
EduBase-V2 Trainer

User's Guide for STM32 Arm

Version 1.16 09/19/2019

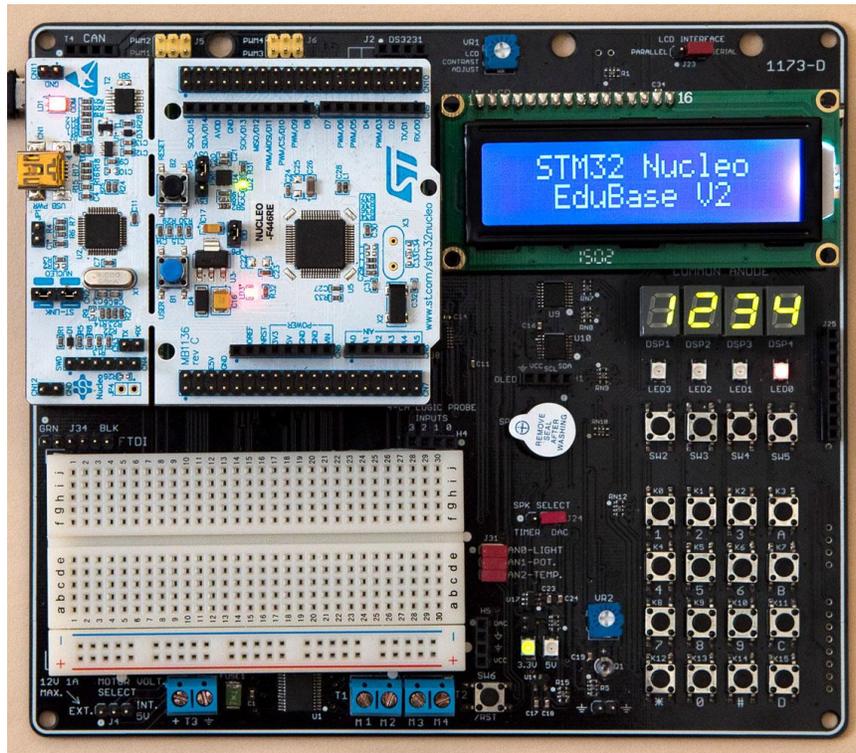


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Chapter 1. Overview

1.1 Welcome

Thank you very much for purchasing our EduBase-V2 All-In-One trainer for the STM32 Nucleo-F446RE development board. The EduBase-V2 trainer is a low-cost, feature-packed universal training board for the STM32 Nucleo-F446RE development board. 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 STM32 Nucleo-F446RE development board and USB cable are not included with your purchase of the EduBase-V2 trainer.

The micro USB cable comes with your STM32 Nucleo board purchase. Digi-Key or Mouser usually have the STM32 Nucleo-F446RE in stock.

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

1.2 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
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Chapter 2. Software development

It is recommended that you become familiar with software development tools for STM32 Nucleo-F446RE development board before working with the EduBase-V2.

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

1, Work on the Nucleo-F446RE development board standalone and familiarize with its software development. Don't plug the Nucleo-F446RE development board 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 Nucleo-F446RE development board standalone.

2. Plug the Nucleo-F446RE development board into the EduBase-V2 via an adapter board. The adapter board is attached to the EduBase-V2 via 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 Nucleo board will always be plugged in correctly. The J19A and J19B are used for Arduino Nano. For working with a Nucleo board the jumpers on the J19A and J19B should be placed on the upper two pins.

There are major IDE's and tools for F446 software development:

- Keil MDK-ARM
- IAR Embedded Workbench
- ST's TrueStudio (<https://atollic.com/truestudio/>)
- Workbench for STM32 (<https://www.st.com/en/development-tools/sw4stm32.html>)
- ST tools (CubeMX, Function Packs, X-CUBE packs, etc.)

Professor Mazidi and Professor Chen have chosen the Keil IDE and wrote a textbook for the STM32 Nucleo-F446RE development board. 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 sample programs for the EduBase-V2. We are very grateful to their hard work. See their website.

http://www.MicroDigitalEd.com/ARM/STM_ARM_books.html

Chapter 3. On-line resources

See more info on <http://www.trainer4edu.com>

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 PB4-PB7 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 PC8-PC11 are connected to 4 push buttons. When a key is down, the Port C input goes HIGH.

