User's Guide

BQ79600-Q1 Evaluation Module

ABSTRACT

The BQ79600-Q1 Evaluation Module user's guide describes the general features, theory of operation, hardware setup, and use of the BQ79600EVM. Throughout this user's guide, the abbreviations *EVM*, *BQ79600EVM*, and the term *evaluation module* are synonymous with the *BQ79600-Q1 Evaluation Module*, unless otherwise noted. This EVM is an evaluation board for the *BQ79600-Q1* device used as a bridge IC to interface between a microcontroller and the TI battery monitoring ICs (for example, BQ7961x-Q1 and BQ79606A-Q1). The device translates between the daisy chain interface and SPI/UART interface.

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1 General Description

TI's *BQ79600EVM Battery Management System* (BMS) is an evaluation board for the *BQ79600-Q1* device used as a bridge IC to interface between a microcontroller and the TI battery monitoring ICs (for example, BQ7961x-Q1 and BQ79606A-Q1). The BQ79600EVM can be powered through a PMIC device or directly through a 12-V battery. The device has an Auto Host Wake-up function that can be utilized with the BQ7961x-Q1 family to automatically wake up the host when an unmasked fault is detected in the battery monitoring ICs when using ring architecture. See the *BQ79600-Q1 data sheet* for more details.

The BQ79600EVM enables communication between a controller and one or more battery modules to perform State of Charge (SOC) and State of Health (SOH) estimation. The EVM is equipped with an UART/SPI to enable a host device to communicate to the BQ79600-Q1 device and an isolated differential daisy chain interface to enable communication to a stack of battery monitoring ICs. The BQ79600EVM acts as a communication bridge between the host and the battery modules.

The BQ79600EVM is controlled using a PC-hosted GUI. Communication between the PC and the BQ79600EVMs is through an USB2ANY UART interface or an USB2ANY SPI. Communication between the BQ79600EVM and all BQ79616EVMs in the stack is via the isolated, daisy-chain differential communication bus. The GUI allows configuration of the BQ79600EVMs to configure the communication interface to the host (UART/SPI) and to the stacked devices, as well as to enable/disable the automatic host wake-up function. The BQ79616EVMs can also be configured using the GUI to monitor cells and other analog data channels, control balancing, and monitor details of any faults.

1.1 Key Features

This EVM includes the following features:

- UART interface for communication to the host, configurable through jumpers
- SPI for communication to the host, configurable through jumpers
- Supports host communication through FTDI (UART only), USB2ANY, or TMS57012 microcontroller (direct connection to XL2-TMS57012 LAUNCHPAD boosterpack)
- Isolated differential daisy chain communications with optional ring architecture
- Jumpers to configure 5-V or 12-V options (use 5-V option when powering through PMIC and 12-V option when powering directly from 12-V battery and to use automatic host wake-up function)
- LEDs to indicate when the device is awake and when there is an unmasked fault

1.2 Key Electrical Parameters

The following table identifies the key electrical parameters:

Table 1-1. Key Electrical Parameters

Parameter	Value
Maximum operating voltage (BAT pin powered by battery)	24 V (J1 and J3 shunts placed in 1-2 position)
Minimum operating voltage (BAT pin powered by battery)	5.5 V (J1 and J3 shunts placed in 1-2 position)
Maximum operating voltage (BAT pin powered by 5-V regulator)	5.25 V (J1 and J3 shunts placed in 2-3 position)
Minimum operating voltage (BAT pin powered by 5-V regulator)	4.75 V (J1 and J3 shunts placed in 2-3 position)
Ambient temperature	–40 °C to 105 °C
SPI clock frequency	2Mbps to 6Mbps
UART baud rate	1Mbps

2 Theory of Operation

Figure 2-1 shows the system stack diagram.

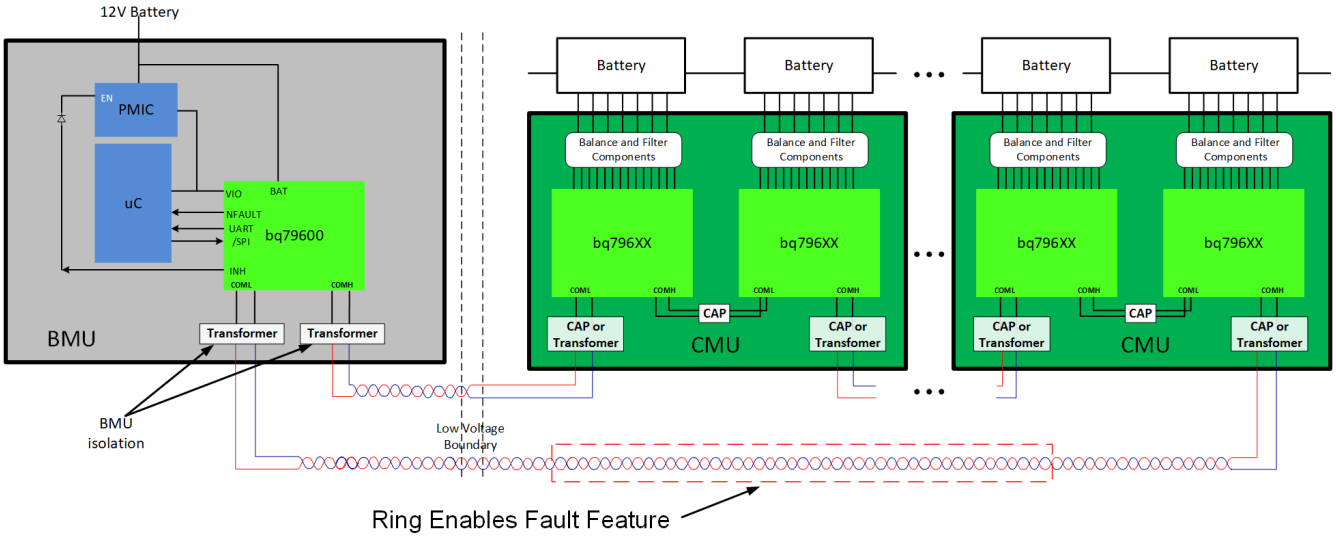

Figure 2-1. System Block Diagram

The typical BMS system consists of a Battery Management Unit (BMU) and one or more stacked Cell Monitoring Units (CMU). The BMU must be isolated from the CMU using transformers to keep the high voltage of the stacked battery modules isolated from the BQ79600 bridge device and the microcontroller.

The typical simplified bridge circuit in the BMU system has three main components, as shown in Figure 2-1:

- Host controller - in this case a TMS570 LaunchPad™
- Power management IC (PMIC)
- BQ79600-Q1 isolated communication bridge device - in this case a BQ79600EVM

The BQ79600 device can be powered from the 12-V battery directly or from the PMIC. When powered from the 12-V battery, the reverse wake-up function on the BQ79600 can be used in a ring architecture to wake up the PMIC and the microcontroller with an unmasked fault is detected.

All commands and data between the host and the BQ79600 bridge device are communicated through either a UART or a SPI communication connection. The BQ79600EVM can support a host PC or microcontroller (via the FTDI connection header, the USB2ANY connection header, or the LAUNCHXL2-TMS57012 LaunchPad boosterpack). The BQ79600 remains idle until a command is received from the host. All commands and data between the BQ79600 and the cell monitoring devices, such as BQ79616, is communicated through the daisy chain interface.

The typical flow for the host to go through is the following simplified sequence:

1. Wake up the BQ79600EVM board by sending a WAKE-UP pulse using the UART/SPI interface.
2. Send a *send wake up* command to the BQ79600EVM to wake up the stacked cell monitoring devices.
3. Autoaddress and initialize bridge and stacked devices.
4. Send a sample command to the BQ79616-Q1 to read the cell measurement results.
5. The host uses the cell measurement data to calculate an average and determine the highest or lowest cells and determine the cells that must be balanced.
6. If no stop command is sent, then the BQ79616-Q1 has a built-in timeout (set by the user), after which time the discharge is stopped automatically.
7. The host can then decide to repeat the process (back to step 4) or return later. When using the BQ79616-Q1 in a ring architecture, the host can enable the sniffer detector on the BQ79600-Q1 and the FAULT tones in the BQ97616-Q1, then send the stacked devices to SLEEP and the bridge and itself to shutdown, and the AUTO reverse wake-up function wakes up the PMIC and MCU if an unmasked fault from the stacked devices is detected by the bridge.

2.1 Compatibility with Battery Monitoring Devices

The BQ79600-Q1 is fully compatible with the BQ7961x-Q1 family, supporting automatic host wake up through the INH pin when an unmasked fault is detected in the high voltage battery pack. The BQ79600-Q1 is also compatible with BQ79606A-Q1 devices without the fault interface.

3 Connectors

3.1 Primary Input and Output Connectors

3.1.1 Jumper Placements

The following table explains each of the jumpers available for user flexibility.

