DRV8313EVM User's Guide

Contents

1 INTRODUCTION

The medium voltage digital motor control (DMC) evaluation module (DRV8313EVM, Figure 1), provides a cost effective sensor-less solution to run a 3-phase BLDC motor in trapezoidal commutation. This document gives the complete detail of the EVM including its hardware details, jumper configuration, operating procedure to run the BLDC motor using GUI and in stand alone.

The available GUI only supports sensor-less commutation. However, a hall sensor connection option is provided in hardware for use with sensor based algorithms.

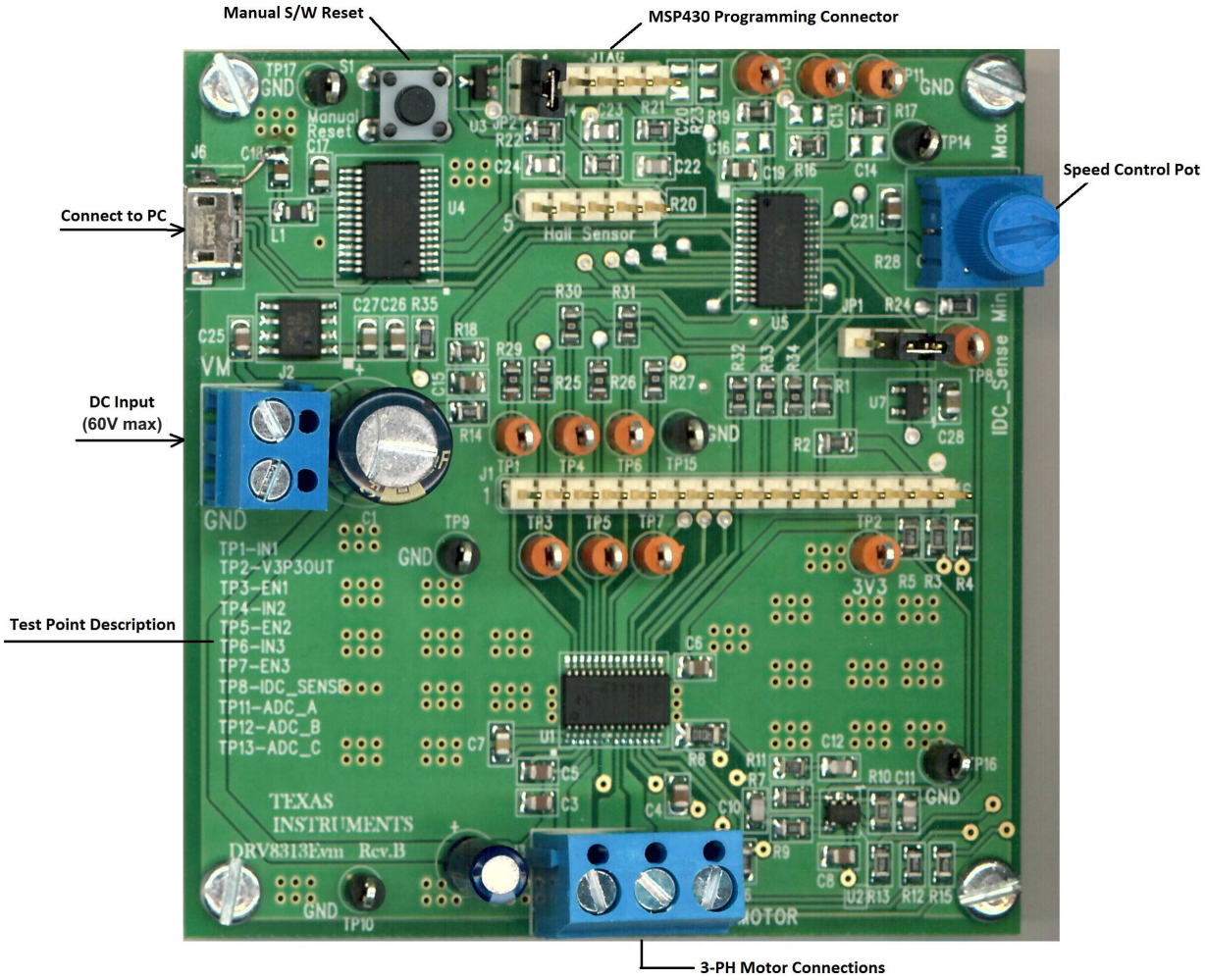

Figure 1. DRV8313EVM Top View

WARNING

This EVM is meant to be operated in a lab environment only and is not considered by TI to be a finished end-product fit for general consumer use. This EVM must be used only by qualified engineers and technicians familiar with risks associated with handling high voltage electrical and mechanical components, systems and subsystems. This equipment operates at voltages and currents that can result in electrical shock, fire hazard and/or personal injury if not properly handled or applied. Equipment must be used with necessary caution and appropriate safeguards employed to avoid personal injury or property damage. It is the user's responsibility to confirm that the voltages and isolation requirements are identified and understood, prior to energizing the board and or simulation. When energized, the EVM or components connected to the EVM should not be touched.

1.1 Hardware Block Diagram

Figure 2 illustrates a typical motor drive system running from dc power supply input (8 V to 60 V). The DRV8313EVM motor control board has all the power and control blocks that constitute a typical motor drive system for 3-phase BLDC motors. The EVM provides an easy to use GUI interface to enable motor operation from an external PC or laptop.

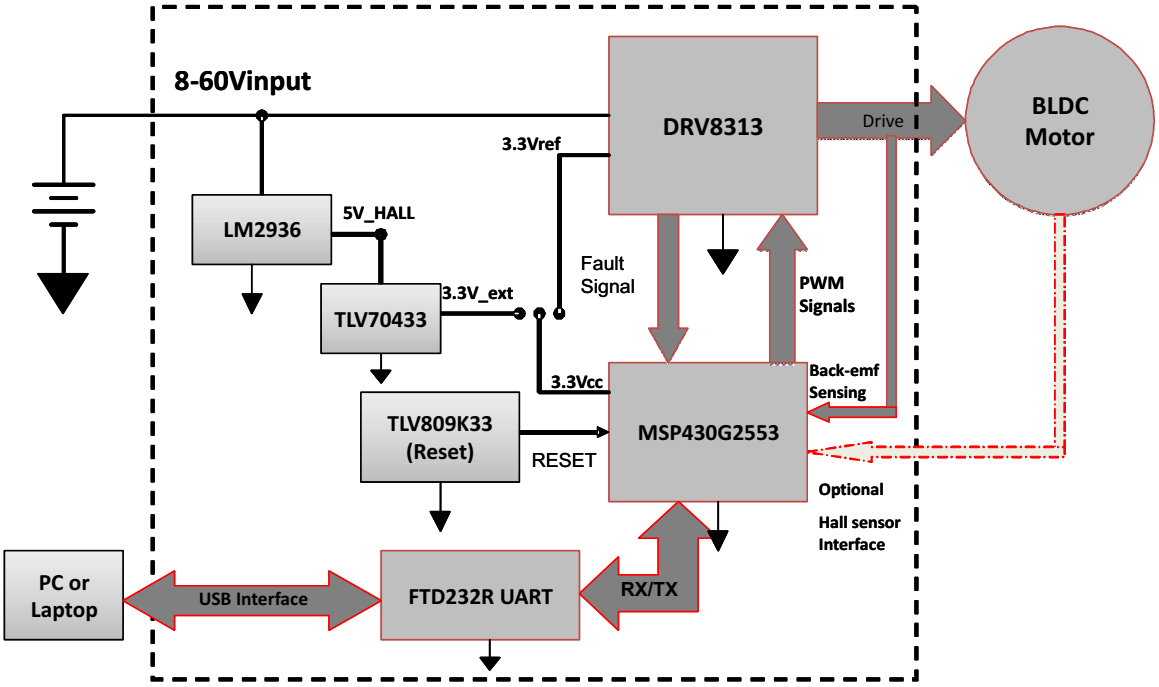

Figure 2. DRV8313EVM Hardware Block Diagram

1.2 DRV8313 EVM Hardware Macro Blocks

The motor control board is separated into functional groups that enable a complete motor drive system; these are referred to as macro blocks. Following is a list of the macro blocks present on the board and their functions:

- DC bus connection at terminal block J2
- 3-phase motor connection at terminal block J3
- DRV8313 – This module includes the DRV8313 three phase PWM motor driver as well as all of the necessary external passive components.
- On board MSP430G2553 value line micro-controller with 8k flash
- USB interface- Micro-USB interface connector is used for serial UART communication with FTDI driver chip to run the EVM using GUI through external PC/Laptop
- Current sense – Low-side shunt current sensing on dc-link current measurement
- On board $5V_{CC}$ control power supply for hall-effect sensors and 3.3-V supply for MCU
- On board potentiometer for speed control to run BLDC motor in stand-alone mode without using GUI
- 4-pin JTAG interface connector for SPI-BY-WIRE Programming
- 16-pin connector – This provides interface to all control signals of DRV8313 and it can be used to drive DRV8313 from an external micro-controller
- Hall effect sensor connections – Connections are available for optional Hall effect at J7. The included GUI only supports sensor-less commutation. Hall connections are provided for use when developing a sensored motor project.
- Manual reset switch to reset the controller

Figure 3 illustrates the position of these macro blocks on the board. The use of a macro block approach for different power stages enables easy debugging and testing of one stage at a time. All the PWM and ADC signals which are the actuation and sense signals have designated test points on the board, which makes it easy for an application developer to try out new algorithms and strategies.

