bq24085/6/7/8 Evaluation Module

1 Introduction

This user's guide describes the bq24085/6/7/8 evaluation module (EVM) that provides a convenient method for evaluating the performance of a charge management solution for portable applications using the bq24085/6/7/8 product family. The charger is designed to deliver up to 750 mA of continuous charge current for single-cell Li-Ion or Li-polymer applications using a DC power supply.

1.1 Background

The bq24085/6/7/8 series are highly integrated Li-Ion and Li-polymer linear chargers, targeted at space-limited portable applications. The bq24085/6/7/8 series offers a variety of safety features and functional options, while still implementing a complete charging system in a small package. The battery is charged in three phases: conditioning, constant or thermally regulated current, and constant voltage. Charge is terminated based on minimum current. An internal programmable charge timer provides a backup safety feature for charge termination and is dynamically adjusted during the thermal regulation phase. The bq24085/6/7/8 automatically re-starts the charge if the battery voltage falls below an internal threshold; sleep mode is set when the external input supply is removed. Multiple versions of this device family enable easy design of the bq24085/6/7/8 in cradle chargers or in the end equipment, while using low-cost or high-end AC adapters.

1.2 Performance Specification Summary

Table 1 and the accompanying table note gives the EVM performance specifications and qualifications.

Table 1. Performance Specification Summary

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input DC Voltage, $V_{I(DC)}$		V_{REG} +0.5	5	12 (1)	Volts
Battery Charge Current, $I_{O(CHG)}$				1 (1)	Amperes
Power Dissipation	$(V_{(DC+)} - V_{(BAT+)}) \times I_{(CHG)}$			1.5	Watts

(1)

- This maximum recommended IC input voltage is **16.5** V. The IC has an OVP (overvoltage protection) input circuit that disables the charging circuit if the threshold is exceeded. Most IC selections are set for 6.5 V, but some are set as high as 12 V (see SLUS784 data sheet). The EVM can handle an input voltage up to the recommended maximum of 16.5 V, but the IC will shut down due to the internal voltage protection.
- It is recommended that in normal operation the IC be designed and run below the thermal regulation junction temperature of 125°C. The thermal loop can run continuously without any issues, but the suggested thermal loop operational use is for more harsh environments where the ambient temperature is high (for example, in an automobile during the summer) or with an incorrect adaptor with a higher input voltage.
- For typical input and ambient conditions with the PowerPAD™ tied to a copper plane, one can expect 1.5 W of heat dissipation prior to the thermal loop reducing the current. $P_{dissIC} = I_{CHG} \times (V_{DC+} - V_{BAT+})$. For the worst-case, steady-state thermal condition, V_{BAT+} = 3.4 VDC (the battery when transitioning from precharge to fast charge reaches a steady-state value after approximately 2 minutes). If the thermal regulation limit of 125°C is reached, then the charging current is adjusted lower.

2 Test Summary

This section describes:

- Input/Output and Jumper Connections
- Test Procedure Using Single Cell Li-ion Battery
- Alternative Test Procedures (Without Battery)
- Required Equipment
- Test Equipment Setup
- Test Procedure

2.1 Input/Output and Jumper Connections

The bq24085/6/7/8 EVM board requires a 5-VDC, 1-A power source to provide input power and a single-cell Li-ion or Li-polymer battery pack. The test setup connections and jumper setting selections are configured for a stand-alone evaluation but can be changed to interface with external hardware such as a microcontroller.

Table 2. I/O and Jumper Connections

Jack	Connect To:
J1-DC+	Power supply positive, preset to 5 VDC, 1-A current limit.
J1-DC–	Power supply ground
J2-BAT+	Positive battery pack terminal
J2-BAT–	Negative battery pack terminal
J2-TS	NC
J2-BAT–	NC
J3-STAT1	External hardware if J4-EXT is jumpered (Not jumpered from factory)
J3-STAT2	External hardware if J5-EXT is jumpered (Not jumpered from factory)
J3-DC–	Return for J3 signals
J3-PG	External hardware if J6-EXT if jumpered (Not jumpered from factory)
JMP1 (Jumper)	LED connection
JMP2 (Jumper)	LED connection
JMP3 (Jumper)	LED connection (bq24085, bq24086, and bq24088). $\overline{CE}$ - without jumper defaults low - Charge Enable, with Jumper - Charge Disable
JMP4 (Jumper)	TMR enable with jumper installed

2.2 Test Procedure Using Single-cell Li-ion Battery

Set up the evaluation board as previously described in Table 2 , making the necessary I/O connections and jumper selections. Prior to test and evaluation, it is important to verify that the maximum IC power dissipation ($P_{(MAX)}$ = 1.5 W) is not exceeded.

