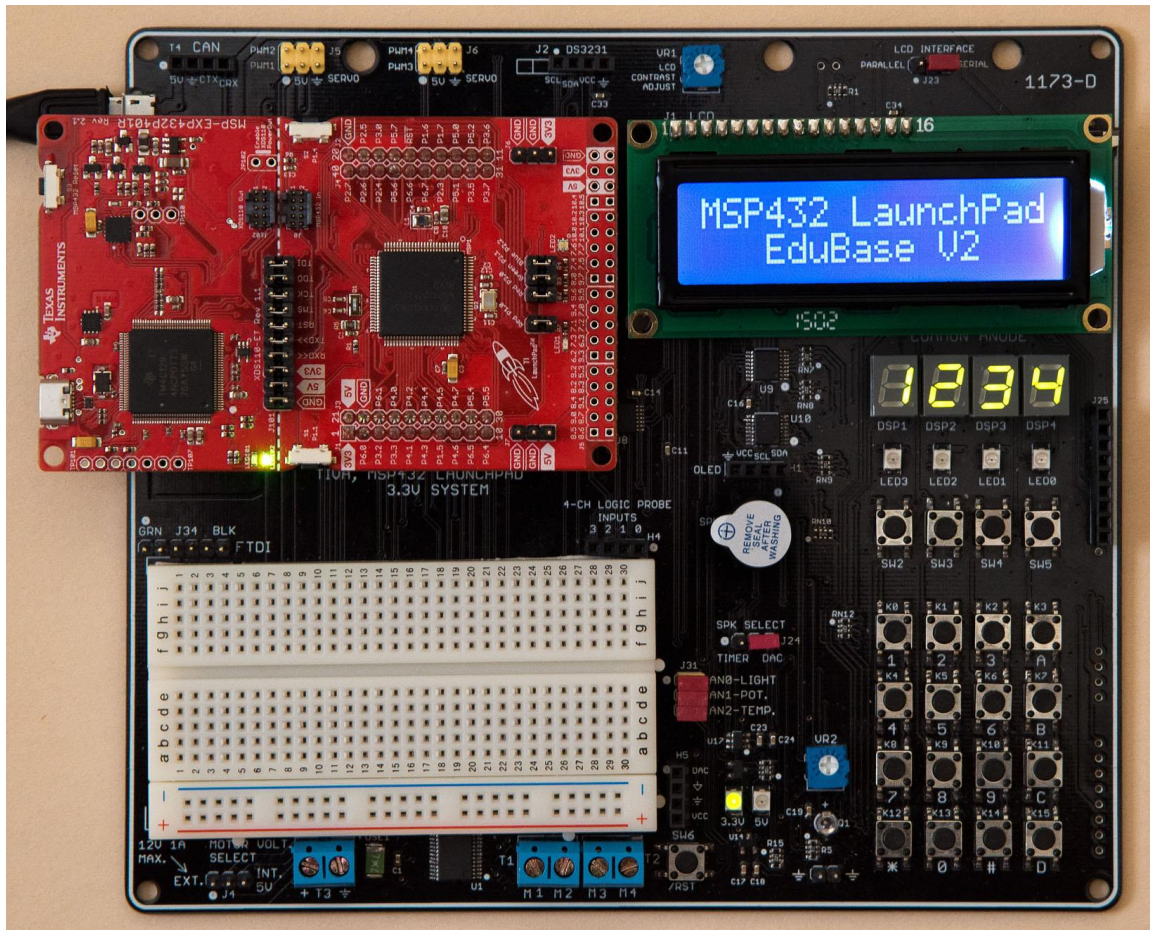

EduBase-V2 Trainer

User's Guide for TI ARM Launchpad

Version 1.13 09/19/2019



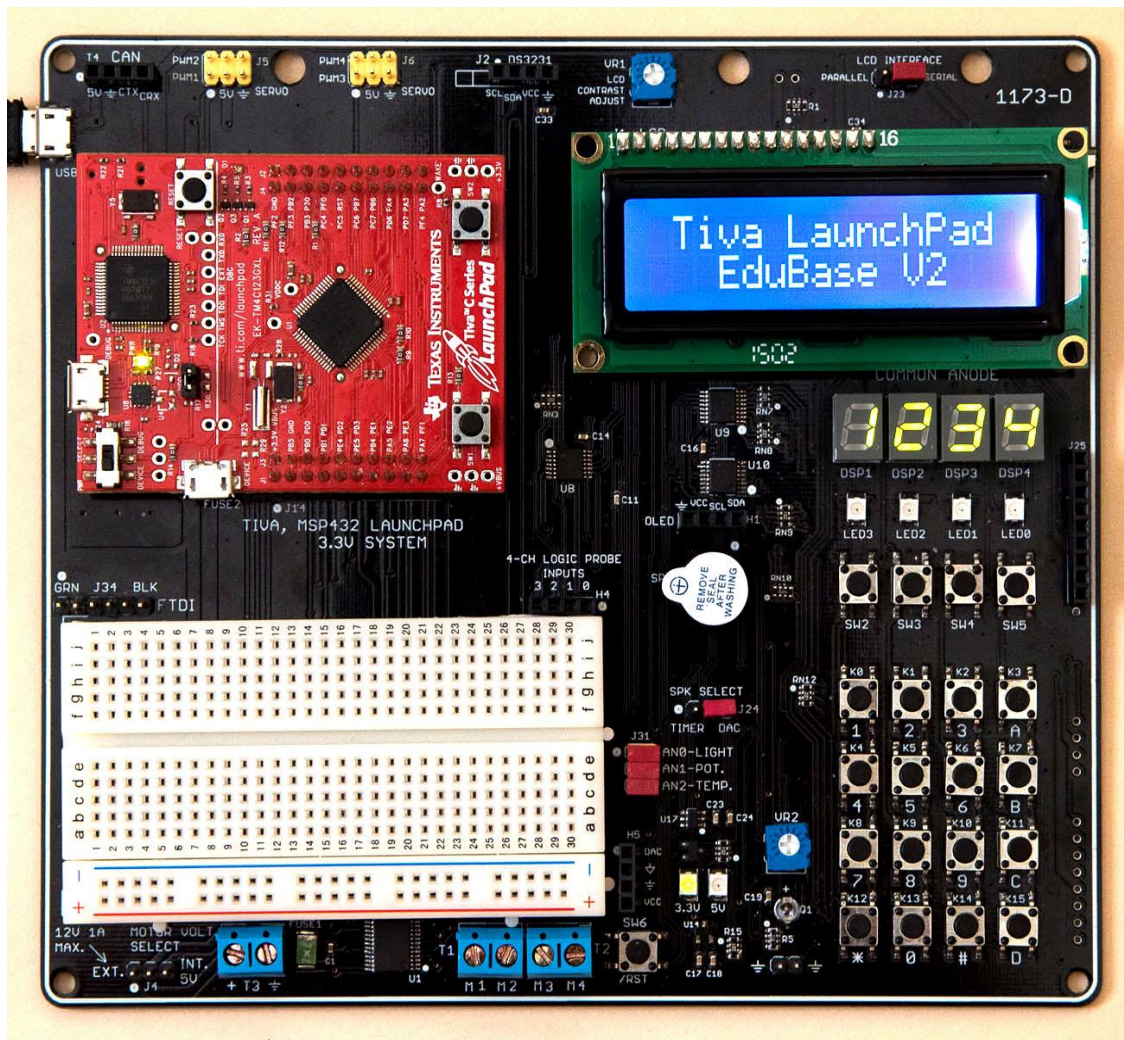


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Chapter 1. Overview

1.1 Welcome

Thank you very much for purchasing our EduBase-V2 All-In-One trainer for the TI Tiva or MSP432 Launchpad. The EduBase-V2 trainer is a low-cost, feature-packed universal training board for the Tiva TM4C123G or MSP432 TI ARM Launchpads. It incorporates onboard peripherals that will make this board an ideal trainer for EE and ECE courses in universities around the world.

For engineers, it is a convenient prototype system suitable for designers who want to rapidly develop and prototype ARM controller applications. For students, it not only can be used as a general trainer for freshman and sophomore but also as a versatile platform for senior projects as well. The features of the EduBase-V2 trainer create a new potential for students at every level.

Please note that the Tiva or MSP432 Launchpad and USB cable are not included with your purchase of the EduBase-V2 trainer.

The micro USB cable comes with your Launchpad purchase from TI on line store.
<http://www.ti.com/tool/EK-TM4C123GXL#buy> To buy MSP432 Launchpad see
<http://www.ti.com/tool/MSP-EXP432P401R> They sell for around \$20. They usually have it in stock. Other distributors, like Mouser and Digi-key also have it in stock, but the price may be a little higher.

The external power supply is not needed for your normal use, it's only needed when in standalone operation without a PC. Most of the smart phone chargers except iPhone have a 5V output with a micro USB connector, they can be used as the external power supply.

Warning:

The Tiva and MSP432 Launchpads don't have a built-in reverse-polarity-protection diode. If you are going to experiment H-Bridge with an external high voltage motor (>5V), please make sure that the high voltage (>5V) cannot touch the 5V supply, or it may damage the USB port of your laptop, or even your whole laptop.

