DRV8308 EVM GUI

This document describes how to use the DRV8308EVM to spin sensored brushless DC motors, as well as a tuning process for the DRV8308 speed control system.

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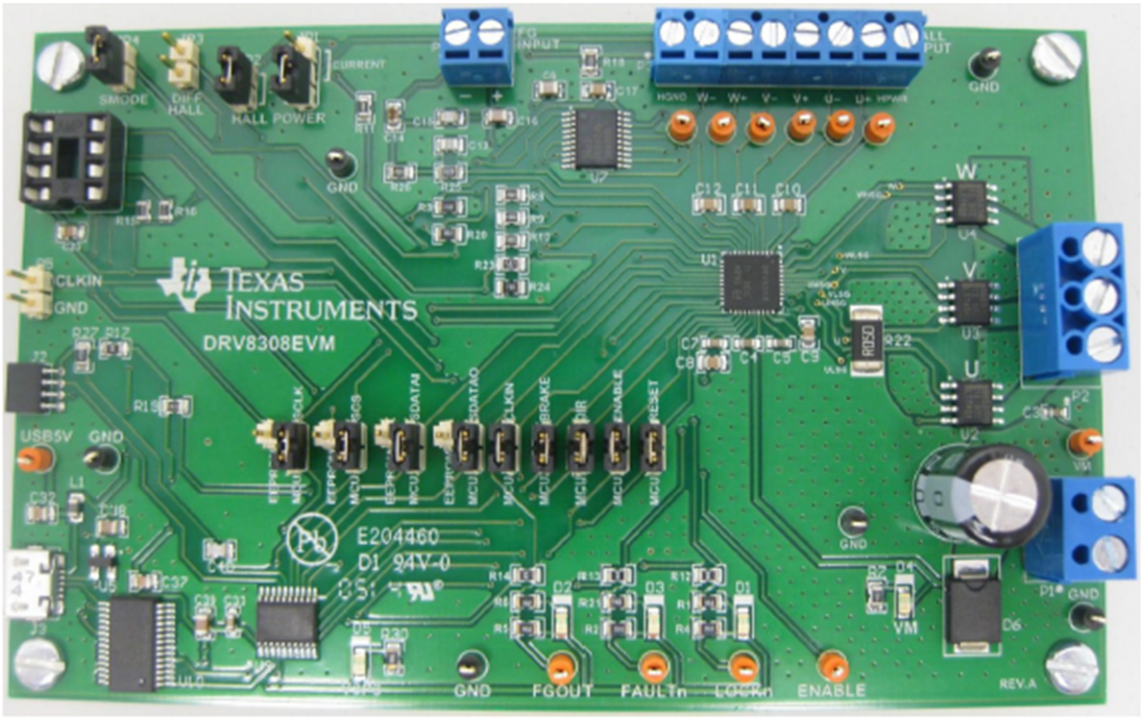
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1 DRV8308 EVM Overview



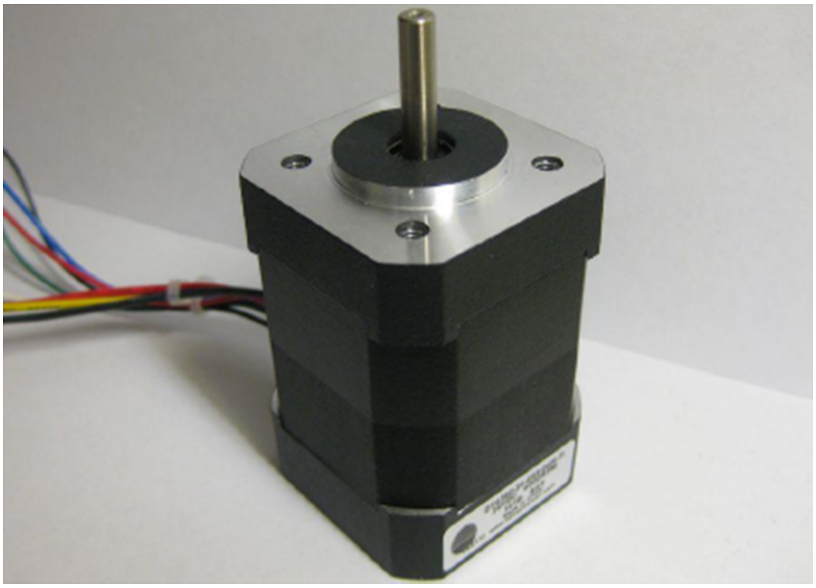
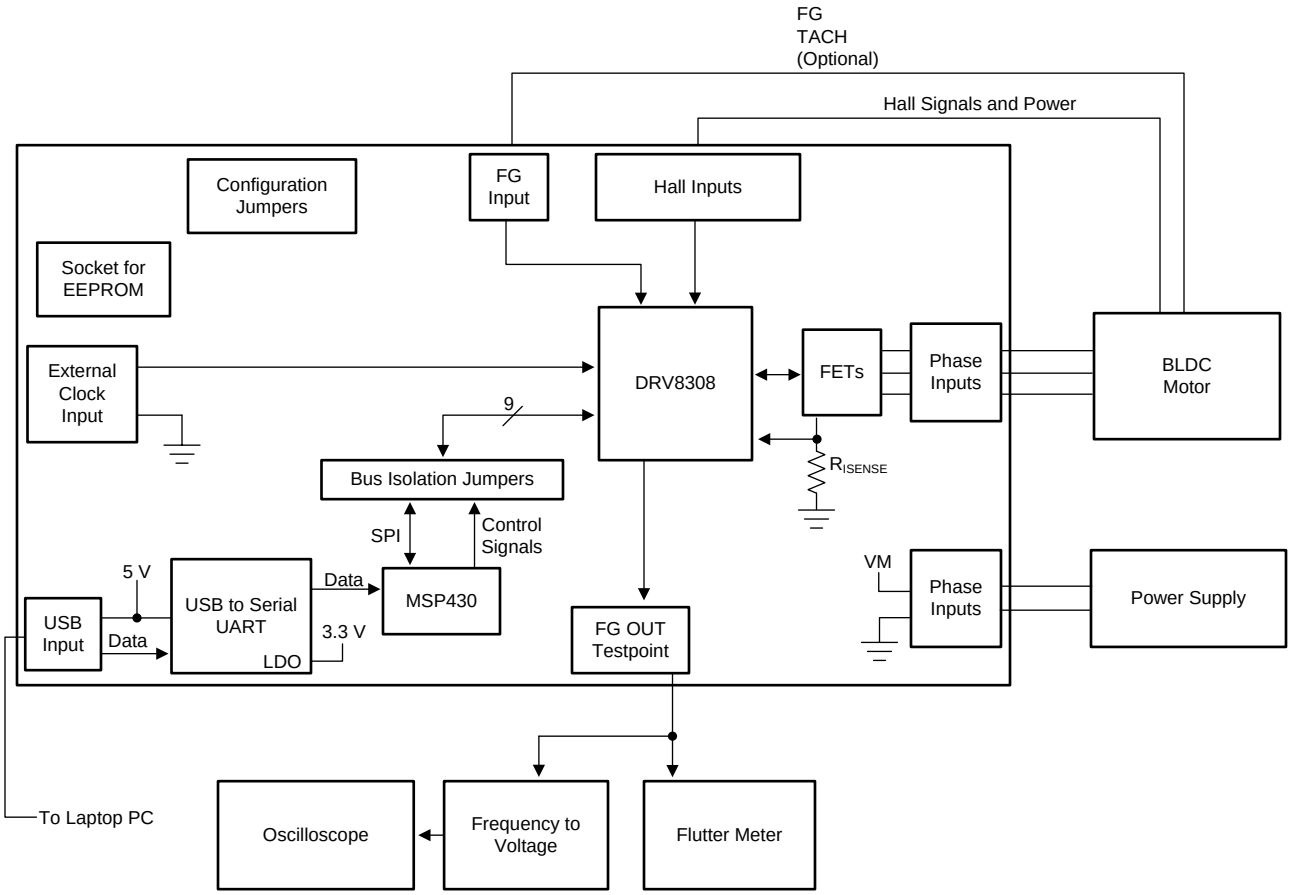


Figure 1. DRV8308 EVM

The DRV8308EVM makes it easy to evaluate the DRV8308 device with different BLDC motors. The kit includes the main PCB, a BLDC motor that uses DRV5013 Hall Effect sensors, a micro USB cable, and a downloadable Windows application that controls and monitors the DRV8308 with a graphical user interface (GUI).

Figure 2 shows the DRV8308 system diagram.