1. Turn on the power supply, which was preset to 5 VDC, and 1 A for the current-limit setting.
2. The bq24085/6/7/8 enters preconditioning mode if the battery is below the V(LOWV) threshold. In this mode, the bq24085/6/7/8 precharges the battery with a low current (typically IO(CHG) /10 = 0.4A/10 = 40 mA) until the battery voltage reaches the $V_{(LOWV)}$ threshold or until the precharge timer expires. If the timer expires, then the charge current is terminated and the bq24085/6/7/8 enters fault mode. Both LEDs turn off when in fault mode. Toggling input power or battery replacement resets fault mode.
3. Once the battery voltage is above the $V_{(LOWV)}$ threshold, the battery enters fast-charge mode. This EVM is programmed for 0.4 A of fast-charging current.
4. Once the battery reaches voltage regulation (4.2 V), the current tapers down as the battery reaches its full capacity.
5. The battery remains at the fast charge mode until either the charge timer expires or the charge termination current threshold is reached.

6. Once the charge terminates, J7 (TMR jumper) can be removed, putting the IC in LDO mode, and the charger should turn on and regulate at 4.2 V or in constant current mode if the battery voltage drops below 4.2 V. Replacing the jumper allows the IC to terminate properly.

Note: Loads across the battery can affect termination.

7. If the battery discharges to the recharge threshold, the charger starts fast charging.

2.3 Alternative Test Procedures (Without Battery)

This are alternative methods of testing the EVM without a battery. These alternative test procedures include:

- Four Quadrant Power Supply (Sinks or Source Current)
- Large Capacitor
- Dynamic Load Board

Because of the battery detection circuit, *it is difficult to test the different charge phases without a battery* (using just resistors); the algorithm sinks and sources current and applies precharge and fast-charge current depending on the mode it is in. Applying a load that would keep the voltage at 3.5 V (3.5 V/0.7 A) would pull the output into precharge mode and keep it there during the battery detection algorithm, which always occurs when the output is discharged to the refresh threshold. Once in precharge mode, a load sufficient to allow the capacitor to charge to $V_{(lowV)}$ would allow the output to jump to voltage regulation once the 0.7-A fast charge function is activated.

2.3.1 Four Quadrant Power Supply (Sinks or Source Current)

A source meter that can sink current can easily be adjusted to test each mode.

2.3.2 Large Capacitor

To briefly see each mode on a scope, connect a 1 mF capacitor in parallel with a 20 kΩ resistor on the output to observe the power up and cycling between voltage regulation and fast charge via the refresh threshold.

2.3.3 Dynamic Load Board

The circuit is adjusted to work with the displayed parts and their inherent thresholds. The sequence of the test procedure is important due to the active battery detection circuit, refresh feature, precharge, and fast-charge current levels (switching the load in and out in different modes has different results). No damage should occur, but one might get different results than anticipated if the procedure is altered.

2.4 Required Equipment

a. Power Source: Current-limited 5-V laboratory power supply with its current limit set to 1 A ± 0.1 A
b. Two Fluke 75 digital multimeters (equivalent equipment or better)
c. Oscilloscope – TDS220 or better
d. Load test board shown in Figure 1