Table 3-1. Jumper Placements

Pinheader	Contacts	Jumper Connection	Populated by Default?
J1	1-2, 2-3	INH connection to 100-k pulldown for 12-V operation (1-2), or to BAT for 5-V operation (2-3)	Yes (2-3)
J3	1-2, 2-3	BAT connection to 12-V power supply (1-2), or to CVDD and 5-V power supply (2-3)	Yes (2-3)
J5	1-2	LED connection on DVDD to indicate the device is awake	Yes
J6	1-2, 2-3	VIO connection to 3.3-V supply from MCU (1-2) or to 5-V supply from MCU (2-3)	Yes (1-2)
J8	1-2	LED connection on nFAULT AVDD to indicate a fault on NFAULT pin (must have J13 shunt connected)	Yes
J10	1-2, 2-3	nUART_SPIRDY pullup to VIO for SPI (1-2), or pulldown to GND for UART (2-3)	Yes (2-3)
J11	1-2, 2-3	nCS pullup to VIO for SPI (1-2), or pulldown to GND for UART (2-3)	Yes (2-3)
J12	1-2, 2-3	SCLK pullup to VIO (1-2) or pulldown to GND for SPI/UART (2-3)	Yes (2-3)
J13	1-2	NFAULT pullup to VIO	Yes

3.1.2 Power Supply

The power supply connection is made from either the 5-V test point or 12-V test point. When powering the EVM directly through the 12-V battery, configure jumpers J1 and J3 in the "12V" configuration and connect the 12-V battery to the 12-V test point. If the EVM is powered up through a PMIC, configure jumpers J1 and J3 in the "5V" configuration and connect the PMIC 5-V output to the 5-V test point.

Figure 3-1. Keystone5010 (reference image only)

Table 3-2. Pin Description

Pin	Name	Comments
1	DVDD	1.8-V regulated output. DVDD supplies the internal digital circuits
2	NFAULT	Fault indication output
3	VIO	Power supply input for UART/SPI input/output pins
4	RX/MOSI	UART receiver input or SPI controller out peripheral in
5	TX/MISO	UART transmitter output or SPI controller in peripheral out
6	SCLK	SPI clock input
7	nCS	Active low chip select pin for SPI
8	nUART/SPI (SPI_RDY)	This pin is used as an input pin to select SPI or UART interface before device finishes wakeup/ reset initialization
9	GND	Ground
10	COMLP	AC coupled bi-directional I/O pin for daisy chain (VIF) communication
11	COMLN	AC coupled bi-directional I/O pin for daisy chain (VIF) communication
12	COMHP	AC coupled bi-directional I/O pin for daisy chain (VIF) communication
13	COMHN	AC coupled bi-directional I/O pin for daisy chain (VIF) communication
14	CVDD	Dedicated 5-V supply used for the daisy chain communications
15	BAT	Battery supply Input
16	INH	Inhibit pin to control system voltage regulators

3.1.3 Host Interface

There are three different ways for the host to connect to the BQ79600EVM: using the USB2ANY interface adaptor, the UART FTDI cable (to communicate through UART only), or using the LAUNCHXL2-TMS57012 microcontroller BoosterPack connector.

The 10-pin J4 - serial connector is used to connect the BQ79600EVM to a PC running the GUI or to a host controller. Texas Instruments recommends using the USB2ANY interface adaptor which includes the proper 10-pin cable.

Figure 3-2. Samtec Inc. TSW-105-08-L-D-RA (reference image only)

Table 3-3. Connector Information

Designator	Manufacturer	Part Number	Mating Connector
J4	Samtec Inc.	Manufacturer: TSW-105-08-L-D-RA	10-pin ribbon connector packaged with USB2ANY

Table 3-4. Pin Description

Pin	Name
1	NC
2	nUART/SPI (SPI_RDY) signal from BQ79600-Q1

Table 3-4. Pin Description (continued)

Pin	Name
3	USB2ANY SCLK (SCLK of BQ79600-Q1)
4	nFAULT signal from BQ79600-Q1
5	GND
6	USB2ANY 3.3 V
7	USB2ANY TX (MOSI_RX of BQ79600-Q1)
8	USB2ANY RX (MISO_TX of BQ79600-Q1)
9	USB2ANY CS (nCS of BQ79600-Q1)
10	NC

The 6-pin J2 - serial connector is used to connect the BQ79600EVM to a PC running the GUI or to a host controller through a TTL-232R-5V FTTI cable. Only UART is supported.

Figure 3-3. Molex 0022124062 (reference image only)

Table 3-5. Connector Information

Designator	Manufacturer	Part Number	Mating Connector
J2	Molex	Manufacturer: 0022124062	6-pin connector in TTL-232R-5V FTTI cable

The 20-pin J7 - serial connector and the 20-pin J9-serial connector are used to connect the BQ79600EVM to a host controller. The BoosterPack in the LAUNCHXL2-TMS57012 LaunchPad™ can be directly plugged into the J7 and J9 connectors.

Figure 3-4. Samtec SSQ-110-03-T-D (reference image only)

Table 3-6. Connector Information

Designator	Manufacturer	Part Number	Mating Connector
J7, J9	Samtec	Manufacturer: SSQ-110-03-T-D	20-pin connector 0.100" (2.54mm) in TMS570LS12x LaunchPad™

Table 3-7. Pin Description - J7

Pin	Name
1	MCU 3.3 V

Table 3-7. Pin Description - J7 (continued)

Pin	Name
2	MCU 5 V
3	NC
4	GND
5	MCU RX (MISO_TX of BQ79600-Q1)
6	NC
7	MCU TX (MOSI_RX of BQ79600-Q1)
8	NC
9	NC
10	NC
11	NC
12	NC
13	MCU SCLK (SCLK of BQ79600-Q1)
14	NC
15	NC
16	NC
17	NC
18	NC
19	NC
20	NC

Table 3-8. Pin Description - J9

Pin	Name
1	NC
2	GND
3	NC
4	NC
5	NC
6	MCU CS (nCS of BQ79600-Q1)
7	NC
8	NC
9	NC
10	NC
11	NC
12	MCU SPI3SIMO (MOSI_RX of BQ79600-Q1)
13	NC
14	MCU SPI3SOMI (MISO_TX of BQ79600-Q1)
15	NC
16	NC
17	nUART/SPI (SPI_RDY) signal from BQ79600-Q1
18	NC
19	nFAULT signal from BQ79600-Q1
20	NC

3.1.4 High-Side and Low-Side Communications

There are two sets of 4-position molex connectors available on each board. These provide high-side (J11) and low-side (J10) communications between stacked EVM devices.

Table 3-9. Connector Information

Designator	Manufacturer	Part Number	Mating Connector
J10/J11	Molex	Manufacturer: 0705510038 Digi-Key: WM14059-ND	Manufacturer: 0050579404 Digi-Key: WM2902-ND

Table 3-10. Pin Description - J10

Pin	Name	Comments
1	COML_N	COM lowside negative
2	COML_P	COM lowside positive
3	N/A	Unused
4	N/A	Unused

Table 3-11. Pin Description - J11

Pin	Name	Comments
1	N/A	Unused
2	N/A	Unused
3	COMH_P	COM highside positive
4	COMH_N	COM highside negative

4 BQ79600EVM Quick Start Guide

This section includes hardware setup instructions, connection procedures, and software and GUI instructions.

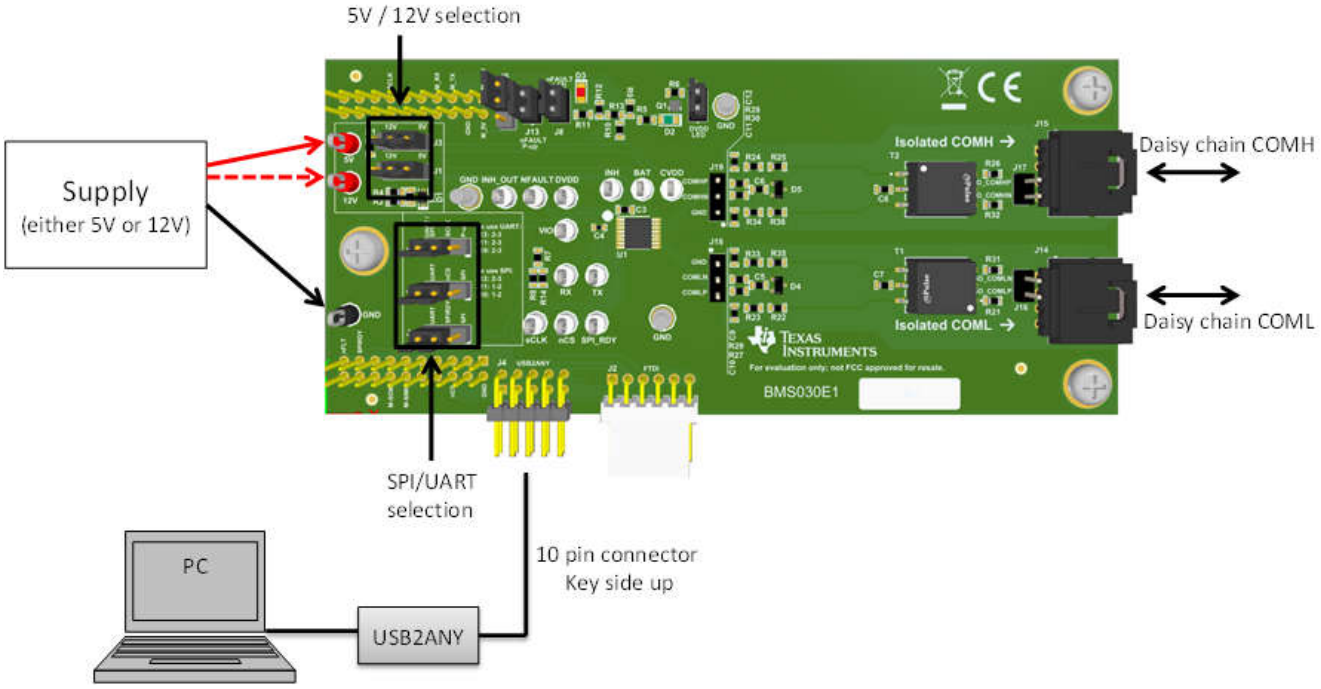

Figure 4-1. Basic EVM Setup

4.1 Required Devices for Using the Example Code *Not Available Yet*

The system example code is implemented using the LAUNCHXL2-TMS57012 LaunchPad™ board (TMS570LS1224 MCU), the BQ79600EVM, and the BQ79616EVM via Code Composer Studio.

