

## 2.5A, Single Input, Single Cell Switchmode Li-Ion BATTERY CHARGER with Power Path Management

Check for Samples: [bq24278](#)

### FEATURES

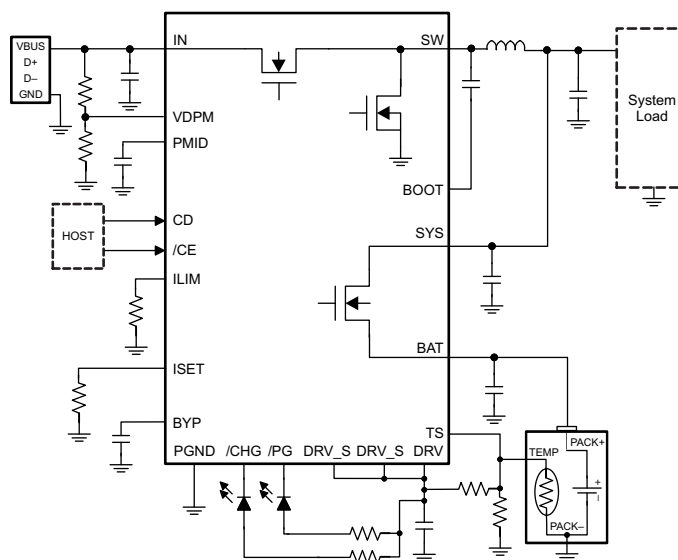
- High-Efficiency Switch Mode Charger with Separate Power Path Control
  - Instantly Startup System from a Deeply Discharged Battery or No Battery
- 20V input rating, with 10.5V Over-Voltage Protection (OVP)
- Integrated FETs for Up to 2.5A Charge Rate
- Highly Integrated Battery N-Channel MOSFET Controller for Power Path Management
- Safe and accurate Battery Management Functions
  - 0.5% Battery Regulation Accuracy
  - 10% Charge Current Accuracy
- Voltage-based, NTC Monitoring Input (TS)
  - Standard Temp Range

- Thermal Regulation Protection for Output Current Control
- Low Battery Leakage Current, BAT Short-Circuit Protection
- Soft-Start feature to reduce inrush current
- Thermal Shutdown and Protection
- Available in small 49-ball WCSP or QFN-24 packages

### APPLICATIONS

- Handheld Products
- Portable Media Players
- Portable Equipment
- Netbook and Portable Internet Devices

### APPLICATION SCHEMATIC



### DESCRIPTION

The bq24278 highly integrated single cell Li-Ion battery charger and system power path management device targeted for space-limited, portable applications with high capacity batteries. The single cell charger operates from a dedicated charging source such as an AC adapter or Wireless Power.



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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## DESCRIPTION (CONTINUED)

The power path management feature allows the bq24278 to power the system from a high efficiency DC to DC converter while simultaneously and independently charging the battery. The charger monitors the battery current at all times and reduces the charge current when the system load requires current above the input current limit. This allows for proper charge termination and timer operation. The system voltage is regulated to the battery voltage but will not drop below 3.5V. This minimum system voltage support enables the system to run with a defective or absent battery pack and enables instant system turn-on even with a totally discharged battery or no battery. The power-path management architecture also permits the battery to supplement the system current requirements when the adapter cannot deliver the peak system currents. This enables the use of a smaller adapter.

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 the internal temperature threshold is exceeded. Additionally, the bq24278 offers a voltage-based battery pack thermistor monitoring input (TS) that monitors battery temperature for safe charging .

## ORDERING INFORMATION

| PART NUMBER | IN OVP | NTC MONITORING (TS) | JEITA COMPATIBLE | MINIMUM SYSTEM VOLTAGE | PACKAGE |
|-------------|--------|---------------------|------------------|------------------------|---------|
| bq24278YFFR | 10.5 V | Yes                 | No               | 3.5 V                  | WCSP    |
| bq24278YFFT | 10.5 V | Yes                 | No               | 3.5 V                  | WCSP    |
| bq24278RGER | 10.5 V | Yes                 | No               | 3.5 V                  | QFN     |
| bq24278RGET | 10.5 V | Yes                 | No               | 3.5 V                  | QFN     |

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                                         |                                                                                                                                   | MIN  | MAX  | UNIT |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|------|------|------|
| Pin voltage range (with respect to VSS) | IN                                                                                                                                | –2   | 20   | V    |
|                                         | PMID, BYP, BOOT                                                                                                                   | –0.3 | 20   | V    |
|                                         | SW                                                                                                                                | –0.7 | 12   | V    |
|                                         | SYS, BAT, BGATE, DRV, $\overline{\text{PG}}$ , $\overline{\text{CHG}}$ , $\overline{\text{CE}}$ , CD, TS, DRV_S, ILIM, ISET, VDPM | –0.3 | 7    | V    |
| BOOT to SW                              |                                                                                                                                   | –0.3 | 7    | V    |
| Output current (continuous)             | SW                                                                                                                                |      | 4.5  | A    |
|                                         | SYS                                                                                                                               |      | 3.5  | A    |
| Input current (continuous)              | IN                                                                                                                                |      | 2.75 | A    |
| Output sink current                     | $\overline{\text{PG}}$ , $\overline{\text{CHG}}$                                                                                  |      | 10   | mA   |
| Operating free-air temperature range    |                                                                                                                                   | –40  | 85   | °C   |
| Junction temperature, T <sub>J</sub>    |                                                                                                                                   | –40  | 125  | °C   |
| Storage temperature, T <sub>STG</sub>   |                                                                                                                                   | –65  | 150  | °C   |
| Lead temperature (soldering, 10 s)      |                                                                                                                                   |      | 300  | °C   |

- (1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability. All voltage values are with respect to the network ground terminal unless otherwise noted.

## THERMAL INFORMATION

| THERMAL METRIC <sup>(1)</sup> |                                              | bq24278       |               | UNITS |
|-------------------------------|----------------------------------------------|---------------|---------------|-------|
|                               |                                              | YFF (48 PINS) | QFN (24 PINS) |       |
| $\theta_{JA}$                 | Junction-to-ambient thermal resistance       | 49.8          | 32.6          | °C/W  |
| $\theta_{JCTop}$              | Junction-to-case (top) thermal resistance    | 0.2           | 30.5          |       |
| $\theta_{JB}$                 | Junction-to-board thermal resistance         | 1.1           | 3.3           |       |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 1.1           | 0.4           |       |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 6.6           | 9.3           |       |
| $\theta_{JCbott}$             | Junction-to-case (bottom) thermal resistance | N/A           | 2.6           |       |

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## RECOMMENDED OPERATING CONDITIONS

|           |                                         | MIN | MAX               | UNITS |
|-----------|-----------------------------------------|-----|-------------------|-------|
| $V_{IN}$  | IN voltage range                        | 4.2 | 18 <sup>(1)</sup> | V     |
|           | IN operating range                      | 4.2 | 10                |       |
| $I_{IN}$  | Input current IN input                  |     | 2.5               | A     |
| $I_{SYS}$ | Output Current from SW, DC              |     | 3                 | A     |
| $I_{BAT}$ | Charging                                |     | 2.5               | A     |
|           | Discharging, using internal battery FET |     | 2.5               |       |
| $T_J$     | Operating junction temperature range    | 0   | 125               | °C    |

(1) The inherent switching noise voltage spikes should not exceed the absolute maximum rating on either the BOOT or SW pins. A tight layout minimizes switching noise.

## ELECTRICAL CHARACTERISTICS

Circuit of [Figure 2](#),  $V_{UVLO} < V_{IN} < V_{OVP}$  AND  $V_{IN} > V_{BAT} + V_{SLP}$ ,  $T_J = 0^{\circ}\text{C} - 125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

| PARAMETER                    |                                                                      | TEST CONDITIONS                                                                                                              | MIN  | TYP                     | MAX  | UNIT |
|------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------|-------------------------|------|------|
| $I_{IN}$                     | Input quiescent current                                              | $V_{UVLO} < V_{IN} < V_{OVP}$ AND $V_{IN} > V_{BAT} + V_{SLP}$ PWM switching                                                 |      | 15                      |      | mA   |
|                              |                                                                      | $V_{UVLO} < V_{IN} < V_{OVP}$ AND $V_{IN} > V_{BAT} + V_{SLP}$ PWM NOT switching                                             |      |                         | 5    |      |
|                              |                                                                      | $0^{\circ}\text{C} < T_J < 85^{\circ}\text{C}$ , High-Z Mode                                                                 |      |                         | 175  | μA   |
| $I_{BATLEAK}$                | Leakage current from BAT to the supply                               | $0^{\circ}\text{C} < T_J < 85^{\circ}\text{C}$ , $V_{BAT} = 4.2\text{V}$ , $V_{IN} = 0\text{V}$                              |      |                         | 5    | μA   |
| $I_{BAT\_HIZ}$               | Battery discharge current in High Impedance mode (BAT, SW, SYS)      | $0^{\circ}\text{C} < T_J < 85^{\circ}\text{C}$ , $V_{BAT} = 4.2\text{V}$ , $V_{IN} = 0\text{V}$ or $5\text{V}$ , High-Z Mode |      |                         | 55   | μA   |
| <b>POWER PATH MANAGEMENT</b> |                                                                      |                                                                                                                              |      |                         |      |      |
| $V_{SYS(REG)}$               | System regulation voltage                                            | $V_{BAT} < V_{MINSYS}$                                                                                                       | 3.6  | 3.7                     | 3.82 | V    |
| $V_{SYSREGFETOFF}$           |                                                                      | Battery FET turned off, Charge disable or termination                                                                        | 4.26 | 4.33                    | 4.37 |      |
| $V_{MINSYS}$                 | Minimum system regulation voltage                                    | $V_{BAT} < V_{MINSYS}$ , Input current limit or VINDPM active                                                                | 3.4  | 3.5                     | 3.62 | V    |
| $V_{BSUP1}$                  | Enter supplement mode threshold                                      | $V_{BAT} > 2.5\text{V}$                                                                                                      |      | $V_{BAT} - 40\text{mV}$ |      | V    |
| $V_{BSUP2}$                  | Exit supplement mode threshold                                       | $V_{BAT} > 2.5\text{V}$                                                                                                      |      | $V_{BAT} - 10\text{mV}$ |      | V    |
| $I_{LIM(Discharge)}$         | Current limit, discharge or supplement mode                          | Current monitored in internal FET only                                                                                       |      | 7                       |      | A    |
| $t_{DGL(SC1)}$               | Deglitch time, OUT short circuit during discharge or supplement mode | Measured from $(V_{BAT} - V_{SYS}) = 300\text{mV}$ to $V_{BGATE} = (V_{BAT} - 600\text{mV})$                                 |      | 250                     |      | μs   |
| $t_{REC(SC1)}$               | Recovery time, OUT short circuit during discharge or supplement mode |                                                                                                                              |      | 60                      |      | ms   |
|                              | Battery range for BGATE operation                                    |                                                                                                                              | 2.5  |                         | 4.5  | V    |

## ELECTRICAL CHARACTERISTICS (continued)

Circuit of [Figure 2](#),  $V_{VLO} < V_{IN} < V_{OVP}$  AND  $V_{IN} > V_{BAT} + V_{SLP}$ ,  $T_J = 0^{\circ}\text{C} - 125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