1.2 Tiva and MSP432 Launchpad features:

The Tiva Launchpad is a low cost evaluation platform for ARM Cortex-M4F microcontrollers made by TI. It has many features. The main features of the Tiva Launchpad are listed below:

- Powerful 32-bit TM4C123GH6PM microcontroller
- 256K bytes of flash memory
- 32K bytes of RAM
- 80 MHz system clock
- On board in-circuit debugger
- USB on-the-go
- Motor control PWM
- RGB LED
- Two user switches
- TivaWare software libraries
- Standard Booster Pack interface

The MSP432 ARM Launchpad features:

The MSP432 Launchpad is a low cost evaluation platform for ARM Cortex-M4F microcontrollers made by TI. It has many features, the main features of the MSP432 Launchpad are listed below:

- Low-power, high performance MSP432P401R MCU
 - 48MHz 32-bit ARM Cortex M4F with Floating Point Unit and DSP acceleration
 - Power consumption: 80uA/MHz active and 660nA RTC standby operation
 - Analog: 24Ch 14-bit differential 1MSPS SAR ADC, Two Comparators
 - Digital: Advanced Encryption (AES256) Accelerator, CRC, DMA, HW MPY32
 - Memory: 256KB Flash, 64KB RAM
 - Timers: 4 x16-bit, and 2 x 32-bit
 - Communication: Up to 4 I2C, 8 SPI, 4 UART
 - 40 pin BoosterPack Connector, and support for 20 pin BoosterPacks
 - Onboard XDS-110ET emulator featuring EnergyTrace+ Technology
 - 2 buttons and 2 LEDs for User Interaction
 - Back-channel UART via USB to PC
-

1.3 EduBase-V2 hardware features:

The EduBase-V2 board includes the following features for teaching an ARM course:

1. Four user LED's
 2. Four pushbutton switches
 3. 12-bit DAC for testing I2C interface and generating analog waveforms
 4. Four digit 7-segment LED display for learning multiplexing technique
 5. Speaker to be driven by timer or DAC for alarm or music applications
 6. Dual H-Bridge motor driver controls two DC motors or one Stepper motor
 7. Controls 4 Servos
 8. 4 Logic probe inputs
 9. 3V and 5V Power-On LED indicators
 10. 4 X 4 keypad
 11. 16X2 character LCD with a jumper selectable for serial or 4-bit parallel interface
 12. Potentiometer for analog input
 13. Temperature sensor
 14. Light sensor
 15. MicroSD memory card slot.
 16. Solderless breadboard included
 17. PC board size: 6.60" X 5.80"
 18. 0.96", 128x64 OLED header
 19. 2.2" TFT QVGA display header
 20. DS3231 RTC interface header
 21. CAN interface header
 22. FTDI header
-

Chapter 2. Software development

It is recommended that you become familiar with the software development tools for Tiva/MSP432 Launchpad before working with the EduBase-V2.

The software development on the EduBase-V2 is a two-step process.

1, Work on the Tiva/MSP432 Launchpad standalone and familiarize with its software development. Don't plug the Tiva/MSP432 Launchpad onto the EduBase-V2 until you feel comfortable in writing a small test program because it's easier to test a small program on the Tiva/MSP432 Launchpad standalone.

TI supplies an utility to program the Tiva Launchpad. It is called LM Flash Programmer. The instructions to program the Tiva Launchpad are listed on the Tiva Launchpad user's guide.

<http://www.ti.com/lit/ug/spmu296/spmu296.pdf> page 14. But you need a toolchain to create an image for the flash programmer. Also see <http://www.MicroDigitalEd.com/> for tutorials on both Tiva and MSP432.

2. Plug the Tiva or MSP432 Launchpad into the EduBase-V2's J14 and J19.

The 2x10 shrouded male header J14 will prevent misalignment in Y-direction.

The two 1x3 male headers, J19A and J19B, with red jumpers on each end of J19 will prevent misalignment in X-direction.

So the Launchpad will always be plugged correctly.

TI listed three major IDE's for Tiva/MSP432 software development:

- Keil MDK-ARM
- IAR Embedded Workbench
- Code Composer Studio

Since Keil was acquired by ARM, the Keil seems to be more popular for an EE or an ECE course,

Professor Mazidi and Professor Chen have chosen the Keil IDE and wrote a textbook for the Tiva Launchpad. Professor Mazidi is a highly regarded author of many textbooks for embedded systems, and Professor Chen is an ARM controller software expert who wrote and tested all C and Energia sample programs for the EduBase-V2. We are very grateful to their hard work.