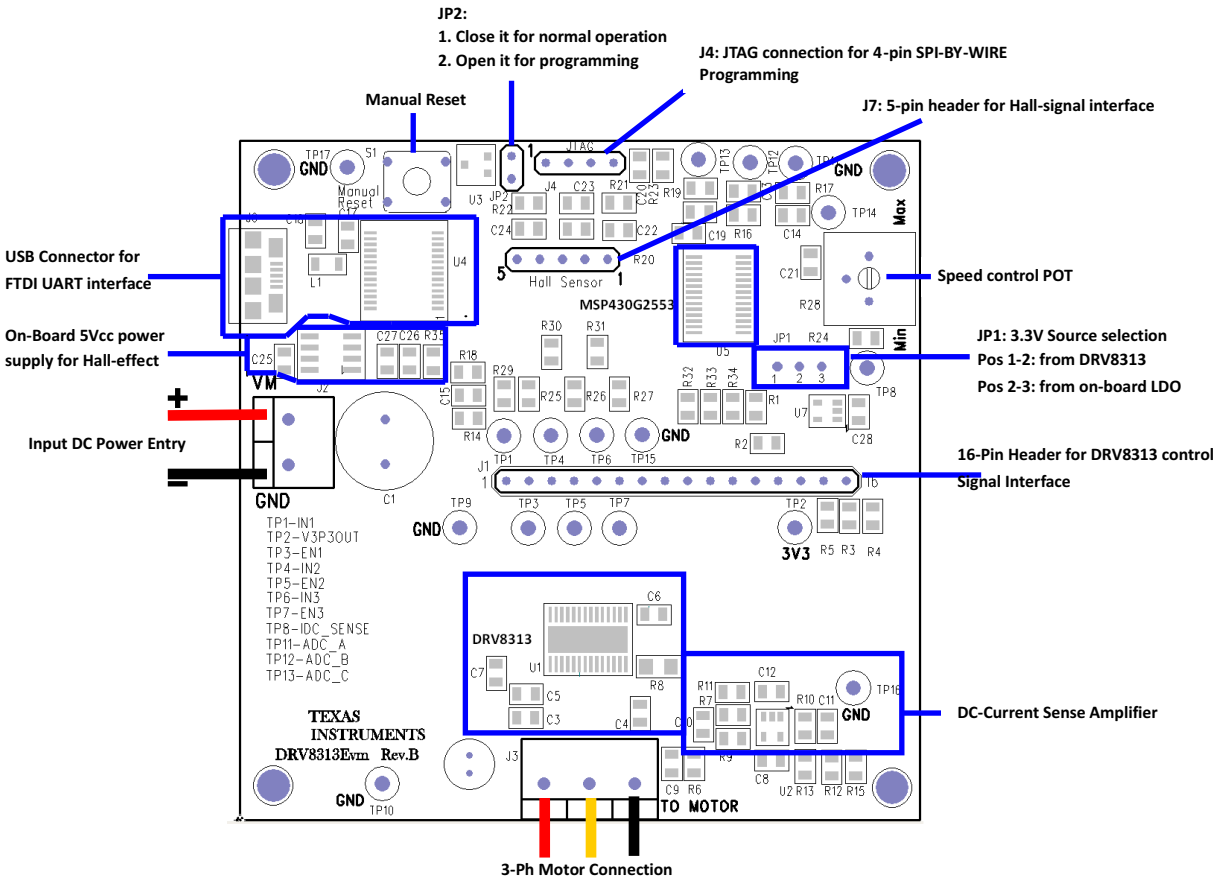

Figure 3. DRV8313EVM Macro Blocks and Jumper Setting

1.3 Jumper Configuration

Two jumpers are used on the DRV8313 EVM:

1. **Three-Pin Jumper JP1**: This jumper gives the user an option to select a 3.3-V source for on-board MCU U5 (MSP430G2553). There are two sources of 3.3 V; one is a 3.3-V reference output of DRV8313 and other is generated from input voltage VM through on-board LDOs U6 (LM2936) and U7 (TLV70433).
   (a) Position 1-2: In this position, MCU U5 is powered from DRV8313. This position is used for input DC voltage range of 8 V to 48 V.
   (b) Position 2-3: In this position, MCU U5 is powered from on board LDOs. This mode is used to avoid over-heating of DRV8313 if input DC voltage VM is higher than 48 V.
2. **Two-Pin Jumper JP2**: This jumper must remain closed during all normal operating conditions of EVM either through GUI or in stand-alone mode. The jumper is open only during the programming of MSP430G2553 through 4-pin SPI-BY-WIRE method.

1.4 Power-Up Sequence

1. Make sure the jumpers are configured as explained in previous section.
2. Connect 3-phase BLDC motor terminal at terminal block J3. It is not important to observe polarity, as it only applies to direction of rotation. Make sure all three pins are connected.
3. Apply VM (+24 V) at terminal block J2. EVM does not have reverse polarity protection, therefore make sure positive terminal of power source is connected to VM and negative terminal is connected to GND.
4. Connect USB connector to the J6 USB connector from external PC/Laptop.
5. Open DRV8313 EVM GUI from location Start → All Programs → Texas Instruments Inc. →

DRV8313EVM to enable motor operation.

2 INSTALLING FTDI DRIVERS

Download the DRV8313EVM software and development package from the TI Web site: http://www.ti.com/tool/drv8313evm. Find and unzip Step 1 - INSTALL_USB_Driver into a separate folder. See instructions on how to install the FTDI USB driver on a Windows® based computer in the FTDI_Drivers_Install_Readme.pdf file.

3 INSTALLING Windows® APPLICATION

The available download also includes a file named DRV8313EVM_Windows7_Application.zip. Copy the contents of this folder to any desired folder on your computer. This causes the Settings.ini file to be written to the desired folder on software exit. This action cannot occur if the application is run within the zip file. Make sure to first unzip all the contents of the zip file into a folder on your computer. After you unzip the contents, your folder should look like the following.

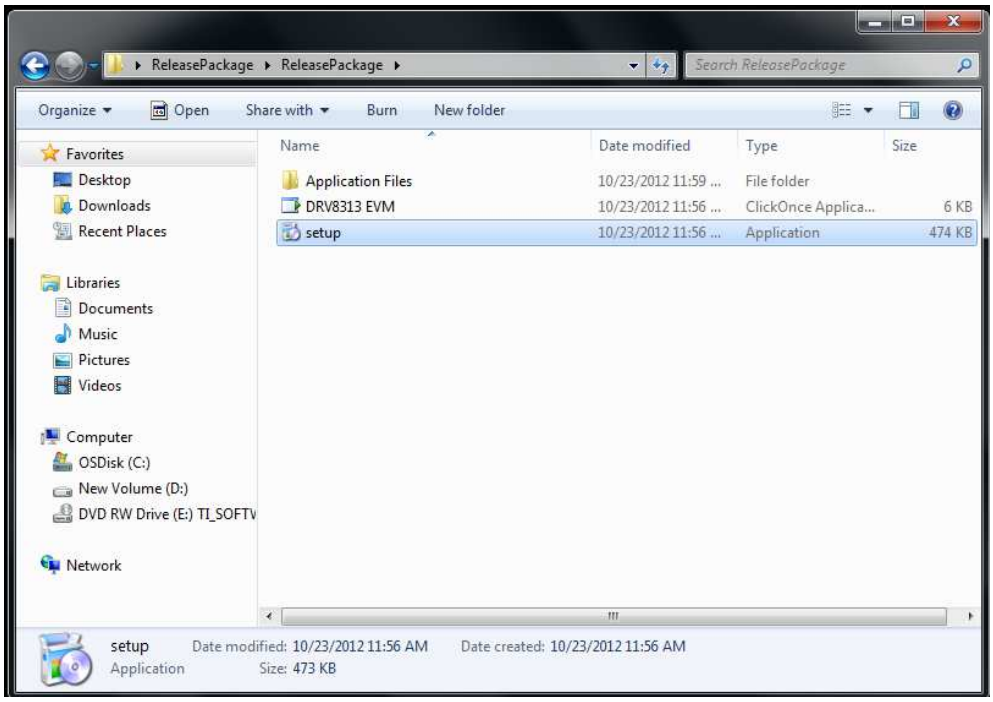

Figure 4. DRV8313EVM_Windows7_Application.zip Contents

Before installing the application, make sure you have the FTDI drivers installed and your hardware connections are in place.

Double click on the icon ‘DRV8313EVM’ of ‘setup’ to run the application. The first time that you run this application you will see the following message.

Figure 5. Security Warning

Click the 'Install' button. You should see the setup in action. Once done extracting the required files, the application will launch itself.

4 RUNNING THE APPLICATION

For future use, the application can be opened from the following path: Start → All Programs → Texas Instruments Inc. → DRV8313EVM

4.1 Connecting the Hardware to GUI

Once the application 'DRV8313EVM' is opened, it tries to connect to the hardware. During this attempt the connection status indicator starts blinking at the rate of ~1 sec.

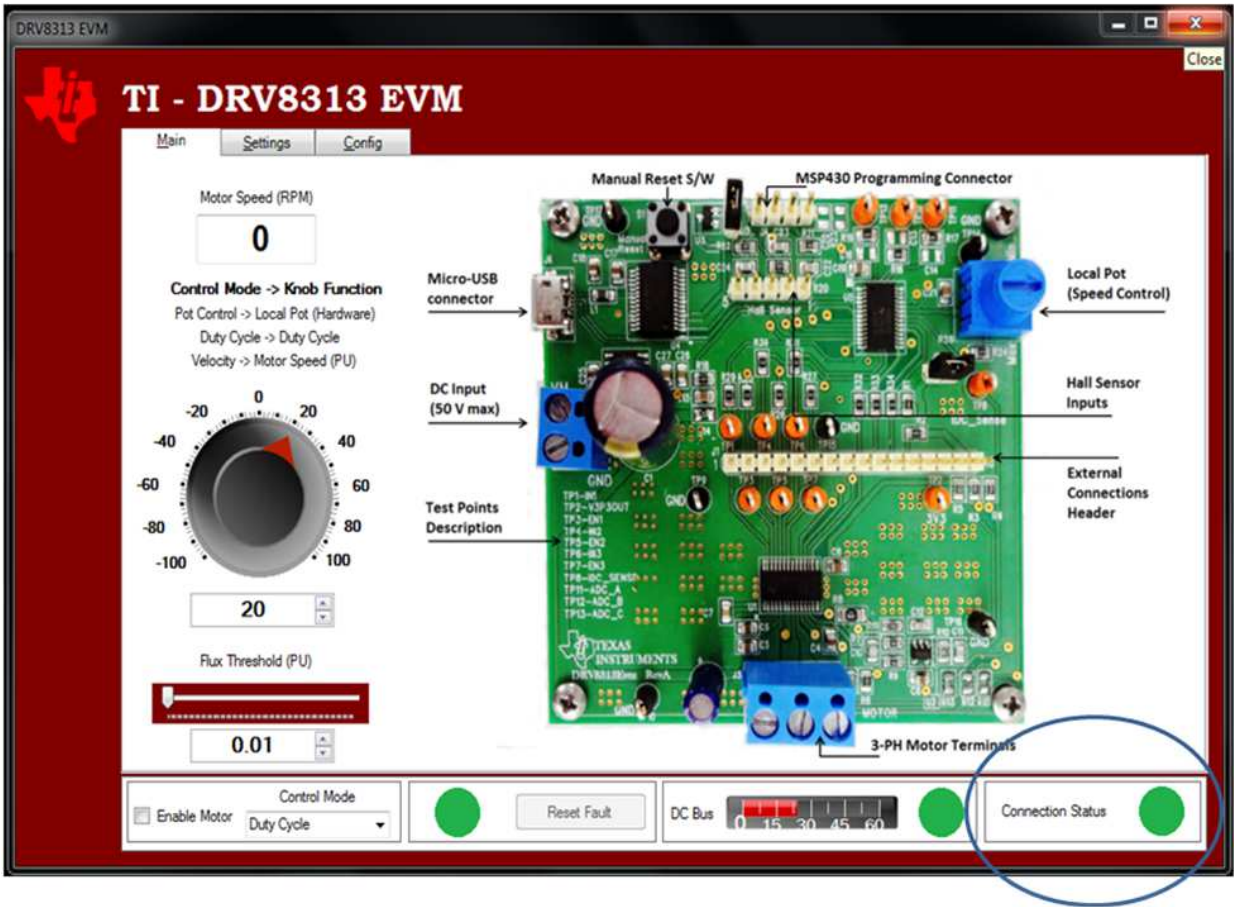

Figure 6. Status Indicator

- If the Indicator starts blinking with green and light green in color, the connection is established between the hardware and GUI.
- If the Indicator starts blinking with green and red in color, the connection attempt is still going on. This attempt will continue for 10 seconds after which the communication error will be indicated as below where the 'Retry' option will be visible.

