# Lithium Ion Pack Supervisor



## Features

- Protects two to four Lithium Ion series cells from overvoltage, undervoltage, and overcurrent
- Designed for battery pack integration
  - Small outline package, minimal external components and space, and low cost
  - Drives external N-FET switches
- User selectable thresholds mask programmable by Benchmarq
- Operates on very low current, < 40µA for 4-cell, <20µA for 3-cell, and < 15 µA for 2-cell configuration
- Operates on very low standby current, < 1µA
- Available in 8-pin 150-mil SOIC and 300-mil DIP

## General Description

The bq2053 Lithium Ion Pack Supervisor is designed to control the charge and discharge voltage safety limits for two to four lithium ion (Li-Ion) series cells, accommodating battery packs containing series/parallel configurations. The very low operating current does not overdischarge the cells during periods of storage, and does not significantly increase the system discharge load. The bq2053 can be part of a low-cost Li-Ion charge control system within the battery pack.

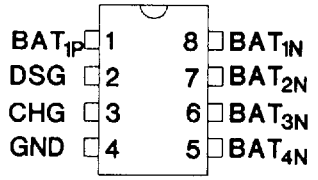
The bq2053 controls two external N-FETs to limit the charge and discharge potentials. Charging is allowed when the per cell voltage is below $V_{CE}$ (charge enable voltage). When the cell voltage on any cell rises above $V_{OV}$ (overvoltage limit), the CHG pin goes low, shutting off the charge to the battery pack. This safety feature prevents overcharge on any individual series cell stack within the battery pack.

Discharge is allowed when the per-cell voltage is above $V_{UV}$ (undervoltage limit). If the voltage across any cell falls below $V_{UV}$, both the DSG and CHG outputs go low, shutting off the battery discharge. This safety feature prevents overdischarge on any individual series cell stack within the battery pack.

Charging and discharging are allowed if the voltage across $BAT_{4N}$ and GND is less than $V_{OC}$ (overcurrent limit). This safety feature prevents excessive pack current.

$V_{UV}$, $V_{CE}$, and $V_{OV}$ are programmed at Benchmarq. The default limits are 2.3V, 4.15V, and 4.25V, respectively. Contact Benchmarq for other options.

## Pin Connections




8-Pin Narrow DIP or SOIC

PN-86

## Pin Names

| | |
|---|---|
| $BAT_{1P}$ | Battery 1 positive input |
| $BAT_{1N}$ | Battery 1 negative input |
| $BAT_{2N}$ | Battery 2 negative input |
| $BAT_{3N}$ | Battery 3 negative input |
| $BAT_{4N}$ | Battery 4 negative input |
| DSG | Discharge control |
| CHG | Charge control |
| GND | Ground |

## Pin Descriptions

**$BAT_{1P}$ Battery 1 positive input**

This input is connected to the positive terminal of the cell designated $BAT_1$ in Figure 2.

**$BAT_{1N}$ Battery 1 negative input**

This input is connected to the negative terminal of the cell designated $BAT_1$ in Figure 2. This input is connected to $BAT_{1P}$ for less than four cells in a series.

**$BAT_{2N}$ Battery 2 negative input**

This input is connected to the negative terminal of the cell designated $BAT_2$ in Figure 2. This input is connected to $BAT_{1P}$ and $BAT_{1N}$ for less than three cells in a series.

**$BAT_{3N}$ Battery 3 negative input**

This input is connected to the negative terminal of the cell designated $BAT_3$ in Figure 2.

**$BAT_{4N}$ Battery 4 negative input**

This input is connected to the negative terminal of the cell designated $BAT_4$ in Figure 2.

**CHG Charge control output**

This output controls the charge path to the battery pack. This output is internally connected to $BAT_{1P}$ when charging is allowed (CHG = High). CHG is internally connected to GND when charging is prohibited (CHG = Low).

**DSG Discharge control output**

This output controls the discharge path to the battery pack. This output is internally connected to $BAT_{1P}$ when discharging is allowed (DSG = High). DSG is internally connected to $BAT_{4N}$ when discharging is prohibited (DSG = Low).

**GND System Ground**

Battery pack return.

## Functional Description

Figure 1 is a block diagram outlining the major components of the bq2053. Figure 2 shows a typical application example. The various functional aspects of the bq2053 are detailed in the following sections.

