TEXAS INSTRUMENTS

*User's Guide*

*SLVUB97–October 2017*

# *BOOSTXL-DRV8304H EVM User's Guide*

This document is provided with the BOOSTXL-DRV8304H customer evaluation module (EVM) as a supplement to the *DRV8304 38-V Three-Phase Smart Gate Driver* data sheet. The scope of this document is to provide the user with a guide to evaluate the DRV8304 device with the MSP430F5529 LaunchPad™ development kit.

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## Trademarks



# 1 Overview

The BOOSTXL-DRV8304H evaluation module (EVM) is an application board designed to allow easy evaluation of the DRV8304 device. The DRV8304 device is a gate driver IC for three-phase motor drive applications. The DRV8304 device provides three high-accuracy trimmed and temperature-compensated half bridge drivers, each capable of driving a high-side and low-side N-type MOSFET.

The DRV8304 device is used in motor control applications that require a high degree of integrated protection, diagnosis, and monitoring. Both SPI (DRV8304S) and hardware (DRV8304H) interface variants provide detailed fault reporting and flexible parameter settings such as current control options for slew-rate control of the gate drivers and various protection features.

This EVM uses a compact and modular form factor for ease of use and is designed to dock with compatible Texas Instruments LaunchPad development kits, or other MCUs for a complete motor-control system. Along with the hardware of the DRV8304 device, the MSP430F5529 microcontroller has loaded reference software that provide the necessary gating pulses to the DRV8304 device to control BLDC motors.

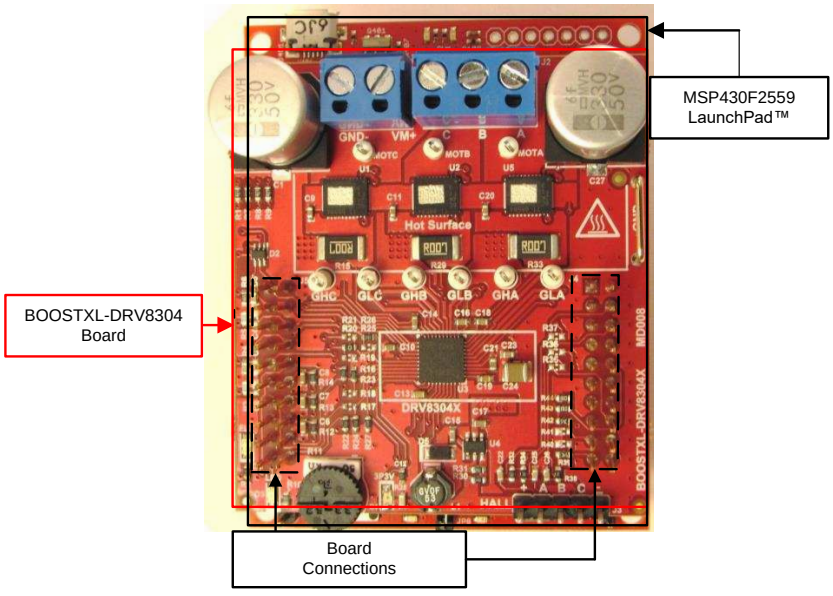


**Figure 1. LaunchPad™ and BOOSTXL-DRV8304H EVM**

## 1.1 Purpose and Scope

This document is designed to be used as a startup guide and to supplement the DRV8304 and MSP430F5529 BLDC motor control demo code kit. This document is intended for the engineers involved in the design, implementation, and validation of DRV8304x and MSP430F5529 reference software.

The scope of this document is to provide the user with a guide to evaluate the DRV8304 device with an MSP430F5529 LaunchPad development kit. This document covers the hardware (HW) connections required between the BOOSTXL-DRV8304H EVM and LaunchPad development kit. When the HW connections are done, the user is required to download the required tools and software (SW) to spin the motor. The following sections provide step-by-step details on the installing the CCS tool, importing the DRV8304 project into CCS, building the project, debugging the project, and spinning the motor, see Section 2.2.

This reference SW comprises trapezoidal sensored and sensorless algorithms for BLDC motor control. For additional information on the algorithms used, refer to *BOOSTXL-DRV8304x Sensored Software User's Guide* and *BOOSTXL-DRV8304x Sensorless Software User's Guide*.

# 2 Hardware and Software Overview

## 2.1 Hardware Overview

### 2.1.1 Features

The following lists the BOOSTXL-DRV8304H EVM features:

- Operating supply range from 6 V to 38 V
- Three CSD88584Q5DC N-channel NexFETs driven by the gate driver
- Protected phase voltages provided to header pins through a voltage divider
- Connector available for Hall sensor inputs connected to the MSP430™ MCU. The 3.3-V supply to the Hall sensors is derived by the LMR16006XDDCR buck converter
- Includes sample code for MSP430F5529 LaunchPad

### 2.1.2 BOOSTXL-DRV8304H EVM Overview

Figure 2 shows the major blocks of the hardware on the BOOSTXL-DRV8304H EVM.

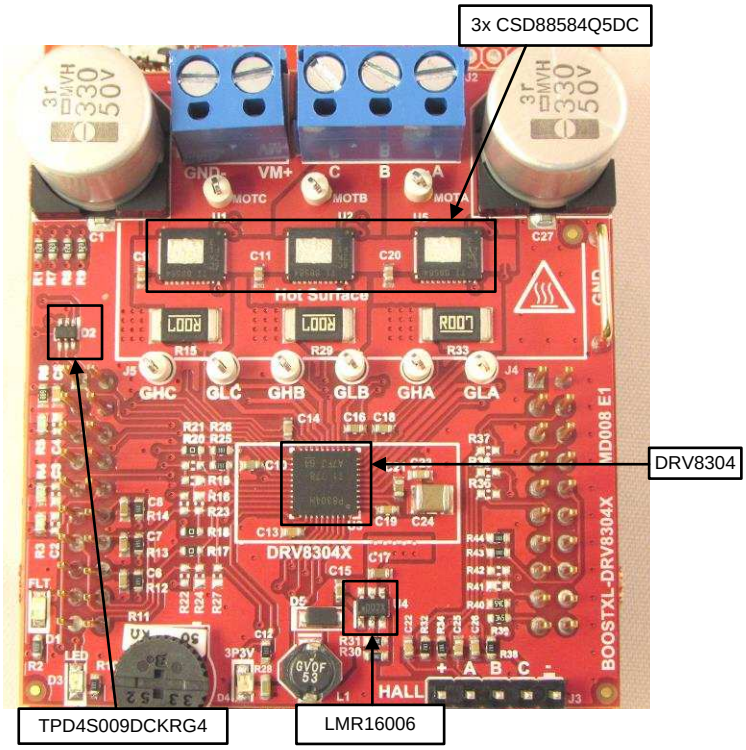


**Figure 2. Hardware Connections Overview**

- **Power Supply (J1):** valid input supply voltages from 6 V to 38 V from a battery or a DC voltage source.
- **DRV8304 (U3):** 3-phase automotive gate driver with three integrated current shunt amplifiers.
- **Drive Stage (U1, U2, U5):** 3× CSD88584Q5DC N-channel NexFETs driven by the gate driver.
- **LMR16006 (U4):** DC/DC buck regulator with 3.3-V output used to support external hall sensors, not required for device operation.
- **To Motor (J2):** switching nodes of the 3-phase bridges for motor connection.
- **LEDs (3P3V[D4], nFault[D1]):** shows the status of the board.

**CAUTION**

Hot surface. Contact may cause burns. Do not touch.

### 2.1.3 Pinout and Jumper Overview

Figure 3 shows the various jumper labels on the BOOSTXL-DRV8304H EVM.

