



# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

MAX6427-MAX6438

## General Description

The MAX6427-MAX6438 are single/dual-level battery monitors with internal hysteresis. These devices are offered with single (MAX6427/MAX6428/MAX6429, MAX6433/MAX6434/MAX6435) or dual (MAX6430/MAX6431/MAX6432, MAX6436/MAX6437/MAX6438) low-battery output indicators, which can be used to indicate three battery conditions: battery is good (operate system in normal mode), battery is weak (operate system in low-power mode), or battery is empty (disable the system).

These devices are ideal for monitoring single lithium-ion (Li+) cells or multicell alkaline/NiCd/NiMH power supplies. When the power-supply voltage drops below the specified low threshold, the low-battery output asserts. When the voltage rises above the specified high threshold, the low-battery output is deasserted following a 140ms minimum timeout period. The timeout period ensures that the supply voltages have stabilized before power-converter or micro-processor activity is enabled.

The MAX6427-MAX6438 family is available with several monitoring options. The MAX6427/MAX6428/MAX6429 offer factory-trimmed battery-monitor thresholds, with a single low-battery output. The MAX6430/MAX6431/MAX6432 also feature factory-trimmed thresholds, but have two low-battery outputs.

The MAX6433-MAX6438 have user-adjustable threshold voltages permitting the user to select the hysteresis range, and consequently the sensitivity of the system to noise. A wide hysteresis range also prevents chattering that can result due to battery recovery after load removal. Single low-battery outputs are supplied by the MAX6433/MAX6434/MAX6435 and dual low-battery outputs by the MAX6436/MAX6437/MAX6438.

The MAX6427-MAX6438 family is available with three output logic options for convenient interface with system power circuitry or microprocessors. The family is offered in small SOT23 and SOT143 packages and is fully specified over temperature.

## Applications

Battery-Powered Systems (Single-Cell Li+ or Two/Three-Cell NiMH, NiCd, Alkaline)

|                             |             |
|-----------------------------|-------------|
| Cell Phones/Cordless Phones | Pagers      |
| Portable Medical Devices    | PDA's       |
| Electronic Toys             | MP3 Players |

*Typical Operating Circuit appears at end of data sheet.*

## Features

- ◆ **Factory-Trimmed or User-Adjustable Threshold Options**
  - Factory-Trimmed Low Thresholds from 1.6V to 2.1V or 2.6V to 3.1V in 100mV Increments (MAX6427-MAX6432)**
  - Factory-Trimmed High Thresholds from 2.3V to 2.6V or 3.3V to 3.6V in 100mV Increments (MAX6427-MAX6432)**
  - User-Adjustable Low/High Thresholds with 615mV Internal Reference (MAX6433-MAX6438)**
- ◆ **Low Current (1µA, typ)**
- ◆ **Single or Dual Low-Battery Outputs**
- ◆ **Push-Pull LBO, Open-Drain LBO, and Open-Drain LBO Options**
- ◆ **140ms Minimum LBO Timeout Period**
- ◆ **Immune to Short Battery Voltage Transients**
- ◆ **Guaranteed Valid LBO Logic State to BATT = 1.0V**
- ◆ **-40°C to +85°C Operating Temperature Range**
- ◆ **Small 3, 4, 5 and 6-Pin SOT Packages**
- ◆ **No External Components Required (MAX6427-MAX6432)**

## Ordering Information

| PART           | TEMP RANGE     | PIN-PACKAGE |
|----------------|----------------|-------------|
| MAX6427 __UR-T | -40°C to +85°C | 3 SOT23-3   |

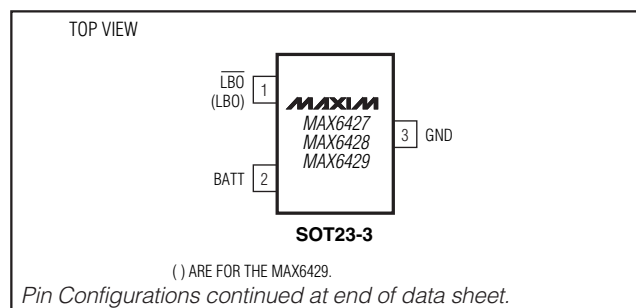
*Ordering Information continued at end of data sheet.*

<sup>†</sup>The MAX6427-MAX6432 are available with factory-trimmed battery-monitor thresholds. Select the desired thresholds using Tables 1 or 2 and enter the corresponding letters in the part number by replacing “\_\_”.