You can purchase their books at Amazon.

https://www.amazon.com/Tiva-ARM-Programming-Embedded-Systems/dp/0997925922/ref=sr_1_6?ie=UTF8&qid=1503622303

https://www.amazon.com/MSP432-Programming-Embedded-Systems-books/dp/0997925914/ref=sr_1_2?s=books&ie=UTF8&qid=1474025605&sr=1-2&keywords=MSP432+ARM+Book+Mazidi+and+Naimi

Sample programs are available at Professor Mazidi's web site:

http://www.MicroDigitalEd.com/ARM/TI_ARM_books.htm
http://www.MicroDigitalEd.com/ARM/MSP432_books.htm
<http://www.MicroDigitalEd.com/ARM/EnergiaForArduino.html>

Chapter 3. On-line resources

Tiva Launchpad user's guide including schematic:

<http://www.ti.com/lit/ug/spmu296/spmu296.pdf>

How to download and install Keil and How to Create a C Project in Keil and sample programs:

http://www.MicroDigitalEd.com/ARM/TI_ARM_books.htm
http://www.microdigitaled.com/ARM/MSP432_books.htm

Both books can be used with the EduBase-V2.

TI Energia

The Energia platform uses the Wiring and Arduino framework to program the TI Arm microcontrollers. The EduBase-V2 can also be used for Energia programming. See the following site for sample programs.

<http://www.MicroDigitalEd.com/ARM/EnergiaForArduino.html>

Getting started with Tiva Launchpad:

http://processors.wiki.ti.com/index.php/Getting_Started_with_the_TIVA%E2%84%A2_C_Series_TM4C123G_LaunchPad

Tiva Launchpad workshop workbook:

http://software-dl.ti.com/trainingTTO/trainingTTO_public_sw/GSW-TM4C123G-LaunchPad/TM4C123G_LaunchPad_Workshop_Workbook.pdf

If you have any technical questions regarding the Tiva Launchpad, you can post a message at the Tiva forum. Many TI engineers are active on the forum to answer your questions.

http://e2e.ti.com/support/microcontrollers/tiva_arm/default.aspx

If you have any question regarding the EduBase-V2 hardware and need a tech support please email your question to trainer4edu@gmail.com

Also see <http://www.trainer4edu.com/index.html>

Chapter 4: Hardware Descriptions

The circuit is designed in such way that the value of all resistors and capacitors are not critical.

4.1 LEDs:

Each pin of the PB0-PB3 is connected to an LED via a buffer (IC U8). In order to turn an LED, you need to program the corresponding port B pin as output and set it high.

4.2 Push button switches:

The PD0-PD3 are connected to 4 push buttons. When a key is down, the PD input goes HIGH.

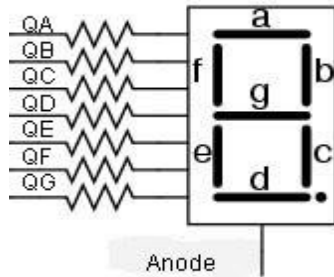
4.3 7-Segment LED multiplexing

There are 4 digits of 7-segment LED display on the EduBase-V2 board. The type of the 7-segment LED display on board is common anode. In an individual digit, all cathodes are driven individually by an output pin and all anodes are internally connected together.

Before sending a number to a 7-segment LED display, the number must be converted to its corresponding 7-segment code depending on how the 7-segment display is connected to an output port.

Because there are not enough I/O pins available, the EduBase-V2 board incorporates 2 daisy chained HCT595 shift registers to multiplex the 7-segment displays. The first HCT595 drives the cathodes and the second HCT595 drives the common anodes. When the cathode is low and anode is high, the LED lights up. We will explain how to multiplex 7-segment by displaying the number 1234 on the display.

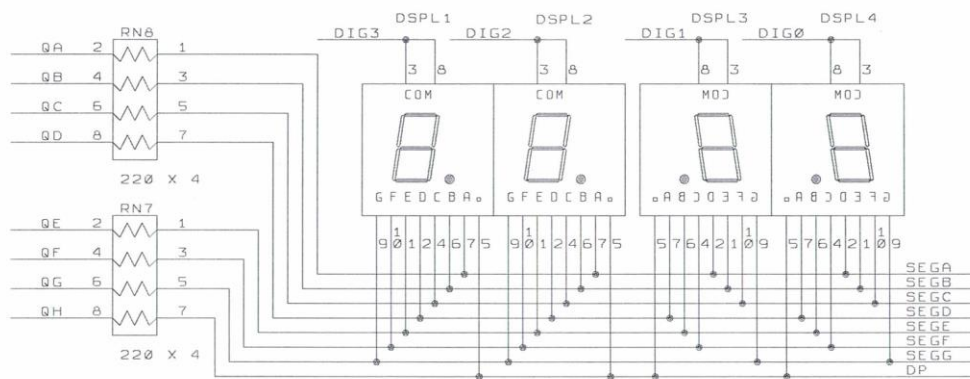
By convention, the 7 segments are called segment A, B, C, D, E, F and G. Their locations in the display are shown below:



The segment A, B, C, D, E, F, G and Decimal Point are driven by QA, QB, QC, QD, QE, QF, QG, and QH, respectively. The hex value of the segment code is shown in the following table:

Number	DP	G	F	E	D	C	B	A	Hex Value (CC)	Hex Value (CA)
1	0	0	0	0	0	1	1	0	0x06	0xF9
2	0	1	0	1	1	0	1	1	0x5B	0xA4
3	0	1	0	0	1	1	1	1	0x4F	0xB0
4	0	1	1	0	0	1	1	0	0x66	0x99

The schematic for multiplexing 4 digits is shown below. The two of the digits at the right are deliberately placed upside down and the hardware connections compensate for this configuration. The reason for the upside down digits is to place two decimal pointers on the middle as a colon for a clock display.



