

EVM User's Guide: MC121EVM

MC121 Single-Phase BLDC EVM



Description

The MC121EVM enables users to evaluate the performance of the MC121 and MC121-Q1 single phase BLDC driver. The EVM includes an on-board FTDI chip to convert USB communication, from the PC, into UART. An on-board MSP430FR2355 microcontroller (MCU) translates the UART communication into either control signals or I2C formatted data, which is sent to the MC121 or MC121-Q1 in the application PCB. There are many user-selectable jumpers, resistors, connectors, and test points to assist with evaluating the many features of the MC121 or MC121-Q1 and the configurable device-specific settings.

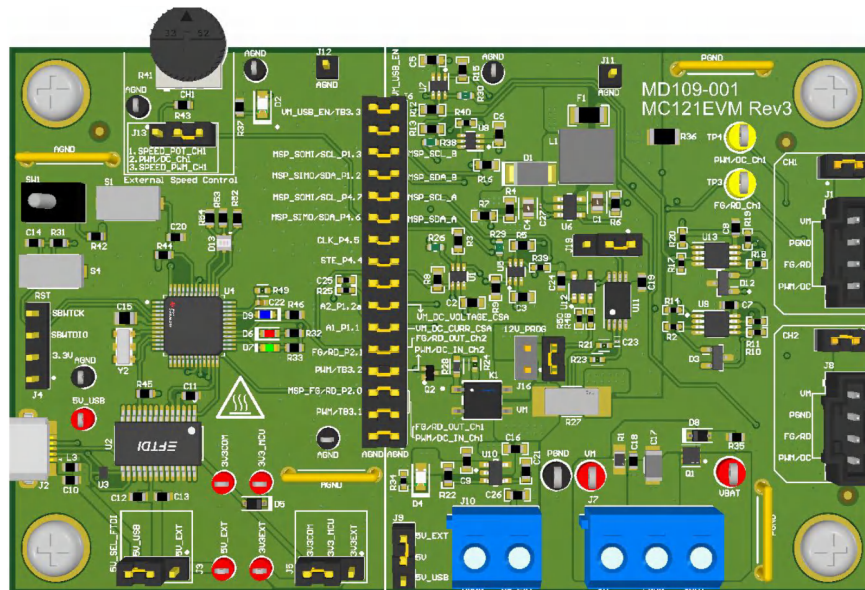
MotorStudio is the GUI which is used to control the MC121EVM.

Features

- One time programmable (OTP) write capability
- GUI software to simplify the MC121 and MC121-Q1 tuning procedure and performance evaluation

Applications

- LED headlamp cooling fans
- Infotainment cooling fans
- ADAS ECU/sensor cooling fans
- Wireless charger cooling fans
- Appliances fans
- Industrial cooling fans



1 Evaluation Module Overview

1.1 Introduction

This user's guide details how to set up, configure, and operate the Motor Studio GUI and MC121EVM. Throughout this document, the terms evaluation board, evaluation module, and EVM are synonymous with the MC121EVM. This document also provides information on the operating procedure, input and output connections, an electrical schematic, printed circuit board (PCB) layout drawings, and a bill of materials (BOM) for the EVM.

1.2 Kit Contents

The contents of the EVM kit are listed in Table 1-1. Contact your nearest Texas Instruments Product Information Center if any components are missing. TI highly recommends that users check the TI website at <https://www.ti.com> to verify that the latest version of the related software is being used

Table 1-1. Kit Contents

Item	Quantity
MC121EVM	1
USB-A to USB-B micro-cable	1

1.3 Specification

The MC121EVM is rated for operation of 35V absolute maximum and currents up to 2A peak. To prevent personal injury, electrical shock hazard, damage to the EVM, or a combination confirm that the EVMs voltage and current specifications are not exceeded.

1.4 Device Information

The MC121-Q1 and MC121 is a 40V, 850mΩ rated integrated motor driver with N-channel full-bridge MOSFETs, charge pump, Hall sensor, commutation control logic, and protection circuitry for single phase brushless DC motors. The Hall sensor provides rotor position information to the commutation logic to maintain continuous rotor motion. The commutation logic can be programmed for square or soft PWM waveforms to reduce acoustic noise or maximize speed/efficiency.

2 Hardware

2.1 Quick Setup – Motor Run Mode

The MC121EVM requires a power supply source with a recommended operating range from 4.5V to 35V. To set up and power the EVM, and to run the motor installed in the motor PCB, follow the sequence below:

1. Connect the VM, GND, FG/RD and PWM/DC pins of the MC121 or MC121-Q1 on the motor PCB (not included in the EVM) to the MC121EVM using J1.
2. Connect the DC power supply to VBAT/VM and PGND on connector J7. Do not turn on the power supply.
 - a. Connect to VBAT to enable reverse polarity protection.
 - b. To disable reverse-polarity protection, connect to VM.
3. Select J3 to 5V_USB and J5 to 3V3COM to power MSP430 from USB power supply.
4. Connect the EVM to the PC with a micro-USB cable.
5. Set the jumper in J13 between Pin 1 and Pin 2 as shown in the image below to enable PWM/DC connection to MCU.
6. Set the jumper in J19 between Pin 2 and Pin 3 to set the ADC measurement to unipolar output for GUI current plot.
7. Remove the Jumper on J16 to disable the connection between onboard 12V boost supply and VM since an external power supply is needed to run the motor.
8. Turn on the motor power supply.
9. Launch MotorStudio GUI to connect to the MC121 or MC121-Q1.

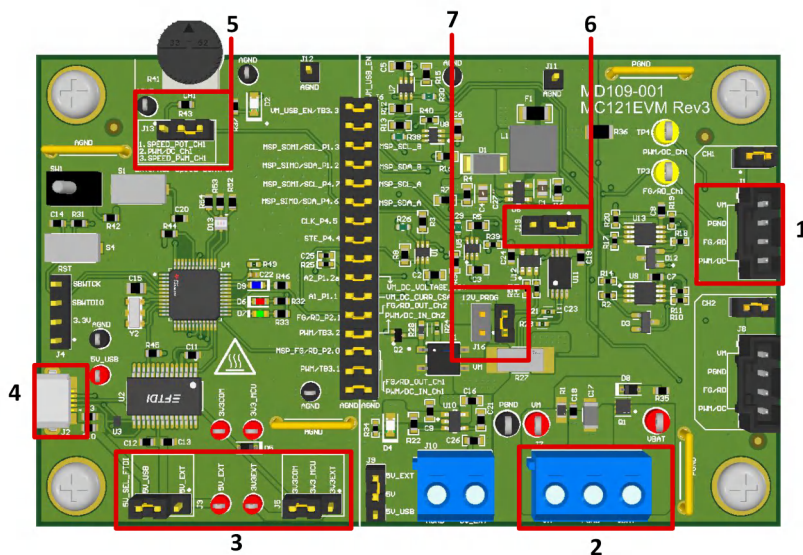


Figure 2-1. Default jumper configuration of the MC121EVM

2.2 Quick Setup – OTP Programming Mode

The MC121EVM requires a power supply source with a recommended operating range from 8V to 35V in programming mode. To set up and power the EVM, and to program the One time Programmable (OTP) memory of the device, follow the sequence below:

1. Connect the VM, GND, FG/RD, and PWM/DC pins of the MC121 or MC121-Q1 on the motor PCB (not included in the EVM) to the EVM using J1.
2. Connect the DC power supply to VBAT/VM and PGND on connector J7. Do not turn on the power supply.
 - a. Connect to VBAT to enable reverse polarity protection.
 - b. To disable reverse-polarity protection, connect to VM.
3. Select J3 to 5V_USB and J5 to 3V3COM to power MSP430 from USB power supply.
4. Connect the EVM to the PC with a micro-USB cable.

5. Set the jumper in J13 between Pin 1 and Pin 2 as shown in the image below to enable PWM/DC connection to MCU.
6. Set the Jumper on J16 to enable connection between onboard 12V boost supply and VM if an external supply is not available to program the OTP memory of the MC121 or MC121-Q1.
7. Launch MotorStudio GUI to connect and configure the MC121 or MC121-Q1.
8. Disable Auto read all registers and Disable Auto read faults in the Fault tab in the MotorStudio GUI.
9. In the Controls tab, Enable Control Via I2C and enter 0% in I2C speed control and click Set button to stop the motor.
10. Configure the registers from the GUI for the desired performance and functionality of the motor.
11. Set the lever switch SW1 to the right position from the default left position and gently press the S1 once to program the OTP memory.

