User's Guide

SLUU445B–September 2010–Revised May 2011

bq24707EVM for Multicell, Synchronous, Switch-Mode Charger With SMBus Interface

The bq24707 evaluation module is a complete charger module for evaluating a multicell (1 to 4 cells) synchronous notebook charger using the bq24707 devices. Included in this document are the bill of materials, board art, and schematic.

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1 Introduction

1.1 EVM Features

- Evaluation module for bq24707
- High-efficiency NMOS-NMOS synchronous buck charger with 750-kHz frequency
- User-selectable 1- to 4-cell Li-ion battery voltage
- Programmable battery voltage, charge current, and ac adapter current via SMBus interface
- Flexible Chargeoption() register control via SMBus interface
- AC adapter operating range 5 V to 24 V
- Test points for key signals available for testing purpose. Easy probe hook-up.
- Jumpers available. Easy-to-change connections.

1.2 General Description

The bq24707 evaluation module, also known as the HPA558, is a complete charger module for evaluating a multicell (1 to 4 cells) synchronous notebook charger using the bq24707 devices. It is designed to deliver up to 4 A of charge current to Li-ion or Li-polymer applications. The charge current is programmable by an SMBus interface through the EV2300 interface board. The bq24707EVM does not come with the EV2300 interface board, so it must be ordered separately.

The bq24707 is a high-efficiency, synchronous battery charger, offering low component count for space-constrained, multichemistry battery-charging applications. The charge voltage, charge current, input current, and flexible charge option are programmable via SMBus interface.

The bq24707 uses the internal input current register or external ILIM pin to throttle down PWM modulation to reduce the charge current.

The bq24707 provides an IFAULT output to alarm if any MOSFET fault or input overcurrent occurs. This alarm output allows users to turn off input power selectors when the fault occurs. Meanwhile, an independent comparator with internal reference is available to monitor input current, output current, or output voltage.

For details, see the bq24707 data sheet (SLUSA78).

1.3 I/O Description

Table 1. I/O Description

Jack	Description
J1–DCIN	AC adapter, positive output
J1–GND	AC adapter, negative output
J2–SYS	Connected to system
J2–BAT	Connected to battery pack
J2–GND	Ground
J3–3.3V	External voltage supply 3.3 V
J3–IOUT	IOUT pin
J3–ACOK	ACOK pin
J4–/IFAULT	IC /IFAULT pin
J4–SDA	SDA pin output, SMBus data line
J4–SCL	SCL pin output, SMBus clock line
J4–GND	External power supply, negative output

1.4 Controls and Key Parameters Setting

Table 2. Controls and Key Parameters Setting

Jack	Description	Factory Setting
JP1	Battery voltage set ACDET connection: Jumper installed: battery voltage can set ACDET voltage when DCIN is unavailable. Jumper uninstalled: only DCIN can set ACDET.	Jumper installed
JP2	External DPM (ILIM control) connection: When jumper installed, external DPM circuit is active. When jumper uninstalled, only internal DPM circuit is active.	Jumper uninstalled
JP3	Battery voltage power VCC connection: Jumper installed: battery can power up Vcc when DCIN is unavailable. Jumper uninstalled: VCC is disconnected from battery.	Jumper installed
JP4	bq24707 internal independent comparator setting: ICMP-2: Internal comparator to monitor Iout. 2-VCMP: Internal comparator to monitor Vout.	Jumper installed on ICMP-2

1.5 Recommended Operating Conditions

Table 3. Recommended Operating Conditions

Symbol	Description	Min	Typ	Max	Unit	Notes
Supply voltage, V_{IN}	Input voltage from ac adapter input	18	19-20	22	V	
Battery voltage, V_{BAT}	Voltage applied at VBAT terminal	0	3-16.8	20	V	
Supply current, I_{AC}	Maximum input current from ac adapter input	0		4.5	A	
Charge current, I_{chrg}	Battery charge current	1	3	4	A	
Operating junction temperature range, T_J		0		125	°C	

2 Test Summary

2.1 Definitions

This procedure details how to configure the HPA558 evaluation board. On the test procedure, the following naming conventions are followed. See the HPA558 schematic for details.

VXXX :	External voltage supply name (VADP, VBT, VSBT)
LOADW:	External load name (LOADR, LOADI)
V(TPyyy):	Voltage at internal test point TPyyy. For example, V(TP12) means the voltage at TP12.
V(Jxx):	Voltage at jack terminal Jxx.
V(TP(XXX)):	Voltage at test point XXX. For example, V(ACDET) means the voltage at the test point which is marked as ACDET.
V(XXX, YYY):	Voltage across point XXX and YYY.
I(JXX(YYY)):	Current going out from the YYY terminal of jack XX.
Jxx(BBB):	Terminal or pin BBB of jack xx
Jxx ON :	Internal jumper Jxx terminals are shorted
Jxx OFF:	Internal jumper Jxx terminals are open
Jxx (-YY-) ON:	Internal jumper Jxx adjacent terminals marked as YY are shorted
Measure: → A,B	Check specified parameters A, B. If measured values are not within specified limits the unit under test has failed.
Observe: → A,B	Observe if A, B occur. If they do not occur, the unit under test has failed.

Assembly drawings have location for jumpers, test points and individual components.

2.2 Equipment

2.2.1 Power Supplies

Power Supply #1 (PS#1): a power supply capable of supplying 20 V at 5 A is required.

Power Supply #2 (PS#2): a power supply capable of supplying 5 V at 1 A is required.

Power Supply #3 (PS#3): a power supply capable of supplying 20 V at 1 A is required.

2.2.2 Load #1

A 30-V (or greater), 5-A (or greater) electronic load that can operate at constant current mode

2.2.3 Load #2

A HP 6060B 3-V to 60-V/0-A to 60-A, 300-W system dc electronic load or equivalent.

2.2.4 Meters

Seven Fluke 75 multimeters (equivalent or better)

Or four equivalent voltage meters and three equivalent current meters.

The current meters must be capable of measuring a 5-A or greater current.

2.2.5 Computer

A computer with at least one USB port and a USB cable. The EV2300 USB driver and the bq24707 SMB evaluation software must be properly installed.

2.2.6 EV2300 SMBUS Communication Kit

An EV2300 SMBUS communication kit

2.2.7 Software

Install the EV2300 driver before installing the bq24707 software: Driver (USB EV2300) Installer XP2K-Last updated Jan28-04.zip or later: This is the EV2300 USB driver. Save and unzip to c:\temp (or other local directory). Double-click on the setup.exe file. Follow the installation steps.

This software needs to be installed after the EV2300 USB driver: bq24725 EVM setup.zip (SLUC202). This is the bq24725 SMB evaluation software. It is also used on the HPA558 evaluation. Save and unzip to c:\temp (or other local directory). Double-click on the SETUP.EXE file. Follow the installation steps:

1. **Note:** On first inserting the EV2300 into the USB port of the personal computer (PC), the user needs to follow the instructions of the Found New Hardware Wizard.
2. Allow Windows™ to connect to Windows Update to search for software. Then click Next.
3. Select Install software automatically (Recommended). Then click Next.
4. If a window pops up informing that the TI USB Firmware Updater has not passed Windows Logo testing, click Continue Anyway.
5. If a target file already exists and is newer, do not overwrite the newer file.
6. Click Finish.