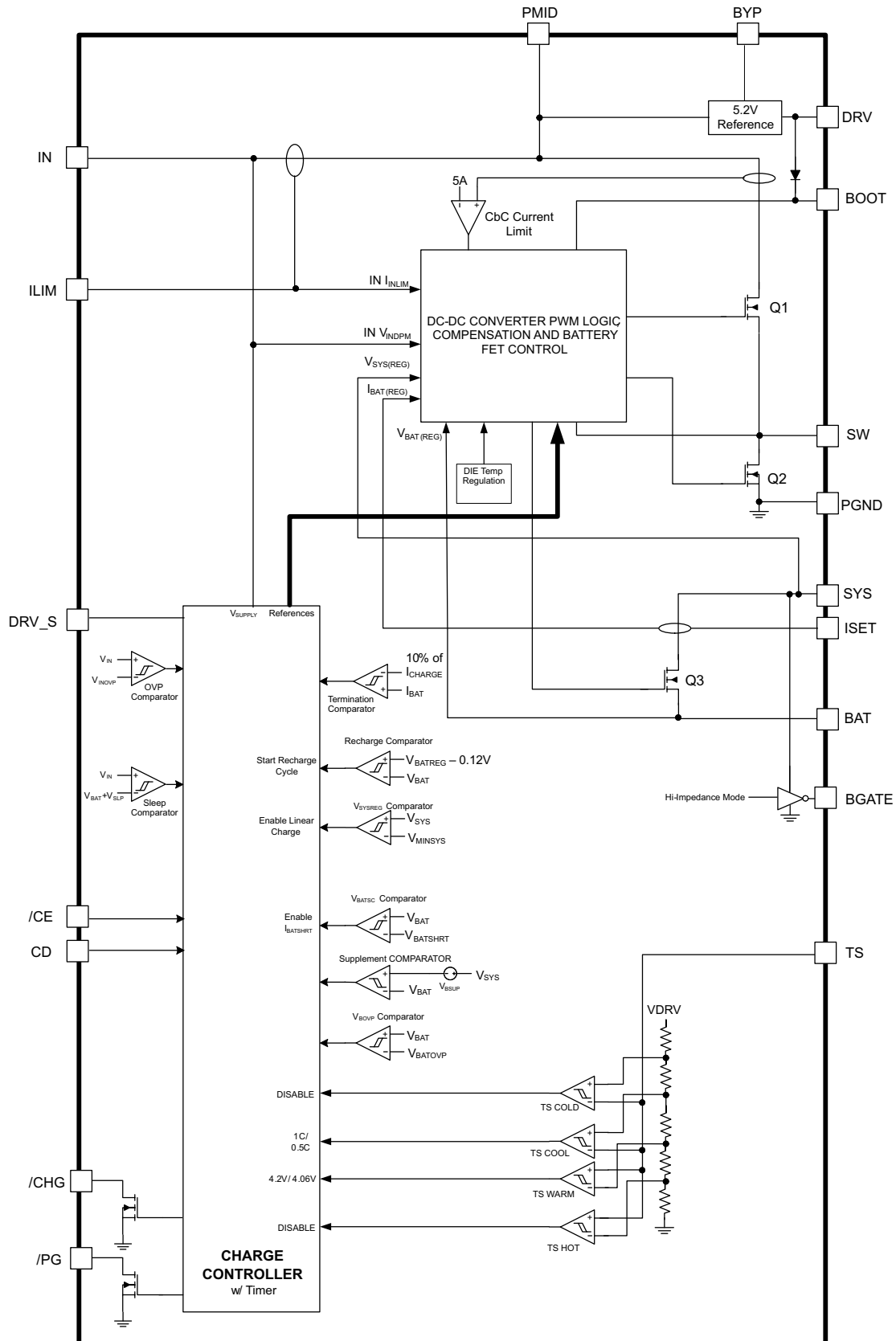
| PARAMETER                 |                                                                               | TEST CONDITIONS                                                                             |                    | MIN                         | TYP                        | MAX                         | UNIT                     |
|---------------------------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------|-----------------------------|----------------------------|-----------------------------|--------------------------|
| BATTERY CHARGER           |                                                                               |                                                                                             |                    |                             |                            |                             |                          |
| R <sub>ON(BAT-SYS)</sub>  | Internal battery charger MOSFET on-resistance                                 | Measured from BAT to SYS,<br>V <sub>BAT</sub> = 4.2 V                                       | YFF pkg<br>RGE pkg | 37<br>50                    | 57<br>70                   |                             | mΩ                       |
| V <sub>BATREG</sub>       | Battery regulation voltage                                                    | T <sub>A</sub> = 25°C                                                                       |                    | 4.179                       | 4.2                        | 4.221                       | V                        |
|                           |                                                                               | V <sub>WARM</sub> < V <sub>TS</sub> < V <sub>COOL</sub>                                     |                    | 4.160                       | 4.2                        | 4.24                        |                          |
|                           |                                                                               | T <sub>A</sub> = 25°C                                                                       |                    | 4.04                        | 4.06                       | 4.08                        |                          |
|                           |                                                                               | V <sub>HOT</sub> < V <sub>TS</sub> < V <sub>WARM</sub>                                      |                    | 4.02                        | 4.06                       | 4.1                         |                          |
| I <sub>CHARGE</sub>       | Charge current programmable range                                             | I <sub>CHARGE</sub> = $\frac{K_{ISET}}{R_{ISET}}$                                           |                    | 550                         |                            | 2500                        | mA                       |
| K <sub>ISET</sub>         | Programmable fast charge current factor                                       | T <sub>A</sub> = 0°C to 125°C, V <sub>WARM</sub> < V <sub>TS</sub> < V <sub>COOL</sub>      |                    | 400                         | 490                        | 560                         | AΩ                       |
|                           |                                                                               | T <sub>A</sub> = 0°C to 125°C, V <sub>COLD</sub> < V <sub>TS</sub> < V <sub>COOL</sub>      |                    | 225                         | 245                        | 270                         |                          |
| V <sub>BATSHRT</sub>      | Battery short threshold                                                       | V <sub>BAT</sub> Rising                                                                     |                    | 2.9                         | 3.0                        | 3.1                         | V                        |
| V <sub>BATSHRThys</sub>   | Battery short threshold hysteresis                                            | V <sub>BAT</sub> Falling                                                                    |                    |                             | 100                        |                             | mV                       |
| I <sub>BATSHRT</sub>      | Battery short current                                                         | V <sub>BAT</sub> < V <sub>BATSHRT</sub>                                                     |                    |                             | 50.0                       |                             | mA                       |
| t <sub>DGL(BATSHRT)</sub> | Deglitch time for battery short to fast charge transition                     |                                                                                             |                    |                             | 32                         |                             | ms                       |
| I <sub>TERM</sub>         | Termination charge current                                                    | I <sub>CHARGE</sub> ≤ 1A                                                                    |                    | 7                           | 10                         | 11.5                        | %I <sub>CHARGE</sub>     |
|                           |                                                                               | I <sub>CHARGE</sub> >1A                                                                     |                    | 8                           | 10                         | 11                          |                          |
| t <sub>DGL(TERM)</sub>    | Deglitch time for charge termination                                          | Both rising and falling, 2-mV over-drive,<br>t <sub>RISE</sub> , t <sub>FALL</sub> = 100 ns |                    |                             | 32                         |                             | ms                       |
| V <sub>RCH</sub>          | Recharge threshold voltage                                                    | Below V <sub>BATREG</sub>                                                                   |                    |                             | 120                        |                             | mV                       |
| t <sub>DGL(RCH)</sub>     | Deglitch time                                                                 | V <sub>BAT</sub> falling below V <sub>RCH</sub> , t <sub>FALL</sub> = 100 ns                |                    |                             | 32                         |                             | ms                       |
| I <sub>DETECT</sub>       | Battery detection current before charge done (sink current)                   |                                                                                             |                    |                             | 2.5                        |                             | mA                       |
| t <sub>DETECT</sub>       | Battery detection time                                                        |                                                                                             |                    |                             | 250                        |                             | ms                       |
| INPUT PROTECTION          |                                                                               |                                                                                             |                    |                             |                            |                             |                          |
| I <sub>INLIM</sub>        | Maximum input current limit programmable range for IN input                   | I <sub>INLIM</sub> = $\frac{K_{ILIM}}{R_{ILIM}}$                                            |                    | 1000                        |                            | 2500                        | mA                       |
| K <sub>ILIM</sub>         | Maximum input current factor for IN input                                     |                                                                                             |                    | 238                         | 251                        | 264                         | AΩ                       |
| V <sub>IN_DPM_IN</sub>    | VIN_DPM threshold programmable range for IN Input                             |                                                                                             |                    | 4.2                         |                            | 10                          | V                        |
|                           | VDPM threshold                                                                |                                                                                             |                    | 1.18                        | 1.2                        | 1.22                        | V                        |
| V <sub>DRV</sub>          | Internal bias regulator voltage                                               |                                                                                             |                    | 5                           | 5.2                        | 5.45                        | V                        |
| I <sub>DRV</sub>          | DRV Output current                                                            |                                                                                             |                    | 10                          |                            |                             | mA                       |
| V <sub>DO_DRV</sub>       | DRV Dropout voltage (V <sub>IN</sub> – V <sub>DRV</sub> )                     | I <sub>IN</sub> = 1A, V <sub>IN</sub> = 5 V, I <sub>DRV</sub> = 10 mA                       |                    |                             |                            | 450                         | mV                       |
| V <sub>UVLO</sub>         | IC active threshold voltage                                                   | V <sub>IN</sub> rising                                                                      |                    | 3.6                         | 3.8                        | 4.0                         | V                        |
| V <sub>UVLO_HYS</sub>     | IC active hysteresis                                                          | V <sub>IN</sub> falling from above V <sub>UVLO</sub>                                        |                    |                             | 150                        |                             | mV                       |
| V <sub>SLP</sub>          | Sleep-mode entry threshold, V <sub>IN</sub> -V <sub>BAT</sub>                 | 2.0 V ≤ V <sub>BAT</sub> ≤ V <sub>OREG</sub> , V <sub>IN</sub> falling                      |                    | 0                           | 40                         | 100                         | mV                       |
| V <sub>SLP_EXIT</sub>     | Sleep-mode exit hysteresis                                                    | 2.0 V ≤ V <sub>BAT</sub> ≤ V <sub>OREG</sub>                                                |                    | 40                          | 100                        | 160                         | mV                       |
|                           | Deglitch time for supply rising above V <sub>SLP</sub> +V <sub>SLP_EXIT</sub> | Rising voltage, 2-mV over drive, t <sub>RISE</sub> = 100 ns                                 |                    |                             | 30                         |                             | ms                       |
| V <sub>OVP</sub>          | Input supply OVP threshold voltage                                            | IN, V <sub>IN</sub> Rising                                                                  |                    | 10.3                        | 10.5                       | 10.7                        | V                        |
| V <sub>OVP(HYS)</sub>     | V <sub>OVP</sub> hysteresis                                                   | Supply falling from V <sub>OVP</sub>                                                        |                    |                             | 100                        |                             | mV                       |
| V <sub>BOVP</sub>         | Battery OVP threshold voltage                                                 | V <sub>BAT</sub> threshold over V <sub>OREG</sub> to turn off charger during charge         |                    | 1.025 × V <sub>BATREG</sub> | 1.05 × V <sub>BATREG</sub> | 1.075 × V <sub>BATREG</sub> | V                        |
|                           | VB <sub>OVP</sub> hysteresis                                                  | Lower limit for V <sub>BAT</sub> falling from above V <sub>BOVP</sub>                       |                    |                             | 1                          |                             | % of V <sub>BATREG</sub> |
| V <sub>BATUVLO</sub>      | Battery UVLO threshold voltage                                                |                                                                                             |                    |                             | 2.5                        |                             | V                        |
| I <sub>LIMIT</sub>        | Cycle by Cycle current limit                                                  |                                                                                             |                    | 4.1                         | 4.9                        | 5.6                         | A                        |
| T <sub>SHUTDWN</sub>      | Thermal shutdown                                                              | 10C Hysteresis                                                                              |                    |                             | 165                        |                             | C                        |
| T <sub>REG</sub>          | Thermal regulation threshold                                                  |                                                                                             |                    |                             | 120                        |                             | C                        |
|                           | Safety Timer                                                                  |                                                                                             |                    | 324                         | 360                        | 396                         | min                      |
| CE, CD, PG, CHG           |                                                                               |                                                                                             |                    |                             |                            |                             |                          |
| V <sub>IH</sub>           | Input high threshold                                                          |                                                                                             |                    | 1.3                         |                            |                             | V                        |
| V <sub>IL</sub>           | Input low threshold                                                           |                                                                                             |                    |                             |                            | 0.4                         | V                        |
| I <sub>IH</sub>           | High-level leakage current                                                    | V <sub>CHG</sub> = V <sub>PG</sub> = 5 V                                                    |                    |                             |                            | 1                           | μA                       |
| V <sub>OL</sub>           | Low-level output saturation voltage                                           | I <sub>O</sub> = 10 mA, sink current                                                        |                    |                             |                            | 0.4                         | V                        |