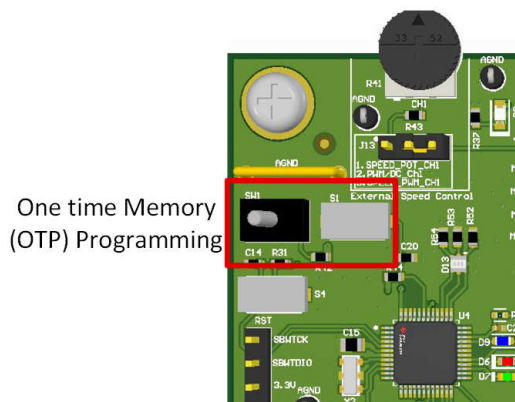


Figure 2-2. Default Lever switch (SW1) configuration with OTP programming mode disabled

2.3 Hardware Overview

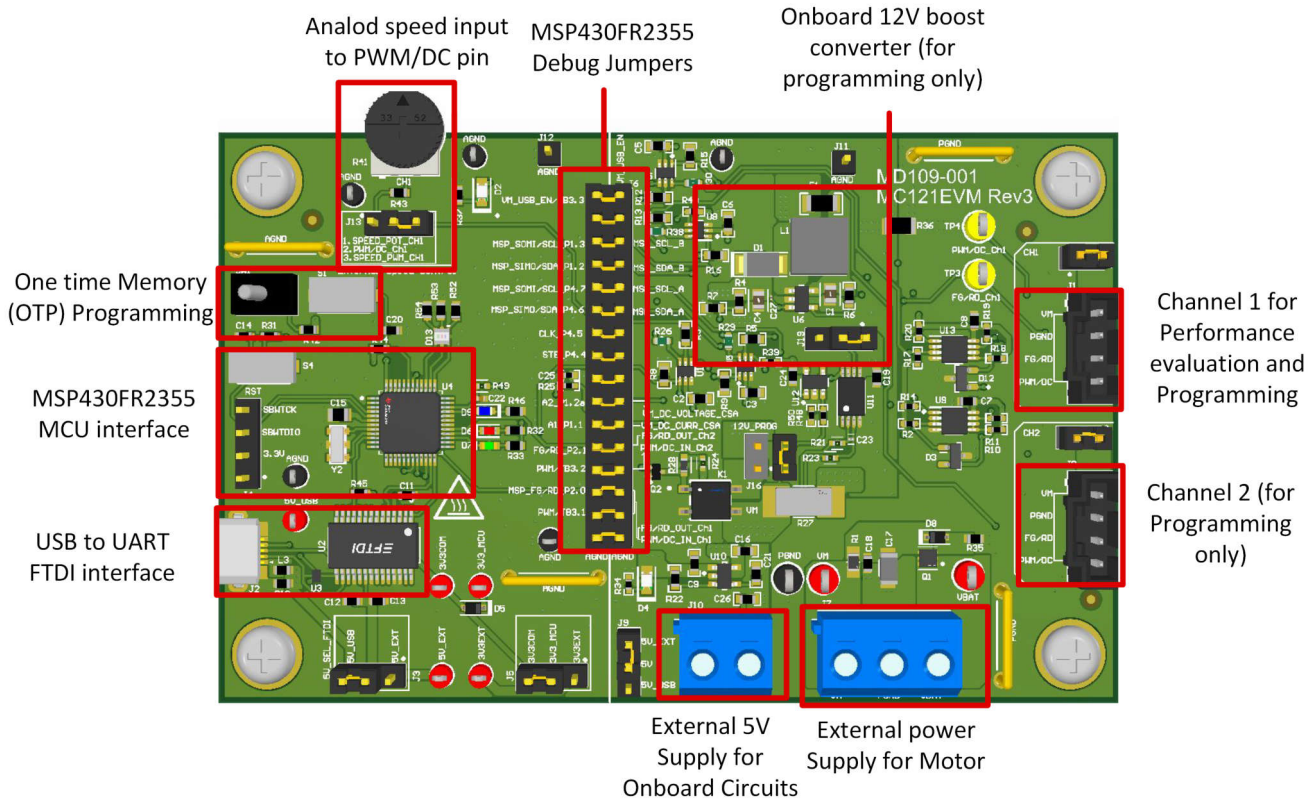


Figure 2-3. Hardware Overview for MC121EVM

2.3.1 Motor PCB connection to MC121EVM

Figure 2-4 shows the connections to be made to the single phase BLDC motor. the MC121 or MC121-Q1 is residing on the PCB on the motor and does not reside on the EVM. Users are expected to design a PCB for the motor with the MC121 or MC121-Q1 and use the MC121EVM to evaluate the motor performance with the EVM

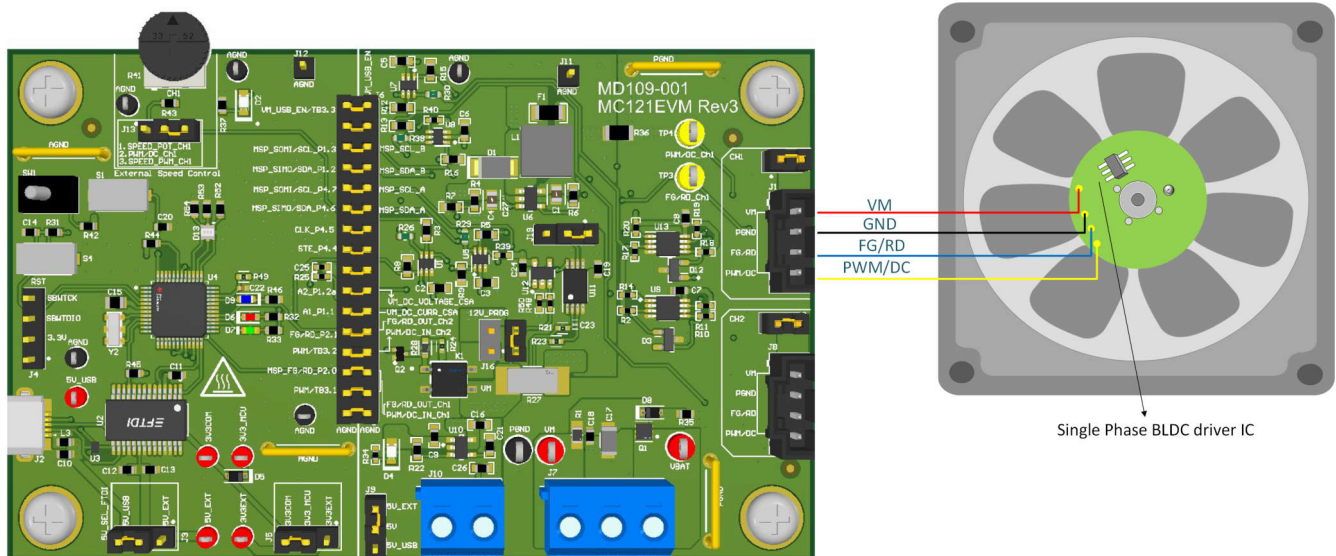


Figure 2-4. EVM and Motor PCB connection

All the necessary pull ups and protections are present on the EVM. An example recommended schematic for the MC121 motor PCB is shown below:

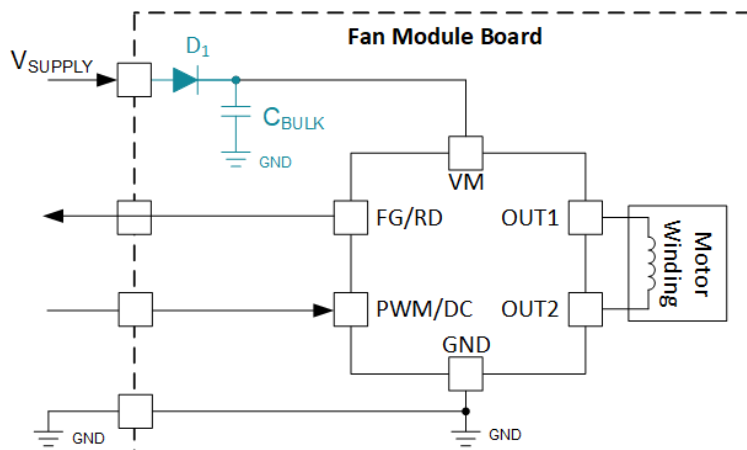


Figure 2-5. Recommended Motor PCB schematics

2.3.2 External Analog Speed Input

The speed input (DIN) to the device can also be provided through an external potentiometer. Once connected to the device, set "Speed pin configuration" under Interface Configuration to accept analog voltage to control motor speed. Set control via I2C to Disabled.