If the connection could not be established please check for the following.

- The EVM is power is present.
- FTDI drivers are installed.
- The reset jumper (JP2) and 3V3 (JP1) jumper is in place.
- The connection cable between the PC and Hardware is connected.

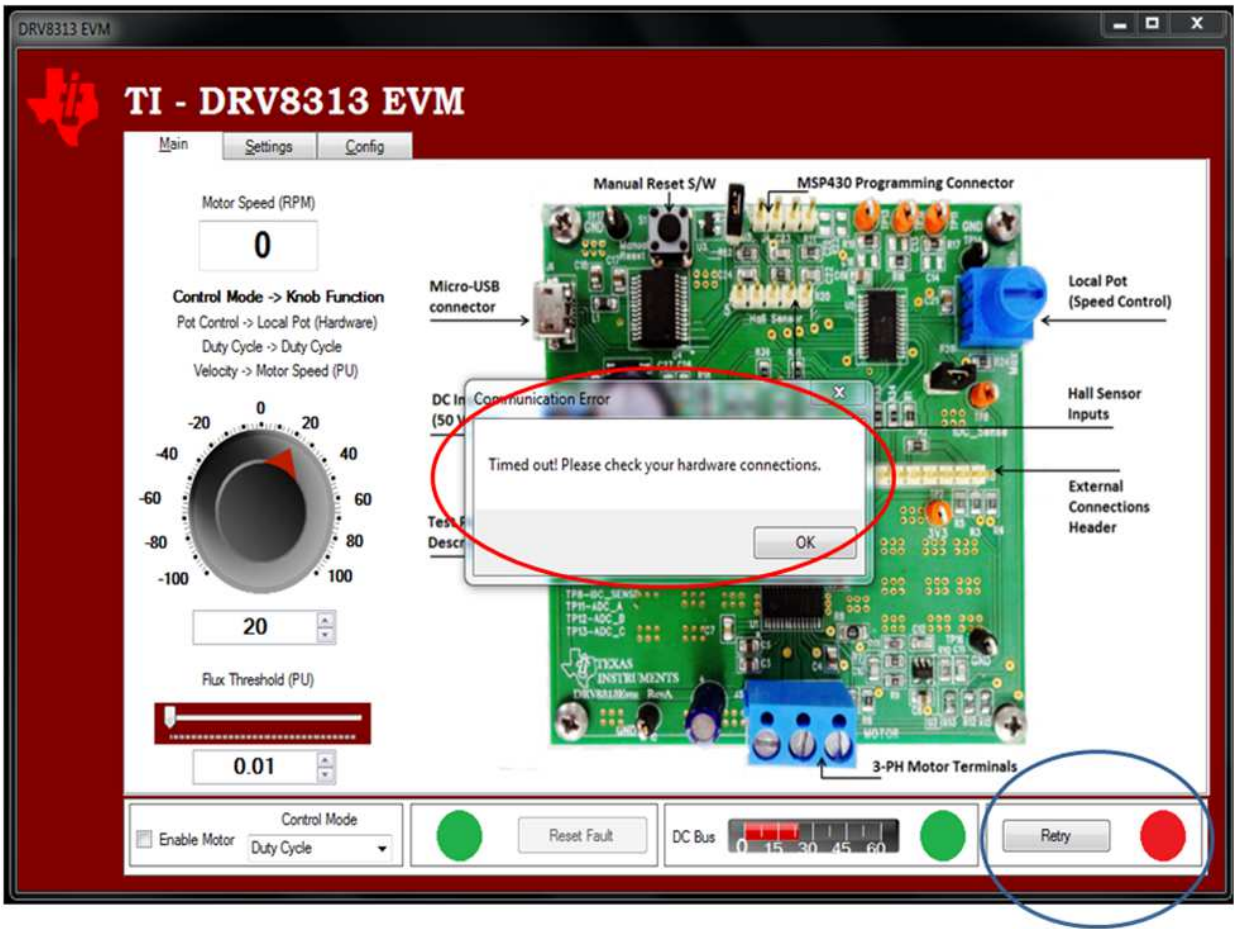

Figure 7. Connection Establishment

After clicking 'Retry' the connection establishment is again attempted for 10 seconds.

4.2 Running the Hardware

Once the connection is established as mentioned in first section, the motor parameters can be tuned with the ‘Main’ and ‘Settings’ tabs. Description of each component is given below.

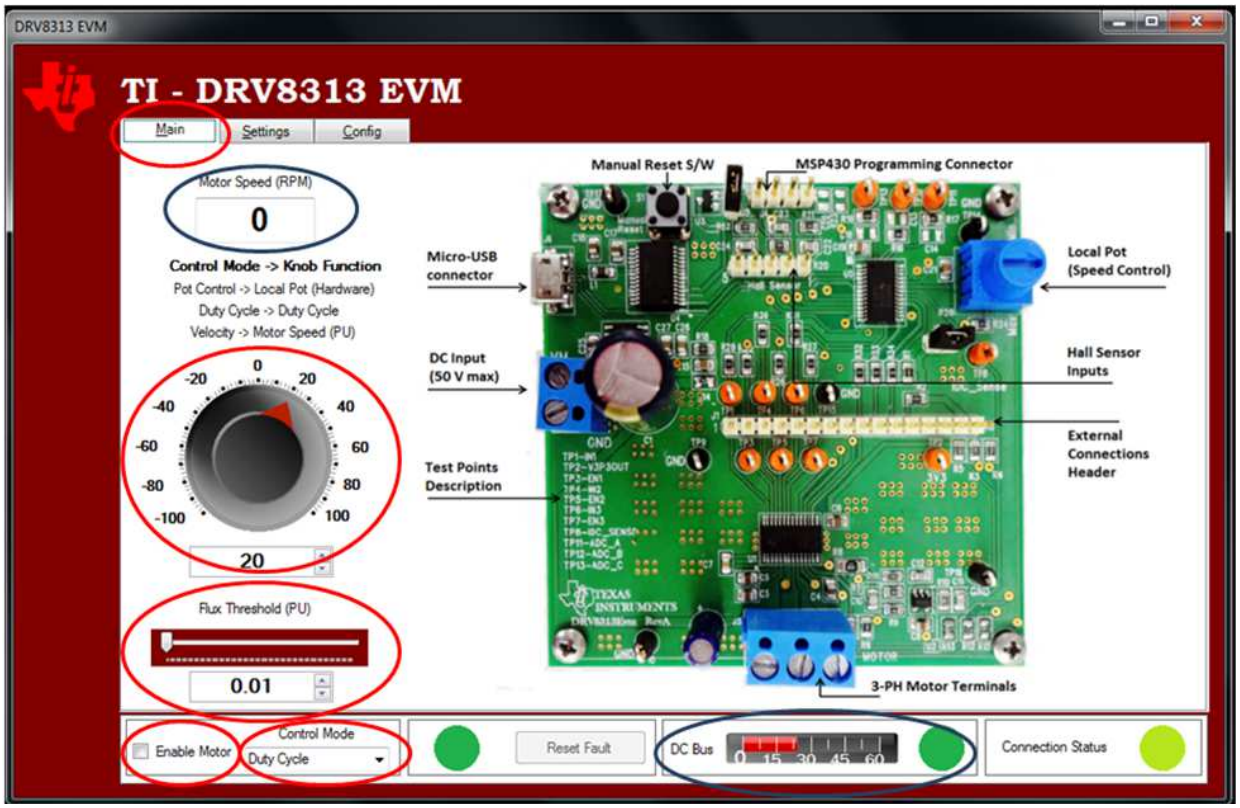

Figure 8. Main Tab

DC Bus: The bar graph will indicate the DC Bus voltage.

Motor Speed (RPM): The motor speed is indicated in the textbox.

Flux Threshold: Flux threshold is the integration constant of the motor. Refer to Appendix A for some of the relevant scope-shots for tuning this value. The flux threshold can be altered during the runtime.

Control Knob: The control knob is used to set duty cycle or required speed during the different speed control modes as explained below. It also is used to reverse the direction of the motor. The parameters can be changed by knob or can be entered directly in text box below the knob.

Control Mode: The motor speed can be controlled in 3 control modes:

1. **Duty Cycle**: Motor runs in open loop mode in this control mode. The control knob can enter the value from 10 to 97 in either direction which represents the % duty cycle needs to be applied to the motor. 10 and 97 are the min and max duty cycle limits applied in the code.
2. **Velocity**: Motor runs in closed loop mode in this control mode. On-Off hysteretic control is implemented here. The control knob can enter the speed which is tried to be matched by the hardware. The speed can be seen in the ‘Motor Speed’ box.
3. **Pot Control**: Motor runs in open loop mode in this control mode. The control knob is disabled in this case and the Pot available on the hardware is used for the speed control purpose.

4.3 Enable Motor

Once the parameters are set, clicking the checkbox should start the motor. Clicking the checkbox again will stop the motor.

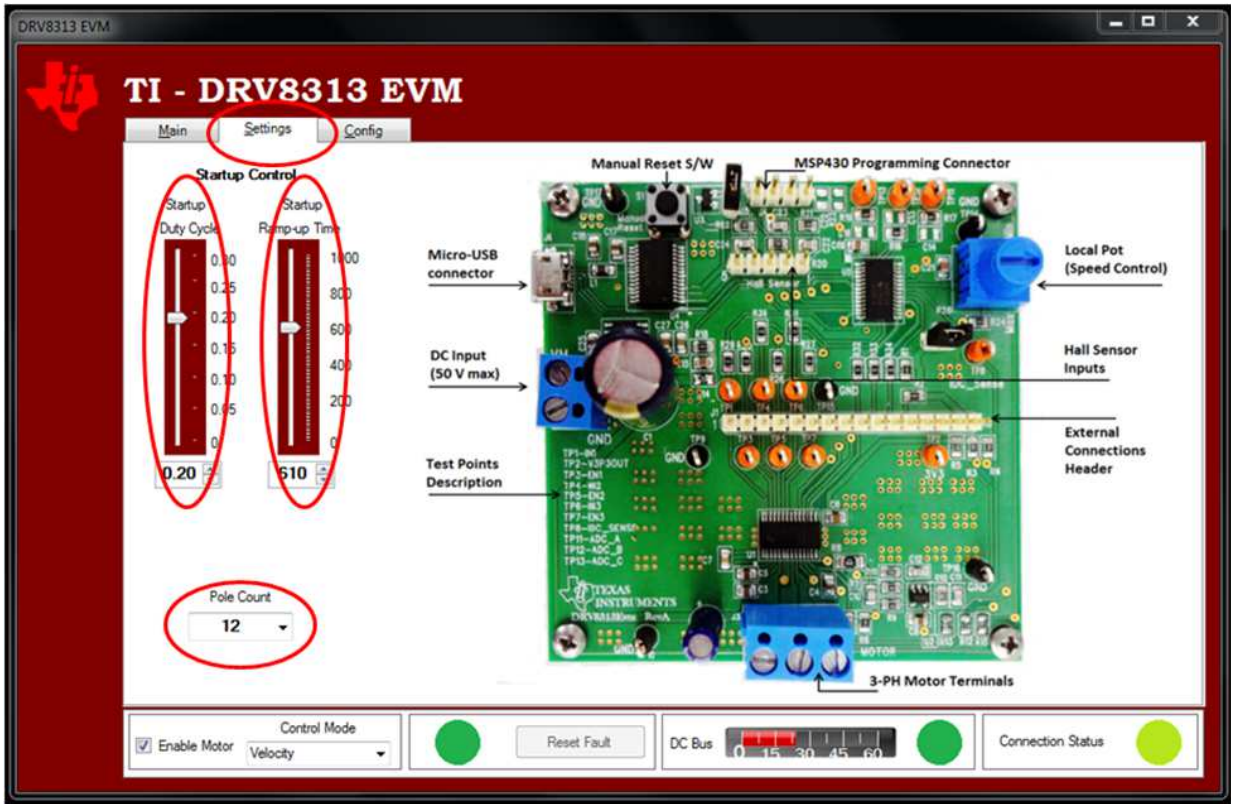

Figure 9. Settings Tab

4.3.1 Start-Up Process

In order to start and run the BLDC motor, the control algorithm applies the “align and go” method.

