0.8-A Single-Input, Single-Cell Li-Ion Battery Charger

This user's guide describes the bq24040 evaluation module (EVM), how to perform a stand-alone evaluation or interface with a host or system. The charger is designed to deliver up to 800mA of continuous current to the battery output when programmed with a resistor on the ISET pin and is programmed at the factory for ~540mA. The USB current limit modes are selected by the ISET2 pin and limits current to a maximum of 500mA (logic high) or 100mA (float or high impedance). A low on the ISET2 pin programs the charge current using the ISET resistor.

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1 Introduction

The bq2404x series of devices are highly integrated Li-ion linear charger devices targeted at space-limited portable applications. The devices operate from either a USB port or AC adapter.

The bq2404x has a single power output that charges the battery. A system load can be placed in parallel with the battery as long as the average system load does not keep the battery from charging fully during the 10 hour safety timer.

The battery is charged in three phases: conditioning, constant current, and constant voltage. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded.

The charger power stage and charge current sense functions are fully integrated. The charger function has high-accuracy current and voltage regulation loops, charge status display, and charge termination. The pre-charge current and termination current threshold are programmed via an external resistor on the bq24040. The fast charge current value is also programmable via an external resistor.

2 Considerations With Evaluating the bq24040/1

Refer to the data sheet for specific details on the charger ICs. The main differences between the bq24040 and bq24041 are that the Pre-Term pin is replaced with an Auto Start (I/O) (ASI/ASO) feature, a different Over-Voltage Protection Threshold, and a Temperature Sense Pin (TS) versus a BAT_EN pin.

The ISET current control loop sets the maximum charge current. This maximum programmed current level can be further reduced by entering a USB mode, selected by the ISET2 pin.

The ASO output is dependent on the OUT pin to power the internal "OR" gate along with at least one high signal on the input (bq24041).

A system load may be connected to the OUT pin, which takes away some of the charge current. Normally it is not recommended to operate the device in pre-charge since the system load keeps the battery from recovering; but, since the PRE_TERM pin can program a higher pre-charge current this restriction is not necessary.

3 Performance Specification Summary

Specification	Test Conditions	MIN	TYP	MAX	UNIT
Input DC voltage, Vin	Recommended input voltage range	4.45		6.45	V
Reduced Performance, Vin(1)	Will not charge with Over Voltage input condition. Limited charging with under voltage input.	3.5		28	V
Power Dissipation(2)	$P_{DISS} = (V_{IN} – V_{OUT}) \times I_{OUT}$			1.5	W
I_{OUT}	RISET = 1k		0.54	0.8	A

(1) Input voltage range is specified for normal operation. Input voltage between UVLO and 4.75 V has limited functionality, but does not damage the IC nor present any safety issue with the battery. Input voltage above OVP and less than 30 Vdc has no operation and will not damage the IC. Lower input voltage (closer to dropout operation) produces less heat dissipation and potentially better performance.

(2) The junction temperature rise above ambient is proportional to the power dissipation. Once the junction temperature reaches ~125°C, thermal regulations reduces the programmed charge current.

4 Test Summary

The bq24040/1 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.

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4.1 Equipment

- Power supply +5.1 ±0.1 V, current limit set to 1.5 ±0.1 A
- Battery: 4.2 V LiCoO2 or equivalent
- Three Fluke 75 DMMs (equivalent or better)
- Oscilloscope, Model TDS220 (equivalent or better)

4.2 Equipment and EVM Setup

Jack/Component	Connect or Adjustment 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
JMP1 (bq24040)	Apply shunt for Pre-TERM connection.
JMP2	Apply shunt for PG LED connection.
JMP3	Apply shunt for ISET2 connection.
JMP4	Apply shunt for CHG LED connection.
JMP5	Apply shunt for TS (BAT_EN on bq24041) connection.
JMP6	No shunt
R2 (R_{ISET})	Adjust R2 for 1k between TP2 and GND
R3 ($R_{PRE-TERM}$)	Adjust R3 for 2k between TP4 and GND
R11 (R_{TS})	Adjust R11 for 10k between TP9 and GND

