



# Li+ Battery-Pack Protector with Integrated Fuse Driver

**MAX1906**

## General Description

The MAX1906 protects against overvoltage conditions in lithium-ion/lithium polymer (Li+) battery packs by blowing a three-terminal protection fuse. The IC should be used in conjunction with resettable protection circuits to provide a high level of safety against overcharging Li+ batteries. It can be used with 2-, 3-, or 4-series cell battery packs.

The MAX1906 monitors individual cell voltages. If any cell voltage exceeds the overvoltage threshold for greater than 2.1s, the MAX1906 activates an internal SCR. The SCR sinks sufficient current to blow an external protection fuse, permanently disabling the battery pack. Alternatively, the IC can drive the gate of an external MOSFET to blow the fuse.

The MAX1906 also offers protection against disconnected voltage sense pins. If a disconnected pin is detected, the DISCON output is forced low. The MAX1906 includes a test mode, which determines if the circuit is operating correctly while in an assembled battery pack.

The low-cost MAX1906 is available in a thermally enhanced 16-pin QFN package.

## Applications

2-, 3-, or 4-Series Li+ Battery Packs for Portable Products

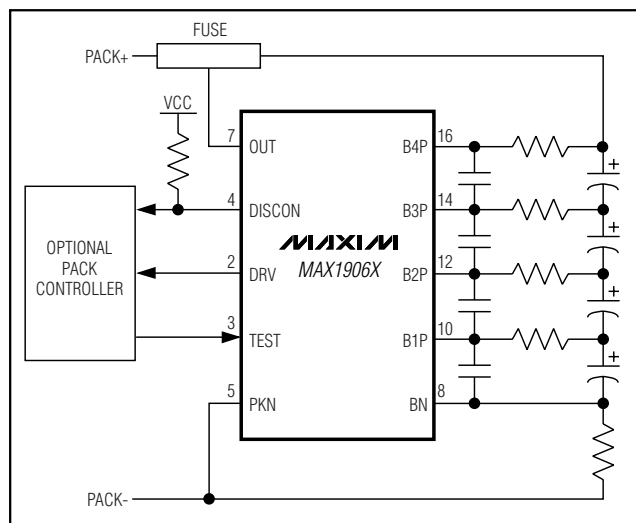
## Features

- ◆ Protects Against Overvoltage
- ◆  $\pm 1\%$  Accurate Protection Thresholds
- ◆ Integrated 2.1s Fault-Delay Timer
- ◆ Built-in 1.5A SCR Fuse Driver
- ◆ Test Mode for Functional Verification in Assembled Pack
- ◆ 8 $\mu$ A (max) Supply Current
- ◆ 1 $\mu$ A (max) Standby Current
- ◆ Protects Against Disconnected B1P–B4P Pins
- ◆ Protects 2-, 3-, or 4-Series Li+ Battery Packs
- ◆ Available in Small 16-Pin QFN Package (5mm x 5mm)

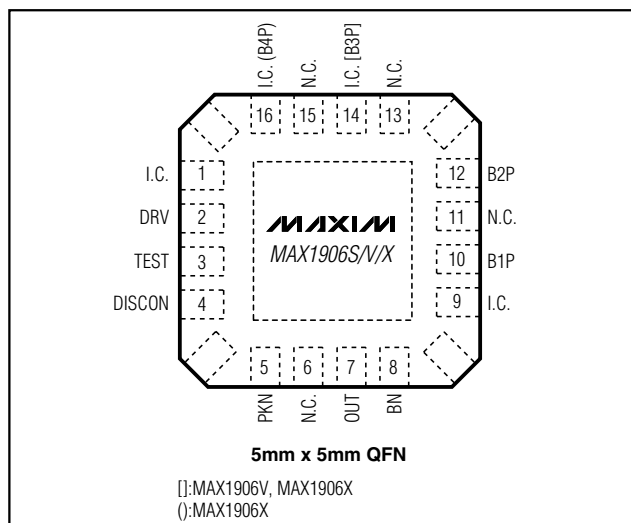
## Ordering Information

| PART        | TEMP RANGE     | PIN-PACKAGE      | CELLS |
|-------------|----------------|------------------|-------|
| MAX1906SEGE | -40°C to +85°C | 16 QFN 5mm x 5mm | 2     |
| MAX1906VEGE | -40°C to +85°C | 16 QFN 5mm x 5mm | 3     |
| MAX1906XEGE | -40°C to +85°C | 16 QFN 5mm x 5mm | 4     |

## Minimal Operating Circuit



## Pin Configuration



# Li+ Battery-Pack Protector with Integrated Fuse Driver

## ABSOLUTE MAXIMUM RATINGS

|                                               |               |
|-----------------------------------------------|---------------|
| B4P to BN                                     | -0.3V to +24V |
| B3P to BN                                     | -0.3V to +18V |
| B2P to BN                                     | -0.3V to +12V |
| B4P to B3P, B3P to B2P, B2P to B1P, B1P to BN | -0.3V to +6V  |
| TEST, DRV, DISCON to PKN                      | -0.3V to +6V  |
| OUT to BN                                     | -0.3V to +24V |
| BN to PKN                                     | -2V to +2V    |

|                                                                           |                                                           |
|---------------------------------------------------------------------------|-----------------------------------------------------------|
| OUT Maximum Current                                                       | 2.5A                                                      |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C, per JEDEC JESD51-7) | 16-Pin QFN (derate 19mW/°C above +70°C ambient) .... 1.5W |
| Operating Temperature Ranges                                              | -40°C to +85°C                                            |
| Storage Temperature                                                       | -65°C to +150°C                                           |
| Junction Temperature                                                      | +150°C                                                    |
| Lead Temperature (soldering, 10s)                                         | +300°C                                                    |

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(T<sub>A</sub> = 0°C to +85°C, individual cell voltages = 4.2V unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.)

| PARAMETER                                  | SYMBOL              | CONDITIONS                               | MIN  | TYP   | MAX  | UNITS |
|--------------------------------------------|---------------------|------------------------------------------|------|-------|------|-------|
| B4P Voltage Range                          |                     |                                          |      |       | 20   | V     |
| B3P Voltage Range                          |                     |                                          |      |       | 15   | V     |
| B2P Voltage Range                          |                     |                                          |      |       | 10   | V     |
| B1P Voltage Range                          |                     |                                          |      |       | 5    | V     |
| Overvoltage Detection Threshold            | V <sub>OV_TH</sub>  | Cell voltage rising                      | 4.4  | 4.45  | 4.5  | V     |
| Overvoltage Detection Threshold, Test Mode |                     | Cell voltage rising, test mode           | 2.0  | 2.225 | 2.4  | V     |
| Overvoltage Detection Hysteresis           | V <sub>OV_HYS</sub> | Cell voltage falling                     |      | 10    |      | mV    |
| SCR Release Threshold                      | V <sub>REL</sub>    | Cell voltage falling                     | 3.85 | 4.0   | 4.15 | V     |
| Standby-Mode Threshold                     |                     | Cell voltage falling                     | 2.3  | 3.3   | 4.1  | V     |
| Overvoltage Delay                          | t <sub>OV</sub>     |                                          | 1.85 | 2.1   | 2.45 | s     |
| Sampling Interval                          |                     | (Note 1)                                 |      | 2.56  |      | s     |
| Supply Current                             | I <sub>SUP</sub>    | (Note 2)                                 |      | 3     | 6    | μA    |
| Supply Current During Sampling             |                     |                                          |      | 300   |      | μA    |
| Standby Current                            |                     | Individual cell voltages = 2.2V          |      |       | 800  | nA    |
| Intermediate Cell Quiescent Current        |                     | (Note 3)                                 |      | 0.5   |      | nA    |
| OUT Output Sink Current                    |                     | OUT = 2V, current not internally limited | 1.0  | 1.5   | 2.0  | A     |
| OUT Voltage (when SCR Is Triggered)        |                     | I <sub>OUT</sub> = 1.5A                  |      | 1.6   | 2.0  | V     |
| OUT Leakage Current                        |                     | OUT = 24V                                | -1   |       | +1   | μA    |
| DRV Output Voltage Low                     | V <sub>DRV_L</sub>  | I <sub>DRV</sub> = 200μA                 |      |       | 0.4  | V     |
| DRV Output Voltage High                    | V <sub>DRV_H</sub>  | I <sub>DRV</sub> = 5μA                   | 4.0  | 4.8   | 5.5  | V     |
|                                            |                     | I <sub>DRV</sub> = -1mA                  | 2.0  | 4.8   | 5.5  |       |
| DRV Sink Current                           | I <sub>DRV</sub>    | V <sub>DRV_H</sub> = 2.5V                | 2    |       |      | mA    |
| DRV Source Current                         | I <sub>DRV</sub>    | V <sub>DRV_L</sub> = 0V                  | 2    |       |      | mA    |
| Test-Mode Delay                            | t <sub>DLY</sub>    | (Note 4)                                 |      |       | 1.2  | ms    |
| Test-Mode Output Duration                  | t <sub>OUT</sub>    | (Note 4)                                 | 100  | 130   | 160  | ms    |
| DISCON Output Voltage Low                  |                     | I <sub>DISCON</sub> = 1mA                |      |       | 0.4  | V     |
| DISCON Leakage Current                     |                     | V <sub>DISCON</sub> = 3.3V               | -1   |       | +1   | μA    |

