).

All code and simulation results must be submitted using the submit command.

| Table 1. Stepper motor phases | | | | |
|-------------------------------|-------|---|---|---|
| State | Phase | | | |
| | A | B | C | D |
| 0 | 1 | 0 | 0 | 1 |
| 1 | 1 | 0 | 0 | 0 |
| 2 | 1 | 0 | 1 | 0 |
| 3 | 0 | 0 | 1 | 0 |
| 4 | 0 | 1 | 1 | 0 |
| 5 | 0 | 1 | 0 | 0 |
| 6 | 0 | 1 | 0 | 1 |
| 7 | 0 | 0 | 0 | 1 |

| Table 2. 10 pin connector | | |
|---------------------------|---------|-------------|
| Pin # | Signal | Level |
| 1 | Phase A | TTL |
| 2 | Phase B | TTL |
| 3 | Phase C | TTL |
| 4 | Phase D | TTL |
| 5 | Home | TTL |
| 6 | End | TTL |
| 7 | | |
| 8 | | |
| 9 | GND | |
| 10 | +5V | for sensors |



Wiper blade module