2.3 Equipment Setup

1. Set the power supply #1 for 0 V ±100 mVdc with the current limit set to >5 A, and then turn off supply.
2. Connect the output of power supply #1 in series with a current meter (multimeter) to J1 (DCIN, GND).
3. Connect a voltage meter across J1 (DCIN, GND).
4. Set the power supply #2 for 3.3 V ±100 mVdc, 0.2 ±0.1-A current limit, and then turn off supply.
5. Connect the output of the power supply #2 to J3 (3.3 V) and J4 (GND).
6. Connect a voltage meter across J2 (BAT, GND).
7. Connect a voltage meter across J2 (SYS, GND).
8. Connect J4 (SDA, SCL) and J4 (GND) to the EV2300 kit SMB port. Refer to Table 4 for a connection reference. Connect the USB port of the EV2300 kit to the USB port of the computer. The connections are shown in Figure 1.

Table 4. EV2300 and bq24707 EVM Connections

Bq24707EVM-558	EV2300
GND (J4)	GND (1)
SCL (J4)	SMBC (2)
SDA (J4)	SMBD (3)

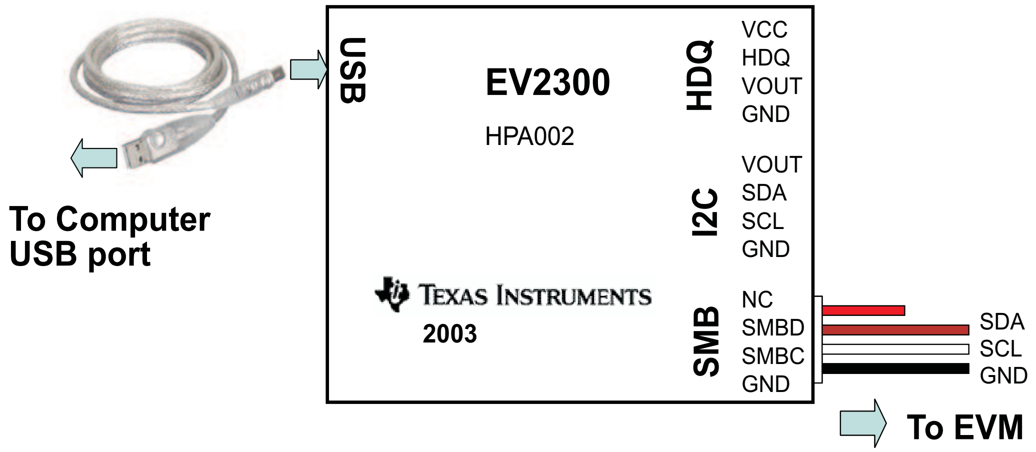

Figure 1. Connections of the EV2300 Kit

9. Install JP1, JP3. Do not install JP2. Install JP4 on ICMP-2
10. After these steps, the test setup for HPA558 appears as is shown in Figure 2.

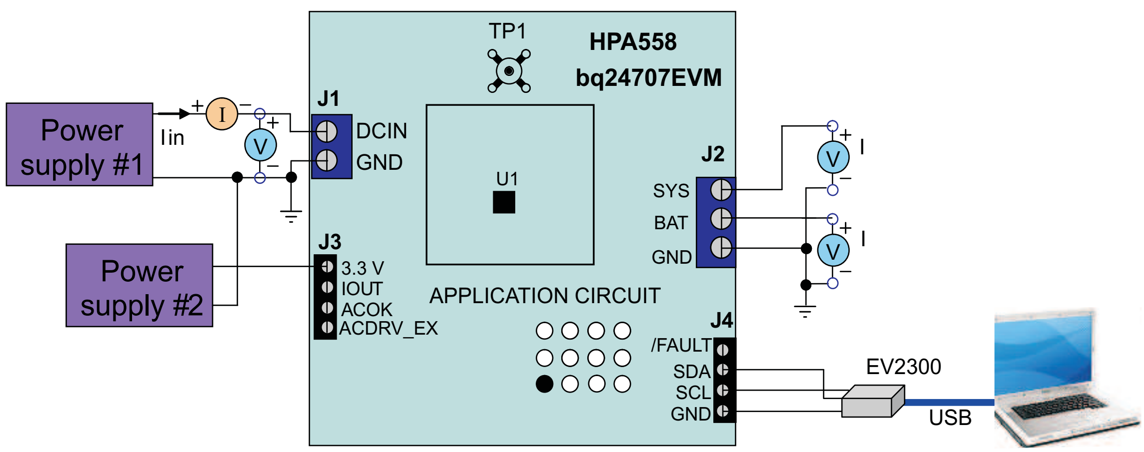

Figure 2. Original Test Setup for bq24707EVM

11. Turn on the computer. Open the bq24707 evaluation software. The main window of the software is

shown in Figure 3.