# Li+ Battery-Pack Protector with Integrated Fuse Driver

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## ELECTRICAL CHARACTERISTICS (continued)

(T<sub>A</sub> = 0°C to +85°C, individual cell voltages = 4.2V unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.)

| PARAMETER                           | SYMBOL | CONDITIONS         | MIN | TYP | MAX | UNITS |
|-------------------------------------|--------|--------------------|-----|-----|-----|-------|
| Disconnected Pin Test Time          |        | Test time per cell |     | 0.2 |     | ms    |
| TEST Input High                     |        |                    | 2.2 |     |     | V     |
| Minimum TEST High Duration          |        |                    |     | 50  |     | μs    |
| TEST Input Low                      |        |                    |     |     | 0.8 | V     |
| TEST Pulldown to PKN                |        |                    | 17  |     | 33  | kΩ    |
| Thermal Impedance, Junction to Case |        |                    |     | 5   |     | °C/W  |

## ELECTRICAL CHARACTERISTICS

(T<sub>A</sub> = -40°C to +85°C, individual cell voltages = 4.2V, unless otherwise noted.)

| PARAMETER                                  | SYMBOL             | CONDITIONS                               | MIN  | TYP | MAX  | UNITS |
|--------------------------------------------|--------------------|------------------------------------------|------|-----|------|-------|
| B4P Voltage Range                          |                    |                                          |      |     | 20   | V     |
| B3P Voltage Range                          |                    |                                          |      |     | 15   | V     |
| B2P Voltage Range                          |                    |                                          |      |     | 10   | V     |
| B1P Voltage Range                          |                    |                                          |      |     | 5    | V     |
| Overvoltage Detection Threshold            | V <sub>OV_TH</sub> | Cell voltage rising                      | 4.35 |     | 4.55 | V     |
| Overvoltage Detection Threshold, Test Mode |                    | Cell voltage rising, test mode           | 1.95 |     | 2.45 | V     |
| SCR Release Threshold                      | V <sub>REL</sub>   | Cell voltage falling                     | 3.80 |     | 4.2  | V     |
| Standby Mode Threshold                     |                    | Cell voltage falling                     | 2.25 |     | 4.15 | V     |
| Overvoltage Delay                          | t <sub>OV</sub>    |                                          | 1.85 |     | 2.45 | s     |
| Supply Current                             | I <sub>SUP</sub>   | (Note 2)                                 |      |     | 8    | μA    |
| Standby Current                            |                    | Individual cell voltages = 2.2V          |      |     | 1    | μA    |
| OUT Output Sink Current                    |                    | OUT = 2V, current not internally limited | 1.0  |     |      | A     |
| OUT Voltage (when SCR Is Triggered)        |                    | I <sub>OUT</sub> = 1.5A                  |      |     | 2.2  | V     |
| DRV Output Voltage Low                     | V <sub>DRV_L</sub> | I <sub>DRV</sub> = 200μA                 |      |     | 0.4  | V     |
| DRV Output Voltage High                    | V <sub>DRV_H</sub> | I <sub>DRV</sub> = 5μA                   | 3.9  |     | 5.5  | V     |
| DRV Output Voltage High                    | V <sub>DRV_H</sub> | I <sub>DRV</sub> = -1mA                  | 2.0  |     | 5.5  | V     |
| DRV Sink Current                           | I <sub>DRV</sub>   | V <sub>DRV_H</sub> = 2.5V                | 2    |     |      | mA    |
| DRV Source Current                         | I <sub>DRV</sub>   | V <sub>DRV_L</sub> = 0V                  | 2    |     |      | mA    |
| Test-Mode Delay                            | t <sub>DLY</sub>   | (Note 4)                                 |      |     | 1.25 | ms    |
| Test-Mode Output Duration                  | t <sub>OUT</sub>   | (Note 4)                                 | 95   |     | 165  | ms    |
| DISCON Output Voltage Low                  |                    | I <sub>DISCON</sub> = 1mA                |      |     | 0.4  | V     |
| TEST Input High                            |                    |                                          | 2.6  |     |      | V     |
| TEST Input Low                             |                    |                                          |      |     | 0.8  | V     |
| TEST Pulldown to PKN                       |                    |                                          | 17   |     | 33   | kΩ    |

**Note 1:** See the *Normal Operating Mode* section.

**Note 2:** The supply current is measured at the top cell and averaged over one sampling interval.

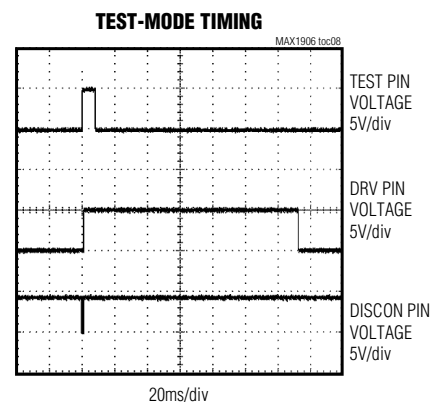
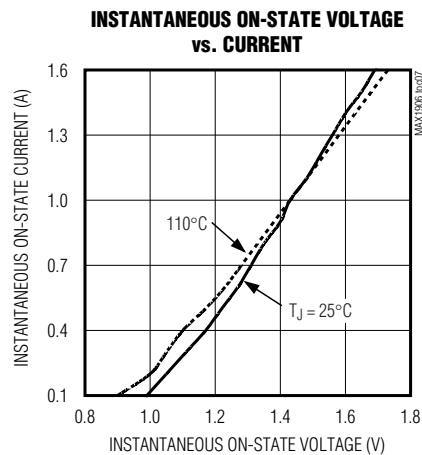
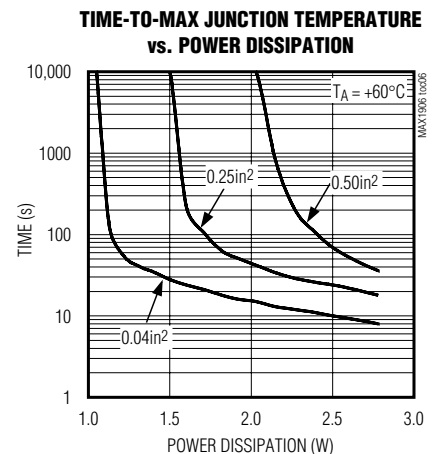
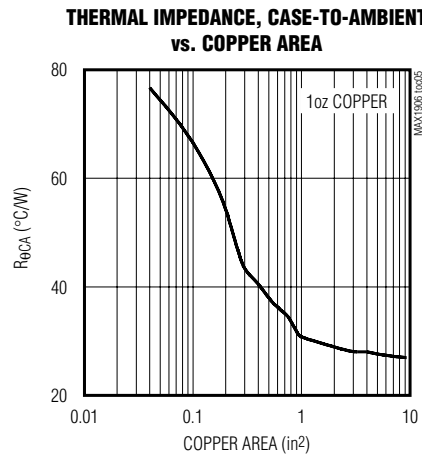
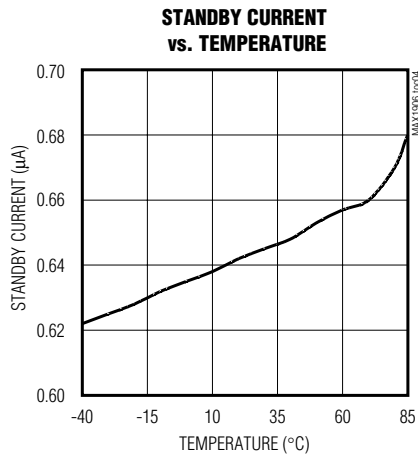
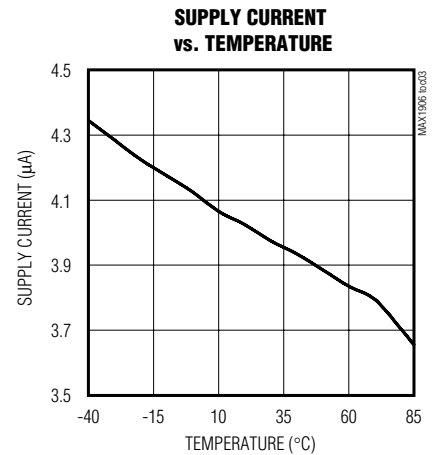
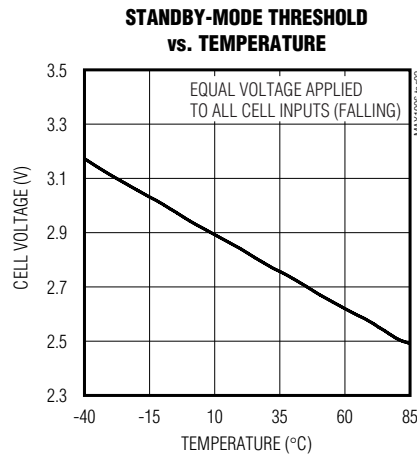
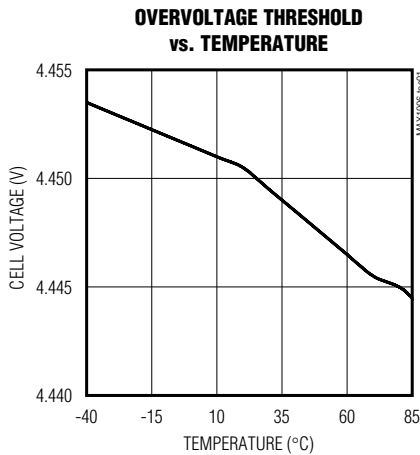
**Note 3:** Guaranteed by design.