The part numbers of the evaluation modules are LAUNCHXL2-TMS57012, BQ79600EVM-030, BQ79616EVM-021. These boards are available from the TI eStore (https://estore.ti.com/) or from your local TI sales representative. For more details and information related to the LaunchPad™ modules, see the specific module user's guide.

4.2 Power Connections

The BQ79600EVM can be powered up either using a 5-V supply or a 12-V supply. To use the 5-V option, make sure that jumpers J1 and J3 are connected in the "5V" position as labeled in the board, and then connect the positive terminal of the 5-V supply to the "5V" testpoint provided on the board, and the power supply negative terminal to the "GND" testpoint provided on the board, or any "GND" standoff provided. To use the 12-V option, verify that jumpers J1 and J3 are connected in the "12V" position as labeled in the board, and then connect the positive terminal of the 12-V supply to the "12V" testpoint provided on the board, and the power supply negative terminal to the "GND" testpoint provided on the board, or any "GND" standoff provided.

4.3 Connecting the BQ79600EVM to TMS570 LaunchPad

The EVMs are connected using the female connectors J7 and J9 on the bottom side of the BQ79600EVM and the male connectors J2, J3, J4, and J5 on the top side of the LAUNCHXL2-TMS57012 LaunchPad™. Connect the J7 20-pin female connector on the bottom side of the BQ79600EVM to the J2 and J3 10-pin male connectors on top side of the LAUNCHXL2-TMS57012 LaunchPad™, and J9 20-pin female connector on the bottom side of the BQ79600EVM to the J4 and J5 10-pin male connectors on the top side of the LAUNCHXL2-TMS57012 LaunchPad™, as shown in the following figure. By default, the TMS570 LaunchPad is powered by the USB port on the host computer. Remove JP1 from the LaunchPad for correct operation.

The microcontroller is used to supply VIO voltage to the device. The user can select either the 3.3-V or 5-V option. To use 3.3 V, make sure that JP2 on the microcontroller LaunchPad is connected and set jumper J6 in

the 1-2 position (this is the default configuration on the EVM). To use 5 V, verify that JP3 on the microcontroller LaunchPad is connected and set jumper J6 in the 2-3 position.

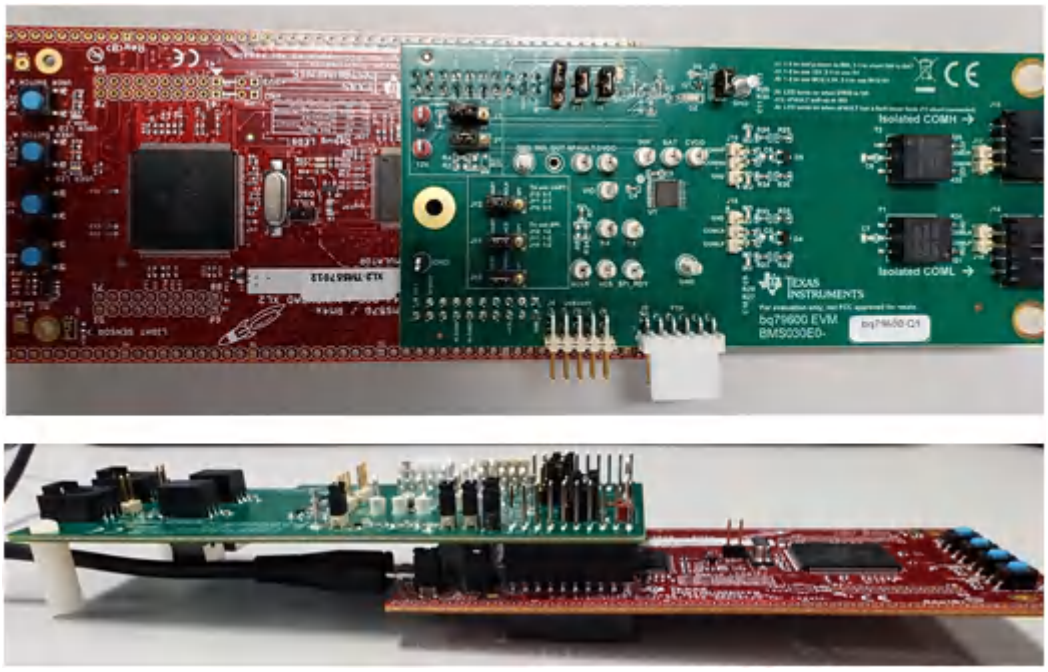

Figure 4-2. Connection Between BQ79600EVM and TMS570 LaunchPad

4.4 Connecting BQ79600EVM to BQ79616EVM

The EVMs are connected using 4-position Molex connectors. The BQ79600EVM has a high side (J15)and low side (J14) communication connector available on each board. By default the isolation filters for the vertical interface on the BQ79600EVM are set to transformer isolation. There are also footprints on the board to populate a different transformer model. More details can be found in the schematic near the end of this user guide. To connect the BQ79600EVM to the BQ79616EVM using NORTH direction for communication, connect J15 on the BQ79600EVM to J10 on the BQ79616EVM. If several BQ79616EVMs are stacked, connect them as indicated in the EVM user's guide for the device. If using ring architecture, connect J11 of the top most BQ79616EVM to J14 on the BQ79600EVM.

Table 4-1. Connections Between BQ79600EVM High Side and BQ79616EVM Low Side

Connection Name	BQ79600EVM High Side	BQ79616EVM Low Side
COMH_N to COML_N	J15 pin 4	J10 pin 1
COMH_P to COML_P	J15 pin 3	J10 pin 2

Table 4-2. Connections Between BQ79616EVM High Side and BQ79600EVM Low Side (for ring architecture only)

Connection Name	BQ79600EVM Low Side	BQ79616EVM High Side
COML_N to COMH_N	J14 pin 1	J11 pin 4
COML_P to COMH_P	J14 pin 2	J11 pin 3

4.5 Connecting BQ79600EVM to BQ79606EVM

The EVMs are connected using 4-position Molex connectors. The BQ79600EVM has a high side (J15) and low side (J14) communication connector available on each board. To connect the BQ79600EVM to the BQ79606EVM using NORTH direction for communication, connect J15 on the BQ79600EVM to J5 on the BQ79606EVM. If several BQ79606EVMs are stacked, connect them as indicated in the EVM user's guide for the device. If using ring architecture, connect J6 of the top most BQ79606EVM to J14 on the BQ79600EVM.

Table 4-3. Connections Between BQ79600EVM High Side and BQ79606EVM Low Side

Connection Name	BQ79600EVM High Side	BQ79606EVM Low Side
COMH_N to COML_N	J15 pin 4	J5 pin 1
COMH_P to COML_P	J15 pin 3	J5 pin 2

Table 4-4. Connections Between BQ79606EVM High Side and BQ79600EVM Low Side (for ring architecture only)

Connection Name	BQ79600EVM Low Side	BQ79606EVM High Side
COML_N to COMH_N	J14 pin 1	J6 pin 4
COML_P to COMH_P	J14 pin 2	J6 pin 3

4.6 Software *Not yet available*

The example code only provides a control interface to the BQ79600-Q1 and BQ79616-Q1 and does not provide any other communications interface to the outside world. The customer is expected to develop their own communication implementation. Examples of communications interfaces available to the TMS570 are SPI, CAN, or UART. For the TMS570 example code, UART is the communication protocol used between the microcontroller and BQ79600-Q1 device.

Importing a project into Code Composer Studio™ :

1. Launch the provided file: *BQ79600-Q1 Example Code 0.1 Installer.exe* and extract files to the default path provided (`C:\ti\bq79600-Q1 Example Code 0.1`).
2. Launch *Code Composer Studio* (CCS):
   Start → Programs → Texas Instruments → Code Composer Studio v8 → Code Composer Studio v8
3. When Code Composer Studio v8 launches, CCS requests a workspace is selected, choose “C:\myWorkspace”. Once CCS loads, go to:
   Project → Import CSS Projects... → Select search-directory
4. In Select search-directory, browse to the folder:
   `C:\ti\bq79600-Q1 Example Code 0.1`
5. In *Discovered projects:*, check BQ79600-Q1 example code

4.7 GUI

For initial evaluation, using the graphical user's interface (GUI) can be beneficial. The GUI provides a *point and click* interface to become familiar with the BQ79600. During the initial sampling phase, contact your local TI FAE to get the latest GUI version.

To get started with the GUI, refer to the *BQAutoEval GUI User Guide* document.