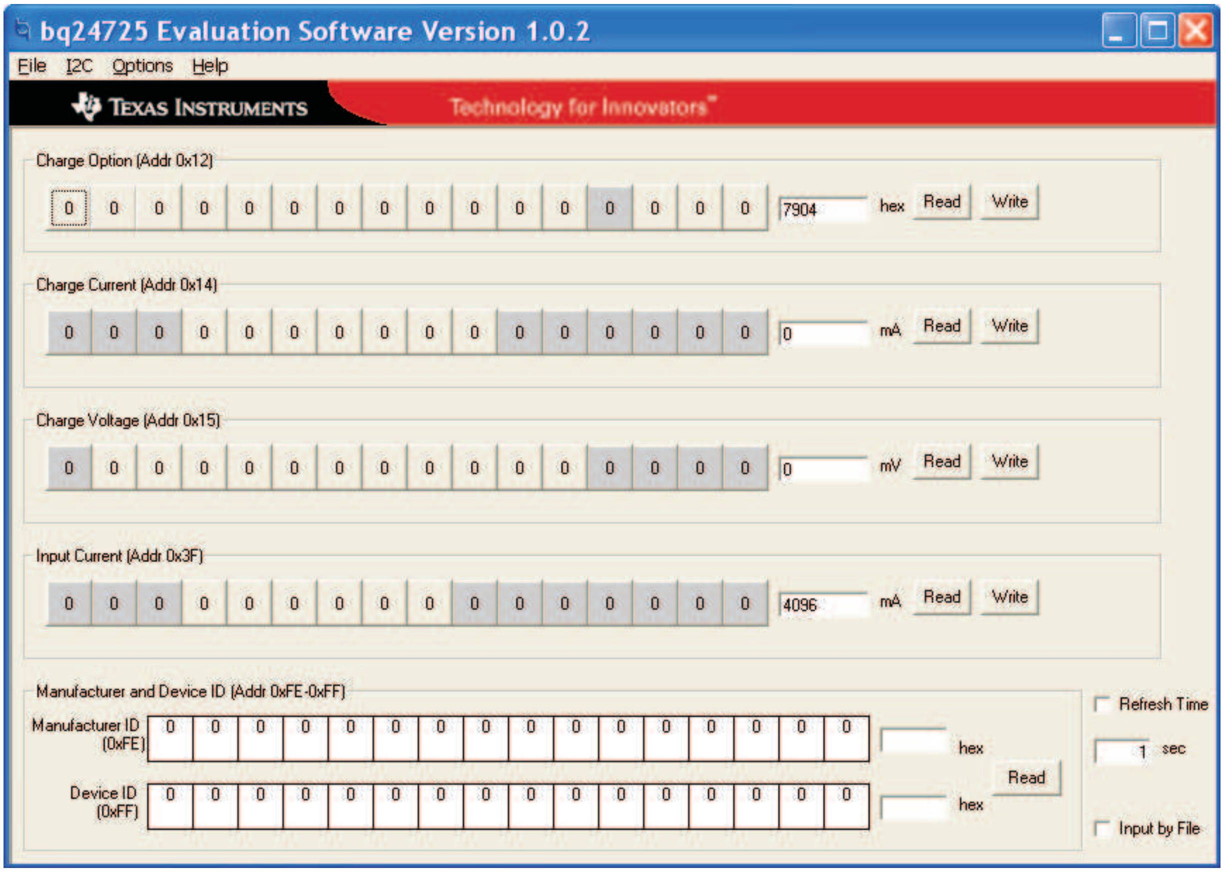

Figure 3. Main Window of the bq24707 Evaluation Software

2.4 Procedure

2.4.1 AC Adapter Detection Threshold

Ensure that the Section 2.3 steps are followed. Turn on PS#2.
Note that Load #1 and Load #2 are not connected during this step.

Turn on PS#1.
Increase the output voltage of PS#1 to 19.5 V.
Measure → V(TP(ACDET)) = 2.6 V ±0.1 V
Measure → V(TP(ACOK)) = 0.1 V ±0.1 V
Measure → V(J2(SYS)) = 19.5 V ±0.5 V
Measure → V(TP(REGN)) = 6 V ±0.5 V
Measure → V(J2(BAT, GND)) = 1 V ±1 V

2.4.2 Charger Parameters Setting

In the software main window, click all the Read buttons. Ensure that no error information is generated.

If a error information window pops up with this message, "USB Error. Insure USB cable is connected and Driver is working." Do the following steps:

1. Click OK. Then close main window that shows as Figure 3, and disconnect USB cable.

2. Check 3.3-V power supply (PS#2) and power supply #1 (PS#1) voltage on the EVM board.
3. Disconnect any other unsure SMBus connection. Plug in USB cable back to the original EVM2300 installation USB port.
4. Open the bq24707 evaluation software. The main window of the software is shown in Figure 3.

In the software main window, click all the Read buttons.

Type in "512" (mA) in the Charge Current DAC, and click Write. This sets the battery charge current regulation threshold.

Type in "12592" (mV) in the Charge Voltage DAC, and click Write. This sets the battery voltage regulation threshold.

Measure → V(J2(BAT)) = 12.6 V ±200 mV

2.4.3 Charge Current and AC Current Regulation (DPM)

Type in "7905" in the Charge Option, and click Write; this disables charging.

Connect the Load #2 in series with a current meter (multimeter) to J2 (BAT, GND). Ensure that a voltage meter is connected across J2 (BAT, GND). Turn on the Load #2. Use the constant voltage mode. Set the output voltage to 10.5 V.

Connect the output of the Load #1 in series with a current meter (multimeter) to J2 (SYS, GND). Ensure that a voltage meter is connected across J2 (SYS, GND). Turn on the power of the Load #1. Set the load current to 30 A ±50 mA but disable the output. The setup is now like that shown in Figure 4 for HPA558. Ensure that Ibat = 0 A ±10 mA and Isys = 0 A ±10 mA.

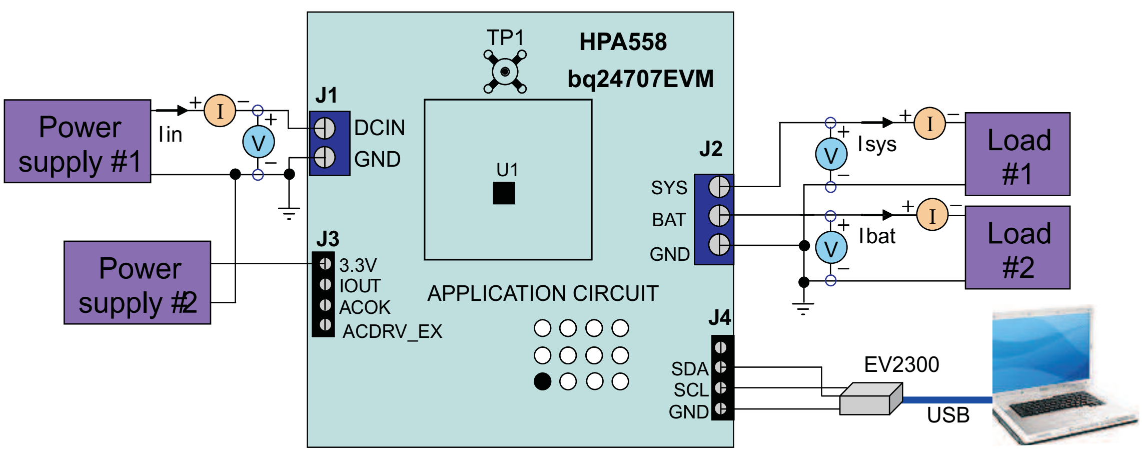

Figure 4. Test Setup for bq24707EVM

Type in "7904" in the Charge Option, and click Write; this enables charging.

Measure → Ibat = 500 mA ±100 mA

Type in "2944" (mA) in the Charge Current DAC, and click Write. This sets the battery charge current regulation threshold to 2.944 A.

Measure → Ibat = 3000 mA ±300 mA

Measure → V(TP(IOUT)):= 340 mV ±40 mV

Enable the output of the Load #1.

Measure → Isys = 3000 mA ±300 mA, Ibat = 1600 mA ±300 mA, Iin = 4100 mA ±400 mA

Measure → V(TP(IOUT)) = 820 mV ±100 mV

Turn off the Load #1.

Measure → Isys = 0 ±100 mA, Ibat = 3000 mA ±300 mA.

2.4.4 Power Path Selection

Type in "7905" in the Charge Option, and click Write; this disables charging.

Replace Load #2 and current meter with PS#3. Ensure that a voltage meter is connected across J2 (BAT, GND). Enable the output of the PS #3. Ensure that the output voltage is 10 V ±500 mV.