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Figure 2. DRV8308 System Diagram

1.1 External Lab Requirements

The following is required:

Power supply — The supply should be set to a voltage from 8.5 V to 32 V, and a current of at least 1 A. A higher current setting is better, as it helps maintain a stable VM voltage, speeds spin-up time, and increases the torque capability. The DRV8308 limits peak current to 5 A on this board, because the sense resistor is sized at 0.05 Ω, and the VLIMITER voltage is 0.25 V.

Flutter meter — When the motor rotates, it generates a periodic waveform on each Hall phase, and optionally on the FG line. The DRV8308 FGSEL register sets which input to use for the speed-control loop and pass to FGOUT .

Flutter meters can analyze the FGOUT signal and calculate a jitter percentage. This jitter, or variation in edge timing, is a measure of motor-speed consistency. Right flutter values are typically from 0.03% to 0.5%. Some causes of jitter are:

- Magnetic cogging force. Motors with high detent torque have more speed variation when spinning.
- Non-ideal motor windings

Improperly-tuned DRV8308 register settings when in Clock Frequency Mode. The speed-control loop of the device has a configurable pole and zero frequencies, and gain values, and they significantly affect jitter performance. Some BLDC outrunner motors have a PCB mounted to the backside with a board trace antenna that senses magnetic reluctance. This *FG trace* is drawn like a square wave leading in a circle. When the motor spins, a low-level sinusoidal voltage is generated on the trace. The DRV8308 can use this signal to sense motor speed with FGSEL set to 10b.

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Because implementations often causes about 30 to 60 FG cycles per physical revolution, and only 3 to 6 Hall U cycles often occur per physical revolution, FG has an advantage of providing faster speed feedback which can improve jitter performance. For motors that lack FG, setting FGSEL to 00b to use HALL U is best. This setting can achieve very similar performance as FG. Setting FGSEL to 01b for XOR has generally produced worse results.

Frequency-to-voltage converter and oscilloscope — Converting the FGOUT frequency to be represented by an analog voltage and sending the signal to a scope is useful. This allows observing spin-up and spin-down profiles, and any overshoot. Some flutter meters have an integrated frequency-to-voltage converter.

Computer — The computer connects to the PCB with a USB cable, and the GUI controls the MSP430G2553 microcontroller (MCU). This MSP430 ™ MCU can generate a clock, set high and low voltages on the control inputs, read the status outputs, and read and write to the DRV8308 registers using SPI. The bus isolation jumpers provide an easy way to disconnect the MCU from the DRV8308 if a different controller must be used.

A function generator (not shown) — Although the MCU can generate a clock with different duty cycles and frequencies, an external clock source attached to the P5 connector can be used instead. When using this connector, disable the MCU clock to prevent contention. Disabling the MCU clock can be done by removing the CLKIN bus isolation jumper, selecting the GUI option, *External Signal* in the first two tabs, or unchecking *Enable MCU CLK* on the third tab. Although the MCU clock is not quite as accurate as a function generator, the difference on flutter is negligible.

1.2 Configuration Jumpers

The DRV8308 board has three groups of configuration. Table 1 lists the jumper configurations.

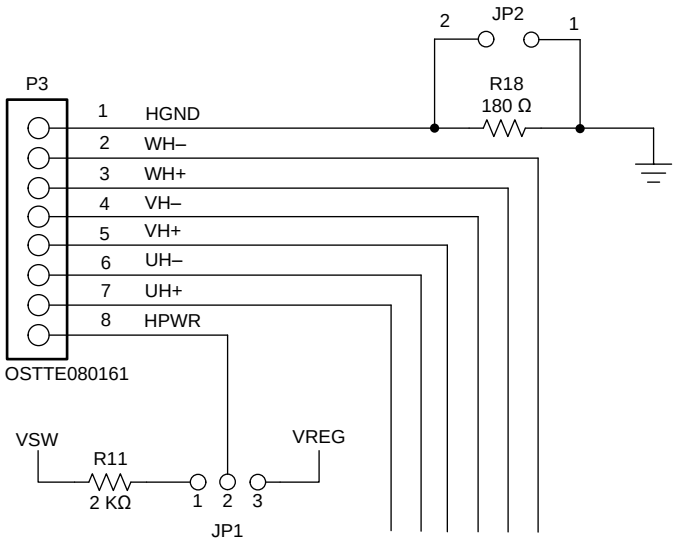
Table 1. Jumper Configuration

Configuration	Jumper	Description
HALL POWER	JP1	Hall sensor power is 5 V or current
	JP2	
DIFF HALL	JP3	Differential or single-ended Hall sensors
SMODE	JP4	SPI (BUI) or EEPROM mode

1.2.1 HALL POWER Jumpers

Sensored BLDC motors typically use either Hall effect integrated circuits (ICs) or elements. Most ICs can use 5-V power, while elements typically have power pins that have an equivalent circuit of a resistor, and current must be limited to approximately 10 mA.

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Figure 3. Hall PWR and GND Circuits

VREG is a regulated 5-V output from the DRV8308. By installing a jumper on pins 2-3 of JP1 and JP2, 5-V power is available on the P3 terminal block for powering Hall ICs. VREG is only powered when the DRV8308 is enabled unless the VREG_EN register is used.

VSW equals VM when the DRV8308 is enabled. By installing a jumper on pins 1-2 of JP1 and removing JP2, this circuit is available for Hall elements as shown in Figure 4.

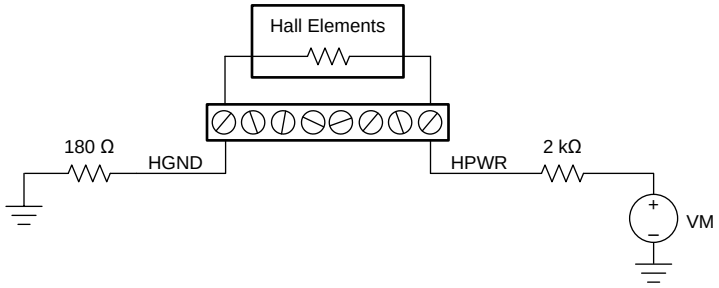


Figure 4. Circuit When Setting Hall Current to Power

The following is an example to calculate current: if VM = 24 V, and 3 Hall elements that have a resistance of 400 Ω are connected in parallel, 10.4 mA will be supplied. Always refer to the Hall element specifications to understand the proper current. The purpose of the 180-Ω resistor is to bias-up the common mode voltage of Hall element differential signals because the DRV8308 requires a VICM voltage from 1.5 V to 3.5 V.

If unsure about whether to apply 5 V or the current-limiting circuit, measure the resistance between the Hall power and ground wires. If the resistance is less than 250 Ω, the current-limiting circuit should be used. Hall elements can be easily damaged if too much current is allowed.

1.2.2 DIFF HALL Jumper

Hall sensors output either a differential signal pair or a single-ended open-drain. Count the number of wires to determine which type of sensor the motor uses. A sensored BLDC typically has 3 phase wires, 2 Hall power wires, and 3 or 6 Hall signal wires. A total of 8 wires indicates a single-ended sensor. A total of 11 wires indicates a differential signal (excluding optional FG or TACH wires).

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The DRV8308 has differential comparators on the Hall inputs, and they can also accommodate single-ended signals with the use of a few passive components. When using differential Hallsensors, directly connect the six Hall signals to the DRV8308 pins. When using single-ended Hallsensors, they require pullup resistors, and the negative (–) pins of the DRV8308 comparator pins should be biased with a middle voltage so that a single-ended swing on the positive (+) pin is detected as a differential voltage.

The JP3 jumper controls U7, an 8-line FET switch, and it decides when to connect the pullup resistors and middle voltage. Install JP3 when using differential Hallsensors. Uninstall JP3 when using single-ended Hallsensors and connect wires to the + terminals of P3.

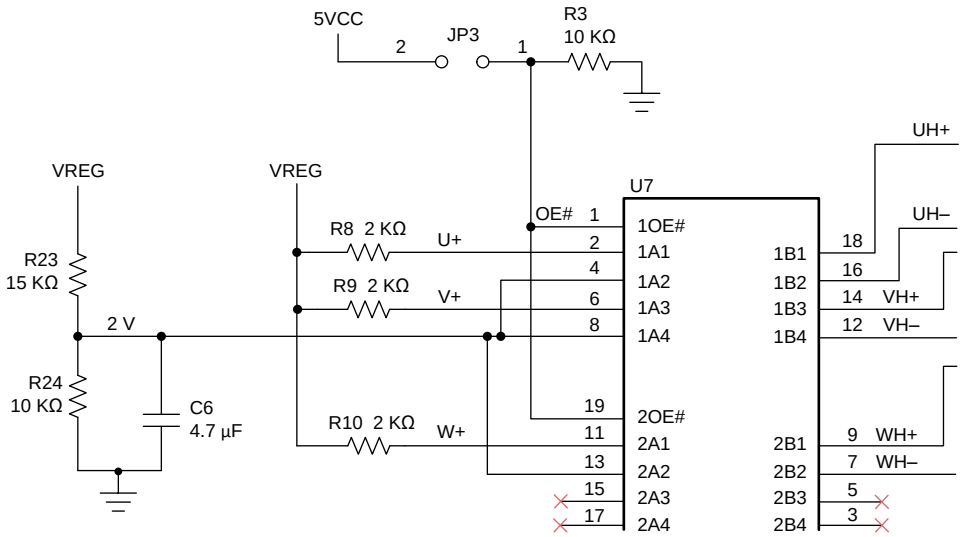


Figure 5. JP3 Control Whether 6 Controls are Made

1.2.3 SMODE Jumper

When the DRV8308 powers up, it checks if pin SMODE is high or low to decide whether to load register data from an external EEPROM, or from the internal nonvolatile one-time-programmable (OTP) memory. When the OTP method is used, the DRV8308 also accepts SPI commands to read and write registers.