- Align State: The main aim of alignment is to align the rotor to a known position. This is done by energizing two of motor phases for pre-fixed duty cycle to generate standstill stator magnetic field for certain duration. This known position is necessary to start rotation in the proper direction and to generate maximum torque at startup.
- Go State: Once the alignment is done, the control algorithm applies the next appropriate voltage vector sequence to produce the stator magnetic field, which is in 90 degree advance to the rotor flux, in order to produce maximum torque at starting. At the same instant the back e-mf integration of non-excited phase is initiated and the next commutation event occurs once the back-emf integration threshold is reached and the process continues for the smooth rotation of motor.

Startup Duty Cycle: Changing the value of the startup duty cycle will change the applied duty cycle during alignment state. Typical value can very from 10% to 30% depending upon the motor load and inertia.

Startup Ramp-up Time: During alignment state of the motor, this ramp-up time defines time duration for which two of the motor phases remain active for alignment; i.e. its simply align state time duration. Please note that initial rotor will experience oscillation when it first moves to get aligned with stator applied field and try to get locked with it. The oscillation time depends upon the mechanical time constant of motor load and inertia. It is very important that before applying ‘go state” rotor oscillation dies down sufficiently to avoid commutation failure. Startup ramp-up time helps to change the timing of align state for different motors to make sure that rotor oscillation have died down and rotor has come very near to standstill.

Pole Count: The number of poles of the motor entered here will be used for the speed calculations.

5 ROTATION REVERSAL RUNTIME

The rotation of the motor can be reversed during runtime. The hardware will try to bring motor to the halt condition first from where it will start to rotate in another direction. During this period of halting the motor by the hardware, the GUI is kept disabled for entering other parameters.

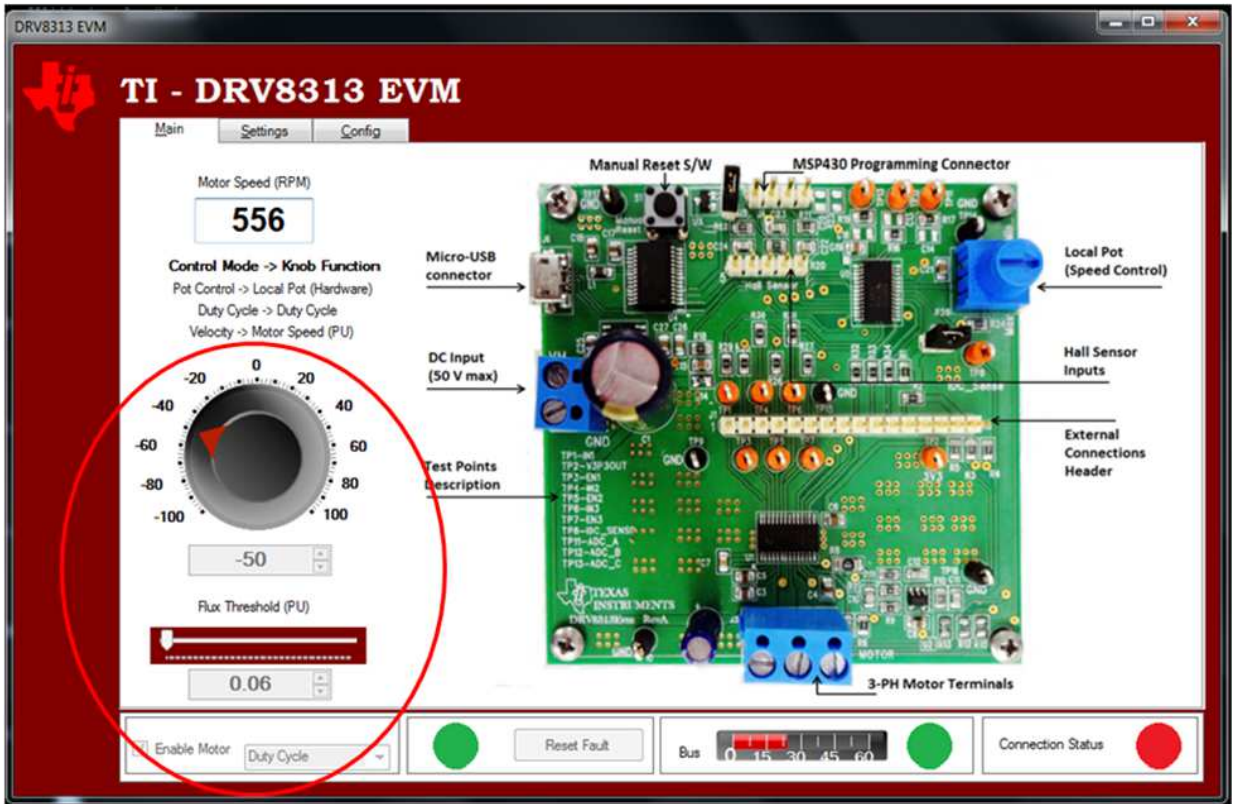

Figure 10. Rotation Reversal

6 FAULT CLEARING

In case of overcurrent/short circuit and overtemperature faults at DRV8313, the fault Indicator turns red as shown below. Clicking on 'Reset Fault' at this time will clear the fault and attempt a fresh start and run.

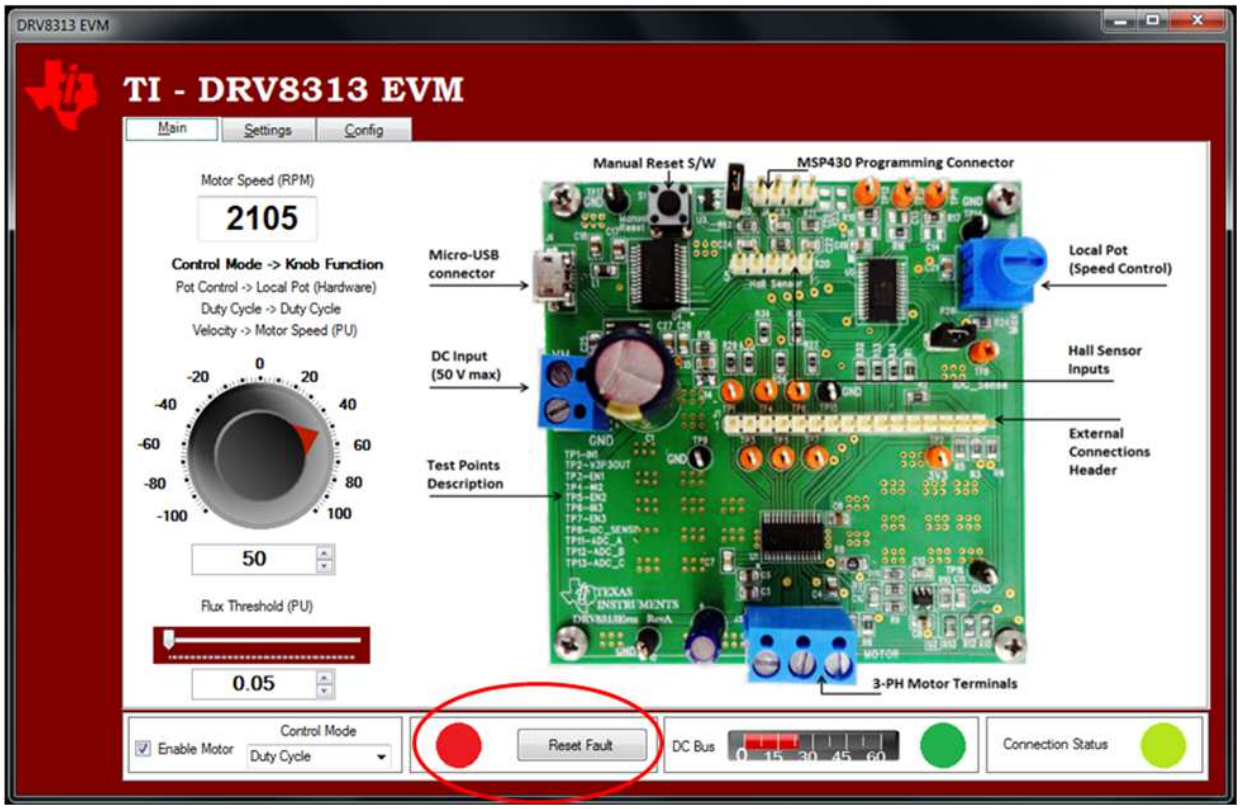

Figure 11. Fault Clearing

7 RUNNING THE HARDWARE IN STAND-ALONE MODE

The firmware loaded by default in the MCU on board is a User Experience code. Using this firmware will need the GUI to run the motor.

However, once motor parameters are tuned, the output of the GUI can be used to operate the hardware in a stand-alone mode (without GUI). These parameters are given by the GUI in form of the 'config.c' file which is further used to change the code inside the MCU on hardware.