4.7.1 GUI UART Connection

The physical setup for the GUI is the same as for the microcontroller, but instead uses an USB2ANY interface and 10-pin cable for the UART/SPI connections on J4. The USB2ANY has a USB Mini-B connector on the right side. Plug the provided USB cable (or any USB cable with a Mini-B connector) into the USB2ANY. Plug the other end of the cable (USB ‘A’) into the computer. Then connect the 10-pin connector cable to J4 of the USB2ANY (middle most connector) and the key side must be facing upwards when connecting to the EVM header J4. Refer to the figure below and this is explained in more detail in the USB2ANY user guide and the BQAutoEval GUI user guide.

5 Physical Dimensions

5.1 Board Dimensions

Board dimensions: 2.300 in. × 5.130 in.

Board height:

- Top - Tallest component (shunts) is 0.35 in. (8.8 mm) above PCB.
- Bottom - Tallest component (transformers) is 0.41 in. (10.5 mm) above PCB.

5.2 Board Mounting

Figure 5-1 illustrates the EVM board dimensions.

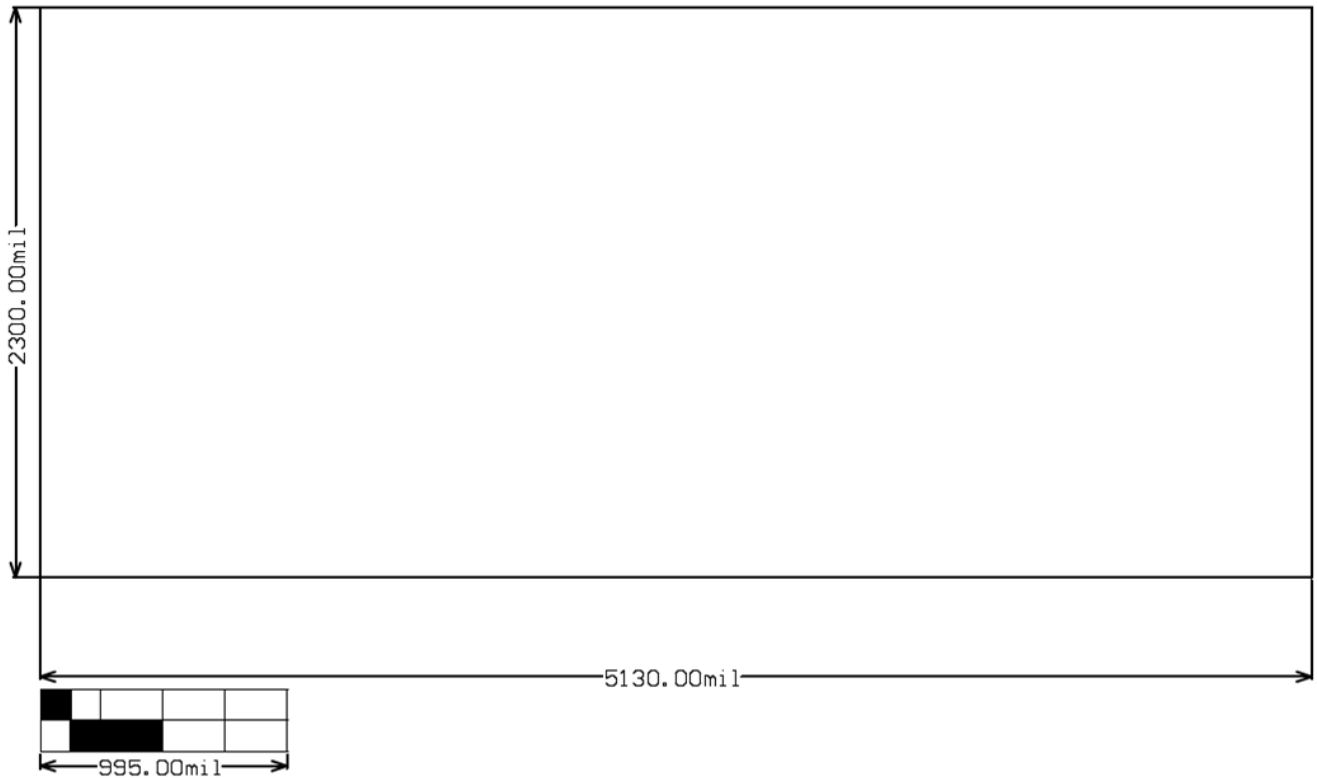

Figure 5-1. Board Dimensions

6 Schematics, Assembly, Layout, and Bill of Materials (BOM)

The BQ79600EVM schematics, assembly, layout, and BOM are provided in their respective sections.

