User's Guide

BQ79631EVM Evaluation Module

ABSTRACT

The BQ79631 Evaluation Module user's guide describes the safety considerations, general features, theory of operation, hardware setup, and use of the BQ79631 EVM. Throughout this user's guide, the abbreviations BMS039, EVM, and the term evaluation module are synonymous with the BQ79631EVM unless otherwise noted. This EVM is an evaluation board for the BQ79631-Q1 to provide monitoring, protecting, and communications in high voltage environments within EV/HEVs.

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Trademarks

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General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

WARNING

Always follow TI's set-up and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center http://ti.com/ customer support for further information.

Save all warnings and instructions for future reference.

> **WARNING**
>
> Failure to follow warnings and instructions can result in personal injury, property damage or death due to electrical shock and burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is *intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments.* If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety:
   a. Keep work area clean and orderly.
   b. Qualified observers must be present anytime circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   e. Use stable and non-conductive work surface.
   f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety:
   a. As a precautionary measure, it is always good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
   b. De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   c. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   d. Once EVM readiness is complete, energize the EVM as intended.

   > **WARNING**
   >
   > While the EVM is energized, never touch the EVM or its electrical circuits, as they can be at high voltages capable of causing electrical shock hazard.
3. Personal Safety
   a. Wear personal protective equipment e.g. latex gloves or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

1 General Description

TI's BQ79631EVM is an evaluation board for the BQ7963X-Q1 family of devices used in EV/HEV applications to provide monitoring, protecting, and communications through measuring divided down high voltage in the battery junction box (BJB) or battery disconnect unit (BDU) system.

The BQ79631EVM is equipped with 16 differential voltage sense inputs to measure across the battery pack, fuse, drive train link, and fast charging connections. The two voltage sense pins (VC14, VC15) connected to HV_Extra1_Plus and HV_Extra2_Plus can be used to measure other parameters within the HV system. An insulation detection circuit is also present on the BQ79631EVM to verify that all high voltage networks are properly insulated from low voltage ones. All differential voltage sense inputs are integrated post ADC in digital low pass filters.

In addition to the voltage sense pins, the BQ79631EVM has integrated current sense with a low shunt resistor. There are also 8 GPIOs/auxiliary inputs that can be used to measure additional voltages, NTC thermistors, and drive relays.

Bi-directional daisy chain ports are also present on the BQ79631EVM and support capacitor, capacitor and choke, and transformer based isolation.

Control of a single EVM or multiple stacked EVMs is accomplished by using a PC-hosted GUI. Communication between the PC and the bridge device occurs via a USB2ANY UART interface. When using the BQ7963x in a system of other stacked BQ796XXEVM devices, communication between all other EVMs in the stack occurs via the isolated, daisy-chain differential communication bus.

The PC GUI allows the configuration of all BQ796XXEVMs to monitor cells and other analog data channels, control balancing, and monitor details of any faults. For more information on the installation and use of the BQAutoEval GUI, please refer to the *BQ79616-Q1 and BQ75614-Q1 GUI User's Guide*.

For more information on specific details pertaining to the BQ79616EVM, please refer to the *BQ79616-Q1, BQ75614-Q1, and BQ79656-Q1 Evaluation Modules User's Guide*.

1.1 Key Features

This EVM includes the following features:

- Differential voltage measurements with integrated filtering
  1. Link ± voltage measurement for connection to drive train
  2. HV_Fuse voltage measurement to monitor a fuse that connects the battery pack to the rest of the BJB
  3. HV ± voltage measurement for connection to battery pack
  4. Charge ± voltage measurement for connection to charging port
  5. Two additional HV voltage measurements to monitor any other location in the HV system
- Insulation detection
- Isolated differential daisy chain communications with optional ring architecture
- 8 NTC/Auxiliary/GPIO channels
- UART interface
- Diagnostics
- Integrated current measurement
- Built-in host controlled hardware reset to emulate POR-like device reset

1.1.1 Key Electrical Parameters

The following table identifies the key electrical parameters:

Table 1-1. Key Electrical Parameters

Parameter	Value
Maximum battery pack voltage (stacked EVMs)	2400 V
Maximum operating voltage	80 V (depends on series R3, R4 value)
Minimum operating voltage	9 V (depends on series R3, R4 value, by default use at least 18V)
Maximum cell open circuit voltage	5 V
Ambient temperature	–40 °C to 105 °C
Nominal operating temperature	–20 °C to 60 °C
Cell balancing current	Approximately 200 mA @ 80 °C

2 Theory of Operation

The BQ79631-Q1 is designed to verify the safe operation of charging, discharging, and power transfer to a load in an EV/HEV system. Various voltage sense measurements are made at critical nodes within the BJB/BDU to make sure that the vehicle is operating as intended at all times. In a typical BMS system, a BQ79631-Q1 is used to gather critical data in the following areas:

- HV ±
- Link ±
- Charge ±
- HV_Fuse
- HV_Extra1_Plus/HV_Extra2_Plus

The typical BMS system with stacked modules has three main sub-systems, as shown in Figure 2-1:

- Host controller - in this case a TMS570 LaunchPad™.
- A BQ79631-Q1 configured as an isolated communication bridge device - a BQ79600EVM , BQ79616EVM, or a BQ79631EVM can also support this .
- BQ79616EVM based modules attached to cells - these can be stacked up to 35 total devices (including the bridge device).

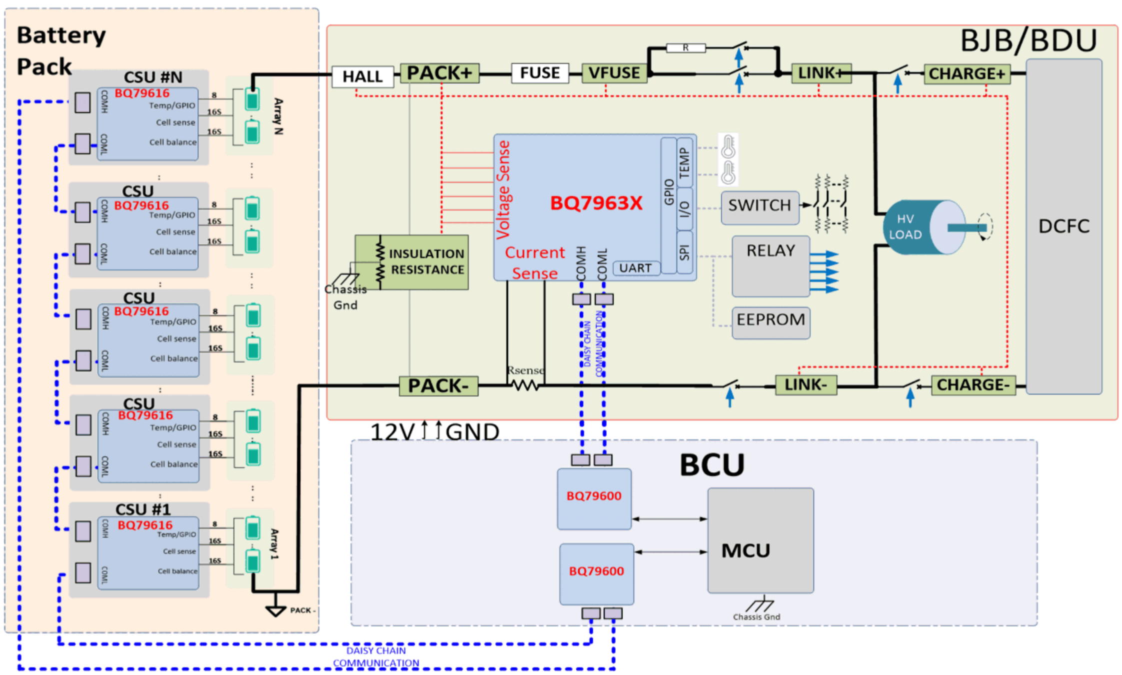


Figure 2-1. Typical BMS System with Stacked Modules

All commands and data are communicated with a host through either a UART or daisy-chain communication connection. The BQ79631 remains idle until a command is received from the host. The BQ79631 can support a host PC or microcontroller (through the UART connection header) or a daisy-chain interface from a BQ79600 implemented as a communication bridge.

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

1. Wakeup the BQ79631EVM board by sending a WAKEUP pulse when using the UART interface, or send a WAKE tone when using the BQ79631EVM in a stack with other BQ79616EVM boards for a large battery pack. (Typically an auto address signal is needed if using the BQ79631EVM in a stack of other BQ devices but is not needed if using a single BQ79631EVM).
2. Send a sample command to the BQ79631-Q1 to read the voltage measurement results.
3. If no stop command is sent, then the BQ79631-Q1 has a built-in timeout (set by the user), after which time the discharge is stopped automatically.

4. The host can then decide to repeat the process (back to step 2) or send commands to shutdown the BQ79631EVM and return later.

2.1 Single Board

A single BQ79631EVM can be used to obtain the measurements outlined in Key Features. When using only using a single board, communications are handled through the UART host interface. This can be accessed on the EVM via the J10 USB2ANY connection at the top of the board. The daisy chain communications bus would remain unused as no other EVM boards are present in this configuration.

2.2 Stacked Systems

A possibility is to use the BQ79631EVM in a system of other BQ devices. If the user wishes to test the BQ79631EVM in a system of other BQ79631EVMs, then this is possible through the use of the daisy chain communications bus. If using both the BQ79631EVM and a stack of BQ79616EVMs simultaneously, then TI recommends to configure the BQ79631EVM as the bridge device by connecting to the host microcontroller through the UART host interface and then using the daisy chain communications bus to connect the BQ79631EVM to the stack of BQ79616EVM devices. This configuration is shown in the figure below.

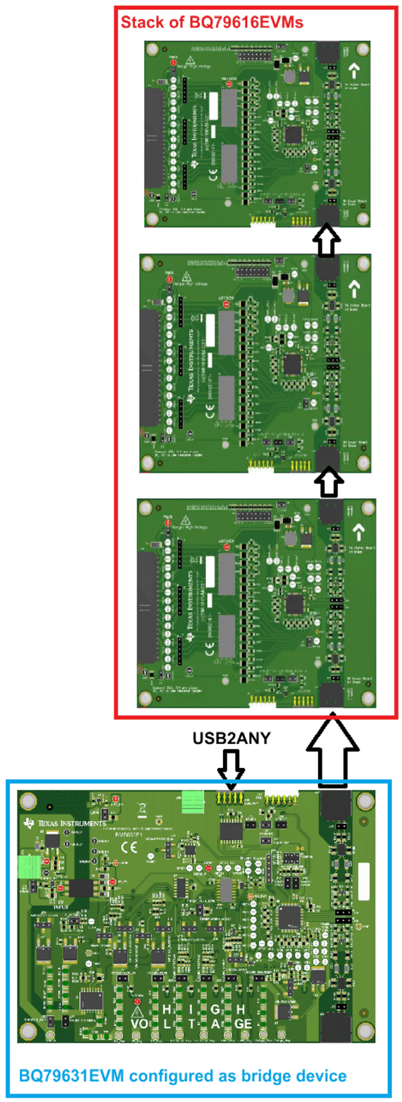


Figure 2-2. BQ79631EVM Bridge Device Configuration

If using the BQ79631EVM in a system with the BQ79600EVM, then TI recommends to configure the BQ79600EVM as the bridge device and the BQ79631EVM as a stack device.

3 Connectors

3.1 Powering the BQ79631EVM

To enable the use of the BQ79731EVM, power is supplied through the 5V_LV connector on the left side of the board. Simply connect the positive and negative terminals of a power supply set to 5 V to the pins 5V_LV and GNDLV, respectively.

3.2 Primary Input and Output Connectors

3.2.1 Jumper Placements

Below is a table explaining each of the jumpers available to the user on the BQ79631EVM.

Table 3-1. Jumper Placements

Pinheader	Contacts	Jumper Connection	Populated by Default?
J2	1-2	VCC40V to Charge_Plus	No

3.2.2 Host Interface

The 10-pin J10 - Serial connector is used to connect the EVM to a PC running the GUI or to a host controller. Texas Instruments recommends using the USB2ANY (available to order through TI.com), which includes the proper 10-pin cable.

Table 3-2. J10 Serial Connector

Designator	Manufacturer	Part Number	Mating Connector
J10	Samtec Inc.	Manufacturer: TSW-105-08-L-D-RA	10-pin ribbon connector packaged with USB2ANY

Table 3-3. Pin Descriptions

Pin	Name
1	NC
2	NC
3	NFAULT signal from BQ79631-Q1
4	NC
5	GND
6	USB2ANY 3.3 V
7	USB2ANY TX (RX of BQ79631-Q1)
8	USB2ANY RX (TX of BQ79631-Q1)
9	NC
10	NC

3.2.3 High-Side and Low-Side Communications

There are two sets of 4-position molex connectors available on each BQ79631EVM board. These provide high-side (J27) and low-side (J26) communications between stacked EVM devices.

Table 3-4. Pin Description - J26

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

Table 3-5. Pin Description - J27

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

Isolation Options

Capacitor Only

If the user wishes to utilize the cap only method, no extra modifications need to be made to the EVM since this is the default configuration.

Capacitor and Choke

For the cap and choke method to be implemented, the user must de-solder the R144, R145, R155 and R154 resistors so that the L4 and L3 chokes are not bypassed.

