

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

This user's guide describes the bq24050/2/5 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 for ~540mA at the factory. 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 bq2405x series of devices are highly integrated Li-ion linear chargers devices targeted at space-limited portable applications. The devices operate from either a USB port or AC adapter.

The bq2405x 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 bq24050/2/5 have an integrated USB detect routine that looks for an USB connection on power-up and initially sets the charge input control to either the programmed ISET level, if an adaptor is detected, or to USB100 mode if an USB port is detected. This aides in a faster charge if the battery is discharged and the USB device transceiver is not powered and an adaptor is connected.

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 bq24050/2/5. The fast charge current value is also programmable via an external resistor

2 Considerations With Evaluating the bq24050/2/5

Refer to the data sheet for specific details on the charger ICs. The main differences between the bq24050/2/5 spins is: (1) The '50 uses a 10k NTC thermistor, (2) the '52 uses a 100k NTC thermistor, and (3) the '55 uses a 10k NTC thermistor and has a PG 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.

A system load may be connected to the OUT pin which will take away some of the charge current. Normally it is not recommended to operate the system in pre-charge mode 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

Specifacaton	Test Conditions	Min	Typ	Max	Units
Input DC voltage, V_{in}	Recommended input voltage range	4.45		6.45	V
Reduced Performance, $V_{in}^{(1)}$	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 bq24050/2/5 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.

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
- Two 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	Apply shunt between IN_IC and DC+; allows use of J1 input.
JMP2	Apply shunt for Pre-Term connection.
JMP3	Remove shunt for USB100 mode operation.
JMP4	Apply shunt for CHG LED connection.
JMP5	Apply shunt for TS potentiometer connection.
JMP6 (bq24050/2)	Apply shunt to simulate an adaptor connection when using J1 as an input.
JMP6 (bq24055)	Apply shunt for PG LED connection.
JMP7 (bq24055)	Apply shunt to simulate an adaptor connection when using J1 as an input.
R2 (R _{ISET})	Adjust R2 for 1k between TP2 and GND
R4 (R _{PRE-TERM})	Adjust R3 for 2k between TP4 and GND
R8 (R _{TS})	Adjust R11 for 10k between TP9 and GND