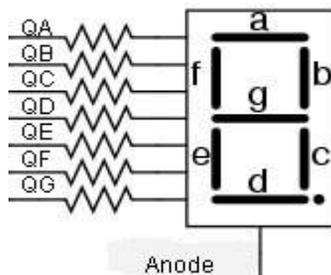
4.3 7-Segment LED multiplexing

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.

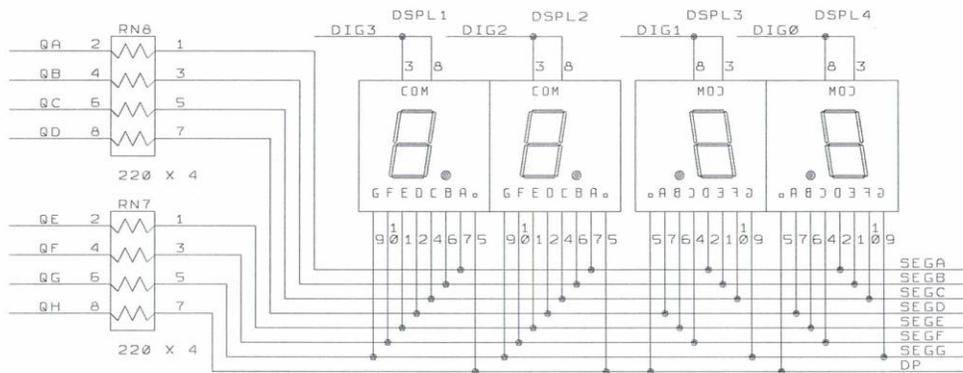
By convention, the 7 segments are called segment A, B, C, D, E, F and G. Their locations in the display are shown below:



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 old versions of EduBase trainers, the 7-segment display was 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

The light sensor is connected to the PA0 of the ADC port.

4.5 Potentiometer

The 5K potentiometer VR2 is connected to the PA1 of the ADC port

4.6 Temperature sensor

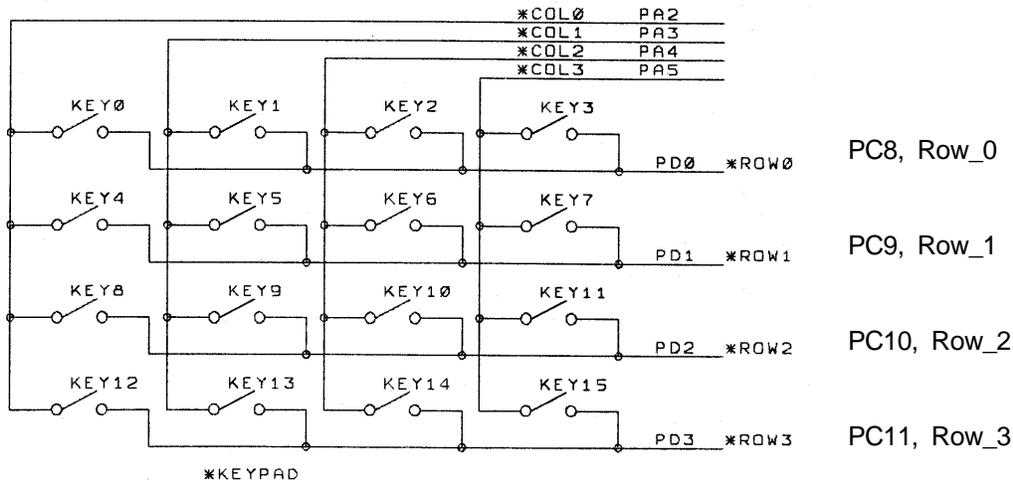
The temperature sensor (LM45 or equivalent) is connected to the PB14 of the ADC port

4.7 Keypad:

PC8-PC11 and PB12-PB15 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:

PB12	PB13	PB14	PB15
Col_0	Col_1	Col_2	Col_3



Keypad connections:

PB12 connects COL0 of the keypad
 PB13 connects COL1 of the keypad
 PB14 connects COL2 of the keypad
 PB15 connects COL3 of the keypad

PC8 connects ROW0 of the keypad
 PC9 connects ROW1 of the keypad
 PC10 connects ROW2 of the keypad
 PC11 connects ROW3 of the keypad

Keypad scan routine sets PB15 high and PB12, PB13, PB14 low, then tests PC8-PC11.

If no key is down, PC8-PC11 remain low.
 If PC11 = high, the key 15 is pressed.
 If PC10 = high, the key 14 is pressed.
 If PC9 = high, the key 13 is pressed.
 If PC8 = high, the key 12 is pressed.

Keypad scan routine sets PB14 high and PB12, PB13, PB15 low, then tests PC8-PC11.

