ABSTRACT
This application report discusses common standalone application circuits for the BQ24040 device. The BQ24040 is a single cell Li-Ion/Li-Pol battery charger that can charge at up to 1 A from a 5-V input source. The device is highly integrated and requires a minimum number of external parts and can be standalone or interface with a microcontroller.

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1 Introduction
Three designs are presented in the following sections: 1-A Fast Charge, 500-mA Fast Charge, and 100-mA Fast Charge. These designs can be implemented as is or modified to meet your requirements. Note this is a simplified explanation of the device and typical values are used and descriptions are brief. The data sheet (SLUS941) provides a full explanation with min and max values.
2 1-A Fast Charge Design

Figure 1 provides a solution that will charge at 1 A with termination at 5% or 50 mA.
- R-ISET will set fast charge current to 1 A, 549 Ω.
- R-PRE-TERM will set termination current to 5%, 1.0 kΩ.
- R-TS is required and 10k NTC in battery pack is typical value.
- CHG LED is used to indicate charge status, this is optional not required.
- PG LED is used to indicate input and output voltage is good, this is optional and not required.
- ISET2 – Grounded to set regulate current using R-ISET

This application will support larger batteries that can be charged at a 1-A fast charge, typically 1.0 Ahr or greater capacity.

3 500-mA Fast Charge Design

Figure 2 provides a lower power charging solution for smaller batteries with input current limited to 500 mA compatible with most USB ports / adapters.
- R-ISET will set fast charge current to 490 mA, 1.1 kΩ.
- R-PRE-TERM will set termination current to 10%, 2.0 kΩ.
- If the pin is open default is 10%
- R-TS is required and 10k NTC in battery pack is typical value.
- In lower power applications the NTC may not be needed or can be on PCB
- CHG LED is used to indicate charge status, this is optional and not required.
- PG LED optional not shown on this design.
- ISET2 – Pulled high to set regulate current to 500mA

This application will support medium power batteries.
4 100-mA Fast Charge Design

Figure 3 provides a low power charging solution for smaller batteries with input current limited to 100 mA. The BQ24040 is a 2 mm x 2 mm package and requires few external components allowing a very small solution for small solution size space limited applications.

- R-ISET will set fast charge current to 100 mA, 5.49 kΩ.
- R-PRE-TERM will set 10%, open to reduce parts count.
- R-TS 10k NTC is shown on the board, typically not on smaller battery pack.
- CHG LED is used to indicate charge status, this is optional and not required.
- PG LED not used.
- ISET2 – Float to set input current to 100 mA
- Power in resistors are very low and a 0201 or 0402 package can be used.

Care should be take on the input and output capacitors and an effective value of 1 µF is required and smaller package performance due to DC bias may be a problem.
5 Pin Configuration

The table below lists a quick summary of the pins of the device.

Table 1. BQ24040 Pin Configuration

<table>
<thead>
<tr>
<th>Pin - Name</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin 1 – IN</td>
<td>Input power USB or AC adapter</td>
<td>Operating range to 6.45 V with Max Vin 28 V</td>
</tr>
<tr>
<td>Pin 10 – OUT</td>
<td>Battery Connection / System Load</td>
<td>Battery Voltage 4.2 V</td>
</tr>
<tr>
<td>Pin 2 – ISET</td>
<td>Resistor R-ISET Sets Fast Charge Current, 549 Ω = 1 A</td>
<td>K-Set 540 A/Ω</td>
</tr>
<tr>
<td>Pin 7 – ISET2</td>
<td>Sets Input Current limit</td>
<td>Hi = 500 mA, Low = ISET, Float = 100 mA</td>
</tr>
<tr>
<td>Pin 4 – Pre-Term</td>
<td>Resistor R-Pre-Term Sets Charge Termination current, 2 k ohm =10% of fast charge</td>
<td>K-Term 200 Ω/%Open = 10%</td>
</tr>
<tr>
<td>Pin 9 – TS</td>
<td>NTC Thermistor or 10-kΩ resistor</td>
<td>10 k = Safe</td>
</tr>
<tr>
<td>Pin 8 – CHG</td>
<td>Open Drain output, Low = Charging</td>
<td></td>
</tr>
<tr>
<td>Pin 5 – PG</td>
<td>Open Drain output, Low = Input and Output voltage good</td>
<td></td>
</tr>
<tr>
<td>Pin 6 – NC</td>
<td>No Connection</td>
<td></td>
</tr>
<tr>
<td>Pin 3 – VSS/GND</td>
<td>Ground Terminal</td>
<td></td>
</tr>
<tr>
<td>Thermal Pad – VSS/GND</td>
<td>Exposed thermal pad and ground connection</td>
<td></td>
</tr>
</tbody>
</table>

