Embedded Control of Electric Vehicle Motor System

EGH456 Embedded Systems

Supporting Material

The specifications in this document are subject to change

1. Assumptions

This document assumes that the Motor driver and adapter board have been installed on Boosterpack 1 (on the Tiva Launchpad) and that the Sensor and LCD Touchscreen have been installed on Boosterpack 2 (on the Tiva Launchpad). Please see the testing station kit image (see assignment specification document) for an example of how the boosterpack hardware should be installed on the Tiva launchpad kit.

2. Pinout Diagram

Figure 1 and 2 provides a pinout diagram of the headers for boosterpack 1 & 2, highlighting pins relevant for this assignment and associated connected devices. This is a subset of the pinout of the boosterpackk 1 and 2 interfaces. If more details are needed for the pinouts of the boosterpack 1 and 2 headers, please refer to the EK-TM4C1294XL user guide and datasheet. The boosterpack headers have a left and right header each containing two rows of pins. Each individual diagram below shows either the left and right side of the boosterpack 1 or 2 header and then illustrates the two rows of pins by highlighting them on either the left or right of the diagram.

The pin maps below should be used to identify any potential conflicts with using pins that are shared across multiple devices. For example the touchscreen drivers may not operate correctly if you reconfigure the ADC pins required to measure the touch position on the screen.

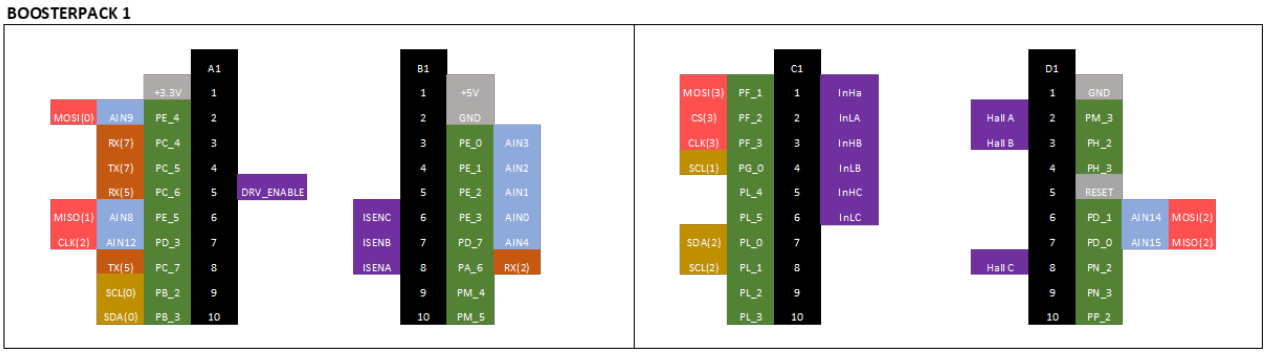


Figure 1: Pin Map of Booster Pack 1 - A1 & B1 is Left Side of Header. C1 & D1 are the right side of the Header. See EK-TM4C1294XL user guide for more info

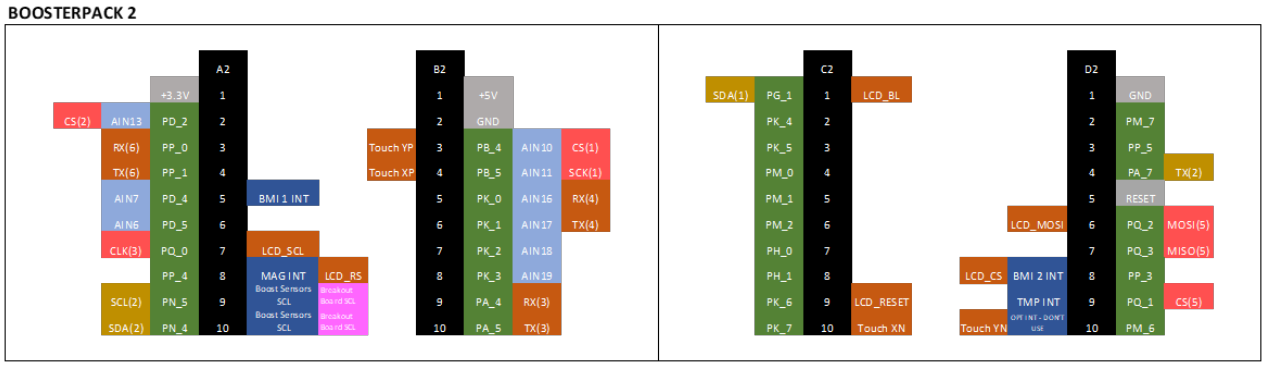
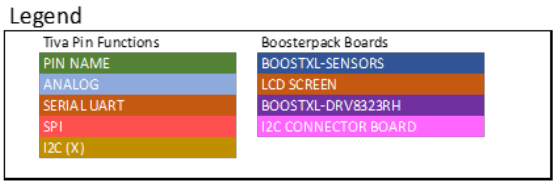