Transformer

If the user wanted the daisy chain communications to be handled by the transformer, then de-solder the following resistors: R148, R149, R150, R151, R146, R147, R152, R153. On the underside of the EVM, populate the R122, R123, R127, R129, R120, R121, R124, and R126 slots with 0-Ω resistors and T2 and T3 with transformers. This allows the signal to flow through the underside of the EVM where the transformers (T2 and T3) are located.

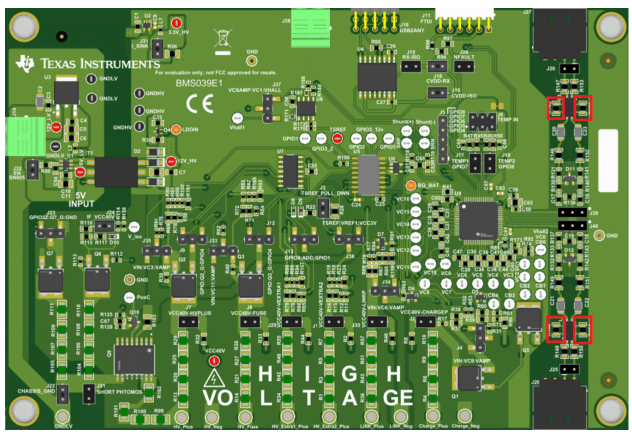


Figure 3-1. Resistors to De-solder Topside

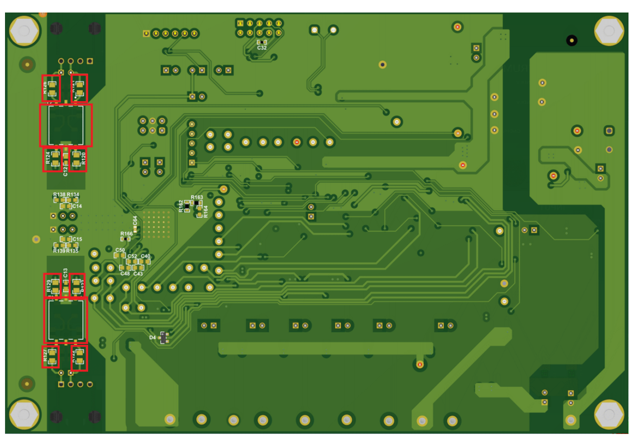
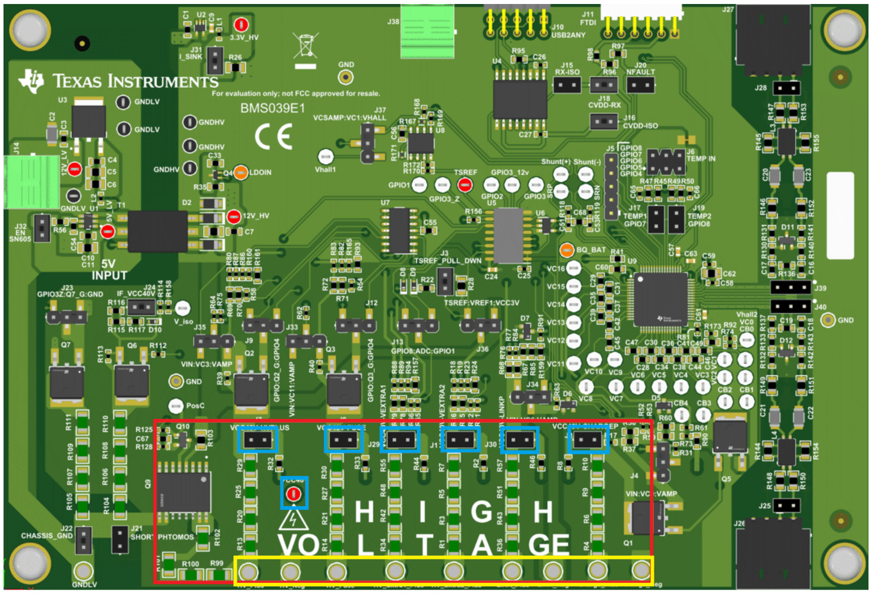


Figure 3-2. Resistors to De-solder Underside

3.3 High Voltage Networks

3.3.1 High Voltage Safety Considerations

When connecting to any of the high voltage networks, TI recommends that extreme safety precautions are taken. The user must assume the entire board is live with high voltage once an HV connection is made. The high voltage connection points and the areas on the EVM where these voltages are dissipated are shown in the figure below. Extra care must be taken around this area of the EVM.



400/800 V connection   High Voltage region of EVM   40 V connections

Figure 3-3. High Voltage Connections

3.3.2 High Voltage Connections

The 5V_LV connector can supply power directly to the BQ79631-Q1 device through supplying the desired high voltages to measure across the resistor divider circuits, which must be supplied through separate connections. These connections are given in the table below.

Table 3-6. Pin Descriptions

Pin	Rated Voltage	Comments
VCC40V	40 V	Alternate supply connection for if the user does not have access to a high voltage lab.
HV_Plus	400/800 V	Positive connection for HV_Plus network.
HV_Neg	400/800 V	Negative connection for HV_Plus network.
HV_Fuse	400/800 V	Positive connection for HV_Fuse network.
HV_Extra1_Plus	400/800 V	Positive connection for the 1st of 2 customizable HV networks available to the user.
HV_Extra2_Plus	400/800 V	Positive connection for the 2nd of 2 customizable HV networks available to the user.
LINK_Plus	400/800 V	Positive connection for the LINK_Plus network.
LINK_Neg	400/800 V	Negative connection for the LINK_Plus network.

Table 3-6. Pin Descriptions (continued)

Pin	Rated Voltage	Comments
Charge_Plus	400/800 V	Positive connection for the charge network.
Charge_Neg	400/800 V	Negative connection for the charge network

Each of these high voltage supply connections supports 400-V inputs. This voltage is divided across a series of 330-kΩ resistors so that the high voltages do not come into contact with any amplifiers or pins on the BQ79631-Q1 device.

Note

The BQ79631EVM is rated for 800 V but the resistor values in the divider networks have been selected for 400-V application. To use this EVM for 800-V testing, swap out each of the 330-kΩ resistors for 660-kΩ resistors.

WARNING

Again, please verify that extreme care is taken around these networks.

3.3.3 High Voltage Alternatives

If the user does not have access to a high voltage lab and proper high voltage lab equipment, then using a 40-V supply and the EVM's 40-V network to provide voltage to the various parameters the user wishes to measure is a possibility. To utilize this 40-V supply option, connect a 40-V power supply to the VCC40V connector located near the bottom of the board. To use this feature, the user must also populate jumpers J7, J8, J29, J1, J30, and J2 with shunts to connect VCC40V to the desired network. The blue regions in the figure above show the jumpers that must be populated to connect each network to the VCC40V supply.

3.3.4 Switches

In each of the high voltage networks on the BQ79631EVM, there are MOSFET switches controlled by GPIO pins that can disconnect the high voltage inputs from the rest of the network. These switches must always remain on while a measurement is taking place but can be turned off to block any leakage current from escaping the battery pack while not in use. These switches are controlled by the GPIO2 pin by default, but switches connected to the HV_Plus and HV_Fuse network can be controlled by GPIO4 by moving the shunt from pins 1-2 over to pins 2-3 on jumpers J9 and J12, respectively.

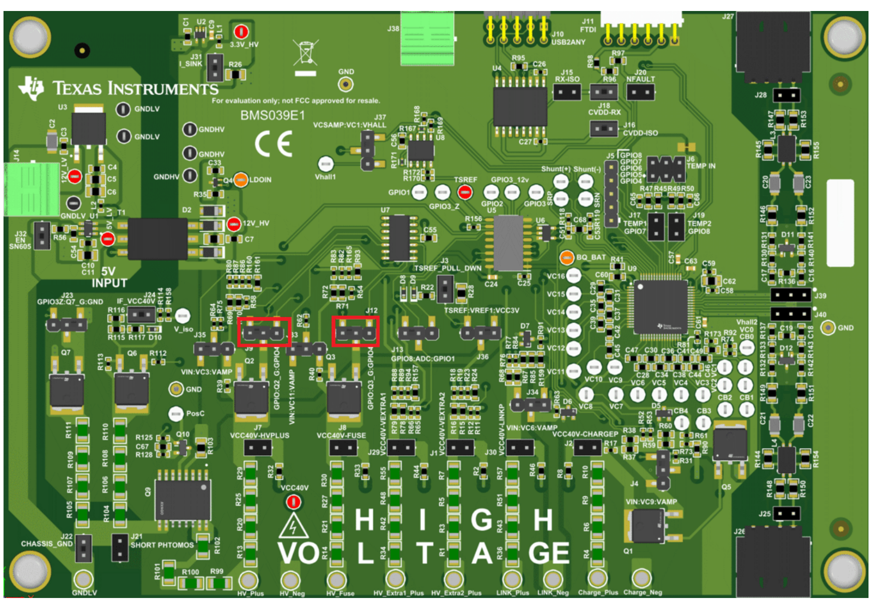


Figure 3-4. GPIO4 Control Option

To close the switch and enable current to flow through each network, the user must set the associated GPIO pin to *output high* from within the GUI.

If the user wishes to use the EVM to test without use of the included switches, then simply populate the following resistor slots with a 0-Ω resistor.

Table 3-7. Resistors

Resistor # on EVM	Switch Being Bypassed	Network
R39	Q2	HV_Plus
R40	Q3	HV_Fuse
R17	Q1	Charge_Plus
R73	Q5	Charge_Neg
R113	Q6	Insulation Detection

3.3.5 Buffers

Prior to the VC measurements in the positive side of each high voltage network (not HV_Extra1_Plus or HV_Extra2_Plus), there is a buffer present to prevent leakage current from flowing back into VC pins. This leakage current creates inaccuracy in the measurements made by the VC pins. While TI recommends that these buffers are implemented in the user's final design for accuracy, if the user wishes to assess impact on accuracy without the buffer, the user can connect to the first pin of the jumper associated with each buffer as shown below. Simply compare the measurement obtained by connecting a DMM to the desired jumper and GNDHV with the measurement seen on the VC pin associated with that network to calculate the percent error that is introduced if a buffer were not to be included in the user's final design.

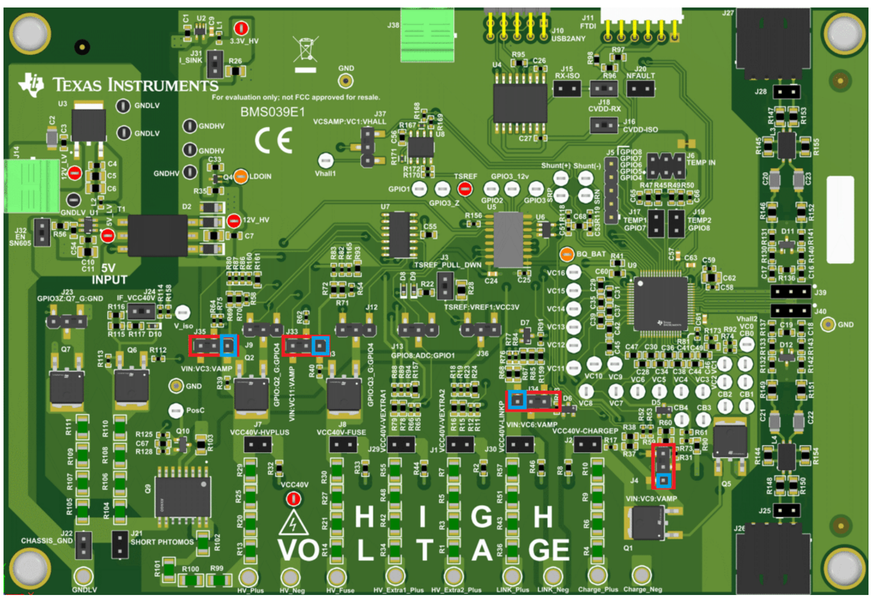


Figure 3-5. Buffer Bypass Jumpers

Table 3-8. Bypass Jumpers

Jumper	Network
J35	HV_Plus
J33	HV_Fuse
J34	LINK_Plus
J4	Charge_Plus

3.3.6 Insulation Detection Network

The insulation detection network on the BQ79631EVM located around HV_plus allows the user to verify that all high voltage networks within their design are properly insulated from low voltage ground. To utilize this feature, first make sure that GPIO2, and GPIO3 are both configured as *output high* and that GPIO1 is set to ADC only input. Next, connect the desired high voltage at either HV_Plus or at VCC40V. If the user is utilizing the VCC40V supply method, then be sure to place a shunt on the J7 jumper in the same method, as mentioned in Section 3.3.3 to connect the network to the 40-V supply. Additionally, for 40-V connection verify that the J24 jumper is depopulated. This adds increased resistance to the bottom side of the network that makes sure the measurement stays accurate.

To test this feature, simply switch GPIO3 from *Output High* to *Output Low* every 5-10 seconds. This connects/disconnects the high voltage supply through the Q9 photoMOS. Measurements are then taken at GPIO1 under both conditions to make sure that the device is properly insulated. The CB1 pin can also be used in place of the GPIO1 pin if the user wishes to utilize this GPIO pin for another purpose.