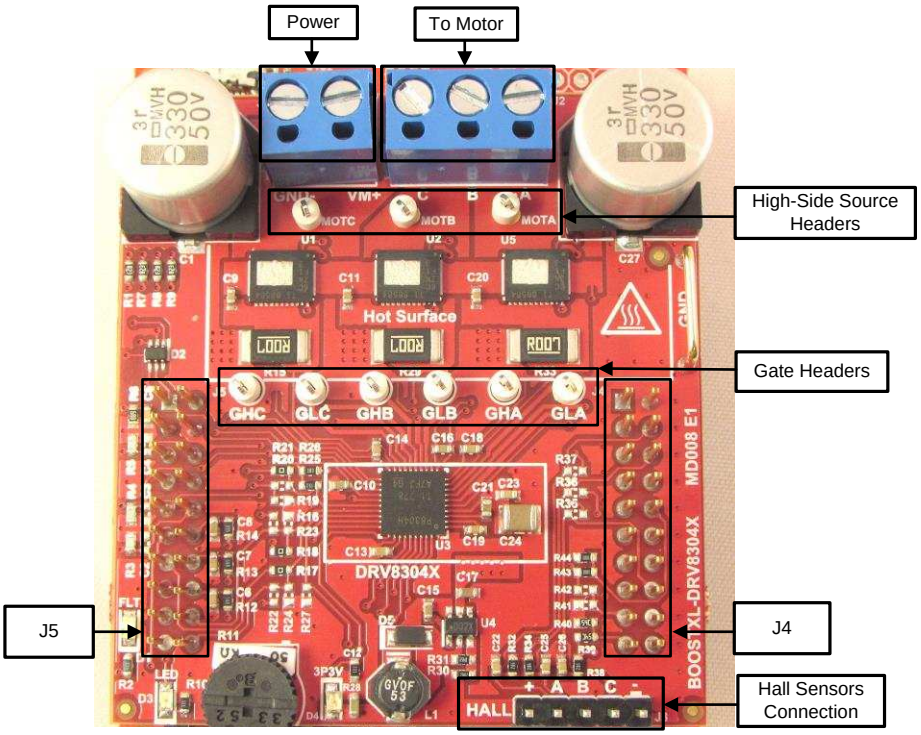


**Figure 3. Connections Overview**

Figure 4 shows the various jumper connection pinouts from the BOOSTXL-DRV8304H EVM to the MCU.

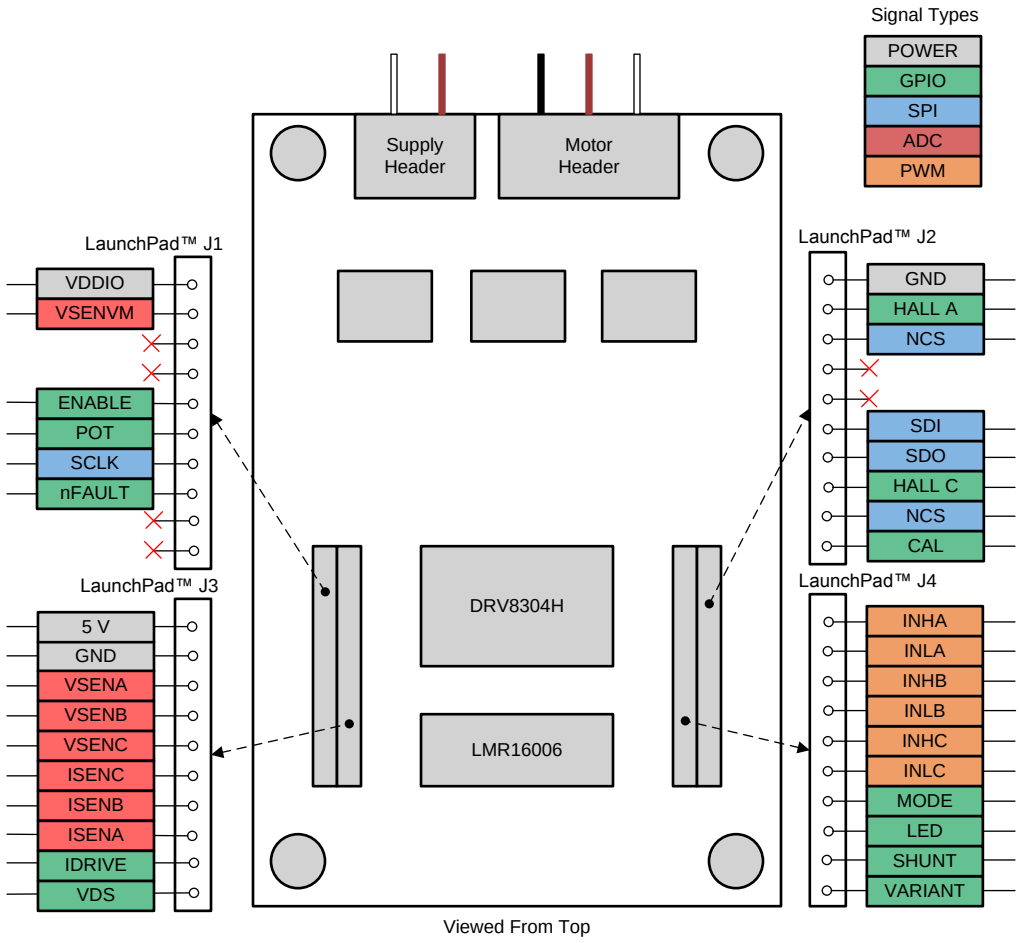


**Figure 4. BOOSTXL-DRV8304H Jumper Connectors Pinout**

### 2.1.4 Connecting the BOOSTXL-DRV8304H EVM to the LaunchPad™

Follow these steps when connecting the BOOSTXL-DRV8304H EVM to the LaunchPad

Step 1. Make sure nothing is connected to the board, and no power is being supplied.

Step 2. Connect the BOOSTXL-DRV8304H connectors J1/J3 and J2/J4, onto the MSP430F5529 LaunchPad development kit (see Figure 1).

Step 3. Connect a USB cable to the PC and directly to the MSP430F5529 LaunchPad development kit.

Step 4. Connect the three phases of the BLDC motor to the three-phase motor socket, J2 (the pins are labeled A, B, and C), provided on the BOOSTXL-DRV8304H EVM board (see Figure 3).

**CAUTION**

Make sure the proper orientation is used, and verify that all pins make proper contact between the boards before powering on.

Step 5. Connect the supply voltage ranging from 6 V to 38 V from a battery or a DC-voltage source to

the voltage supply pin, J1.

Step 6. Confirm that the 3P3V LED is turned on and the nFAULT LED turned off after powering the device (see Figure 5).

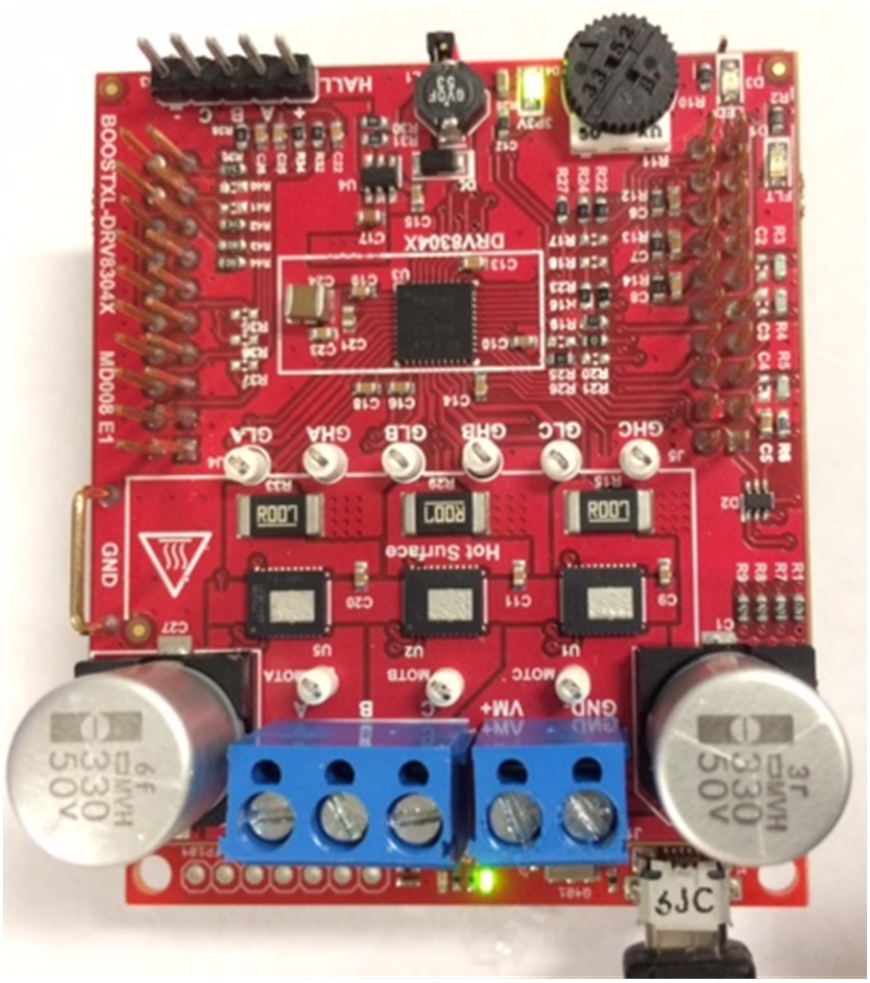


**Figure 5. EVM Showing the Position of LEDs**

### 2.1.5 Hardware, Software, and Tools Required for Evaluation

The software, hardware, and tools required to optimally evaluate the reference software code with the BOOSTXL-DRV8304H EVM are listed as follows:

- BOOSTXL-DRV8304H EVM
- MSP430F5529 LaunchPad development kit
- Voltage supply from 6 V to 38 V
- Code Composer Studio™ software V.6.1 and above
- BOOSTXL-DRV8304H reference software development package
- BOOSTXL-DRV8304H GUI software

### 2.1.6 Interfacing DRV8304x and MSP430F5529 LaunchPad™

The DRV8304 device has 40 pins with different functions. These pins are interfaced with the MSP430F5529XL LaunchPad development kit which is mapped appropriately to receive the functionality of the BoosterPack™ plug-in module. These 40 pins are grouped into 4 ports. Table 1 and Table 2 list the interfacing of these ports with the MSP430F5529 device.