Install the JP4 jumper when using the GUI and SPI. Uninstall JP4 when using an external EEPROM, and also install the JP5a, JP6a, JP7a, and JP8a jumpers and a 93C46B-compatible EEPROM into the DIP socket (U6).

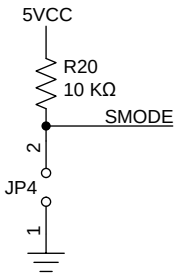


Figure 6. SMODE

2 GUI Software Installation

The following section explains the location and the procedure for properly installing the software.

NOTE: Ensure that no USB connections are made to the EVM until the installation is complete. The installer also installs the GUI Composer V2 Runtime along with the GUI installation.

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2.1 System Requirements

The system requires:

- Supported operating system (OS): Windows 7 or higher (32 Bit or 64 Bit)
- Recommended RAM: 4 GB or higher
- Recommended CPU operating speed: 3.3 GHz or higher

2.2 Installation Procedure

Follow these steps to install the DRV8308 GUI:

Step 1. Double click the *GUIComposerApp-0.1.0.setup-win_2.0.4* application fileshown in Figure 7 to launch the installation file.

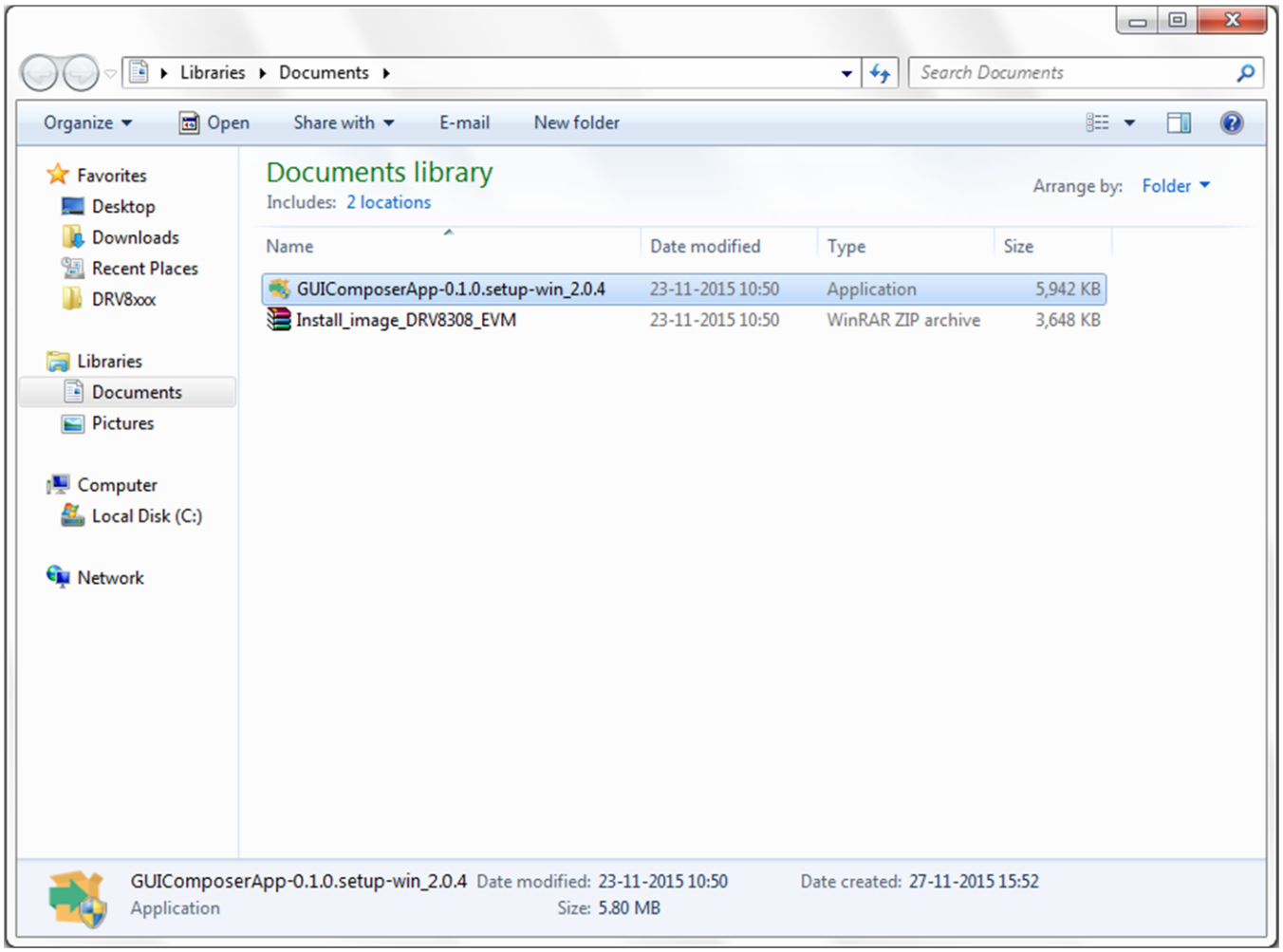


Figure 7. GUIComposerApp-0.1.0.setup-win_2.0.4

Step 2. Click the *Next* button when the window in Figure 8 appears which indicates installer initialization..

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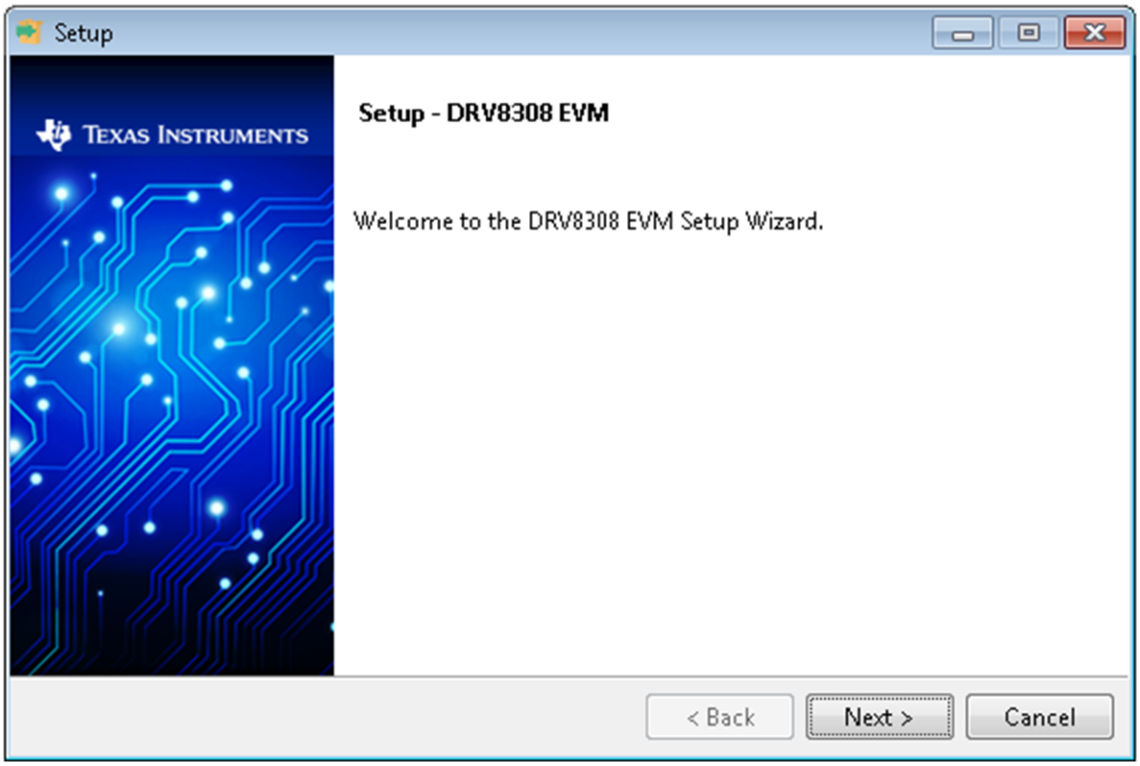


Figure 8. Installation Initialization

Step 3. Read the license agreement for the DRV8308 EVM GUI.