If additional accuracy is required, then the user can utilize the Q7 switch by populating pins 1-2 on J23 shown below. This switch is controlled by an inverted GPIO3 signal so that the Q7 FET switches opposite to the Q9 photoMOS. This introduces no delay in the system and is simply an option available to the user to implement in their design.

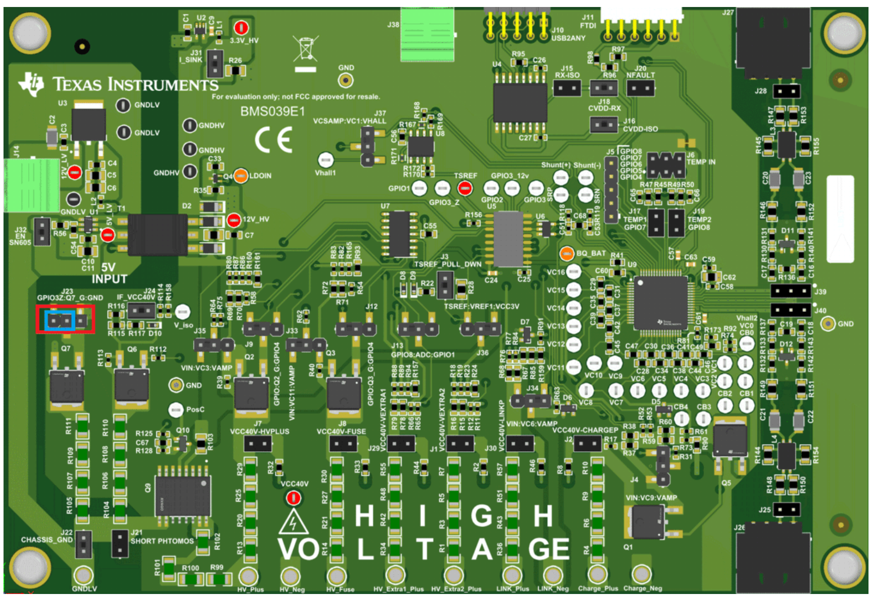


Figure 3-6. Additional FET Option

3.4 Current Sense

3.4.1 SRP/SRN

Current sense in the BQ79631-Q1 device is handled through the SRP and SRN pins that feed into a dedicated current sense ADC. This measurement occurs through a 50-µΩ shunt resistor that can be measured directly on the EVM through the shunt(+) and shunt(-) connectors.

3.4.2 VCSamp_Out

For bidirectional over current detection, TI recommends to utilize the VCSamp_Out circuit on the EVM. This circuit connects to VC1 and utilizes dedicated analog UV/OV comparators found within the BQ79631-Q1 device. While this method cannot be used to give precise readings on the voltage from Shunt(+) to Shunt(-), the method provides a quick response to any over current fault and can be instrumental in preventing catastrophic failures from arising within the system. In addition to over current detection, the VC1 measurement ADC can also be used as an alternate, less accurate, current measurement path. To enable the VCSamp_Out measurements to be made via VC1, simply place a shunt across pins 1 and 2 (top-middle) of J37.

The VCSamp_Out connection can be used simultaneously with the measurements being taken through SRP and SRN.

3.5 GPIO Connections

On the BQ79631EVM there are 8 GPIO pins that can be used for a variety of purposes and can be configured in the following manners:

- ADC and OTUT inputs
- ADC only input
- Digital input
- Output high
- Output low
- ADC input and weak pull-up
- ADC input and weak pull down

Signals from each of the GPIO pins flows through an ADC from within the BQ79631-Q1 much like the VC pins used to measure the high voltage branches. However, unlike the VC pins, the GPIO pins can be configured to flow through the main ADC, which has a digital low pass filter, or to flow through an AUX ADC that does not have this LPF present. If the user intends to make measurements that prioritize low latency over high accuracy, then TI recommends to configure the GPIO pins to use the AUX ADC.

The user can access GPIO1-3 on the connection points near the center of the board and GPIO4-8 on J5 located just above the BQ79631-Q1 device. Only the GPIO4-8 pins on J5 must be used to measure external thermistor inputs as the GPIO1-3 pins are used to control FET switches throughout the EVM. GPIO4-7 can also be used as Controller SPI pins to control external devices such as EEPROM or Relay/Contactor Driver.

4 Quick Start Guide

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

4.1 Launch Pad Connection and Example Code

4.1.1 Required Devices for Using the Example Code

The system example code is implemented using the TMS570LS12LaunchPad™ board (TMS570LS1224 MCU) and the BQ79631EVM via Code Composer Studio.

The part numbers of the evaluation modules are LAUNCHXL2-TMS57012 and BQ79631EVM-039 (for BQ79631-Q1 evaluation). 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.

4.1.2 Power Connections

As briefly mentioned in Powering the BQ79631EVM, power to the EVM itself is handled through the 5V_LV connection on the top left side of the board. All of the high voltage connections for testing purposes are found along the bottom of the board as is the VCC40V pin for use in the event that the user does not have access to a high voltage lab.

4.1.3 Connecting the EVM to the TMS570 LaunchPad

The EVMs are connected using a standard wire jumper; Table 4-1 shows the connections between the two EVMs. By default, the TMS570 LaunchPad is powered by the USB port on the host computer.

Table 4-1. Connections

Connection Name	EVM	TMS570 LaunchPad
TX	J11 pin 5	J2 pin 3 (UARX)
RX	J11 pin 4	J2 pin 4 (UATX)
nFAULT	J11 pin 2	J2 pin 5 (PA7)
GND	J11 pin 1	J3 pin 2 (GND)

4.1.4 Software

The software provides a command API and drivers that are capable of implementing the examples provided in BQ79631-Q1 Software Design Reference.

The example code only provides a control interface to the BQ79631-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 BQ79631-Q1 device.

This firmware provided with this application note provides source code examples of the command sequences described in the BQ79631-Q1 Software Design Reference.

Importing a project into Code Composer Studio™: 1. Launch the provided file: BQ79631-Q1 Example Code 0.1 Installer.exe and extract files to the default path provided (C:\ti\bq79631-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 it 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\bq79631-Q1 Example Code 0.1 5. In Discovered projects:, check BQ79616-Q1 example code

4.2 USB2ANY Connection with GUI

4.2.1 GUI

For initial evaluation, it may be more beneficial to use the graphical user's interface (GUI), which provides a "point and click" interface to become familiar with the BQ79631-Q1. During the initial sampling phase, please contact your local TI FAE to get the latest GUI version.

To get started with the GUI, please refer to the *BQ79616-Q1 and BQ75614-Q1 GUI User's Guide*.

4.2.2 GUI UART Connection

The physical setup for the GUI is the same as for the microcontroller, but will instead use an USB2ANY interface and a 10 pin cable for the UART connections on J10. 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 the10-pin connector cable to J4 of the USB2ANY (middle most connector) and must have the key side facing upwards when connecting to the EVM header J10. Please refer to the picture below and this is explained in more detail in the *USB2ANY Interface Adapter User's Guide* and the *BQ79616-Q1 and BQ75614-Q1 GUI User's Guide*.

5 Physical Dimensions

This section provides board dimension and board mounting information.

5.1 Board Dimensions

The EVM board dimensions follow:

Board dimensions: 4.400 in 6.500 in

Board height:

- Top - Tallest component (GPIO, Shunts) is x.xx in (x.x mm) above PCB
- Bottom - Tallest component if populated (Transformers) is x.xx in (x.xx mm) above PCB (Depopulated by default)

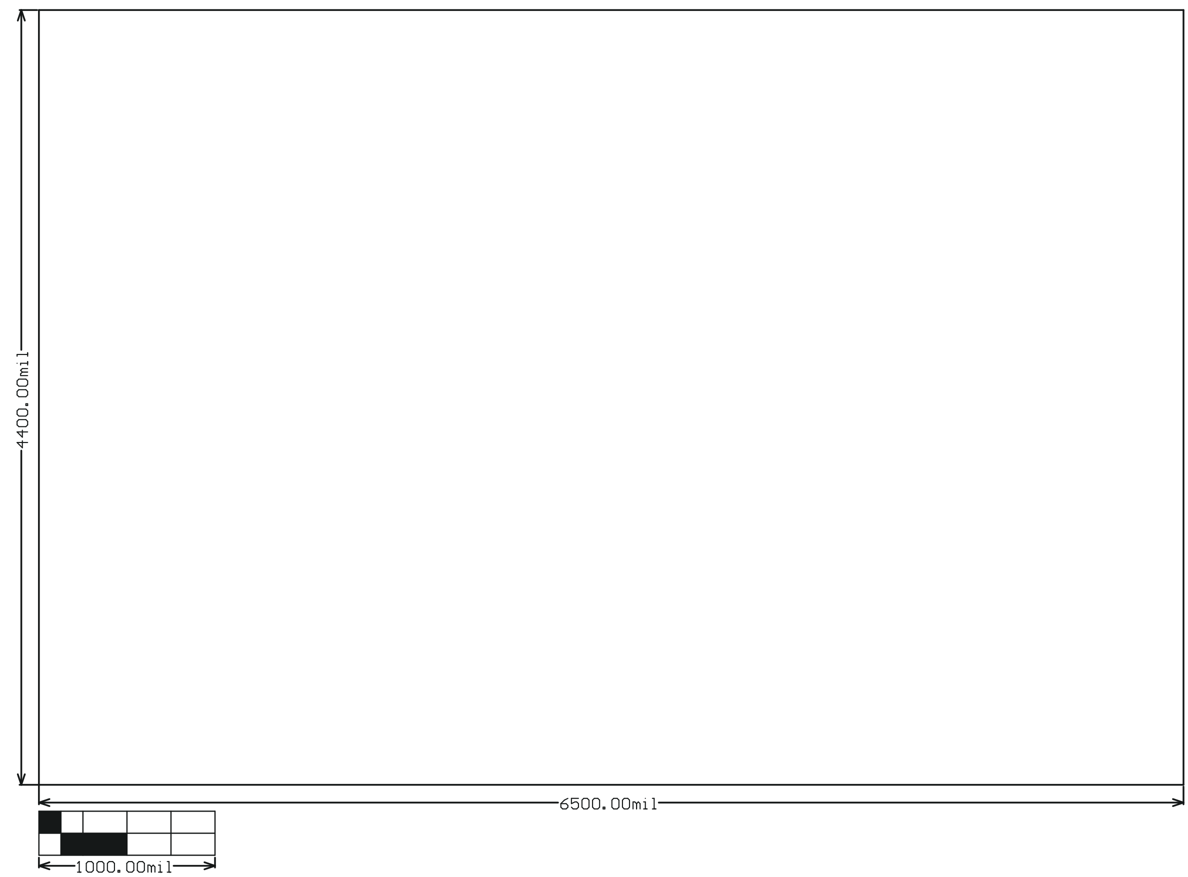


Figure 5-1. Board Dimensions

6 BQ79631-Q1 EVM Schematic, Assembly, Layout, and BOM

This section provides the EVM schematic, assembly, layout and BOM in their respective sections.