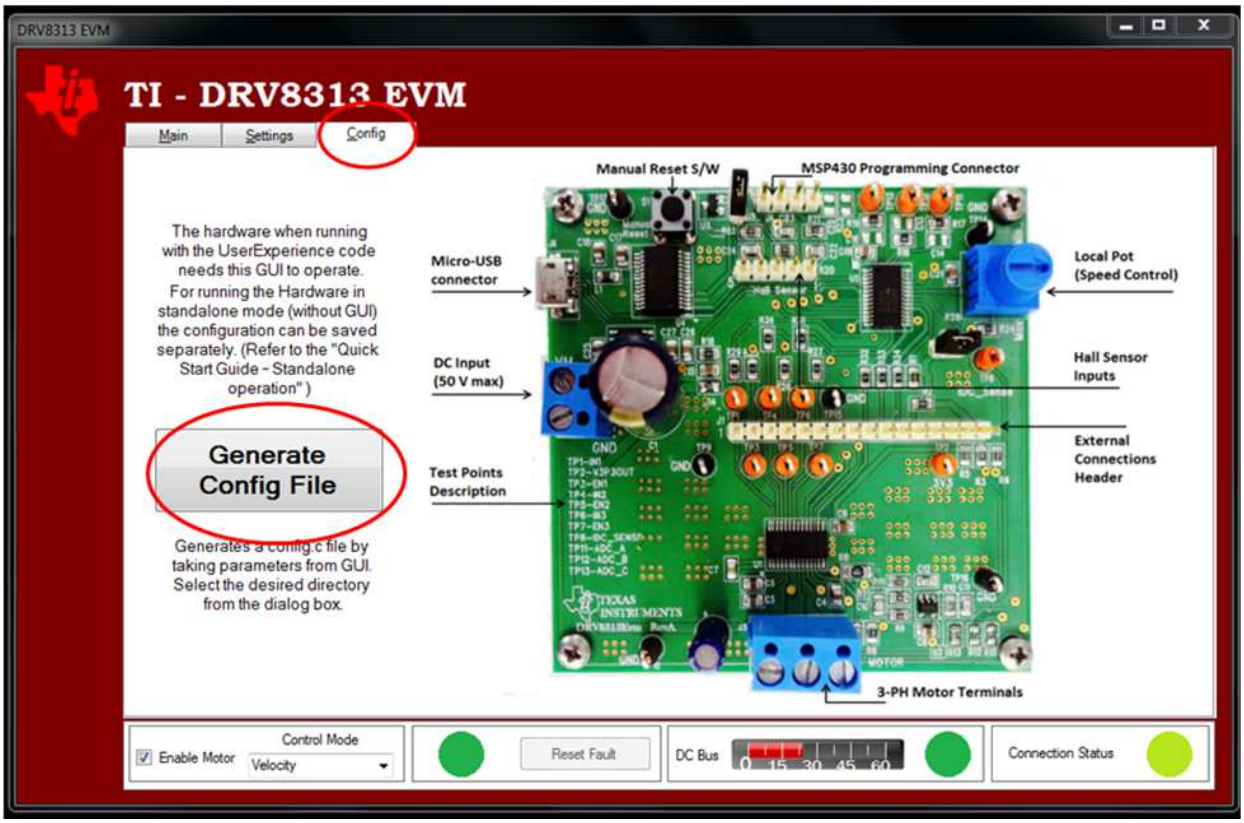

Figure 12. Config Tab

Once the parameters are tuned, clicking on 'Generate Config File' will generate a config.c file which will be used for the creating new firmware for the MSP430 device on the hardware. This new code can be flashed via MSP430 Programming Connector using Spy-Bi Wire programming method as explained in Appendix B.

User Experience code can be downloaded from http://www.ti.com/tool/drv8313evm. Importing "DRV8313_Release" project in CCS will get us the following view.

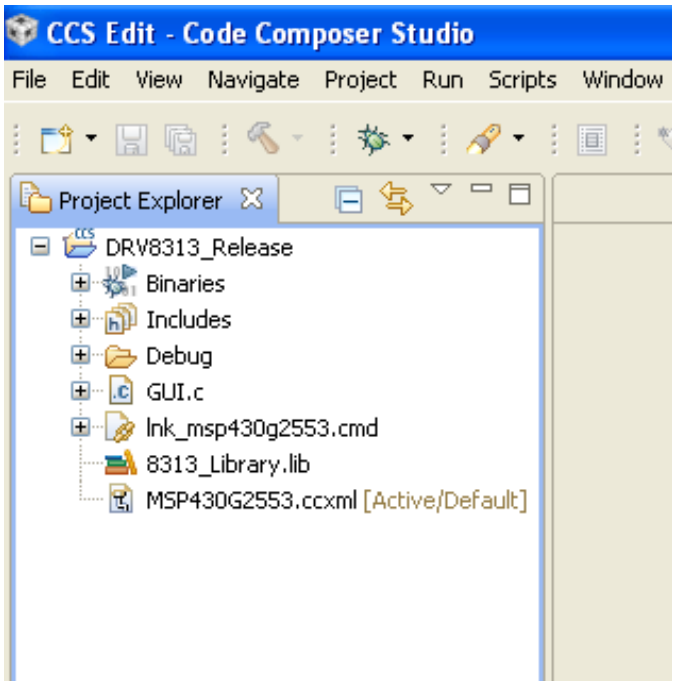

Figure 13. CCS Imported Project

Generated config.c file shall be added to the project and then GUI.c must be excluded from the project to create the firmware for the stand-alone mode.

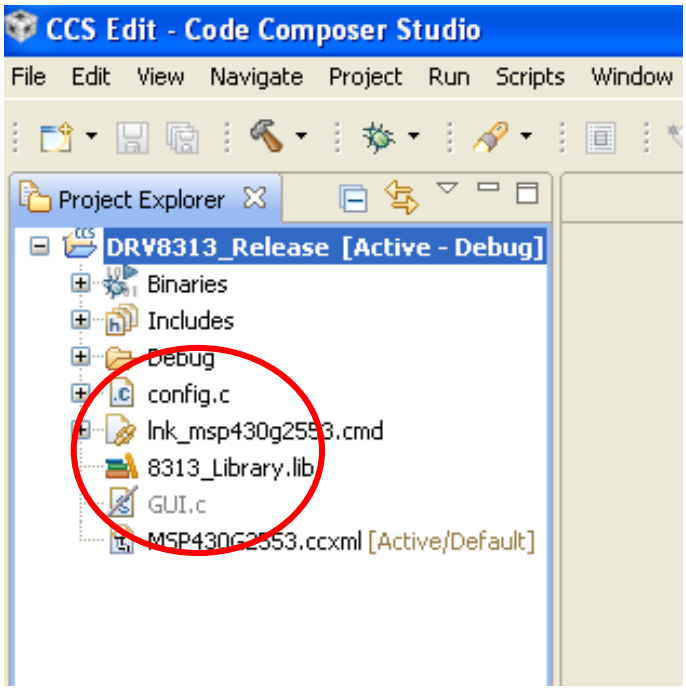

Figure 14. Firmware Creation for Stand-Alone Mode

Appendix A InstaSPIN-BLDC Implementation

InstaSPIN-BLDC is TI's one of the key flagship motor control technology targeted for cost sensitive sensor-less BLDC applications. This sensor-less technique uses traditional trapezoidal or 120° commutation and monitors motor flux by integrating back-EMF of non-energized phase to determine the commutation instances. For certain market, such as fan, pumps, and blowers etc which do not require high accuracy speed control and fast dynamic torque response, InstaSPIN-BLDC implementation from TI's MSP430G2x Value line device is right way to meet low cost requirements.

For any trapezoidal control of BLDC Motor, for each 60 electrical degrees, only two inverter legs are active and deliver the power to motor while third inverter leg is kept in High impedance state by switching off both high side and low side switches. In case of Uni-polar two quadrant drive, PWM is applied only to high side switch of one active leg while low side switch of other active leg is kept ON continuously for one 60 electrical degree, we need 3 PWM outputs and 3 active signals.

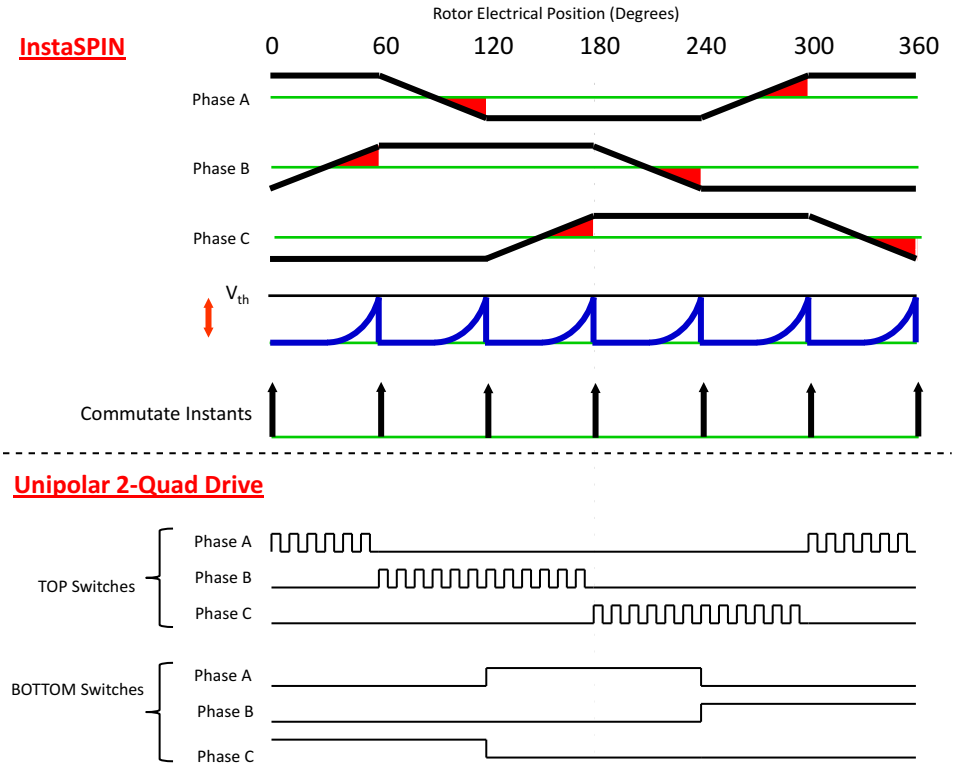

Figure 15. Implementation of 2-Quardent Uni-Polar PWM

InstaSPIN-BLDC method requires precise sensing of back-EMF of open-phase of motor to determine the commutation instant. As shown in Figure 15, for first 0 to 60 degree interval, PWM is applied only to phase-A top switch and in phase-C bottom switch is continuously ON, back-EMF of open-phase B is rising and can be measured and integrated to determine the commutation instant. As shown in Figure 16, during on-time of PWM pulse, with Top switch of phase-A connected to VDC, and bottom switch of phase-C connected to GND, motor neutral terminal potential rises to VDC/2 with respect to GND and back-EMF of phase B appears at VDC/2 level above GND. By capturing the absolute value of voltage across phase-B during PWM on pulse and subtracting it with VDC/2, actual value of motor back-EMF can be derived.