Step 4. Select the *I accept the agreement* radio button and click the *Next* button to proceed (see Figure 9).

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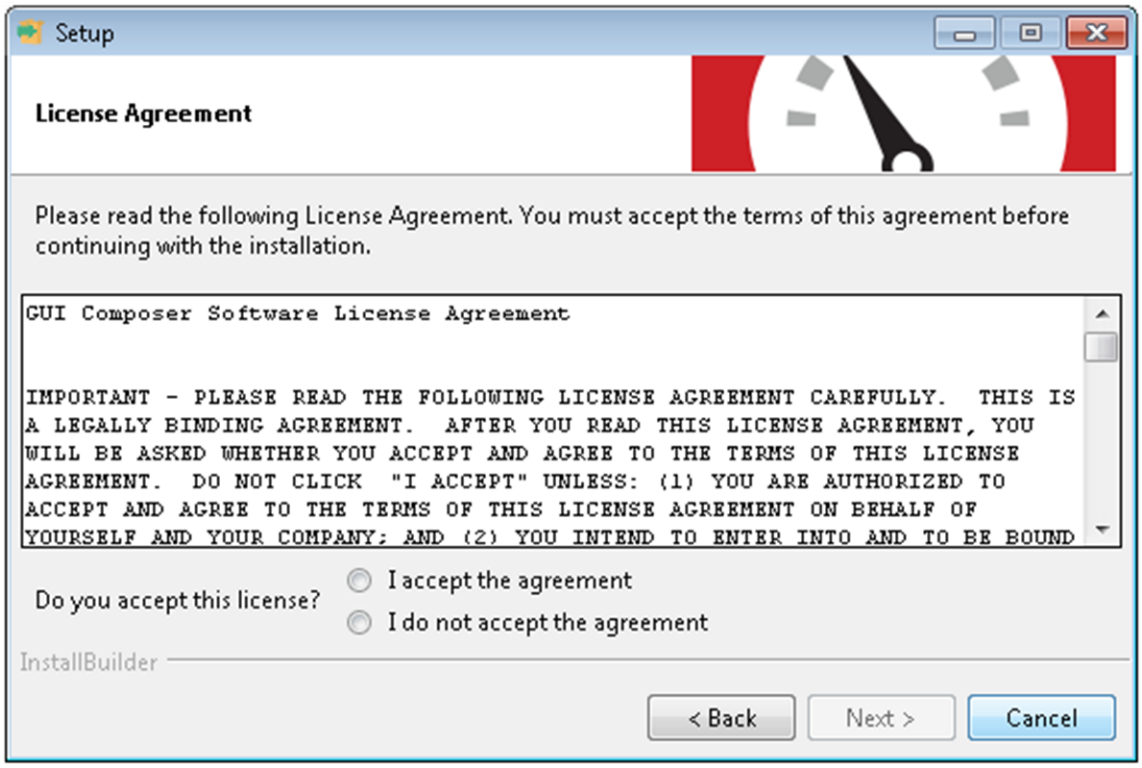


Figure 9. License Agreement

Step 5. Set the default directory for the GUI installation and click the *Next* button.

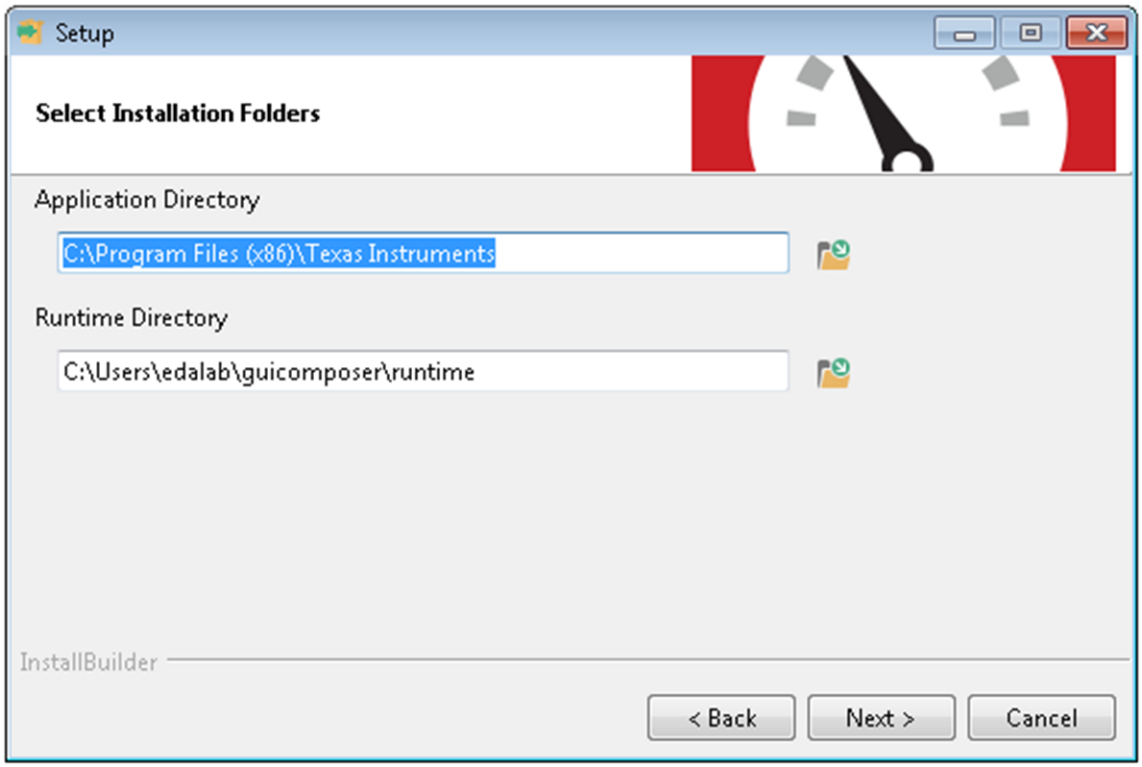


Figure 10. Installation Directory

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NOTE: TI recommends keeping the default values as provided by the installer.

Step 6. If the GUI Composer V2 Runtime is not available on the PC, the installer displays the window shown in Figure 11. Either enter a location or download from the web and click the *Next* button.

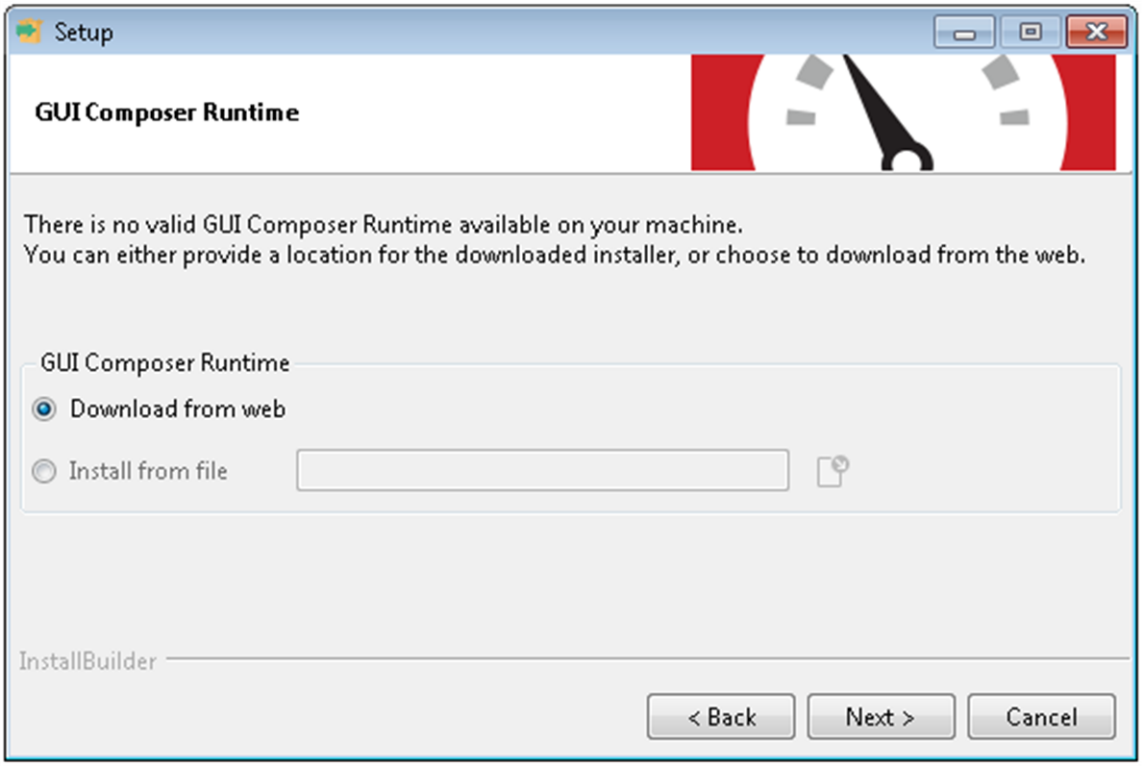


Figure 11. GUI Composer Runtime

Step 7. If the GUI Composer Runtime downloaded from the web, it will then download the GUI Composer Runtime.