6.1 Schematics

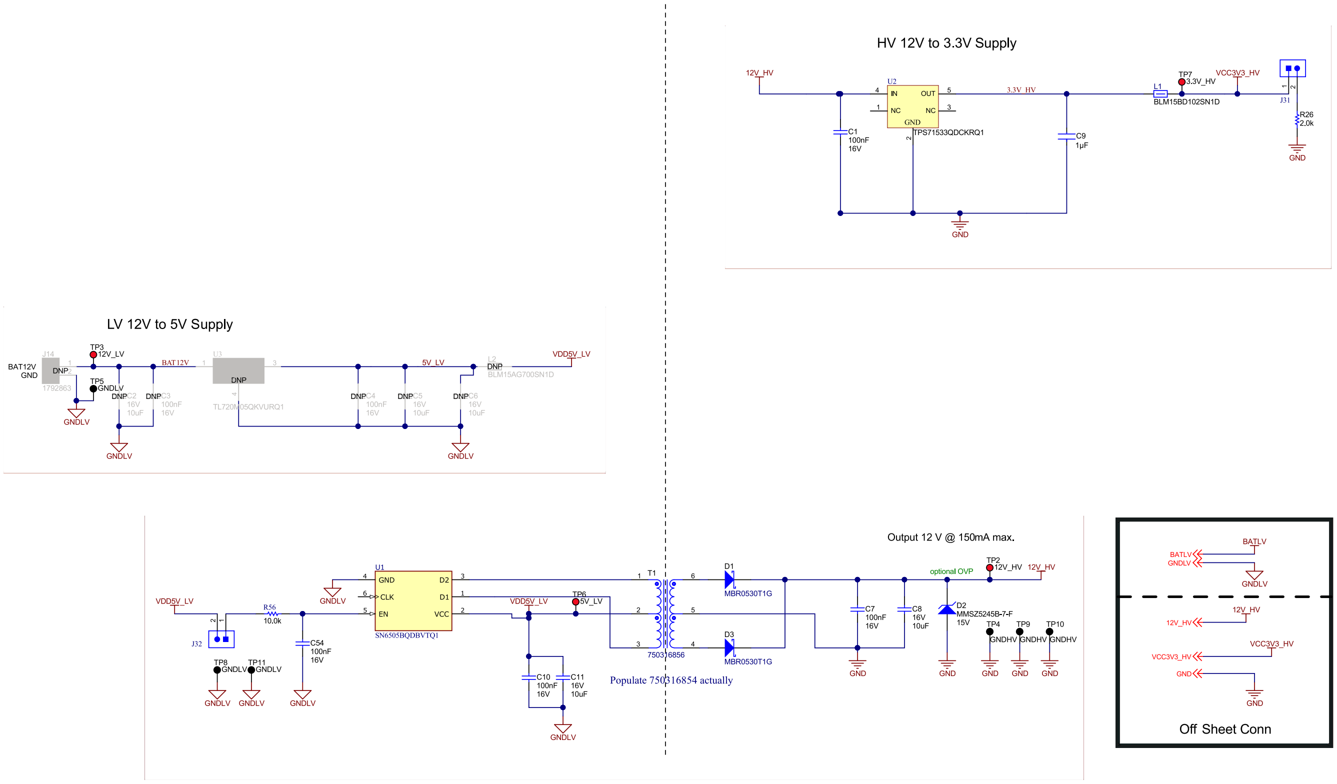


Figure 6-1. Power Supply

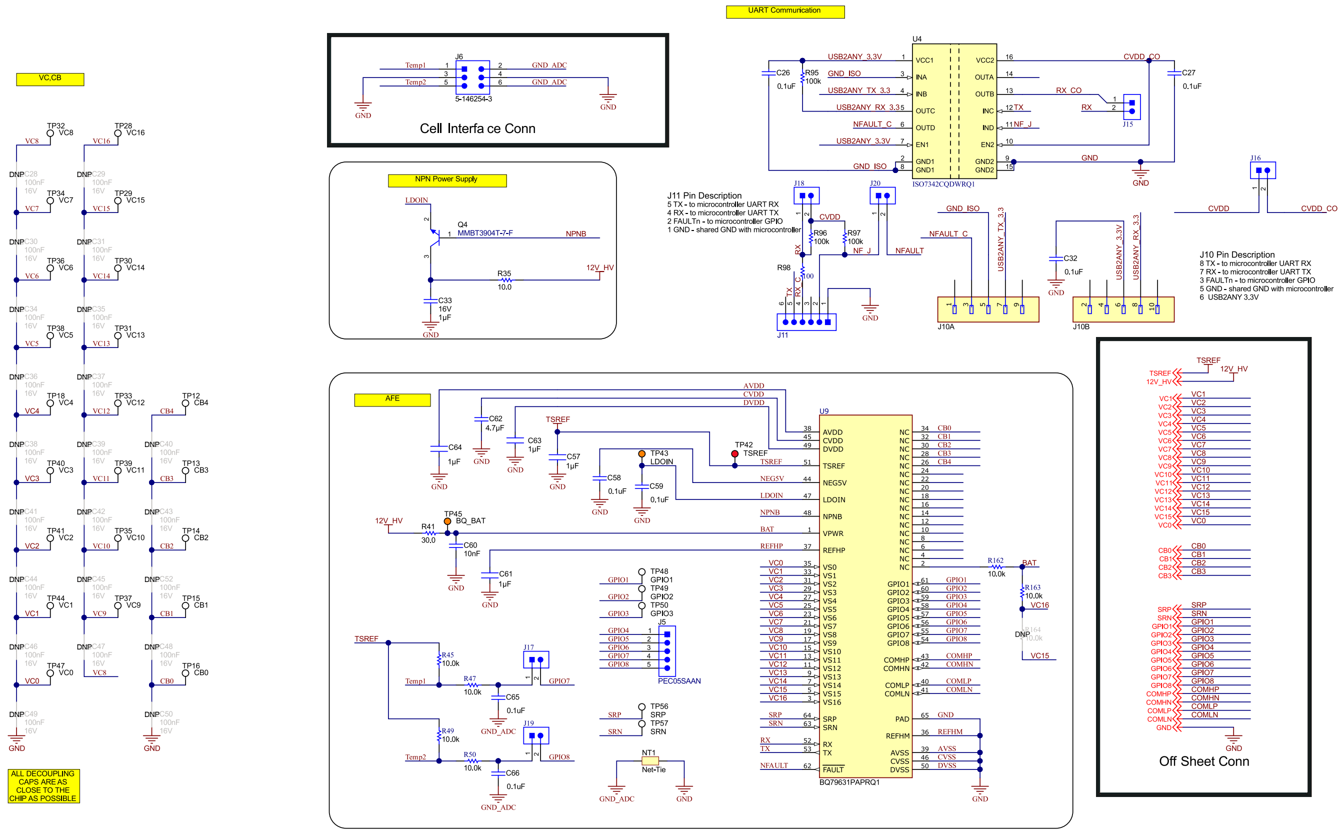


Figure 6-2. AFE

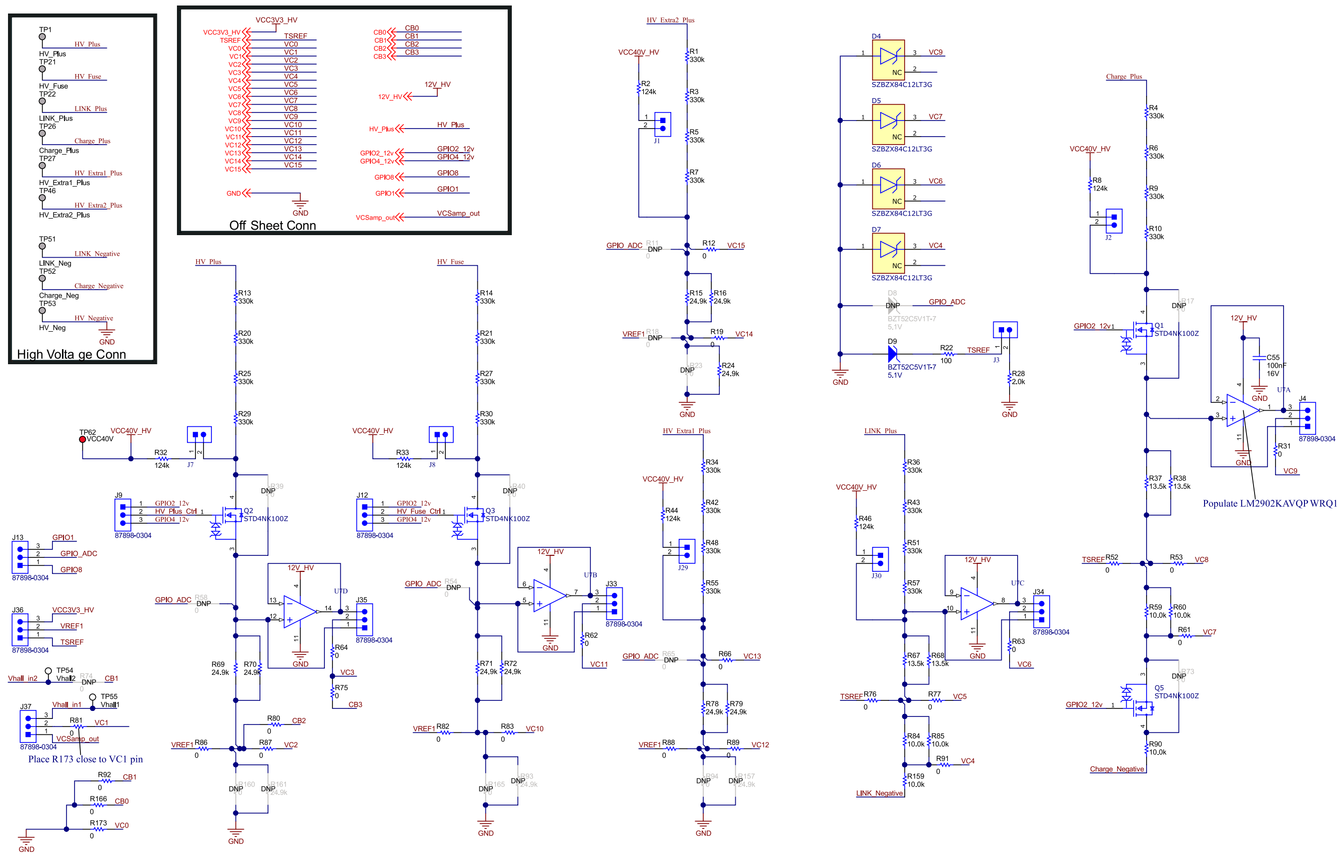


Figure 6-3. High Voltage Sense

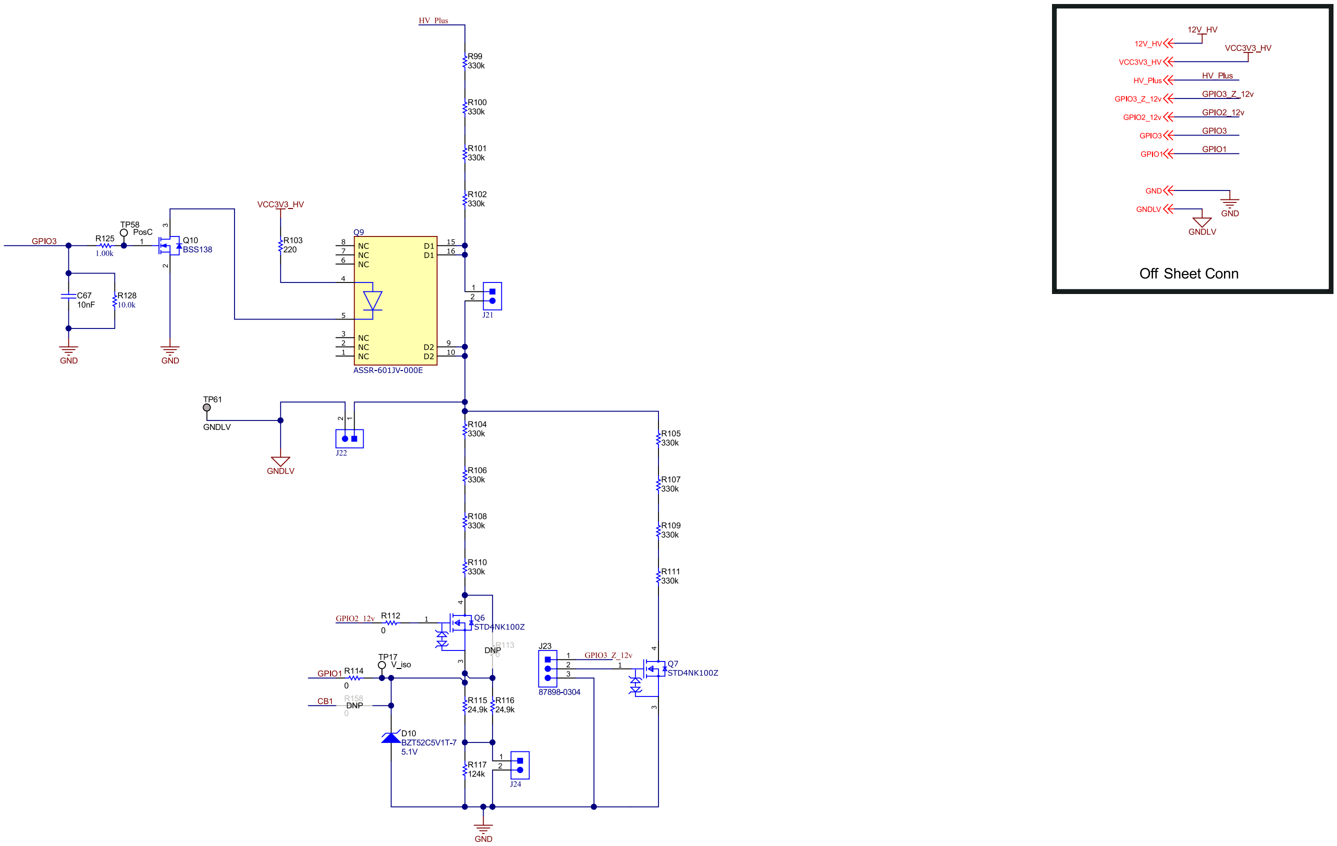


Figure 6-4. Insulation Detection

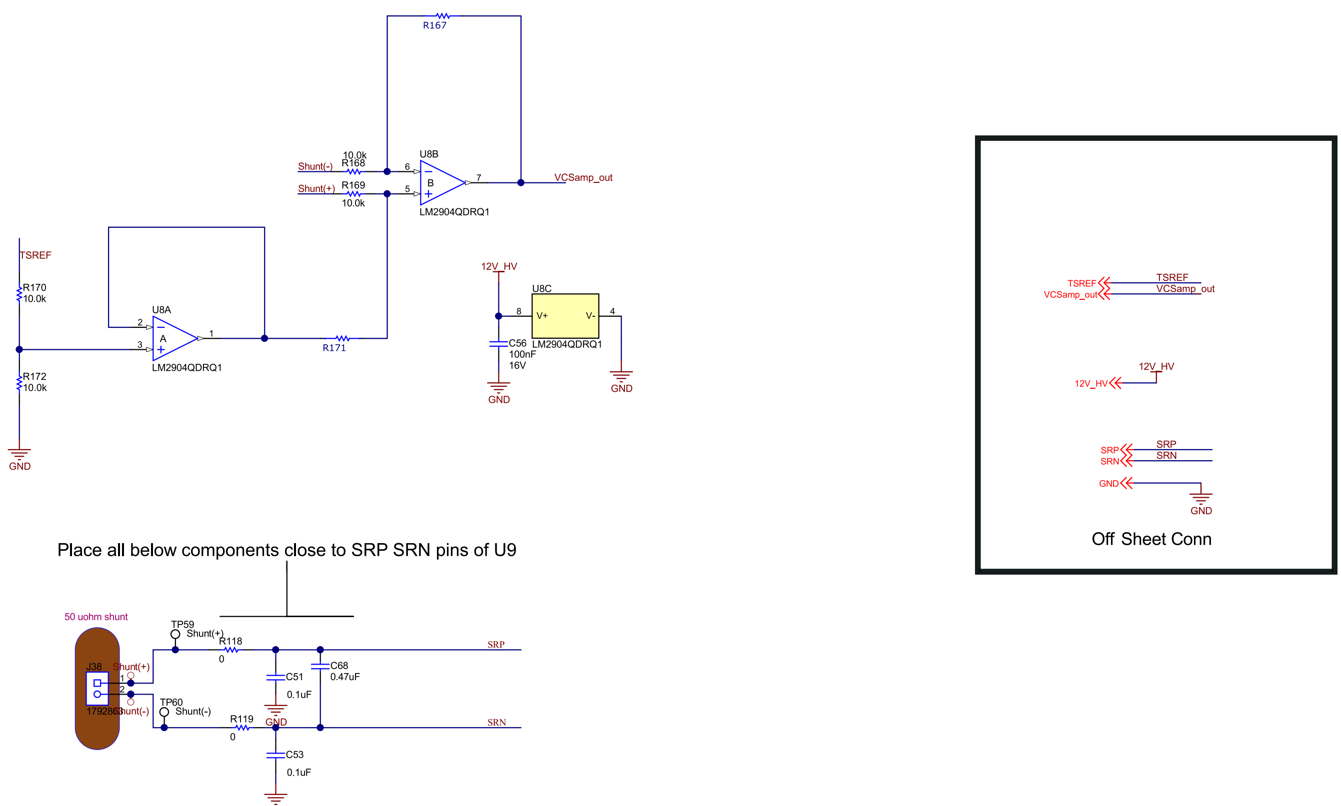


Figure 6-5. Current Sense

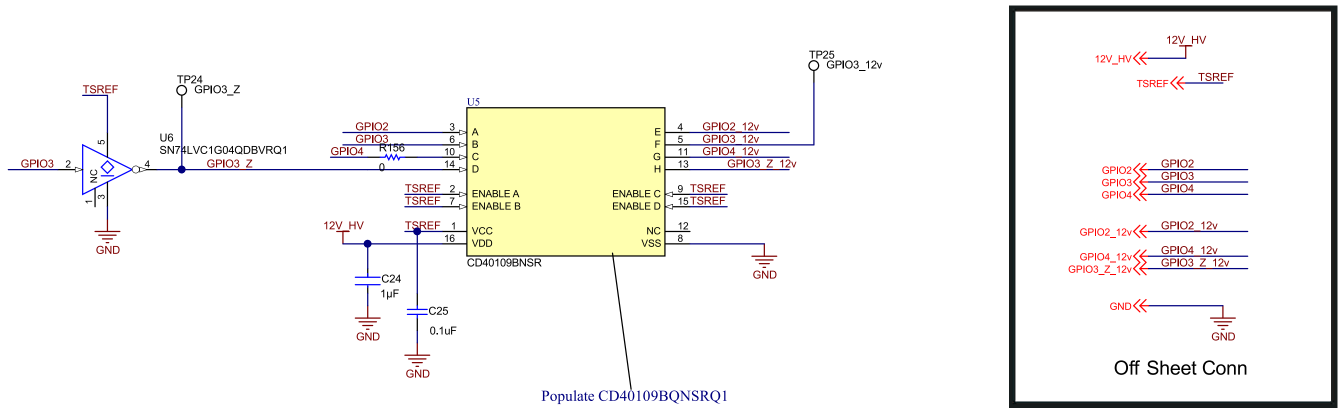


Figure 6-6. Voltage Shifter