## ELECTRICAL CHARACTERISTICS (continued)

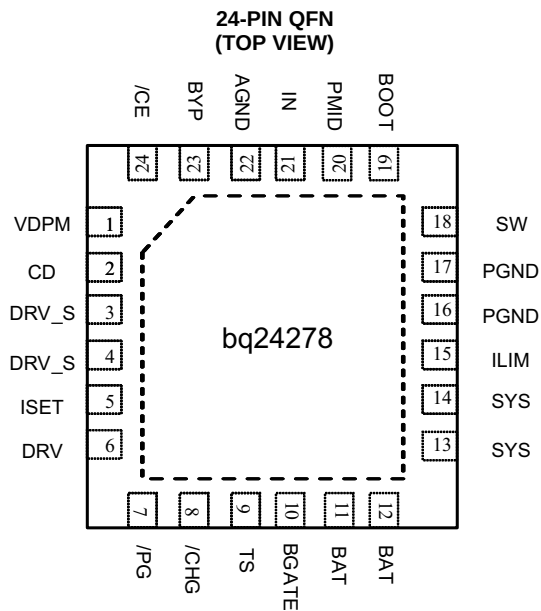
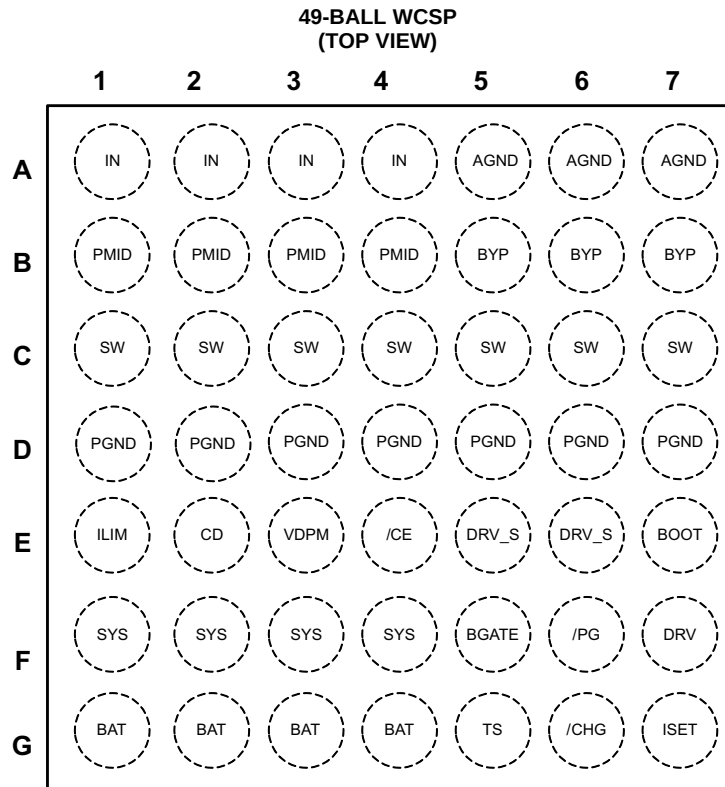
Circuit of [Figure 2](#),  $V_{U_{VLO}} < V_{IN} < V_{OVP}$  AND  $V_{IN} > V_{BAT} + V_{SLP}$ ,  $T_J = 0^{\circ}\text{C} - 125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

| PARAMETER                       |                                                       | TEST CONDITIONS                                                   | MIN  | TYP  | MAX  | UNIT  |
|---------------------------------|-------------------------------------------------------|-------------------------------------------------------------------|------|------|------|-------|
| <b>PWM CONVERTER</b>            |                                                       |                                                                   |      |      |      |       |
|                                 | Internal top reverse blocking MOSFET on-resistance    | $I_{IN\_LIMIT} = 500\text{ mA}$ , Measured from $V_{IN}$ to PMIDU |      | 95   | 175  | mΩ    |
|                                 | Internal top N-channel Switching MOSFET on-resistance | Measured from PMIDU to SW                                         |      | 100  | 175  | mΩ    |
|                                 | Internal bottom N-channel MOSFET on-resistance        | Measured from SW to PGND                                          |      | 65   | 115  | mΩ    |
| $f_{OSC}$                       | Oscillator frequency                                  |                                                                   | 1.35 | 1.50 | 1.65 | MHz   |
| $D_{MAX}$                       | Maximum duty cycle                                    |                                                                   |      | 95%  |      |       |
| $D_{MIN}$                       | Minimum duty cycle                                    |                                                                   | 0    |      |      |       |
| <b>BATTERY-PACK NTC MONITOR</b> |                                                       |                                                                   |      |      |      |       |
| $V_{HOT}$                       | High temperature threshold                            | $V_{TS}$ falling                                                  | 29.7 | 30   | 30.5 | %VDRV |
| $V_{HYS(HOT)}$                  | Hysteresis on high threshold                          | $V_{TS}$ rising                                                   |      | 1    |      |       |
| $V_{COLD}$                      | Low temperature threshold                             | $V_{TS}$ rising                                                   | 59.5 | 60   | 60.4 |       |
| $V_{WARM}$                      | Warm temperature threshold                            | $V_{TS}$ falling                                                  | 37.9 | 38.3 | 39.6 |       |
| $V_{HYS(WARM)}$                 | Hysteresis on warm threshold                          | $V_{TS}$ rising                                                   |      | 1    |      |       |
| $V_{COOL}$                      | Cool temperature threshold                            | $V_{TS}$ rising                                                   | 56.0 | 56.5 | 56.9 |       |
| $V_{HYS(COOL)}$                 | Hysteresis on cool threshold                          | $V_{TS}$ falling                                                  |      | 1    |      |       |
| $V_{HYS(COLD)}$                 | Hysteresis on low threshold                           | $V_{TS}$ falling                                                  |      | 1    |      |       |
| $TSOFF$                         | TS Disable threshold                                  | $V_{TS}$ rising, 2% $V_{DRV}$ Hysteresis                          | 70   |      | 73   |       |
| $t_{DGL(TS)}$                   | Deglitch time on TS change                            |                                                                   |      | 50   |      | ms    |