**Table 1. BOOSTXL-DRV8304H J4 Pin Connections**

| J4 Pin Number | BOOSTXL-DRV8304H Function | MSP430F5529 Function | Description |
|---|---|---|---|
| 1 | INHA | P2.5, TA2.2 | Secondary function, Timer 2 comparator output to generate PWM for A phase high-side switches |
| 2 | GND | GND | ADC GND connections |
| 3 | INLA | P2.4, TA2.1 | Secondary function, Timer 2 comparator output to generate PWM for A phase low-side switches |
| 4 | HALLA | P2.0, SPI enable | Hall sensor A from motor |
| 5 | INHB | P1.5, TA0.4 | Secondary function, Timer 1 comparator output to generate PWM for B phase high-side switches |
| 6 | HALLB | P2.2, I/O PIN with Interrupt | Hall sensor B from motor |
| 7 | INLB | P1.4, TA0.3 | Secondary function, Timer 1 comparator output to generate PWM for B phase low-side switches |
| 8 | No function | P7.4, I/O pin | No function |
| 9 | INHC | P1.3, TA0.2 | Secondary function, Timer 1 comparator output to generate PWM for C phase high-side switches |
| 10 | No function | RST | No function |
| 11 | INLC | P1.2, TA0.1 | Secondary function, Timer 1 comparator output to generate PWM for C phase low-side switches |
| 12 | SDI | P3.0, UCBOSIMO | Secondary function for data input to DRV8304S |
| 13 | MODE | P4.3, I/O pin | Sets the input control mode, 4-level input pin (DRV8304H devices only) |
| 14 | SDO | P3.1, UCBOSOMI | Secondary function for data output from DRV8304S |
| 15 | LED | P4.0, I/O pin | Visual feedback for faults. |
| 16 | HALLC | P2.6, I/O pin With Interrupt | Hall sensor C from motor enable the gate driver and current shunt amplifiers |
| 17 | SHUNT | P3.7, I/O pin | This pin is pulled high for 3 shunt variant and pulled low for single shunt variant |
| 18 | nSCS/GAIN | P2.2, I/O PIN with Interrupt | Active low enables serial interface communication and sets the gain of the shunt amplifiers, 4-level input pin (DRV8304H devices only) |
| 19 | VARIANT | P8.2, I/O pin | Pulled low for DRV8304H, high for DRV8304S devices |
| 20 | CAL | P8.1, I/O pin | Pull logic high to internally short all amplifier inputs together |

**Table 2. BOOSTXL-DRV8304H J5 Pin Connections**

| J5 Pin Number | BOOSTXL-DRV8304H Function | MSP430F5529 Function | Description |
|---|---|---|---|
| 1 | 3.3 V | 3.3 V | 3.3-V LaunchPad supply |
| 2 | No function | 5 V | 5-V supply |
| 3 | VSENVM | P6.5, ADC channel – A5 | Sensing VCC supply voltage |
| 4 | GND | GND | ADC - GND connections |
| 5 | No function | P3.4, I/O PIN | Software debug pins (optional) |
| 6 | VSENA | P6.0, ADC channel – 0 | Sensing A phase voltage |
| 7 | No function | P3.3, I/O PIN | Software debug pins (optional) |
| 8 | VSENB | P6.1, ADC channel – 1 | Sensing B phase voltage |
| 9 | ENABLE | P1.6, I/O pin with Interrupt | Logic low to enter a low-power sleep mode |
| 10 | VSENC | P6.2, ADC channel – 2 | Sensing C phase voltage |
| 11 | POT | P6.6, ADC channel – A6 | Optional POT to vary the voltage 0-3.3 V on pin |
| 12 | ISENC | P6.3, ADC channel – 3 | Sensing C phase current |
| 13 | SCLK | P3.2, UCBOCLK – SPI CLK | Secondary function for pin SPI CLK |
| 14 | ISENB | P6.4, ADC channel – 4 | Sensing B phase current |
| 15 | nFAULT | P2.7, I/O pin with Interrupt | Pulled logic low during a fault condition |
| 16 | ISENA | P7.0, ADC channel – 12 | Sensing A phase current |
| 17 | No function | P4.2, I/O pin | Software debug pins (optional) |
| 18 | IDRIVE | P3.6, I/O pin | Sets gate drive peak current, 7-level input pin (DRV8304H devices only) |
| 19 | No function | P4.1, I/O pin | Software debug pins (optional) |
| 20 | VDS | P3.5, I/O pin | Sets VDS monitor threshold voltage, 7-level input pin (DRV8304H devices only) |

### 2.1.7 Hardware Connections for Hall Sensor Operation

Table 3 lists the signal connections from the Hall sensor of the motor connected to jumper J3 on the BOOSTXL-DRV8304H EVM.

**Table 3. Hall Sensor Signal Connections to the BOOSTXL-DRV8304H EVM**

| Signal Description | Equivalent on BOOSTXL-DRV8304H EVM |
|---|---|
| GND | J3–1(-) |
| Hall C | J3–2(C) |
| Hall B | J3–3(B) |
| Hall A | J3–4(A) |
| V3P3 | J3–5(+) |

## 2.2 Software and Tools Overview

### 2.2.1 Installing CCS for Software Evaluation

Code Composer Studio (CCS) versions 5.x.x and 6.x.x were used and tested for DRV8304X reference code. Install an authorized version from www.ti.com/tool/ccstudio.

**NOTE:** A myTI login account is required to download CCS as well as the SDK package. This section describes the installation procedure for CCS5.4; however, installing other versions of CCS v5.x, including CCS, v6.x is similar.

After following the required steps to download the CCS installer, the ccs_setup_5.4.0.00091.exe file should be located in the specified download directory. Figure 6 shows this file.

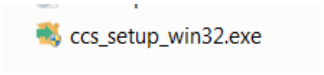


**Figure 6. Downloaded Executable for Code Composer Studio Installation**

Follow the installation process listed:

Step 1. Run the installer by double clicking the *ccs_setup_win32.exe* file.

Step 2. Read through and accept the license agreement to proceed with the installation (see Figure 7).

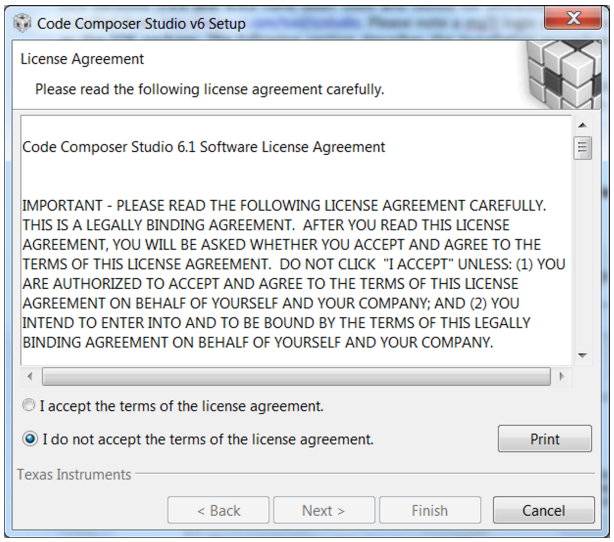


**Figure 7. CCS License Agreement**

Step 3. Choose a destination directory. Using the default (c:\ti) removes a step in the SDK installation procedure (see Figure 8).