Use J13 to select between Analog input to PWM/DC pin. Rotate R41 to different speeds.

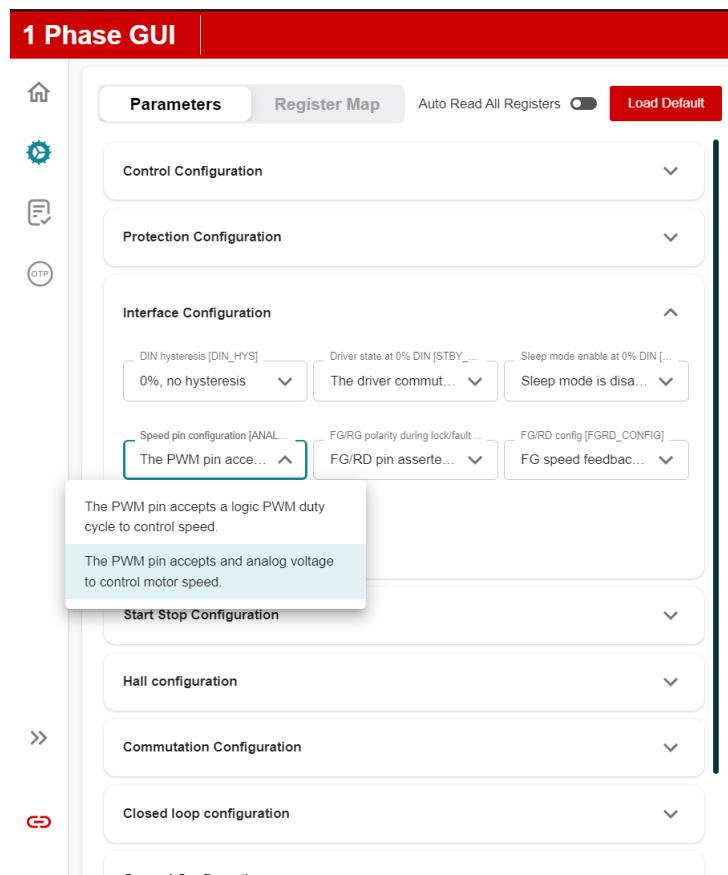


Figure 2-6. Option to change PWM/DC input to accept analog voltage

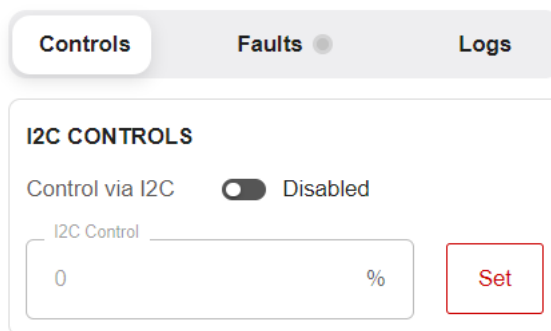


Figure 2-7. Disable option for control Via I2C

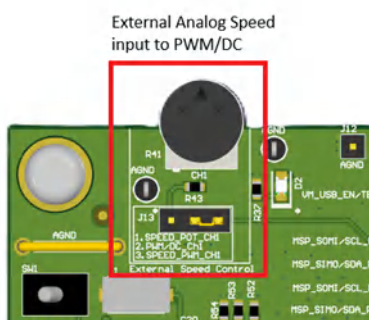


Figure 2-8. External Analog Speed control input to PWM/DC pin

2.3.3 Onboard 12V Boost Circuit

An on-board boost circuit is provided for register read and writes only. The boost converter does not support running a motor. Connect the jumper in J16 to enable 12V boost supply output to VM. The boost converts 5V to 12V. The 5V input to the boost converter can be selected between the USB input or an external 5V using the jumper J9. If the external 5V supply is used the supply is connected to J10.

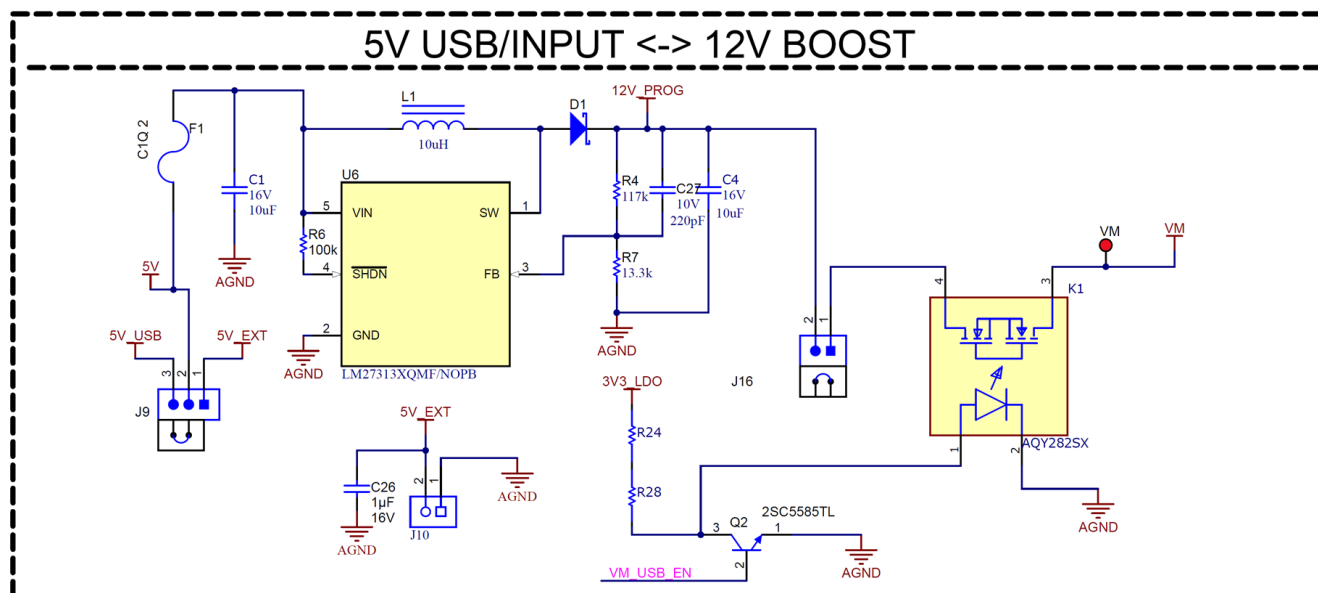


Figure 2-9. On-board 12V Boost Circuit Schematics

2.4 MSP430FR2355 Microcontroller

The MC121EVM includes a MSP430FR2355 low-power MCU, shown in Figure below, to communicate via I2C with the MC121 or MC121-Q1 device.

To program the MSP430FR2355, an external MSP430 programmer must be connected to the Spy-Bi-Wire (SBW) interface connector J4. Many MSP430 LaunchPads™ provide an onboard eZ-FET Debug Probe that can be jumper-wired to the MC121EVM to flash the firmware into the onboard MSP430FR2355 microcontroller.

The user can use the Reset (RST) button S4 at any time to restart the MCU program.

The 32-pin shunt jumper bridge J6 ties all signals between the microcontroller and the EVM circuits.

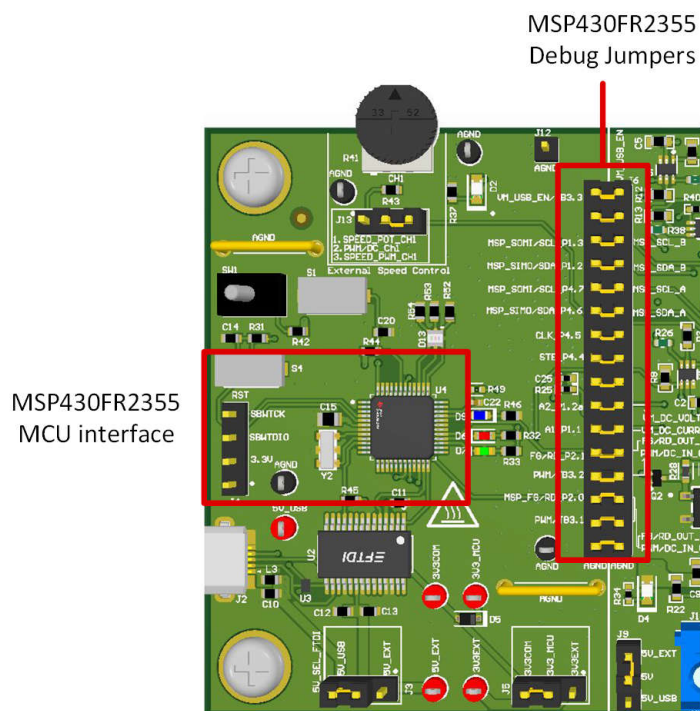


Figure 2-10. MSP430FR2355 MCU interface and debug

3 Software

3.1 EVM Firmware

The MC121EVM includes a USB-to-UART interface, using a MSP430FR2355 microcontroller, that serves as a communication bridge between a host PC and the MC121 or MC121-Q1 device for configuring various device settings and reading fault diagnostic information.