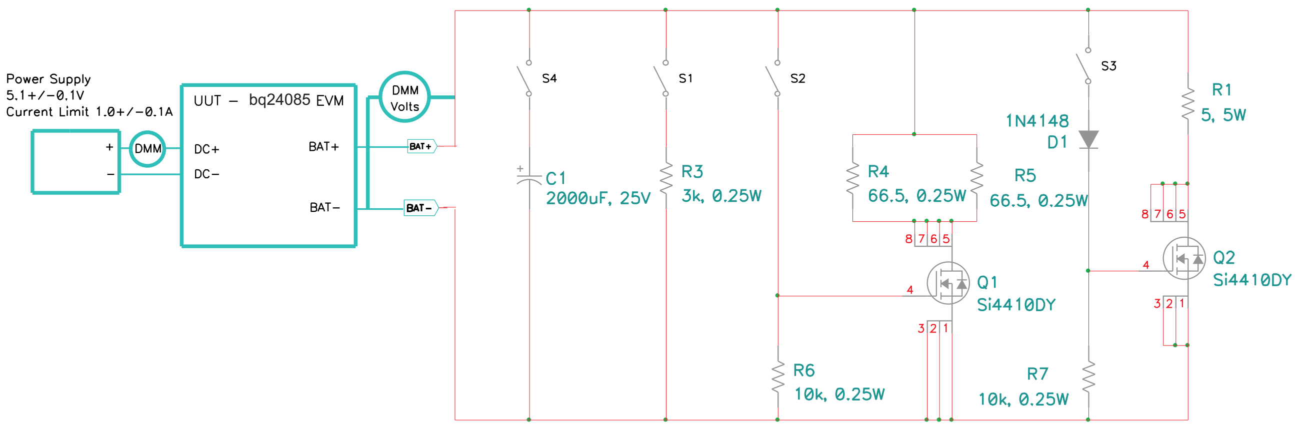


Figure 1. Load Test Board

2.5 Test Equipment Setup

a. Connect the load board to the BAT+ and BAT- terminals. Set SW1 through SW4 in the ON position.
b. Connect a voltage meter to the BAT+/BAT- output to monitor the output voltage range (0 to 5 V).
c. Set the lab supply for 5.1 V ± 0.1 VDC and a 1.0 ± 0.1 A current limit.
d. Turn off supply.
e. Connect the source supply to a current meter and to J1, noting polarity (may use an internal source current meter, if it has 5% or better accuracy).