## BLOCK DIAGRAM



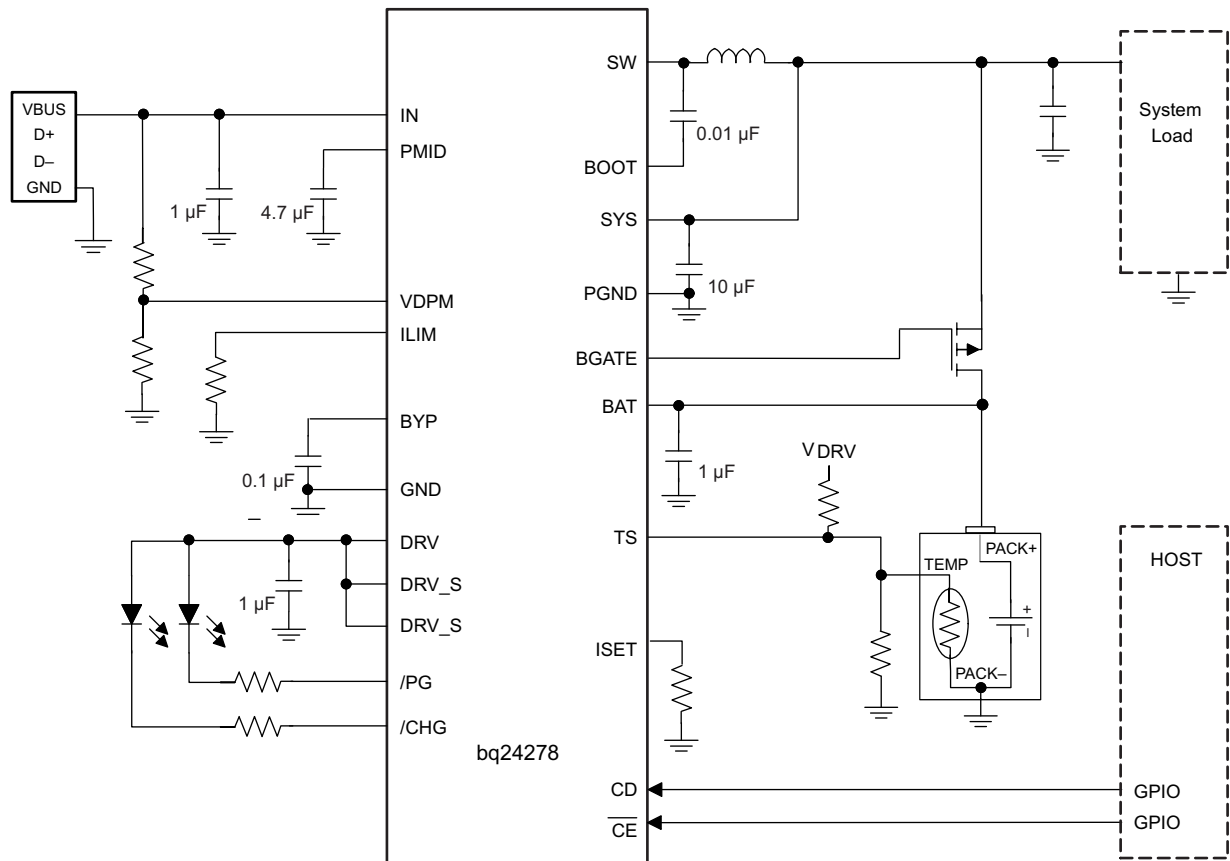
## PIN CONFIGURATION



## PIN FUNCTIONS

| PIN                     |        |        | I/O | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------|--------|--------|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                    | NUMBER |        |     |                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | YFF    | RGE    |     |                                                                                                                                                                                                                                                                                                                                                                                 |
| IN                      | A1-A4  | 21     | I   | Input power supply. IN is connected to the external DC supply (AC adapter or alternate power source). Bypass IN to PGND with at least a 1μF ceramic capacitor.                                                                                                                                                                                                                  |
| AGND                    | A5-A7  | 22     | I   | Ground terminal. Connect to the thermal pad (for QFN only) and the ground plane of the circuit.                                                                                                                                                                                                                                                                                 |
| PMID                    | B1-B4  | 20     | O   | Reverse Blocking MOSFET and High Side MOSFET Connection Point for High Power Input. Bypass PMID to PGND with at least a 4.7μF ceramic capacitor. Use caution when connecting an external load to PMID. The PMID output is not current limited. Any short on PMID will result in damage to the IC.                                                                               |
| BYP                     | B5-B7  | 23     | O   | Bypass for internal supply. Bypass BYP to GND with at least a 0.1μF ceramic capacitor.                                                                                                                                                                                                                                                                                          |
| SW                      | C1–C7  | 18     | O   | Inductor Connection. Connect to the switched side of the external inductor.                                                                                                                                                                                                                                                                                                     |
| PGND                    | D1–D7  | 16, 17 | —   | Ground terminal for Switching FET. Connect to the thermal pad (for QFN only) and the ground plane of the circuit.                                                                                                                                                                                                                                                               |
| ILIM                    | E1     | 15     | I   | IN Input Current Limit Programming Input. Connect a resistor from ILIM to GND to program the input current limit for IN. The current limit is programmable from 1A to 2.5A.                                                                                                                                                                                                     |
| CD                      | E2     | 2      | I   | IC Hardware Disable Input. Drive CD high to place the bq24278 in high-z mode. Drive CD low for normal operation.                                                                                                                                                                                                                                                                |
| VDPM                    | E3     | 1      | I   | Input DPM Programming Input. Connect a resistor divider from IN to PGND with VDPM connected to the center tap to program the Input Voltage based Dynamic Power Management (VIN_DPM) threshold. The input current is reduced to maintain the supply voltage at VIN_DPM. See the <i>Input Voltage based Dynamic Power Management</i> section for a detailed explanation.          |
| $\overline{\text{CE}}$  | E4     | 24     | I   | Charge Enable Input. $\overline{\text{CE}}$ is used to disable or enable the charge process. A low logic level (0) enables charging and a high logic level (1) disables charging. When charging is disabled, the SYS output remains in regulation, but BAT is disconnected from SYS. Supplement mode is still available if the system load demands cannot be met by the supply. |
| DRV_S                   | E5, E6 | 3, 4   | I   | Supply for Internal Circuits. Connect DRV_S to DRV directly.                                                                                                                                                                                                                                                                                                                    |
| BOOT                    | E7     | 19     | I   | High Side MOSFET Gate Driver Supply. Connect a 0.01μF ceramic capacitor (voltage rating > 10V) from BOOT to SW to supply the gate drive for the high side MOSFETs.                                                                                                                                                                                                              |
| SYS                     | F1–F4  | 13,14  | I/O | System Voltage Sense and Charger FET Connection. Connect SYS to the system output at the output bulk capacitors. Bypass SYS locally with 1μF.                                                                                                                                                                                                                                   |
| BGATE                   | F5     | 10     | O   | External Discharge MOSFET Gate Connection. BGATE drives an external P-Channel MOSFET to provide a very low resistance discharge path. Connect BGATE to the gate of the external MOSFET. BGATE is low during supplement mode and when no input is connected.                                                                                                                     |
| $\overline{\text{PG}}$  | F6     | 7      | I   | Power Good Open Drain Output. /PG is pulled low when a valid supply is connected to IN. A valid supply is between $V_{\text{BAT}}+V_{\text{SLP}}$ and $V_{\text{OVP}}$ . If no supply is connected or the supply is out of this range, $\overline{\text{PG}}$ is high impedance.                                                                                                |
| DRV                     | F7     | 6      | O   | Gate Drive Supply. DRV is the bias supply for the gate drive of the internal MOSFETs. bypass DRV to PGND with a 1μF ceramic capacitor. DRV may be used to drive external loads up to 10mA. DRV is active whenever the input is connected and $V_{\text{SUPPLY}} > V_{\text{UVLO}}$ and $V_{\text{SUPPLY}} > (V_{\text{BAT}} + V_{\text{SLP}})$                                  |
| BAT                     | G1–G4  | 11, 12 | I/O | Battery Connection. Connect to the positive terminal of the battery. Additionally, bypass BAT to GND with a 1μF capacitor.                                                                                                                                                                                                                                                      |
| TS                      | G5     | 9      | I   | Battery Pack NTC Monitor. Connect TS to the center tap of a resistor divider from DRV to GND. The NTC is connected from TS to GND. The TS function in the bq24278 provides 2 thresholds for Hot/ Cold shutoff, with 2 additional thresholds for JEITA compliance. See the <i>NTC Monitor</i> section for more details on operation and selecting the resistor values.           |
| $\overline{\text{CHG}}$ | G6     | 8      | O   | Charge Status Open Drain Output. $\overline{\text{CHG}}$ is pulled low when a charge cycle starts and remains low while charging. CHG is high impedance when the charging terminates and when no supply exists. $\overline{\text{CHG}}$ does not indicate recharge cycles.                                                                                                      |
| ISET                    | G7     | 5      | I   | Charge Current Programming Input. Connect a resistor from ISET to GND to program the fast charge current. The charge current is programmable from 550mA to 2.5A.                                                                                                                                                                                                                |
| Thermal Pad             | —      | Pad    | —   | There is an internal electrical connection between the exposed thermal pad and the VSS pin of the device. The thermal pad must be connected to the same potential as the VSS pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device. VSS pin must be connected to ground at all times.                                         |

## TYPICAL APPLICATION CIRCUIT



**Figure 1. bq24278 Application Circuit, External Discharge FET Connected**

## DETAILED DESCRIPTION

The bq24278 is a highly integrated single cell Li-Ion battery charger and system power path management devices targeted for space-limited, portable applications with high capacity batteries. The power path management feature allows the bq24278 to power the system from a high efficiency DC to DC converter while simultaneously and independently charging the battery. The charger monitors the battery current at all times and reduces the charge current when the system load requires current above the input current limit. This allows for proper charge termination and enables the system to run with a defective or absent battery pack. Additionally, this enables instant system turn-on even with a totally discharged battery or no battery. The power-path management architecture also permits the battery to supplement the system current requirements when the adapter cannot deliver the peak system currents. This enables the use of a smaller adapter. 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 the internal temperature threshold is exceeded.

## Charge Mode Operation

### Charge Profile

Charging is done through the internal battery MOSFET. When the battery voltage is above 3.5V, the system output (SYS) is connected to the battery to maximize the charging efficiency. There are 5 loops that influence the charge current; constant current loop (CC), constant voltage loop (CV), thermal regulation loop, minimum system voltage loop (MINSYS) and input voltage dynamic power management loop ( $V_{IN-DPM}$ ). During the charging process, all five loops are enabled and the dominant one takes control. The bq24278 supports a precision Li-Ion or Li-Polymer charging system for single-cell applications. The minimum system output feature regulates the system voltage to a minimum of  $V_{SYS(REG)}$ , so that startup is enabled even for a missing or deeply discharged battery. Figure 2 shows a typical charge profile including the minimum system output voltage feature.

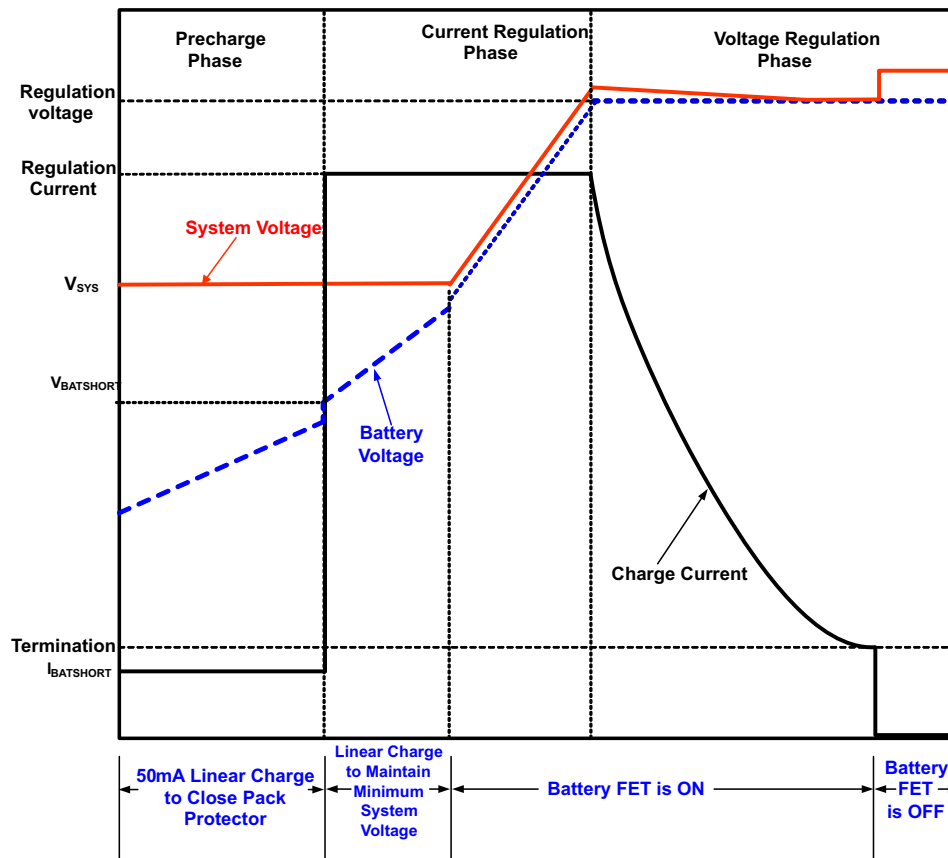


Figure 2. Typical Charging Profile of bq24278

## PWM Controller in Charge Mode

The bq24278 provides an integrated, fixed 1.5 MHz frequency voltage-mode controller with to power the system and supply the charge current. The converter is internally compensated and provides enough phase margin for stable operation, allowing the use of small ceramic capacitors with very low ESR.

The bq24278 input scheme prevents battery discharge when the supply voltage is lower than  $V_{BAT}$ . The high-side N-MOSFET (Q1) switches to control the power delivered to SYS. The DRV LDO supplies the gate drive for the internal MOSFETs. The high-side MOSFET is supplied by a boot strap circuit with external boot-strap capacitor (BST).

The input is protected from short circuit by a cycle-by-cycle current limit that is sensed through the high-side MOSFET. The threshold is set to a nominal 5-A peak current. The input also utilizes an input current limit that limits the current from the power source.

## Battery Charging Process

When the battery is deeply discharged or shorted, the bq24278 applies a 50mA current to charge the battery voltage up to acceptable charging levels. During this time, the battery FET is linearly regulated to maintain the system output regulation at  $V_{SYS(REG)}$ . Once the battery rises above  $V_{SHORT}$ , the charge current increases to the fastcharge current setting. The SYS voltage is regulated to  $V_{SYS(REG)}$  while the battery is linearly charged through the battery FET. Additionally, the thermal regulation loop reduces the charge current to maintain the die temperature at safe levels. Under normal conditions, the time spent in this region is a very short percentage of the total charging time, so if the charge current is reduced, the reduced charge rate does not have a major negative effect on total charge time. If the current limit for the SYS output is reached (limited by the input current limit, or  $V_{IN\_DPM}$ ), the charge current is reduced to provide the system with all the current that is needed. If the charge current is reduced to 0mA, pulling further current from SYS causes the output to fall to the battery voltage and enter supplement mode (see the “Dynamic Power Path Management” section for more details).

Once the battery is charged enough to where the system voltage begins to rise above  $V_{SYSREG}$  (depends on the charge current setting), the battery FET is turned on fully and the battery is charged with the programmed charge current programmed using the ISET input,  $I_{CHARGE}$ . The slew rate for fast charge current is controlled to minimize the current and voltage over-shoot during transient. The charge current is programmed by connecting a resistor from ISET to GND. The value for  $R_{ISET}$  is calculated using [Equation 1](#).

$$R_{ISET} = \frac{K_{ISET}}{I_{CHARGE}} \quad (1)$$

Where  $I_{CHARGE}$  is the programmed fast charge current and  $K_{ISET}$  is the programming factor found in the Electrical Characteristics table.

The charge current is regulated to  $I_{CHARGE}$  until the battery is charged to the regulation voltage. Once the battery voltage is close to the regulation voltage,  $V_{BATREG}$ , the charge current is tapered down as shown in [Figure 2](#) while the SYS output remains connected to the battery. The voltage regulation feedback occurs by monitoring the battery-pack voltage between the BAT and PGND pins.