6 FAQ / Tips and Tricks:

- During OVP unit cannot operate --- see Data Sheet (SLUS941) section 8.3.5
  - Max input voltage is 28 V but unit turns off above 7.5 V and will not operate above that point. Device will not be damaged up to 30 V, absolute maximum rating.
- Min input voltage --- Input to output voltage difference --- see Electrical Characteristics table VDO(IN-OUT)
  - Typical value is 325 mV but test condition is 50% reduction from 1-A output to 500 mA as V-in is reduced.
  - To hold output current at 1 A will require about 700 mV.
- Float TERM pin to set pre-charge and termination to typical value --- see Data Sheet section 8.4.6.
  - Termination can be set with a resistor at TERM pin, but if a typical value of pre-charge to 20% and termination to 10% is desired the pin can be floated.
- Limited output current at low battery voltage.
  - Battery voltage less than 0.8-V output current is limited to 15 mA, Battery Short Protection.
  - Battery voltage between 0.8-V and 2.5-V output current is limited to precharge current set by TERM pin typically 20% of fast charge.
  - Battery voltage above 2.5-V current will be a maximum value set by ISET pin.
- Termination disable (TTDM) using TS pin --- see Data Sheet section 8.4.8
  - 4.2-V power supply mode when battery is fully charged.
  - Start up in this mode will require very light load, must pass Battery Short Protection and Precharge to provide full current.
  - If no battery is present it may require load disable or load switch to allow voltage to reach 2.5 V to start up.
- Efficiency of charge, what is power dissipation, how to reduce power dissipation
  - Linear charger will act as a LDO and efficiency will be Vout / Vin.
  - Closer Vin is to Vout the better the efficiency and lower the power dissipation.
- Power good pin — see Data Sheet section 8.3.6
  - Open drain output and low indicates input power good.
  - Input power above UVLO (3.5 V) and VBAT +VDT (VDT = 80 mV)
• Charge complete pin — see Data Sheet section 8.3.7
  – Open drain output and low indicates charge in progress.
  – Active only for first charge, no indication on recharge.
  – Can be reset by cycling input power.
• Output current monitor at ISET — see Data Sheet section 8.4.5
  – ISET is a current source that is proportional to output current. Voltage developed on the R-ISET
    resistor will represent output current and can be monitored by external circuit.
• Open Battery — see Data Sheet section 8.4.12
  – With no battery present open battery detect circuit will result in a 50-ms square wave at OUT.
• Thermal Regulation, limit output current
  – If the die temperature reaches 125°C, the output current is reduced to control temperature.
  – If the die temperature increases to 155°C, the unit shuts down until temperature decreases.
• Thermal Pad for improved heat dissipation.
  – The device has an exposed thermal pad that should be soldered to PCB with sufficient copper area
    to manage power dissipation. Electrical connection is to ground.
• TS pin in a battery temperature application will use JEITA standard
  – The operating temperature range is 0°C to 60°C, with reduced current 0°C to 10°C, and reduced
    voltage from 45°C to 60°C.

7 R-ISET and R-TERM Common Values
Calculations for resistors ISET and TERM are provided in the data sheet. The following table provides a
quick reference. Note that values shown are calculated and are not the nearest standard resistor value.

<table>
<thead>
<tr>
<th>I-SET (mA)</th>
<th>R-ISET</th>
<th>%-Term</th>
<th>R-TERM</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5400</td>
<td>5</td>
<td>1000</td>
</tr>
<tr>
<td>200</td>
<td>2700</td>
<td>10</td>
<td>2000</td>
</tr>
<tr>
<td>300</td>
<td>1800</td>
<td>15</td>
<td>3000</td>
</tr>
<tr>
<td>400</td>
<td>1350</td>
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<td>4000</td>
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<tr>
<td>500</td>
<td>1080</td>
<td>25</td>
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<td>700</td>
<td>771</td>
<td>35</td>
<td>7000</td>
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<td>675</td>
<td>40</td>
<td>8000</td>
</tr>
<tr>
<td>900</td>
<td>600</td>
<td>45</td>
<td>9000</td>
</tr>
<tr>
<td>1000</td>
<td>540</td>
<td>50</td>
<td>10000</td>
</tr>
</tbody>
</table>

8 Simplified EVM Schematic
The EVM schematic shown is simplified for the BQ24040 application.
Figure 4. Simplified Schematic of EVM for Reference
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