### Configuration

The bq2053 may be configured to supervise two-, three-, or four-series cell packs. For two-series cell configurations, $BAT_{1N}$ and $BAT_{2N}$ are connected to $BAT_{1P}$. For three-series cell configurations, $BAT_{1N}$ is connected to $BAT_{1P}$. See Table 1. The bq2053 controls two external N-FETs connected for low side control of the battery pack. Contact Benchmarq for application examples.

**Table 1. Pin Configuration for 2-, 3-, and 4-Series Cells**

| Number of Cells | Configuration Pins | Battery Pins |
|---|---|---|
| 2-cell | $BAT_{1N}$, $BAT_{2N}$ tied to $BAT_{1P}$ | $BAT_{2N}$ – Positive terminal of first cell |
| | | $BAT_{3N}$ – Negative terminal of first cell |
| | | $BAT_{4N}$ – Negative terminal of second cell |
| 3-cell | $BAT_{1N}$ tied to $BAT_{1P}$ | BAT1N – Positive terminal of first cell |
| | | $BAT_{2N}$ – Negative terminal of first cell |
| | | $BAT_{3N}$ – Negative terminal of second cell |
| | | $BAT_{4N}$ – Negative terminal of third cell |
| 4-cell | | $BAT_{1P}$ – Positive terminal of first cell |
| | | $BAT_{1N}$ – Negative terminal of first cell |
| | | $BAT_{2N}$ – Negative terminal of second cell |
| | | $BAT_{3N}$ – Negative terminal of third cell |
| | | $BAT_{4N}$ – Negative terminal of fourth cell |