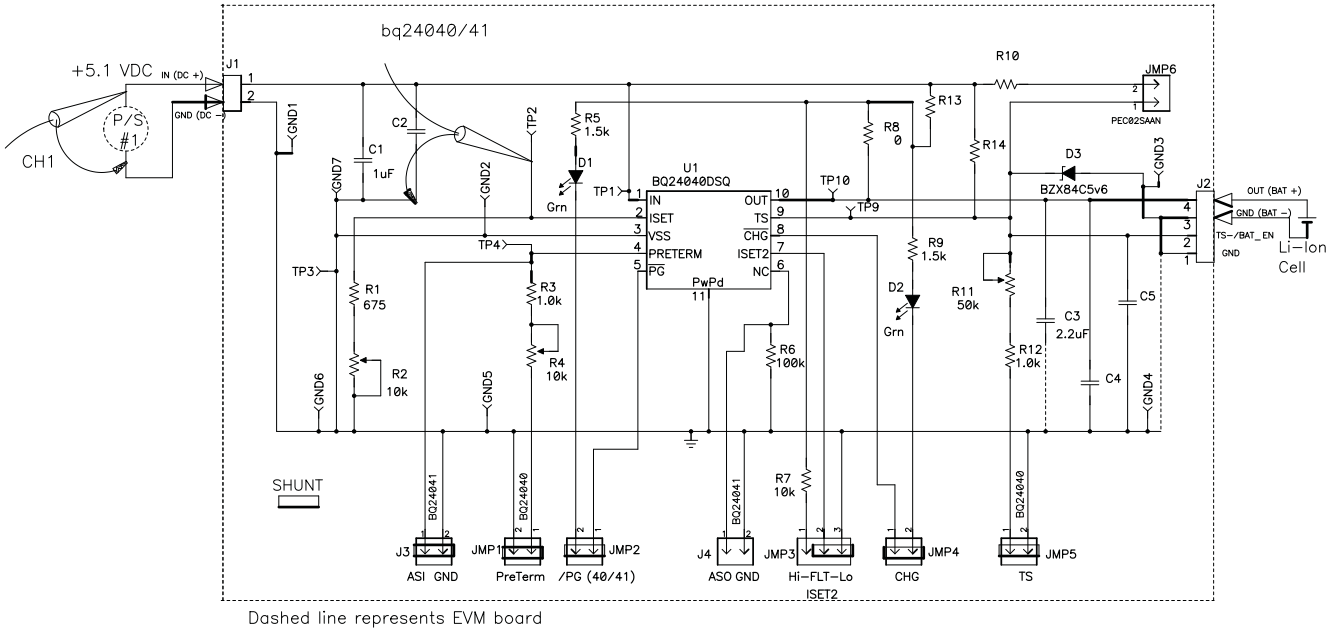

Figure 1. EVM Setup

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4.3 Test Procedure Using a Single Cell Li-Ion Battery

1. Verify that the setup is correct and turn on the power supply, which was preset to 5 VDC, and 1 A for the current-limit setting.
2. The bq24040/1 enters preconditioning mode if the battery is below the $V_{(LOWV)}$ threshold. In this mode, the bq24040/1 pre-charges the battery with a low current programmed by the PRE-TERM resistor (typically set to 10% of fast charge) until the battery voltage reaches the $V_{(LOWV)}$ threshold or until the pre-charge timer expires. If the timer expires, then the charge current is terminated and the bq24040/1 enters fault mode. The CHG LED turns off when in timer fault mode. Toggling input power, toggling TS (BAT_EN) or battery replacement resets fault mode.
3. When the battery voltage rises above the $V_{(LOWV)}$ threshold, the battery enters fast-charge constant current mode. This EVM is programmed for 0.54 A of fast-charging current.
4. Remove the shunt from JMP3 and see the IC go into USB100 mode (charge current drops); place shunt between ISET2 and HI and see the USB500 mode (500mA–bq24040, or 410mA–bq24041); return shunt to ISET2-GND for programmed current.
5. Once the battery reaches the voltage regulation threshold (4.2 V), the voltage control loop takes over and the current tapers down as the battery reaches its full capacity.
6. The battery remains at the fast-charge mode until either the charge timer expires or the charge termination current threshold is reached.
7. When the charge terminates, the CHG LED turns off.
8. Remove JMP5 (TS) and the charger turns on. This mode is Termination and Timer Disable Mode (TTDM). This allows continuous power applied from the input to the output, regulated to 4.2V with a maximum current programmed by the ISET resistor (can be restricted further if in USB mode). The system can operate without a battery in this mode as long as the system does not exceed the supplied input current.
9. If the battery discharges to the recharge threshold, the charger starts fast charging, but the CHG LED will not come on for the subsequent charges. Cycling the input power, replacing the battery, or toggling the TS pin low starts a new charge with the CHG LED on.