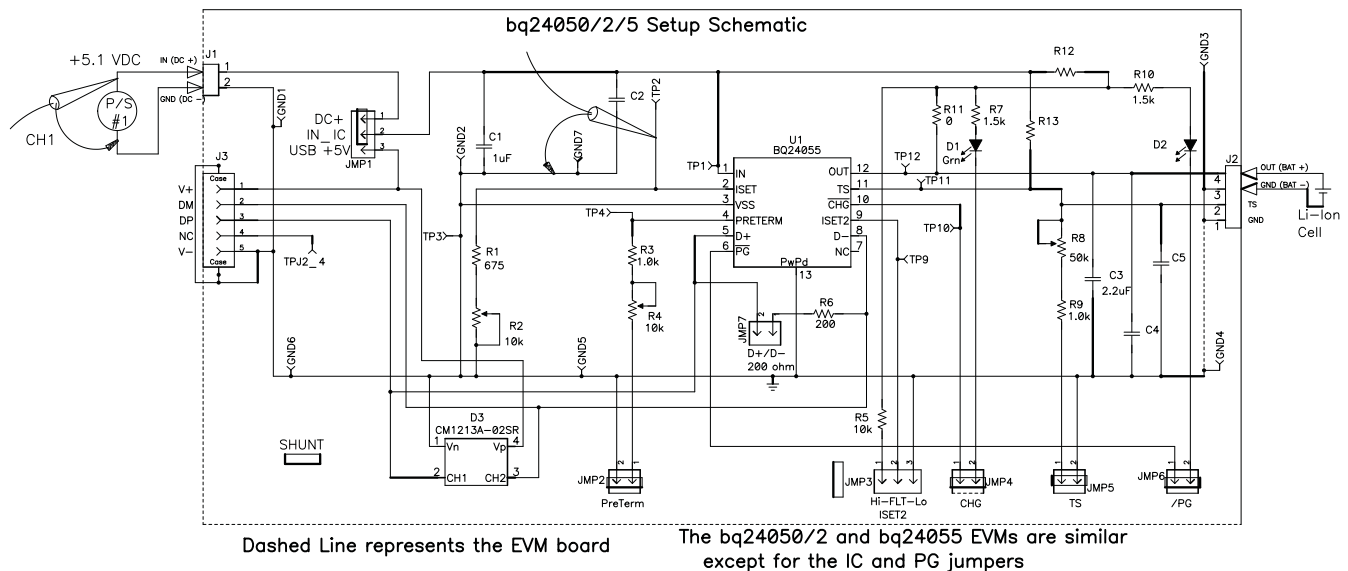


Figure 1. bq24050/2/5 Setup Schematic

4.3 Test Procedure Using a Single Cell Li-Ion Battery

1. Connect one DMM across the BAT+ to BAT- connection at J2. Since this is a linear charger the output current display on the input power supply is approximately the current delivered to the OUT pin. The charge current may be monitored independently by placing a 100mΩ resistor in the battery pack return and using a DMM to monitor the sense resistor.

2. Verify that the setup was performed correctly and turn on the power supply, which was preset to 5 VDC, and 1 A for the current-limit setting. The current was programmed for ~540 mA fast charge, or ~108 mA if in pre-charge, from the factory.
3. Shunt JMP6 (bq24050/2) and JMP7 (bq24055) short the D+ and D- input together simulating an adaptor connection. After applying input power the USB detection routine will detect an adaptor and start charging as if an adaptor is applied. One will notice about 540ma once the battery voltage charges above the $V_{(LOWV)}$ threshold. The ISET2 pin voltage is proportional to the amount of programmed current delivered to the OUT pin. The voltage on the ISET2 pin is 1.5V when the output current is 100% of the programmed value.
4. The bq24050/2/5 enters preconditioning mode if the battery is below the $V_{(LOWV)}$ threshold. In this mode, the bq24050/2/5 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 bq24050/2/5 enters fault mode. The CHG LED turns off when in timer fault mode (Toggling input power, toggling TS low or battery replacement resets fault mode).
5. Once the battery voltage is above the $V_{(LOWV)}$ threshold, the battery enters fast-charge constant current mode. This EVM is programmed, by the ISET resistor for 0.54 A of fast-charging current. The IC should be in this mode since the USB detection routine detected an adaptor.
6. Apply a shunt to JMP3 ISET2-HI and see (charge current drops) the IC go into USB500 mode, remove the shunt and see the mode change to USB100, place the shunt between ISET2 and GND to see the programmed current mode. The USB detection routine always sets the mode at power-up and the user (processor) has to change the state of the ISET2 pin for the IC to unlatch the charge mode and set according to the ISET2 pin.
7. 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.
8. The battery remains at the fast charge mode until either the charge timer expires or the charge termination current threshold is reached.
9. Once the charge terminates, the CHG LED will turn off.
10. Remove JMP5 (TS) and the charger will turn 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 (may 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.
11. If the battery discharges to the recharge threshold, the charger starts fast charging, but the CHG LED will not come on for the subsequent chargers. Cycling the input power, replacing the battery, or toggling the TS pin low will start a new charge with the CHG LED on.
12. Discharge the battery below 4.0 V and above 3.0 V, remove Shunt 6 (bq24050/2) or Shunt 7 (bq24055). Remove and re-apply input power and verify the USB mode is detected. Remove shunt from JMP3 and replace on JMP3: ISET2-GND. Verify current is set to the ISET resistor programmed level.
13. Procedure may be repeated using a mini USB cable connected to J3 on the EVM, and to either a USB port or adapter for the power source. Remove shunt JMP6 (bq24050/2) or JMP7 (bq24055), and move JMP1 to IN_IC / USB +5V prior to applying power with the USB mini cable.