The MC121EVM is supported on the MOTORSTUDIO GUI which can be used to configure the MC121 or MC121-Q1 through this communication interface. The MOTORSTUDIO GUI simplifies the tuning process of the MC121 or MC121-Q1 by offering guided tuning instructions, a virtual oscilloscope for real-time variable monitoring, and more.

By default, the onboard MSP430 microcontroller already contains the firmware needed to communicate with the Motor Studio GUI. If there is a firmware update or the GUI does not connect to the EVM, then the user must flash the firmware code into the MSP430FR2355 by following the steps outlined in [Section 2.4](#).

Flashing the firmware code onto the MSP430 requires an integrated development environment (IDE) or UniFlash tool.

3.2 GUI Installation

Download and install the latest version of the [MOTORSTUDIO](#) for use with the MC121EVM. Refer to this [e2e FAQ](#) to maintain a reliable installation of the GUI.

3.3 Getting Started With Motorstudio for MC121

Step1. Launch the MOTORSTUDIO GUI and select the "Single Phase Motor" to choose single phase BLDC drivers.

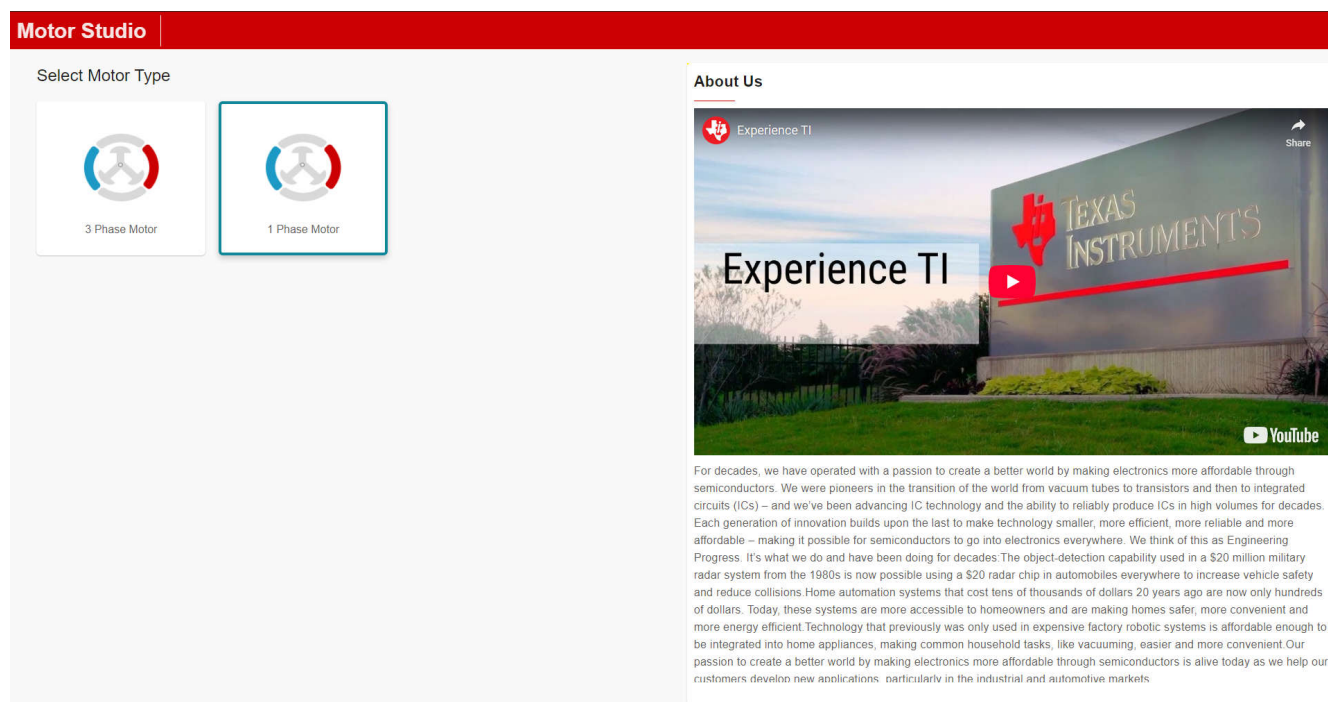


Figure 3-1. MOTORSTUDIO Single Phase Motor GUI

Step2. If all the hardware connections are made properly according to section 2. The device is automatically detected

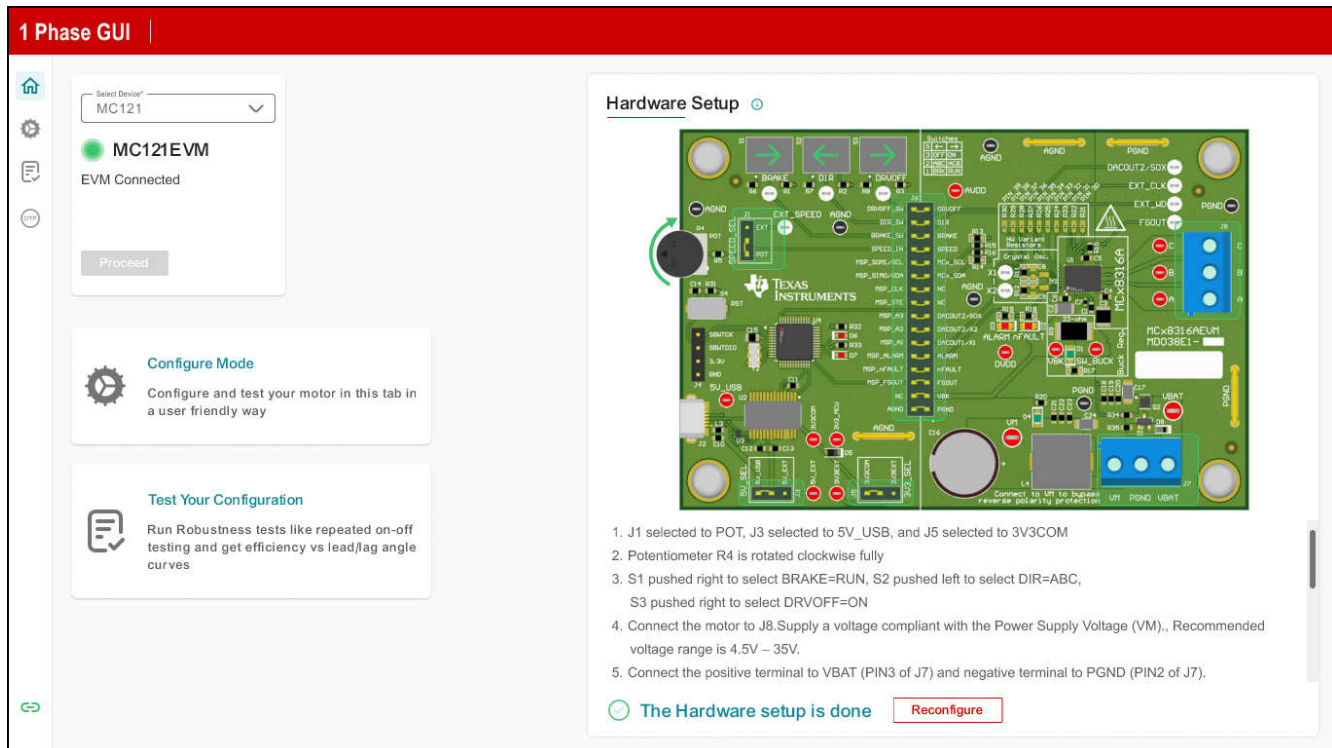


Figure 3-2. Auto-detect the MC121 or MC121-Q1

Step3. Now enter "Configure Mode" to configure the MC121 and tune to meet the application, Single Phase GUI provides the following options for tuning and evaluation of the device and motor.

1. "Parameters and Register Map" section to configure the settings.
2. "I2C controls" to give a speed command to the motor.