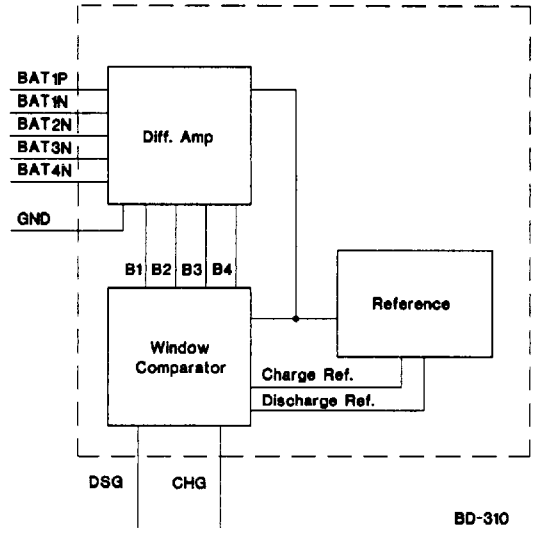



**Figure 1. Block Diagram**

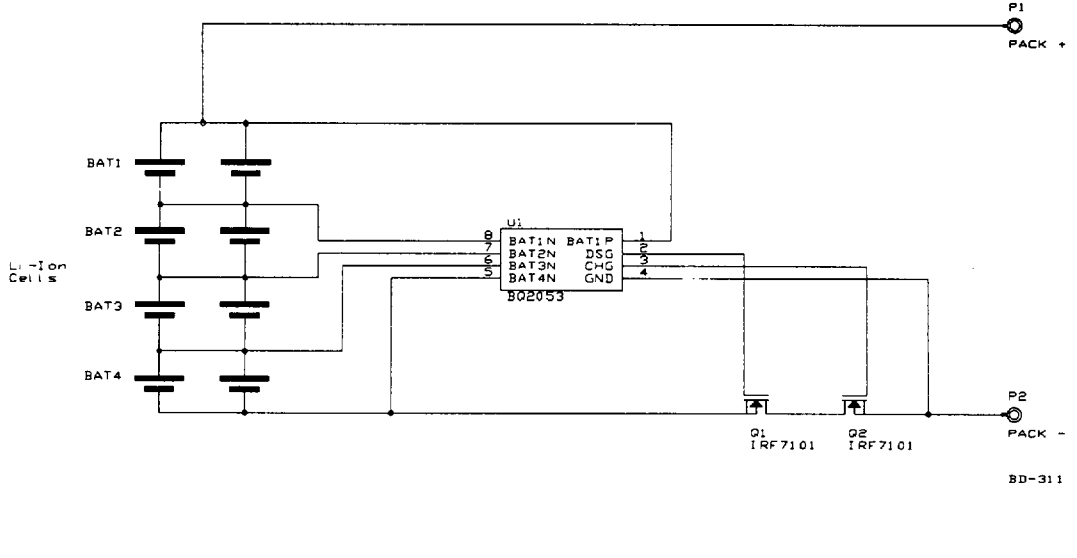



**Figure 2. Application Diagram: 4x2 Cell Configuration**

## Thresholds

The bq2053 monitors four thresholds for overcharge, overdischarge, and overcurrent protection. The default values are:

$V_{OV}$ = 4.25 ± 1.5% (overvoltage during charge)

$V_{CE}$ = $V_{OV}$ – 100mV ± 50mV (charge enable voltage)

$V_{UV}$ = 2.3V ± 100mV (undervoltage during discharge)

$V_{OC}$ = ±250mV, ±25mV (Over-current limit during charge and discharge)

The thresholds are programmed at Benchmarq. Please contact Benchmarq for other voltage options.

The bq2053 samples a cell every 25ms (typical) and each measurement is fully differential. During this sample period, the cell is checked for a $V_{OV}$, $V_{UV}$, $V_{OC}$, $V_{MIN}$, and $V_{CE}$ condition. Please refer to Figure 3 for the cell monitoring timing.

### Initialization

During the initial connection of the bq2053 circuit to the battery pack, the bq2053 recognizes a low voltage condition, and disables the CHG and DSG outputs respectively. A charging supply must be applied to the bq2053 circuit to enable the pack. The charging supply must produce a voltage of greater than 30mV between $BAT_{4N}$ and GND for the bq2053 to recognize a valid charge condition, and enable CHG and DSG outputs.

The bq2053 operating current is less than 40µA for 4-cell configurations. The operating current is less for 3-cell and 2-cell operation. See the DC Electrical Characteristics table for details. This avoids possible cell damage due to overdischarging the battery pack, and extends the storage time between recharge.

## Discharge Supervision

Overdischarge protection is asserted when any cell voltages fall below the $V_{UV}$ threshold. Once $V_{UV}$ is reached, both DSG and CHG go low, disabling the discharge of the pack. The bq2053 then enters the low-power standby mode.

## Low-Power Standby Mode

When the bq2053 enters the low power mode, CHG and DSG are disabled and the device consumes less than 1µA. The differential signal between $BAT_{4N}$ and GND is then continuously monitored to determine if a valid charge condition exists. If the condition exists, the outputs are enabled to allow charging of the lithium ion cells. The charging supply must produce a voltage greater than 30mV between $BAT_{4N}$ and GND for the bq2053 to enable the CHG and DSG outputs. If charging is terminated while any cell is below the $V_{UV}$ limit, both DSG and CHG will go low and the bq2053 will return to the low-power mode.

## Charge Supervision

Overvoltage protection is asserted when any cell voltage exceeds the $V_{OV}$ threshold. Once $V_{OV}$ is reached, the CHG pin goes low, disabling charge into the battery pack. Charging is disabled until all cell voltages fall below $V_{CE}$. This indicates that the overcharge has stopped and the pack is ready to accept further charge.

The bq2053 can be part of a cost-effective charge control system which utilizes the pack protection circuit to limit the charge voltage to the lithium ion cells. The hysteresis between $V_{OV}$ and $V_{CE}$ allows the lithium ion cell voltage to fall sufficiently before re-enabling the charge current.