Figure 2: Pin Map of Booster Pack 2 - A2 & B2 is Left Side of Header. C2 & D2 are the right side of the Header. See EK-TM4C1294XL user guide for more info



Figures 1 and 2 display key pins associated with various functions for the assignment. This is for use as a quick reference only and may not contain all required information. Consult appropriate datasheets for complete data. Booster pack 1, shown in Figure 1, refer to the headers that should have the motor kit installed on. Booster pack 2, shown in Figure 2 refer to the headers which the touch screen, sensor booster pack and I2C breakout board is on.

3. Devices Utilised

Part Name	Part Number	Details
Tiva C Launchpad	EK-TM4C1294XL	Development Board featuring TM4C series microcontroller
Booster Pack K350QVG	BOOSTXL-K350QVG-S1	LCD Display and Resistive Touch Screen Interface
Sensors Boosterpack	BOOSTXL-SENSORS	Sensor board which includes a BMI160 Accelerometer & Gyro, BMM150 Compass, OPT3001 Ambient Light Sensor and BME280 Environment Sensor
Digital IR Temperature Sensor	MLX90615	Temperature sensor providing ambient and ranged temperature sensing infrared and using I2C communication
Digital Time of Flight Distance Sensor	VL53L0X	Time of Flight Distance Sensor is a high speed, high accuracy and long-range distance sensor using I2C communication.
Three-Phase Smart Gate Driver	DRV8323	Motor Control
EGH456 Motor Adapter Board V2.2	NA	Interface and current protection to Brushless Motor.
EGH456 I2C breakout board	NA	Interface for digital temperature and distance sensor I2C bus
Maxon Three Phase Motor	267121	3 phase brushless Motor with ribbon cable