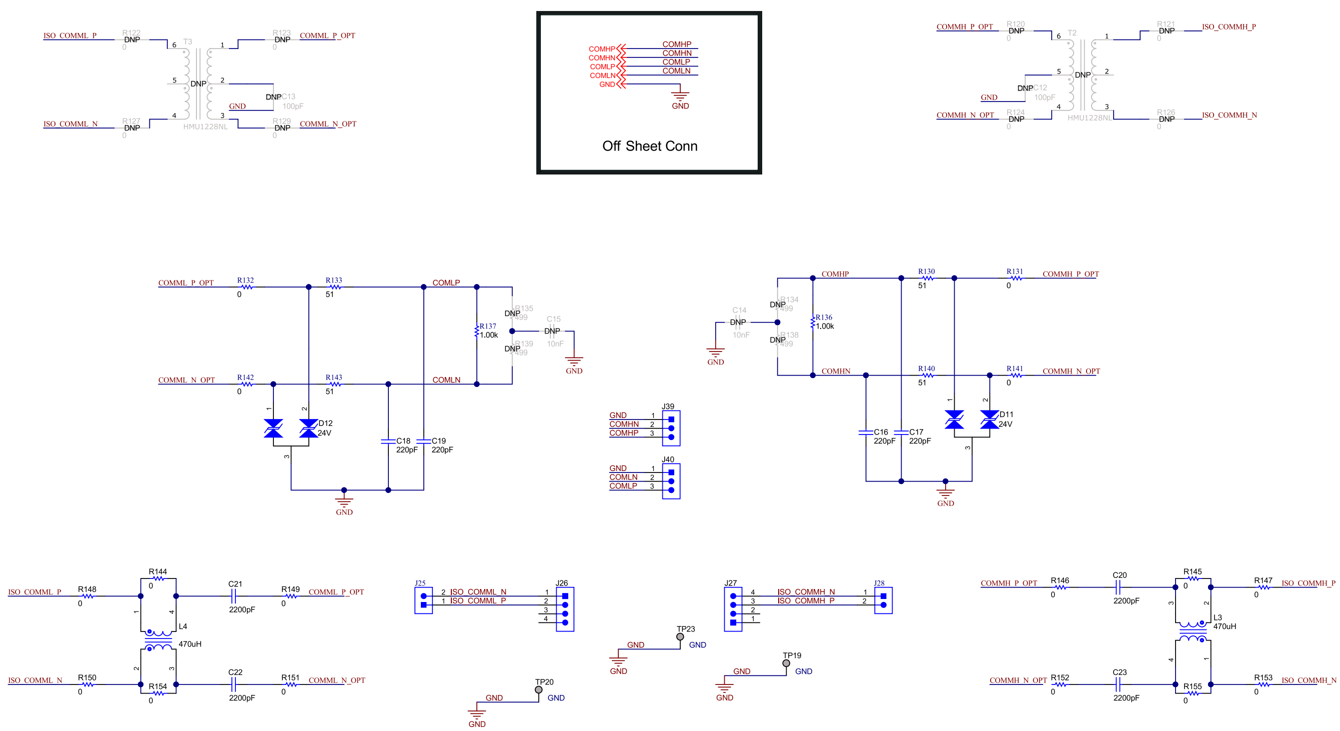
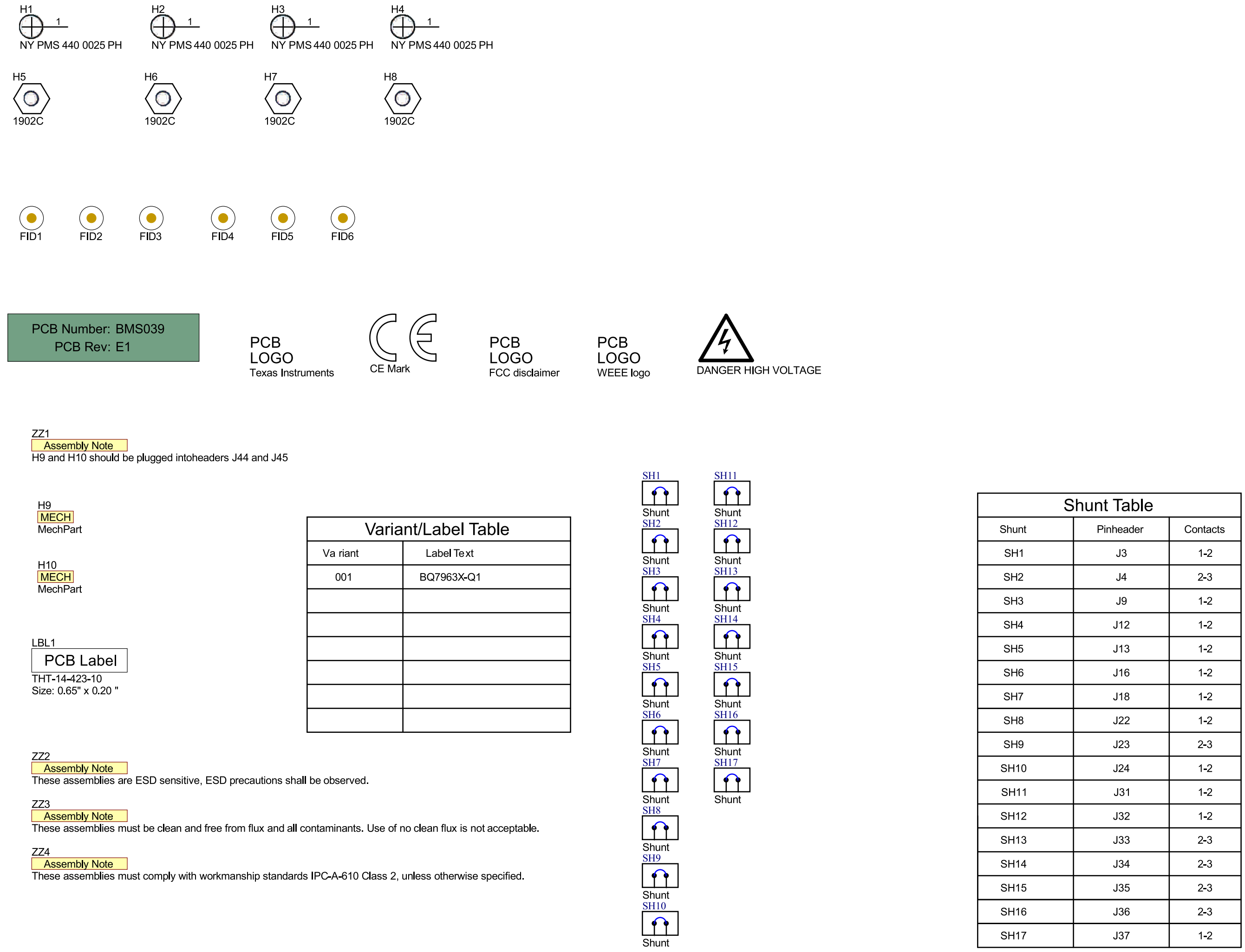


Figure 6-7. Communications (COMMH and COMML)



Variant/Label Table

Va riant	Label Text
001	BQ7963X-Q1

Shunt Table

Shunt	Pinheader	Contacts
SH1	J3	1-2
SH2	J4	2-3
SH3	J9	1-2
SH4	J12	1-2
SH5	J13	1-2
SH6	J16	1-2
SH7	J18	1-2
SH8	J22	1-2
SH9	J23	2-3
SH10	J24	1-2
SH11	J31	1-2
SH12	J32	1-2
SH13	J33	2-3
SH14	J34	2-3
SH15	J35	2-3
SH16	J36	2-3
SH17	J37	1-2