The digit 3, 2, 1, and 0 are driven by QA, QB, QC and QD of the second HCT595, respectively. The 7-segment LED display is turned on one at a time at a high refresh rate. It's fast that our eyes will perceive that all 4 digits are turned on at the same time. To display the number 1234 on the 7-segment display, the following steps should be taken:

1. Output \$F9 to the 1st HCT595, then output \$08 to the 2nd HCT595 to set QD high and QA, QB and QC low. The number 1 is shown on the digit 3 (the leftmost digit), but other 3 digits are turned off.
2. Delay 1-5ms.
3. Output \$A4 to the 1st HCT595, then output \$04 to the 2nd HCT595 to set QC high and QA, QB and QD low. The number 2 is shown on the digit 2, but other 3 digits are turned off.
4. Delay 1-5ms.
5. Output \$B0 to the 1st HCT595, then output \$02 to the 2nd HCT595 to set QB high and QA, QC and QD low. The number 3 is shown on the digit 1, but other 3 digits are turned off.
6. Delay 1-5ms.
7. Output \$99 to the 1st HCT595, then output \$01 to the 2nd HCT595 to set QA high and QB, QC and QD low. The number 4 is shown on the digit 0 (the rightmost digit), but other 3 digits are turned off.
8. Delay 1-5ms.
9. Go back to step 1.

In the olde version of EduBase trainers, the 7-segment display is Common Cathode. If you already have software written for the 7-segment display on the old trainers, only thing you need to modify is to invert the segment and digit data before outputting it to the HC595 shift registers.

4.4 Light sensor (AN0)

The light sensor is connected to the PE1 (AIN2) of the ADC port.

4.5 Potentiometer (AN1)

The 5K potentiometer VR2 is connected to the PE2 (AIN1) of the ADC port

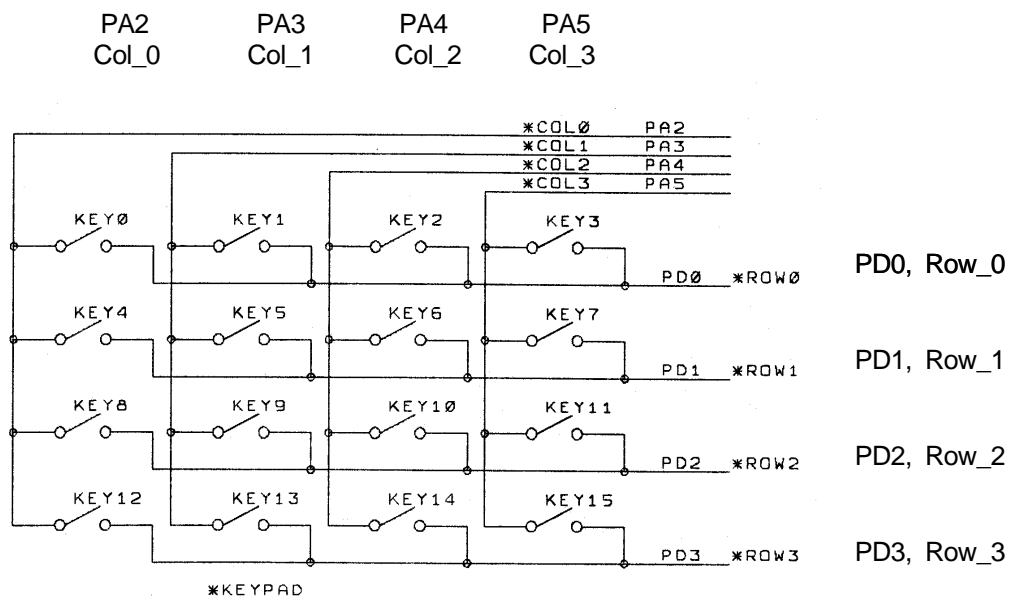
4.6 Temperature sensor (AN2)

The temperature sensor (LM45 or equivalent) is connected to the PE5 (AIN8) of the ADC port

4.7 Keypad:

PD0-PD3 and PA2-PA5 are used for a 4X4 keypad. If they are not used for the keypad, they can be used as general-purpose I/O pins.