Devices are available in both leaded and lead-free packaging. Specify lead-free by replacing “-T” with “+T” when ordering.

**Note:** There are 26 standard versions with a required order minimum of 2500 pieces. Sample stock is generally held on the standard versions only (see Standard Versions Table). Required order increment is 10,000 pieces for nonstandard versions. Contact factory for availability. All devices available in tape-and-reel only.

## Pin Configurations



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## ABSOLUTE MAXIMUM RATINGS

BATT, V<sub>DD</sub> to GND .....-0.3V to +6.0V  
 HTHIN, LTHIN Inputs to GND.....-0.3V to (V<sub>DD</sub> + 0.3V)  
 Open-Drain L<sub>BO</sub>/LBO, L<sub>BOH</sub>/LBOH,  
 L<sub>BOL</sub>/LBOL to GND .....-0.3V to +6.0V  
 Push-Pull L<sub>BO</sub>/LBO, L<sub>BOH</sub>/LBOH,  
 L<sub>BOL</sub>/LBOL to GND .....-0.3V to (BATT or V<sub>DD</sub> + 0.3V)  
 Input Current (all pins) .....20mA  
 Output Current (all pins) .....20mA

Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
 3-Pin SOT23-3 (derate 4.0mW/°C above +70°C) .....320mW  
 4-Pin SOT143-4 (derate 4.0mW/°C above +70°C) .....320mW  
 5-Pin SOT23-5 (derate 7.1mW/°C above +70°C) .....571mW  
 6-Pin SOT23-6 (derate 8.7mW/°C above +70°C) .....696mW  
 Operating Temperature Range .....-40°C to +85°C  
 Junction Temperature .....+150°C  
 Storage Temperature Range .....-65°C to +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

(BATT = 1.0V to 5.5V or V<sub>DD</sub> = 1.6V to 5.5V, T<sub>A</sub> = -40°C to +85°C, unless otherwise specified. Typical values are at T<sub>A</sub> = +25°C.)  
 (Note 1)

| PARAMETER                                         | SYMBOL            | CONDITIONS                                                                                                                  | MIN  | TYP | MAX  | UNITS |
|---------------------------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------|------|-----|------|-------|
| Operating Voltage Range                           | V <sub>BATT</sub> | T <sub>A</sub> = -40°C to +85°C                                                                                             | 1.2  |     | 5.5  | V     |
|                                                   |                   | T <sub>A</sub> = 0°C to +70°C                                                                                               | 1.0  |     | 5.5  |       |
| Operating Voltage Range                           | V <sub>DD</sub>   | T <sub>A</sub> = -40°C to +85°C                                                                                             | 1.6  |     | 5.5  | V     |
| BATT Supply Current                               | I <sub>BATT</sub> | V <sub>BATT</sub> = 3.7V, no load (MAX6427-MAX6432)                                                                         |      | 1   | 1.5  | μA    |
| V <sub>DD</sub> Supply Current                    | I <sub>DD</sub>   | V <sub>DD</sub> = 3.7V, no load<br>(MAX6433-MAX6438)                                                                        |      | 1   | 1.5  | μA    |
| <b>FACTORY-FIXED THRESHOLDS (MAX6427-MAX6432)</b> |                   |                                                                                                                             |      |     |      |       |
| HTH Threshold<br>(Note 2)                         | V <sub>HTH</sub>  | Factory-fixed options, BATT rising,<br>LBO deasserted when BATT rises above<br>V <sub>HTH</sub> (MAX6427/MAX6428/MAX6429)   | -2.5 |     | +2.5 | %     |
| LTH Threshold<br>(Note 2)                         | V <sub>LTH</sub>  | Factory-fixed options, BATT falling,<br>LBO asserted when BATT falls below V <sub>LTH</sub><br>(MAX6427/MAX6428/MAX6429)    | -2.5 |     | +2.5 | %     |
| HTH- Threshold<br>(Note 2)                        | V <sub>HTH-</sub> | Factory-fixed options, BATT falling, LBOH<br>asserted when BATT falls below V <sub>HTH-</sub><br>(MAX6430/MAX6431/MAX6432)  | -2.5 |     | +2.5 | %     |
| HTH+ Threshold<br>(Note 3)                        | V <sub>HTH+</sub> | Factory-fixed options, BATT rising,<br>LBOH deasserted when BATT rises above<br>V <sub>HTH+</sub> (MAX6430/MAX6431/MAX6432) | -2.5 |     | +2.5 | %     |
| LTH- Threshold<br>(Note 2)                        | V <sub>LTH-</sub> | Factory-fixed options, BATT falling,<br>LBOL asserted when BATT falls below V <sub>LTH-</sub><br>(MAX6430/MAX6431/MAX6432)  | -2.5 |     | +2.5 | %     |
| LTH+ Threshold<br>(Note 3)                        | V <sub>LTH+</sub> | Factory-fixed options, BATT rising,<br>LBOL deasserted when BATT rises above<br>V <sub>LTH+</sub> (MAX6430/MAX6431/MAX6432) | -2.5 |     | +2.5 | %     |