Measure → V(J2(SYS)) = 19.5 V ±1 V (adapter connected to system)

Turn off PS#1.

Measure → V(J2(SYS)) = 10 V ±1 V (battery connected to system)

Measure → V(J2(BAT)) = 10 V ±1 V (battery connected to system)

3 PCB Layout Guideline

The switching node rise and fall times must be minimized for minimum switching loss. Proper layout of the components to minimize high-frequency current path loop is important to prevent electrical and magnetic field radiation and high-frequency resonant problems. A printed-circuit board (PCB) layout priority list for proper layout follows. Lay out the PCB according to this specific order is essential.

1. Place the input capacitor as close as possible to the switching MOSFET's supply and ground connections, and use the shortest copper trace connection. These parts must be placed on the same PCB layer instead of on different layers, and use vias to make this connection.
2. The integrated circuit (IC) must be placed close to the switching MOSFET's gate terminals. Keep the gate drive signal traces short for a clean MOSFET drive. The IC can be placed on the other side of the PCB of switching MOSFETs.
3. Place inductor input terminal as close as possible to switching MOSFET's output terminal. Minimize the copper area of this trace to lower electrical and magnetic field radiation, but make the trace wide enough to carry the charging current. Do not use multiple layers in parallel for this connection. Minimize parasitic capacitance from this area to any other trace or plane.
4. The charging current sensing resistor must be placed right next to the inductor output. Route the sense leads connected across the sensing resistor back to the IC in the same layer, close to each other (minimize loop area), and do not route the sense leads through a high-current path. Place decoupling capacitor on these traces next to the IC.
5. Place output capacitor next to the sensing resistor output and ground.
6. Output capacitor ground connections need to be tied to the same copper that connects to the input capacitor ground before connecting to system ground.
7. Use single ground connection to tie charger power ground to charger analog ground. Just beneath the IC, use analog ground copper pour, but avoid power pins to reduce inductive and capacitive noise coupling.
8. Route analog ground separately from power ground. Connect analog ground, and connect power ground separately. Connect analog ground and power ground together using power pad as the single ground connection point, or use a 0-Ω resistor to tie analog ground to power ground (power pad must tie to analog ground in this case, if possible).
9. Decoupling capacitors must be placed next to the IC pins; make trace connection as short as possible.
10. It is critical that the exposed power pad on the backside of the IC package be soldered to the PCB ground. Ensure that sufficient thermal vias are directly under the IC, connecting to the ground plane on the other layers.

4 Bill of Materials, Board Layouts, and Schematic

4.1 Bill of Materials

Table 5. Bill of Materials

bq24707 -001	RefDes	Value	Description	Size	Part Number	MFR
1	C1	2.2 µF	Capacitor, Ceramic, 25V, X7R, 10%	1210	Std	Std
6	C2, C3, C4, C5, C6, C7	10 µF	Capacitor, Ceramic, 25V, X7R, 10%	1206	Std	Std
0	C8, C13, C18, C27	OPEN	Capacitor, Ceramic, 25V, X7R, 10%	603	Std	Std
4	C9, C10, C20,C28	1 µF	Capacitor, Ceramic, 25V, X5R, 10%	603	Std	Std
2	C11, C26	0.01 µF	Capacitor, Ceramic, 25V, X7R, 10%	603	Std	Std
1	C12	6.8 nF	Capacitor, Ceramic, 25V, X7R, 10%	603	Std	Std
8	C14, C15, C16, C17, C19, C23, C24, C25	0.1 µF	Capacitor, Ceramic, 25V, X7R, 10%	603	Std	Std
1	C21	0.047 µF	Capacitor, Ceramic, 25V, X7R, 10%	603	Std	Std
1	C22	100 pF	Capacitor, Ceramic, 25V, X7R, 10%	603	Std	Std
1	C29					
2	D1, D4	BAT54-V-G	Diode, Schottky, 200-mA, 30-V	SOT23	BAT54-V-G	Vishay-Liteon
1	D2	BAT54C-V-G	Diode, Dual Schottky, 200-mA, 30-V	SOT23	BAT54C-V-G	Vishay-Liteon
1	D3	1SS400	Diode, High-Speed Switching 80V, 100mA	SOD-523	1SS400	Toshiba
1	D5	PDS1040	Diode, 10A 40V Schottky Barrier Rectifier	PowerDI 5	PDS1040	Diodes
1	D6	BAT30K	Small signal Schottky diodes, 300mA, 30V	SOD-523	BAT30KFILM	STMicroelectronics
1	J1	ED120/2DS	Terminal Block, 2-pin, 15-A, 5.1mm	0.40 x 0.35 inch	ED120/2DS	OST
1	J2	ED120/3DS	Terminal Block, 3-pin, 15-A, 5.1mm	0.60 x 0.35 inch	ED120/3DS	OST
2	J3, J4	ED555/4DS	Terminal Block, 4-pin, 6-A, 3.5mm	0.55 x 0.25 inch	ED555/4DS	OST
3	JP1, JP2, JP3	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (2-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
1	JP4	PEC03SAAN	Header, Male 3-pin, 100mil spacing, (3-pin strip)	0.100 inch x 3	PEC03SAAN	Sullins
4		929950-00	Shorting jumpers, 2-pin, 100mil spacing,		929950-00	3M/ESD
1	L1	4.7 µH	Inductor, SMT	0.255 x 0.270 inch	IHLP2525CZER4R7M01	Vishay
2	Q1, Q3	Si4435DDY-T1	MOSFET, PChan, -30V, -9A, 35millohm	PWRPAK S0-8	Si4435DDY-T1	Vishay
0	Q2	FDS6680A	MOSFET, NChan, 30V, 12.5A, 9.5millohm	PWRPAK S0-8	FDS6680A	Fairchild
2	Q4, Q5	Sis412DN-T1	MOSFET, NChan, 30V, 12A, 30millohm	PWRPAK 1212	Sis412DN-T1	Vishay
1	Q6	MMST3904-7-F	Trans, NPN, 40V, 200mA	SOT-323	MMST3904-7-F	Diodes
0	Q7	BSS138W-7-F	MOSFET, Nch, 50V, 200mA,	SOT-323	BSS138W-7-F	Diodes
0	Q8	Si1304BDL-T1	MOSFET, Nch, 30V, 0.9A, 270 mΩ	SOT-323	Si1304BDL-T1	Vishay
1	Q9	Si1304BDL-T1	MOSFET, Nch, 30V, 0.9A, 270 mΩ	SOT-323	Si1304BDL-T1	Vishay
1	Q10	DCX124EK-7-F	Transistor, Dual Complimentary Pre-Biased 50V, 100mA	SC-74	DCX124EK-7-F	Diodes
2	R1, R2	0.01	Resistor, Chip, 3/4W, 1% 150PPM, Resistor, Chip, 1W, 1% 75 PPM	1206	PMR18EZPFU10L0 or WSLP1206R0100FEA	Rohm Vishay/Dale
2	R3, R5	0	Resistor, Chip, 1/16W, 5%	603	Std	Std
1	R4	7.5	Resistor, Chip, 0.5W, 5%	603	Std	Std
2	R6, R7	3.9	Resistor, Chip, 0.5W, 5%	1210	Std	Std
0	R8, R9	4.02k	Resistor, Chip, 1/10W, 1%	603	Std	Std
0	R10	OPEN	Resistor, Chip, 1/16W, 1%	603	Std	Std