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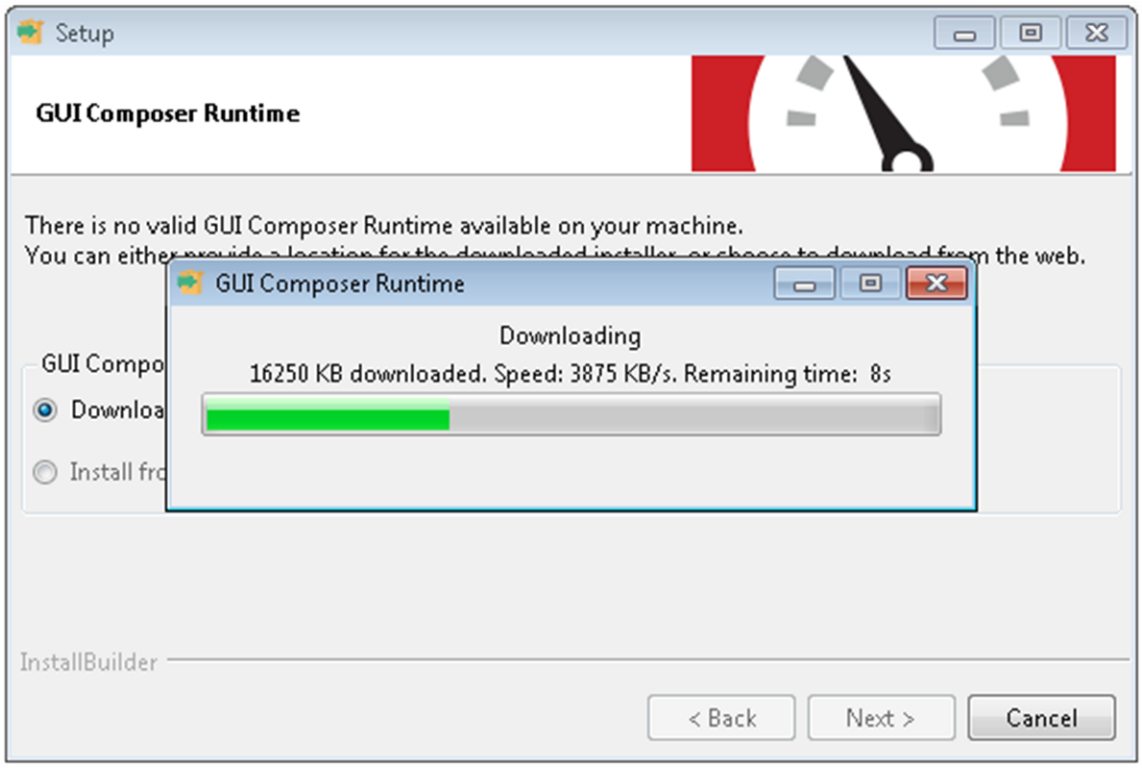


Figure 12. Downloading GUI Composer Runtime

Step 8. The installer extracts the GUI Composer component and continues with the installation as shown in Figure 13.

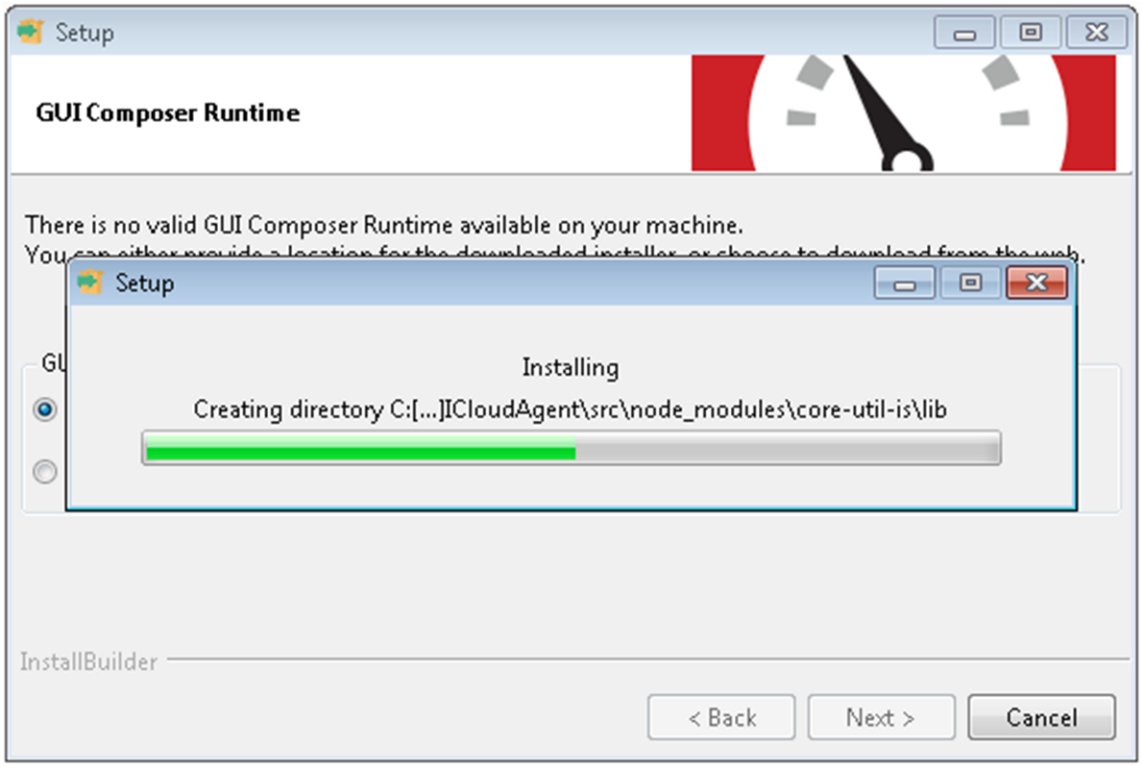


Figure 13. Self-Extraction of GUI Composer Runtime

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Step 9. After the extraction of GUI Composer component, the installer continues with the setup installation as shown in Figure 14.

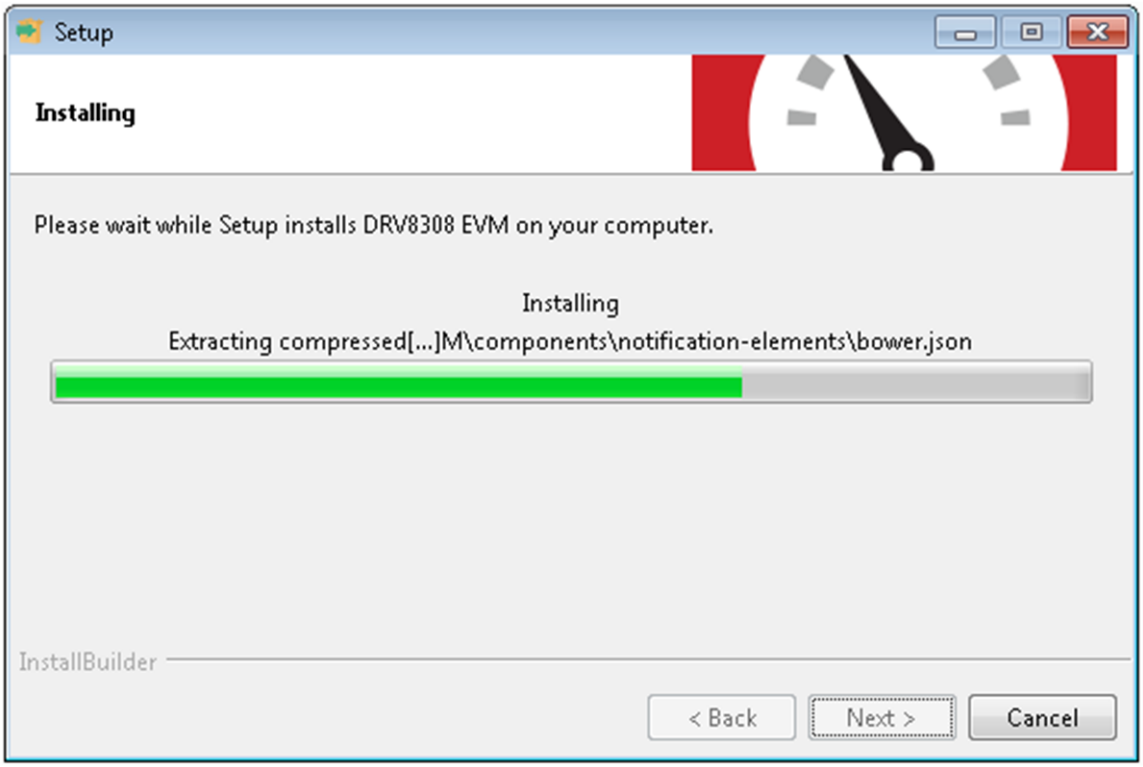


Figure 14. Installation in Progress

Step 10. The window in Figure 15 displays when installation is complete. Click the *Finish* button to complete the installation.