The bq24278 monitors the charging current during the voltage regulation phase. Once the termination threshold,  $I_{TERM}$ , is detected and the battery voltage is above the recharge threshold, the bq24278 terminates charge and turns off the battery charging FET and begins battery detection. The system output is regulated to the  $V_{BAT(REG)}$  voltage and supports the full current available from the input and the battery supplement mode (see the “Dynamic Power Path Management” section for more details) is still available.

A charge cycle is initiated when one of the following conditions is detected:

1. The battery voltage falls below the  $V_{BAT(REG)} - V_{RCH}$  threshold.
2.  $V_{IN}$  Power-on reset (POR)
3.  $\overline{CE}$  toggle
4. Toggle Hi-Impedance mode (using CD)

If the battery voltage is ever greater than  $V_{BAT(REG)}$ , the PWM converter is turned off and the battery is discharged to  $V_{BAT(REG)}$ . This prevents further overcharging the battery and allows the battery to discharge to safe operating levels.

## Battery Detection

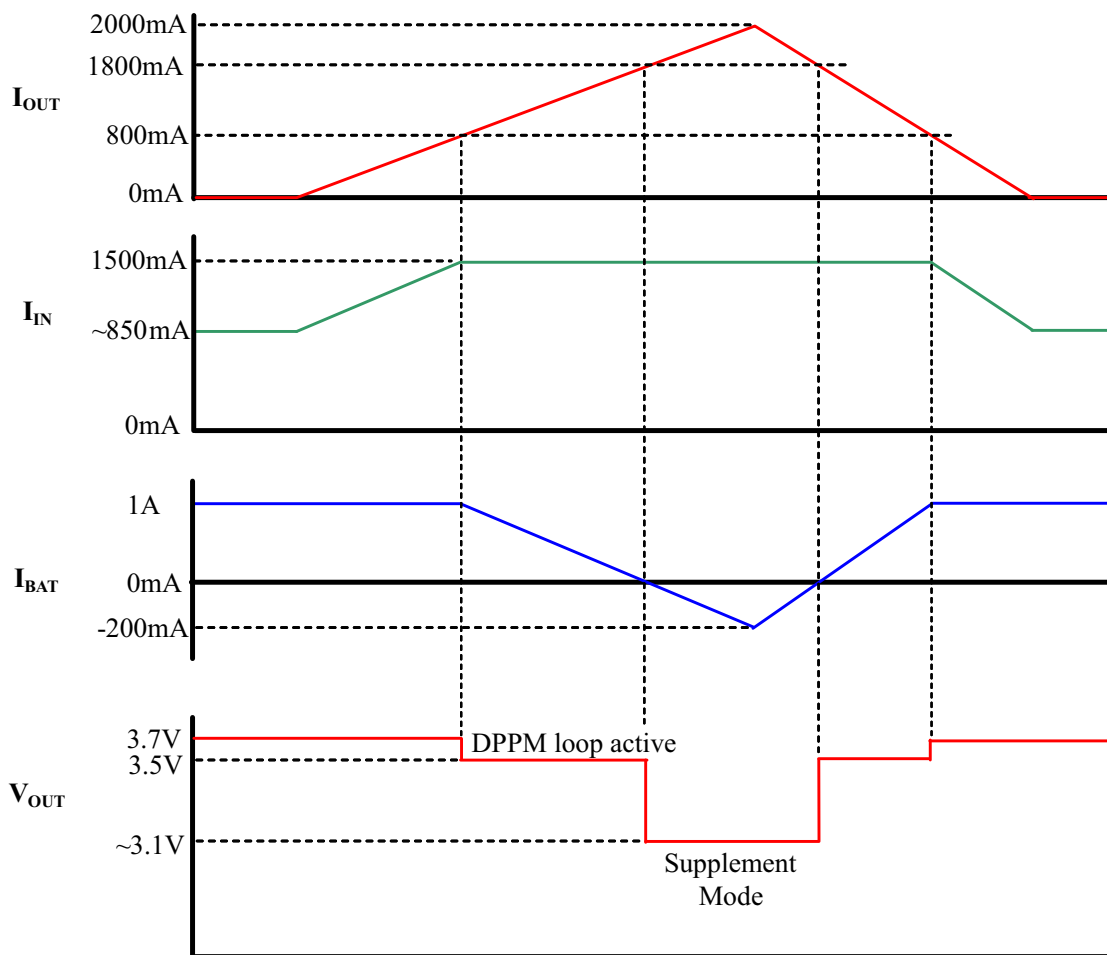
When termination conditions are met, a battery detection cycle is started. During battery detection,  $I_{\text{DETECT}}$  is pulled from  $V_{\text{BAT}}$  for  $t_{\text{DETECT}}$  to verify there is a battery. If the battery voltage remains above  $V_{\text{DETECT}}$  for the full duration of  $t_{\text{DETECT}}$ , a battery is determined to be present and the IC enters “Charge Done”. If  $V_{\text{BAT}}$  falls below  $V_{\text{DETECT}}$ , a “Battery Not Present” fault is signaled and battery detection continues. During the next cycle of battery detection, the bq24278 turns on  $I_{\text{BATSHORT}}$  for  $t_{\text{DETECT}}$ . If  $V_{\text{BAT}}$  rises to  $V_{\text{DETECT}}$ , the current source is turned off and after  $t_{\text{DETECT}}$ , the battery detection continues through another current sink cycle. Battery detection continues until charge is disabled or a battery is detected. Once a battery is detected, the fault status clears and a new charge cycle begins. Battery detection is disabled when termination is disabled.

## Dynamic Power Path Management

The bq24278 features a SYS output that powers the external system load connected to the battery. This output is active whenever a source is connected to IN or BAT. The following sections discuss the behavior of SYS with a source connected to the supply or a battery source only.

### Input Source Connected

When a source is connected to IN, and the bq24278 is enabled, the buck converter starts up. If charging is enabled using  $\overline{\text{CE}}$ , the charge cycle is initiated. When  $V_{\text{BAT}} > 3.5\text{V}$ , the SYS output is connected to  $V_{\text{BAT}}$ . If the SYS voltage falls to  $V_{\text{SYS(REG)}}$ , it is regulated to that point to maintain the system output even with a deeply discharged or absent battery. In this mode, the SYS output voltage is regulated by the buck converter and the battery FET is linearly regulated to regulate the charge current into the battery. The current from the supply is shared between charging the battery and powering the system load at SYS. The dynamic power path management (DPPM) circuitry of the bq24278 monitors the SYS voltage continuously and if  $V_{\text{SYS}}$  falls to  $V_{\text{MINSYS}}$ , adjusts charge current to maintain the load on SYS while preventing the system voltage from crashing. If the charge current is reduced to zero and the load increases further, the bq24278 enters battery supplement mode. During supplement mode, the battery FET is turned on and the battery supplements the system load. When the charge current is reduced by the DPPM regulation loop, the safety timer runs at half speed, so that it is twice as long. This prevents false safety timer faults. See the *Safety Timer* section for more details.



**Figure 3. Example DPPM Response ( $V_{\text{Supply}}=5\text{V}$ ,  $V_{\text{BAT}} = 3.1\text{V}$ , 1.5A Input current limit)**

If the  $V_{\text{BAT(REG)}}$  threshold is ever less than the battery voltage, the battery FET is turned off to allow the battery to relax down to  $V_{\text{BAT(REG)}}$  and the SYS output is regulated to  $V_{\text{SYSREG(FETOFF)}}$ . If the battery is ever above  $V_{\text{BOVP}}$ , the battery OVP circuit shuts the PWM converter off and the battery FET is turned on to discharge the battery to safe operating levels.

The input current limit for IN is programmable using the ILIM input. Connect a resistor from ILIM to GND to set the maximum input current limit. The programmable range for the IN input current limit is 1000mA to 2.5A.  $R_{\text{ILIM}}$  is calculated using Equation 2:

$$R_{\text{ILIM}} = \frac{K_{\text{ILIM}}}{I_{\text{IN\_LIM}}} \quad (2)$$

Where  $I_{\text{IN\_LIM}}$  is the programmed input current limit and  $K_{\text{ILIM}}$  is the programming factor found in the Electrical Characteristics table.

### Battery Only Connected

When the battery is connected with no input source, the battery FET is turned on similar to supplement mode. In this mode, the current is not regulated; however, there is a short circuit current limit. If the short circuit limit is reached, the battery FET is turned off for the deglitch time. After the deglitch time, the battery FET is turned on to test and see if the short has been removed. If it has not, the FET turns off and the process repeats until the short is removed.

## Battery Discharge FET (BGATE)

The bq24278 contains a MOSFET driver to drive an external P-Channel MOSFET between the battery and the system output. This external FET provides a low impedance path for supply the system from the battery. Connect BGATE to the gate of the external discharge MOSFET. BGATE is on under the following conditions:

1. No valid input supply connected.
2. CD=high (High-Impedance Mode)

This FET is optional and runs in parallel with the internal charge FET during discharge. Note that this FET is not protected by the short circuit current limit.

## Safety Timer

At the beginning of charging process, the bq24278 starts the 6 hour safety timer. This timer is active during the entire charging process. If charging has not terminated before the safety timer expires, the charge cycle is terminated and the battery FET is turned off. A new charge cycle must be entered using CE or High Impedance mode or input power must be toggled in order to clear the safety timer fault.

During the fast charge phase, several events increase the timer durations.

1. The system load current reduces the available charging current
2. The input current is reduced because the  $V_{INDPM}$  loop is preventing the supply from crashing.
3. The device has entered thermal regulation because the IC junction temperature has exceed  $T_{J(REG)}$

During these events, the timer is slowed by half to extend the timer and prevent any false timer faults. Starting a new charge cycle by toggling the input, toggling the CE pin to disable/enable charge, resets the safety timer. Additionally, thermal shutdown events cause the safety timer to reset.

## LDO Output (DRV)

The bq24278 contains a linear regulator (DRV) that is used to supply the internal MOSFET drivers and other circuitry. Additionally, DRV supplies up to 10mA external loads to power the STAT LED or other external circuitry. The LDO is on whenever a supply is connected to the input of the. The DRV is disabled under the following conditions:

1.  $V_{IN} < UVLO$
2.  $V_{IN} < V_{BAT} + V_{SLP}$
3. Thermal Shutdown

## External NTC Monitoring (TS)

The I<sup>2</sup>C interface allows the user to easily implement the JEITA standard for systems where the battery pack thermistor is monitored by the host. Additionally, the bq24278 provides a flexible, voltage-based TS input for monitoring the battery pack NTC thermistor, [Figure 4](#). The voltage at TS is monitored to determine that the battery is at a safe temperature during charging. The bq24278 enables the user to easily implement the JEITA standard for charging temperature. The JEITA specification is shown in [Figure 5](#).