Table 5. Bill of Materials (continued)

bq24707 -001	RefDes	Value	Description	Size	Part Number	MFR
7	R11, R18, R19, R30, R31, R34	10.0k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R12	33.0k	Resistor, Chip, 1/16W, 1%	603	Std	Std
0	R13	1.00M	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R14	66.5k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R15	430k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R16	10.0	Resistor, Chip, 1/4W, 1%	1206	Std	Std
0	R17	10.0k	Resistor, Chip, 1/4W, 1%	1206	Std	Std
4	R20, R28, R29, R37	100k	Resistor, Chip, 1/16W, 1%	603	Std	Std
0	R21	12.1k	Resistor, Chip, 1/4W, 1%	1206	Std	Std
2	R22, R27	316k	Resistor, Chip, 1/16W, 1%	603	Std	Std
2	R23, R24	220k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R25	60.4k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R26	9.09k	Resistor, Chip, 1/16W, 1%	603	Std	Std
2	R32, R40	0	Resistor, Chip, 1/16W, 5%	603	Std	Std
1	R33	3.01M	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R35	10.0k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R36	39.2k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R38	30.1k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R39	422k	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R41	100	Resistor, Chip, 1/16W, 1%	603	Std	Std
0	R42	3.01M	Resistor, Chip, 1/16W, 1%	603	Std	Std
1	R43	10.0	Resistor, Chip, 1/4W, 1%	1206	Std	Std
1	TP1	131-4244-00	Adaptor, 3.5-mm probe clip (or 131-5031-00)	0.200 inch	131-4244-00	Tektronix
11	TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12		Test Point, White, Thru Hole Color Keyed	0.100 x 0.100 inch	5002	Keystone
1	TP13		Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	5001	Keystone
4			6-32 NYL nuts		NY HN 632	Building Fasteners
4	ST1,ST2,ST3,ST4	4816	STANDOFF M/F HEX 6-32 NYL 0.500"	sf_thvt_325_rnd	4816	Keystone
1	U1	bq24707RGR	IC, SMBus Charge Controller		bq24707RGR	TI
1	U2	LMV321IDBV	IC, Op-Amp Low Voltage Rail-to-Rail Output		LMV321IDBV	TI
1	–		Label	1.25 x 0.25 inch	THT-13-457-10	Brady
1	–	HPA558	2.75x3inch 4 layer 2oz. PCB	inch	HPA558	Any