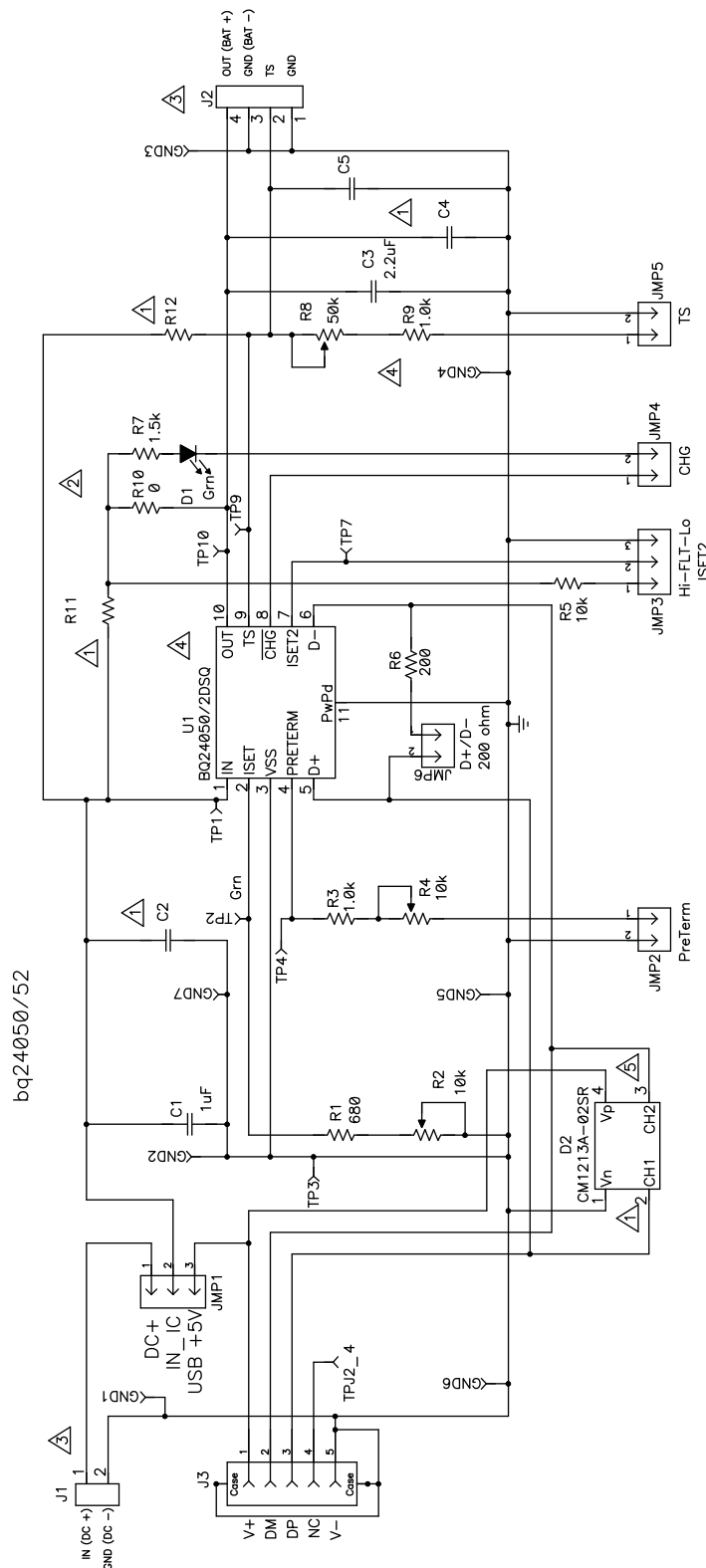
NOTE: Loads across the battery can affect termination. The pre-term pin can be adjusted to offset the system current. See data sheet for more details.

4.4 Alternate Test Methods

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

5 Schematics, Physical Layouts, and Bill of Materials

5.1 Schematics – HPA388A



- 1 R11, R12, D2, C2, C4 and C5 not installed.
- 2 R10 connects OUTpull-up for the LED and ISET2s.
Can move R10 to R11 if Vin is desired as the pull-up source (note Vin should be <7V for this configuration).
R12 may be used in a future development.
- 3 Input Voltage: 4.5V to 5.5VDC Typical, Consider Thermal Issues for > 5.5V to OVP; No charging above OVP.
- 4 OUT is a 4.2V regulated output with a programmable output current of 1A maximum.
TP1 → TP10 are associated with U1 pin out. TP5,6,8 are omitted.
- 5 bq24050 uses the 50k potentiometer, R8. Remove jumper JMP5 to use external 10k thermistor.
bq24052 use the 500k potentiometer, R8. Remove jumper JMP5 to use external 100k thermistor.
D2: A USB ESD protection component may be installed here for ESD strikes above the 2kV HBM IC rating.