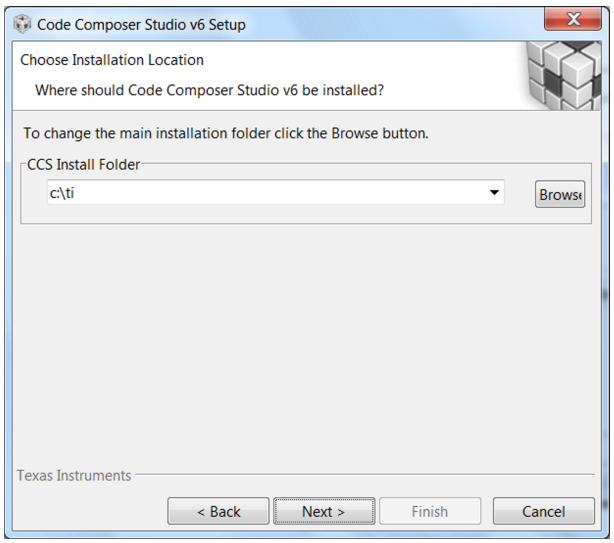


**Figure 8. Default Installation Location for CCS**

Step 4. Choose the processor architectures to install (see Figure 9).

For the DRV83xx, the MSP430 and C28x are the only needed processor packages. The compiler tools

are required. Ensure that the box for the *TI MSP430 Compiler Tool* is checked.

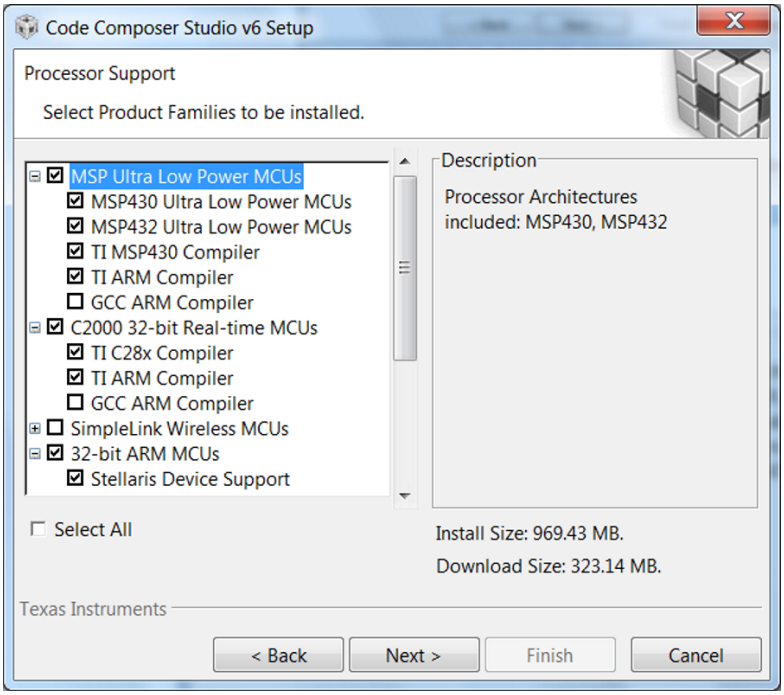


**Figure 9. Processors Supported by CCS**

Step 5. Select the emulator components to install.

For the provided tool, the MSP430 USB FET emulator is required.

Step 6. Review the installation size and click the *Finish* button to begin installation of the CCS software (see Figure 10).

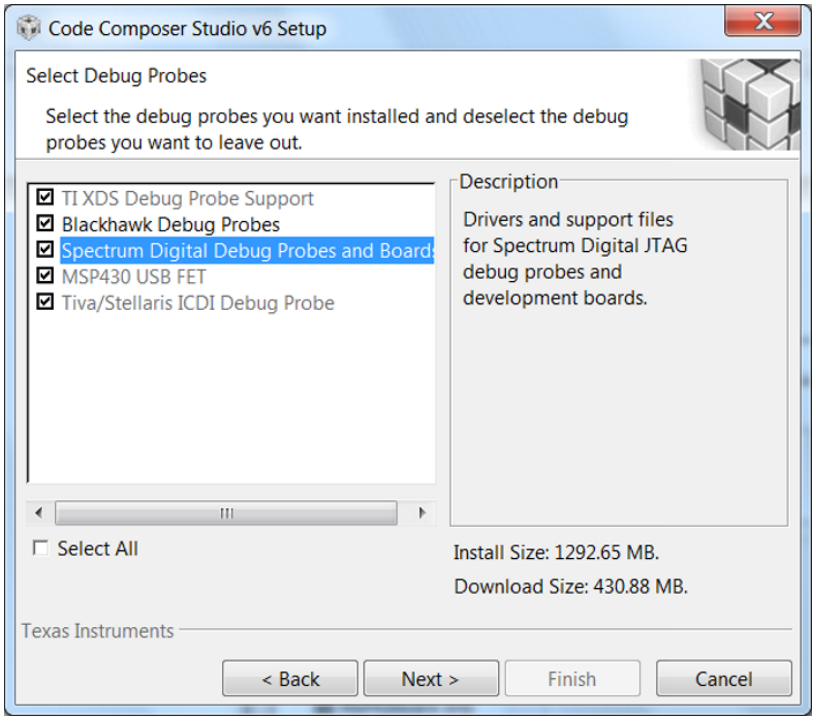


**Figure 10. Components Available for Installation**

Step 7. Choose add-on software (this step is optional).

Step 8. Review the installation and click the *Finish* button to finalize (see Figure 11).


**Figure 11. Emulators Available for Installation**

Step 9. After the installation is complete, click the *Finish* button to exit the set-up.

### 2.2.2 Installing DRV8304 Reference Software Development Package

The DRV8304 reference software contains the files required to program DRV8304 devices along with the MSP430F5529 using CCS v5.x or CCS v6.x. All of these files are included in the installation package. To access this package, contact the DRV8x applications team or the respective field-sales engineer.

Install the reference software development package using these steps:

Step 1. Double click the executable file (.exe) for the DRV8304 reference software installer (see Figure 12).

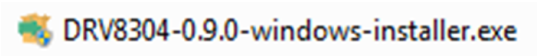


**Figure 12. DRV8304 Firmware Installer Executable File**

Step 2. Follow the prompts to select another language from the default of English (see Figure 13).

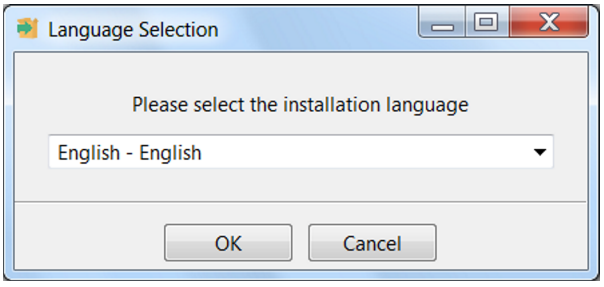


**Figure 13. Language Selection**

Step 3. Click the *Next* button on the DRV8304 installer welcome screen (see Figure 14).

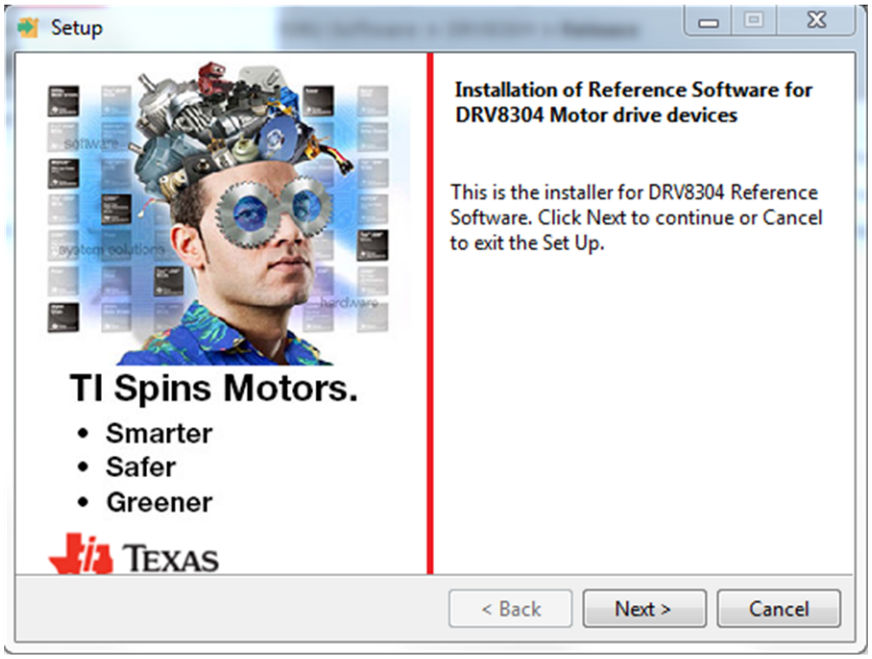


**Figure 14. Setup Home Screen**

Step 4. Read though and accept the license agreement to proceed with the installation (see Figure 15).