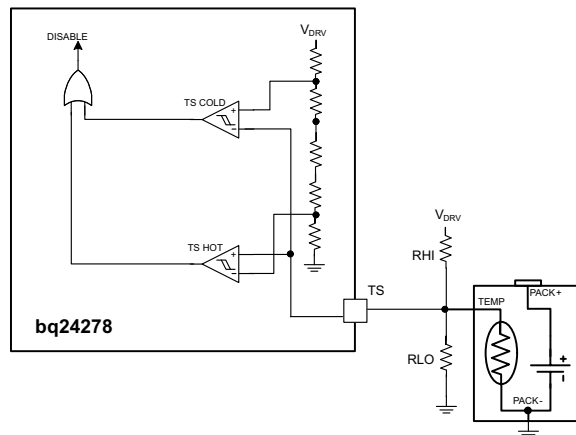


Figure 4. TS Circuit

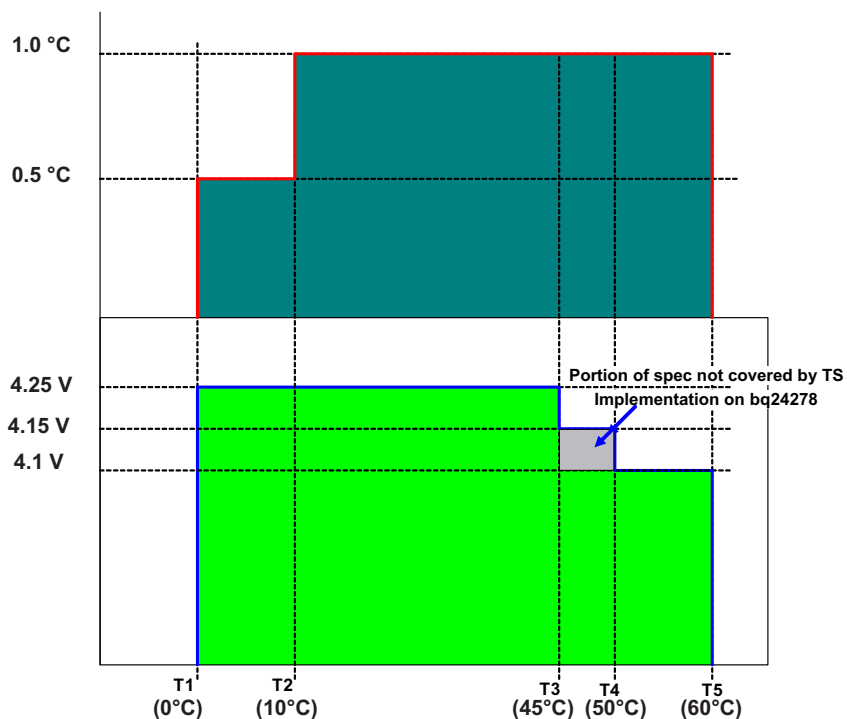


Figure 5. Charge Current During TS Conditions

To satisfy the JEITA requirements, four temperature thresholds are monitored; the cold battery threshold; the cold battery threshold ( $T_{NTC} < 0^{\circ}\text{C}$ ), the cool battery threshold ( $0^{\circ}\text{C} < T_{NTC} < 10^{\circ}\text{C}$ ), the warm battery threshold ( $45^{\circ}\text{C} < T_{NTC} < 60^{\circ}\text{C}$ ) and the hot battery threshold ( $T_{NTC} > 60^{\circ}\text{C}$ ). These temperatures correspond to the  $V_{COLD}$ ,  $V_{COOL}$ ,  $V_{WARM}$ , and  $V_{HOT}$  thresholds. Charging is suspended and timers are suspended when  $V_{TS} < V_{HOT}$  or  $V_{TS} > V_{COLD}$ . When  $V_{HOT} < V_{TS} < V_{WARM}$ , the battery regulation voltage is reduced by 140 mV from the programmed regulation threshold. When  $V_{COOL} < V_{TS} < V_{COLD}$ , the charging current is reduced to half of the programmed charge current.

The TS function is voltage based for maximum flexibility. Connect a resistor divider from DRV to GND with TS connected to the center tap to set the threshold. The connections are shown in Figure 10. The resistor values are calculated using the following equations:

$$RLO = \frac{V_{DRV} \times RCOLD \times RHOT \times \left[ \frac{1}{V_{COLD}} - \frac{1}{V_{HOT}} \right]}{RHOT \times \left[ \frac{V_{DRV}}{V_{HOT}} - 1 \right] - RCOLD \times \left[ \frac{V_{DRV}}{V_{COLD}} - 1 \right]} \quad (3)$$

$$RHI = \frac{\frac{V_{DRV}}{V_{COLD}} - 1}{\frac{1}{RLO} + \frac{1}{RCOLD}} \quad (4)$$

Where:

$$V_{COLD} = 0.60 \times V_{DRV}$$

$$V_{HOT} = 0.30 \times V_{DRV}$$

Where RHOT is the NTC resistance at the hot temperature and RCOLD is the NTC resistance at cold temperature.

The WARM and COOL thresholds are not independently programmable. The COOL and WARM NTC resistances for a selected resistor divider are calculated using the following equations:

$$RCOOL = \frac{RLO \times 0.564 \times RHI}{RLO - RLO \times 0.564 - RHI \times 0.564} \quad (5)$$

$$RWARM = \frac{RLO \times 0.383 \times RHI}{RLO - RLO \times 0.383 - RHI \times 0.383} \quad (6)$$

## Thermal Regulation and Protection

During the charging process, to prevent the IC from overheating, bq24278 monitor the junction temperature,  $T_J$ , of the die and begins to taper down the charge current once  $T_J$  reaches the thermal regulation threshold,  $T_{CF}$ . The charge current is reduced to zero when the junction temperature increases about 10°C above  $T_{CF}$ . Once the charge current is reduced, the system current is reduced while the battery supplements the load to supply the system. This may cause a thermal shutdown of the bq24278 if the die temperature rises too high. At any state, if  $T_J$  exceeds  $T_{SHTDWN}$ , bq24278 suspends charging and disables the buck converter. During thermal shutdown mode, PWM is turned off, and the timer is reset. The charging cycle resets when  $T_J$  falls below  $T_{SHTDWN}$  by approximately 10°C.

## Input Voltage Protection in Charge Mode

### Sleep Mode

The bq24278 enters the low-power sleep mode if the voltage on VIN falls below sleep-mode entry threshold,  $V_{BAT} + V_{SLP}$ , and  $V_{VBUS}$  is higher than the undervoltage lockout threshold,  $V_{UVLO}$ . This feature prevents draining the battery during the absence of VIN. When  $V_{IN} < V_{BAT} + V_{SLP}$ , the bq24278 turns off the PWM converter, and turns the battery FET and BGATE on. Once  $V_{IN} > V_{BAT} + V_{SLP}$ , the device initiates a new charge cycle.

### Input Voltage Based DPM

During normal charging process, if the input power source is not able to support the programmed or default charging current, the supply voltage decreases. Once the supply drops to  $V_{IN\_DPM}$  (set by VDPM), the input current limit is reduced down to prevent the further drop of the supply. This feature ensures IC compatibility with adapters with different current capabilities without a hardware change. Figure 6 shows the  $V_{IN\_DPM}$  behavior to a current limited source. In this figure the input source has a 750mA current limit and the charging is set to 750mA. The SYS load is then increased to 1.2A.

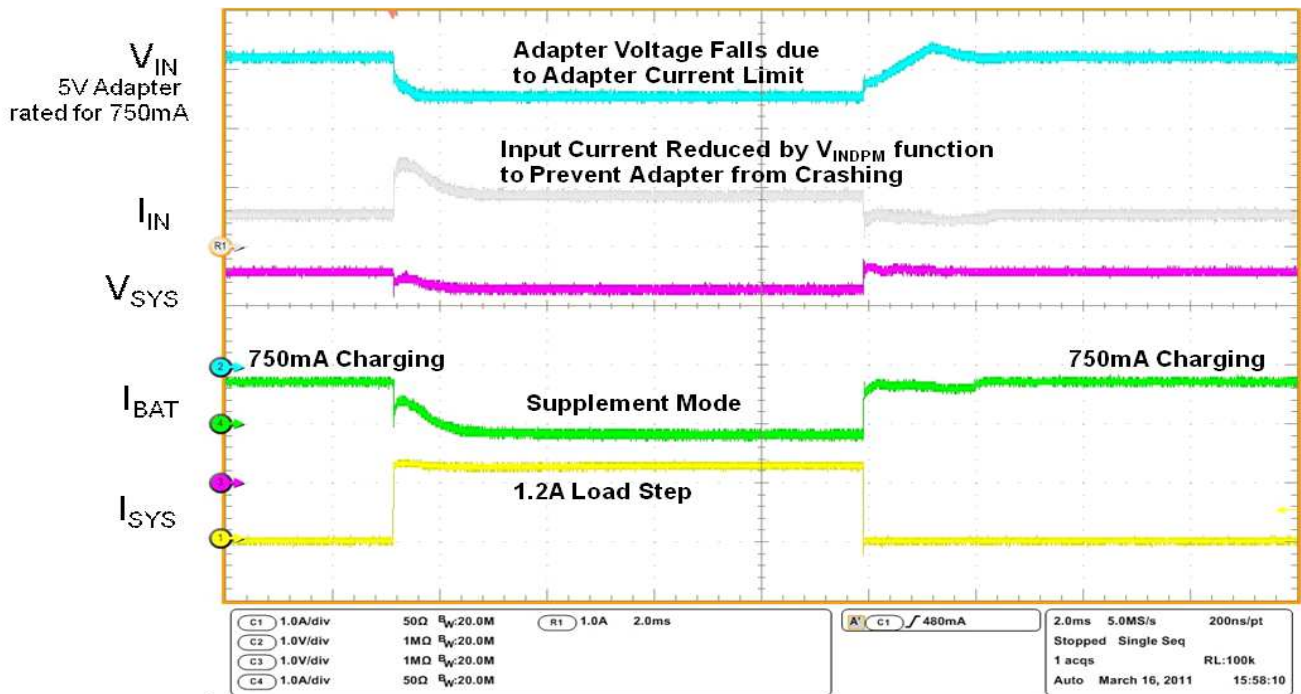


Figure 6. bq24278 V<sub>IN-DPM</sub>

The V<sub>INDPM</sub> threshold for the IN input is set using a resistor divider with VDPM connected to the center tap. Select 10kΩ for the bottom resistor. The top resistor is selected using Equation 7:

$$R_{TOP} = \frac{10k\Omega \times (V_{INDPM} - V_{DPM})}{V_{DPM}} \quad (7)$$

Where V<sub>INDPM</sub> is the desired V<sub>INDPM</sub> threshold and V<sub>DPM</sub> is the regulation threshold specified in the Electrical Characteristics table.

### Bad Source Detection

When a source is connected to IN, the bq24278 runs a Bad Source Detection procedure to determine if the source is strong enough to provide some current to charge the battery. A current sink is turned on (70mA) for 32ms. If the source is valid after the 32ms ( $V_{BAD\_SOURCE} < V_{IN} < V_{OVP}$ ), the buck converter starts up and normal operation continues. If the supply voltage falls below V<sub>BAD\_SOURCE</sub> during the detection, the current sink shuts off for 2s and then retries. The detection circuit retries continuously until a valid source is detected after the detection time. If during normal operation the source falls to V<sub>BAD\_SOURCE</sub>, the bq24278 turns off the PWM converter, turns the battery FET on and runs the bad source detection. Once a good source is detected, the device returns to normal operation.

### Input Over-Voltage Protection

The bq24278 provides over-voltage protection on the input that protects downstream circuitry. The built-in input over-voltage protection to protect the device and other components against damage from overvoltage on the input supply (Voltage from V<sub>IN</sub> to PGND). When V<sub>IN</sub> > V<sub>OVP</sub>, the bq24278 turns off the PWM converter, suspends the charging cycle and turns the battery FET on. Once the OVP fault is removed, the device returns to the operation it was in prior to the OVP fault.

### Status Indicators ( $\overline{CHG}$ , $\overline{PG}$ )

The bq24278 contains two open-drain outputs that signal its status. The  $\overline{PG}$  output indicates that a valid input source is connected to IN.  $\overline{PG}$  is low when  $(V_{BAT} + V_{SLP}) < V_{IN} < V_{OVP}$ . When there is no supply connected to the input within this range,  $\overline{PG}$  is high impedance. Table 1 illustrates the  $\overline{PG}$  behavior under different conditions.