NOTE: Loads across the battery can affect termination. The pre-term pin can be adjusted to offset the system current. See data sheet for more details.

4.4 Alternate Test Methods

A 4-quadrant power supply that can source and sink current can be used in place of the battery pack to evaluate the charger. It allows each transfer between pre-charge, constant-current and constant voltage fast charge. Keep leads short to avoid adding too much inductance which may cause an interaction between the power supply and charger. A large capacitor across the output helps cancel the inductance if long leads are necessary.

5 Schematic, Physical Layouts and Bill of Materials

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5.1 Schematic

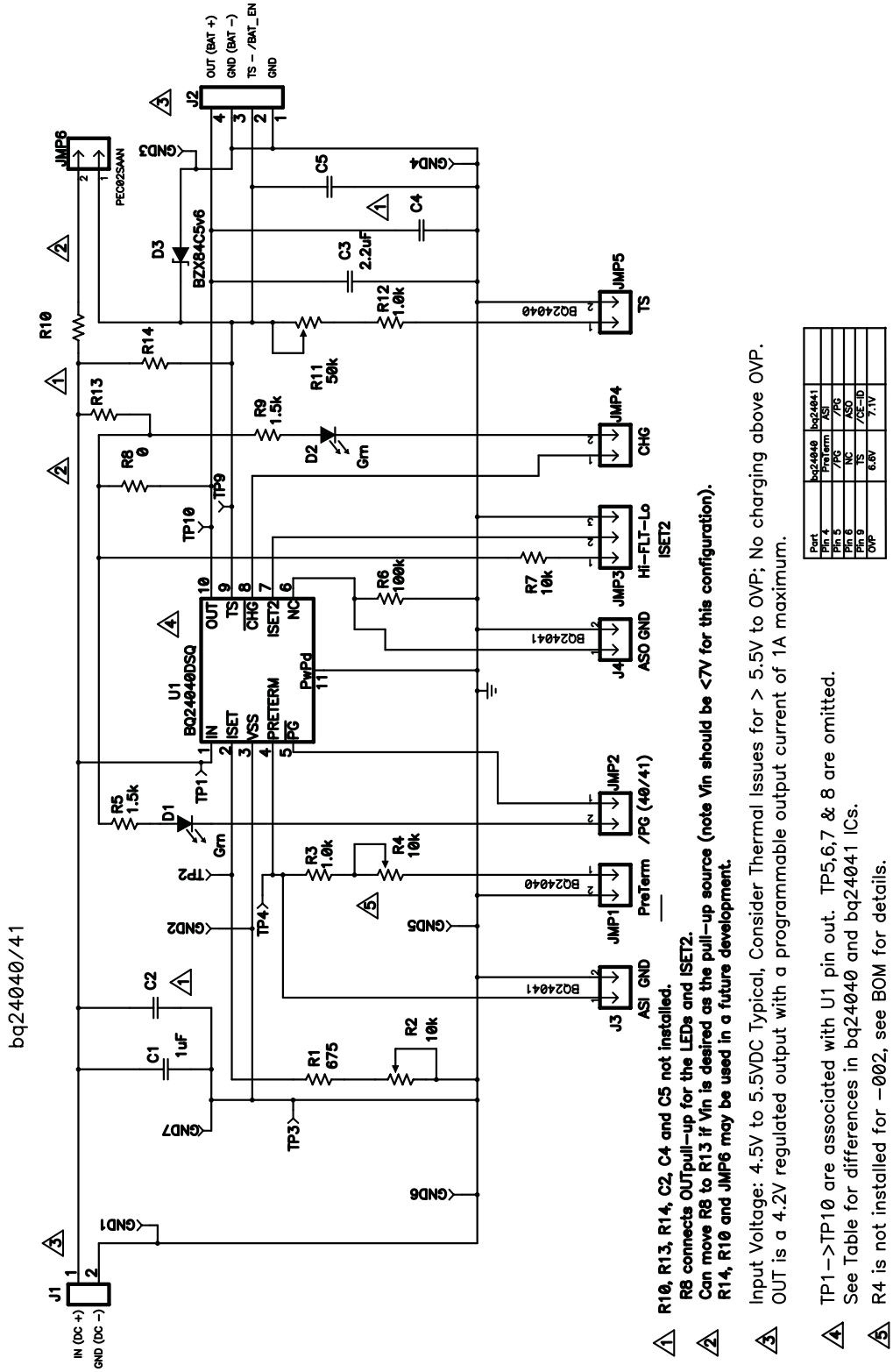

Figure 2. bq24040/41 EVM Board Schematic

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5.2 Physical Layouts

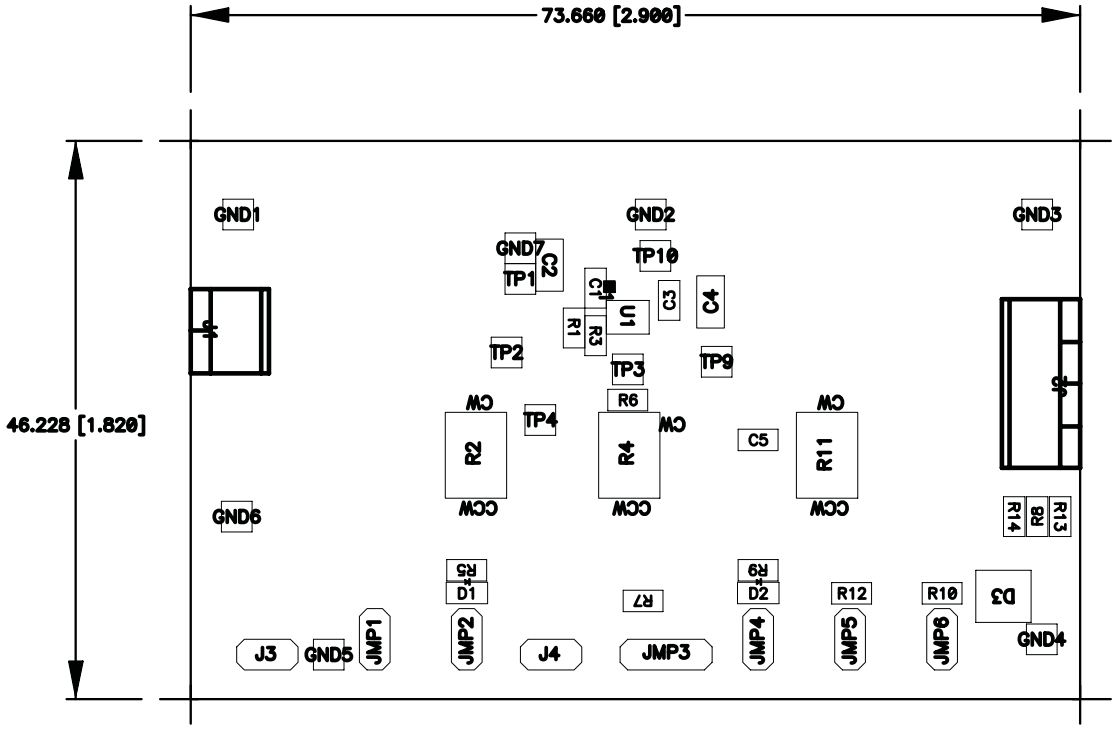

Figure 3. Assembly Layer

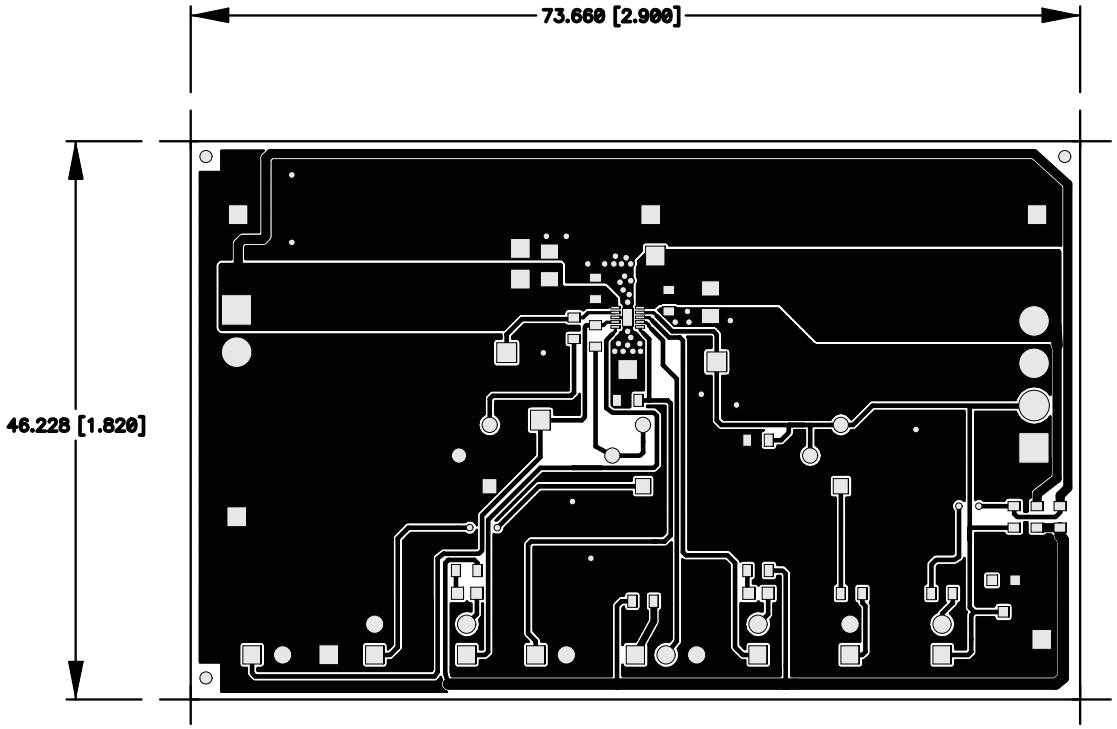

Figure 4. Top Layer

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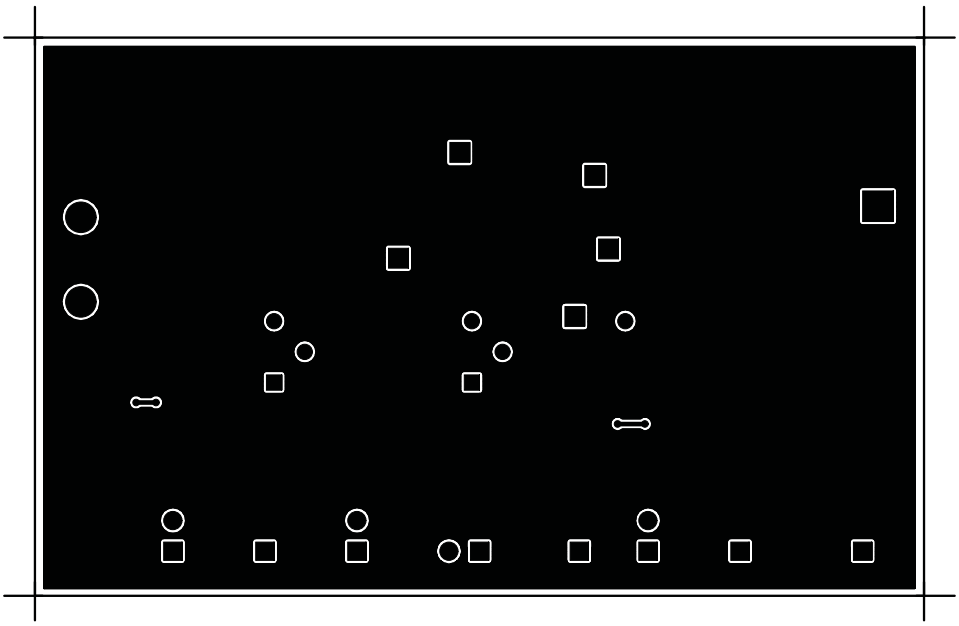