The schematic for the keypad connections is shown below:



Keypad connections:

PA2 connects COL0 of the keypad
PA3 connects COL1 of the keypad
PA4 connects COL2 of the keypad
PA5 connects COL3 of the keypad

PD0 connects ROW0 of the keypad
PD1 connects ROW1 of the keypad
PD2 connects ROW2 of the keypad
PD3 connects ROW3 of the keypad

Keypad scan routine sets PA5 high and PA2, PA3, PA4 low, then tests PD0-PD3.

If no key is down, PD0-PD3 remain low.

If PD3 = high, the key 15 is pressed.

If PD2 = high, the key 14 is pressed.

If PD1 = high, the key 13 is pressed.
If PD0 = high, the key 12 is pressed.

Keypad scan routine sets PA4 high and PA2, PA3, PA5 low, then tests PD0-PD3.

If no key is down, PD0-PD3 remain low.
If PD3 = high, the key 11 is pressed.
If PD2 = high, the key 10 is pressed.
If PD1 = high, the key 9 is pressed.
If PD0 = high, the key 8 is pressed.

Keypad scan routine sets PA3 high and PA2, PA4, PA5 low, then tests PD0-PD3.

If no key is down, PD0-PD3 remain low.
If PD3 = high, the key 7 is pressed.
If PD2 = high, the key 6 is pressed.
If PD1 = high, the key 5 is pressed.
If PD0 = high, the key 4 is pressed.

Keypad scan routine sets PA2 high and PA3, PA4, PA5 low, then tests PD0-PD3.

If no key is down, PD0-PD3 remain low.
If PD3 = high, the key 3 is pressed.
If PD2 = high, the key 2 is pressed.
If PD1 = high, the key 1 is pressed.
If PD0 = high, the key 0 is pressed.

Note: For the best result, after setting a COL. high, then delay a few us
(like a few NOP instructions) before testing the ROW inputs at PD0-PD3,

4.8 LCD display

4.8.1. Serial interface LCD: (the jumper is placed on the 2 right-hand pins of J23)

The EduBase-V2 board incorporates a 74HCT595 shift register (U6) to control the LCD display.
The chip select for the HCT595 is PC6

The U6 outputs QA-QH as the control and data bits D0-D1, D4-D7 for the LCD.

The pinouts of J1 are as follows:

Pin 1	GND	
Pin 2	VCC (5V)	
Pin 3	Connect to GND via the VR1 for contrast adjustment	
Pin 4	QA (D0)	RS pin for LCD module
Pin 5	GND	Write only for LCD module
Pin 6	QB (D1)	EN pin for LCD module
Pin 7	Not used	
Pin 8	Not used	
Pin 9	Not used	
Pin 10	Not used	
Pin 11	QE (D4)	DB4 pin for LCD module
Pin 12	QF (D5)	DB5 pin for LCD module
Pin 13	QG (D6)	DB6 pin for LCD module
Pin 14	GH (D7)	DB7 pin for LCD module

Pin 15	Via a 22 Ohm resistor to VCC	LED backlight for LCD module
Pin 16	Backlight ground	EN/DIS for LED back light

The 74HCT595 is connected to the LCD controller with QE ~ QH to DB4 ~ DB7, QA to RS, QB to enable. The QC and QD are not used.

The LCD module is hardwired for write-only operation

4.8.2. Parallel interface LCD: (the jumper is placed on the 2 left-hand pins of J23)

The EduBase-V2 also incorporates a parallel interface for the LCD, the COL0-COL3 PA2-PA5) are connected to the D4-D7 of LCD via a 74HCT245 buffer (U18). The control pins are PE0 for LCD R/S and PC6 for LCD EN.

4.9 Digital-to-Analog Converters (DAC)

The MCP4725, a 12-bit I2C based DAC is installed for learning I2C communication. It converts a digital binary code to an analog signal, so a program can generate different waveforms from the DAC.

The DAC 's analog outputs, labeled as DCA, are provided on the H5. One way of testing the DAC is to connect the DAC output to an ADC input, so a user can send a binary code to the DAC and read the code back from the ADC.

4.10 Speaker

The speaker is a 5V audio magnetic transducer and it's driven by the PC4 as a timer or by the DAC output from U17 (MCP4725). The signal source of the speaker is selected by the jumper J24.

4.11 H-Bridge

The H-bridge TB6612FNG is similar to the SN754410N, but has MOSFET outputs, It's much more efficient than the SN754410N, especially for controlling low voltage motors. The control software are the same for both IC's. It can control two DC motors or one stepper motor.

It takes two pins (PB0 and PB1) to control direction, one must be set at high, the other one must be set at low. If PB0 is high and PB1 is low the motor will turn clockwise, then if PB0 is low and PB1 is high the motor will turn count clockwise. If both PB0 and PB1 are set at the same state, the motor stops.

A DC motor is connected to the terminals labeled with M1 and M2, If the motor is turned in the opposite direction from what you expect, just swap the motor connections on the M1 and M2, you don't need to change your software.