The  $\overline{\text{CHG}}$  output indicates new charge cycles. When a new charge cycle is initiated by  $\overline{\text{CE}}$ , toggling High Impedance mode or toggling the input power,  $\overline{\text{CHG}}$  goes low and remains low until termination. After termination,  $\overline{\text{CHG}}$  remains high impedance until a new charge cycle is initiated.  $\overline{\text{CHG}}$  does not go low during recharge cycles. [Table 2](#) illustrates the  $\overline{\text{CHG}}$  behavior under different conditions.

Connect  $\overline{\text{PG}}$  and  $\overline{\text{CHG}}$  to the DRV output through an LED for visual indication, or connect through a 100k $\Omega$  pullup to the required logic rail for host indication.

**Table 1.  $\overline{\text{PG}}$  Status Indicator**

| CHARGE STATE                                                         | $\overline{\text{PG}}$ BEHAVIOR |
|----------------------------------------------------------------------|---------------------------------|
| $V_{\text{IN}} < V_{\text{UVLO}}$                                    | High-Impedance                  |
| $V_{\text{IN}} < (V_{\text{BAT}} + V_{\text{SLP}})$                  | High-Impedance                  |
| $(V_{\text{BAT}} + V_{\text{SLP}}) < V_{\text{IN}} < V_{\text{OVP}}$ | Low                             |
| $V_{\text{IN}} > V_{\text{OVP}}$                                     | High-Impedance                  |

**Table 2.  $\overline{\text{CHG}}$  Status Indicator**

| CHARGE STATE                                                                            | $\overline{\text{CHG}}$ BEHAVIOR |
|-----------------------------------------------------------------------------------------|----------------------------------|
| Charge in progress                                                                      | Low (first charge cycle)         |
| Charging suspended by thermal loop                                                      | High-Impedance (recharge cycles) |
| Charge Done                                                                             | High-Impedance                   |
| Recharge Cycle after Termination                                                        |                                  |
| Timer Fault                                                                             |                                  |
| No Valid Supply, $V_{\text{IN}} > V_{\text{OVP}}$ or $V_{\text{IN}} < V_{\text{SLEEP}}$ |                                  |
| No Battery Present                                                                      |                                  |

## APPLICATION INFORMATION

### Output Inductor and Capacitor Selection Guidelines

When selecting an inductor, several attributes must be examined to find the right part for the application. First, the inductance value should be selected. The bq24278 is designed to work with 1.5μH to 2.2μH inductors. The chosen value will have an effect on efficiency and package size. Due to the smaller current ripple, some efficiency gain is reached using the 2.2μH inductor, however, due to the physical size of the inductor, this may not be a viable option. The 1.5μH inductor provides a good tradeoff between size and efficiency.

Once the inductance has been selected, the peak current must be calculated in order to choose the current rating of the inductor. Use [Equation 8](#) to calculate the peak current.

$$I_{PEAK} = I_{LOAD(MAX)} \times \left( 1 + \frac{\%RIPPLE}{2} \right) \quad (8)$$

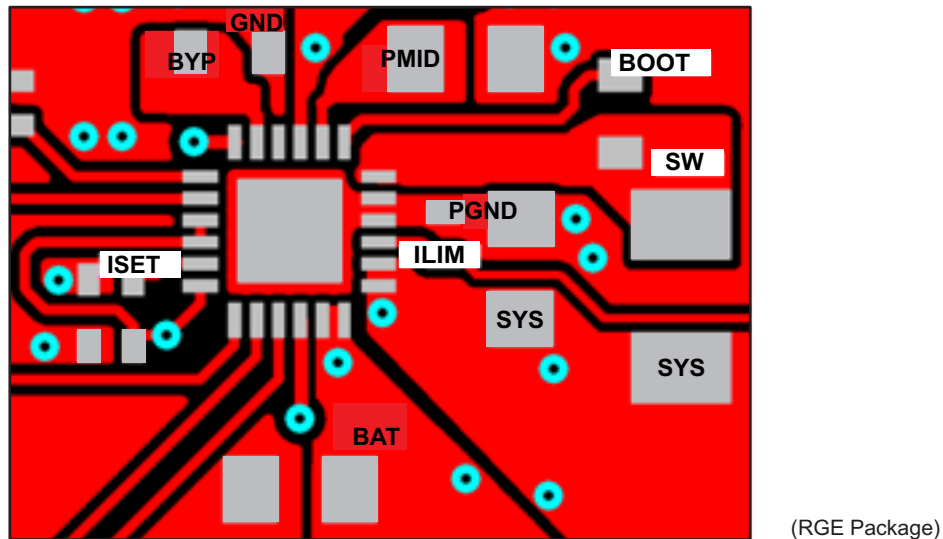
The inductor selected must have a saturation current rating less than or equal to the calculated  $I_{PEAK}$ . Due to the high currents possible with the bq24278, a thermal analysis must also be done for the inductor. Many inductors have 40°C temperature rise rating. This is the DC current that will cause a 40°C temperature rise above the ambient temperature in the inductor. For this analysis, the typical load current may be used adjusted for the duty cycle of the load transients. For example, if the application requires a 1.5A DC load with peaks at 2.5A 20% of the time, a Δ40°C temperature rise current must be greater than 1.7A:

$$I_{TEMPRISE} = I_{LOAD} + D \times (I_{PEAK} - I_{LOAD}) = 1.5 \text{ A} + 0.2 \times (2.5 \text{ A} - 1.5 \text{ A}) = 1.7 \text{ A} \quad (9)$$

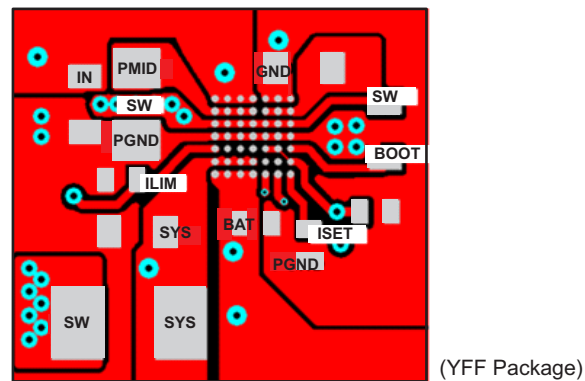
The bq24278 provides internal loop compensation. Using this scheme, the bq24278 is stable with 10μF to 200μF of local capacitance. The capacitance on the SYS rail can be higher if distributed amongst the rail. To reduce the output voltage ripple, a ceramic capacitor with the capacitance between 10μF and 47μF is recommended for local bypass to SYS.

## PCB Layout Guidelines

It is important to pay special attention to the PCB layout. Figure 7 provides a sample layout for the high current paths of the bq24278.



**Figure 7. Recommended bq24278 PCB Layout for RGE Device**



**Figure 8. Recommended bq24278 PCB Layout for YFF Device**

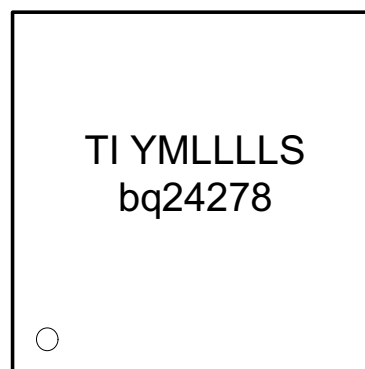
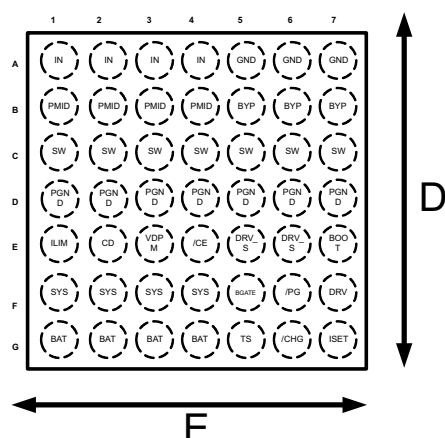
The following provides some guidelines:

- To obtain optimal performance, the power input capacitors, connected from the PMID input to PGND, must be placed as close as possible to the bq24278
- Place 4.7μF input capacitor as close to PMID pin and PGND pin as possible to make high frequency current loop area as small as possible. Place 1μF input capacitor GNDs as close to the respective PMID cap GND and PGND pins as possible to minimize the ground difference between the input and PMID.
- The local bypass capacitor from SYS to GND should be connected between the SYS pin and PGND of the IC. The intent is to minimize the current path loop area from the SW pin through the LC filter and back to the PGND pin.
- Place ISET resistor very close to the ISET pin.
- Place ILIM resistor very close to the ILIM pin.
- Place all decoupling capacitor close to their respective IC pin and as close as to PGND (do not place components such that routing interrupts power stage currents). All small control signals should be routed away from the high current paths.
- The PCB should have a ground plane (return) connected directly to the return of all components through vias (two vias per capacitor for power-stage capacitors, one via per capacitor for small-signal components). It is

also recommended to put vias inside the PGND pads for the IC, if possible. A star ground design approach is typically used to keep circuit block currents isolated (high-power/low-power small-signal) which reduces noise-coupling and ground-bounce issues. A single ground plane for this design gives good results. With this small layout and a single ground plane, there is no ground-bounce issue, and having the components segregated minimizes coupling between signals.

- The high-current charge paths into IN, BAT, SYS and from the SW pins must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces. The PGND pins should be connected to the ground plane to return current through the internal low-side FET.
- For high-current applications, the balls for the power paths should be connected to as much copper in the board as possible. This allows better thermal performance as the board pulls heat away from the IC.

## PACKAGE SUMMARY



0-Pin A1 Marker, TI-TI Letters, YM- Year Month Date Code ,  
LLLL-Lot Trace Code , S-Assembly Site Code

## CHIP SCALE PACKAGING DIMENSIONS

The bq2427x devices are available in a 49-bump chip scale package (YFF, NanoFree™). The package dimensions are :

D – 2.78mm ± 0.05mm

E – 2.78mm ± 0.05mm

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| BQ24278RGER      | ACTIVE        | VQFN         | RGE                | 24   | 3000           | Green (RoHS<br>& no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | BQ<br>24278             | <a href="#">Samples</a> |
| BQ24278RGET      | ACTIVE        | VQFN         | RGE                | 24   | 250            | Green (RoHS<br>& no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | BQ<br>24278             | <a href="#">Samples</a> |
| BQ24278YFFR      | ACTIVE        | DSBGA        | YFF                | 49   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | BQ24278                 | <a href="#">Samples</a> |
| BQ24278YFFT      | ACTIVE        | DSBGA        | YFF                | 49   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | BQ24278                 | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ24278RGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| BQ24278RGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| BQ24278YFFR | DSBGA        | YFF             | 49   | 3000 | 180.0              | 8.4                | 2.93    | 2.93    | 0.81    | 4.0     | 8.0    | Q1            |
| BQ24278YFFT | DSBGA        | YFF             | 49   | 250  | 180.0              | 8.4                | 2.93    | 2.93    | 0.81    | 4.0     | 8.0    | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