**Note 4:** See Figure 7.

# Li+ Battery-Pack Protector with Integrated Fuse Driver

## Typical Operating Characteristics

( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



# Li+ Battery-Pack Protector with Integrated Fuse Driver

## Pin Description

MAX1906

| PIN           |               |               | NAME   | DESCRIPTION                                                                                                                                                                                                        |
|---------------|---------------|---------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX1906S      | MAX1906V      | MAX1906X      |        |                                                                                                                                                                                                                    |
| 1, 9          | 1, 9          | 1, 9          | I.C.   | Internal Connection. Float pins 1 and 9.                                                                                                                                                                           |
| 6, 11, 13, 15 | 6, 11, 13, 15 | 6, 11, 13, 15 | N.C.   | No Connection                                                                                                                                                                                                      |
| 2             | 2             | 2             | DRV    | MOSFET Driver Output. High when an overvoltage condition is detected. Connect the DRV pin to the gate of an external MOSFET to blow the protection fuse.                                                           |
| 3             | 3             | 3             | TEST   | Test-Mode Input. Test mode is enabled with a pulse of minimum 50μs duration on the TEST pin.                                                                                                                       |
| 4             | 4             | 4             | DISCON | Disconnected Pin Output. This is an open-drain output and is high-Z during normal operation. If B4P, B3P, B2P, or B1P is disconnected, this pin is pulled low (see the <i>Disconnected Pin Detection</i> section). |
| 5             | 5             | 5             | PKN    | Pack Negative. A sense resistor may be connected between BN and PKN.                                                                                                                                               |
| 7             | 7             | 7             | OUT    | Anode Output of the SCR. Connect OUT to the fuse's heater connection (see the <i>Protection Fuse Selection</i> section).                                                                                           |
| 8             | 8             | 8             | BN     | Negative Terminal of Cell 1. Connect BN to the negative terminal of the first series Li+ cell. BN is also chip ground, which is connected to the backside paddle on the QFN package.                               |
| 10            | 10            | 10            | B1P    | Positive Terminal of Cell 1. Connect B1P to the positive terminal of the first series Li+ cell.                                                                                                                    |
| 12            | 12            | 12            | B2P    | Positive Terminal of Cell 2. Connect B2P to the positive terminal of the second series Li+ cell.                                                                                                                   |
| —             | 14            | 14            | B3P    | Positive Terminal of Cell 3. Connect B3P to the positive terminal of the third series Li+ cell.                                                                                                                    |
| —             | —             | 16            | B4P    | Positive Terminal of Cell 4. Connect B4P to the positive terminal of the fourth series Li+ cell.                                                                                                                   |

## Detailed Description

The MAX1906 protects 2-, 3-, or 4-series Li+ battery packs from overcharge by controlling a three-terminal protection fuse. Figures 1 and 2 show two application circuits using the MAX1906. The MAX1906 checks the voltage of each cell at regular intervals. An overcharge condition is detected if any cell voltage exceeds the overvoltage threshold for more than 2.1s. The MAX1906 responds to an overcharge condition by turning on an internal SCR (Figure 1) or an external MOSFET (Figure 2) to blow a three-terminal protection fuse placed in series with the charging path.

The MAX1906 checks for disconnected voltage sense pins every time it exits the standby mode or test mode. If a disconnected pin is detected, the DISCON pin is latched low. The MAX1906 also includes a test mode, which determines if the circuit is operating correctly while in an assembled battery pack. A pulse on the TEST pin

enables the test mode. Figure 3 shows the cell connections for 2- and 3-series battery packs and Figure 4 shows the functional diagram for the MAX1906.

The MAX1906 can be used together with other resettable protection circuits to provide a high level of safety against overcharging Li+ batteries. Figure 5 shows a typical application circuit using the MAX1906 together with the MAX1924. The MAX1924 has a lower overvoltage threshold than the MAX1906. If any cell voltage exceeds 4.35V (typ), the MAX1924 turns off the TKO and CGO MOSFETs and opens the charging path. If the TKO or CGO MOSFET fails and charging continues, the MAX1906 blows the protection fuse and opens the charging path permanently once any cell voltage reaches 4.45V (typ). The MAX1924 also protects the battery pack against undervoltage, charge current, discharge current, and pack-short fault conditions. Refer to the MAX1894/ MAX1924 data sheets for complete details.

# Li+ Battery-Pack Protector with Integrated Fuse Driver

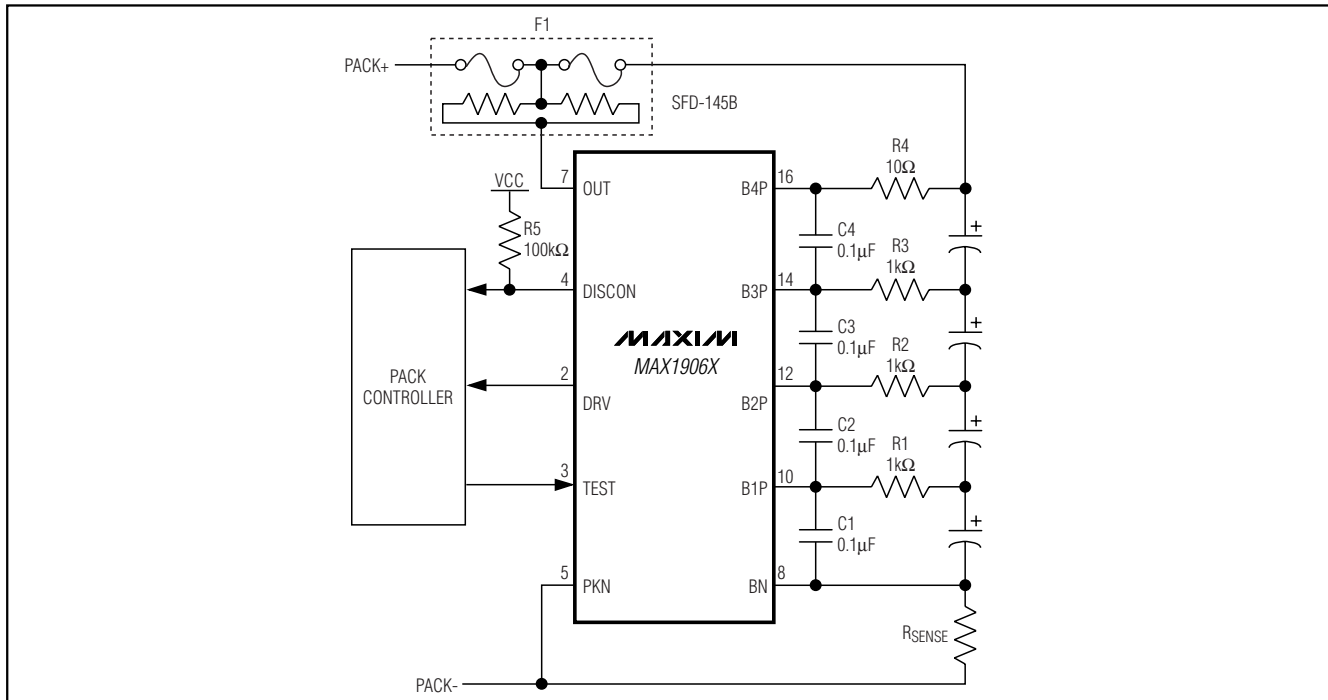


Figure 1. Typical Application Circuit for 4-Series Battery Packs—Using the Internal SCR to Blow the Protection Fuse