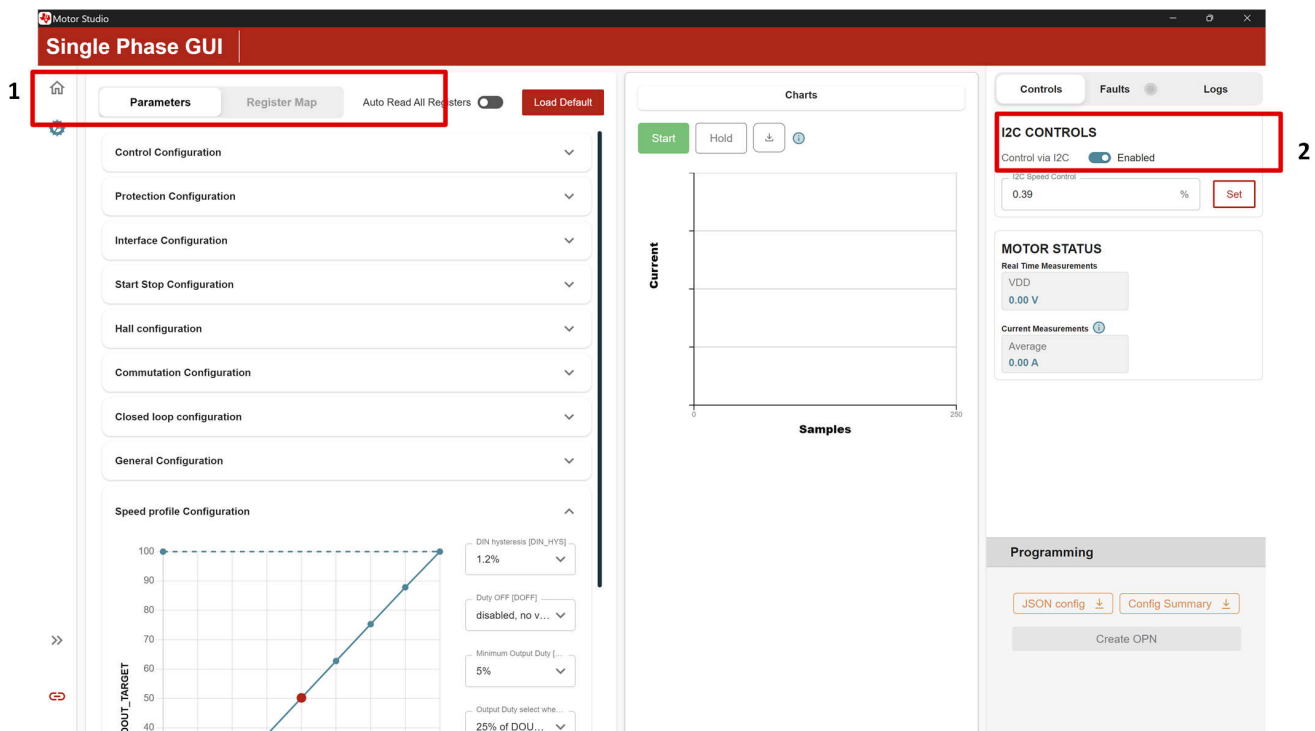


Figure 3-3. Parameters Tab, Register Map Tabs, and I2C Controls in Single Phase GUI