6.1 Schematics

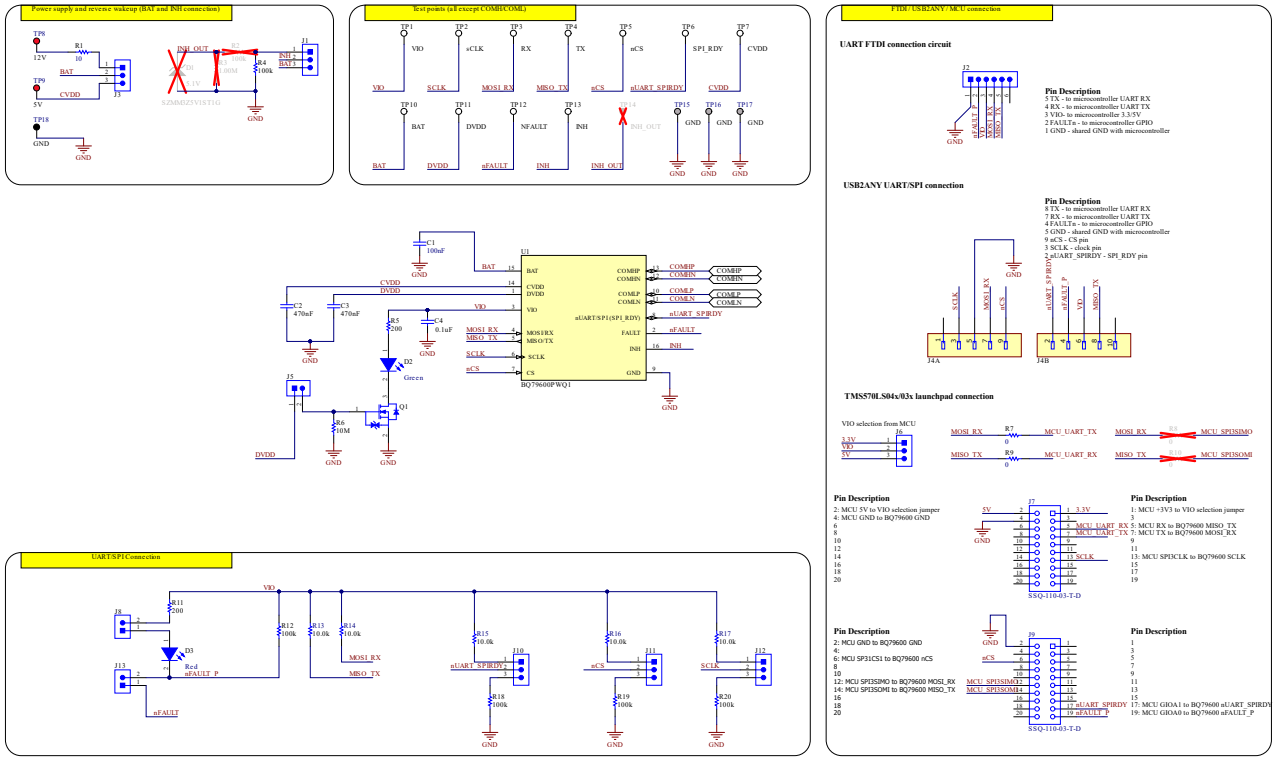

Figure 6-1. BQ79600EVM Schematic Part 1

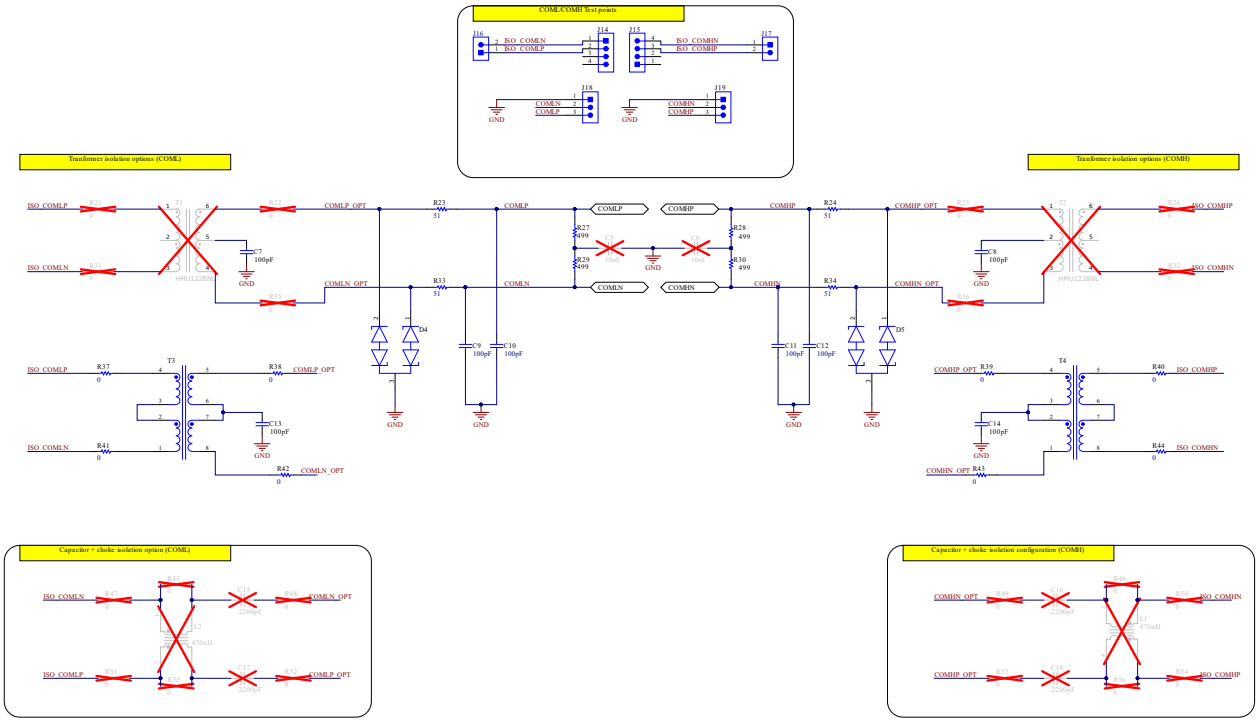

Figure 6-2. BQ79600EVM Schematic Part 2

6.2 Assembly

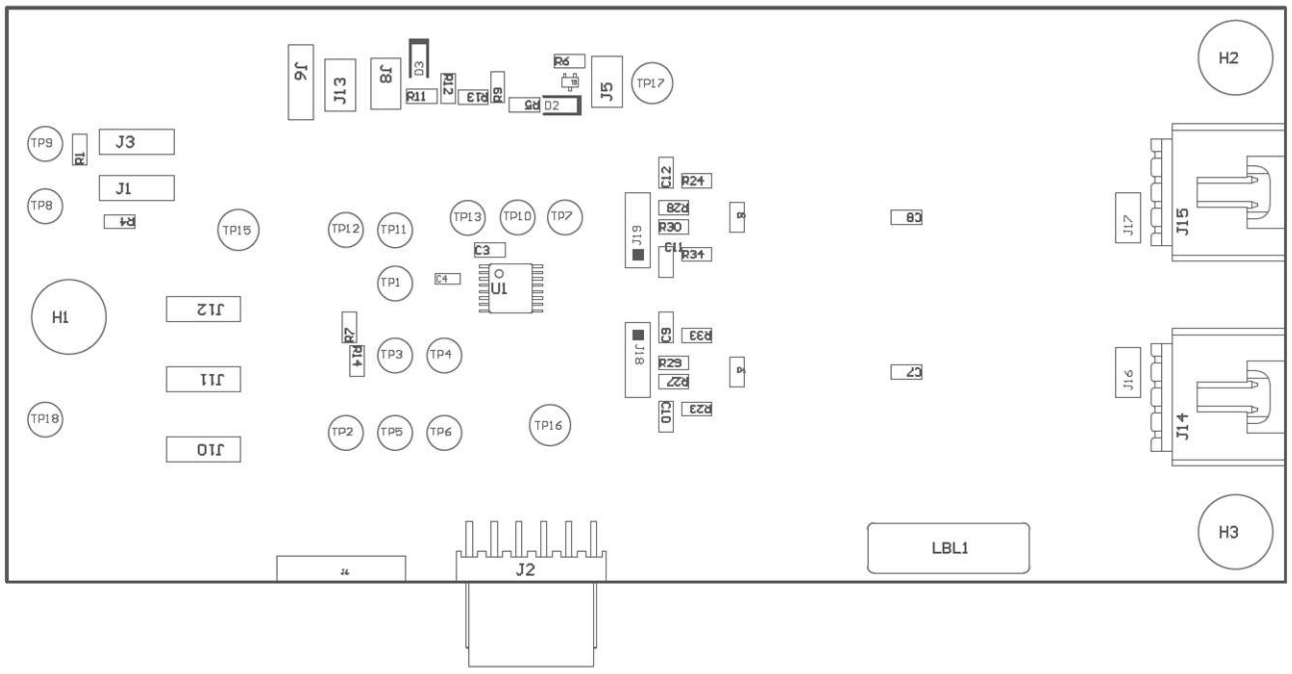

Figure 6-3. BQ79600EVM Assembly Top

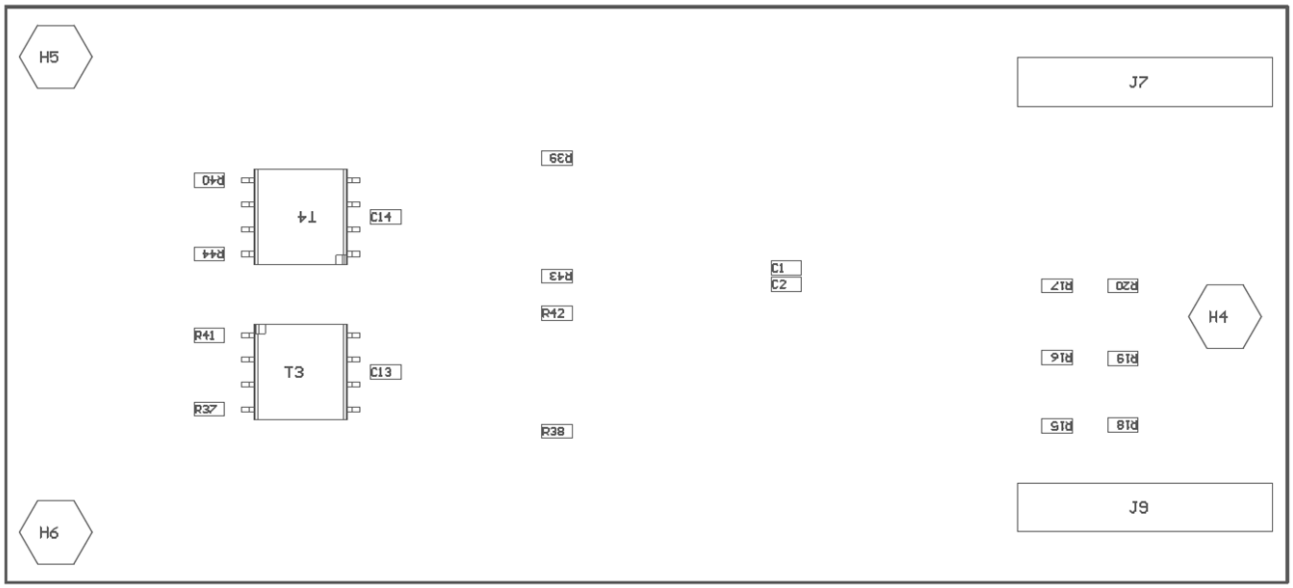

Figure 6-4. BQ79600EVM Assembly Bottom

6.3 Layout

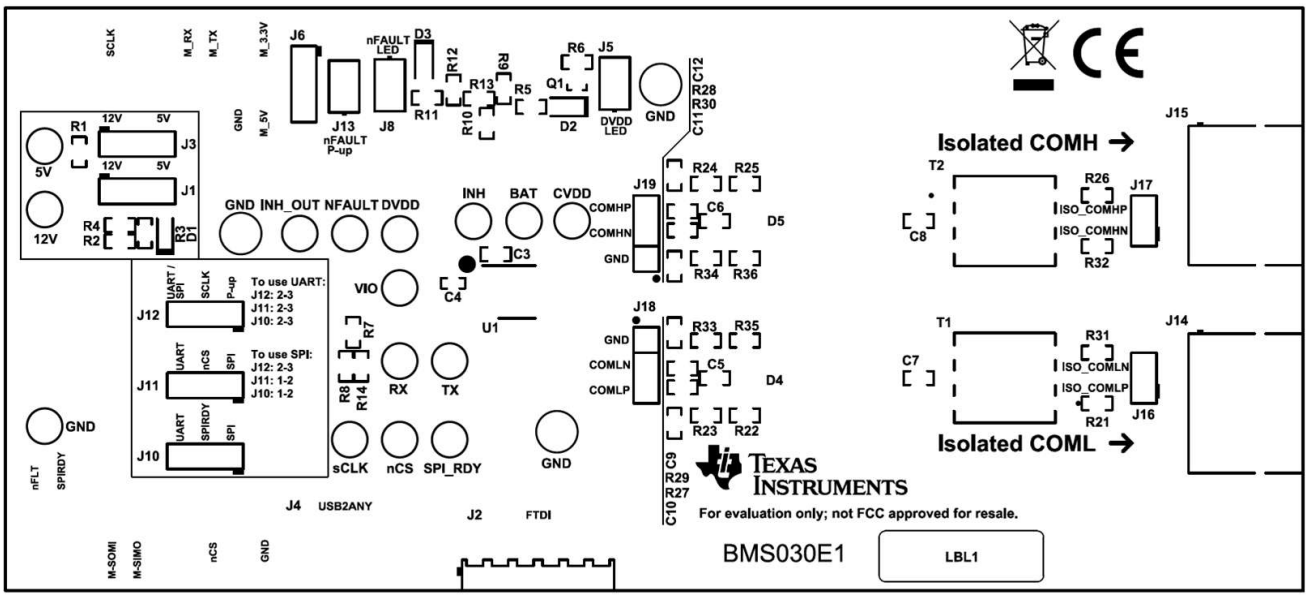

Figure 6-5. BQ79600EVM Top Overlay

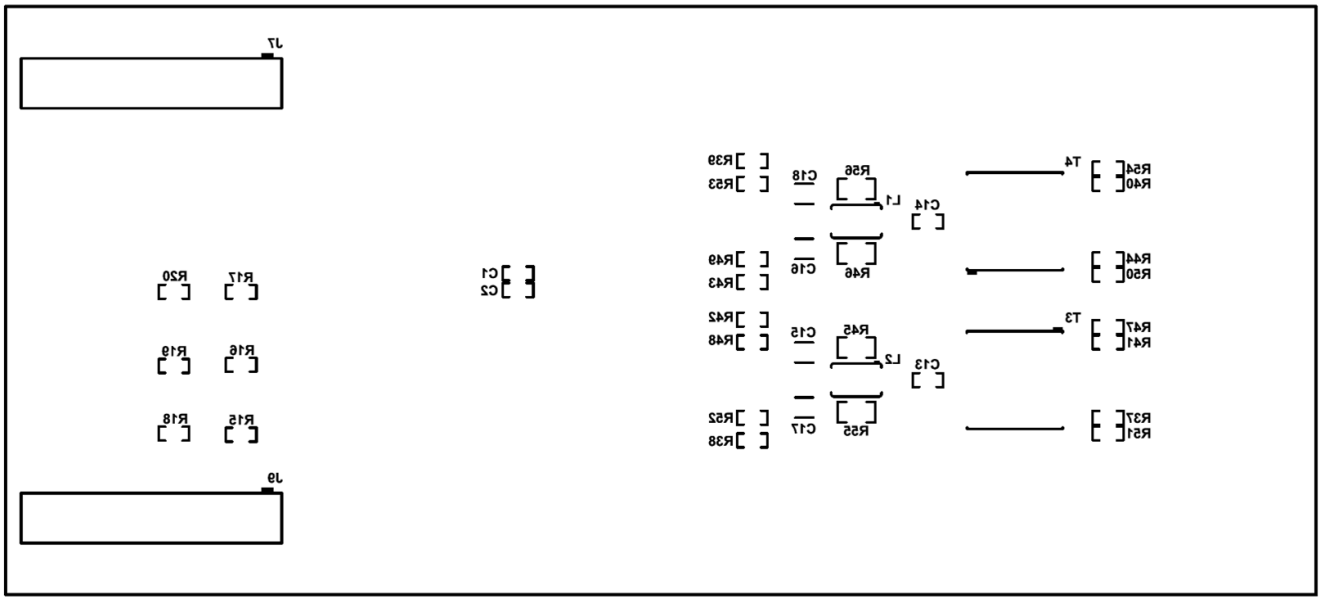

Figure 6-6. BQ79600EVM Bottom Overlay

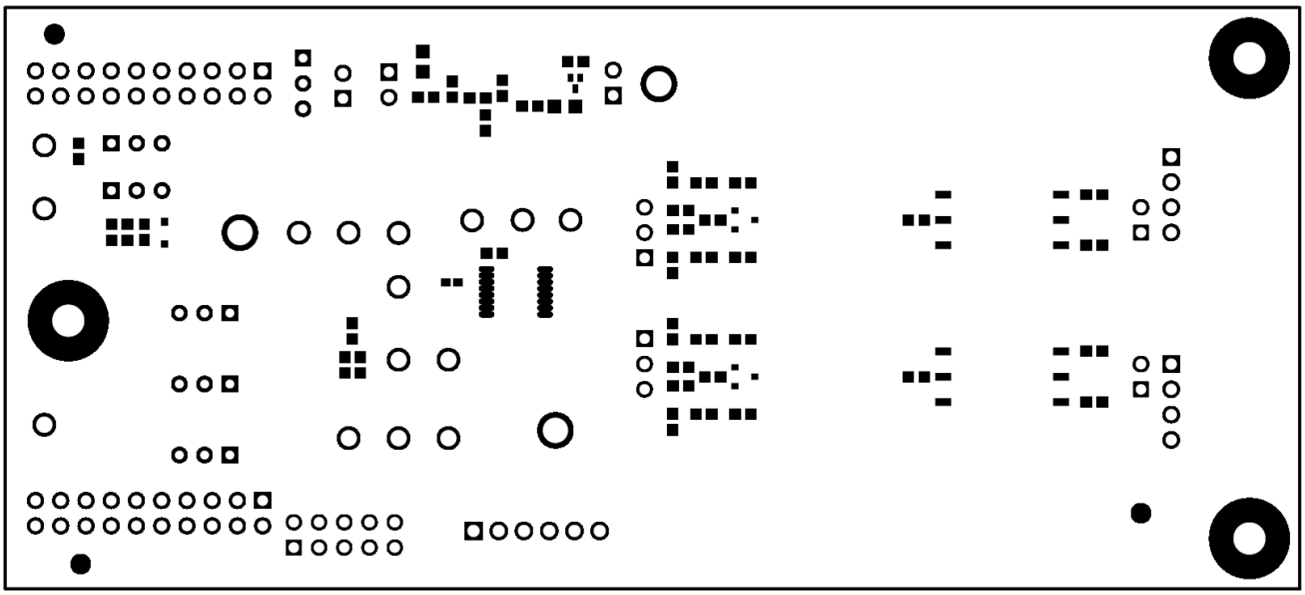