Figure 2. bq24050/2 EVM Schematic

5.2 Physical Layouts – HPA388A

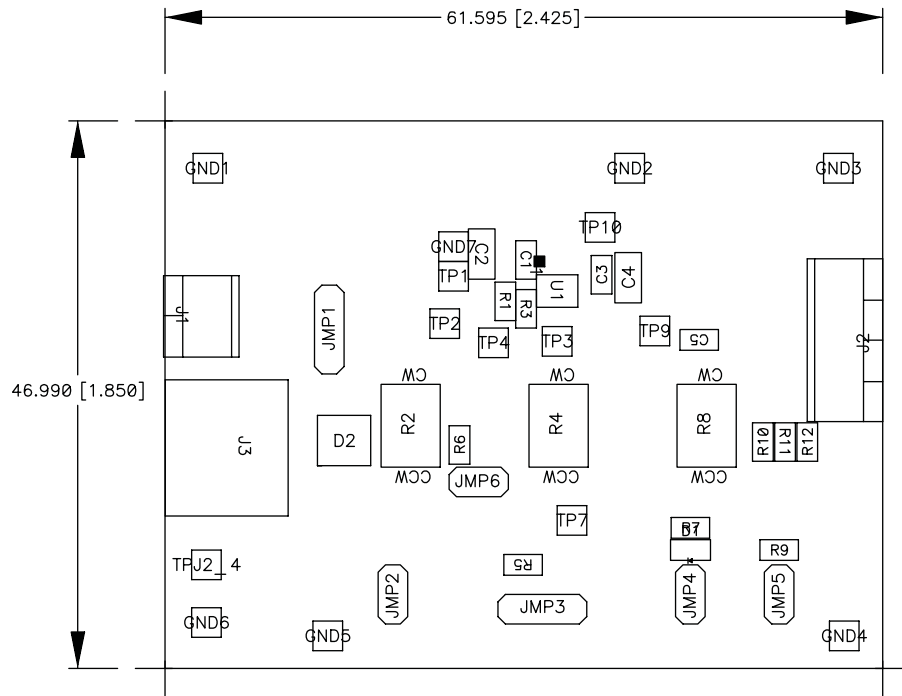


Figure 3. Top Assembly

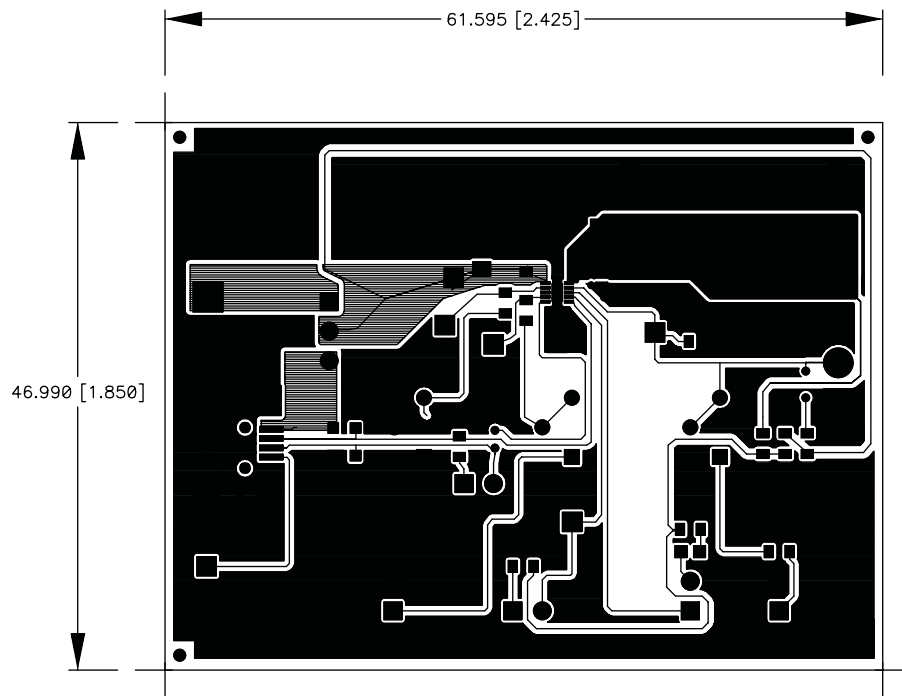
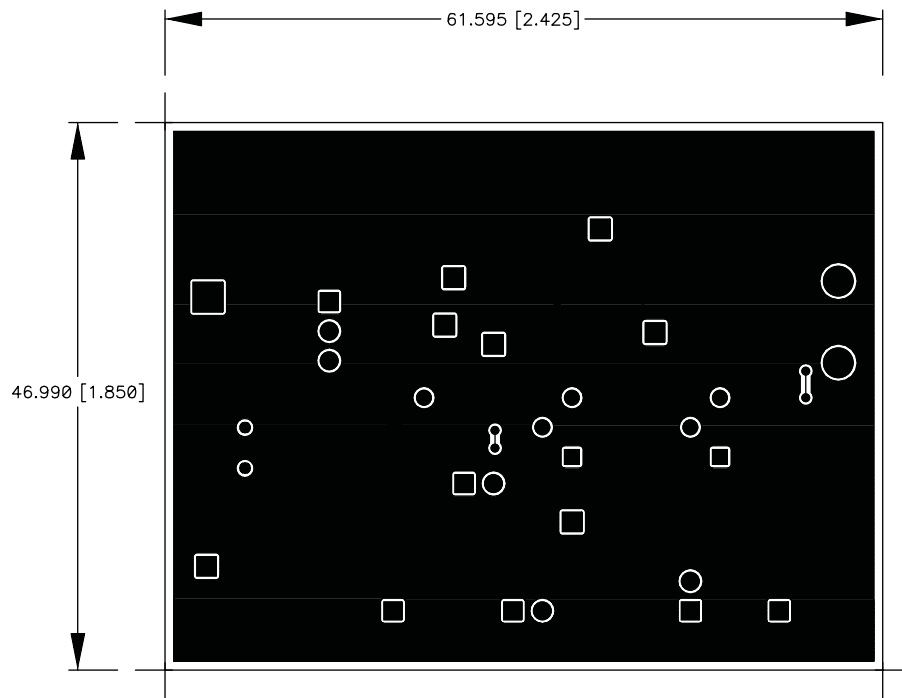