4 Hardware Design Files

4.1 Schematics

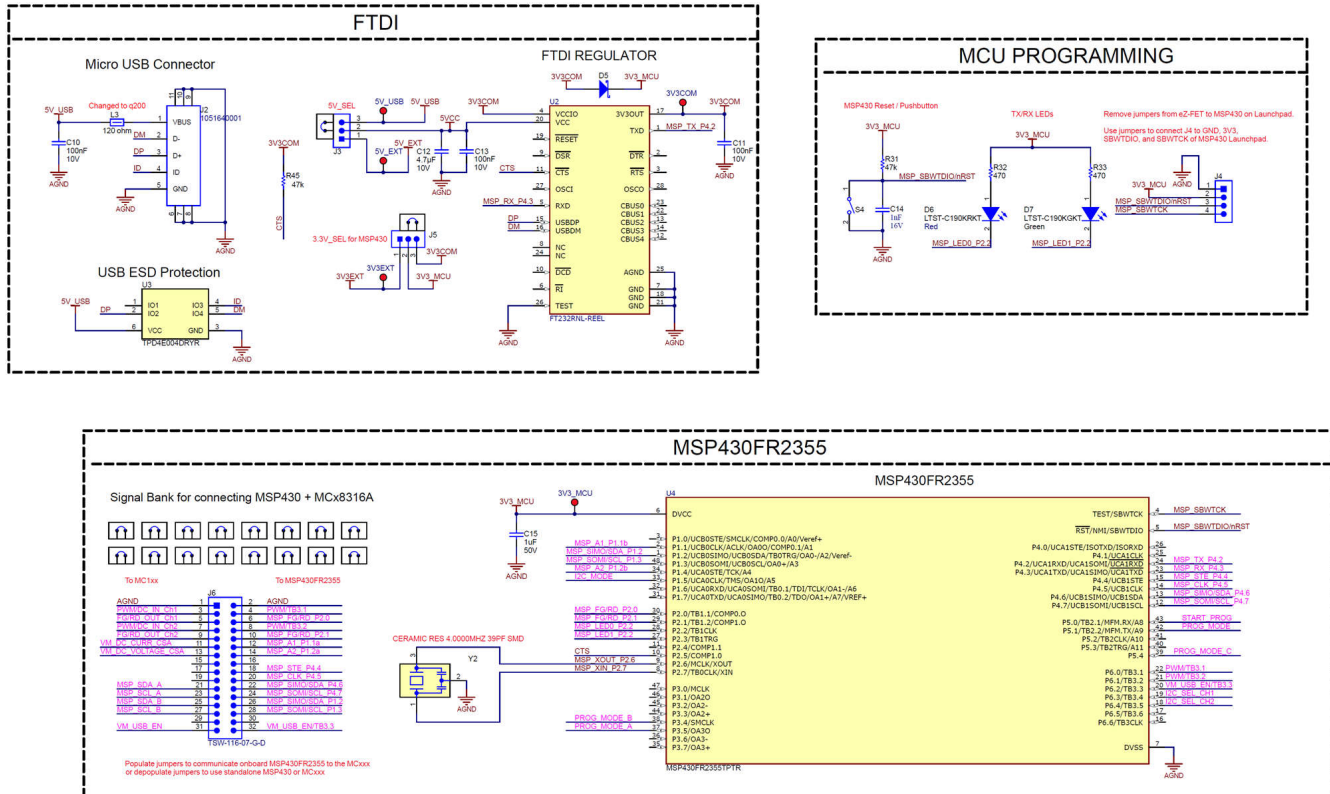


Figure 4-1. MC121EVM Schematic - FTDI, MSP430FR2355 and MCU Programming

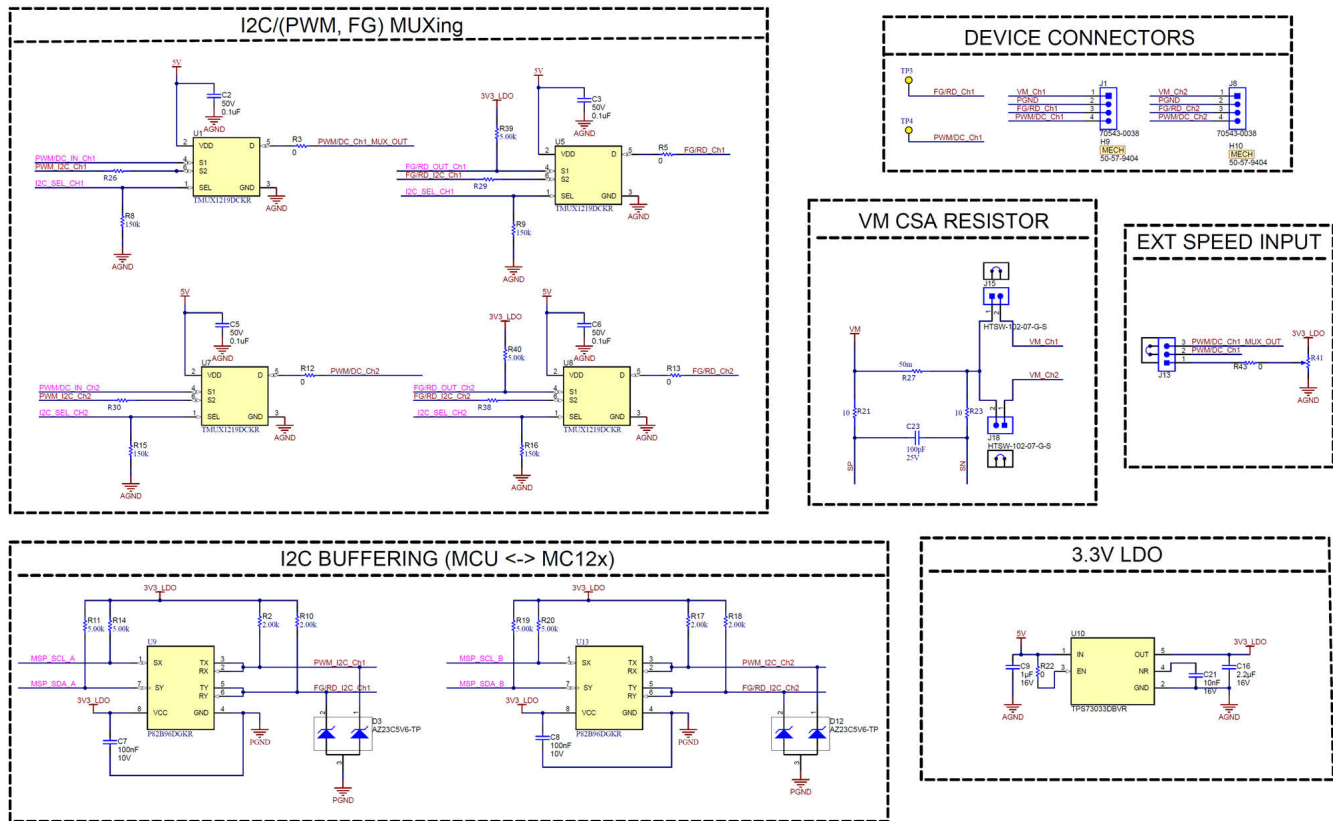


Figure 4-2. MC121EVM Schematic - I2C Mux, I2C Buffer, LDO and connectors

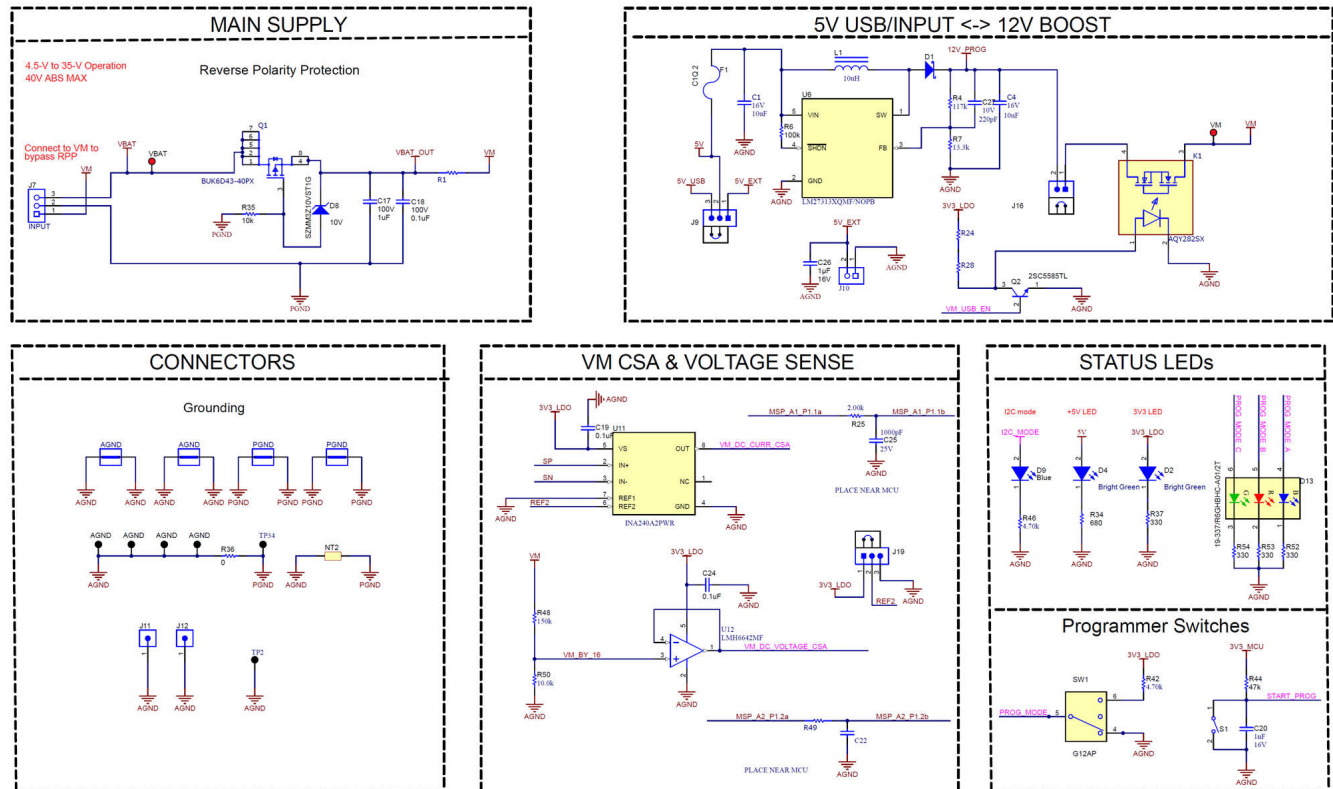


Figure 4-3. MC121EVM Schematic - Power supply, Boost converter, Current and Voltage sense