4. Motor State Diagram

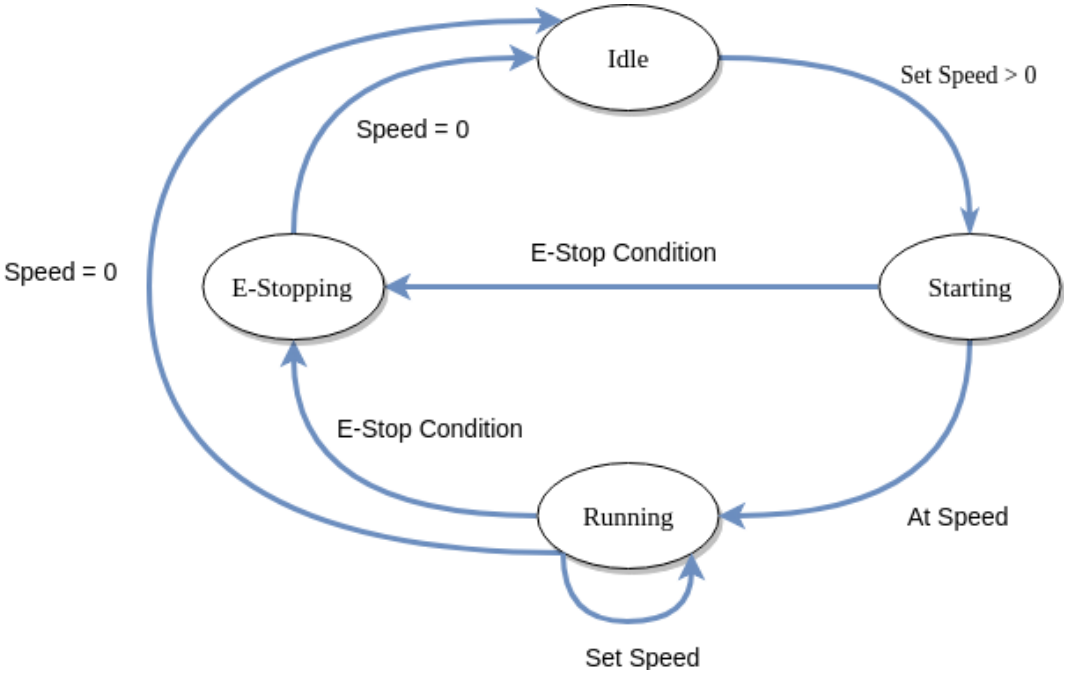


Figure 3: State Diagram for Controlling the Motor

Figure 3 shows the state machine that the motor controller should follow when starting and stopping the motor. See the assignment document for a description of when E-stop conditions have occurred.

5. Speed Control Diagram

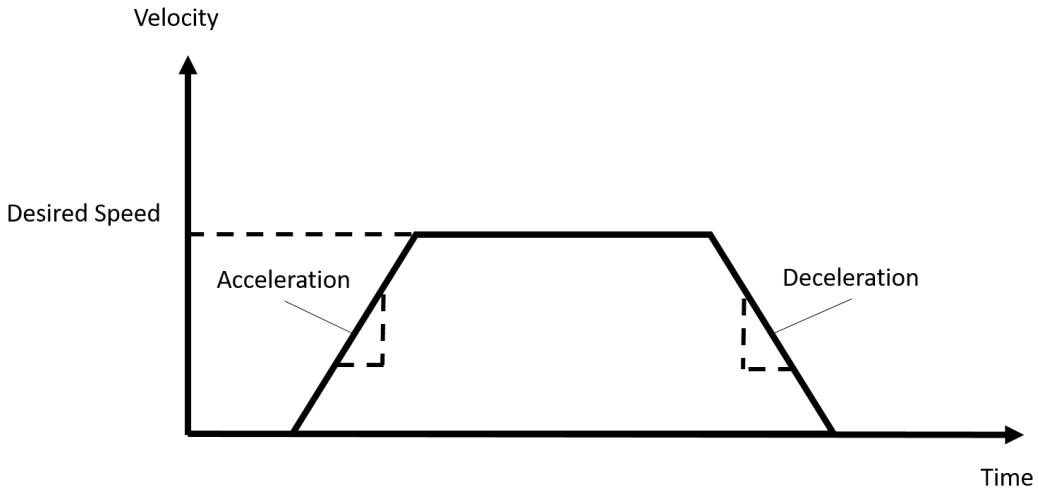


Figure 4: Diagram for Controlling the Speed of the Vehicle

Figure 4 indicates the desired behaviour of the speed control system. The acceleration and deceleration should be used to change the speed of the motor to the desired speed. Note that there is a different deceleration requirement depending on whether an e-stop condition has occurred.