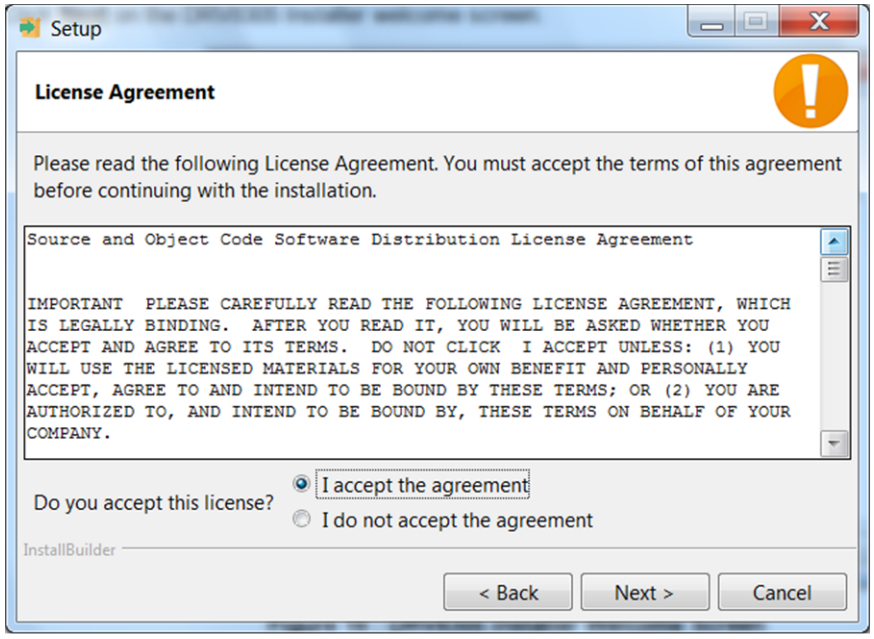


**Figure 15. DRV8304 Software License Agreement**

Step 5. Choose the destination location for the example CCS projects and the documentation (see Figure 16). This destination can be set to any location in the PC.

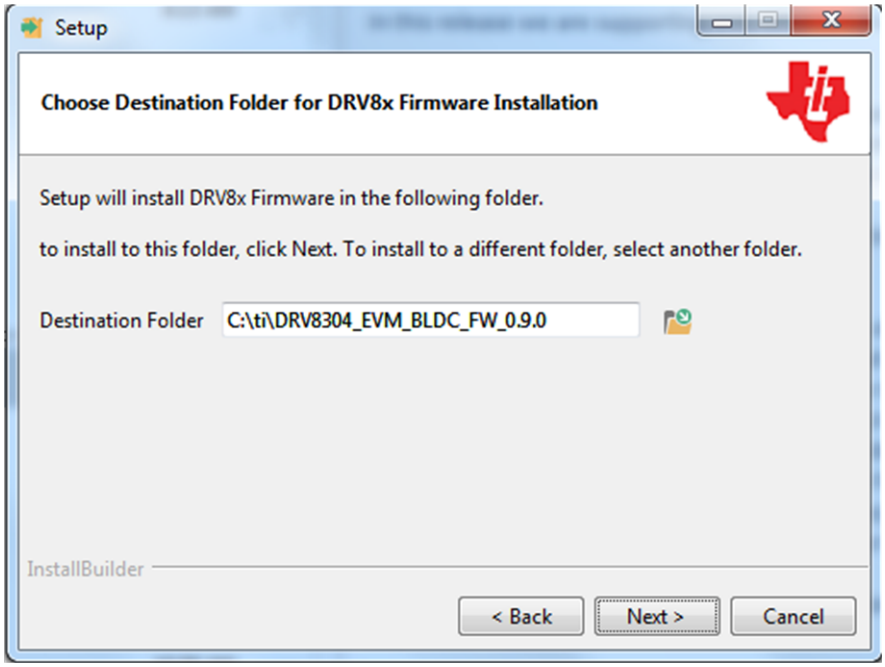


**Figure 16. Setup Destination Folder**

Step 6. Select each DRV83x component to install (see Figure 17).

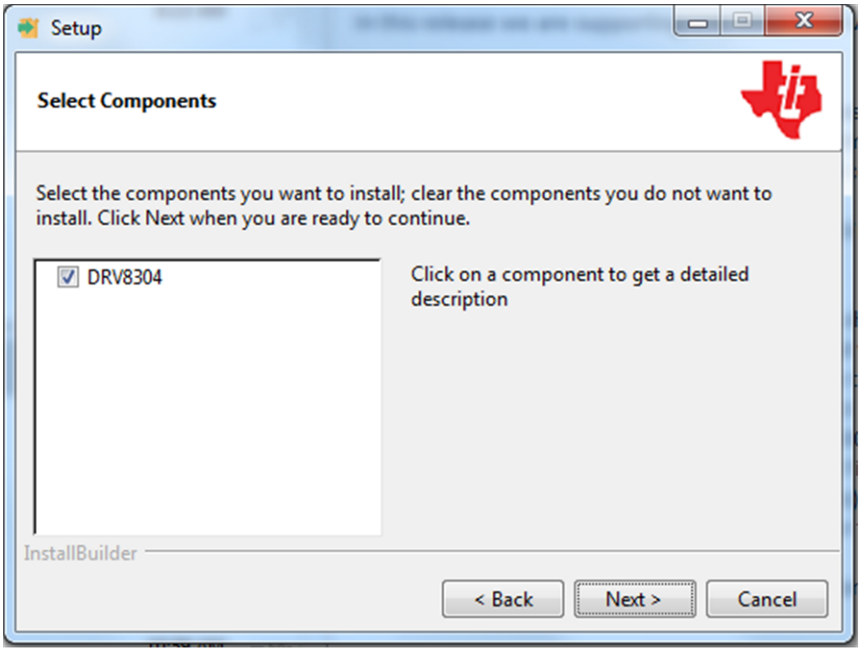


**Figure 17. Select DRV8304 Setup Components**

Step 7. Ensure all running instances of CCS are closed (see Figure 18).

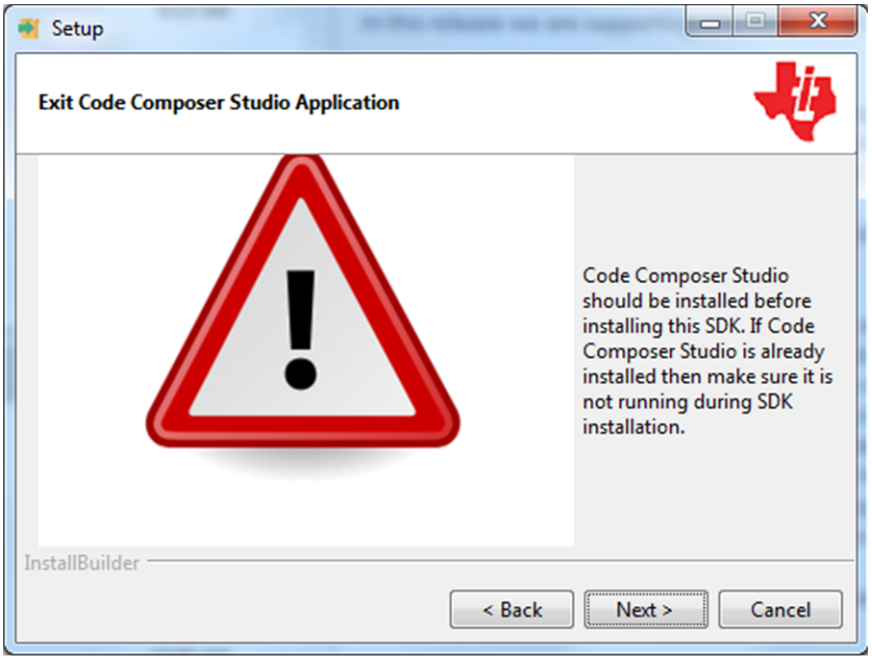


**Figure 18. Warning Message to Close CCS**

Step 8. Continue with the installation process.