Figure 4. Top View


Figure 5. Bottom View

5.3 Bill of Materials – HPA388A

Table 1. HPA388A BOM – bq24050/2

-001	-002	RefDes	Value	Description	Size	Part Number	MFR
1	1	C1	1 μ F	Capacitor, Ceramic, 25V, X5R, 10%	0603	ECJ-1VB1E105K	Panasonic
0	0	C2	Optional	Capacitor, Ceramic, 25V, X5R, 10%	0805	ECJ-2FB1E***K	Panasonic
1	1	C3	2.2 μ F	Capacitor, Ceramic, 10V, X5R, 10%	0603	ECJ-1VB1A225K	Panasonic
0	0	C4	Optional	Capacitor, Ceramic, 10V, X5R, 10%	0805	ECJ-2FB1A***K	Panasonic
0	0	C5	Optional	Capacitor, Ceramic, 25V, X5R, 10%	0603	ECJ-1VB1E224K	Std
1	1	D1	LTST-C190GKT	Diode, LED, Green, 2.1-V, 20-mA, 6-mcd	0603	LTST-C190GKT	Lite On
0	0	D2	CM1213A-02SR	Diode, ESD Protection Arrays, 2 Channel	SOT143	CM1213A-02SR	CMD
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
1	1	J3	UX60-MB-5ST	Connector, Recpt, USB-B, Mini, 5-pins, SMT	0.354 x 0.303 Inches	UX60-MB-5ST	
2	2	JMP1, JMP3	PEC03SAAN	Header, Male 3-pin, 100mil spacing	0.100 inch x 3	PEC03SAAN	Sullins
4	4	JMP2, JMP4, JMP5, JMP6	PTC02SAAN	Header, Male 2-pin, 100mil spacing	0.100 inch x 2	PEC02SAAN	Sullins
1	1	R1	680	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R10	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	0	R11, R12	DNI	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	2	R2, R4	10k Ω	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-103LF	Bourns
2	2	R3, R9	1.0k Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R5	10k Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R6	200 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	1	R7	1.5k Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	0	R8	50k Ω	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-503LF	Bourns

Table 1. HPA388A BOM – bq24050/2 (continued)

-001	-002	RefDes	Value	Description	Size	Part Number	MFR
0	1	R8	500kΩ	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-504LF	Bourns
1	0	U1	BQ24050DSQ	IC, 750mA, Single-Input, Single Cell Li-Ion BATTERY CHARGER	SON-10	BQ24050DSQ	TI
0	1	U1	BQ24052DSQ	IC, 750mA, Single-Input, Single Cell Li-Ion BATTERY CHARGER	SON-10	BQ24052DSQ	TI
6	6	Shunt (Note 5)		Shunt, 100-mil, Black	0.1	929950-00	3M
1		–		PCB, 2.45 In x 1.85 In x 0.031 In		HPA388	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 MFG's components.
5. Apply shunt to JMP2/4/5/6 and JMP1:1/2 and JMP3:2/3.