6. Motor Phase Diagram

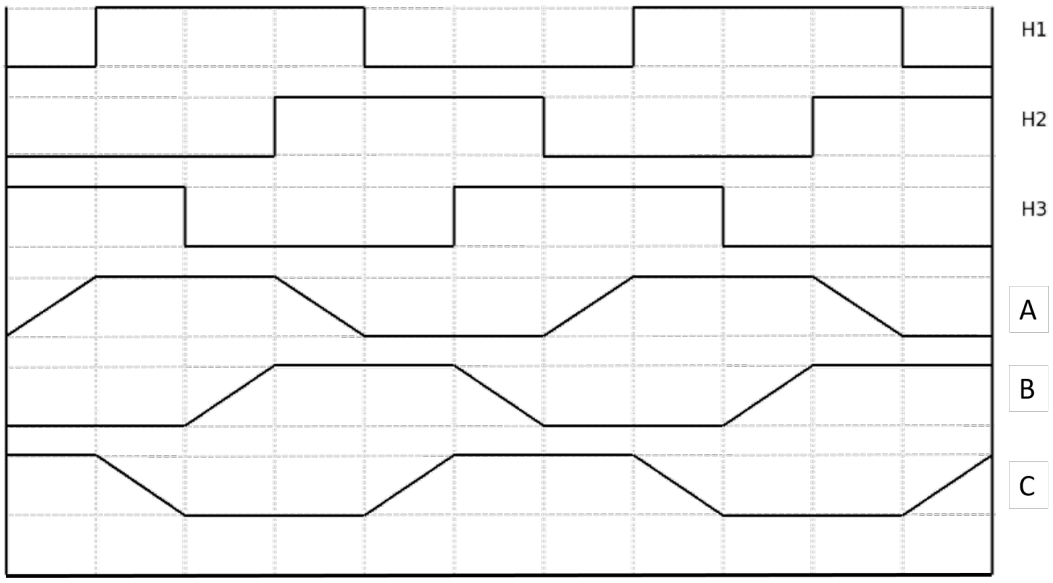


Figure 5: Phase Diagram for Driving the Motor - This diagram does not indicate one revolution of the motor

Figure 6 shows the different phases and hall effect sensor state diagram of the 3-phase brushless DC motor. Depending on the number of pole pairs for a brushless motor, this corresponds to a different number of degrees of rotation for the motor. This diagram can be used to determine how to drive each phase (high or low) of the motor depending on the state of the hall effect sensors. H1, H2 and H3 indicate the voltage level of each hall effect sensors which indicate the current position of the motor. A, B and C indicate the corresponding required voltage of the three phases of the brushless motor. For example, during the initial phase, H1 and H2 are low and H3 is high which corresponds to driving phase B low, phase C high and leaving phase A floating (indicated by the ramped voltage). Think of this diagram as a state machine where each column (indicated by the vertical dotted lines) is a state depending on the hall effect sensors and the transition occurs when a change in a hall effect sensor occurs. For every hall effect transition the motor phases need to be updated by calling the updateMotor() function within the motor library. It is recommended to do this within an interrupt handler routine.

7. I2C Breakout Board

A breakout board has been provided which connects to the Launchpad Boosterpack Headers. The schematic of the breakout board is shown below. Each connector of the breakout board is connected to the same I2C bus of the boosterpack header. See the pin map figure to check which I2C bus is used.