The motors to be used to test your software should be small, low current and low voltage DC motors, like under 12V and 300mA.

The third pin is the PWM input for receiving different pulse widths to vary the motor speed. It is driven by pin PF3 of the Tiva Launchpad. The sample program is available on Professor Mazidi's web site.

The other half of the H-bridge driver is controlled by PB3, PB2 for direction and PF2 for PWM. The outputs are M3 and M4. Combining M1, M2, M3, and M4, the H-bridge driver can be used to drive a bipolar or unipolar stepper motor.

4.12 UART communication

When PB0 and PB1 are not used for the Lab assignment #1 (see above paragraph #4.1 and #4.2) or not used for driving the on-board H-Bridge, they can be used as a UART.

The UART can be used by user's application programs. It supports direct 3.3V digital signal interface with other boards, or use a 3.3V USB serial adapter (FTDI cable) for interfacing with a PC.

4.13 CAN interface

CAN interface header T4 is provided. If you are interested in CAN programming, purchase a CAN module (\$2) and plug it into the header T4. The PF0 and PF3 will be used as CANRX and CANTX signals.

4.14 TFT

J25 is for a common 2.2" TFT QVGA display with SPI interface. The pinouts are listed below:

Pin1	5V	
Pin2	Ground	
Pin3	Chip select	PD6
Pin4	Reset	
Pin5	R/S	PE0
Pin6	MOSI	PB7
Pin7	SCLK	PB4
Pin8	Backlight	
Pin9	MISO	PB6

4.15 OLED

H1 is used for an 0.96" OLED with I2C interface. The connections are:

Pin1	SDA1 (PA7)
Pin2	SCL1 (PA6)
Pin3	VCC
Pin4	Ground

4.16 SD-Card

The SD-Card slot uses SPI interface. The pinouts are listed below:

Chip select	PC5
MOSI	PB7
SCLK	PB4
MISO	PB6

4.17 DS3231 RTC interface

The popular DS3231 RTC module can be used for time stamp of a data logger. It's battery backed by an on-module CR2032 coin battery, it can last for years.

4.18 FTDI USB to TTL interface

The FTDI USB to TTL interface must be 3.3V. To communicate with a PC, you need a 3.3V FTDI cable. The VCC of the cable is connected to an empty pin on the EduBase-V2, so it can be 3.3V or 5V, but the RX and TX signals must be 3.3V. If you use your own 3.3V FTDI cable, you only need to connect 3 wires, RX, TX and GND.

Many sample programs are downloadable from Professor Mazidi's web site

<http://www.MicroDigitalEd.com>

4.19 All jumper settings

All on-board jumpers:

- J1 LCD connector for a 16x2 LCD.
 - J4 DC motor power source select. If a jumper is installed on the two lower pins, motors are powered by the on-board 5V (USB 5V). If a jumper is installed on the upper two pins, motors are powered by external voltage source that is less than 13V/0.5A at the terminal block T3.
 - J5 Two servo outputs, controlled by PF2 and PF3. Servos are supplied with 5V.
 - J6 Two servo outputs, controlled by PF0 and PF1. Servos are supplied with 5V

 - J14 Tiva main pin header 1.
 - J19 Tiva main pin header 2.
 - J23 LCD interface type select, serial or parallel.
 - J24 Speaker source select, Timer or DAC.
 - J25 2.2" QVGA TFT display interface.
-

J31	Light, potentiometer and temperature enable jumpers.
J33	Disable EEPROM (located on the solder side).
J34	FTDI connector
H1	0.96" OLED
H2	D3231 RTC
H5	DAC output and power supply header.
H10	SPI signals
H11	I2C header
H12	4 logic probes

4.20 I/O pin usage

All I/O pins, but PD7, PF0 and PF4, are used by on-board peripherals. Fortunately, it's unlikely that all on-board peripherals will be used by one application program. So the I/O pins on unused peripheral devices can still be used by your circuits on the breadboard. For instance, if you don't touch the 4x4 on-board keypad, the pins for the keypad will be available to your circuits. If you don't care about the RGB LED, the PF1,PF2 and PF3 available as well. Just ignore the LED's color.