Figure 6-8. Hardware

6.2 Layout

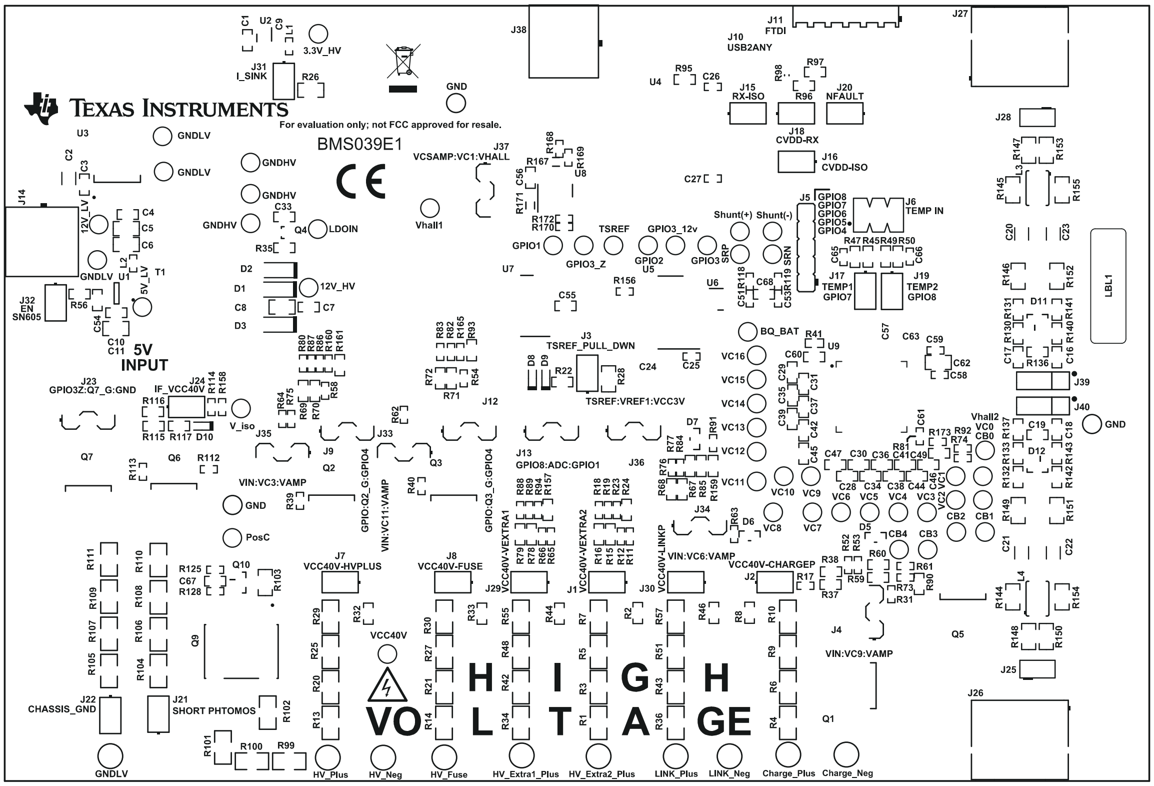


Figure 6-9. Top Overlay

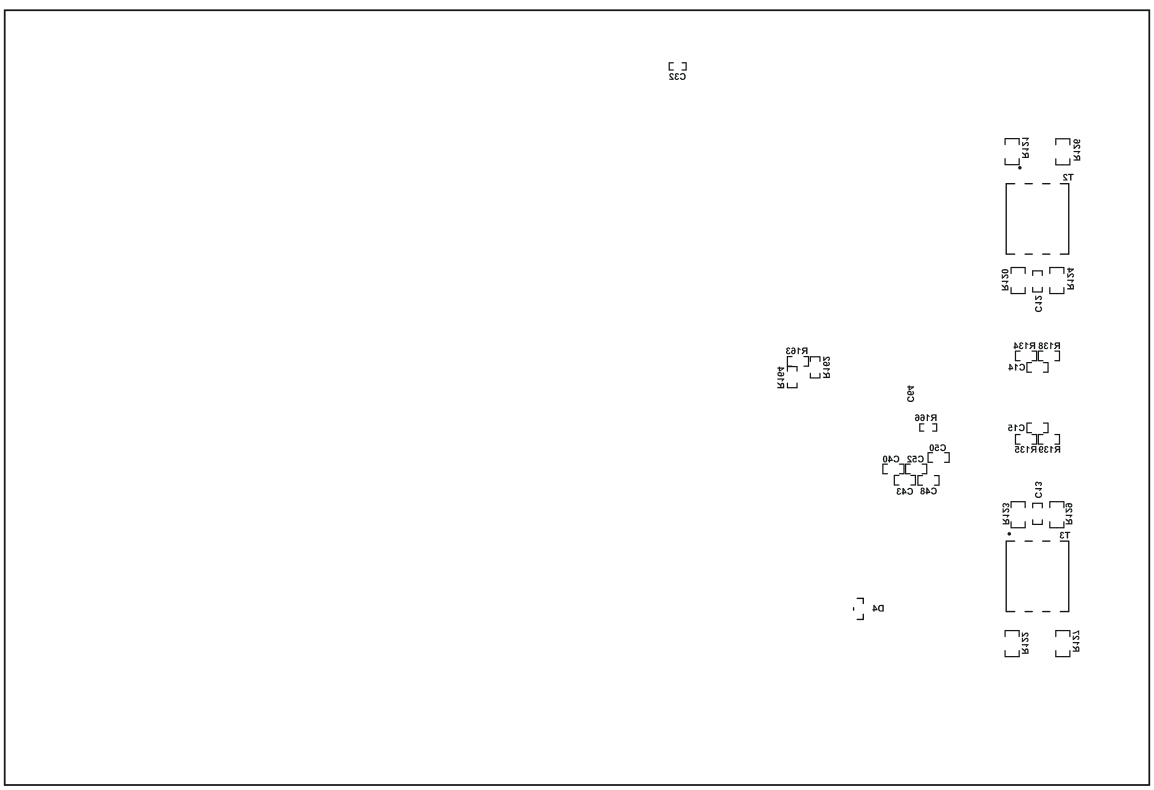


Figure 6-10. Bottom Overlay

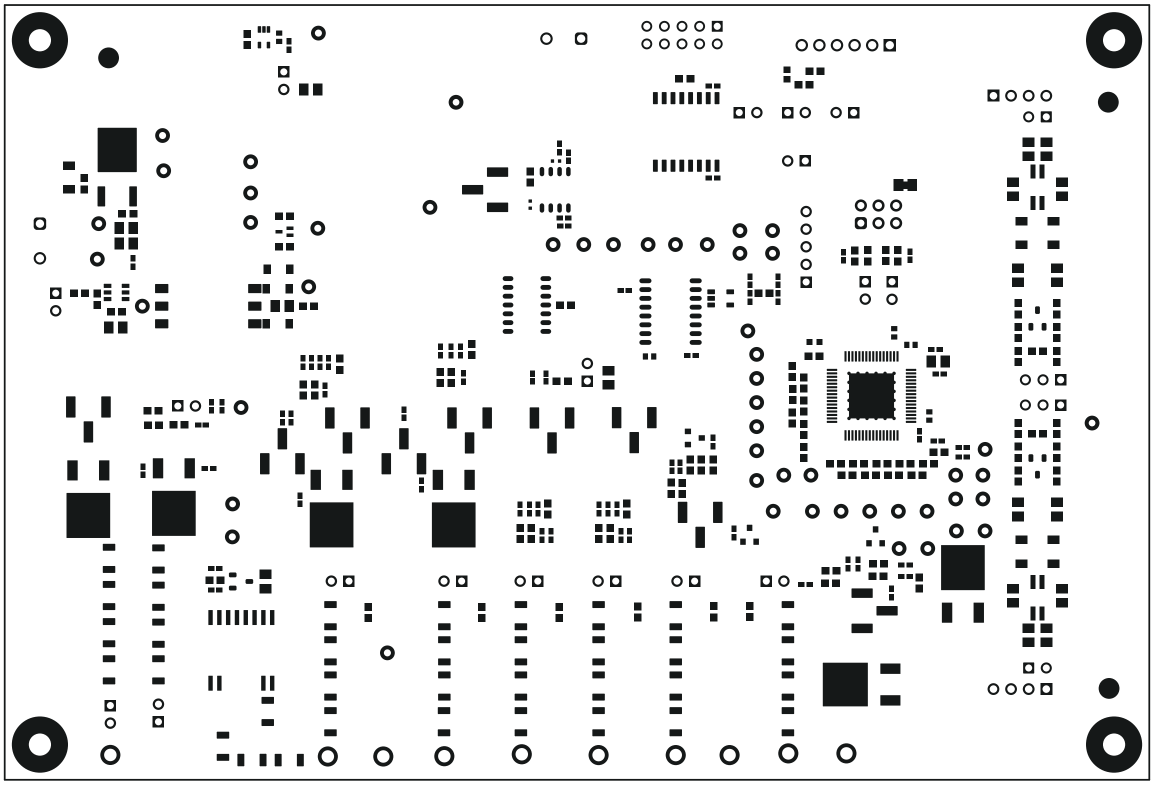


Figure 6-11. Top Solder

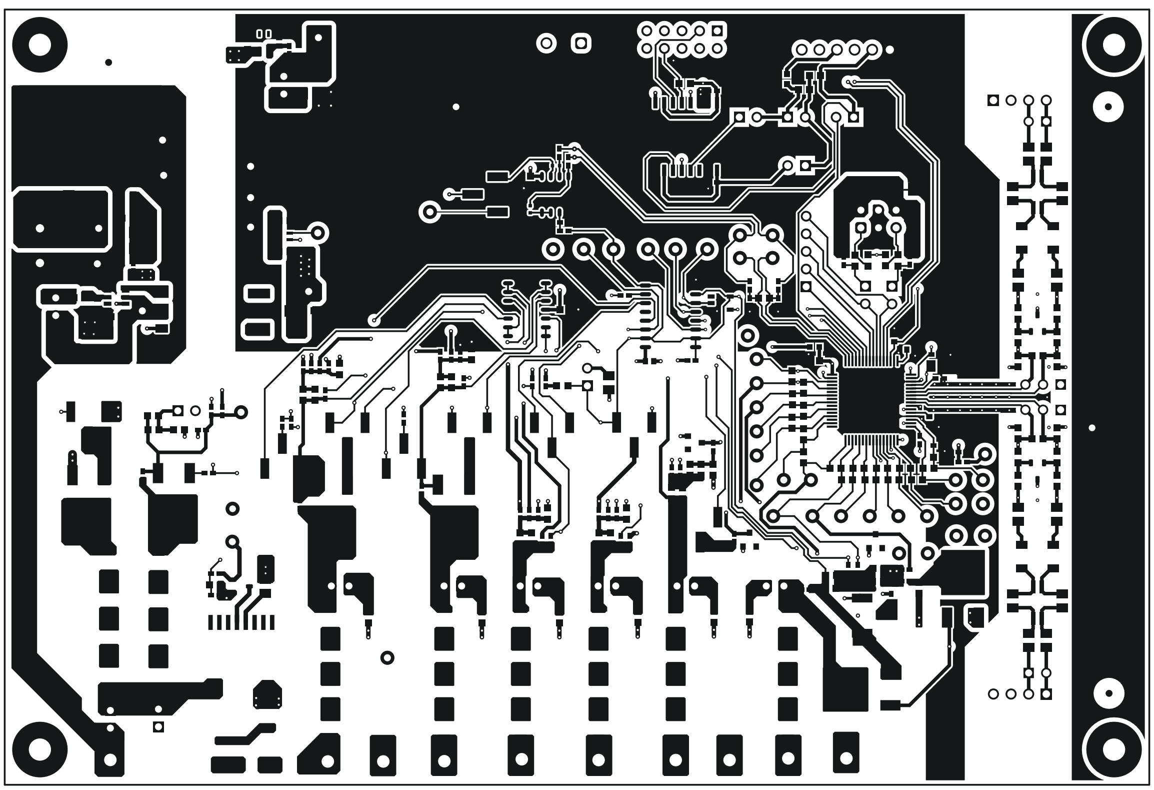


Figure 6-12. Top Layer

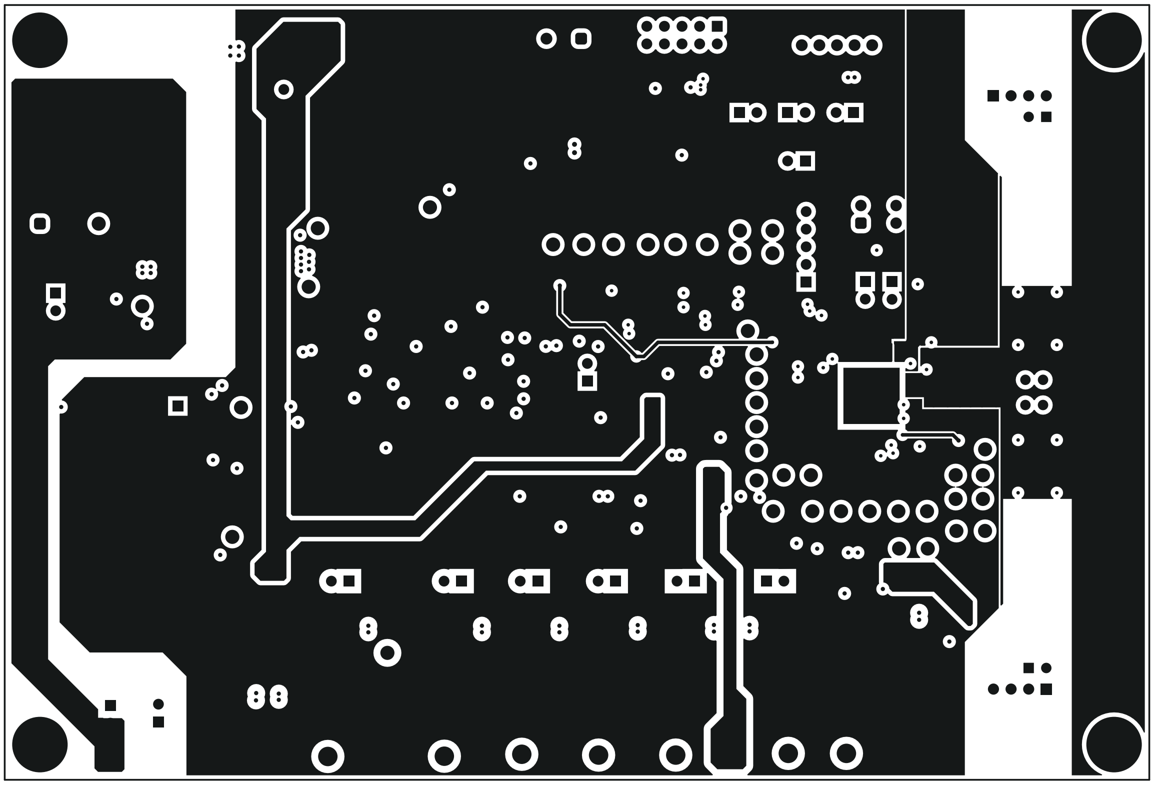


Figure 6-13. Signal Layer 1