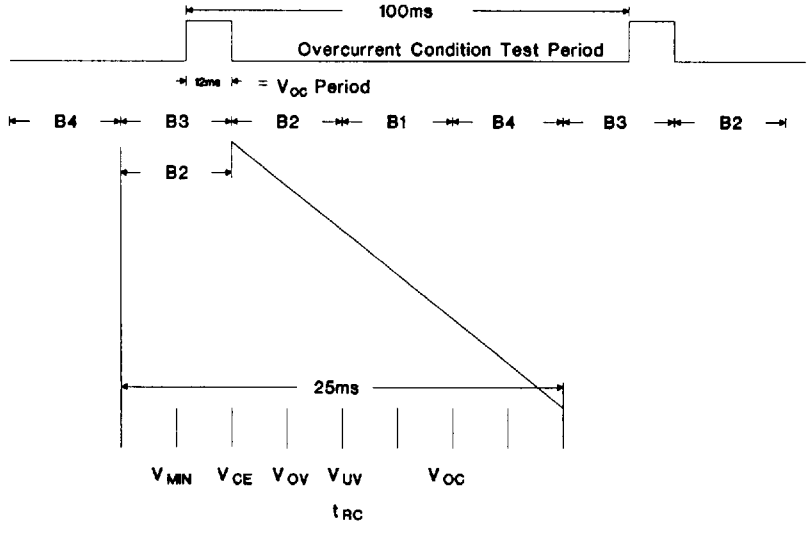
## Over-Current Supervision

The voltage across the $BAT_{4N}$ and GND pins is sampled approximately every 25ms for an overcurrent condition. If the bq2053 determines an overcurrent condition exists (either charge or discharge), it will disable the CHG and DSG outputs. The bq2053 will then re-enable the CHG and DSG outputs for approximately 12ms every 100ms to determine if the condition still exists. If the voltage between $BAT_{4N}$ and GND is less than 250mV (typical), the bq2053 will allow charging or discharging to continue, reset the overcurrent test, and once again begin sampling for an overcurrent situation.

## Absolute Maximum Ratings

| Symbol | Parameter | Value | Unit | Conditions |
|---|---|---|---|---|
| $V_T$ | Voltage applied on any pin relative to $BAT_{1P}$ | -18 to +0.31 | V | |
| $T_{OPR}$ | Operating temperature | -30 to +85 | °C | Commercial |
| $T_{STG}$ | Storage temperature | -55 to +125 | °C | |
| $T_{SOLDER}$ | Soldering temperature | 260 | °C | For 10 seconds |

**Note:** Permanent device damage may occur if **Absolute Maximum Ratings** are exceeded. Functional operation should be limited to the Recommended DC Operating Conditions detailed in this data sheet. Exposure to conditions beyond the operational limits for extended periods of time may affect device reliability.




$V_{MIN}$ = Check for cell present
$V_{CE}$ = Check for charge enable (only if cell present)
$V_{OV}$ = Check for overvoltage (only if cell present)
$V_{UV}$ = Check for undervoltage (only if cell present)
$V_{OC}$ = Check for overcurrent
$t_{RC}$ = Reset $V_{OC}$ current limit (only on B3)

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**Figure 3. Cell Monitor Timing**

## DC Electrical Characteristics ($T_A$ = $T_{OPR}$)

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Conditions/Notes |
|---|---|---|---|---|---|---|
| $V_{OH}$ | Output high voltage | $BAT_{1P}$ - 0.5 | - | - | V | $I_{OH}$ = 50µA, CHG, DSG |
| $V_{OP}$ | Operating voltage | 3.0 | - | 18 | V | |
| $V_{OL}$ | Output low voltage | - | - | $BAT_{4N}$ +0.5 | V | $I_{OL}$ = 50µA, DSG |
| | | - | - | GND + 0.5 | V | $I_{OL}$ = 50µA, CHG |
| $I_{CC}$ | Operating current 2-cell | - | 7 | 15 | µA | |
| | Operating current 3-cell | - | 12 | 25 | µA | |
| | Operating current 4-cell | - | 25 | 40 | µA | |
| $I_{CCLP}$ | Low power current | - | - | 1 | µA | |
| $R_{BAT1N, 2N, 3N}$ | Battery input impedance | - | 10 | - | MΩ | |

## DC Thresholds ($T_A$ = $T_{OPR}$)

| Symbol | Parameter | Value | Tolerance | Unit |
|---|---|---|---|---|
| $V_{OV}$ | Overvoltage limit | 4.25 | ± 1.5% | V |
| $V_{CE}$ | Charge enable voltage | $V_{OV}$ - 100mV | ± 50mV | V |
| $V_{UV}$ | Undervoltage limit | 2.3 | ± 100mV | V |
| $V_{OC}$ | Overcurrent limit | ± 250 | ± 25 | mV |

Note: Standard device. Contact Benchmarq for different threshold options.

## Ordering Information