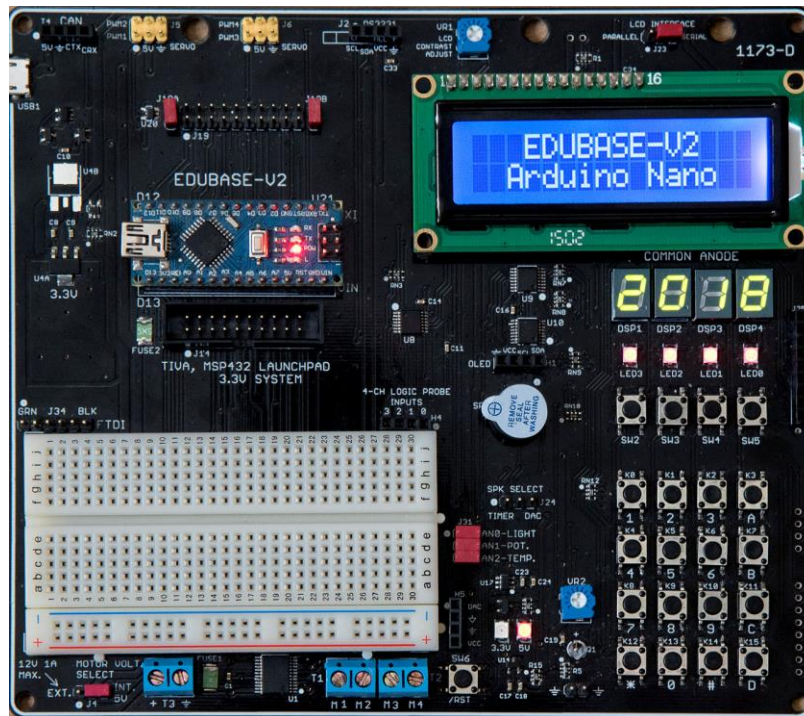
Pin Name	Pin # on EduBase-V2	I/O Usage
PA2 (output)	Pin 20 of J19	COL0 of keypad
PA3 (output)	Pin 18 of J19	COL1 of keypad
PA4 (output)	Pin 16 of J19	COL2 of keypad
PA5 (output)	Pin 15 of J14	COL3 of keypad
PA6 (output)	Pin 17 of J14	SCL
PA7 (bi-directional)	Pin 19 of J14	SDA
PB0 (bi-directional)	Pin 5 of J14	LED0 or UART's RX or H-Bridge
PB1 (output)	Pin 7 of J14	LED1 or UART's TX or H-Bridge
PB2 (output)	Pin 4 of J19	LED2 or H-bridge
PB3 (output)	Pin 5 of J19	LED3 or H-bridge
PB4 (output)	Pin 13 of J14	SCLK of SPI
PB5 (output)	Pin 3 of J14	not used
PB6 (input)	Pin 14 of J19	MISO of SPI
PB7 (output)	Pin 12 of J19	MOSI of SPI
PC4 (output)	Pin 7 of J19	Speaker
PC5 (output)	Pin 9 of J19	/CS of Micro SD card
PC6 (output)	Pin 11 of J19	/CS of LCD
PC7 (output)	Pin 13 of J19	/CS of 7-segment
PD0 (input)	Pin 6 of J14	ROW0 of keypad
PD1 (input)	Pin 8 of J14	ROW1 of keypad

PD2 (input)	Pin 10 of J14	ROW2 of keypad
PD3 (input)	Pin 12 of J14	ROW3 of keypad
PD6 (output)	Pin 15 of J19	/CS of TFT display
PD7		not used
PE0 (input)	Pin 6 of J19	/SS of SPI
PE1 (output)	Pin 14 of J14	Light sensor
PE2 (output)	Pin 16 of J14	Potentiometer
PE3		not used
PE4 (input)	Pin 9 of J14	CANRX
PE5 (output)	Pin 11 of J14	CANTX or temperature sensor
PF0 (input)	Pin 8 of J19	CAN2RX
PF1 (output)	Pin 20 of J14	Red LED of RGB on Tiva launchpad
PF2 (output)	Pin 1 of J19	Blue LED of RGB on Tiva launchpad
PF3 (output)	Pin 3 of J19	CAN2TX, Green LED of RGB on Tiva launchpad
PF4		not used

Chapter 5. Arduino Nano support

To support Arduino programming development we added two female headers on the EduBase-V2, so you can plug in a low cost Nano module to interface all peripherals on the EduBase-V2.

Some universities use **Arduino** in an introductory course for freshmen, then move up to an ARM course later. So they can use the same EduBase-V2 without an adapter for two different EE/ECE courses. For sample program, see <http://www.MicroDigitalEd.com/Arduino/ArduinoBook.html>



The board will switch VCC from 3V to 5V automatically when a Arduino Nano is plugged in.

Arduino Nano does not have enough I/O pins to interface all peripherals on the EduBase-V2. There are limitations for the Nano:

1. The 4x4 keypad is not available for the Nano.
2. Two pushbutton switches, SW2 and SW3, are not available for the Nano.
3. The TFT display normally is not available for the Nano, but it can be available to the Nano if the H-Bridge is not used. If the jumpers on the J19A and J19B are moved to the lower 2 positions, the PWM1 and PWM2 pins can be used to control /CSTFT and LCD_RS, respectively. When the TFT display is working, the H-Bridge won't work. When you need to work on a motor application, don't forget to put the jumpers to the upper two positions.