Step 9. Click the *Next* button to install after reviewing the settings.

Step 10. Click the *Finish* button when the files are successfully installed in the destination folder (see Figure 19).

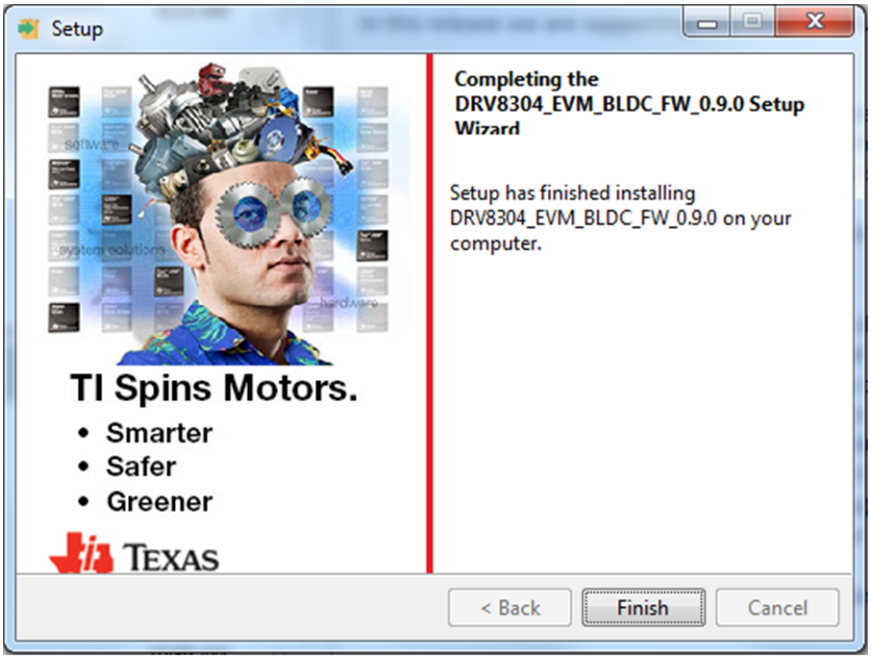


**Figure 19. Firmware Setup Complete**

### 2.2.3 Creating or Importing a DRV8304 Project Into CCS

When the CCS software is started, the user must first select a workspace. A workspace is the structure in which projects are kept. Multiple projects can be saved in one workspace. After importing an existing project, the user can explore the features of CCS to become familiar with the IDE. Follow these steps to import the provided project:

Step 1. Double click the CCS icon to open the application. A CCS icon is placed on the desktop after installation.


**Figure 20. Open CCS Application**

Step 2. Select the location and name of the workspace. The location and naming convention can be changed. (see Figure 21).

Step 3. Click the *OK* button to accept.

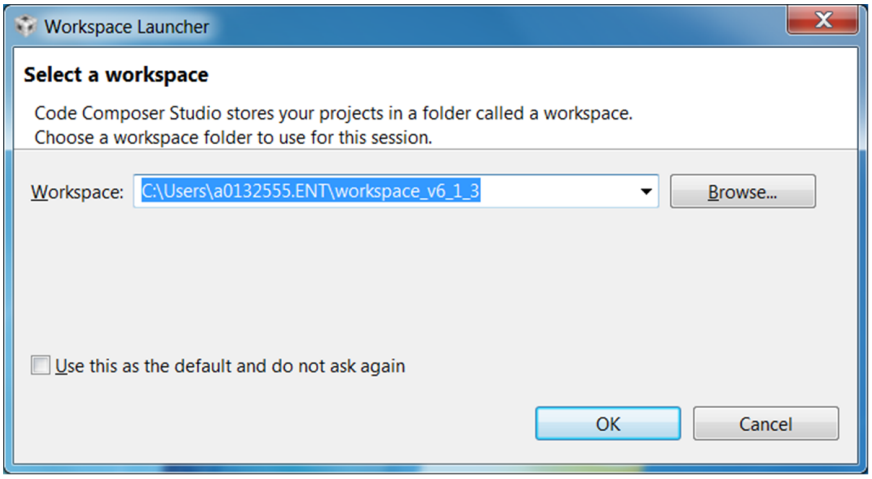


**Figure 21. Workspace Selection**

After selecting the workspace, the CCS software opens displaying a welcome menu.

Step 4. Import a project either from the welcome menu by selecting *Import Project* or go to the *Project* menu and select *Import Existing CCS Eclipse Project* (see Figure 22).

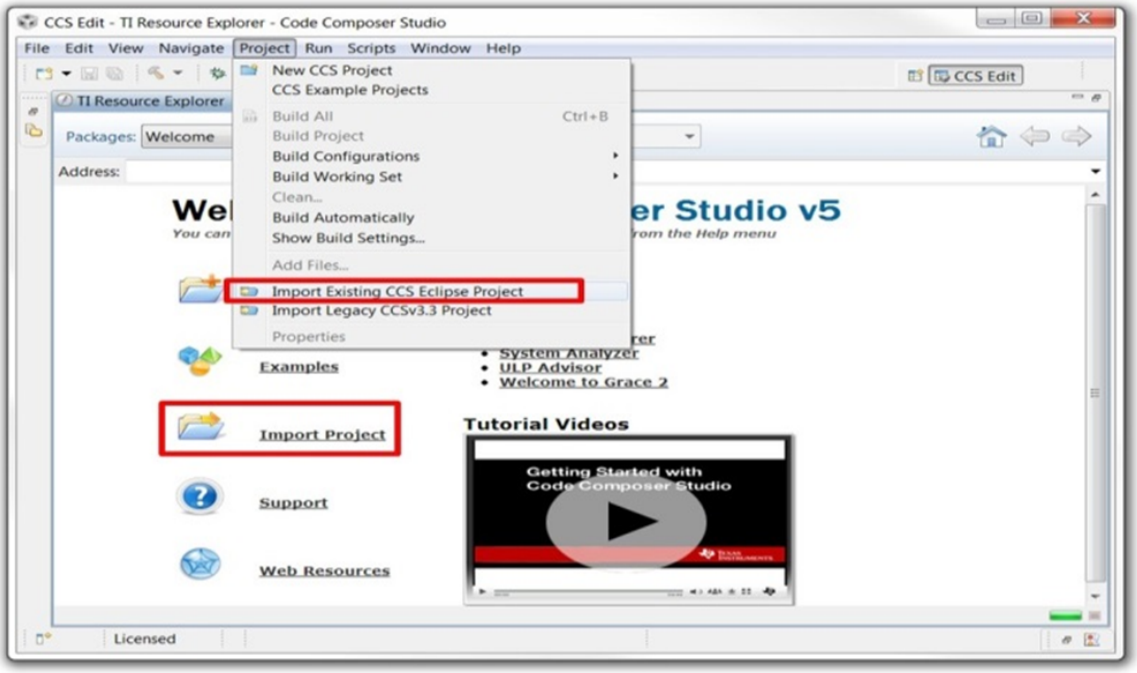


**Figure 22. Importing CSS Project**

Step 5. In the new window that appears showing the import options, click the *Browse...* button and find the provided projects through the folder browser. These projects are located in the SDK installation directory. The default location of the root folder is under C:\ti (see Figure 23). When selected, the provided project appears under *Discovered Projects*.

Step 6. Make sure the correct box is checked and then click the *Finish* button (see Figure 23).

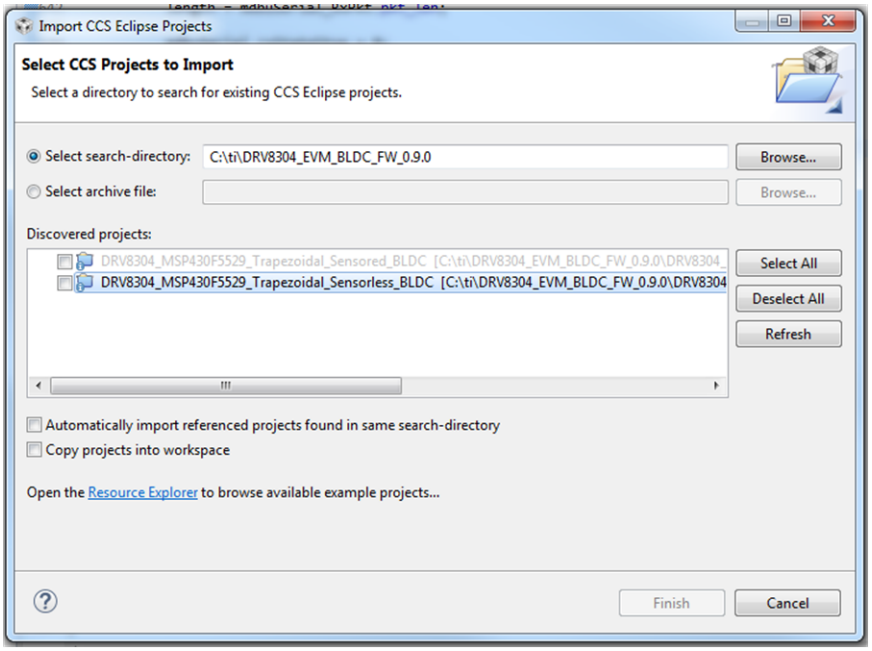


**Figure 23. Select Projects to Import**

When the projects are imported to the workspace, the project should appear in the *Project Explorer* window as shown in Figure 24.