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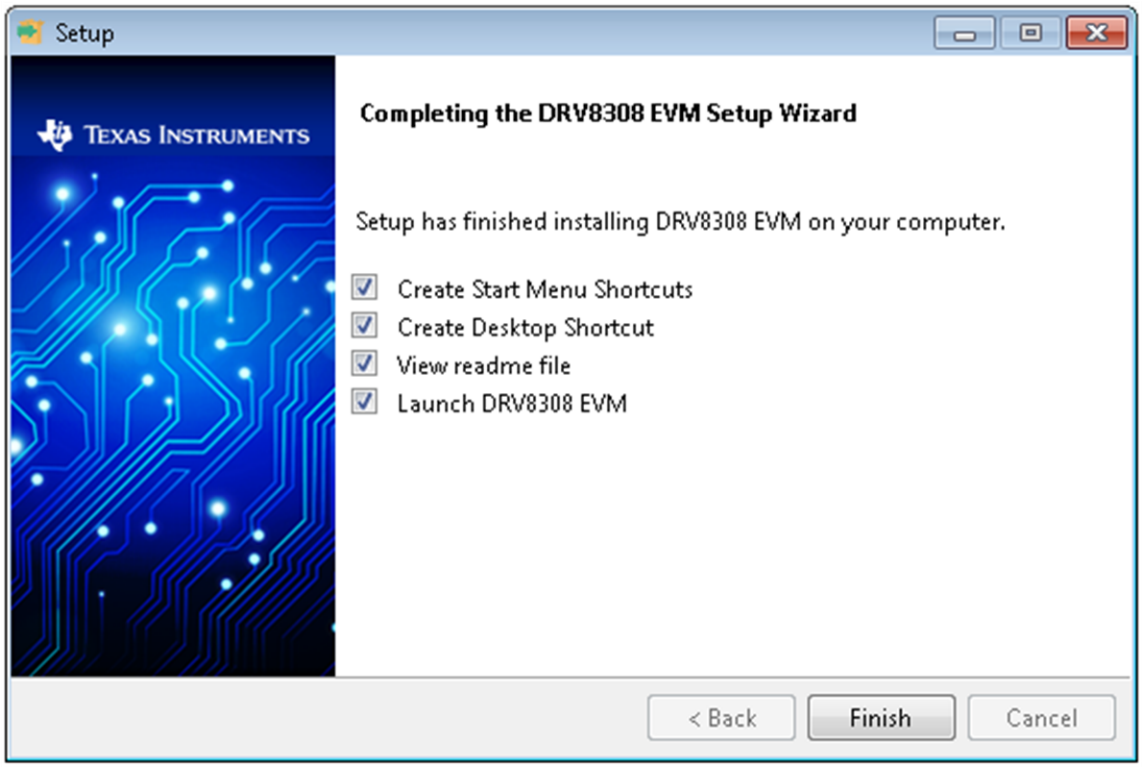


Figure 15. Setup Completion

Step 11. After clicking the *Finish* button, a readme window (see Figure 16) appears, displaying the link for LV 2014 RTE.

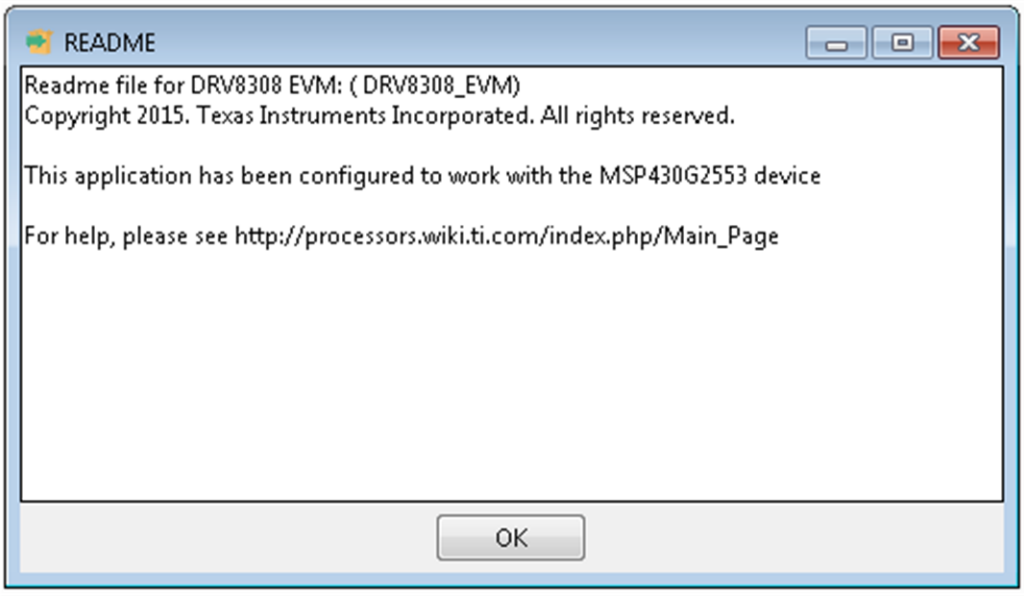


Figure 16. Readme Window

NOTE: The DRV8308 EVM GUI requires the GUI Composer Runtime V2 to be installed before the GUI is executed.

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3 DRV8308 EVM GUI

3.1 Quick Guide to Spin With Open-Loop PWM

To spin the motor with open-loop PWM, follow these steps:

Step 1. Set the jumpers shown in Figure 17.

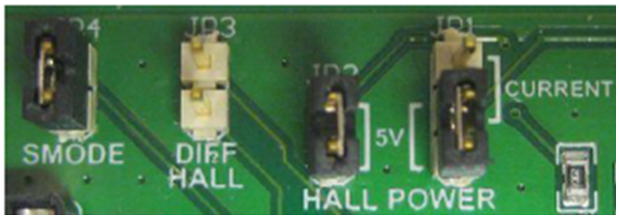


Figure 17. Jumpers

Step 2. Connect the USB cable between the board and the computer.

Step 3. Run the GUI.

Step 4. Wire the included motor to the terminal blocks as shown in Figure 18.

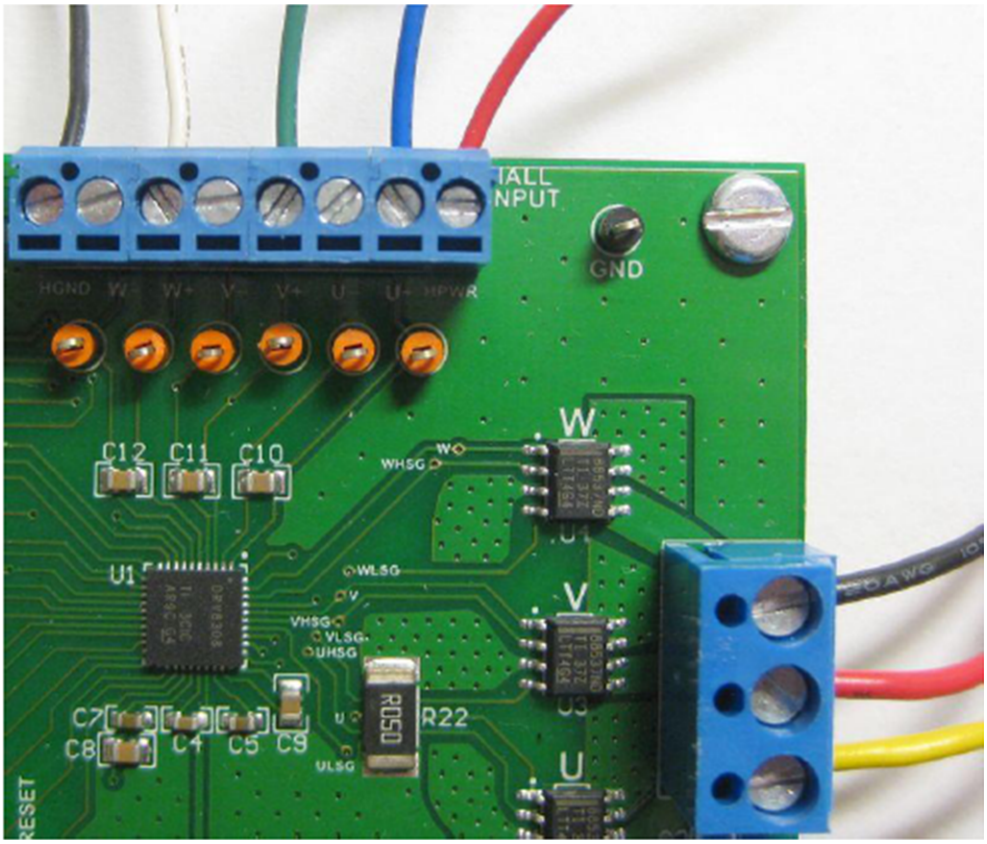


Figure 18. Wiring the Motor

Step 5. Connect the power supply to the board at the VM and GND terminals.