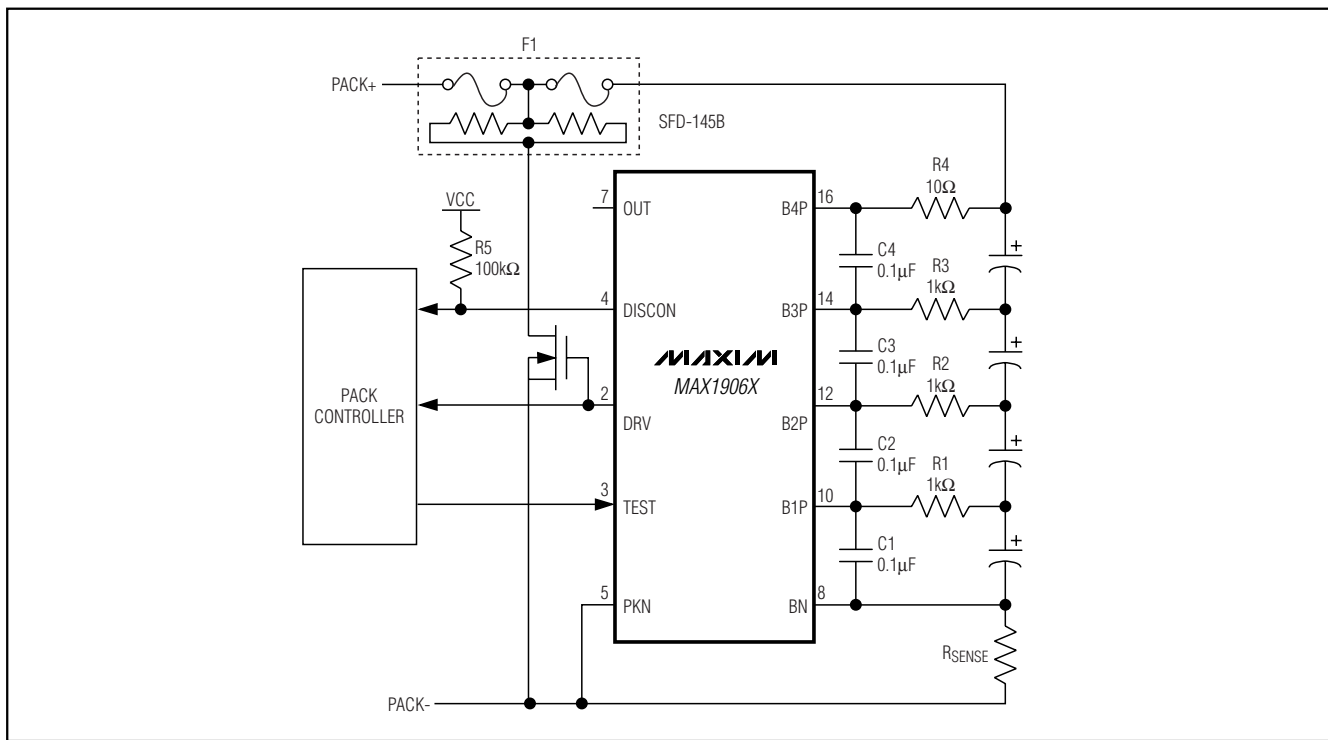


Figure 2. Typical Application Circuit for 4-Series Battery Packs—Using the External MOSFET to Blow the Protection Fuse