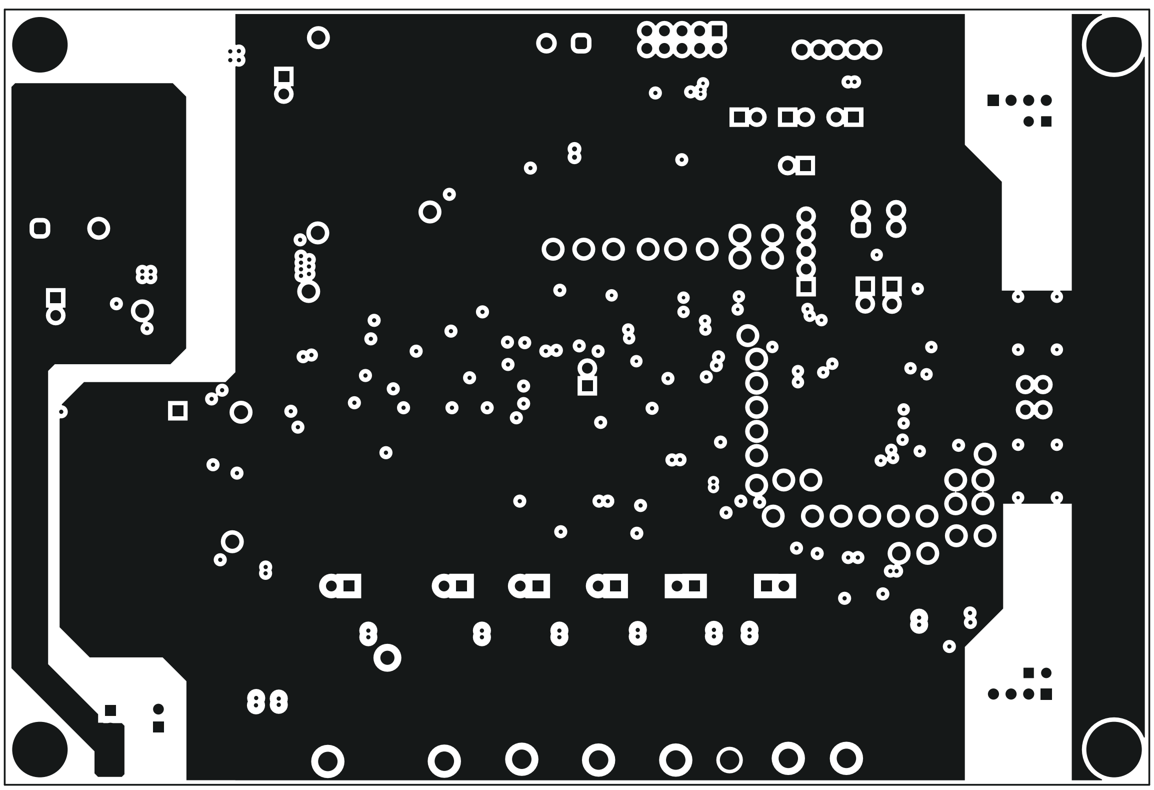


Figure 6-14. Signal Layer 2

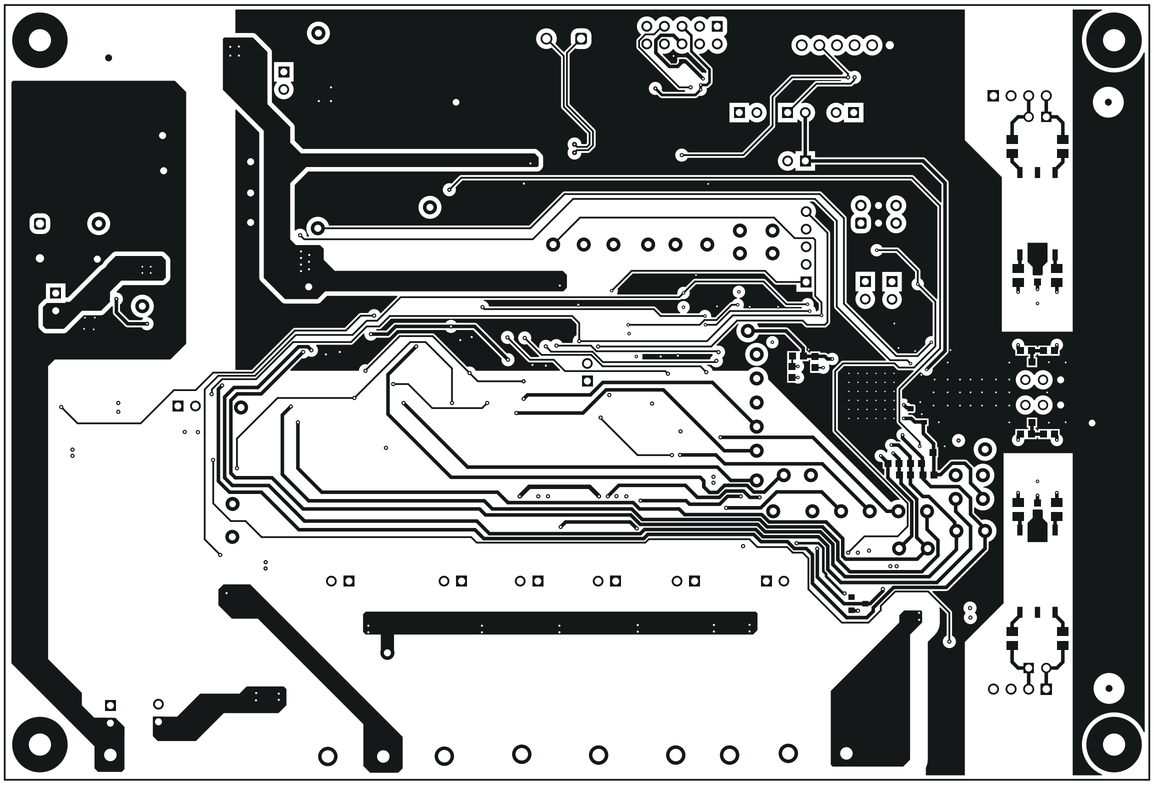


Figure 6-15. Bottom Layer

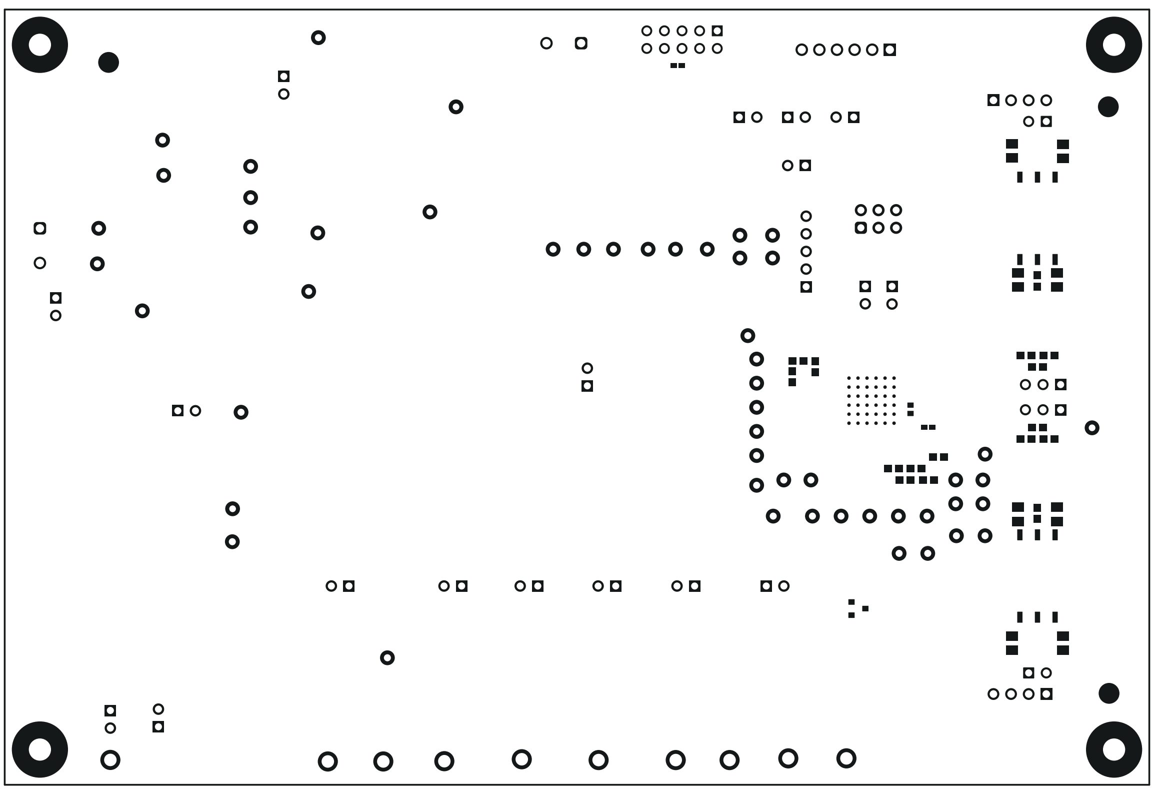


Figure 6-16. Bottom Solder

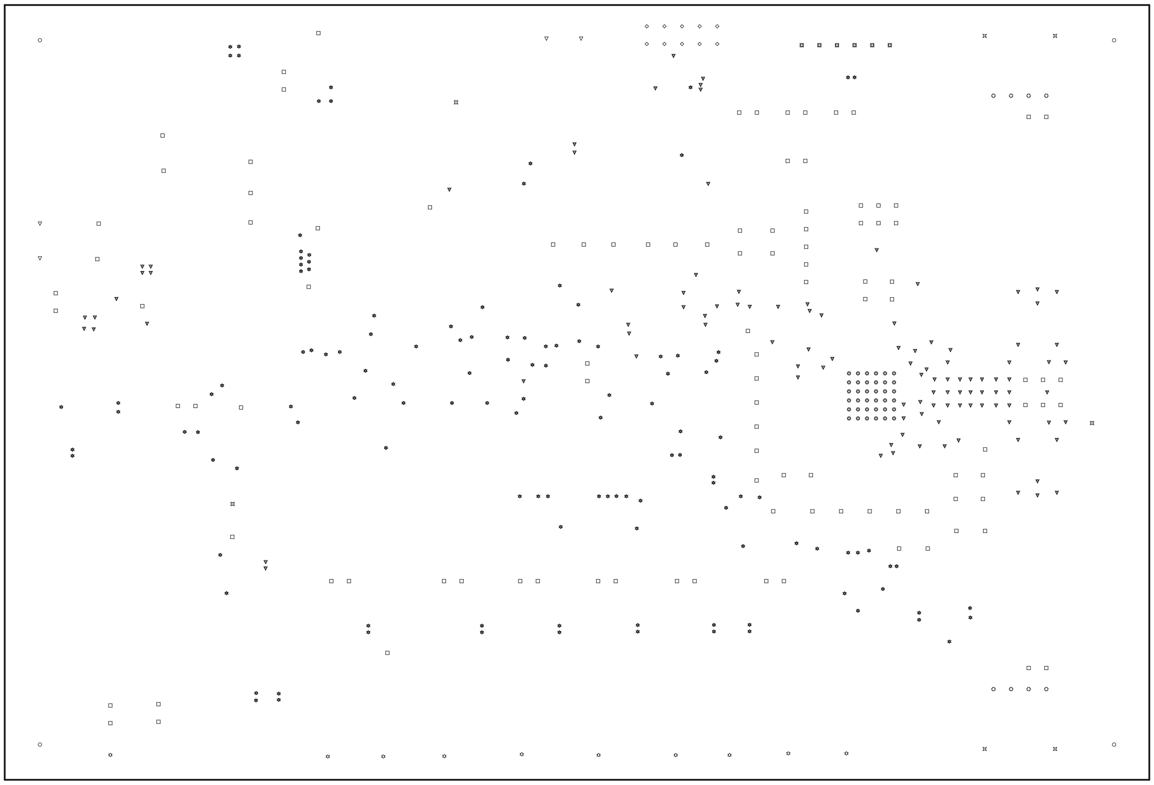


Figure 6-17. Drill Drawing

6.3 Bill of Materials

The following table details the EVM bill of materials.