Step 6. Set the supply to 24 V with at least 1 A of current (higher current is better).

Step 7. Set the PWM duty cycle to 40% with the GUI loaded and no symbols.

Step 8. Click ENABLE tospin the motor.

Changes to the motor can be made as follows:

- To change from counter-clockwise to clockwise, click *DIR*.

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- To change speed, use the duty cycle knob.
- To apply sinusoidal commutation, first change MOD120 from 2048 to 3970, and then select *180° Sine Commutation*.

NOTE: When MOD120 = 3970, a 2.1x factor is applied to the input duty cycle and therefore a 40% duty cycle input is treated as 84%.

- To use no clock and command speed from a register, select *PWM from SPEED Register*. Then the *SPEED* decimal value divided by 4095 is the input duty cycle.

3.2 Quick Guide to Spin With Speed Control

The second GUI tab operates the DRV8308 in clock frequency mode which uses the closed-loop speed-control system. Determining the correct frequency for the desired revolutions per minute (RPM) is important. For example, if FGSEL is set to 00b (Hall U), and the motor rotor has 8 magnet poles, four Hall U cycles occur per revolution and the RPM is $f_{CLKIN}/4 \times 60$. If FGSEL is set to 10b (FG), and 42 FG cycles occur per physical revolution, then the RPM is $f_{CLKIN}/42 \times 60$.

If unsure of the number of Hall U cycles of the motor per revolution, test the motor by disconnecting the three-phase wires, enabling the DRV8308 (to apply Hall power), probing the Hall U test point, and manually rotating the motor 360° while counting the number of cycles.

The included TelcoMotion motor has 8 magnetic poles. The following steps use a 100-Hz f_{CLKIN} and therefore the RPM is 1500.

Step 1. Unclick *ENABLE* to stop the motor.

Step 2. Select the second GUI tab and then:

- Set AG_SETPT to 5 to 95 Hz.
- Set LOOPGAIN to 200.
- Set MOD120 to 3970.
- Select CLK from MSP430.

Step 3. Click *ENABLE* to spin the motor at exactly 1500 RPM. Connecting a scope probe to the FGOUT test point allows observation of the Hall U frequency. If the motor is loaded manually, an increase in the power-supply current occurs but the Hall U frequency stays the same because the speed is locked. If the motor can be stopped manually by squeezing hard enough, the power-supply current is probably set to 1 A or less.

3.3 The Third GUI tab

The last tab of the GUI shows all the device registers for the highest level of complexity and control. Changes made to this tab stay in effect when switching back to the first two tabs. By default, the *Auto Write* checkbox is enabled and therefore changes are written immediately through SPI.

The *Burn OTP Memory* button permanently writes the DRV8308 nonvolatile memory with the registers shown. ENABLE must be active for the burn to work. After writing the OTP, whenever the DRV8308 is powered up with SMODE set tolow, the default registers will be what was programmed. To verify that the OTP was successfully written, uncheck *Auto Write*, cycle power to the EVM, type a random number into one of the register fields, click the *Read All* button, and verify that the random number is overwritten to the correct

(OTP) value.

3.4 If the GUI Has Slow Performance

Some computers exhibit slow performance when using the third GUI tab. Two common causes are:

- Too many ports in the *Device Manager*. From the computer, click the *Start* button and then *Control Panel*to find the system *Device Manager*. Under the *Ports* list, the port for the EVM is named *USB Serial Port*. If other ports are listed, try disabling them by right-clicking the port name and selecting *Disable* from the menu. Restart the GUI.
- Too many programs running in the background. Try closing all other programs and disk scanners.

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3.5 Menu Options

This section lists the different GUI menu options.

3.5.1 File

The *File* menu contains the options as shown in Figure 19. The options are defined as follows:

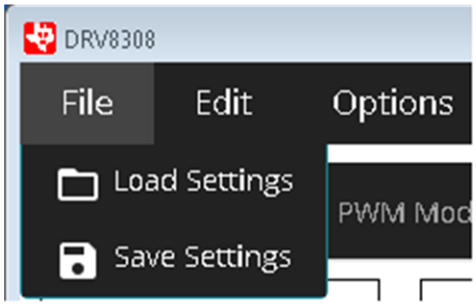


Figure 19. File Menu

Load settings — If this option is clicked, it loads the configuration file which was saved earlier to bring the device to a known state.

NOTE: Loading a configuration overwrites the existing data in the registers with the value specified in the .json file that is loaded.

Save settings — If this option is clicked, the current register configuration is saved into a file which can be loaded into the GUI in the future using the *Load* option.

3.5.2 Edit

The *Edit* menu contains the *Undo* and *Redo*options for changes done in the GUI (see Figure 20).



Figure 20. Edit Menu

3.5.3 Options

The *Options* menu contains the option to connect to the serial port and configure the serial port (see Figure 21).

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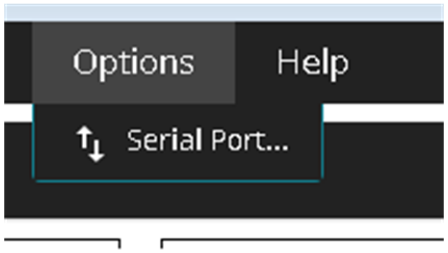


Figure 21. Options Menu

3.5.4 Help

The *Help* menu contains the options as shown in Figure 22. The options are defined as follows:

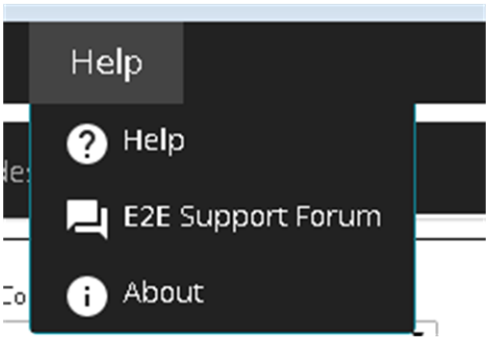


Figure 22. Help Menu

Help — The *Help* option connects the GUI to the E2E™online community.

E2E™ Support Forum— *The Help connects to the E2E™ forum.*

About— The *About* option provides information about the GUI as shown in Figure 23.