# Li+ Battery-Pack Protector with Integrated Fuse Driver

MAX1906

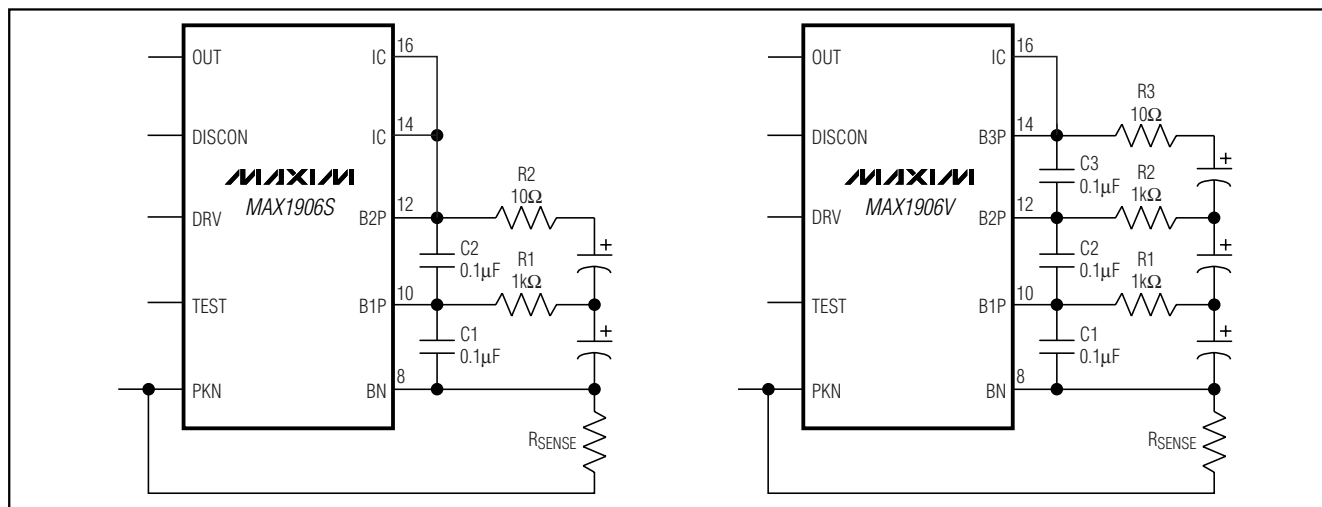


Figure 3. Cell Connections for 2- and 3-Series Battery Packs

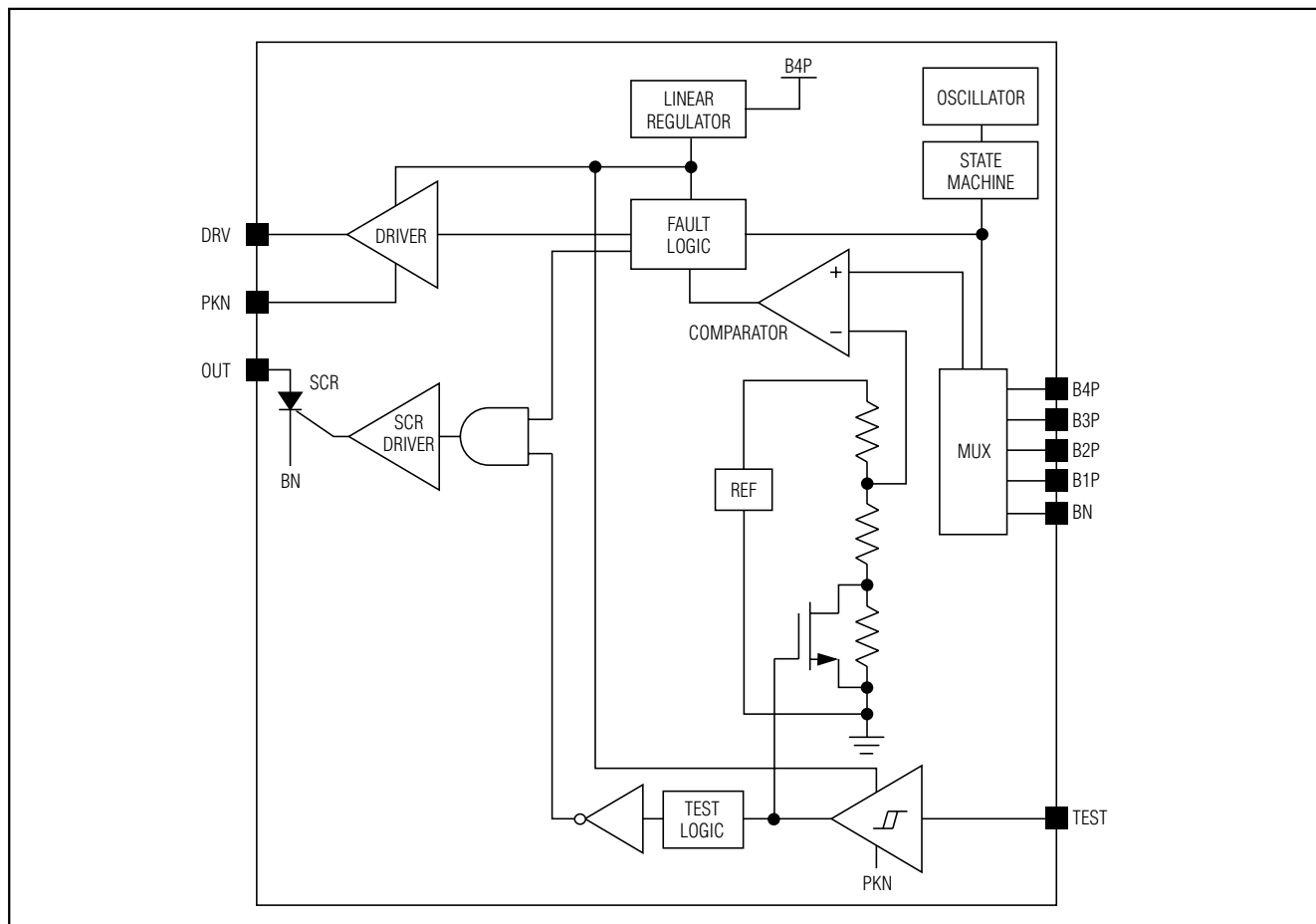


Figure 4. MAX1906 Functional Diagram

# Li+ Battery-Pack Protector with Integrated Fuse Driver

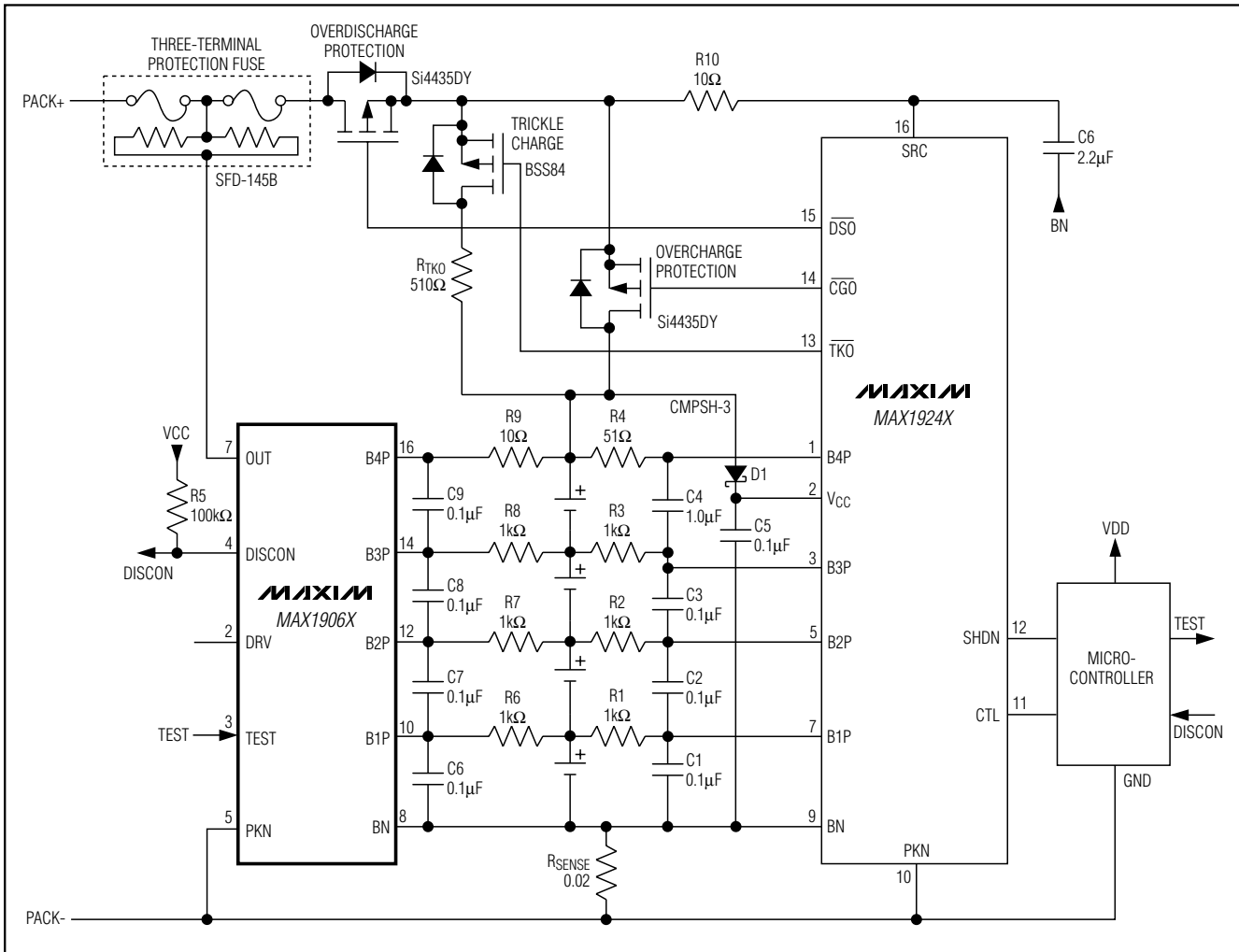


Figure 5. Typical Application Circuit—Using the MAX1906 with a MAX1924 Protection Circuit

## Modes of Operation

### Normal Operating Mode

The MAX1906 operates in normal mode when at least 1 cell voltage is above the standby-mode threshold. In this mode, the average supply current from the top cell is 8 $\mu$ A (max). The MAX1906 works by sampling cell voltages for 0.8ms and then goes into an idle state for 2.56s to complete a cycle. During the sampling period, the MAX1906 typically consumes 300 $\mu$ A. In the idle state, the MAX1906 typically consumes 3.2 $\mu$ A. Figure 6 shows the device current consumption in different states.

### Standby Mode

When all the cell voltages are below the standby-mode threshold, the MAX1906 goes into the standby mode. In

this mode, the device draws 1 $\mu$ A (max) from the top cell. Once any cell voltage goes above the standby-mode threshold, the MAX1906 wakes up and goes into the normal mode.

### Test Mode

The test mode is designed to verify the overvoltage detection function in a fully assembled battery pack without blowing the three-terminal protection fuse. Test mode is invoked by a pulse with minimum duration of 50 $\mu$ s on the TEST pin. The MAX1906 changes the overvoltage threshold from 4.45V to 2.225V in the test mode and samples each of the cell voltages. Individual cell voltages are expected to be above 2.225V during the test mode. If the MAX1906 detects overvoltage condition on all cells during one sampling period, the DRV pin goes