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MAX6427-MAX6438

## ELECTRICAL CHARACTERISTICS (continued)

(BATT = 1.0V to 5.5V or V<sub>DD</sub> = 1.6V to 5.5V, T<sub>A</sub> = -40°C to +85°C, unless otherwise specified. Typical values are at T<sub>A</sub> = +25°C.)  
(Note 1)

| PARAMETER                                           | SYMBOL              | CONDITIONS                                                                                                                                                         | MIN  | TYP | MAX  | UNITS |
|-----------------------------------------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|------|-------|
| <b>USER-ADJUSTABLE THRESHOLDS (MAX6433-MAX6438)</b> |                     |                                                                                                                                                                    |      |     |      |       |
| HTHIN Threshold<br>(Note 4)                         | V <sub>HTHIN</sub>  | User-adjustable options, HTHIN rising,<br>LBO is deasserted when HTHIN rises above<br>V <sub>HTHIN-</sub> , V <sub>REF</sub> = 615mV<br>(MAX6433/MAX6434/MAX6435)  | -2.5 |     | +2.5 | %     |
| LTHIN Threshold<br>(Note 4)                         | V <sub>LTHIN</sub>  | User-adjustable options, LTHIN falling,<br>LBOH is asserted when LTHIN falls below<br>V <sub>LTHIN-</sub> , V <sub>REF</sub> = 615mV<br>(MAX6433/MAX6434/MAX6435)  | -2.5 |     | +2.5 | %     |
| HTHIN+ Threshold<br>(Note 4)                        | V <sub>HTHIN+</sub> | User-adjustable options, HTHIN rising,<br>LBOH is deasserted when HTHIN rises<br>above V <sub>HTHIN+</sub> , V <sub>REF</sub> = 615mV<br>(MAX6436/MAX6437/MAX6438) | -2.5 |     | +2.5 | %     |
| HTHIN- Threshold<br>(Note 5)                        | V <sub>HTHIN-</sub> | User-adjustable options, HTHIN falling,<br>LBOH is asserted when HTHIN falls below<br>V <sub>HTHIN-</sub> , V <sub>REF</sub> = 585mV<br>(MAX6436/MAX6437/MAX6438)  | -2.5 |     | +2.5 | %     |
| LTHIN+ Threshold<br>(Note 4)                        | V <sub>LTHIN+</sub> | User-adjustable options, LTHIN rising,<br>LBOL is deasserted when LTHIN rises<br>above V <sub>LTHIN+</sub> , V <sub>REF</sub> = 615mV<br>(MAX6436/MAX6437/MAX6438) | -2.5 |     | +2.5 | %     |
| LTHIN- Threshold<br>(Note 5)                        | V <sub>LTHIN-</sub> | User-adjustable options, LTHIN falling,<br>LBOL is asserted when LTHIN falls below<br>V <sub>LTHIN-</sub> , V <sub>REF</sub> = 585mV<br>(MAX6436/MAX6437/MAX6438)  | -2.5 |     | +2.5 | %     |
| HTHIN/LTHIN Leakage Current<br>(Note 6)             | I <sub>LKG</sub>    | V <sub>HTHIN</sub> or V <sub>LTHIN</sub> > 400mV                                                                                                                   |      |     | 20   | nA    |