4.2 Board Layouts

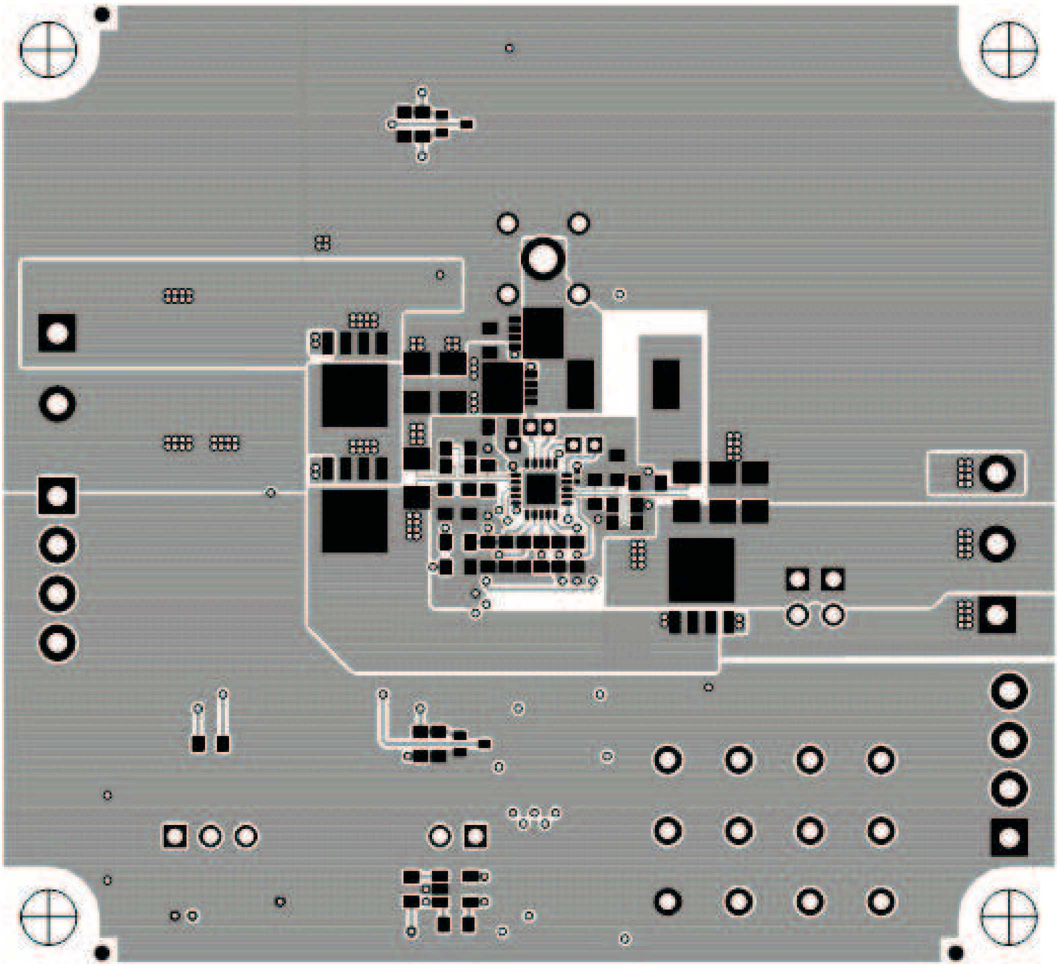

Figure 5. Top Layer

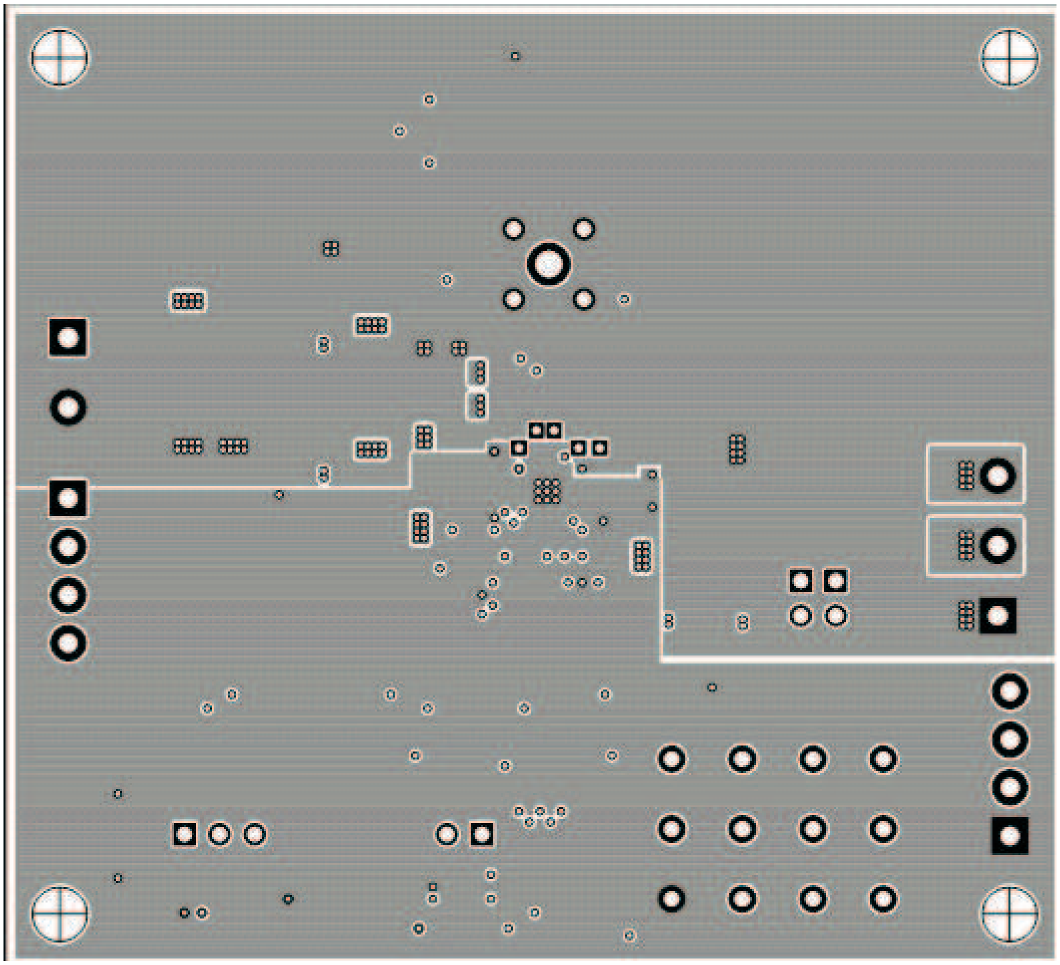

Figure 6. Second Layer

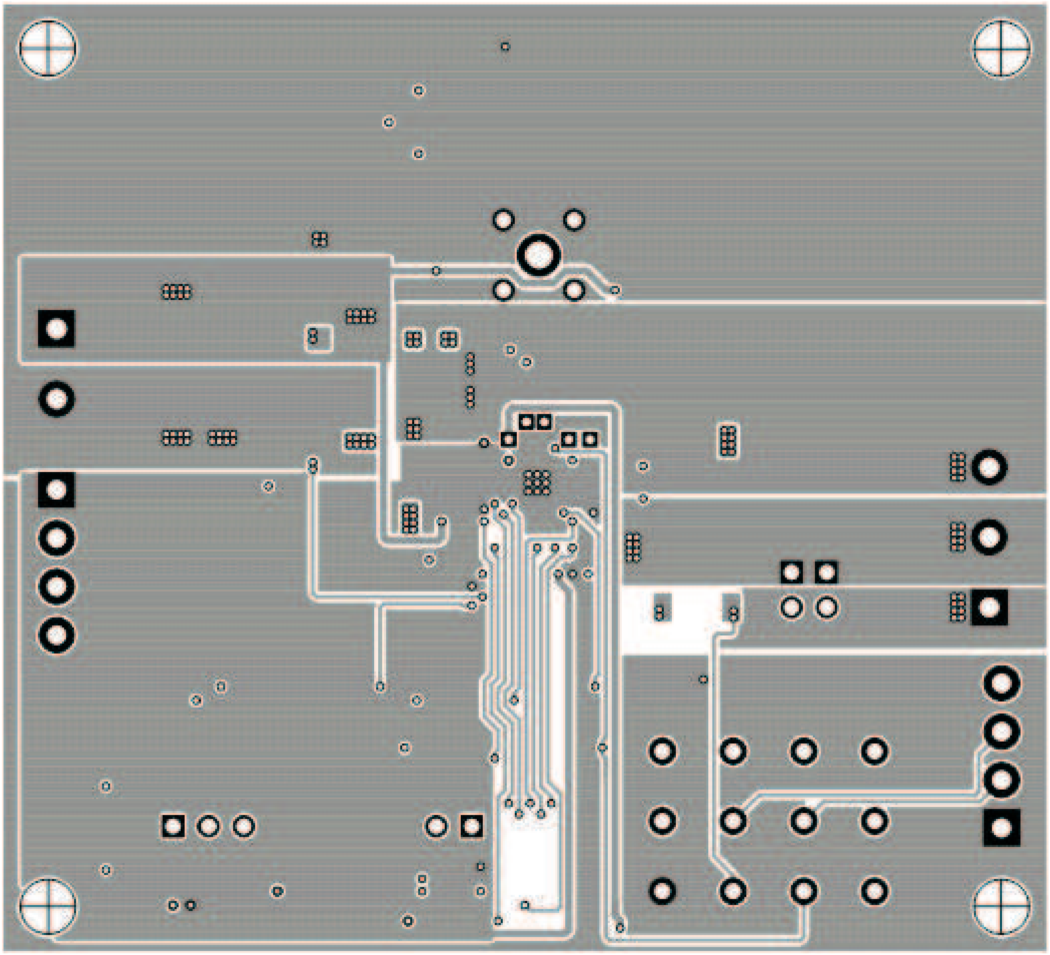

Figure 7. Third Layer

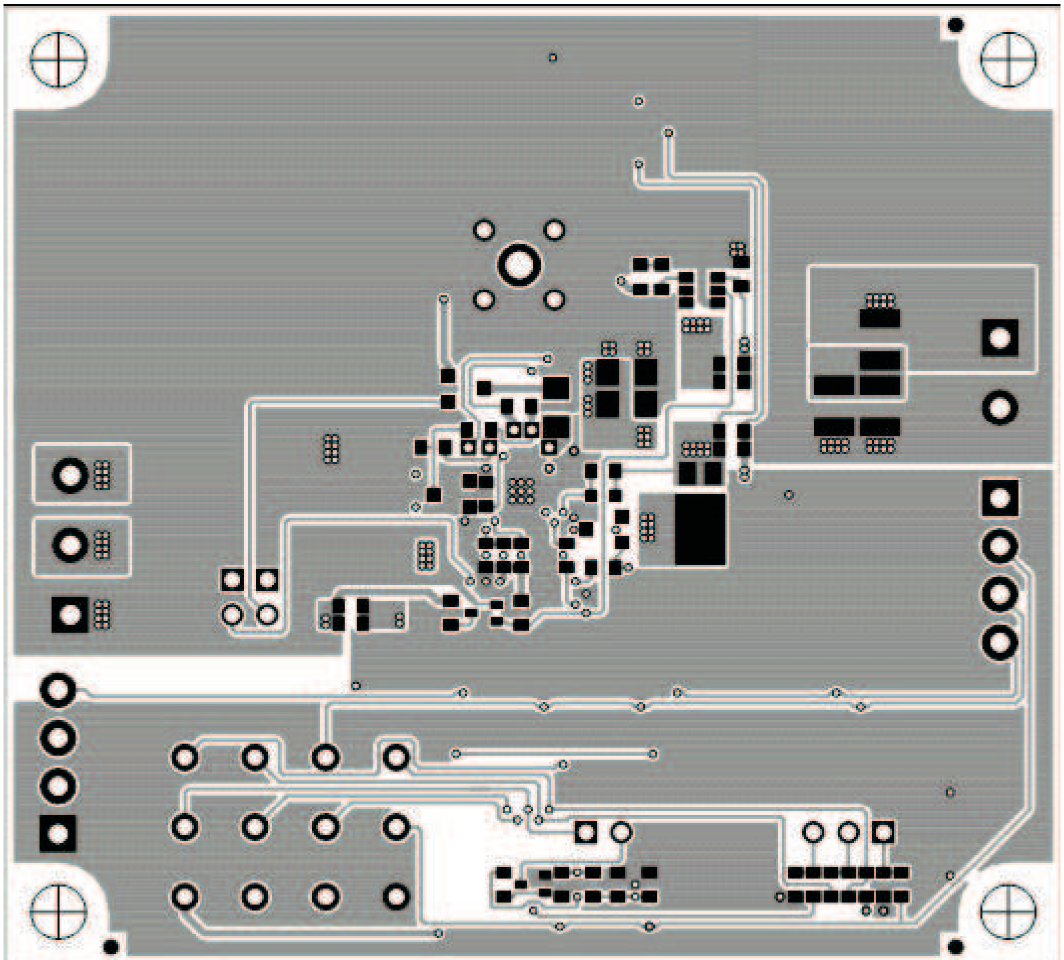

Figure 8. Bottom Layer