# Li+ Battery-Pack Protector with Integrated Fuse Driver

MAX1906

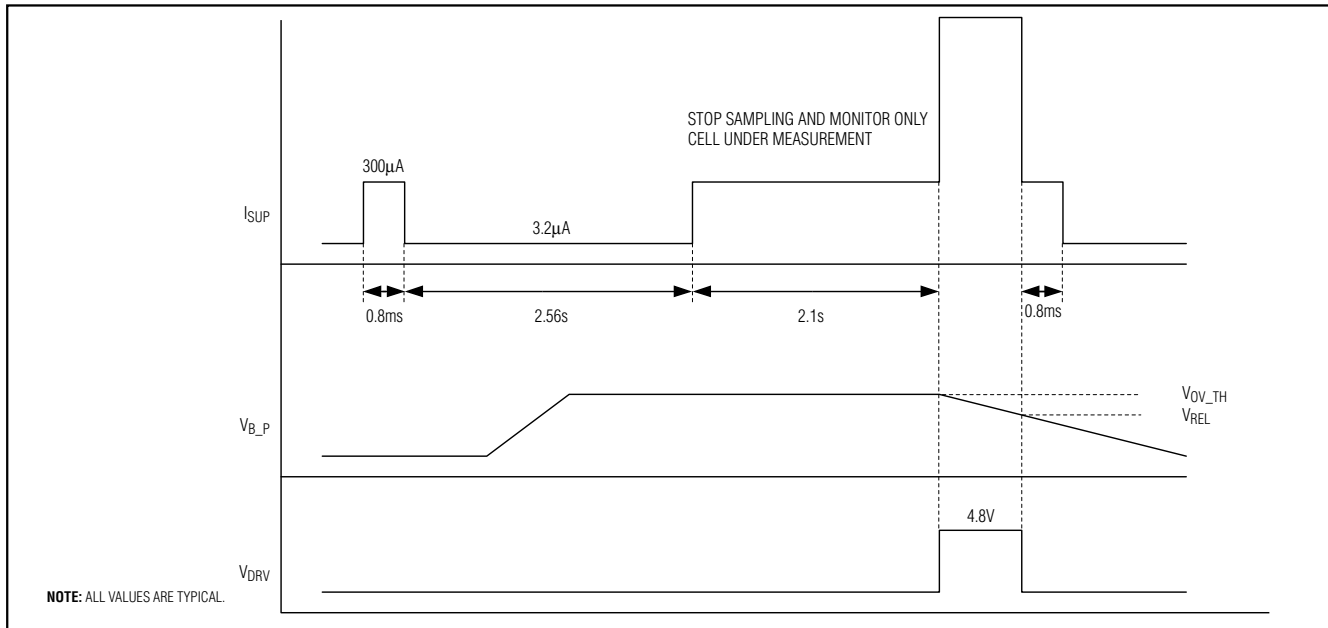


Figure 6. Current Consumption of Chip in Different States

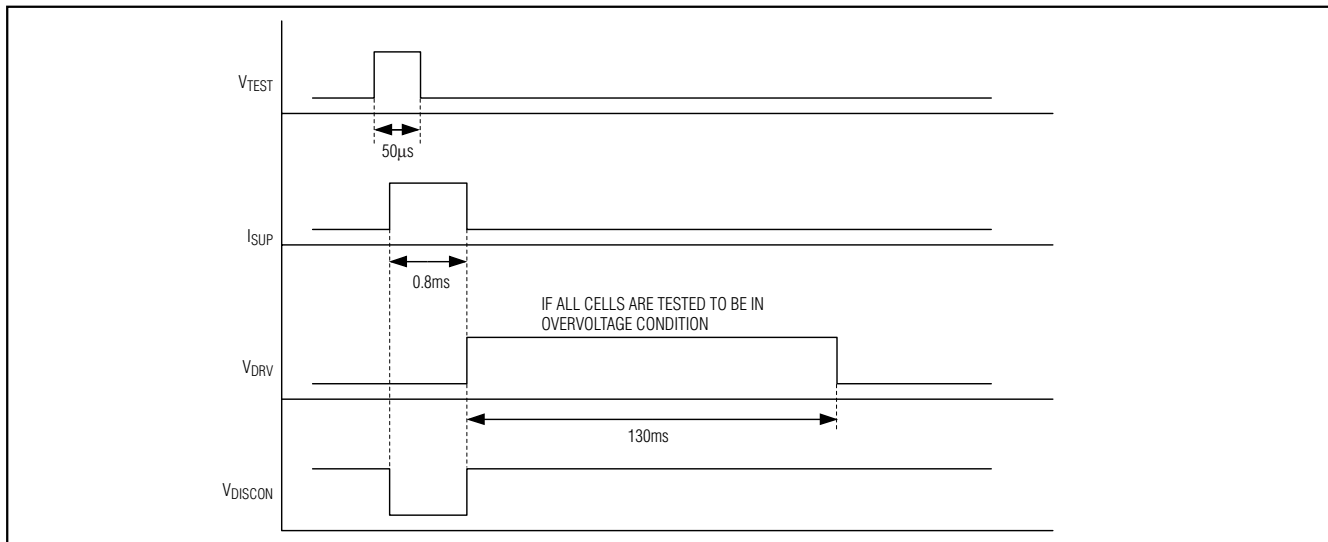


Figure 7. Timing Diagram for Test Mode

high and the DISCON pin is set to its high-impedance state. After 130ms, the DRV pin is pulled low by the MAX1906, exiting the test mode. The time period of 130ms has been chosen not to stress the three-terminal protection fuse if an external MOSFET is used to blow the fuse. The OUT pin is not affected by the test mode. See the timing diagram for the test mode in Figure 7.

Entry into test mode is ignored if the MAX1906 has detected an overvoltage condition and has activated the 2.1s delay. Test mode remains disabled until the MAX1906 exits the overvoltage condition. The MAX1906 continues normal operation upon exit from the test mode.

# Li+ Battery-Pack Protector with Integrated Fuse Driver

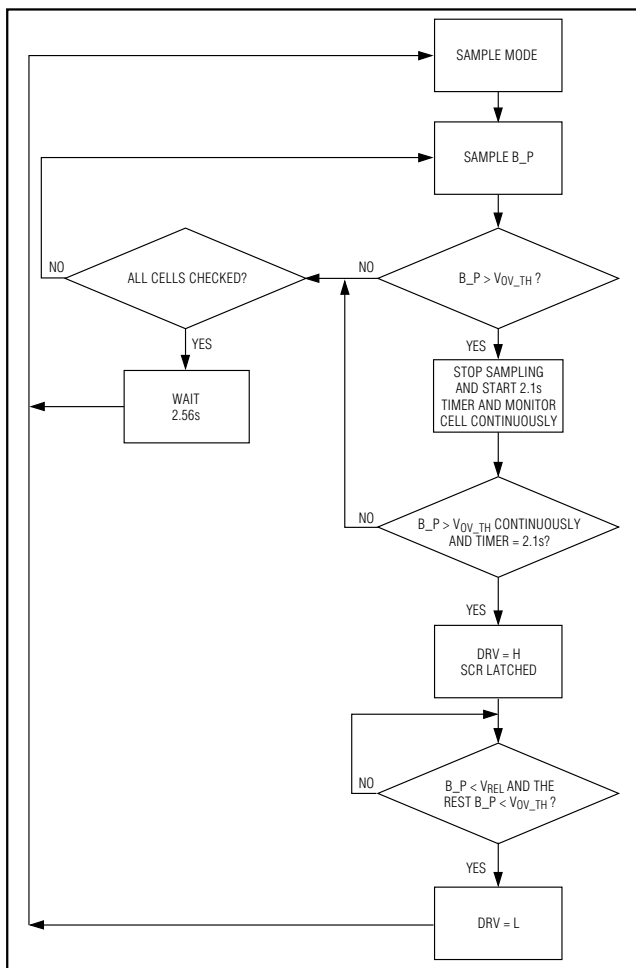


Figure 8. Overt Voltage Protection

## Protection Features

### Overt Voltage Detection

If any cell voltage exceeds the overvoltage threshold, the MAX1906 stops sampling and monitors the cell voltage continuously. If the overvoltage condition persists for more than 2.1s, the device turns on an internal SCR and also drives the DRV pin high. The internal SCR or the external MOSFET sinks sufficient current to blow the three-terminal protection fuse and permanently open the battery pack's charge path. See the overvoltage protection flowchart in Figure 8. Also see the *Fuse Drive Options* section for discussion on current capability for both the internal SCR and external MOSFET.

The MAX1906 remains in overvoltage mode until the cell voltage drops to 90% of the overvoltage threshold (VREL) and the rest of cells are below the overvoltage

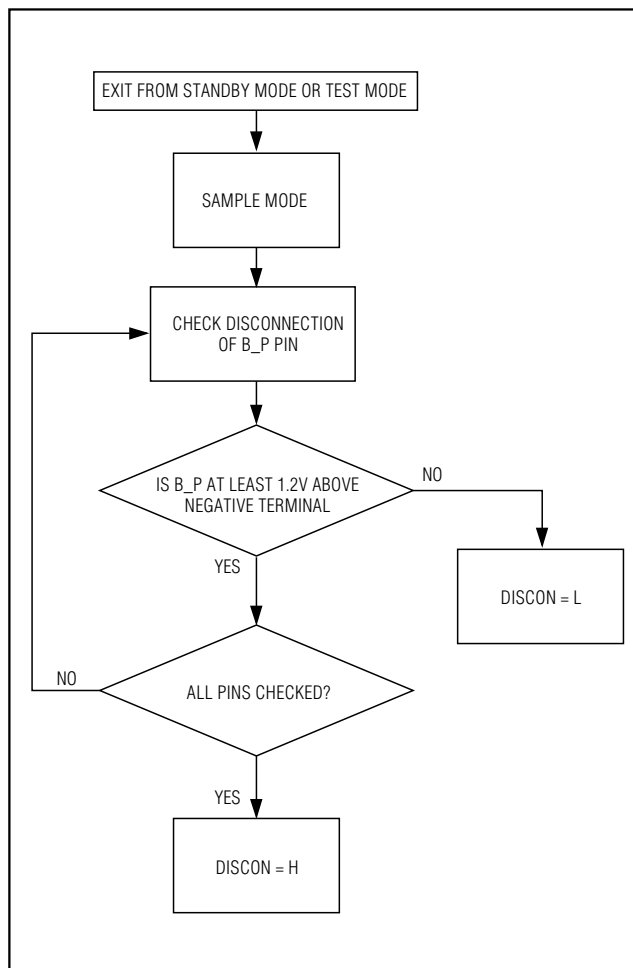


Figure 9. Disconnected Pin Detection

threshold. The DRV pin then goes low, which turns off an external MOSFET. The internal SCR does not unlatch until power is removed.