Figure 5. Bottom Layer

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5.3 Bill of Materials

-001	-002	RefDes	Value	Description	SIZE	Part Number	MFR
1	1	C1	1µF	Capacitor, Ceramic, 25V, X5R, 10%	0603	ECJ-1VB1E105K	Panasonic
0	0	C2		Capacitor, Ceramic, 25V, X5R, 10%	0805	–	–
1	1	C3	2.2µF	Capacitor, Ceramic, 10V, X5R, 10%	0603	ECJ-1VB1A225K	Panasonic
0	0	C4		Capacitor, Ceramic, 10V, X5R, 10%	0805	–	–
0	0	C5		Capacitor, Ceramic, 25V, X5R, 10%	0603	–	–
2	2	D1, D2	LTST-C190GKT	Diode, LED, Green, 2.1-V, 20-mA, 6-mcd	0603	LTST-C190GKT	Lite On
0	1	D3	BZX84C5v6-7-F	Diode, Zener, 5.6-V, 350-mW	SOT-23	BZX84C5v6-7-F	Diodes
1	1	J1**	ED555/2DS	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25 inch	ED555/2DS	OST
1	1	J2**	ED555/4DS	Terminal Block, 4-pin, 6-A, 3.5mm	0.55 x 0.25 inch	ED555/4DS	OST
0	2	J3, J4	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (2-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
3	3	JMP2, JMP4, JMP5	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (2-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
0	0	JMP6	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (2-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
1	0	JMP1	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (2-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
1	1	JMP3	PEC03SAAN	Header, Male 3-pin, 100mil spacing, (3-pin strip)	0.100 inch x 3	PEC03SAAN	Sullins
1	1	R1	675	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R11	50k	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-503LF	Bourns
0	0	R13, R14		Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R2	10k	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-103LF	Bourns
1	0	R4	10k	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-103LF	Bourns
2	2	R3, R12	1.0k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	2	R5, R9	1.5k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	2	R6, R10	100k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R7	10k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R8	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	0	U1	BQ24040DSQ	IC, 800mA, Single-Input, Single Cell Li-Ion BATTERY CHARGER w/wo Auto Start (ASI/ASO)	SON-10	BQ24040DSQ	TI
0	1	U1	BQ24041DSQ	IC, 800mA, Single-Input, Single Cell Li-Ion BATTERY CHARGER w/wo Auto Start (ASI/ASO)	SON-10	BQ24041DSQ	TI
5	5	Shunt (Note 5)		Shunt, 100-mil, Black	0.1	929950-00	3M
1	1	--		PCB, 2.9 In x 1.8 In x 0.031 In		HPA387	Any

Notes: 1. These assemblies are ESD sensitive, ESD precautions shall be observed.

2. These assemblies must be clean and free from flux and all contaminants. Use of no-clean flux is not acceptable.

3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.

4. Ref designators marked with an asterisk ('**') cannot be substituted. All other components can be substituted with equivalent MFR's components.

5. Apply shunt to JMP1/2/4/5 and JMP3:2/3. Note J3 and J4 are test pins and do not have shunts (jumpers).

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the power supply voltage range of 4.45 V and 6.45 V. Input voltage range is specified for normal operation. Input voltage between UVLO and 4.75 V has limited functionality, but does not damage the IC nor present any safety issue with the battery. Input voltage above OVP and less than 30 Vdc has no operation and will not damage the IC. Lower input voltage (closer to dropout operation) produces less heat dissipation and potentially better performance.

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.

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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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