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## ELECTRICAL CHARACTERISTICS (continued)

(BATT = 1.0V to 5.5V or V<sub>DD</sub> = 1.6V to 5.5V, T<sub>A</sub> = -40°C to +85°C, unless otherwise specified. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                                                                                                                                                   | SYMBOL            | CONDITIONS                                                                | MIN                       | TYP | MAX | UNITS |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|---------------------------------------------------------------------------|---------------------------|-----|-----|-------|
| <b>LOW-BATTERY OUTPUTS (<math>\overline{\text{LBO}}</math>, LBO, <math>\overline{\text{LBOH}}</math>, LBOH, <math>\overline{\text{LBOL}}</math>, LBOL )</b> |                   |                                                                           |                           |     |     |       |
| Timeout Period                                                                                                                                              | t <sub>LBOP</sub> | BATT or V <sub>DD</sub> /HTHIN/LTHIN rising above threshold               | 140                       | 210 | 280 | ms    |
| Delay                                                                                                                                                       | t <sub>LBOD</sub> | BATT or V <sub>DD</sub> /HTHIN/LTHIN falling below threshold              |                           | 100 |     | μs    |
| $\overline{\text{LBO}}$ / $\overline{\text{LBOL}}$ / $\overline{\text{LBOH}}$ Output LOW (Push-Pull or Open-Drain)                                          | V <sub>OL</sub>   | BATT or V <sub>DD</sub> ≥ 1.6V, I <sub>SINK</sub> = 100μA, asserted low   |                           |     | 0.3 | V     |
|                                                                                                                                                             |                   | BATT or V <sub>DD</sub> ≥ 2.7V, I <sub>SINK</sub> = 1.2mA, asserted low   |                           |     | 0.3 |       |
|                                                                                                                                                             |                   | BATT or V <sub>DD</sub> ≥ 4.5V, I <sub>SINK</sub> = 3.2mA, asserted low   |                           |     | 0.4 |       |
| $\overline{\text{LBO}}$ Output HIGH (Push-Pull Only) (Note 7)                                                                                               | V <sub>OH</sub>   | BATT or V <sub>DD</sub> ≥ 1.6V, I <sub>SOURCE</sub> = 200μA, deasserted   | 0.8 × V <sub>SUPPLY</sub> |     |     | V     |
|                                                                                                                                                             |                   | BATT or V <sub>DD</sub> ≥ 2.7V, I <sub>SOURCE</sub> = 500μA, deasserted   | 0.8 × V <sub>SUPPLY</sub> |     |     |       |
|                                                                                                                                                             |                   | BATT or V <sub>DD</sub> ≥ 4.5V, I <sub>SOURCE</sub> = 800μA, deasserted   | 0.8 × V <sub>SUPPLY</sub> |     |     |       |
| $\overline{\text{LBO}}$ Output Leakage Current (Open-Drain Only)                                                                                            | I <sub>LKG</sub>  | $\overline{\text{LBO}}$ deasserted                                        |                           |     | 500 | nA    |
| LBO/LBOL/LBOH Output LOW (Open-Drain Only)                                                                                                                  | V <sub>OL</sub>   | BATT or V <sub>DD</sub> ≥ 1.6V, I <sub>SINK</sub> = 100μA, deasserted low |                           |     | 0.3 | V     |
|                                                                                                                                                             |                   | BATT or V <sub>DD</sub> ≥ 2.7V, I <sub>SINK</sub> = 1.2mA, deasserted low |                           |     | 0.3 |       |
|                                                                                                                                                             |                   | BATT or V <sub>DD</sub> ≥ 4.5V, I <sub>SINK</sub> = 3.2mA, deasserted low |                           |     | 0.4 |       |
| LBO Output Leakage Current (Open-Drain Only)                                                                                                                | I <sub>LKG</sub>  | LBO asserted                                                              |                           |     | 500 | nA    |