Figure 6-7. BQ79600EVM Top Solder

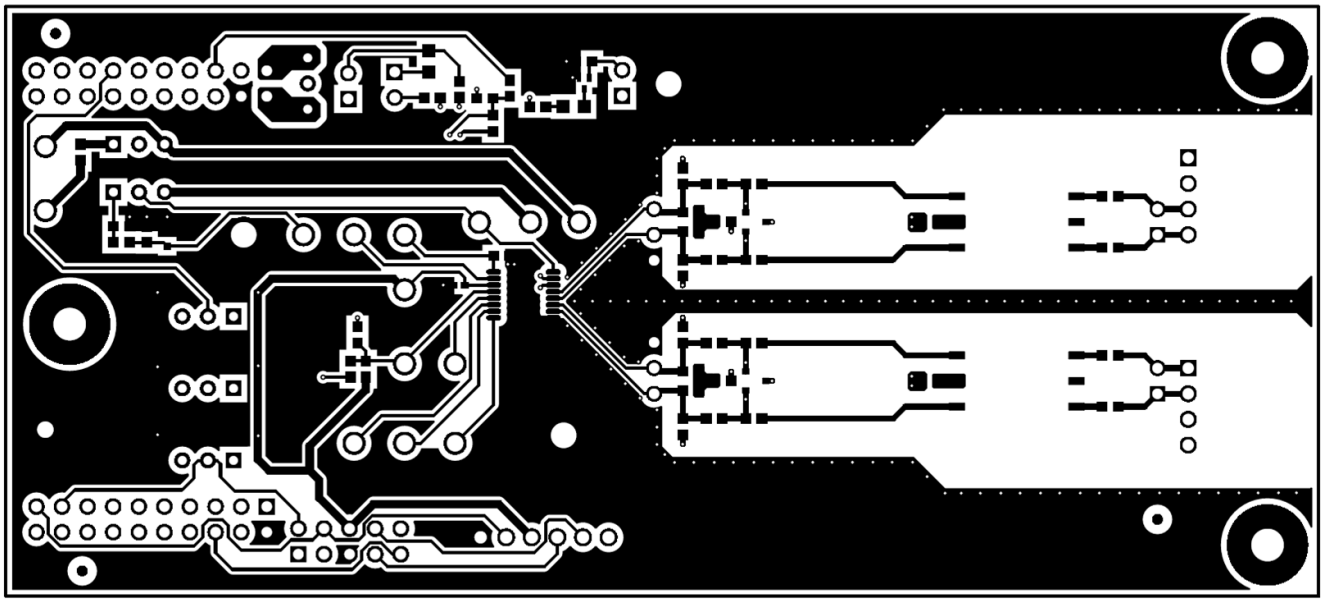

Figure 6-8. BQ79600EVM Top Layer

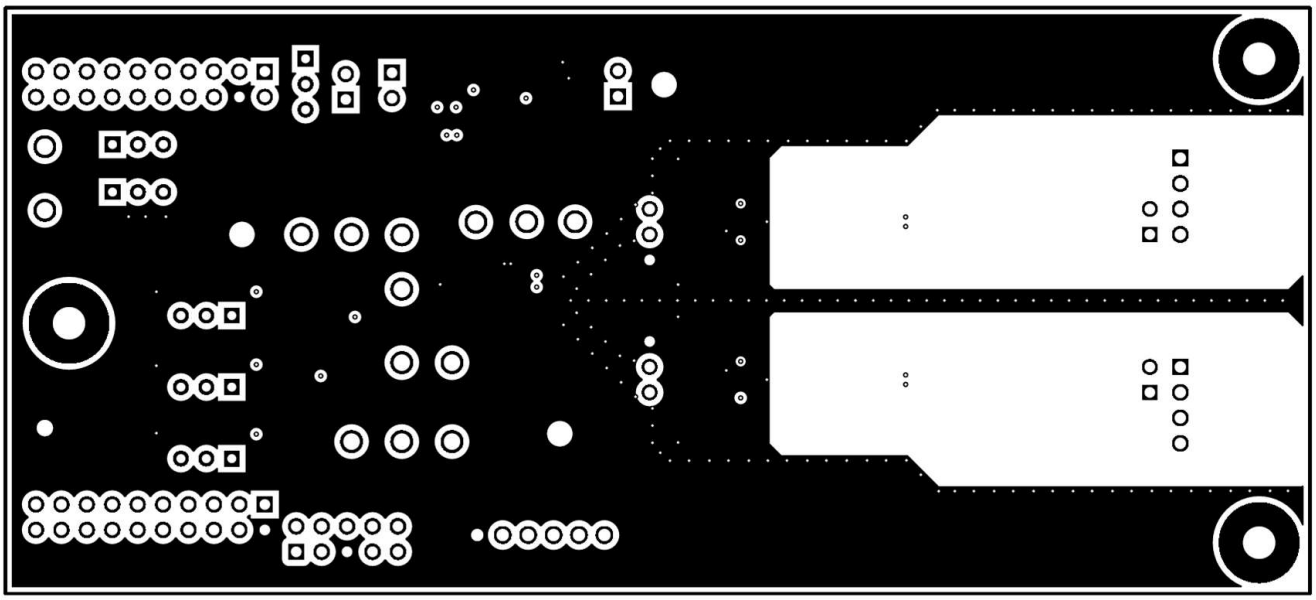

Figure 6-9. BQ79600EVM Internal Signal Layer 1 - GND Plane

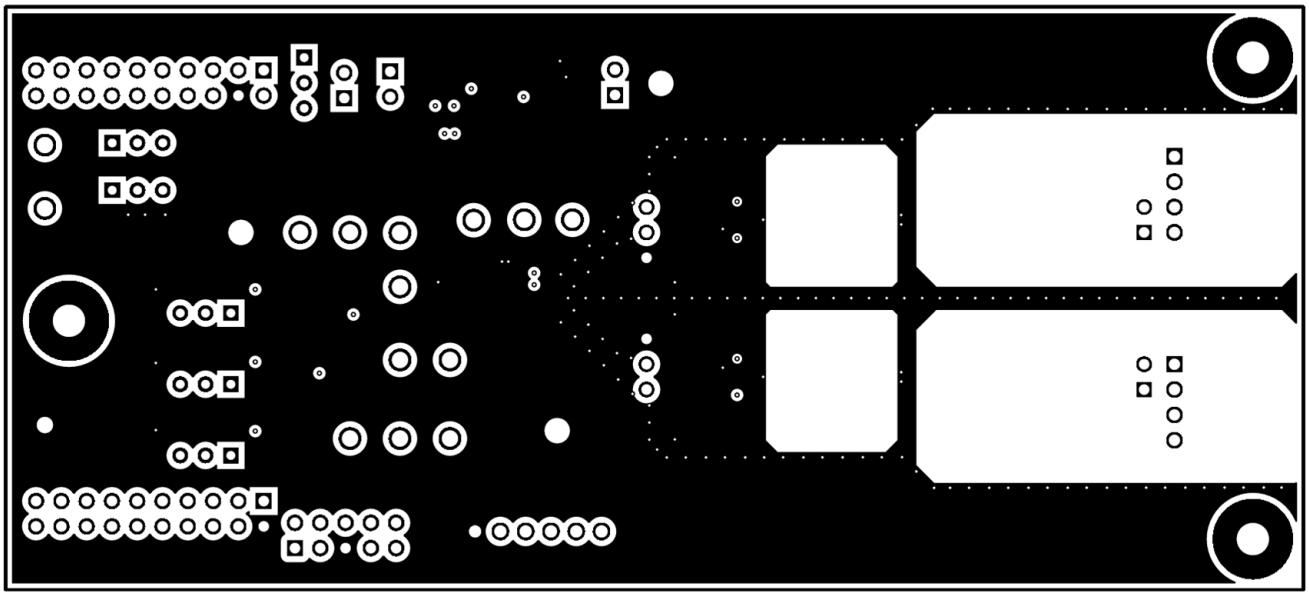

Figure 6-10. BQ79600EVM Internal Signal Layer 2 - GND Plane

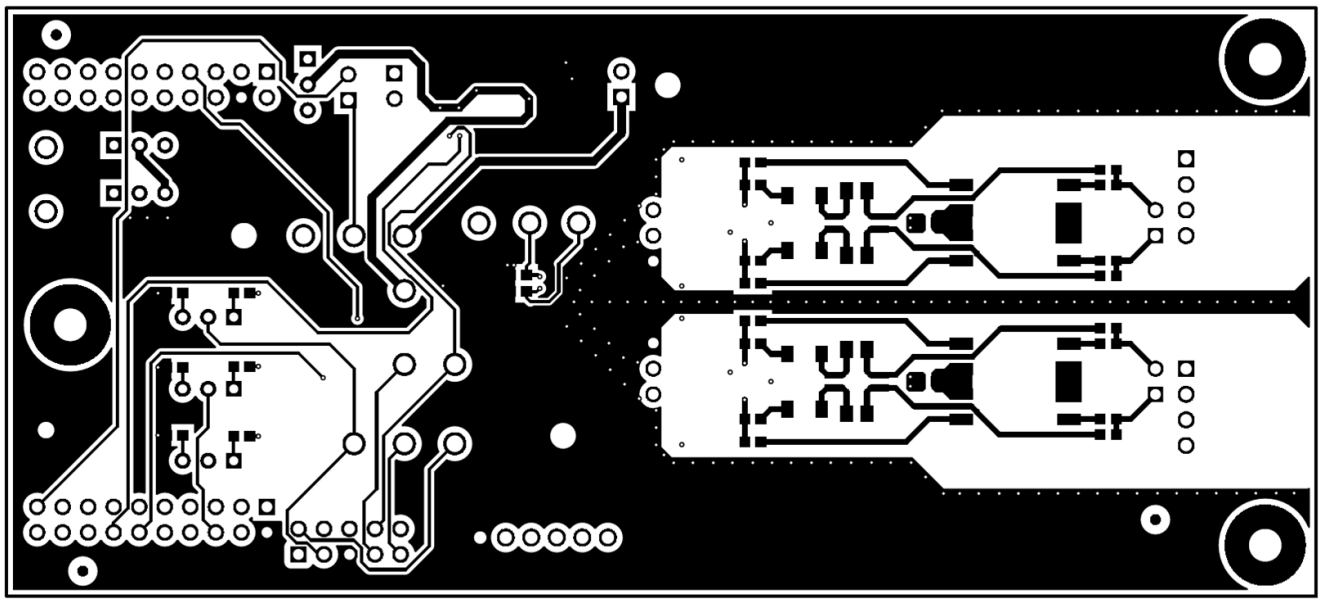

Figure 6-11. BQ79600EVM Bottom Layer

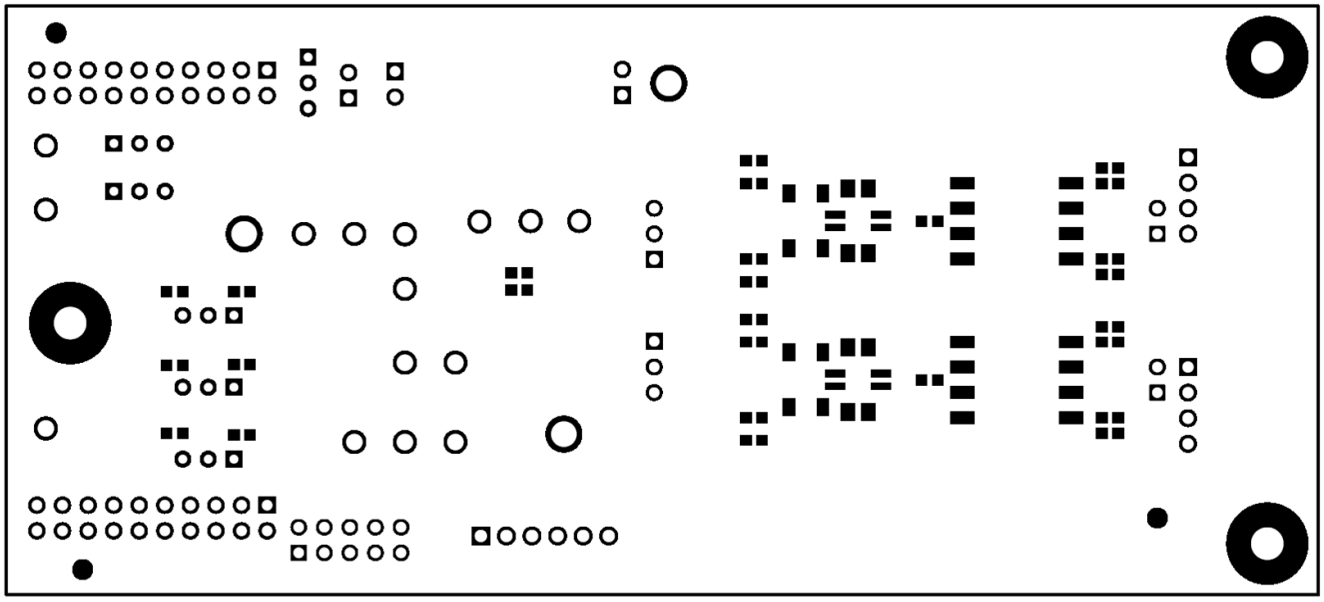

Figure 6-12. BQ79600EVM Bottom Solder

Symbol	Quantity	Finished Hole Size	Plated	Hole Type	Drill Layer Pair	Hole Tolerance
▽	4	133.86mil (3.400mm)	NPTH	Round	Top Layer - Bottom Layer	
▼	177	10.00mil (0.254mm)	PTH	Round	Top Layer - Bottom Layer	
⊠	18	33.47mil (0.850mm)	PTH	Round	Top Layer - Bottom Layer	
□	16	40.00mil (1.016mm)	PTH	Round	Top Layer - Bottom Layer	
■	50	40.16mil (1.020mm)	PTH	Round	Top Layer - Bottom Layer	
☼	8	42.91mil (1.090mm)	PTH	Round	Top Layer - Bottom Layer	
◉	6	46.85mil (1.190mm)	PTH	Round	Top Layer - Bottom Layer	
✪	15	63.00mil (1.600mm)	PTH	Round	Top Layer - Bottom Layer	
◇	3	98.43mil (2.500mm)	PTH	Round	Top Layer - Bottom Layer	
○	3	125.98mil (3.200mm)	PTH	Round	Top Layer - Bottom Layer	
	300 Total					