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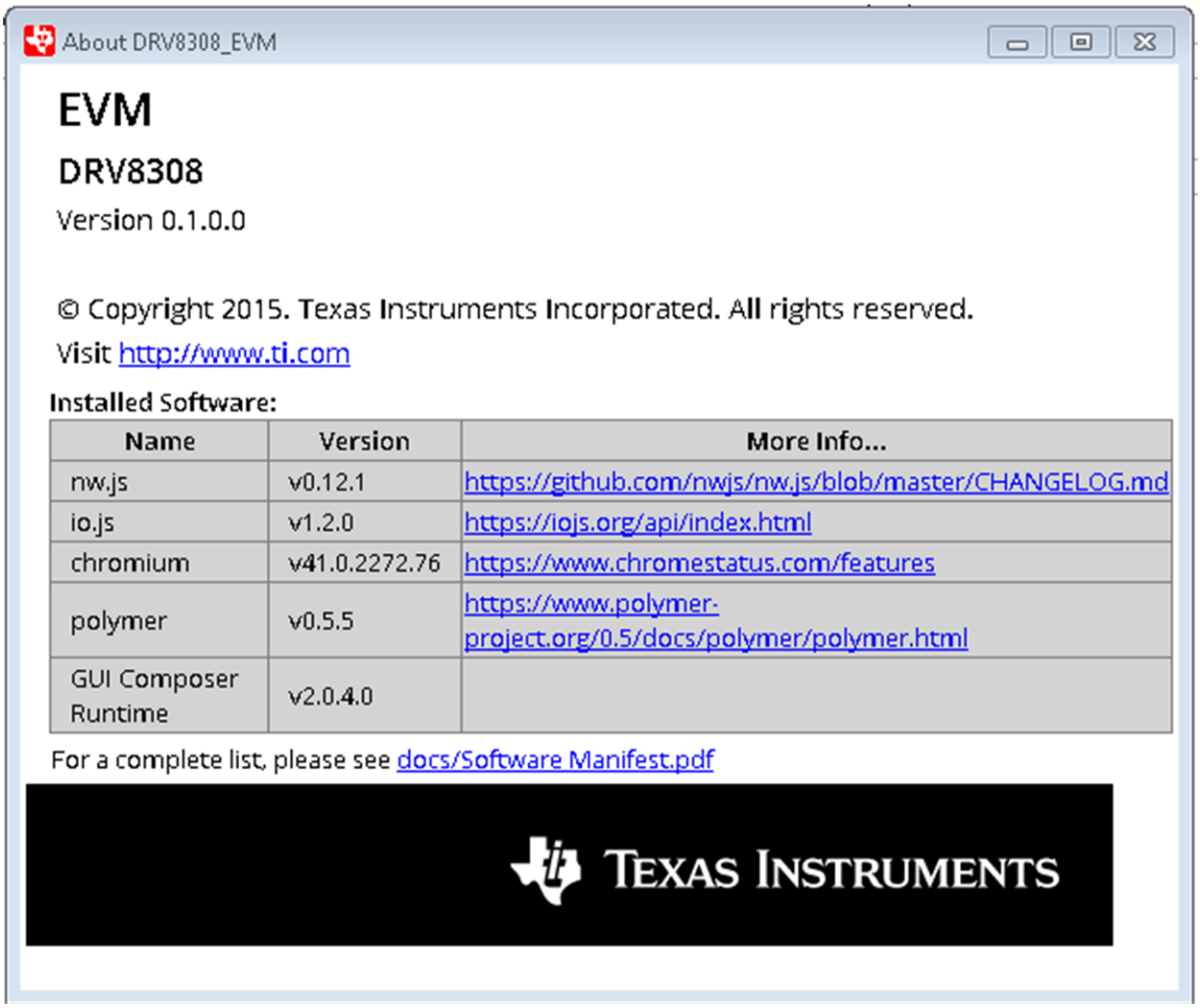


Figure 23. About Page

4 Tuning the Speed-Control System

The DRV8308 clock frequency mode for speed control performs best when the device registers are tuned for the motor, inertia, speed, and load torque of a particular system.

4.1 Key Registers

This first set of registers must be configured correctly:

MOD120 — Always set this register to 3970.

SPEED — This register is the open-loop gain during spin-up before LOCKn goes low. This register must be set high enough to reach the commanded RPM.

AUTOGAIN — When enabled, the DRV8308 scales LOOPGAIN with RPM because more gain is required for more speed. AUTOGAIN is a valuable feature and should generally be left enabled. Then ScaledGain = LOOPGAIN × f_{CLKIN}/AG_SETPT.

AG_SETPT — This set point effectively sets the range for AUTOGAIN. Use the setting that is closest to see the DRV8308 data sheet register descriptions fCLKIN).

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AUTOADV — When enabled, the DRV8308 aggressively scales ADVANCE with RPM: Scaled Advance = ADVANCE × f_{HALLU}/AA_SETPT. Without this setting, ADVANCE already scales with speed because each value shifts timing by 0.1% of the Hall U period. Disable AUTOADV initially. Then, when the system is well-tuned, experiment with AUTOADV to potentially improve performance.

AA_SETPT— This register only applies when AUTOADV is enabled. Use the setting that is closest to the frequency of Hall U.

IDRIVE — This register sets the predriver output current and directly controls the external FET VGS turnon time. Unless high-current FETs are used, lower values are generally better to minimize switching noise.

FGSEL — If an FG sense trace is not used, setting FGSEL to 0 (HALL_U) is generally best.

These registers should be tuned for a particular system:

ADVANCE — This register adjusts the timing shift between when the DRV8308 receives Hall signals and commutation. While a motor is running, the ADVANCE register can be modified in real-time (if AUTOADV is disabled). The difference in power-supply current occurs instantly. A lower current is generally better, but flutter performance can be a tradeoff of higher current.

LOOPGAIN — This gain primarily affects the maximum RPM, maximum torque, and startup-speed overshoot. If the gain is too low, the motor does not spin up to the commanded RPM or the torque capability may be limited. If the gain is too high, the motor speed overshoots at first.

SPDGAIN — This gain affects how aggressively error is compensated. If the gain is too high, the speed oscillates around the target speed. If the gain is too low, flutter may be higher.

FILK1 — This register sets the Pole1 frequency.

FILK2 — This register sets the Zero1 frequency.

COMK1 — This register sets the Pole2 frequency.

COMK2 — This register sets the Zero2 frequency.

4.2 Tuning Process

Tuning a motor system is a trial-and-error process. The following steps are a general guide. The GUI loads with the default register values that attempt to have reasonable filter settings.

1. Use the first tab to run the motor in PWM mode. Trying different wire connections and HALLPOL to achieve a consistent motor spin may be necessary. After that, while spinning the motor, change the ADVANCE register and find the value that causes the lowest power-supply current and audible motor noise. Then stop the motor by bringing ENABLE low.
2. Determine the appropriate clock frequency, f_{CLKIN}. Select the third GUI tab, and:
   - Set AG_SETPT closest to the target f_{CLKIN}.
   - Set MOD120 to 3970.
   - Set SPEED to 4000.
3. Turn on the clock, and start the motor with ENABLE. If the motor spins very roughly,
   - Try reducing or increasing f_{CLKIN} to find a practical case as a baseline reference.
   - Try changing the filters (FILK1, FILK2, COMK1, or COMK2) with different combinations in increments of 150. Spend some time to find good values.
   - Try increasing SPDGAIN and LOOPGAIN.
4. By now the motor should spin smoothly, but the frequency of the signal on FGOUT might not match f_{CLKIN}. If the two frequencies do not match, the speed is not locked. Many times that can be fixed by increasing LOOPGAIN or SPEED.
5. Now the motor should be spinning with the FGOUT frequency matching f_{CLKIN}. If the motor was loaded manually, it should maintain the same RPM and FGOUT frequency. To increase the load capability, try increasing LOOPGAIN or decreasing the value of the RSENSE resistor to allow more motor current.

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At this point, determining the minimum *total gain*required to reach the target RPM and torque drive is useful. To do find this value, continue decreasing LOOPGAIN and toggling ENABLE to find the LOOPGAIN that prevents f_{FGOUT} from reaching f_{CLKIN}. The filter registers affect pole and zero frequencies of the control system. Filter registers also affect gain in the same way as LOOPGAIN, where Total gain = LOOPGAIN × (2× FILK2/FILK1) × (0.5× COMK2/COMK1).

Inside the downloaded board files and software, open the file, \Application\Filter calculator.xls. Enter the filter values and LOOPGAIN into the green cells and review the *Total gain*. This value is the minimum gain required by the system to reach the commanded RPM.

In future trials, changing the filters (to improve flutter and dynamic performance) will also change total gain, and the calculator should be used to determine the correct value for LOOPGAIN to keep the total gain at least 20% above the minimum. Being 1.5x to 3x above the minimum value is often acceptable and the first consequence of having too much total gain is that start-up speed can overshoot..

NOTE: More gain is required to drive more torque

6. To optimize flutter performance, vary ADVANCE, SPDGAIN, and many combinations of the FILK1, FILK2, COMK1, and COMK2 filters. These filter settings can be changed in real-time while the motor is spinning, but the new *total gain* is only updated when the motor restarts (technically when LOCKn transitions to low if AUTOGAIN is enabled).

   In many cases, setting Pole1 to a much higher frequency than the others and setting Zero2 to Pole2 to a frequency band between Zero1 and Pole1 works well. Try many combinations to find the correct settings. Feel free to post any questions to the TI E2E Forum online.

NOTE: If additional assistance is needed, post questions to the motor drivers section of the TI E2E Support Community.

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from E Revision (May 2015) to F Revision **Page**

- Changed pass to FGOUT 4
- Added Improperly-tuned DRV8308 register settings when in Clock Frequency Mode. 4
- Added (not shown) 5
- no symbols 15
- Changed DIR 15
- duty cycle knob 16
- MOD120 16
- Changed PWM from SPEED Register 16
- Changed The following steps 16
- Added test point 16
- Added closest to see the DRV8308 data sheet register descriptions fCLKIN) 19

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- *Reorient or relocate the receiving antenna.*
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