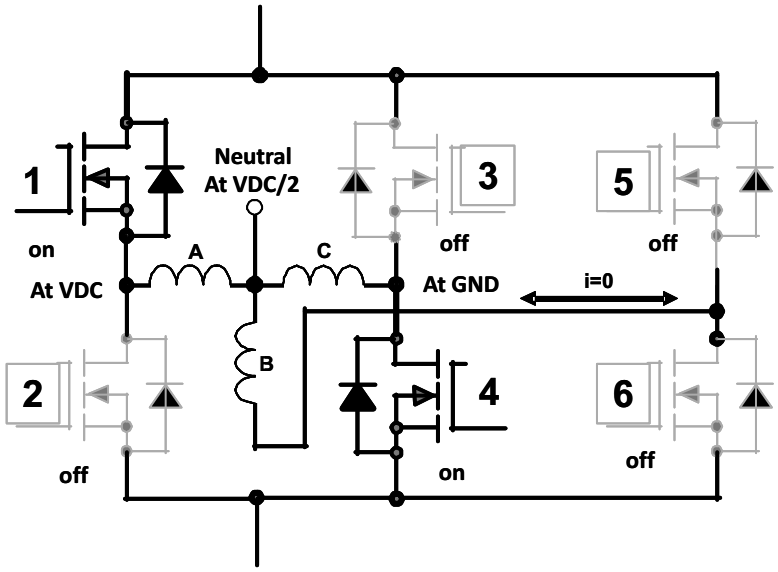

Figure 16. Motor Neutral Voltage During PWM On Period

A.1 Tuning the Motor With Proper Flux Threshold

As shown in Figure 15, the commutation instance is derived by integrating back-emf of non-energized phase (obtain during each PWM on pulse) and comparing the integrated value to pre-defined threshold. This threshold is in fact equivalent to flux of the motor because it is compared with integrated value of back-emf. Value of flux threshold depends upon motor phase resistance, inductance and back-emf constant; therefore this value needs to be tuned for the each different motor for commutation. For tuning purpose usually oscilloscope is used to see the symmetry of the motor input voltages and/or motor phase current. Please refer to the following scope-shots for the different flux threshold values.

The scope-shots show the motor input voltage and a current waveform for one phase.

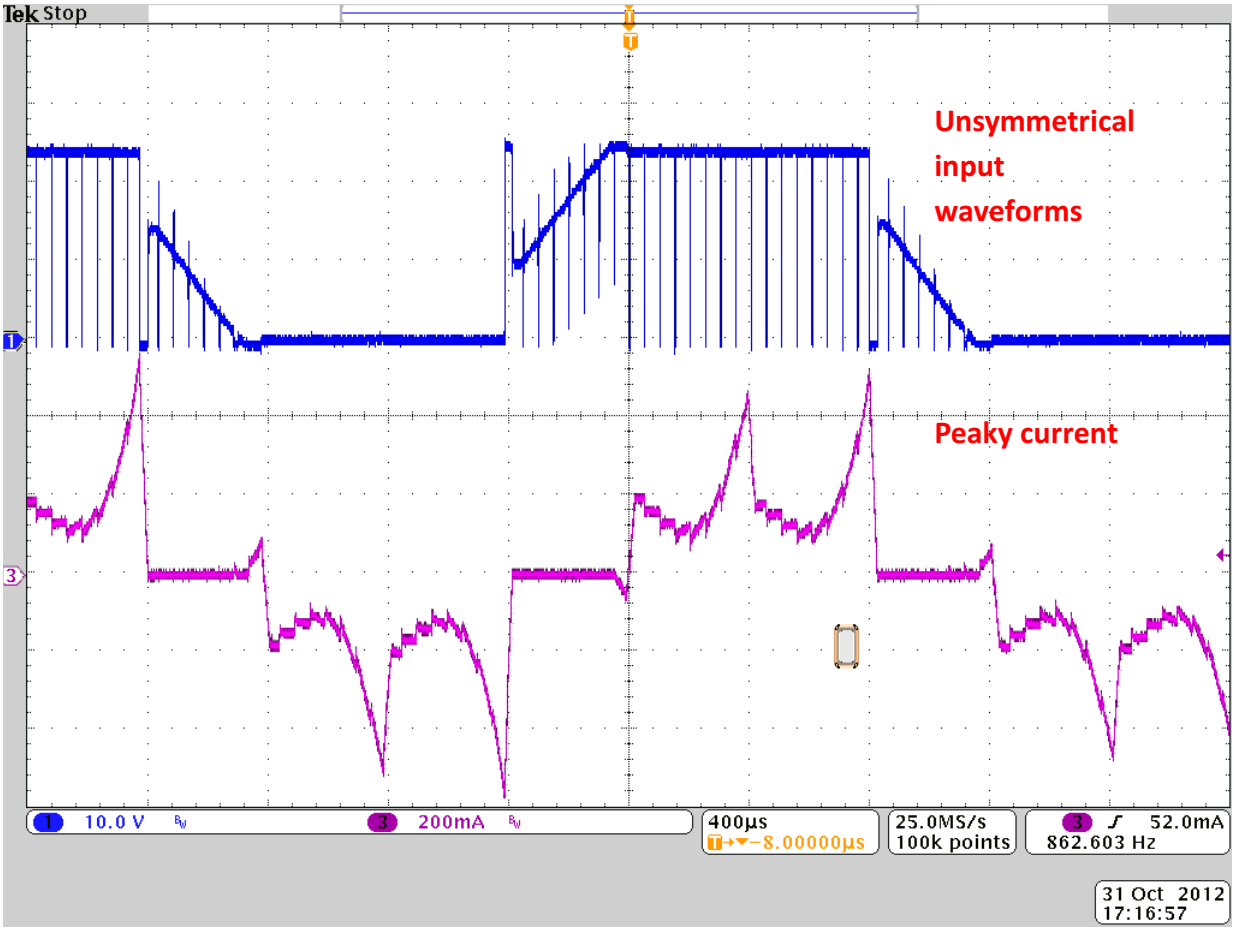

Figure 17. Typical Waveform for the HIGHER Flux Threshold

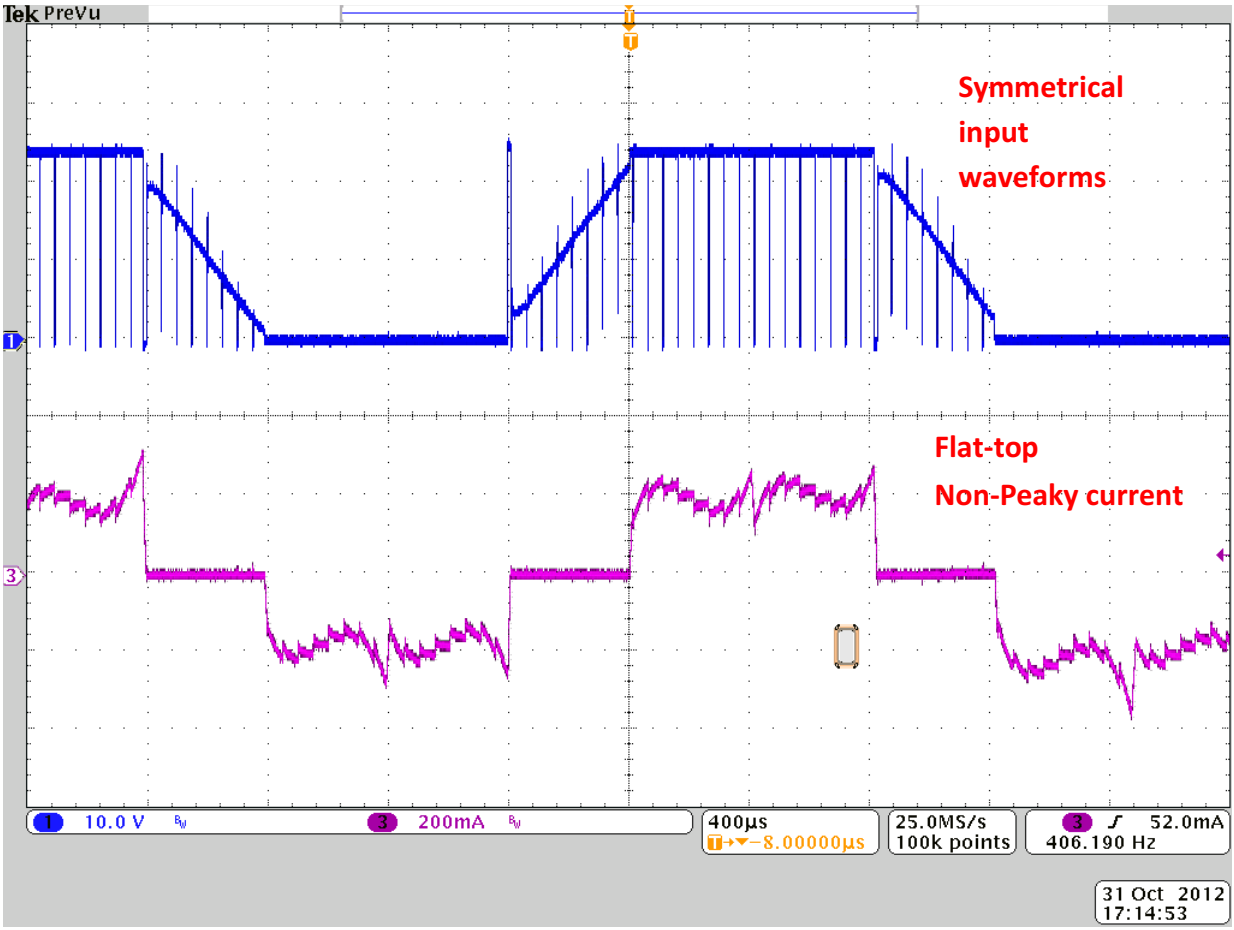

Figure 18. Typical Waveform for the OPTIMUM Flux Threshold

Appendix B MSP430 Programming Using Code Composer Studio (V5)

After opening Code Composer Studio, under the Project menu, select Import Existing CCS Eclipse Project.

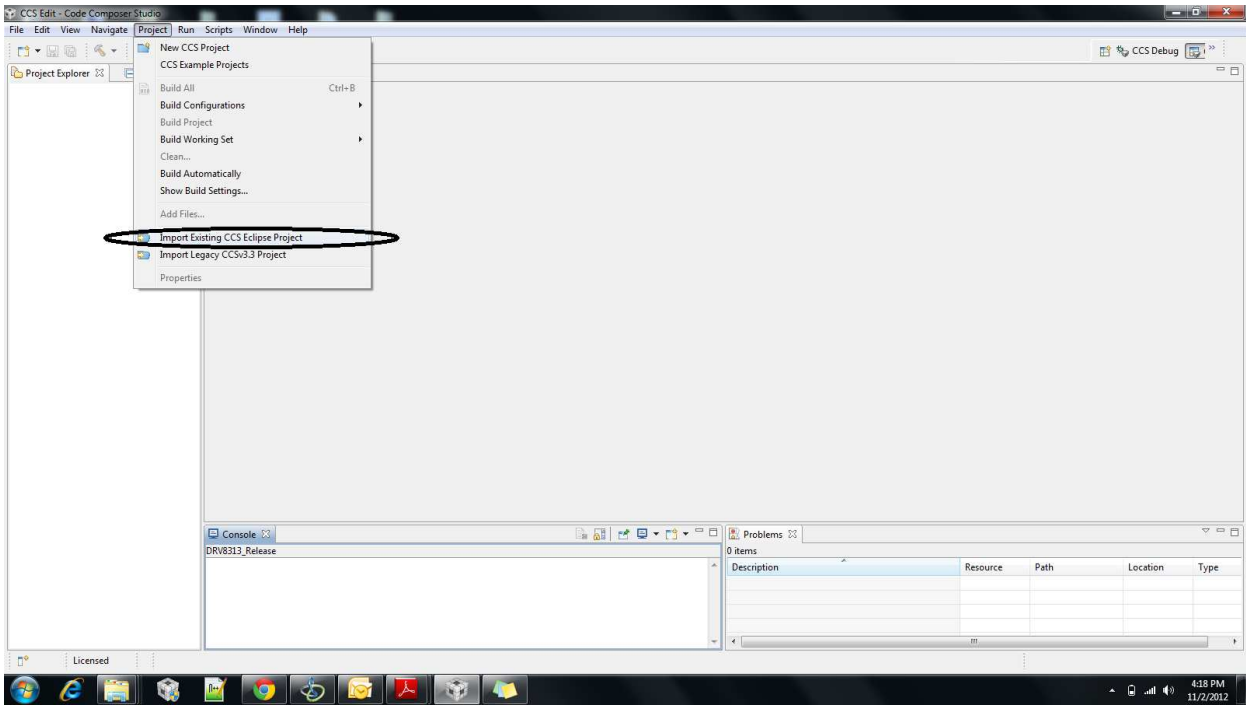

Figure 19. Import Existing CCS Eclipse Project

Browse to the directory containing the firmware. Check the CCS project found and click on the Finish button. You may choose to copy the project into workspace before this.