**Note 1:** Production testing done at T<sub>A</sub> = +25°C, limits over temperature guaranteed by design only.

**Note 2:** Percentage of selected factory-fixed HTH- or LTH- threshold voltage.

**Note 3:** Percentage of 1.05 × (selected factory-fixed threshold voltage).

**Note 4:** Percentage of 615mV voltage reference.

**Note 5:** Percentage of 585mV voltage reference.

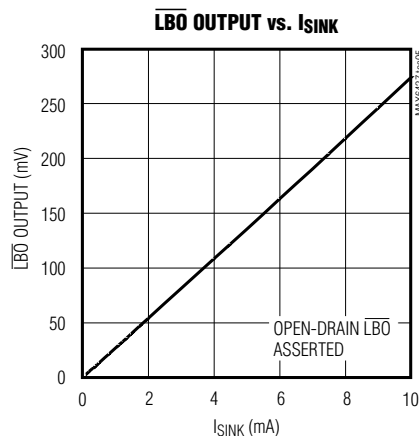
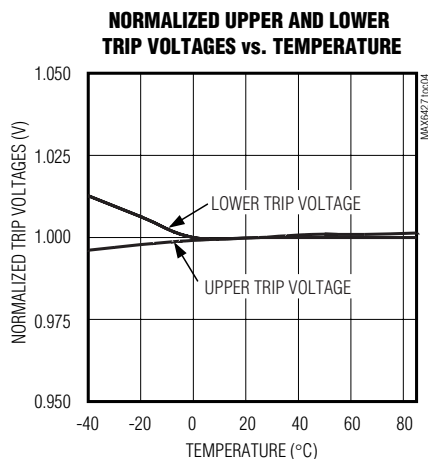
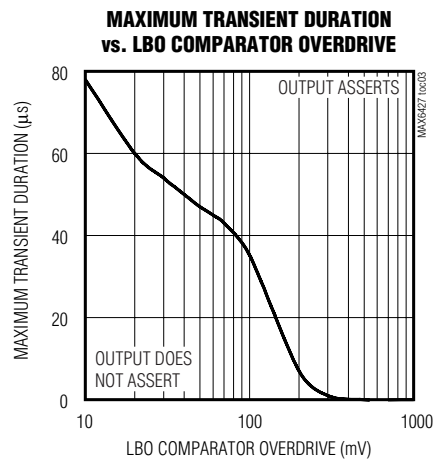
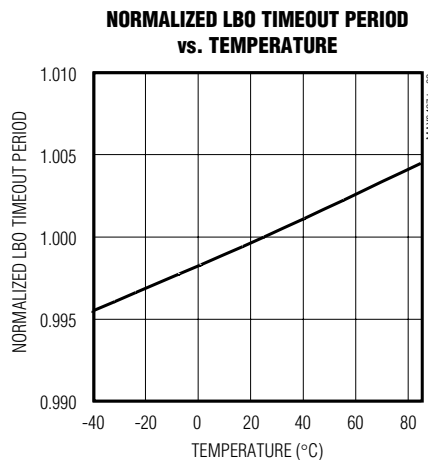
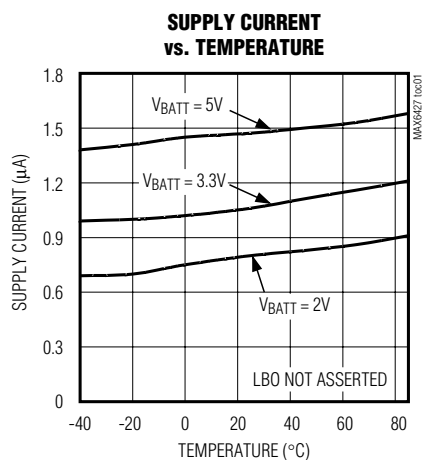
**Note 6:** Guaranteed by design.