### Disconnected Pin Detection

The MAX1906 tests for disconnected voltage sense pins each time it exits the standby or test mode. To check for a disconnection, the MAX1906 applies a 10µA current source to each B\_P pin. A disconnected pin is detected if the B\_P pin under test falls to within 1.2V of the cell's negative terminal. The DISCON pin is then pulled low. This condition persists while the MAX1906 is in normal operating mode, and resets only when the MAX1906 enters the standby or test mode. See Figure 9 for the disconnected pin detection flowchart.

# Li+ Battery-Pack Protector with Integrated Fuse Driver

## Design Procedure

### Fuse Drive Options

The MAX1906 supports two methods for blowing the external protection fuse: the internal SCR can be directly connected to the fuse's heater terminal or an external MOSFET can be used to drive the heater. The design procedure for both methods requires matching the drive capabilities in the SCR or the MOSFET with the dissipation required to blow the fuse.

The SCR configuration is simple, low cost, and does not require external components. The circuit in Figure 1 is appropriate for fuses that require heater currents up to 2A. Since the voltage drop across the SCR can be up to 2V, care must be taken not to exceed the device's power ratings. When greater than 1in<sup>2</sup> of copper plane is available to conduct heat away from the MAX1906, it can dissipate 1.6A at typically 1.7V indefinitely. When smaller copper planes are used, the time to clear the fuse must be less than the time for the MAX1906 to exceed its absolute maximum thermal ratings.

The transient thermal characteristics for the MAX1906 are shown in the *Typical Operating Characteristics*. Since the thermal resistance varies inversely with the area of the copper plane attached to the device, the time to reach thermal limit also varies with copper area.

External MOSFETs should be used with the MAX1906 when the heater current must be greater than 2.0A. MOSFETs with the required thermal characteristics are available from multiple manufacturers (see Table 1). Figure 2 shows the typical application circuit using an external MOSFET.

### Protection Fuse Selection

Protection fuse characteristics can vary considerably from manufacturer to manufacturer. Always review the data sheet carefully when selecting the protection fuse. Table 2 lists the contact information for manufacturers of compatible fuses.

There are two methods for opening the protection fuse. The fuse can be blown through the heater or by too much dissipation along the high-current path. The fuse must be selected to accommodate the required operating current without placing stress on the fuse. Once the nominal current-handling characteristics of the fuse are set, determine the amount of drive current and the time required to blow the fuse through the heater terminal. These quantities are also listed in the fuse manufacturer's data sheet.

The fuse blows when sufficient power is dissipated in the heater resistor to melt the fuse's internal solder joints:

$$P_{\text{HEATER}} = V_{\text{HEATER}} \times I_{\text{HEATER}} = \frac{(V_{\text{BATT\_OV}} - V_{\text{SWITCH}})^2}{R_{\text{HEATER}}}$$

V<sub>BATT\_OV</sub> is the battery-pack voltage in the overvoltage condition, which is typically 4.45V per cell. V<sub>SWITCH</sub> is the voltage drop on the internal SCR or an external MOSFET. R<sub>HEATER</sub> is the resistance of the heater resistor.

The time required to blow the protection fuse, or clearing time, depends upon the power dissipation in the heater resistor and the ambient temperature. Fuse manufacturers typically provide a curve of clearing time vs. voltage, and the clearing time vs. ambient temperature. The greater the power dissipation in the heater resistor, the quicker the fuse blows. Clearing time is also inversely proportional to ambient temperature. The heater resistance for different operating current specifications can range from a few ohms to a few hundred ohms. The resistance should be selected based on the acceptable clearing time and operating temperature range.

For a battery pack requiring 4A of operating current, a fuse with a 5A nominal current rating is appropriate. An SFD-145B device made by Sony Chemical Corp. is selected, which has a 22Ω fusible resistor. Based on safety considerations, the clearing time should be no more than 1s or 2s. This is commensurate with the delay time required to detect the fault condition. The power dissipated in the SCR when the fuse is blown is approximately 1.3V × 0.75A or 1W. To ensure that the junction temperature in the MAX1906 never exceeds 150°C at 60°C ambient temperature, the required thermal resistance must be:

$$\begin{aligned} R_{\theta\text{CA}} + R_{\theta\text{JC}} &< (T_{\text{MAX}} - T_{\text{A}}) / (P_{\text{d}}) \\ &< (150^{\circ}\text{C} - 60^{\circ}\text{C}) / (1\text{W}) \\ &< 90^{\circ}\text{C/W} \end{aligned}$$

where R<sub>θJC</sub> is the thermal impedance from junction to case, and R<sub>θCA</sub> is the thermal impedance from case to ambient. R<sub>θJC</sub> is fixed, and is about 5°C/W for the 16-lead 5mm × 5mm QFN package. R<sub>θCA</sub> varies with copper area, and is shown in the *Typical Operating Characteristics*. Even though a combined thermal resistance of 90°C/W is achievable with less than 0.04in<sup>2</sup> of copper area, it is advisable to include some margin to reduce the rise in device temperature. Using 0.25in<sup>2</sup> copper area is conservative, and is available in most designs.

# Li+ Battery-Pack Protector with Integrated Fuse Driver

## RC Filters On Cell Inputs

The MAX1906 has an unused pin placed between each of the cell connections. These extra pins minimize the risk of a solder short between pins during the assembly process. Resistors in series with each B\_P pin are recommended to limit the current in case there is a short between adjacent B\_P pins (see the *Typical Application Circuits*).

The MAX1906 is powered from the top cell during the sampling period. The 300 $\mu$ A typical sampling current, multiplied by a 10 $\Omega$  series resistor can move the overvoltage trip point on the top cell by 3mV. The intermediate cell quiescent current is typically 500pA. A 1k $\Omega$  resistor in series with any cell except the top one alters the overvoltage trip point by typically 0.5mV. It is recommended to use a resistor of 10 $\Omega$  in series with the top cell and 1k $\Omega$  resistors in series with the rest of the cells to achieve the desired overvoltage threshold tolerance while limiting the potential short-circuit current.

The MAX1906 has internal ESD diodes on each B\_P pin for ESD protection up to 2kV. When higher ESD ratings are needed, capacitors (typically 0.1 $\mu$ F) can be added across adjacent B\_P pins (see the *Typical Application Circuits*). The RC filters improve the device immunity to ESD.

## Layout Guidelines

Good layout is important to minimize the effects of noise on the system and ensure accurate voltage measurements. Use appropriate trace widths for the high-current paths and keep traces short to minimize parasitic inductance and capacitance. Provide adequate space and board area for the sense resistor to dissipate heat. Place RC filters close to B1P–B4P pins. If some amount of heat sinking is needed to use the internal SCR, connect the exposed backside paddle to as large a copper area as practical.