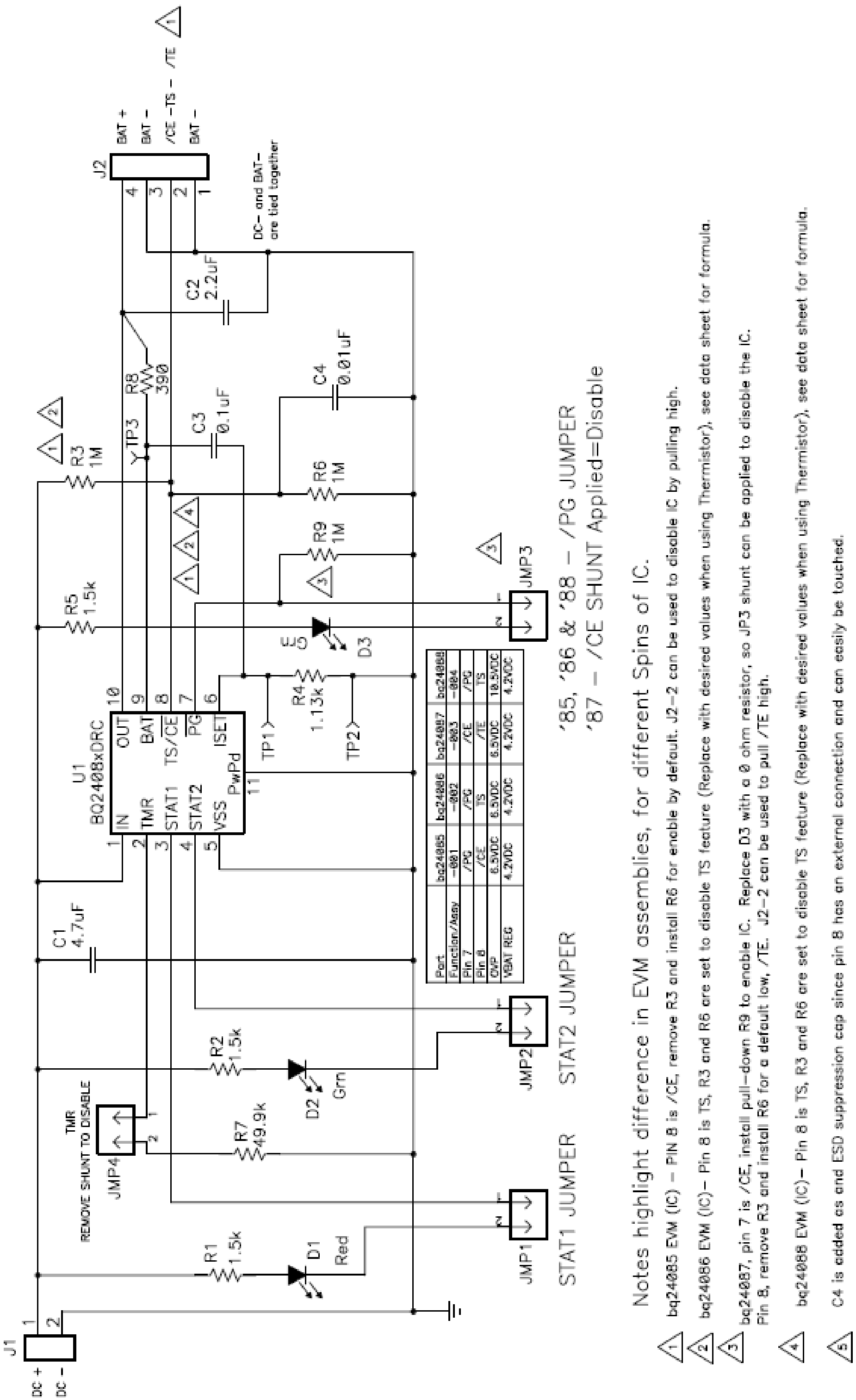
2.6 Test Procedure

1. Ensure that all Test Equipment Setup steps are performed. Switches should be in the ON position and power source set to 5.1 V ± 0.1 VDC.
   - **bq24085 and bq24086**—place shunts on pins 1 and 2 for jumpers JMP1, JMP2, and JMP3, JMP4.
   - **bq24087**—place shunts on pins 1 and 2 for jumpers JMP1, JMP2, and JMP4. For JMP3, place shunt on just one pin (do not short the pins).
2. Turn on the power source.
3. Verify output voltage, BAT+, charges up to between 2.5 V to 2.9 V and the red STAT1 LED (D1) and green STAT2 LED light (all dash #s).
4. Verify the green PG LED (D3) lights for bq24085-001 and bq24086-002.
5. For bq24085 and bq24087, verify that J2-2 with respect to ground is less than 0.3 volts.
6. For bq24085, apply input voltage, J1-1 (+5 V) to J2-2, verify that charging stops (I_{in} or I_{bat} < 30 mA). Remove 5 V from J2-2.
7. For bq24087, apply input voltage, J1-1 (+5 V) to J2-2, verify that charging continues. Remove 5 V from J2-2.
8. For bq24087, apply shunt across pins 1 and 2 of JMP3, verify that charging stops (I_{in} or I_{bat} < 30 mA) and STAT1 (D1) and STAT2 (D2) LEDs turn off. Remove JMP3 shunt and place on just one pin.
9. For bq24086, verify that J2-2 with respect to ground is between 2 V and 3 V.
10. Adjust the Input Voltage to 7.0±0.1 V. Verify charging stops (I_{in} or I_{bat} < 30 mA) stops for bq24085, bq24086, and bq24087, plus continues (no change) for bq24088.

Note: The bq24088 charge current may cycle on and off due to thermal cutoff. This is normal.

11. Open SW2 switch and close SW2 switch. Verify the green LED STAT2 (D2) turned off.
12. Verify output voltage, BAT+, settles between 3.1 V and 3.9 V.
13. Verify that the input current is between 0.3 A and 0.55 A.
14. Open SW3 switch.
15. Verify that the input current is between 100 mA and 150 mA.
16. Verify the output voltage, BAT+, is between 4.15 VDC and 4.25 VDC.
17. Open SW2 switch.
18. Verify, with a scope (250 ms/div, 1 V/div), that output, BAT+, charges and discharges between the maximum value of 4.5 V and minimum value of 3 V (smaller range is typical 3.6 to 4.3), with a period between 550ms and 850ms.
19. Verify that the LEDs flash between RED (D1) and GREEN (D2, mostly on green).
20. For bq24085 and bq24086, remove shunt JMP4 and verify that BAT+ is between 4.15 VDC and 4.25 VDC, plus the red LED (D1) lights.
21. For bq24085 and bq24086, install JMP4 shunt.
22. Close SW2 and SW3 switches. All switches should be closed.
23. Power down supply.

3 Schematic



NOTE: C3 is optional and not installed.

Figure 2. EVM Schematic Diagram

4 Physical Layouts

This section provides the board layout and assembly drawings for the EVM, that include the top layer (Figure 3), the bottom layer (Figure 4), and top assembly view (Figure 5) of the EVM.