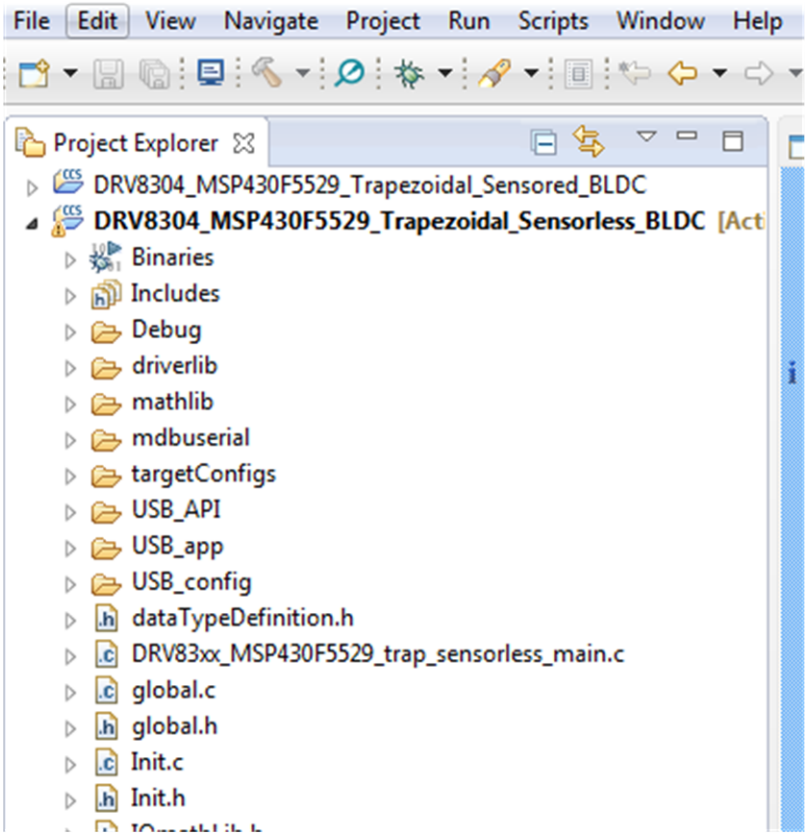


**Figure 24. Project Explorer**

Step 7. Explore the project files, build the project to create an image to be downloaded on the MSP430F5529 hardware, and download the project from here. Make sure the MSP430F5529 is connected to the PC through USB interface before downloading the code.

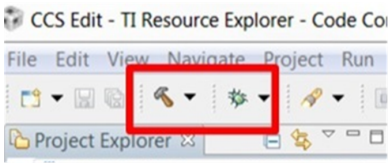


**Figure 25. Build and Debug**

Step 8. When the CCS software is connected to the device, run the program from CCS to execute the program in hardware by clicking the green play button (see Figure 26). Click the red stop button (see Figure 26) to disconnect from the device debugger.

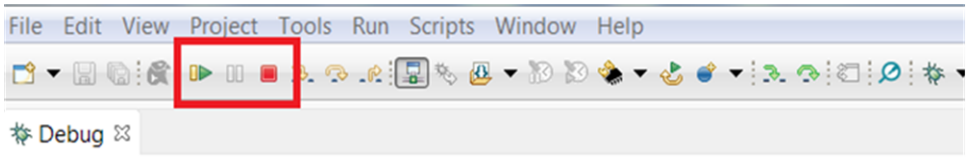


**Figure 26. Run and Pause Debug Session**

Step 9. Start a new project by clicking on the *File* menu, selecting *New*, and then *CCS Project*. A new window appears. Complete these steps to proceed:

1. Fill in the *Project Name* text field.
2. Under the *Family* drop-down menu, select *MSP430x5xx*.
3. Select *MSP430F5529* from the *Variant* drop-down menu and the specific device in the adjoining field.

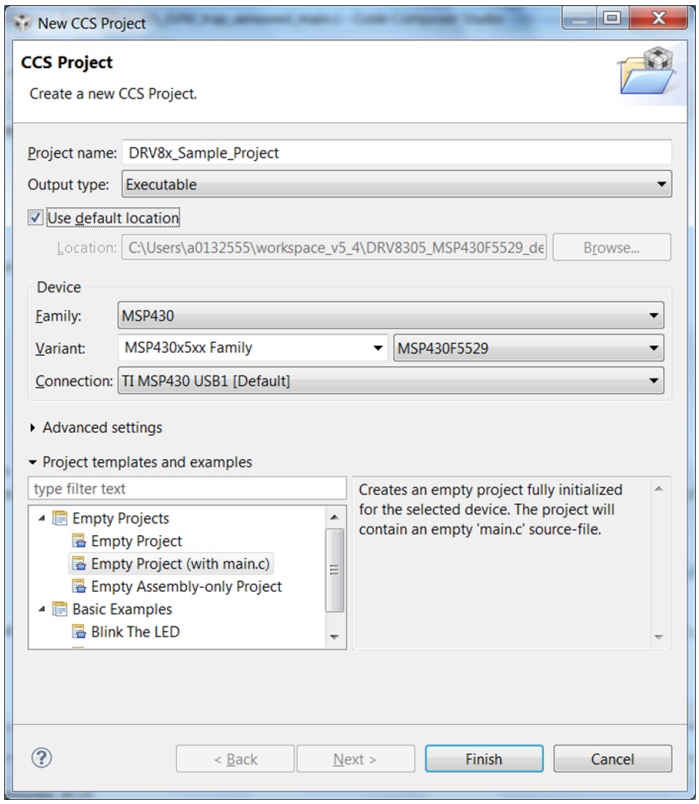


**Figure 27. New CCS Project**

### 2.2.4 Updating the MSP430 USB-FET

After the reference project is imported and selected in the CCS software, the provided software builds and runs on the MSP430 device. The device is programmed by the MSP430 USB-FET. When this device is used, the CCS software automatically detects the firmware version and notifies of an update. The process takes a few minutes, let the update finish before unplugging the USB cable or closing CCS. Figure 28 and Figure 29 show the update process.

**CAUTION**

To help prevent any device damage, wait for the update to finish before unplugging the MSP430 device or closing CCS.

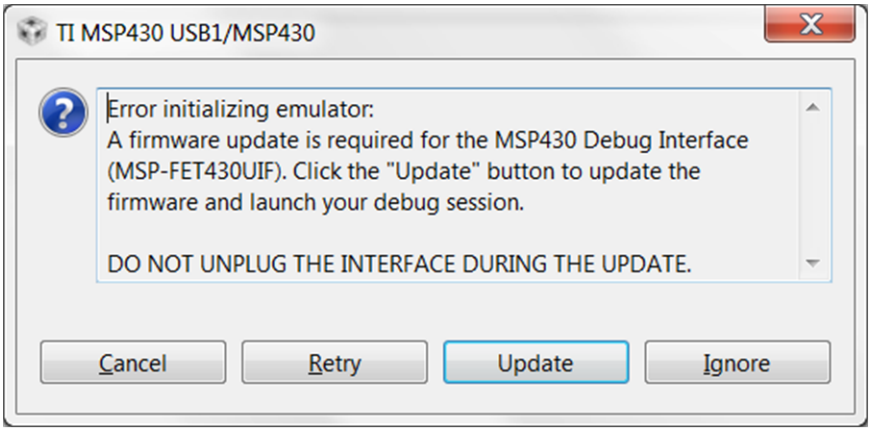


**Figure 28. Error Initializing Emulator**

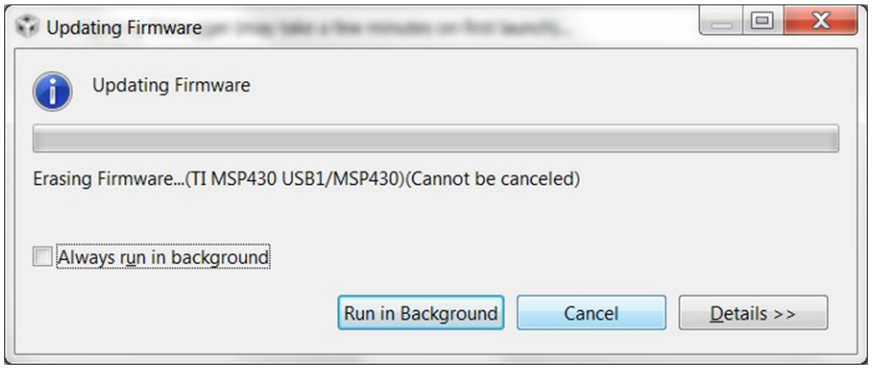


**Figure 29. Updating LaunchPad™ Development Kit Firmware**

### 2.2.5 GUI Application

#### 2.2.5.1 Installation

Follow these steps to install the GUI application:

Step 1. Download and run the *Setup_DRV8304x-0.9.0_EVM.exe* installer file to install the GUI application.

Step 2. Install the COM port driver for *TI MSP430 USB* (the firmware on MSP430F5529 LaunchPad development kit plug-in module).

This driver is automatically installed during the GUI installation process. Click the *Install* button when the window shown in Figure 30 appears during the GUI installation. If this pop-up does not appear, then the drivers are already installed.

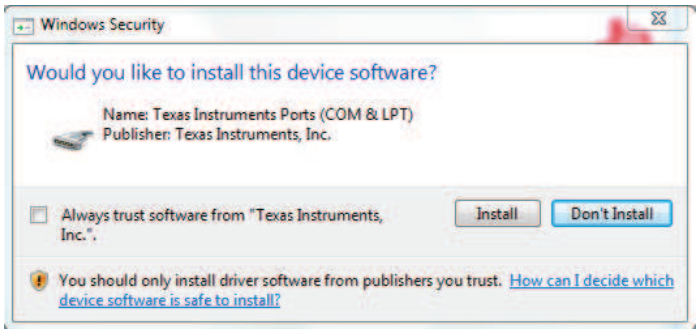


**Figure 30. TI MSP430 USB Installer**

If the automatic driver installation fails for some reason, or if the *Don't Install* button was clicked, install the drivers manually. First, find the driver .inf file (msp430_ti_signed.inf) in the following folder: C:\Program Files (x86)\Texas Instruments\DRV8304x\TI MSP430 USB Driver. Right click on the .inf file and select the *Install* option. Follow the installation instructions to successfully install the driver.

If any issues occur during the driver installation steps or to learn more about the process, download and extract the *MSP430 USB Developers Package* from www.ti.com/tool/msp430usbdevpack and refer to the Microsoft® Windows ® 7 and Windows 8 sections in the document *Examples_Guide_MSP430_USB.pdf*, based on the appropriate Windows. This document is found under the *MSP430USBDevelopersPackage_5_10_00_17\MSP430_USB_Software\Documentation* directory of the extracted *MSP430 USB Developers Package*.

#### 2.2.5.2 Hardware Setup

The hardware required to run the motor control is an MSP430F5529 LaunchPad development kit, the BOOSTXL-DRV8304x BoosterPack plug-in module, a micro-USB cable, and a power supply with a DC output from 6 to 38 V. Follow these steps to start up the BoosterPack plug-in module:

Step 1. Dock the BOOSTXL-DRV8304x BoosterPack plug-in module to the MSP430F5529 LaunchPad development kit through the two 40-pin headers J4 and J5.

**NOTE:** Observe the correct polarity of the 40-pin LaunchPad headers. The MSP430F5529 LaunchPad header J1 should be connected to BOOSTXL-DRV8304x BoosterPack header J5 and MSP430F5529 LaunchPad header J2 should be connected to BOOSTXL-DRV8304x BoosterPack header J4.

Step 2. Connect the three phases from the brushless DC motor to the J2 connector on the BOOSTXL-DRV8304x BoosterPack plug-in module. Phase A, B, and C are labeled in white silkscreen on the PCB top layer.

**NOTE:** If using the sensored firmware on the MSP430F5529 LaunchPad development kit, connect a brushless DC motor Hall sensor input to header J3. If using sensorless firmware, header J3 can be left unconnected.

**NOTE:** If using 1x PWM Mode with the **sensored firmware** R35, R36, and R37 must be populated with 0-Ω resistors.

Step 3. Connect the DC power supply to header J1.

**NOTE:** Observe the correct polarity of +VM and GND connections on the BOOSTXL-DRV8304x BoosterPack connection J1

Step 4. Connect a micro-USB cable to the LaunchPad development kit and computer.

Step 5. Turn on the power supply and power up the PCB.

#### *2.2.5.3 Launching BOOSTXL-DRV8304X EVM GUI*

The BOOSTXL-DRV8304X EVM GUI facilitates the control of brushless DC motors. The BOOSTXL-DRV8304x GUI provides functionality for adjusting the speed and direction of the motor, setting various fault parameters such as voltage and current-protection limits, observing the motor drive speed, and monitoring the device fault status. The GUI can also be used to tune the motor for best performance using various parameters available in the motor control parameter page.

To launch the GUI, click on the BOOSTXL-DRV8304x EVM shortcut on the desktop or navigate to the Windows Start Menu and click *All Programs*. Navigate to the *Texas Instruments* folder and select the BOOSTXL-DRV8304x folder.

The Device *Launch* page (see Figure 31) is displayed to launch one of the 2 device variants (DRV8304S, DRV8304H). Click on one of the *Launch* buttons to launch either the **DRV8304S** or **DRV8304H** labels.

For a guide on the different attributes of the BOOSTXL-DRV8304x EVM GUI, refer to the *BOOSTXL-DRV8304x GUI User's Guide*.

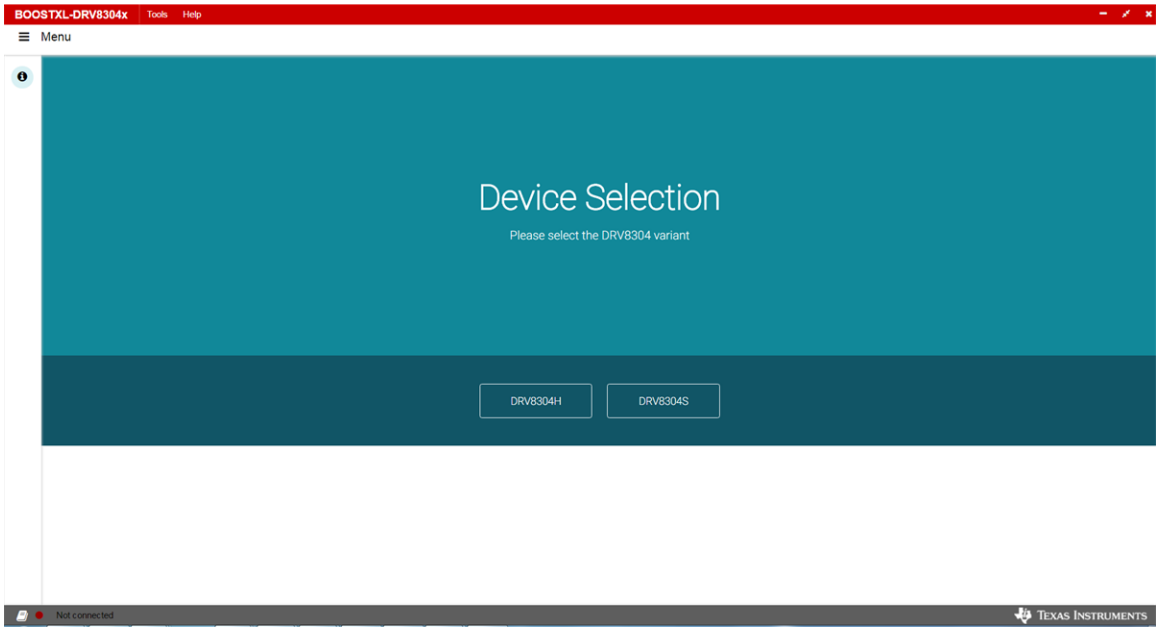


**Figure 31. BOOSTXL-DRV8304X EVM Device Launch**

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