## Chip Information

TRANSISTOR COUNT: 4027

PROCESS: BiCMOS

**Table 1. MOSFET Suppliers**

| SUPPLIER                | USA PHONE    | FACTORY FAX  | WEBSITE               |
|-------------------------|--------------|--------------|-----------------------|
| Fairchild               | 408-721-2181 | 408-721-1635 | www.fairchildsemi.com |
| International Rectifier | 310-322-3331 | 310-322-3332 | www.irf.com           |
| Vishay Siliconix        | 408-988-8000 | 408-567-8979 | www.vishay.com        |

**Table 2. Recommended Fuse Manufacturers**

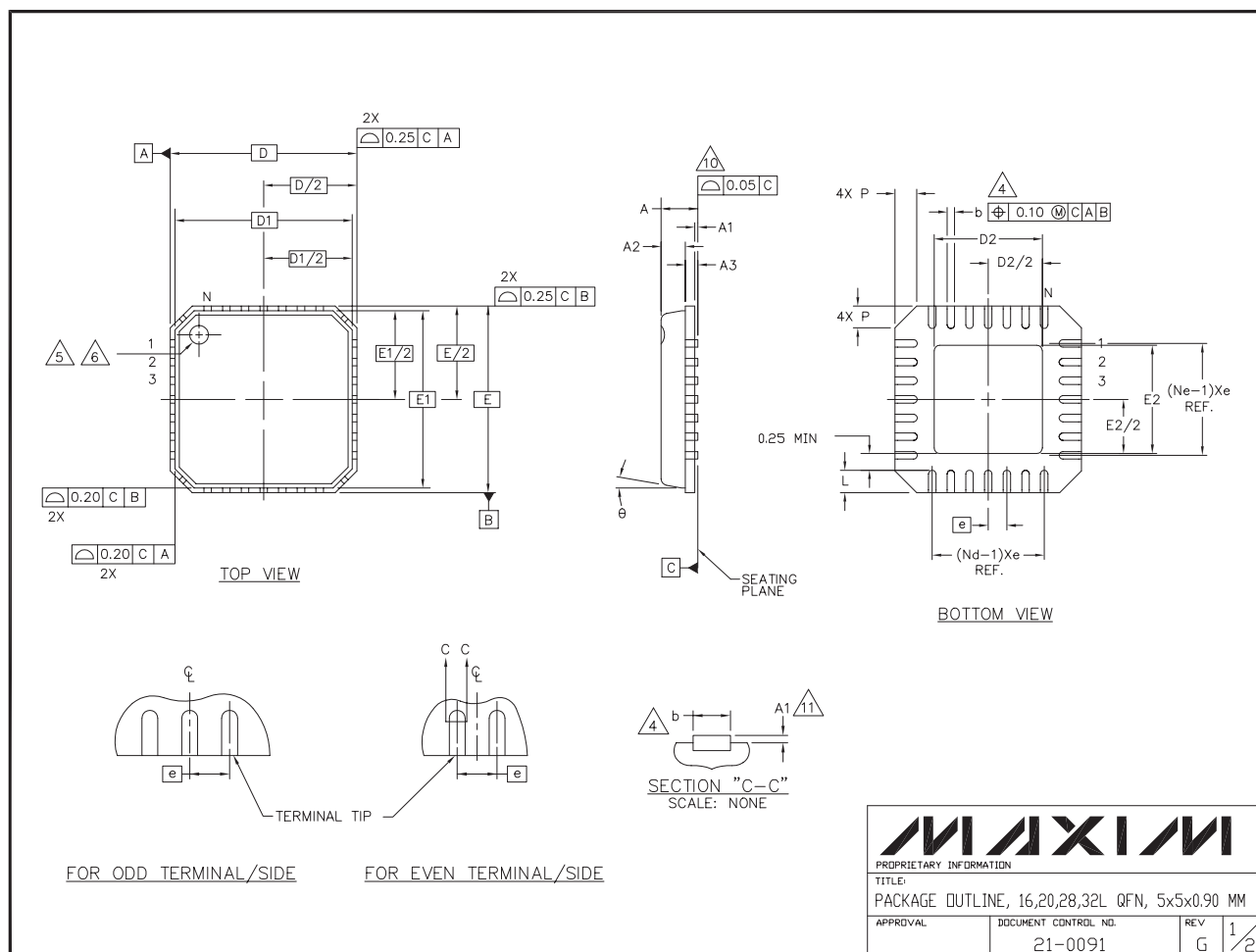
| MANUFACTURER             | PHONE           | FAX             | WEBSITE                |
|--------------------------|-----------------|-----------------|------------------------|
| Sony Chemicals Corp.     | +81-3-3279-0448 | +81-3-5255-8448 | www.sccj.co.jp/html_e/ |
| Uchihashi Estec Co., Ltd | +81-6-6962-6661 | +81-6-6962-6669 | www.uchihashi.co.jp/   |

# Li+ Battery-Pack Protector with Integrated Fuse Driver

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

MAX1906



# Li+ Battery-Pack Protector with Integrated Fuse Driver

## Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

### NOTES:

1. DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM (.012 INCHES MAXIMUM)
2. DIMENSIONING & TOLERANCES CONFORM TO ASME Y14.5M. – 1994.
3. N IS THE NUMBER OF TERMINALS.  
Nd IS THE NUMBER OF TERMINALS IN X-DIRECTION &  
Ne IS THE NUMBER OF TERMINALS IN Y-DIRECTION.
4. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25mm FROM TERMINAL TIP.
5. THE PIN #1 IDENTIFIER MUST BE EXISTED ON THE TOP SURFACE OF THE PACKAGE BY USING INDENTATION MARK OR INK/ LASER MARKED.
6. EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
7. ALL DIMENSIONS ARE IN MILLIMETERS.
8. PACKAGE WARPAGE MAX 0.05mm.
9. APPLIED FOR EXPOSED PAD AND TERMINALS.  
EXCLUDE EMBEDDED PART OF EXPOSED PAD FROM MEASURING.
10. MEETS JEDEC MO220.
11. THIS PACKAGE OUTLINE APPLIES TO ANVIL SINGULATION (STEPPED SIDES) AND TO SAW SINGULATION (STRAIGHT SIDES) QFN STYLES.

| SYMBOL | COMMON DIMENSIONS |      |      | NOTES |
|--------|-------------------|------|------|-------|
|        | MIN.              | NOM. | MAX. |       |
| A      | 0.80              | 0.90 | 1.00 |       |
| A1     | 0.00              | 0.01 | 0.05 |       |
| A2     | 0.00              | 0.65 | 1.00 |       |
| A3     | 0.20 REF.         |      |      |       |
| D      | 5.00 BSC          |      |      |       |
| D1     | 4.75 BSC          |      |      |       |
| E      | 5.00 BSC          |      |      |       |
| E1     | 4.75 BSC          |      |      |       |
| θ      | 0°                | —    | 12°  |       |
| P      | 0                 | —    | 0.60 |       |
| D2     | 1.25              | —    | 3.25 |       |
| E2     | 1.25              | —    | 3.25 |       |

| SYMBOL | PITCH VARIATION B |      |      | NOTES | SYMBOL | PITCH VARIATION B |      |      | NOTES | SYMBOL | PITCH VARIATION C |      |      | NOTES | SYMBOL | PITCH VARIATION D |      |      | NOTES |
|--------|-------------------|------|------|-------|--------|-------------------|------|------|-------|--------|-------------------|------|------|-------|--------|-------------------|------|------|-------|
|        | MIN.              | NOM. | MAX. |       |        | MIN.              | NOM. | MAX. |       |        | MIN.              | NOM. | MAX. |       |        | MIN.              | NOM. | MAX. |       |
| Ⓔ      | 0.80 BSC          |      |      |       | Ⓔ      | 0.65 BSC          |      |      |       | Ⓔ      | 0.50 BSC          |      |      |       | Ⓔ      | 0.50 BSC          |      |      |       |
| N      | 16                |      |      | 3     | N      | 20                |      |      | 3     | N      | 28                |      |      | 3     | N      | 32                |      |      | 3     |
| Nd     | 4                 |      |      | 3     | Nd     | 5                 |      |      | 3     | Nd     | 7                 |      |      | 3     | Nd     | 8                 |      |      | 3     |
| Ne     | 4                 |      |      | 3     | Ne     | 5                 |      |      | 3     | Ne     | 7                 |      |      | 3     | Ne     | 8                 |      |      | 3     |
| L      | 0.35              | 0.55 | 0.75 |       | L      | 0.35              | 0.55 | 0.75 |       | L      | 0.35              | 0.55 | 0.75 |       | L      | 0.30              | 0.40 | 0.50 |       |
| b      | 0.28              | 0.33 | 0.40 | 4     | b      | 0.23              | 0.28 | 0.35 | 4     | b      | 0.18              | 0.23 | 0.30 | 4     | b      | 0.18              | 0.23 | 0.30 | 4     |

|                                                                                       |                                 |          |     |
|---------------------------------------------------------------------------------------|---------------------------------|----------|-----|
|  |                                 |          |     |
| PROPRIETARY INFORMATION                                                               |                                 |          |     |
| TITLE:<br>PACKAGE OUTLINE, 16,20,28,32L QFN, 5x5x0.90 MM                              |                                 |          |     |
| APPROVAL                                                                              | DOCUMENT CONTROL NO.<br>21-0091 | REV<br>G | 2/2 |

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