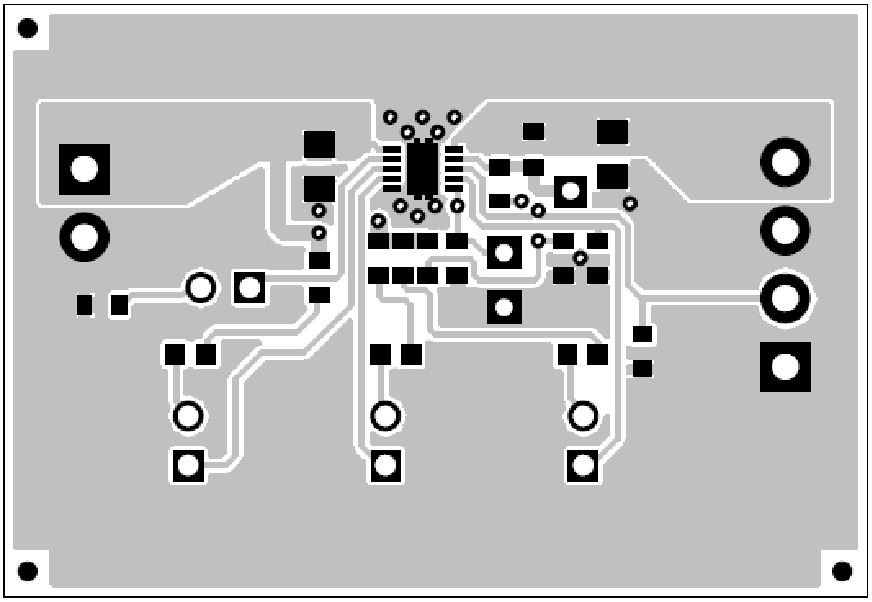


Figure 3. Top Layer Routing

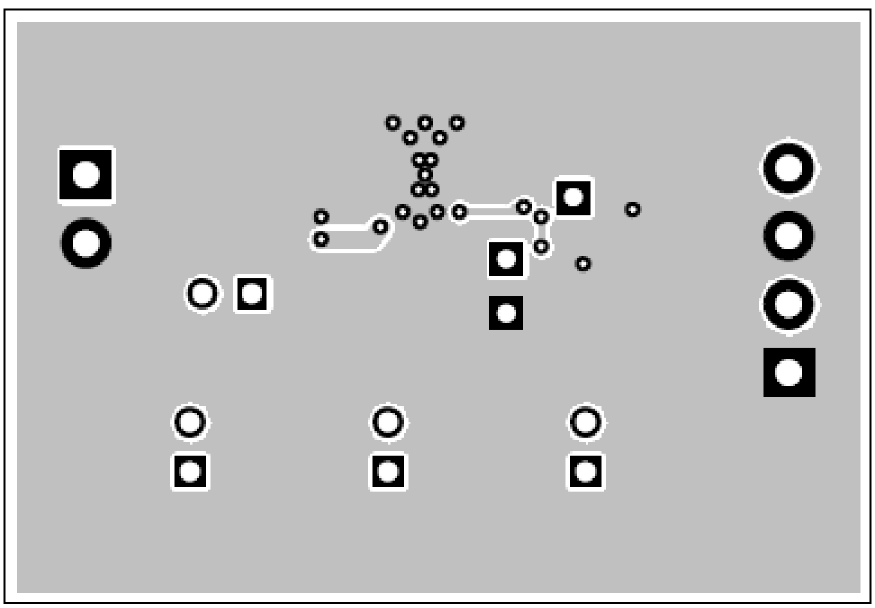


Figure 4. Bottom Layer Routing

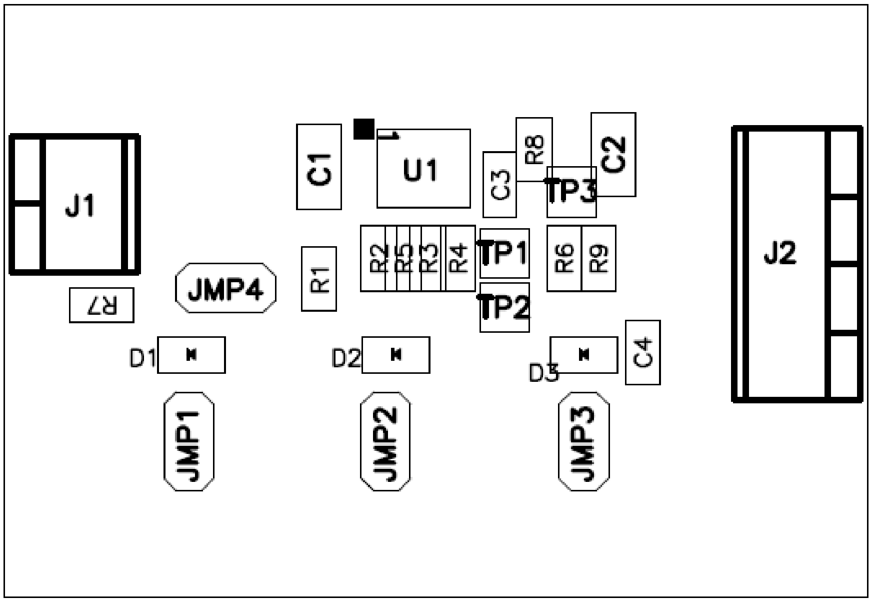


Figure 5. Top Assembly View

5 Bill of Materials

HPA314A Bill of materials for bq24085, bq24086, bq24087, and bq24088 parts.

Table 3. HPA314A Bill of Materials

24085	24086	24087	24088	Ref Des	Value	Description	Size	Part Number	MFR
1	1	1	1	C1	4.7 µF	Capacitor, Ceramic, 16 V, X5R, 10%	0805	ECJ-2FB1C475K	Panasonic
1	1	1	1	C2	2.2 µF	Capacitor, Ceramic, 16 V, X5R, 10%	0805	ECJ-2FB1C225K	Panasonic
1	1	1	1	C3	0.1 µF	Capacitor, Ceramic, 50 V, X7R, 10%	0603	Std	Std
1	1	1	1	C4	0.01 µF	Capacitor, Ceramic, 50 V, X7R, 10%	0603	Std	Std
1	1	1	1	D1	LTST-C190CKT	Diode, LED, Red, 2.1 V, 20 mA, 6-mcd	0603	LTST-C190CKT	Lite On
1	1	1	1	D2	LTST-C190GKT	Diode, LED, Green, 2.1 V, 20 mA, 6-mcd	0603	LTST-C190GKT	Lite On
1	1	0	1	D3	LTST-C190GKT	Diode, LED, Green, 2.1 V, 20 mA, 6-mcd	0603	LTST-C190GKT	Lite On
0	0	1	0	D3	0 Ohm	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	1	1	J1	ED555/2DS	Terminal Block, 2-pin, 6 A, 3.5 mm	0.27 x 0.25 inch	ED555/2DS	OST
1	1	1	1	J2	ED555/4DS	Terminal Block, 4-pin, 6-A, 3.5 mm	0.55 x 0.25 inch	ED555/4DS	OST
4	4	4	4	JMP1, JMP2, JMP3, JMP4	PTC36SAAN	Header, Male 2-pin, 100 mil spacing, (36-pin strip)	0.100 inch x 2	PTC36SAAN	Sullins