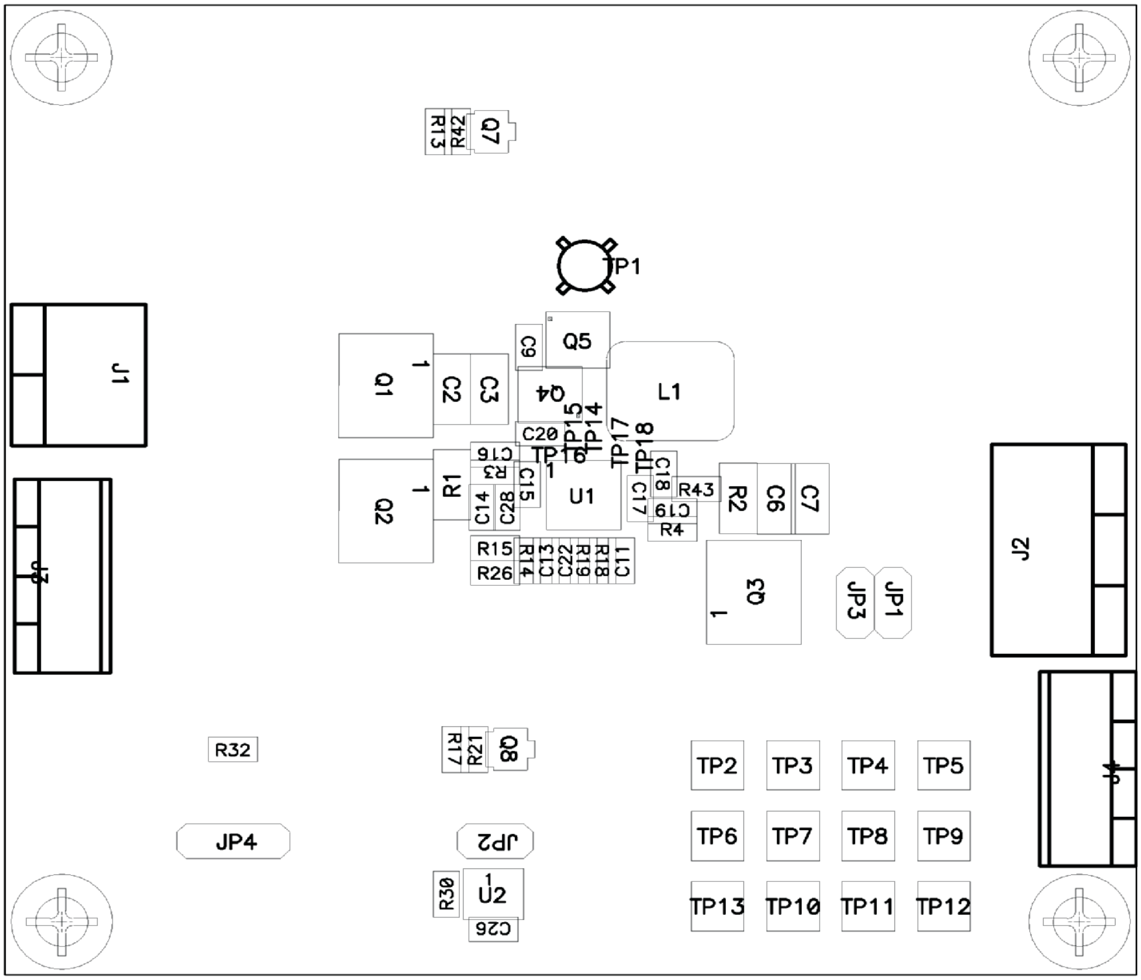

Figure 9. Top Assembly

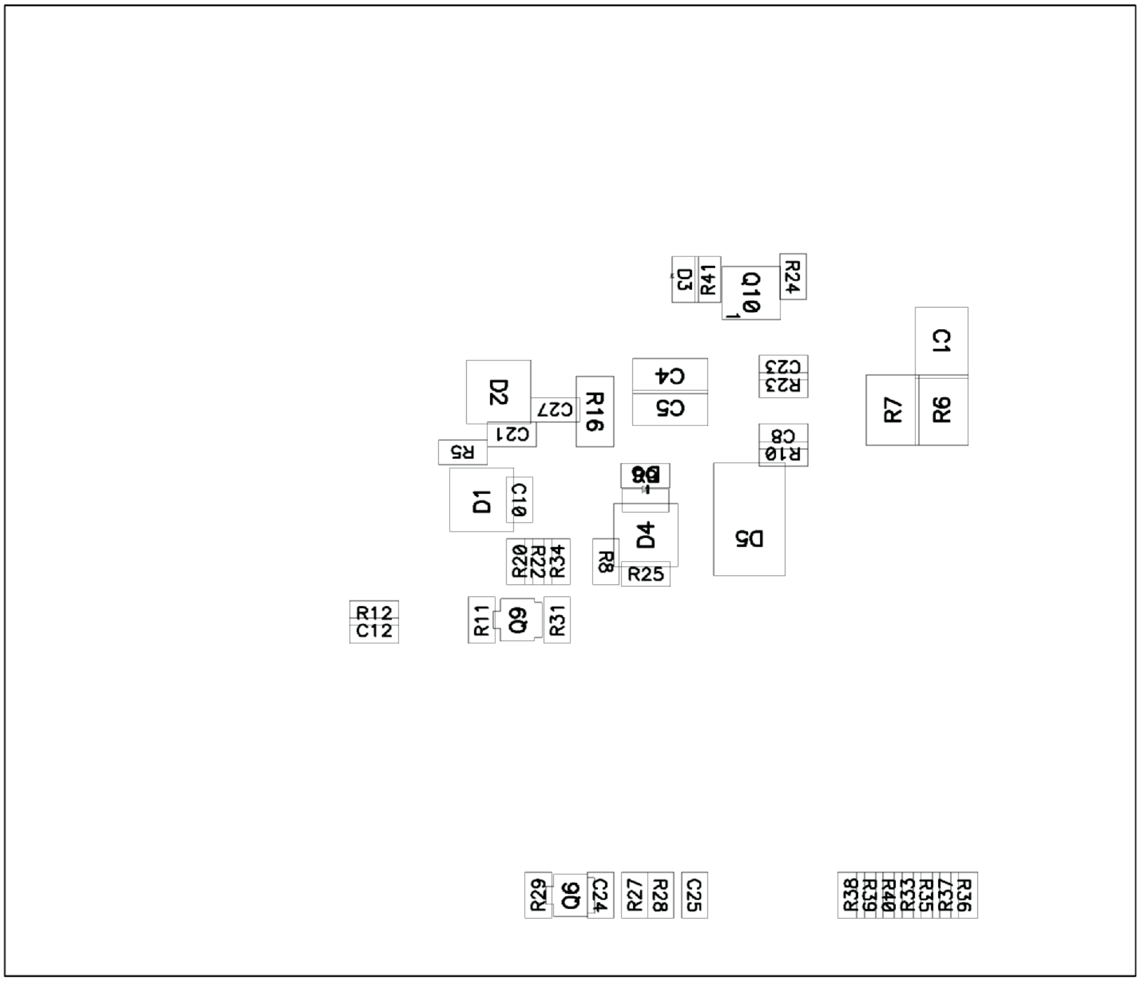

Figure 10. Bottom Assembly

4.3 Schematic

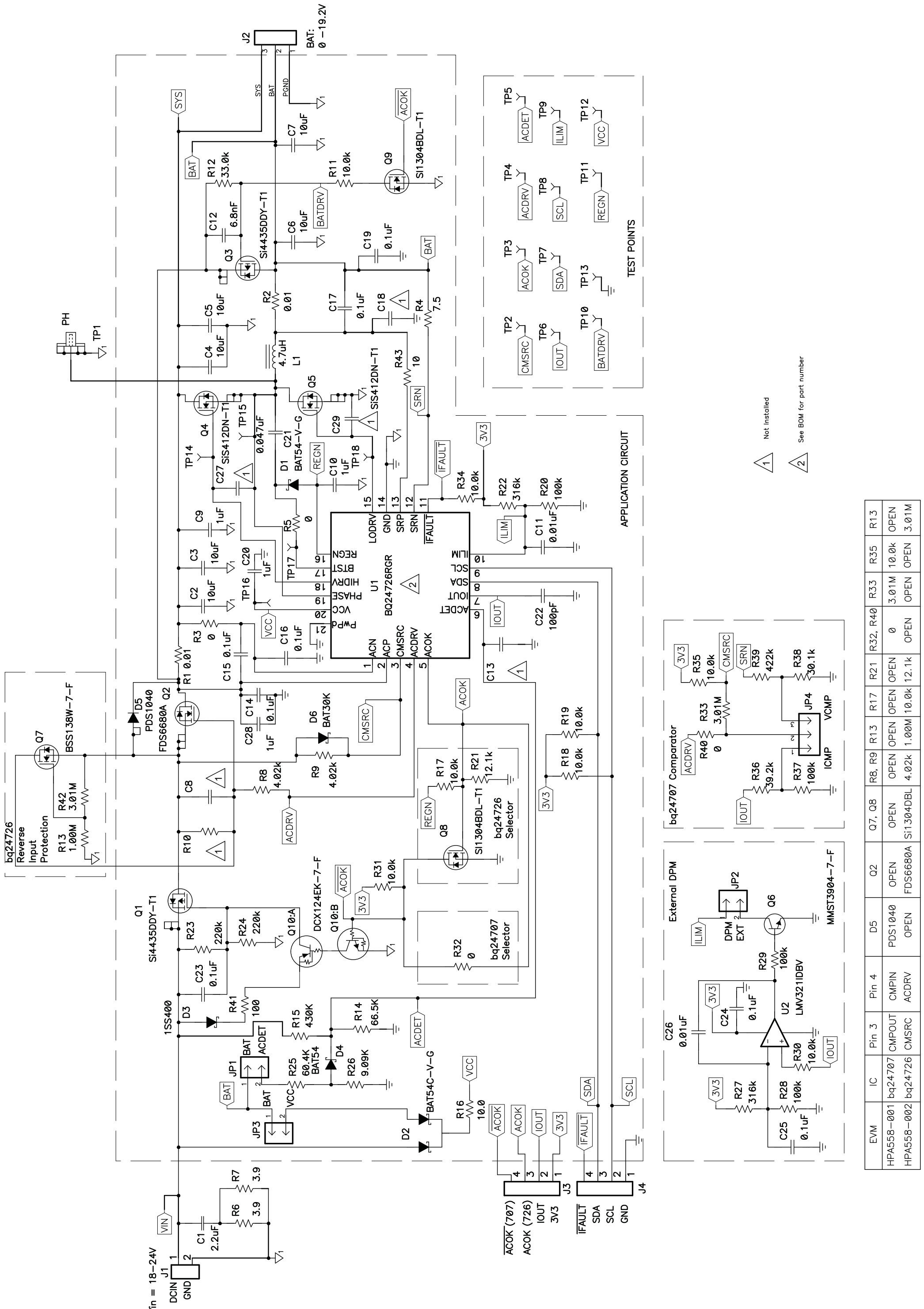

Figure 11. Schematic

Evaluation Board/Kit Important Notice

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 18 V to 22 V and the output voltage range of 3 V to 16.8 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60° C. The EVM is designed to operate properly with certain components above 60° C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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