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		BMS039	Any		
C1, C7, C10, C54, C55, C56	6	0.1uF	CAP, CERM, 0.1 µF, 16 V,±10%, X7R, 0603	0603	CL10B104KO8WPNC	Samsung Electro-Mechanics		
C8, C11	2	10uF	CAP, CERM, 10 uF, 16 V, ±10%, X7S, AEC-Q200 Grade 1, 0805	0805	CGA4J1X7S1C106K125AC	TDK		
C9, C24, C57, C61, C63, C64	6		CAP CER 0603 1UF 10 V X7R 10%	0603 (1608 Metric)	C0603C105K8RACAUTO	KEMET		
C16, C17, C18, C19	4	220 pF	CAP, CERM, 220 pF, 50 V, ±5%, X7R, 0603	0603	CL10B221JB8NNNC	Samsung Electro-Mechanics		
C20, C21, C22, C23	4	2200 pF	CAP, CERM, 2200 pF, 2000 V, ±10%, X7R, AEC-Q200 Grade 1, 1206	1206	1206J2K00222KXR	Knowles Capacitors		
C25, C26, C27, C32, C51, C53, C58, C59, C65, C66	10	0.1uF	CAP, CERM, 0.1 uF, 10 V, ±10%, X7R, AEC-Q200 Grade 1, 0402	0402	GCM155R71A104KA55D	MuRata		
C33	1	1uF	CAP, CERM, 1 µF, 16 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	CL10B105KO8VPNC	Samsung Electro-Mechanics		
C60, C67	2	0.01uF	CAP, CERM, 0.01 uF, 50 V, ±10%, X7R, 0603	0603	CL10B103KB8NCNC	Samsung Electro-Mechanics		
C62	1	4.7uF	CAP, CERM, 4.7 uF, 10 V, ±20%, X7R, 0805	0805	C2012X7R1A475M125AC	TDK		
C68	1	0.47uF	CAP, CERM, 0.47 uF, 16 V, ±10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71C474KA55D	MuRata		
D1, D3	2	30 V	Diode, Schottky, 30 V, 0.5 A, SOD-123	SOD-123	MBR0530T1G	ON Semiconductor		
D2	1	15 V	Diode, Zener, 15 V, 500 mW, SOD-123	SOD-123	MMSZ5245B-7-F	Diodes Inc.		
D4, D5, D6, D7	4		DIODE ZENER 12 V 225MW SOT23-3	SOT23-3	SZBZX84C12LT3G	On Semiconductor		
D9, D10	2	5.1V	Diode, Zener, 5.1 V, 300 mW, SOD-523	SOD-523	BZT52C5V1T-7	Diodes Inc.		
D11, D12	2	24 V	Diode, TVS, Bi, 24 V, 70 Vc, AEC-Q101, SOT-23	SOT-23	PESD1CAN,215	NXP Semiconductor		
FID1, FID2, FID3, FID4, FID5, FID6	6		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, J2, J3, J7, J8, J15, J16, J17, J18, J19, J20, J21, J22, J24, J29, J30, J31, J32	18		Header, 2.54mm, 1x2, Tin, Black, TH	Header, 2.54mm, 2x1, TH	PEC01DAAN	Sullins Connector Solutions		

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
J4, J9, J12, J13, J23, J33, J34, J35, J36, J37	10		Header, 2.54mm, 3x1, Gold, SMT	Header, 2.54mm, 3x1, SMT	87898-0304	Molex		
J5	1		Header, 2.54mm, 5x1, Tin, TH	Header, 2.54mm, 5x1, TH	PEC05SAAN	Sullins Connector Solutions		
J6	1		Header, 100mil, 3x2, Tin, TH	Header, 100mil, 3x2, TH	5-146254-3	TE Connectivity		
J10	1		CONN HEADER 10POS .100 DL R/A AU	HDR10	TSW-105-08-L-D-RA	Samtec		
J11	1		Header, 0.5mm, 6x1, R/A, Gold, TH	Header, 0.5mm, 6x1, R/A, TH	22-12-4062	Molex		
J25, J28	2		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions		
J26, J27	2		Header(shrouded), 2.54mm, 4x1, R/A, Gold, TH	Header(shrouded), 2.54mm, 4x1, R/A, TH	70551-0038	Molex		
J38	1		Terminal Block, 5 mm, 2x1, R/A, TH	Terminal Block, 5 mm, 2x1, R/A, TH	1792863	Phoenix Contact		
J39, J40	2		Header, 100mil, 3x1, Tin, TH	Header, 3 PIN, 100mil, Tin	PEC03SAAN	Sullins Connector Solutions		
L1	1	1000 ohm	Ferrite Bead, 1000 ohm @ 100 MHz, 0.2 A, 0402	0402	BLM15BD102SN1D	MuRata		
L3, L4	2	470uH	Coupled inductor, 470 uH, 0.4 A, 0.35 ohm, SMD	5x3.3mm	744242471	Wurth Elektronik		
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, Q2, Q3, Q5, Q6, Q7	6		N-Channel 1000 V 2.2A (Tc) 90W (Tc) Surface Mount DPAK	DPAK	STD4NK100Z	STMicroelectronics		
Q4	1	40 V	Transistor, NPN, 40 V, 0.2 A, SOT-523	SOT-523	MMBT3904T-7-F	Diodes Inc.		
Q9	1		Solid State SPST-NO (1 Form A) 16-SOIC (0.295", 7.50mm Width), 12 Leads	SO-16	ASSR-601JV-000E	Broadcom		
Q10	1	50 V	MOSFET, N-CH, 50 V, 0.22 A, SOT-23	SOT-23	BSS138	Fairchild Semiconductor		None
R1, R3, R4, R5, R6, R7, R9, R10, R13, R14, R20, R21, R25, R27, R29, R30, R34, R36, R42, R43, R48, R51, R55, R57, R99, R100, R101, R102, R104, R105, R106, R107, R108, R109, R110, R111	36	330k	RES, 330 k, 0.1%, 1 W, 1206	1206	TNPV1206330KBEEN	Vishay Draloric		
R2, R8, R32, R33, R44, R46, R117	7	124k	RES, 124 k, 0.1%, 0.1 W, 0603	0603	RG1608P-1243-B-T5	Susumu Co Ltd		

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R12, R19, R31, R52, R53, R61, R62, R63, R64, R66, R75, R76, R77, R80, R81, R82, R83, R86, R87, R88, R89, R91, R92, R112, R114, R118, R119, R156, R166, R173	30	0	RES, 0, 0%, 0.2 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0EDHP	Vishay-Dale		
R15, R16, R24, R69, R70, R71, R72, R78, R79, R115, R116	11	24.9k	RES, 24.9 k, 0.1%, 0.1 W, 0603	0603	RG1608P-2492-B-T5	Susumu Co Ltd		
R22	1	100	RES, 100, 0.1%, 0.1 W, 0603	0603	RG1608P-101-B-T5	Susumu Co Ltd		
R26, R28	2	2.0k	RES, 2.0 k, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6GEYJ202V	Panasonic		
R35	1	10.0	RES, 10.0, 1%, 0.25 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310R0FKEAHP	Vishay-Dale		
R37, R38, R67, R68	4	13.5k	RES, 13.5 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD0713K5L	Yageo America		
R41	1	30.0	RES, 30.0, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	ERJ-3EKF30R0V	Panasonic		
R45, R47, R49, R50, R56, R162, R163	7	10.0k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R59, R60, R84, R85, R90, R159	6	10.0k	RES, 10.0 k, 0.1%, 0.1 W, 0603	0603	RG1608P-103-B-T5	Susumu Co Ltd		
R95, R96, R97	3	100k	RES, 100 k, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KJNEA	Vishay-Dale		
R98	1	100	RES, 100, 5%, 0.25 W, AEC-Q200 Grade 0, 0603	0603	ESR03EZPJ101	Rohm		
R103	1	220	RES, 220, 5%, 0.125 W, AEC-Q200 Grade 0, 0805	0805	ERJ-6GEYJ221V	Panasonic		
R125	1	1.00k	RES, 1.00 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04021K00FKED	Vishay-Dale		
R128	1	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW040210K0FKED	Vishay-Dale		
R130, R133, R140, R143	4	51	RES, 51, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060351R0JNEA	Vishay-Dale		
R131, R132, R141, R142	4	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL	Yageo		
R136, R137	2	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	ERJ-3EKF1001V	Panasonic		
R144, R145, R146, R147, R148, R149, R150, R151, R152, R153, R154, R155	12	0	RES, 0, 5%, 0.333 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EAHP	Vishay-Dale		

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R167, R171	2		Res Thin Film 0402 100K Ohm 0.1% 1/16W ±25ppm/°C Molded SMD SMD Punched Carrier T/R	0402	ERA-2AEB104X	Panasonic		
R168, R169, R170, R172	4	10.0k	RES, 10.0 k, .1%, .0625 W, 0402	0402	RT0402BRD0710KL	Yageo America		
SH1, SH2, SH3, SH4, SH5, SH6, SH7, SH8, SH9, SH10, SH11, SH12, SH13, SH14, SH15, SH16, SH17	17		Shunt, 100mil, Gold plated, Black	Shunt 2 pos. 100 mil	881545-2	TE Connectivity		
T1	1	200uH	Transformer, 200 uH, SMD	11.43x8.3mm	750316856	Wurth Elektronik		
TP1, TP21, TP22, TP26, TP27, TP46, TP51, TP52, TP53, TP61	10		Terminal, Turret, TH, Double	Keystone1593-2	1593-2	Keystone		
TP2, TP3, TP6, TP7, TP42, TP62	6		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone		
TP4, TP5, TP8, TP9, TP10, TP11	6		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone		
TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP24, TP25, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP36, TP37, TP38, TP39, TP40, TP41, TP44, TP47, TP48, TP49, TP50, TP54, TP55, TP56, TP57, TP58, TP59, TP60	35		Test Point, Miniature, White, TH	White Miniature Testpoint	5002	Keystone		
TP43, TP45	2		Test Point, Miniature, Orange, TH	Orange Miniature Testpoint	5003	Keystone		
U1	1		Transformer Driver PMIC SOT-23-6	SOT-23-6	SN6505BQDBVTQ1	Texas Instruments		
U2	1		Single Output Automotive LDO, 50 mA, Fixed 3.3 V Output, 3 to 24 V Input, 5-pin SC70 (DCK), -40 to 125 degC, Green (RoHS & no Sb/Br)	DCK0005A	TPS71533QDCKRQ1	Texas Instruments		
U4	1		Automotive, Low Power, Quad-Channel 2/2 Digital Isolator, DW0016B (SOIC-16)	DW0016B	ISO7342CQDWRQ1	Texas Instruments	ISO7342CQDWQ1	Texas Instruments
U5	1		CMOS Quad Low-to-High Voltage Level Shifter, 3 to 18 V, -55 to 125 degC, 16-Pin SO (NS16), RoHS, Tape and Reel		CD40109BNSR	Texas Instruments		
U6	1		Automotive Catalog Single Inverter, DBV0005A, LARGE T&R	DBV0005A	SN74LVC1G04QDBVRQ1	Texas Instruments		Texas Instruments
U7	1		Low Power Quad Operational Amplifier, 14-pin Narrow SOIC			Texas Instruments		
U8	1		Automotive Catalog Dual Operational Amplifier, D0008A (SOIC-8)	D0008A	LM2904QDRQ1	Texas Instruments		Texas Instruments

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
U9	1		14S or 16S Standalone Precision Automotive Battery Monitor, Balancer and Integrated Current Sense with up to SafeTITM-26262 ASIL-D ASIL-D Compliance	HTQPF64	BQ79631PAPRQ1	Texas Instruments		
C2	0	10uF	CAP, CERM, 10 uF, 16 V, ±10%, X7R, AEC-Q200 Grade 1, 1206_190	1206_190	CGA5L1X7R1C106K160AC	TDK		
C3, C4, C28, C29, C30, C31, C34, C35, C36, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50, C52	0	0.1uF	CAP, CERM, 0.1 µF, 16 V, ±10%, X7R, 0603	0603	CL10B104KO8WPNC	Samsung Electro-Mechanics		
C5, C6	0	10uF	CAP, CERM, 10 uF, 16 V, ±10%, X7S, AEC-Q200 Grade 1, 0805	0805	CGA4J1X7S1C106K125AC	TDK		
C12, C13	0	100 pF	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, AEC-Q200 Grade 1, 0603	0603	GCM1885C1H101JA16J	MuRata		
C14, C15	0	0.01uF	CAP, CERM, 0.01 uF, 50 V, ±10%, X7R, 0603	0603	CL10B103KB8NCNC	Samsung Electro-Mechanics		
D8	0	5.1V	Diode, Zener, 5.1 V, 300 mW, SOD-523	SOD-523	BZT52C5V1T-7	Diodes Inc.		
J14	0		Terminal Block, 5 mm, 2x1, R/A, TH	Terminal Block, 5 mm, 2x1, R/A, TH	1792863	Phoenix Contact		
L2	0	70 ohm	Ferrite Bead, 70 ohm @ 100 MHz, 0.6 A, 0402	0402	BLM15AG700SN1D	MuRata		
R11, R17, R18, R23, R39, R40, R54, R58, R65, R73, R74, R94, R113, R158, R160, R165	0	0	RES, 0, 0%, 0.2 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0EDHP	Vishay-Dale		
R93, R157, R161	0	24.9k	RES, 24.9 k, 0.1%, 0.1 W, 0603	0603	RG1608P-2492-B-T5	Susumu Co Ltd		
R120, R121, R122, R123, R124, R126, R127, R129	0	0	RES, 0, 5%, 0.333 W, AEC-Q200 Grade 0, 0805	0805	CRCW08050000Z0EAHP	Vishay-Dale		
R134, R135, R138, R139	0	499	RES, 499, 1%, 0.1 W, 0603	0603	RC0603FR-07499RL	Yageo		
R164	0	10.0k	RES, 10.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
T2, T3	0		BMS TRANSFORMER	SMT_TRANSFORMER_8MM89_10MM09	HMU1228NL	Pulse		
U3	0		Single Output Automotive LDO, 700 mA, Fixed 5 V Output, 5.5 to 42 V Input, 3-pin PFM (KVU), -40 to 125 degC, Green (RoHS & no Sb/Br)	KVU0003A	TL720M05QKVURQ1	Texas Instruments		

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