4.2 PCB Layouts

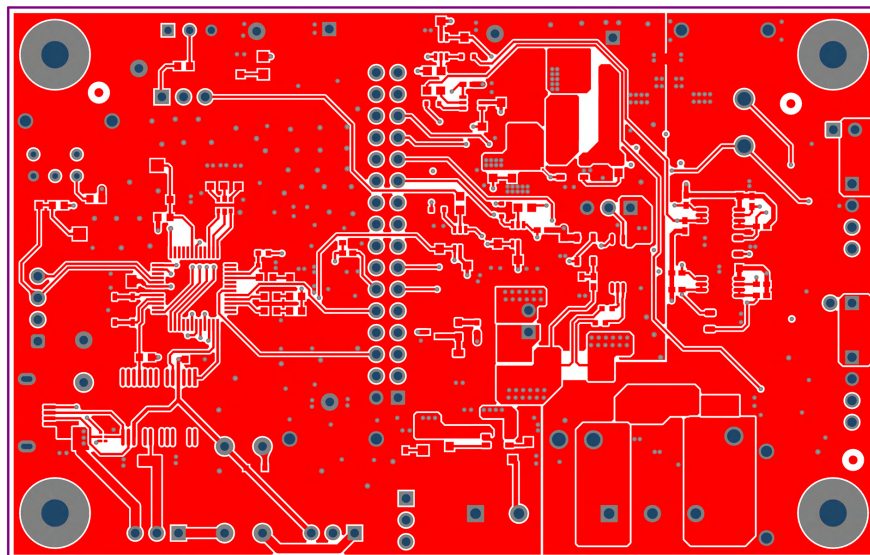


Figure 4-4. PCB Layer 1

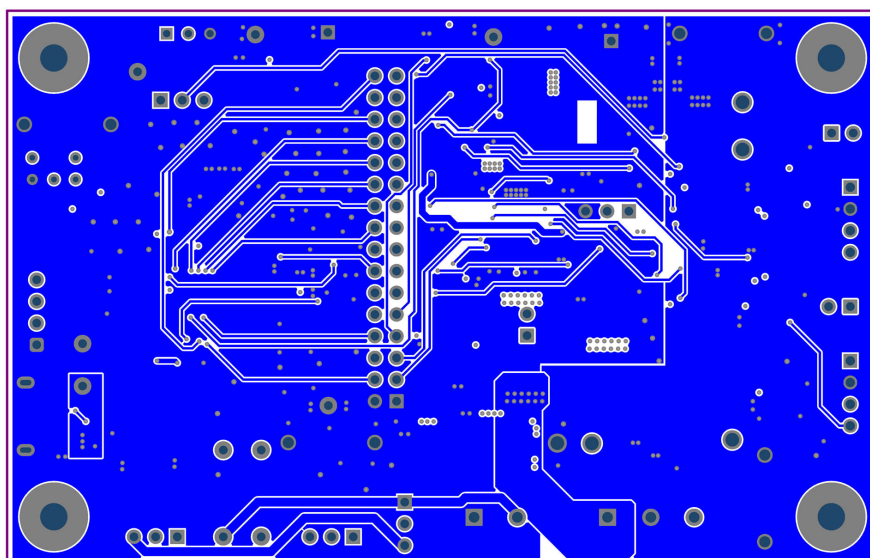


Figure 4-5. PCB Layer 2

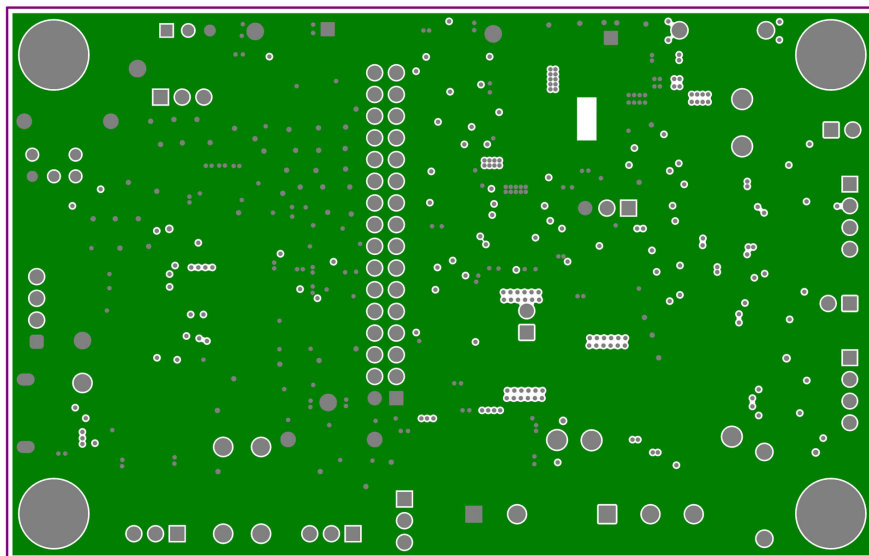


Figure 4-6. PCB Layer 3

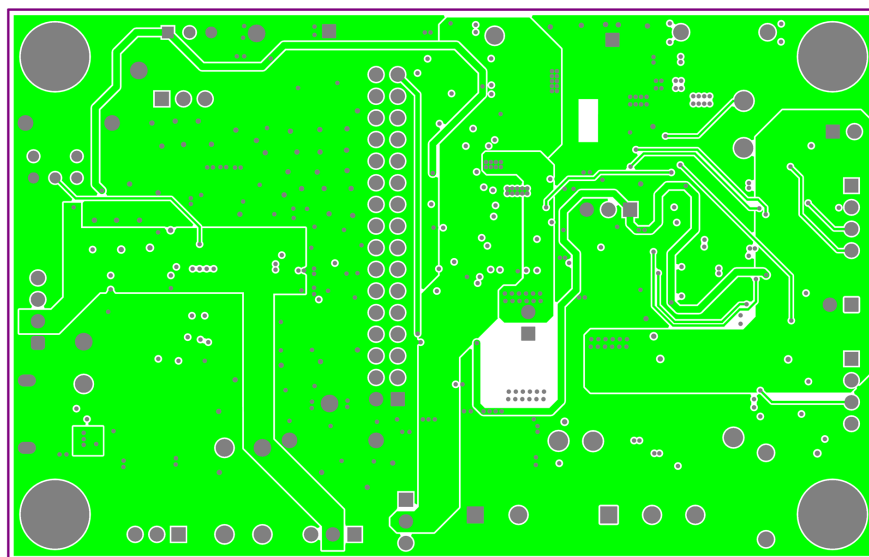


Figure 4-7. PCB Layer 4

4.3 Bill of Materials (BOM)

The bill of materials for MC121EVM is listed in [Table 4-1](#)

Table 4-1. Bill of Materials

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
!PCB1	1		Printed Circuit Board		MC121EVM	Any
C1, C4	2	10 μ F	CL21 Series 0805 10uF 16V $\pm$ 10% Tolerance X7S Multilayer Ceramic Chip Capacitor	0805	CL21Y106KOQ4PNE	Samsung
C2, C3, C5, C6	4	0.1 μ F	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X8R, AEC-Q200 Grade 0, 0603	0603	CGA3E3X8R1H104K080AB	TDK
C7, C8, C10, C11, C13	5	0.1 μ F	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X7R, 0603	0603	0603ZC104KAT2A	AVX

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
C9, C26	2	1uF	CAP, CERM, 1 μ F, 16 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	EMK107B7105KAHT	Taiyo Yuden
C12	1	4.7uF	CAP, CERM, 4.7 μ F, 10 V, +/- 20%, X7R, 0603	0603	GRM188Z71A475ME15D	MuRata
C14, C20	2	1000pF	CAP, CERM, 1000 pF, 16 V, +/- 10%, X7R, 0603	0603	8.85012E+11	Würth Elektronik
C15	1	1uF	CAP, CERM, 1 μ F, 50 V, +/- 10%, X7R, 0805	0805	8.85012E+11	Würth Elektronik
C16	1	2.2uF	CAP, CERM, 2.2 μ F, 16 V, +/- 10%, X7R, 0603	0603	EMK107BB7225KA-T	Taiyo Yuden
C17	1	1uF	CAP, CERM, 1 μ F, 100 V, +/- 10%, X7R, 1206	1206	CL31B105KCHNNNE	Samsung
C18, C19, C24	3	0.1uF	CAP, CERM, 0.1 μ F, 100 V, +/- 10%, X7S, AEC-Q200 Grade 1, 0603	0603	CGA3E3X7S2A104K080AB	TDK
C21	1	0.01uF	CAP, CERM, 0.01 μ F, 16 V, +/- 10%, X7R, 0603	0603	8.85012E+11	Würth Elektronik
C22	1		WCAP-CSGP Multilayer Ceramic Chip Capacitor, General Purpose, size 0402, NP0, 47pF, 10VDC			Würth Elektronik
C23	1	100pF	Chip Multilayer Ceramic Capacitors for General Purpose, 0201, 100pF, C0G, 30ppm/°C, 2%, 50V	0201	GRM0335C1H101GA01D	Murata
C25	1	1000pF	CAP, CERM, 1000 pF, 25 V, +/- 5%, C0G/NP0, 0402	0402	C0402C102J3GACTU	Kemet
C27	1	220pF	CAP, CERM, 220 pF, 10 V, +/- 10%, X7R, 01005	01005	GRM022R71A221KA01	MuRata
D1	1	40V	Diode, Schottky, 40 V, 3 A, SOD-128	SOD-128	RBR3LAM40ATR	Rohm
D2, D4	2	Bright Green	LED, Bright Green, SMD	LED_0805	150080VS75000	Würth Elektronik
D3, D12	2	5.6V	Diode, Zener, 5.6 V, 300 mW, SOT-23	SOT-23	AZ23C5V6-TP	Micro Commercial Components
D5	1	40V	Diode, Schottky, 40 V, 0.75 A, AEC-Q101, SOD-323	SOD-323	BAT165E6327HTSA1	Infineon Technologies
D6	1	Red	LED, Red, SMD	Red LED, 1.6x0.8x0.8mm	LTST-C190KRKT	Lite-On
D7	1	Green	LED, Green, SMD	1.6x0.8x0.8mm	LTST-C190KGKT	Lite-On
D8	1	10V	Diode, Zener, 10 V, 300 mW, AEC-Q101, SOD-323	SOD-323	SZMM3Z10VST1G	ON Semiconductor
D9	1	Blue	LED, Blue, SMD	LED_0603	150060BS75000	Würth Elektronik
D13	1	RGB	LED, RGB, TH	1.6x1.6mm	19-337/R6GHBHC-A01/2T	Everlight