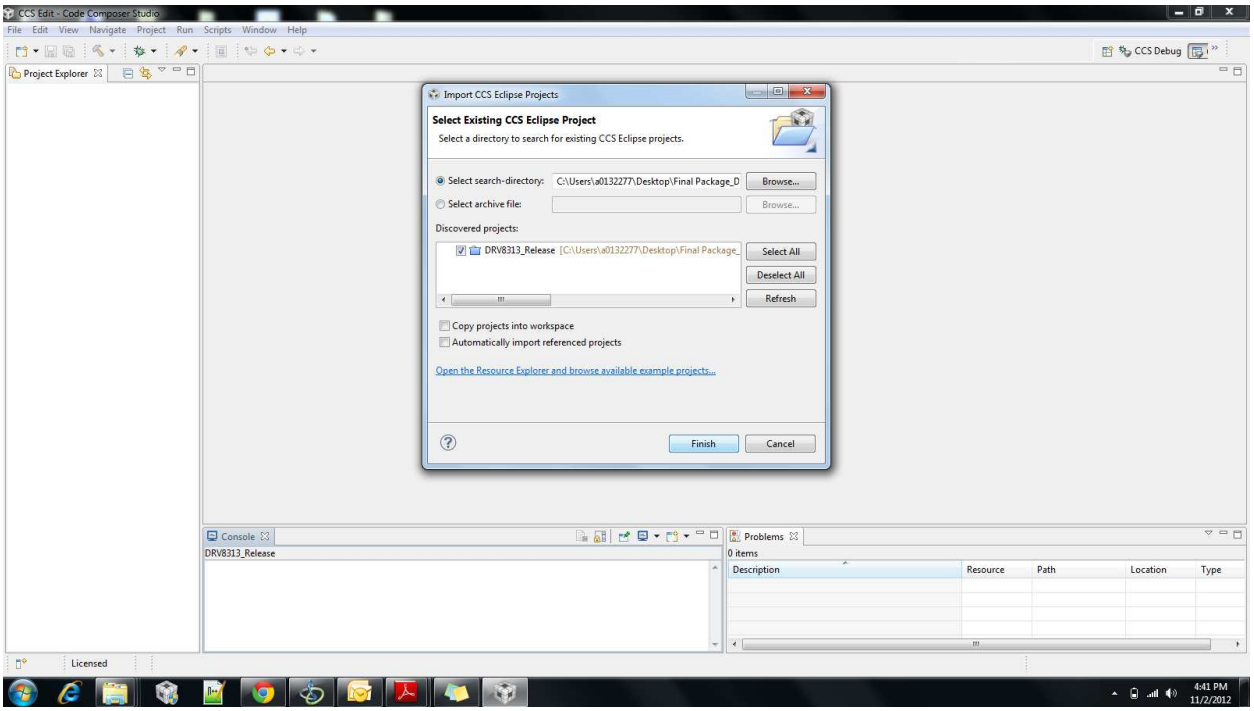

Figure 20. Selecting CCS Eclipse Project

Build the project by clicking on the title and then clicking the Build button as shown in the image below.

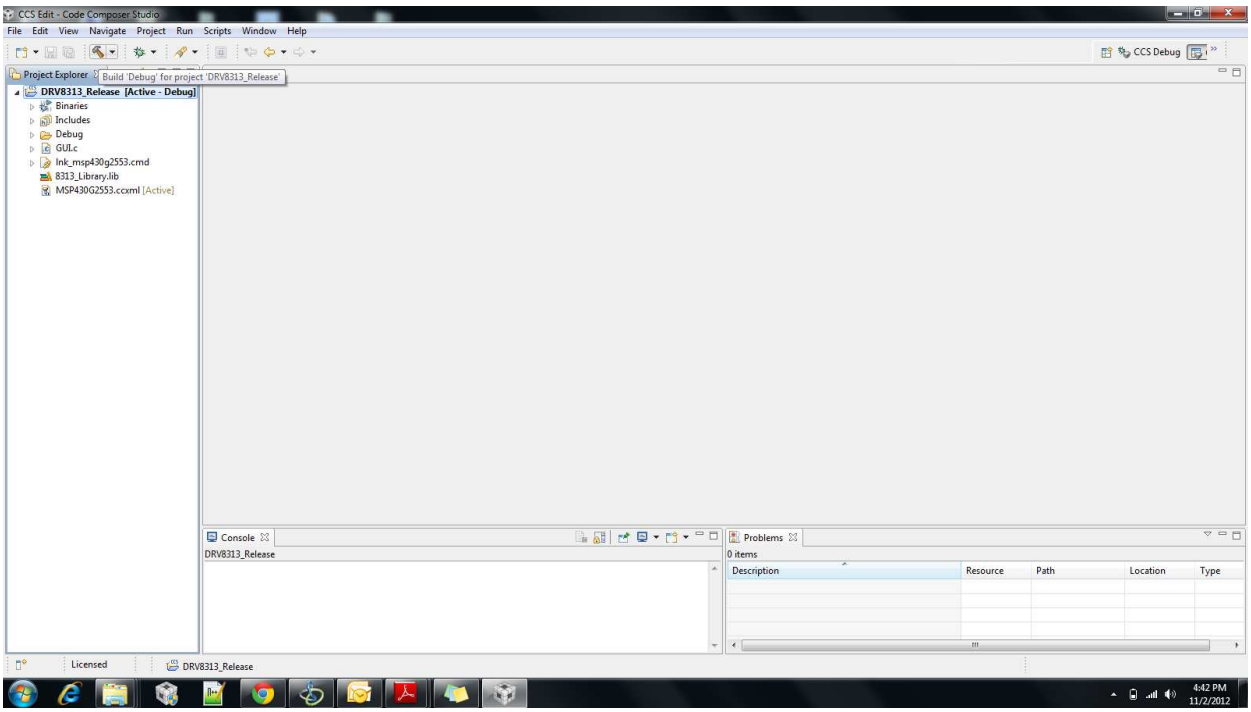

Figure 21. Build Project

Download the code onto the board by clicking the Debug button as shown in the following image.

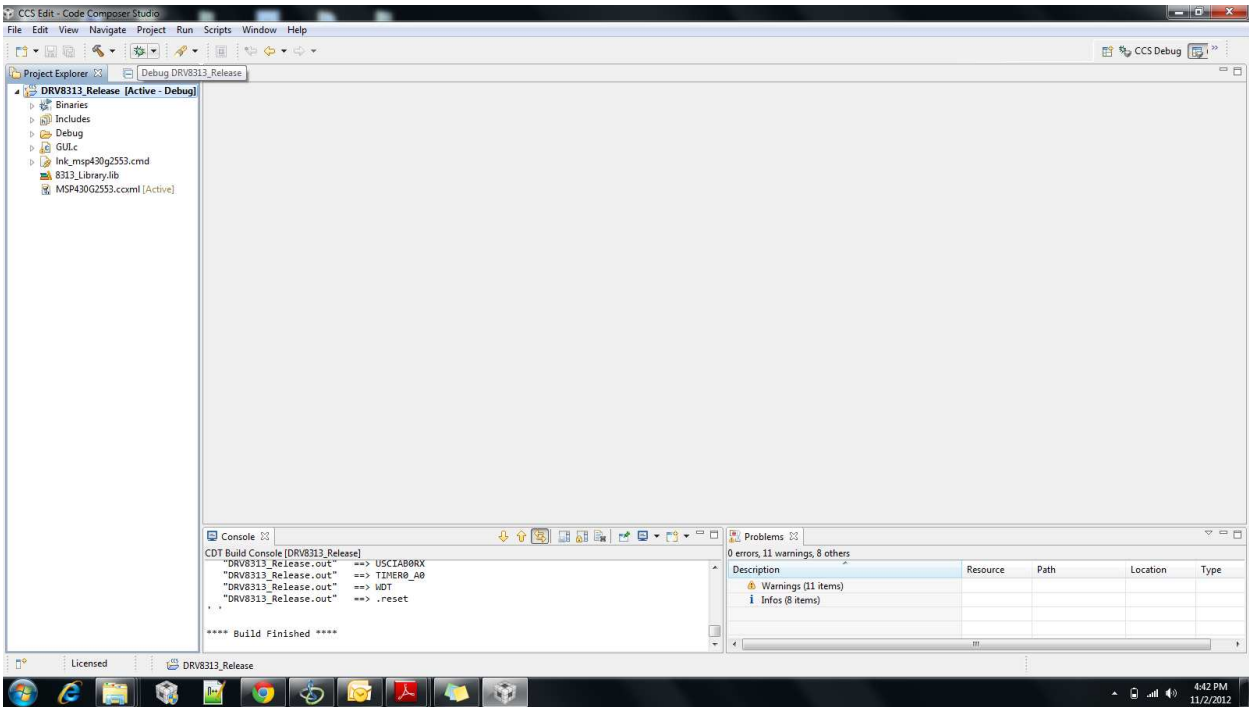

Figure 22. Debug

Once the download is successful, click the Resume button as shown in the image below.