If no key is down, PC8-PC11 remain low.
 If PC11 = high, the key 11 is pressed.
 If PC10 = high, the key 10 is pressed.
 If PC9 = high, the key 9 is pressed.
 If PC8 = high, the key 8 is pressed.

Keypad scan routine sets PB13 high and PB12, PB14, PB15 low, then tests PC8-PC11.

If no key is down, PC8-PC11 remain low.
 If PC11 = high, the key 7 is pressed.
 If PC10 = high, the key 6 is pressed.
 If PC9 = high, the key 5 is pressed.
 If PC8 = high, the key 4 is pressed.

Keypad scan routine sets PB12 high and PB13, PB14, PB15 low, then tests PC8-PC11.

If no key is down, PC8-PC11 remain low.
 If PC11 = high, the key 3 is pressed.
 If PC10 = high, the key 2 is pressed.
 If PC9 = high, the key 1 is pressed.
 If PC8 = 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 PC8-PC11,

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 PA12

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 (PB12-PB15) are connected to the D4-D7 of LCD via a 74HCT245 buffer (U18). The control pins are PA11 for LCD R/S and PA12 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 PB2 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 (PB4 and PB5) to control direction, one must be set at high, the other one must be set at low. If PB4 is high and PB5 is low the motor will turn clockwise, then if PB4 is low and PB5 is high the motor will turn count clockwise. If both PB4 and PB5 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 PB0 of the NucLeo-F446RE development board. The sample program is available on Professor Mazidi's web site.

The other half of the H-bridge driver is controlled by PB6, PB7 for direction and PB1 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 PB4 and PB5 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. Unfortunately the current adapter for the STM32-F446RE mapped the wrong signals for the CAN, so it does not support the CAN. It will be corrected with the future update in the adapter or when we add the F446 headers on the EduBase-V2.

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	PC1
Pin4	Reset	
Pin5	R/S	PA11
Pin6	MOSI	PA7
Pin7	SCLK	PA5
Pin8	Backlight	
Pin9	MISO	PA6

4.15 OLED

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

Pin1	SDA1 (PB9)
Pin2	SCL1 (PB8)
Pin3	VCC
Pin4	Ground

4.16 SD-Card

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

Chip select	PC12
MOSI	PA7
SCLK	PA5
MISO	PA6

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.

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 Main pin header 1.
- J19 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.

- 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

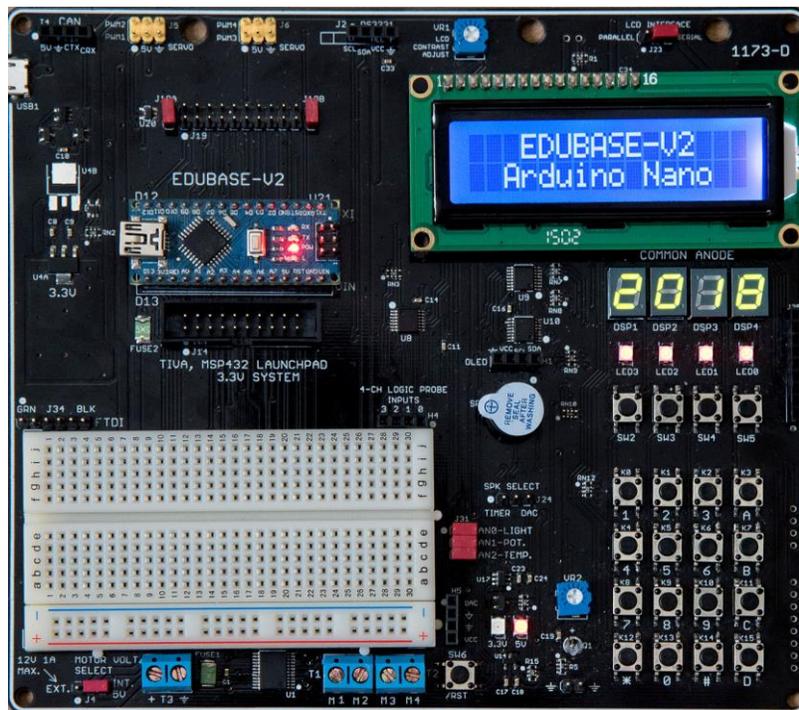
4.20 I/O pin usage

Most I/O pins are used by on-board peripherals. Fortunately, it's unlikely that all on-board peripherals will be used by one lab assignment. 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.

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 programs, 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.