5.4 Schematics – HPA379A

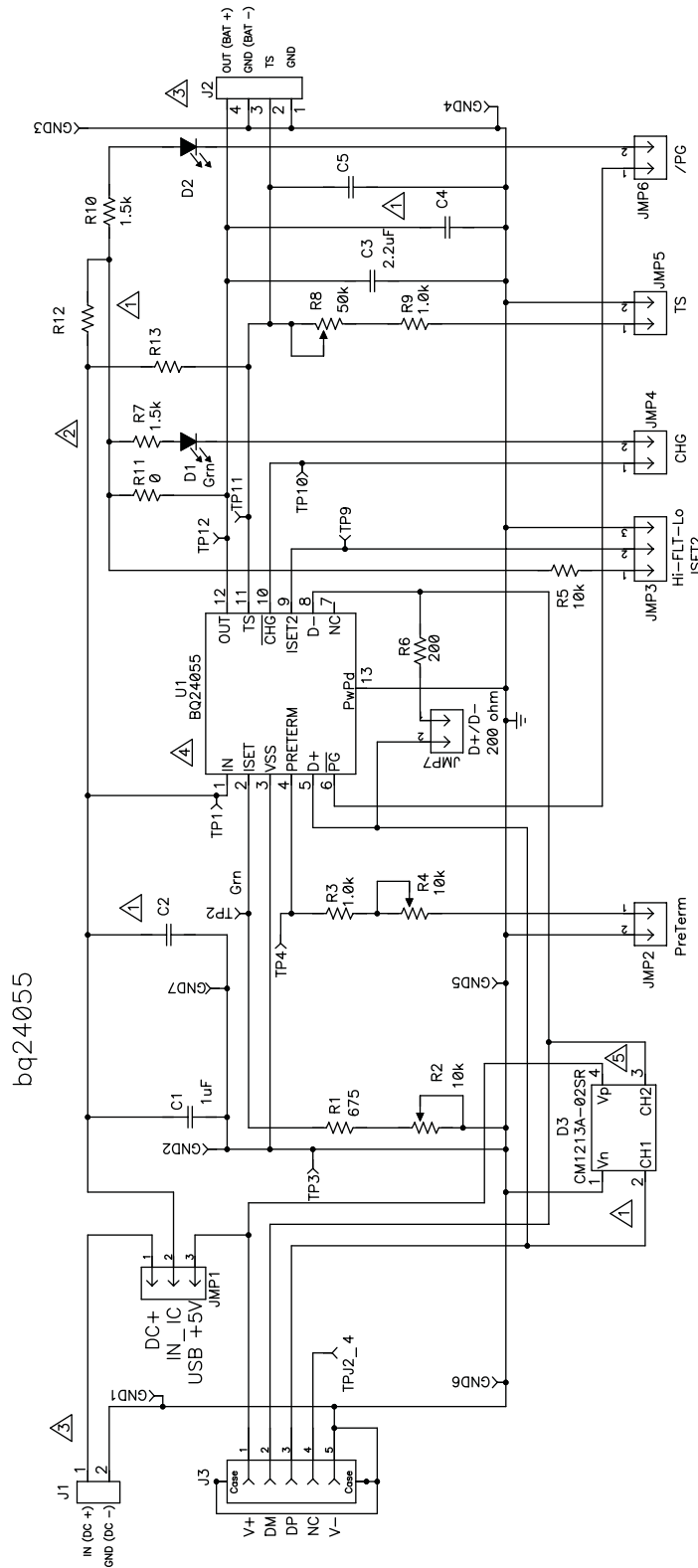


Figure 6. bq24055 EVM Schematic

- ⚠ R12, R13, D3, C2, C4 and C5 not installed.
- ⚠ R11 connects OUT pull-up for the LED and ISET2.
Can move R11 to R12; if Vin is desired as the pull-up source (note Vin should be <7V for this configuration).
R13 may be used in a future development.
- ⚠ Input Voltage: 4.5V to 5.5VDC Typical, Consider Thermal Issues for > 5.5V to OVP; No charging above OVP.
OUT is a 4.2V regulated output with a programmable output current of 1A maximum.
- ⚠ TP1→TP10 are associated with U1 pin out. TP5,6,7 & 8 are omitted.
- ⚠ A USB ESD protection component may be installed here for ESD strikes above the 2kV HBM IC rating.