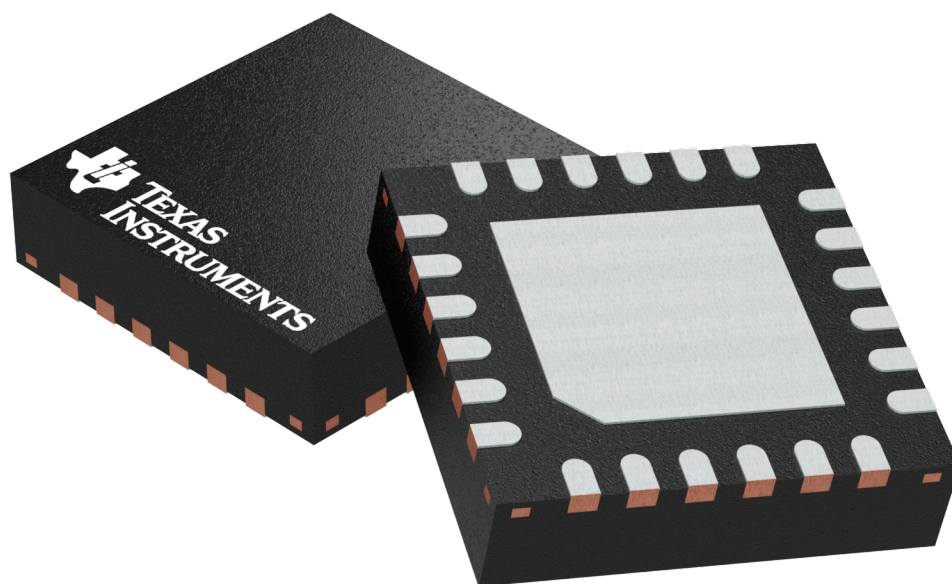
| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ24278RGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ24278RGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| BQ24278YFFR | DSBGA        | YFF             | 49   | 3000 | 182.0       | 182.0      | 20.0        |
| BQ24278YFFT | DSBGA        | YFF             | 49   | 250  | 182.0       | 182.0      | 20.0        |

**RGE 24**

**GENERIC PACKAGE VIEW**

**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

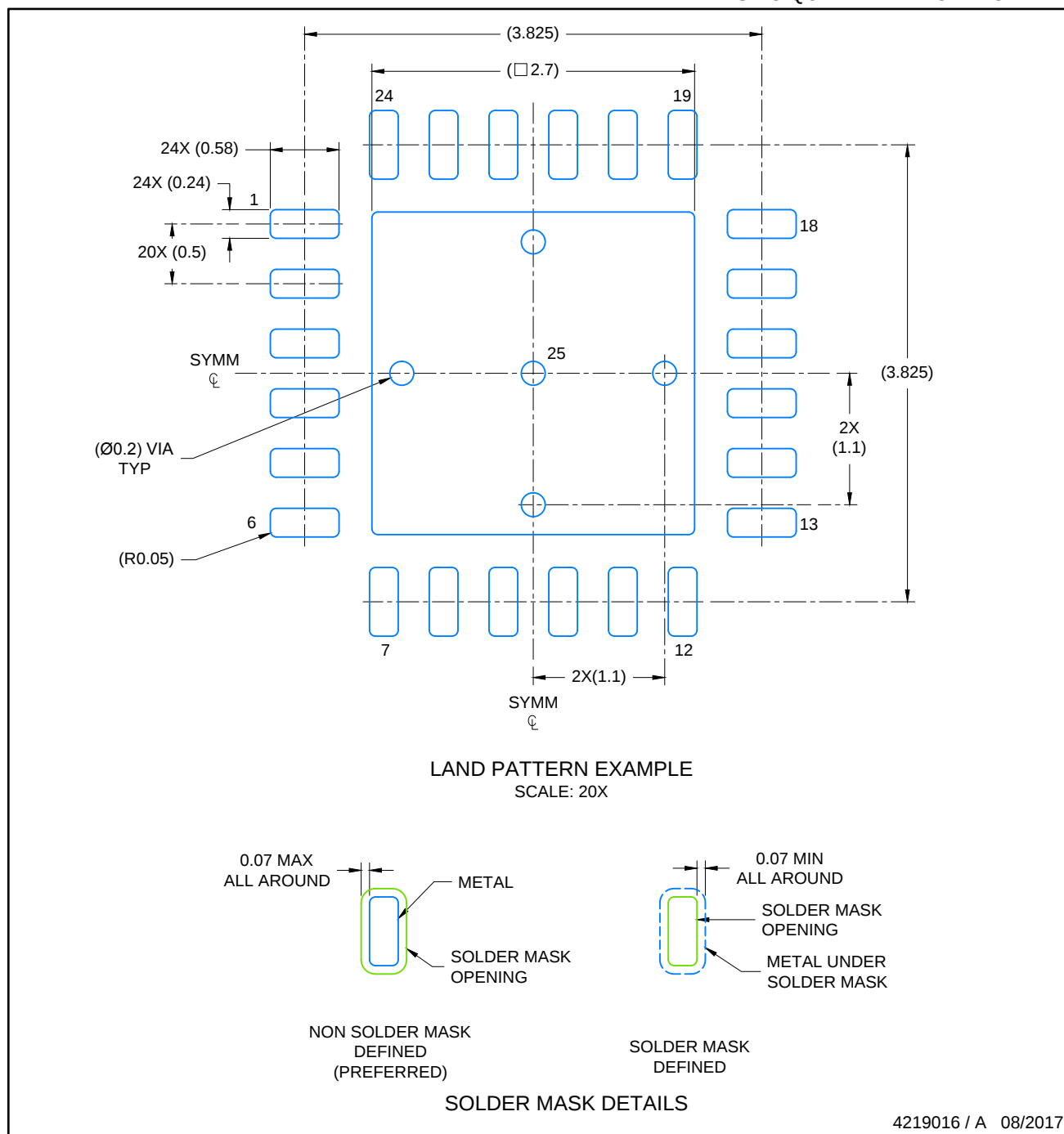
4204104/H

**VQFN - 1 mm max height**

[illegible]

NOTES:

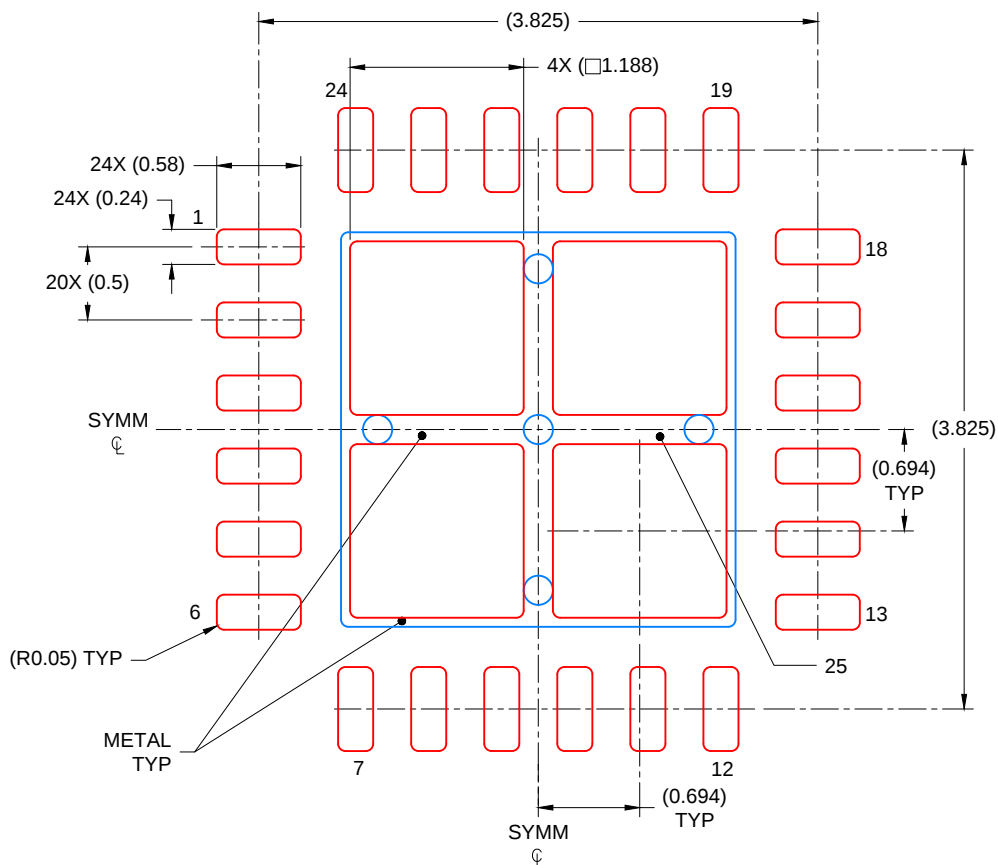
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



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NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD  
78% PRINTED COVERAGE BY AREA  
SCALE: 20X

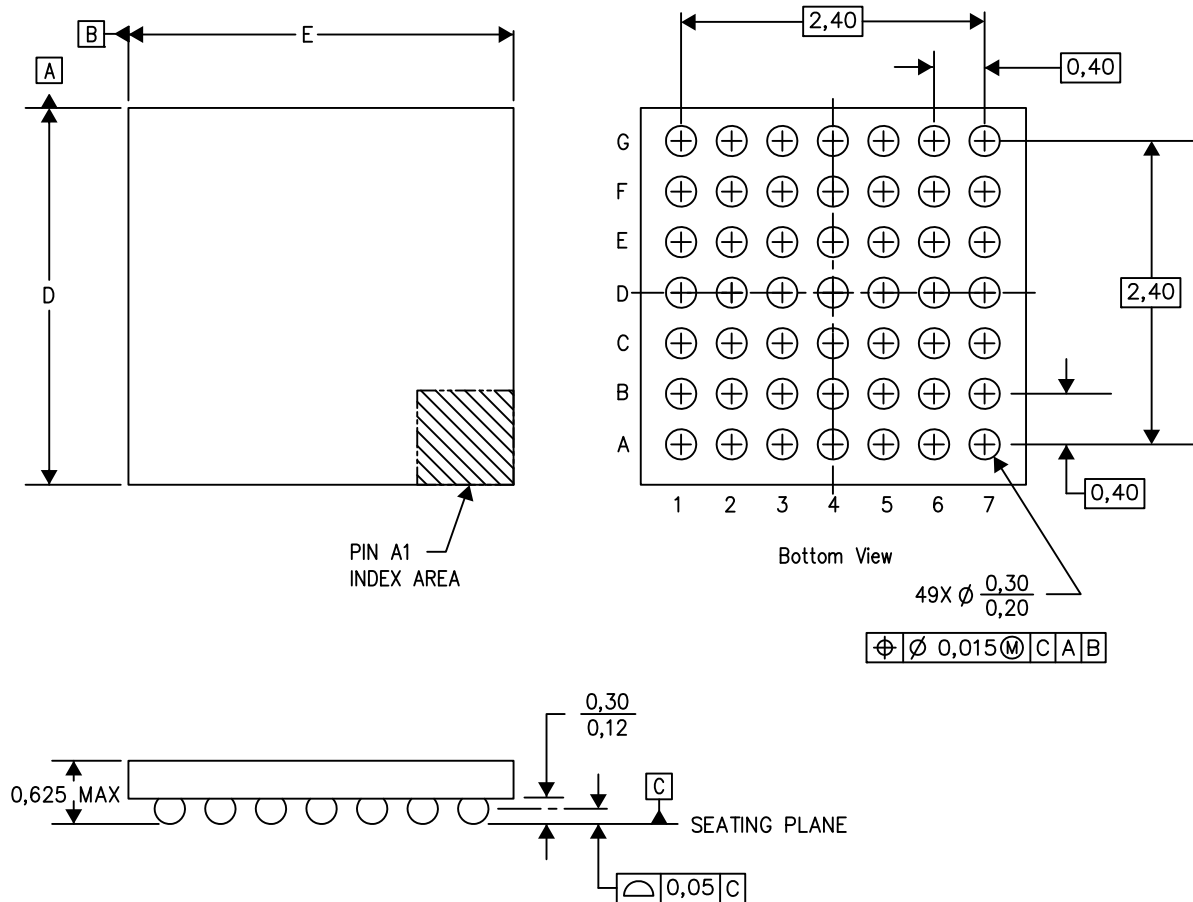
4219016 / A 08/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations..

YFF (R-XBGA-N49)

DIE-SIZE BALL GRID ARRAY



4207625-16/AO 12/13

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

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