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
F1	1		Fuse, 2 A, 125 VAC, 63 VDC, SMD	1206	C1Q 2	Bel Fuse
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
H9, H10	2		Rectangular Housing Connector, 4 Pos, 2.54mm		50-57-9404	Molex
J1, J8	2		Header(shrouded), 2.54mm, 4x1, Tin, TH	Header(shrouded), 2.54mm, 4x1, TH	70543-0038	Molex
J2	1		Receptacle, USB 2.0, Micro B, 5 Position, R/A, SMT	Receptacle, USB 2.0, Micro B, 5 Pos, 0.65mm Pitch, R/A, SMT	1051640001	Molex
J3, J5, J9, J13, J19	5		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
J4	1		Header, 100mil, 4x1, Gold, TH	4x1 Header	TSW-104-07-G-S	Samtec
J6	1		Header, 100mil, 16x2, Gold, TH	16x2 Header	TSW-116-07-G-D	Samtec
J7	1		Terminal Block, 5.08 mm, 3x1, Brass, TH	3x1 5.08 mm Terminal Block	ED120/3DS	On-Shore Technology
J10	1		Terminal Block, 5.08 mm, 2x1, Brass, TH	2x1 5.08 mm Terminal Block	ED120/2DS	On-Shore Technology
J11, J12	2		Header, 100mil, 1pos, Gold, TH	Testpoint	TSW-101-07-G-S	Samtec
J15, J16, J18	3		Header, 100mil, 2x1, Gold, TH	Header, 100mil, 2x1, TH	HTSW-102-07-G-S	Samtec
K1	1		SSR RELAY SPST-NO 500MA 0-60V	SOP4	AQY282SX	Panasonic
L1	1	10uH	Inductor, Wirewound, Ferrite, 10 uH, 3.4 A, 0.047 ohm, SMD	6x6m	VLS6045EX-100M	TDK
L3	1		Inductor, Ferrite Bead, Ferrite, 3 A, 120 ohm, AEC-Q200 Grade 1, SMD	0603	BLM18SG121TZ1D	MuRata
LBL1	1			PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1	1		P-Channel 40 V 6A (Ta) 15W (Tc) Surface Mount DFN2020MD-6	SOT1220	BUK6D43-40PX	Nexperia
Q2	1	12 V	Transistor, NPN, 12 V, 0.5 A, SOT-416	SOT-416	2SC5585TL	Rohm
R1	1	0	0 Ohms Jumper 0.5W, 1/2W Chip Resistor 0805 (2012 Metric) Automotive AEC-Q200 Metal Foil	0805	HCJ0805ZT0R00	Stackpole

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
R2, R10, R17, R18	4	2.00k	RES, 2.00 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF2001X	Panasonic
R3, R5, R12, R13, R22, R43	6	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3GEY0R00V	Panasonic
R4	1	117k	RES, 117 k, 0.5%, 0.1 W, 0603	0603	RT0603DRE07117KL	Yageo America
R6	1	100k	RES, 100 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KJNEA	Vishay-Dale
R7	1	13.3k	RES, 13.3 k, 0.5%, 0.1 W, 0603	0603	RT0603DRE0713K3L	Yageo America
R8, R9, R15, R16	4	150k	RES, 150 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603150KFKEA	Vishay-Dale
R11, R14, R19, R20, R39, R40	6	5.00k	RES, 5.00 k, 0.1%, 0.05 W, 0402	0402	PNM0402E5001BST1	Vishay-Dale
R21, R23	2	10	10 Ohms $\pm 0.1\%$ 0.05W, 1/20W Chip Resistor 0402 (1005 Metric) RF, High Frequency Thin Film	0402	FC0402E10R0BST0	Vishay Dale
R24, R49	2	100	100 Ohms $\pm 0.1\%$ 0.05W, 1/20W Chip Resistor 0402 (1005 Metric) RF, High Frequency Thin Film	0402	FC0402E1000BST0	Vishay Dale
R25	1	2.00k	RES, 2.00 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022K00FKED	Vishay-Dale
R26, R29, R30, R38	4	100	100 Ohms $\pm 5\%$ 0.2W, 1/5W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200, Moisture Resistant, Pulse Withstanding Thick Film	0603	SG73S1JTTD101J	KOA Speer
R27	1	50m	50 mOhms $\pm 1\%$ 2W Chip Resistor 2512 (6432 Metric) Current Sense, Flame Retardant Coating, Safety Metal Element	2512	MCS3264R050FER	Ohmite
R28	1	500	500 Ohms $\pm 0.1\%$ 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Thin Film	0603	RT0603BRC07500RL	YAGEO
R31, R44, R45	3	47k	RES, 47 k, 5%, 0.1 W, 0603	0603	RC0603JR-0747KL	Yageo
R32, R33	2	470	RES, 470, 5%, 0.1 W, 0603	0603	RC0603JR-07470RL	Yageo
R34	1	680	RES, 680, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402680RJNED	Vishay-Dale
R35	1	10k	RES, 10 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0JNEA	Vishay-Dale
R36	1	0	RES, 0, 5%, 0.25 W, AEC-Q200 Grade 0, 1206	1206	RCA12060000ZSEA	Vishay-Dale
R37, R52, R53, R54	4	330	RES, 330, 1%, 0.1 W, 0603	0603	RC0603FR-07330RL	Yageo
R41	1	25 kohm	Trimmer Potentiometer, 25kohm, 0.5W, TH	9.53x8.89mm	3352T-1-253LF	Bourns

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
R42, R46	2	4.70k	RES, 4.70 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD074K7L	Yageo America
R48	1	150k	RES, 150 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF1503X	Panasonic
R50	1	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	AC0402FR-0710KL	Yageo America
S1, S4	2		Switch, Tactile, SPST, 12 V, SMD	SMD, 6x3.9mm	4.34121E+11	Wurth Elektronik
SH-J2, SH-J5, SH-J9, SH-J13, SH-J15, SH-J16, SH-J18, SH-J19, SH-J20, SH-J21, SH-J22, SH-J23, SH-J24, SH-J25, SH-J26, SH-J27, SH-J28, SH-J29, SH-J30, SH-J31, SH-J32, SH-J33, SH-J34, SH-J35	24	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
SW1	1		Switch, Toggle, SPDT 1Pos, TH	7 X 11 X4.5 mm	G12AP	NKK Switches
TP1, TP23	2		Test Point, Compact, Red, TH	Red Compact Testpoint	5005	Keystone
TP2, TP30, TP31, TP32, TP33	5		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
TP3, TP4	2		Test Point, Compact, Yellow, TH	Yellow Compact Testpoint	5009	Keystone Electronics
TP18, TP19, TP20, TP21, TP22	5		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone
TP26, TP27, TP28, TP29	4		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
TP34	1		Test Point, Compact, Black, TH	Black Compact Testpoint	5006	Keystone Electronics
U1, U5, U7, U8	4		1-ch, 2:1 general-purpose analog multiplexer with 1.8-V logic control, DCK0006A (SOT-SC70-6)	DCK0006A	TMUX1219DCKR	Texas Instruments
U2	1		UART Interface IC USB Full Speed to Serial UART IC, Includes Oscillator and EEPROM, SSOP-28	SSOP28	FT232RNL-REEL	FTDI
U3	1		4-Channel ESD Protection Array for High-Speed Data Interfaces, DRY0006A (USON-6)	DRY0006A	TPD4E004DRYR	Texas Instruments

Table 4-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	PackageReference	PartNumber	Manufacturer
U4	1		CPU16 MSP430™ FRAM Microcontroller IC 16-Bit 24MHz 32KB (32K x 8) FRAM 48-LQFP (7x7)	LQFP48	MSP430FR2355TPTR	Texas Instruments
U6	1		1.6 MHz Boost Converter With 30V Internal FET Switch in SOT-23, DBV0005A (SOT-23-5)	DBV0005A	LM27313XQMF/NOPB	Texas Instruments
U9, U13	2		Dual Bidirectional Bus Buffer, DGK0008A (VSSOP-8)	DGK0008A	P82B96DGKR	Texas Instruments
U10	1		Low-Noise, High PSRR, RF 200-mA Low-Dropout Linear Regulators, DBV0005A (SOT-23-5)	DBV0005A	TPS73033DBVR	Texas Instruments
U11	1		High/Low Side, Bi-Directional Zero-Drift Current Sense Amp w/ Enhanced PWM Rejection, PW0008A (TSSOP-8)	PW0008A	INA240A2PWR	Texas Instruments
U12	1		Low Power, 130MHz, 75mA Rail-to- Rail Output Amplifier, DBV0005A (SOT-23-5)	DBV0005A	LMH6642MF/NOPB	Texas Instruments
Y2	1		Resonator, 4 MHz, 39 pF, AEC- Q200 Grade 1, SMD	4.5x1.2x2 mm	CSTCR4M00G55B-R0	MuRata

5 Additional Information

Trademarks

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1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.
 - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software
 - 1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.
2. *Limited Warranty and Related Remedies/Disclaimers:*
 - 2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
 - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.
 - 2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI's recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI's recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI's instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGRADATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 Regulatory Notices:

3.1 United States

3.1.1 Notice applicable to EVMs not FCC-Approved:

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 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

NOTE: 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 instructions, 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

NOTE: 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.*

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. 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.

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.

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.

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.

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/sds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

<https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html>

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs 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 EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/sds/ti_ja/general/eStore/notice_02.page

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3.4 European Union

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):*

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should 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 also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure 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. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

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9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.
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