5.5 Physical Layouts – HPA379A

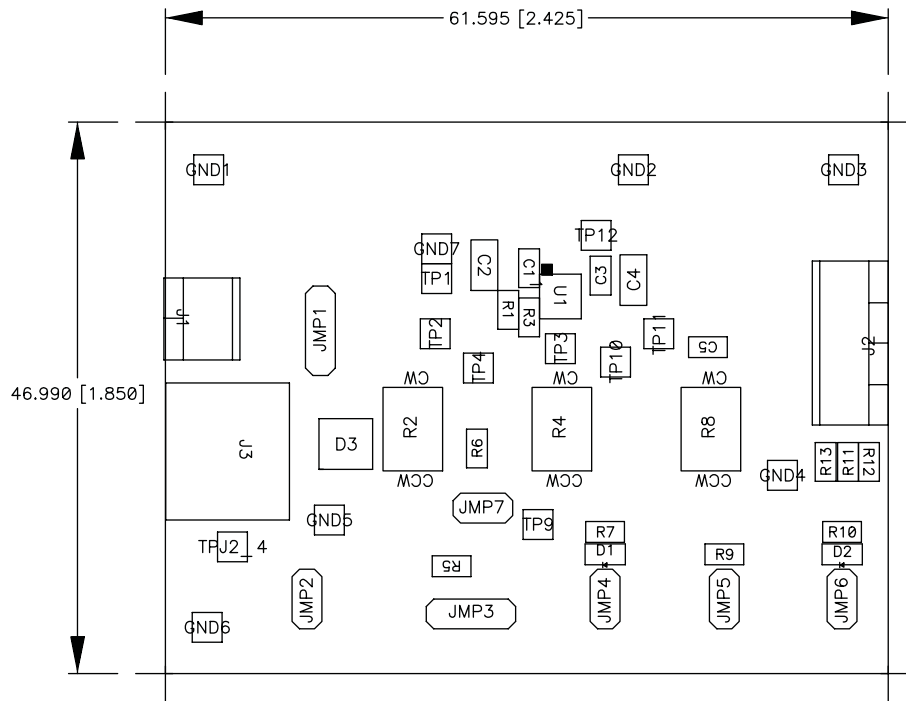


Figure 7. Top Assembly

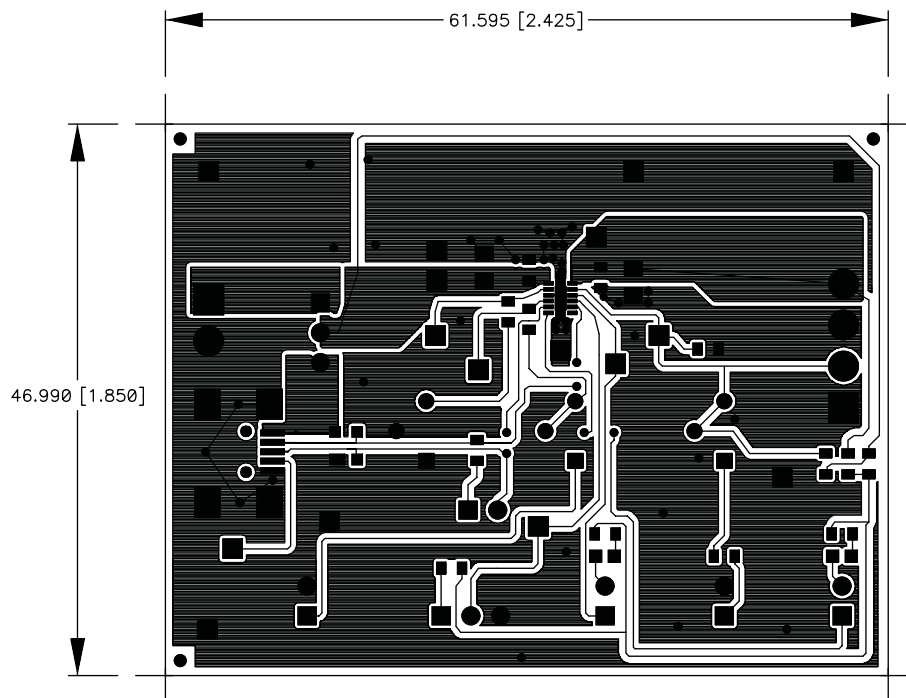


Figure 8. Top View

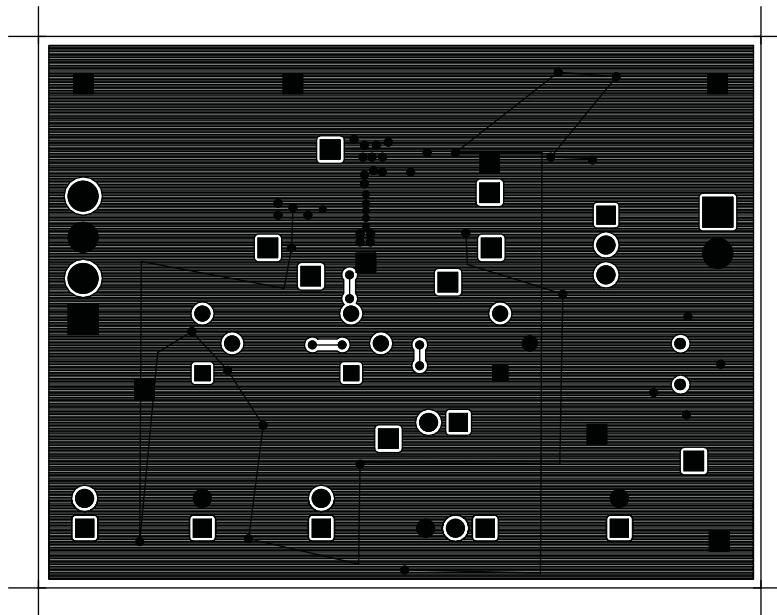


Figure 9. Bottom View

5.6 Bill of Materials – HPA379A

Table 2. HPA379A BOM – bq24055

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C1	1 μ F	Capacitor, Ceramic, 25V, X5R, 10%	0603	ECJ-1VB1E105K	Panasonic
0	C2		Capacitor, Ceramic, 25V, X5R, 10%	0805		
1	C3	2.2 μ F	Capacitor, Ceramic, 10V, X5R, 10%	0603	ECJ-1VB1A225K	Panasonic
0	C4		Capacitor, Ceramic, 10V, X5R, 10%	0805		
0	C5		Capacitor, Ceramic, 10V, X5R, 10%	0603		
2	D1, D2	LTST-C190GKT	Diode, LED, Green, 2.1-V, 20-mA, 6-mcd	0603	LTST-C190GKT	Lite On
0	D3	CM1213A-02SR	Diode, ESD Protection Arrays, 2 Channel	SOT143	CM1213A-02SR	CMD
1	J1**	ED555/2DS	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25 inch	ED555/2DS	OST
1	J2**	ED555/4DS	Terminal Block, 4-pin, 6-A, 3.5mm	0.55 x 0.25 inch	ED555/4DS	OST
1	J3	UX60-MB-5ST	Connector, Recpt, USB-B, Mini, 5-pins, SMT	0.354 X 0.303 Inches	UX60-MB-5ST	Hirose Electric Co Ltd
2	JMP1, JMP3	PEC03SAAN	Header, Male 3-pin, 100mil spacing, (3-pin strip)	0.100 inch x 3	PEC03SAAN	Sullins
5	JMP2, JMP4, JMP5, JMP6, JMP7	PEC02SAAN	Header, Male 2-pin, 100mil spacing, (2-pin strip)	0.100 inch x 2	PEC02SAAN	Sullins
1	R1	675 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R11	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R12, R13	DNI	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	R2, R4	10k Ω	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-103LF	Bourns
2	R3, R9	1.0k Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	10k Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R6	200 Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std
2	R7, R10	1.5k Ω	Resistor, Chip, 1/16W, 1%	0603	Std	Std

Table 2. HPA379A BOM – bq24055 (continued)

Count	RefDes	Value	Description	Size	Part Number	MFR
1	R8	50kΩ	Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust	0.25x0.17	3266W-1-503LF	Bourns
1	U1	BQ24055	IC, 800mA, Single-Input, Single Cell Li-Ion BATTERY CHARGER with Automatic AC/USB Detection	SON-12	BQ24055DSS	TI
6		929950-00	Shunts	100 mill	Black	3M
1	--		PCB, 2.4 In x 1.9 In x 0.031 In		HPA379	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 MFG's components.
 5. Apply shunt to JMP1:DC+/IN_IC; JMP2:GND/PreTerm; JMP3:GND/ISET2; JMP4:LED/CHG; JMP5:GND/TS; JMP6:LED/PG

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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.

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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