3	3	3	3	R1, R2, R5	1.5 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	1	0	1	R3	1MΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	1	1	R6	1MΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	0	1	0	R9	1MΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	1	1	R4	1.13 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	1	1	R7	49.9 kΩ	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	1	1	R8	390 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	0	0	0	U1	BQ24085DRC	IC, 750 mA Single Chip, Li Ion/Li POL, Charger	DRC10	BQ24085DRC	TI
0	1	0	0	U1	BQ24086DRC	IC, 750 mA Single Chip, Li Ion/Li POL, Charger	DRC10	BQ24086DRC	TI
0	0	1	0	U1	BQ24087DRC	IC, 750mA Single Chip, Li Ion/Li POL, Charger	DRC10	BQ24087DRC	TI
0	0	0	1	U1	BQ24088DRC	IC, 750mA Single Chip, Li Ion/Li POL, Charger	DRC10	BQ24088DRC	TI
1	1	1	1	–		PCB, 1.75 In x 1.2 In x 0.031 In		PCB	Any
4	4	4	4	Shunt		Shunt, 100-mil, Black	0.1	929950-00	3M

6 References

bq24085/6/7 data sheet (SLUS784)

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 4.4 V to 16 V and the output voltage range of 2.3 V to 4.4 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 75°C. The EVM is designed to operate properly with certain components above 100°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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