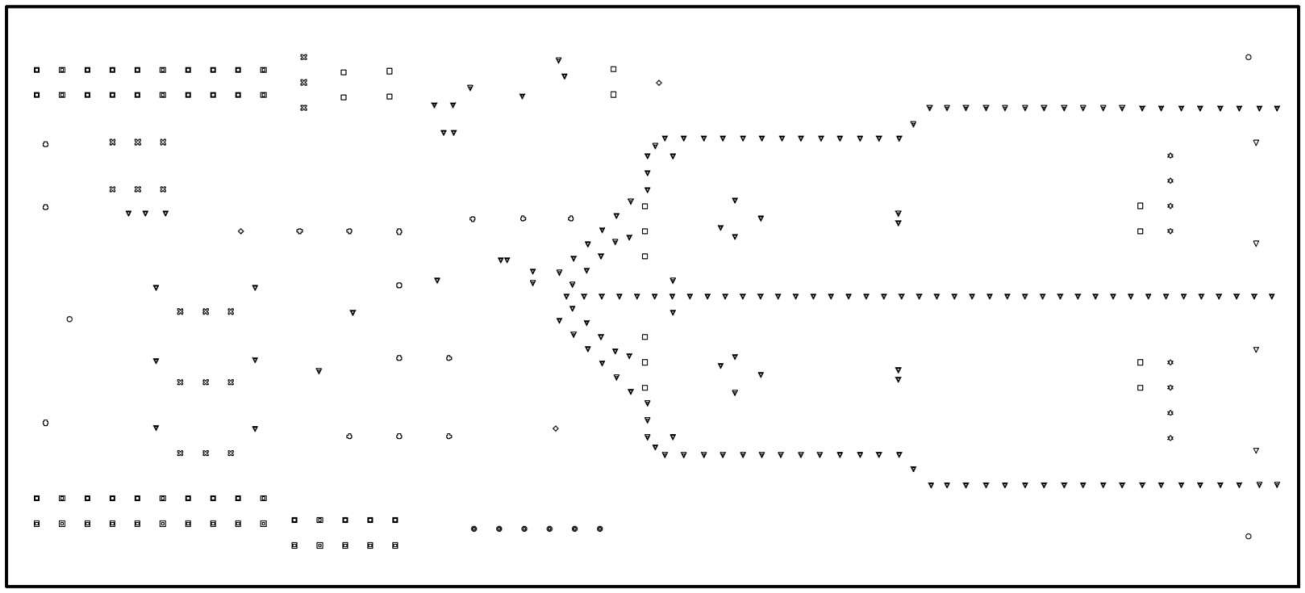

Figure 6-13. BQ79600EVM Drill Drawing

6.4 Bill of Materials (BOM)

Table 6-1 lists the bill of materials for BQ79600EVM.

Table 6-1. Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		BMS030	Any
C1	1	0.1µF	CAP, CERM, 0.1 µF, 50 V, ±5%, X7R, 0603	0603	C0603C104J5RACTU	Kemet
C2, C3	2	0.47µF	CAP, CERM, 0.47 µF, 16 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71C474KA55D	MuRata
C4	1	0.1µF	CAP, CERM, 0.1 µF, 10 V, ±10%, X7R, AEC-Q200 Grade 1, 0402	0402	GCM155R71A104KA55D	MuRata
C7, C8, C9, C10, C11, C12, C13, C14	8	100 pF	CAP, CERM, 100 pF, 50 V,±5%, C0G/NP0, AEC-Q200 Grade 1, 0603	0603	GCM1885C1H101JA16J	MuRata
D2	1	Green	LED, Green, SMD	LED_0805	LTST-C170KGKT	Lite-On
D3	1	Red	LED, Red, SMD	Red 0805 LED	LTST-C170KRKT	Lite-On
D4, D5	2		28 V Clamp 13 A (8/20µs) Ipp Tvs Diode Surface Mount TO-236AB	SOT23-3	PESD5V0L2BT,215	Nexperia
H1, H2, H3	3		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fastener Supply
H4, H5, H6	3		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone
J1, J3, J6, J10, J11, J12	6		Header, 100mil, 3x1, TH	Header, 3x1, 100mil, TH	800-10-003-10-001000	Mill-Max
J2	1		Header, 0.5mm, 6x1, R/A, Gold, TH	Header, 0.5mm, 6x1, R/A, TH	22-12-4062	Molex
J4	1		CONN HEADER 10POS .100 DL R/A AU	HDR10	TSW-105-08-L-D-RA	Samtec
J5, J8, J13	3		Header, 2.54mm, 1x2, Tin, Black, TH	Header, 2.54mm, 2x1, TH	PEC01DAAN	Sullins Connector Solutions
J7, J9	2		Receptacle, 2.54mm, 10x2, Tin, TH	Receptacle, 2.54mm, 10x2, TH	SSQ-110-03-T-D	Samtec
J14, J15	2		Header(shrouded), 2.54mm, 4x1, R/A, Gold, TH	Header(shrouded), 2.54mm, 4x1, R/A, TH	70551-0038	Molex
J16, J17	2		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
J18, J19	2		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
Q1	1	20 V	MOSFET, N-CH, 20 V, 0.2 A, AEC-Q101, SC-89	SC-89	RE1C002UNTCL	Rohm
R1	1	10	RES, 10, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310R0JNEA	Vishay-Dale
R4, R12, R18, R19, R20	5	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R5, R11	2	200	RES, 200, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603200RJNEA	Vishay-Dale
R6	1	10Meg	RES, 10 M, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310M0JNEA	Vishay-Dale
R7, R9, R37, R38, R39, R40, R41, R42, R43, R44	10	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL	Yageo

Table 6-1. Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
R13, R14, R15, R16, R17	5	10.0k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R23, R24, R33, R34	4	51	RES, 51, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060351R0JNEA	Vishay-Dale
R27, R28, R29, R30	4	499	RES, 499, 1%, 0.1 W, 0603	0603	RC0603FR-07499RL	Yageo
SH1, SH2, SH3, SH4, SH5, SH6, SH7, SH8, SH9	9		Shunt, 100mil, Gold plated, Black	Shunt 2 pos. 100 mil	881545-2	TE Connectivity
T3, T4	2		Transformer, 618 uH, SMT	9.7x9.5mm	CEP99	Sumida
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP10, TP11, TP12, TP13	11		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone
TP8, TP9	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
TP15, TP16, TP17	3		Terminal, Turret, TH, Triple	Keystone1598-2	1598-2	Keystone
TP18	1		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
U1	1		BQ79600PWQ1, PW0016A (TSSOP-16)	PW0016A	BQ79600PWQ1	Texas Instruments
C5, C6	0	0.01µF	CAP, CERM, 0.01 µF, 50 V, ±10%, X7R, 0603	0603	CL10B103KB8NCNC	Samsung Electro-Mechanics
C15, C16, C17, C18	0	2200 pF	CAP, CERM, 2200 pF, 2000 V, ±10%, X7R, AEC-Q200 Grade 1, 1206	1206	1206J2K00222KXR	Knowles Capacitors
D1	0	5.1V	Diode, Zener, 5.1 V, 300 mW, AEC-Q101, SOD-323	SOD-323	SZMM3Z5V1ST1G	ON Semiconductor
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
L1, L2	0	470 µH	Coupled inductor, 470 µH, 0.4 A, 0.35 ohm, SMD	5x3.3mm	744242471	Wurth Elektronik
R2	0	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R3	0	1.00Meg	RES, 1.00 M, 1%, 0.1 W, 0603	0603	RC0603FR-071ML	Yageo
R8, R10, R21, R22, R25, R26, R31, R32, R35, R36, R47, R48, R49, R50, R51, R52, R53, R54	0	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL	Yageo
R45, R46, R55, R56	0	0	RES, 0, 5%, 0.333 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EAHP	Vishay-Dale
T1, T2	0		BMS TRANSFORMER	SMT_TRANSFORMER_8MM89_10MM09	HMU1228NL	Pulse
TP14	0		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone

7 Revision History

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

Changes from Revision A (June 2020) to Revision B (August 2023)	Page
• Changed all instances of legacy terminology to controller and peripheral where SPI is mentioned	1

Changes from Revision * (October 2019) to Revision A (June 2020)	Page
• Changed from *Advance Information* to *Production Data* release	1

STANDARD TERMS FOR EVALUATION MODULES

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 DEGREDATION 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 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

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/lsds/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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

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西新宿三井ビル

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

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

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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