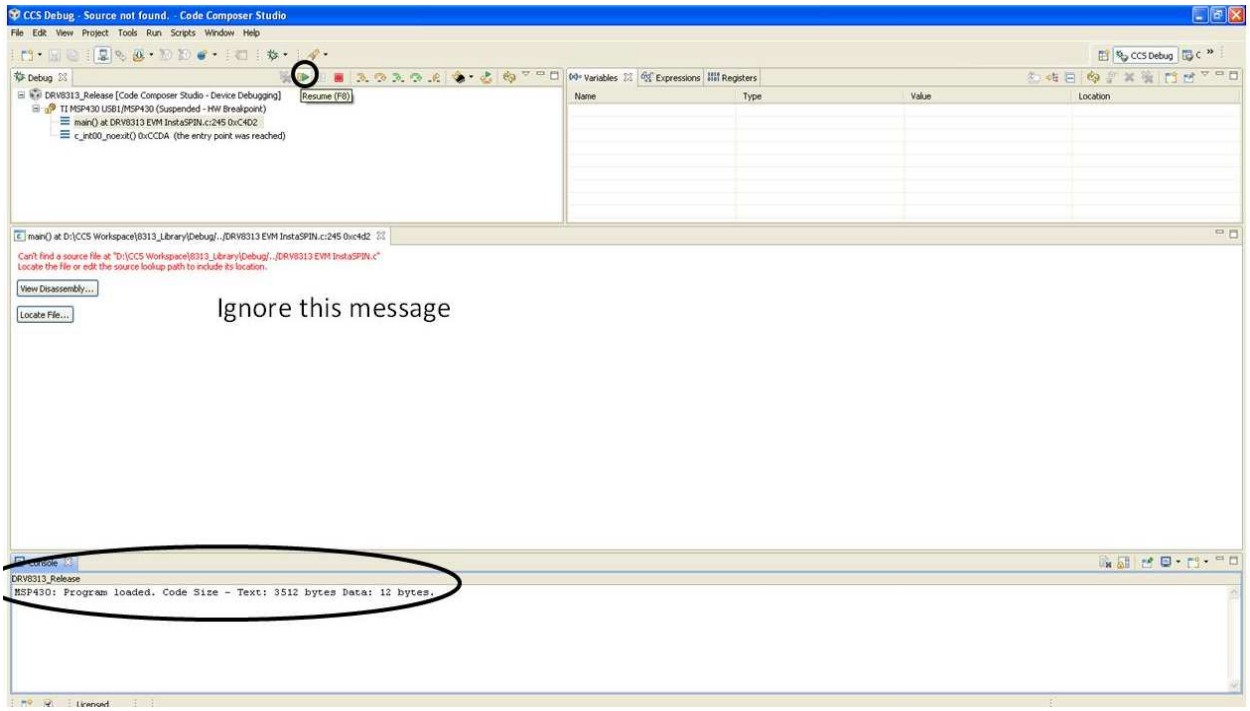

Figure 23. Resume

B.1 Compiling Without GUI.c

For stand-alone mode GUI.c can be excluded from the build and config.c can be added. Refer to the below screen shots for exclusion of GUI from the project build.

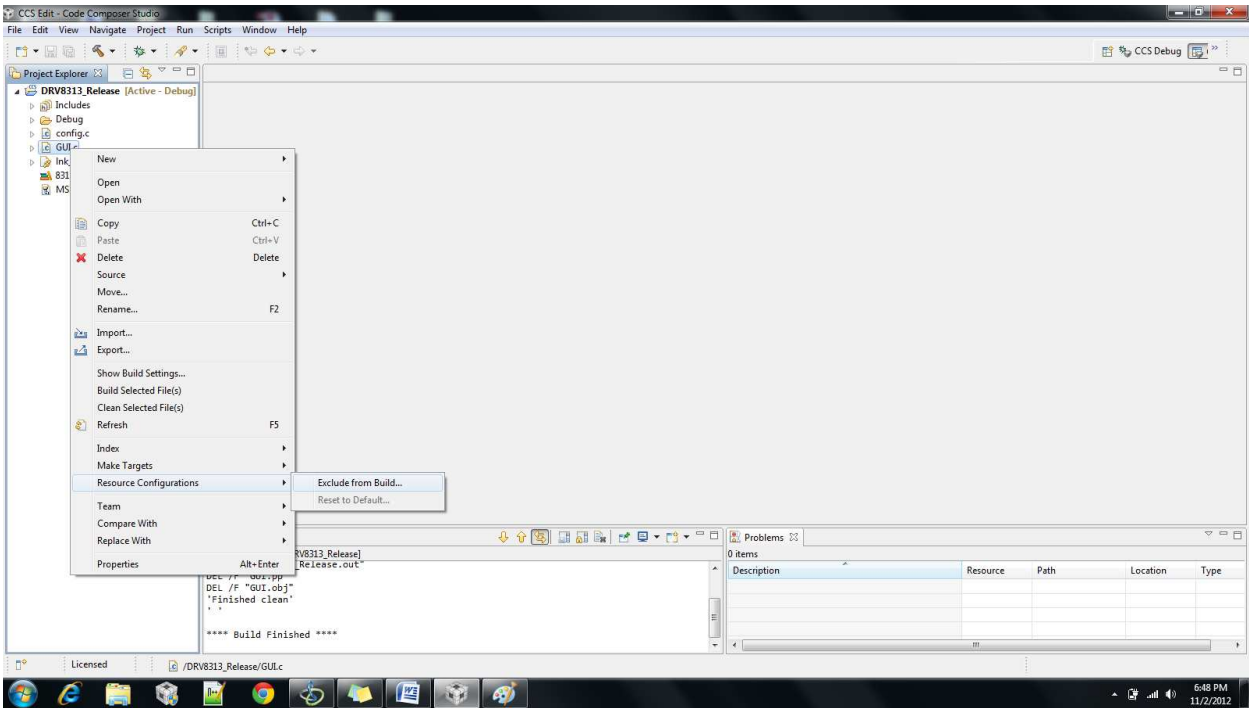

Figure 24. Exclude from Build

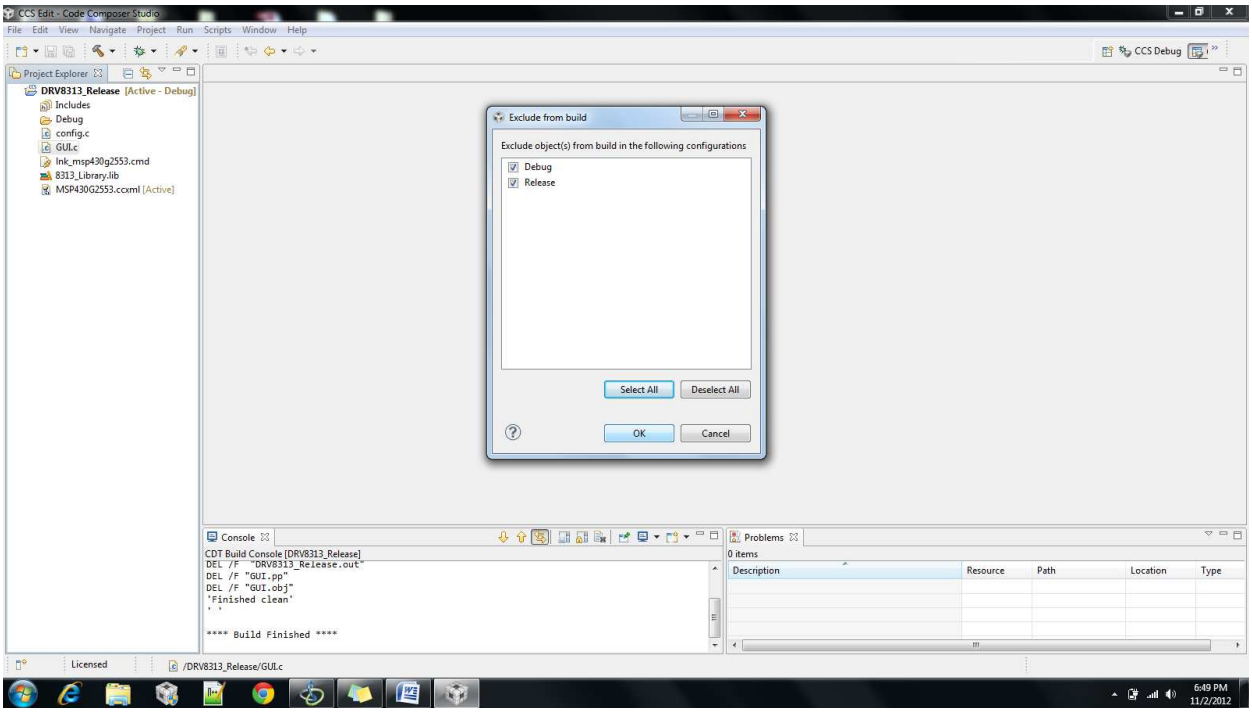

Figure 25. Excluding Objects

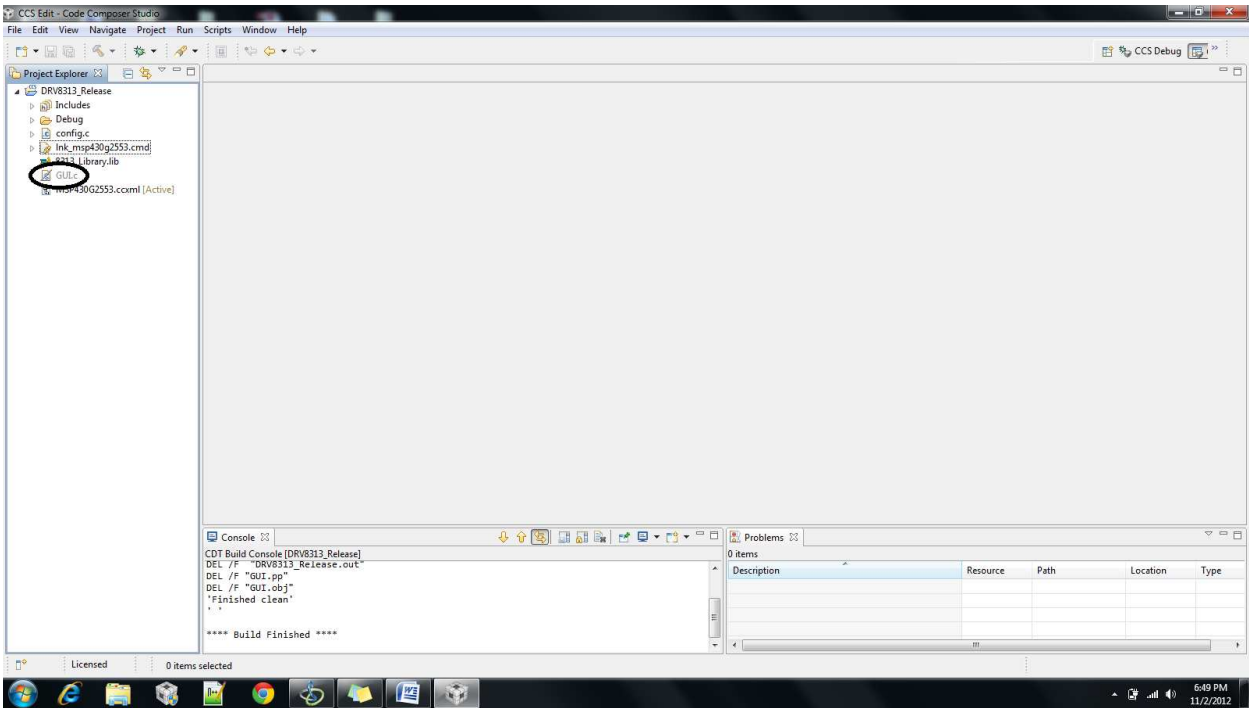

Figure 26. Build Finished

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

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For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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