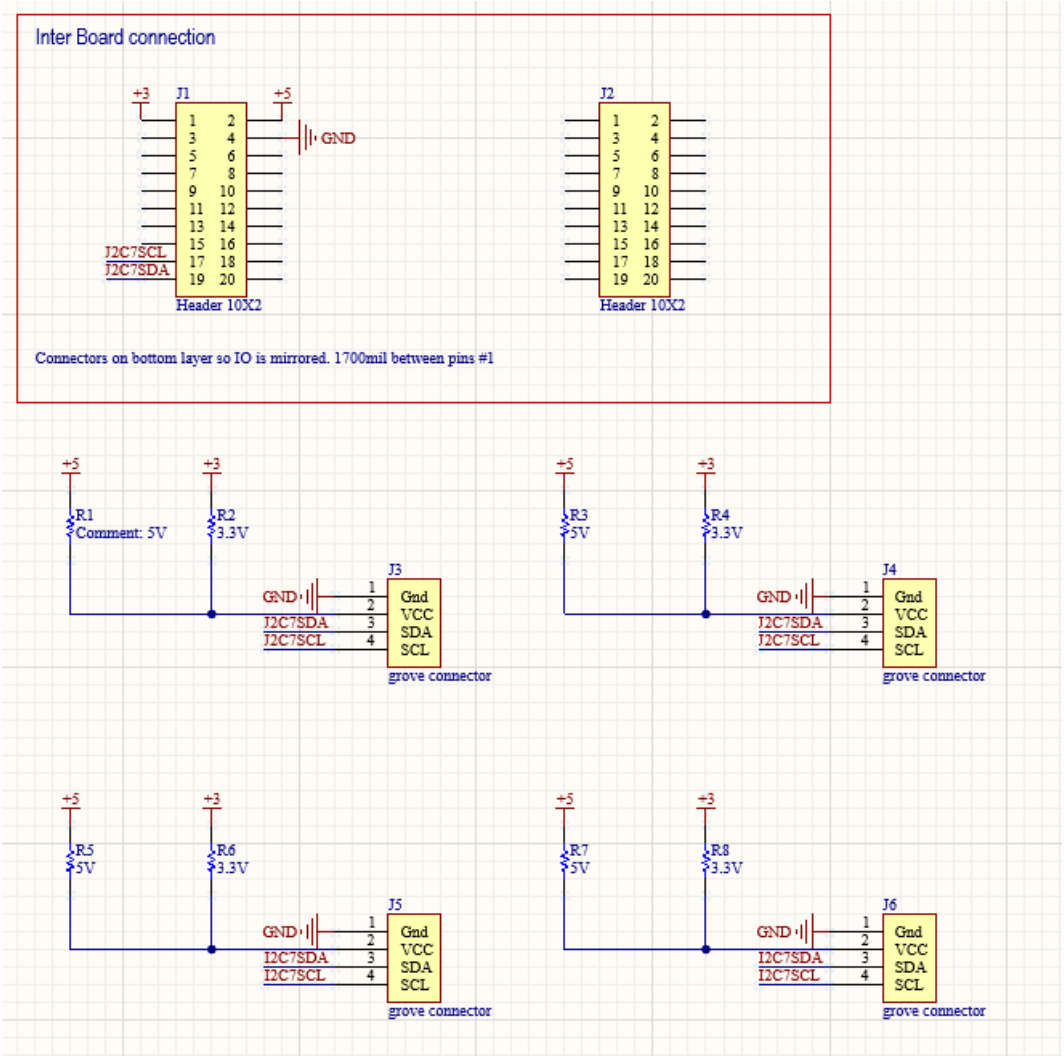


Figure 6: Schematic diagram of the I2C breakout board to connect the Temperature and ToF Distance Sensor

8. Tips and Additional Info

Motor

The DRV8232 Motor Driver Kit has the following settings (Please see the DRV8232RH datasheet for more detail):

- The GAIN pin has been tied to GND with a 47k resistor so has a gain of 10 for the current amplifier
- The current shunt resistor values are 0.007 Ohms for each current sense line. See section 8.3.4.1 for an equation to calculate current from the voltage measurement
- Vref is 3.3V for the motor driver and VSOx is the voltage that you are measuring.
- We recommend empirically counting the number of edges triggered by all three hall effect sensors during one revolution of the motor. This can be done by turning the motor by hand and printing out the number of edges triggered (both falling and rising) of the hall effect lines.

Motor Library

Use the error block argument to check if PWM hardware is failing to be created. You can see the error message by inspecting the return error block value. Ensure you don't use timer0 in your implementation as the motor library uses this timer.

Sensors

Feel free to use opensource libraries for sensors if they are available. Some examples can be found in the sensorlib folder within Tivaware (C:\ti\tivaware_c_series_2_1_4_178\sensorlib).

Touch Screen & ADC

The touchscreeninthandler needs to be setup within a hwi for it to work within the TI-RTOS framework. Use int number 33 as the interrupt. Alternatively, add these lines to your .cfg file to setup a hwi statically for your touchscreen:

```
var halHwi0Params = new halHwi.Params();
halHwi0Params.instance.name = "TouchScreenIntHandlerHandle";
Program.global.TouchScreenIntHandlerHandle =
    halHwi.create(33, "&TouchScreenIntHandler", halHwi0Params);
```

The touchscreen also uses ADC0 within it's implementation so make sure you don't cause conflict by using ADC0 for current sensing. Timer 1 is used by the touch screen so make sure you also don't use it for your application, or it will interfere with the touch interface

TI-RTOS & Tivaware Conflicts

One issue that can come up is when trying to use Tivaware IntRegister functions to setup interrupt handlers. This actually corrupts the interrupt vector table that the TI-RTOS libraries sets up via the Hwi module. Make sure to not use IntRegister but use Hwi_create instead to register interrupt functions with their respective vector numbers.

Reference Documents

- DRV832x 6 to 60-V Three-Phase Smart Gate Driver Datasheet
- DRV832XX EVM Sensored Software User's Guide
- BOOSTXL-DRV8323Rx EVM User's Guide
- TI-RTOS User's Guide
- TI-RTOS SYS/BIOS User's Guide
- EK-TM4C1294XL User's Guide
- TM4C1294NCPDT Datasheet
- OPT3001 Ambient Light Sensor Datasheet
- BOOSTXL-SENSORS Sensors BoosterPack User's Guide
- Grove Digital IR Temperature Sensor - MLX90615
- Grove Time of Flight Distance Sensor - VL53LOX