**Note 7:** V<sub>SUPPLY</sub> is BATT or V<sub>DD</sub>.

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## Typical Operating Characteristics

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



# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## Pin Description

| PIN                             |                                 |                                 |                                 | NAME                               | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX6427/<br>MAX6428/<br>MAX6429 | MAX6430/<br>MAX6431/<br>MAX6432 | MAX6433/<br>MAX6434/<br>MAX6435 | MAX6436/<br>MAX6437/<br>MAX6438 |                                    |                                                                                                                                                                                                                                                                                                                                                                                          |
| 1                               | —                               | 4                               | —                               | $\overline{\text{LBO}}$ /<br>LBO   | Low-Battery Output. $\overline{\text{LBO}}$ /LBO is asserted when BATT drops below $V_{\text{LTH}}$ (MAX6427/MAX6428/MAX6429) or when LTHIN (MAX6433/MAX6434/MAX6435) drops below $V_{\text{LTHIN}}$ , and remains asserted for at least 140ms after BATT exceeds $V_{\text{HTH}}$ (MAX6427/MAX6428/MAX6429) or $V_{\text{HTHIN}}$ (MAX6433/MAX6434/MAX6435).                            |
| 2                               | 3                               | —                               | —                               | BATT                               | Battery-Voltage Input. Input for battery-voltage threshold monitors and device power supply for factory-trimmed threshold versions.                                                                                                                                                                                                                                                      |
| 3                               | 1                               | 2                               | 2                               | GND                                | Ground                                                                                                                                                                                                                                                                                                                                                                                   |
| —                               | 2                               | —                               | 5                               | $\overline{\text{LBOH}}$ /<br>LBOH | Low-Battery Output High. $\overline{\text{LBOH}}$ /LBOH is asserted when BATT drops below $V_{\text{HTH-}}$ (MAX6430/MAX6431/MAX6432) or when HTHIN drops below $V_{\text{HTHIN-}}$ (MAX6436/MAX6437/MAX6438). It remains asserted for at least 140ms after BATT exceeds $V_{\text{HTH+}}$ (MAX6430/MAX6431/MAX6432) or HTHIN rises above $V_{\text{HTHIN+}}$ (MAX6436/MAX6437/MAX6438). |
| —                               | 4                               | —                               | 4                               | $\overline{\text{LBOL}}$ /<br>LBOL | Low-Battery Output Low. $\overline{\text{LBOL}}$ /LBOL is asserted when BATT drops below $V_{\text{LTH-}}$ (MAX6430/MAX6431/MAX6432) or when LTHIN drops below $V_{\text{LTHIN-}}$ (MAX6436/MAX6437/MAX6438). It remains asserted for at least 140ms after BATT exceeds $V_{\text{LTH+}}$ (MAX6430/MAX6431/MAX6432) or LTHIN rises above $V_{\text{LTHIN+}}$ (MAX6436/MAX6437/MAX6438).  |
| —                               | —                               | 1                               | 1                               | HTHIN                              | HTH Threshold Monitor Input. A resistor-divider network sets the high threshold associated with $\overline{\text{LBOH}}$ /LBOH.                                                                                                                                                                                                                                                          |
| —                               | —                               | 3                               | 3                               | LTHIN                              | LTH Threshold Monitor Input. A resistor-divider network sets the low threshold associated with $\overline{\text{LBOL}}$ /LBOL.                                                                                                                                                                                                                                                           |
| —                               | —                               | 5                               | 6                               | $V_{\text{DD}}$                    | $V_{\text{DD}}$ Supply Voltage Input. Device power supply for adjustable threshold versions.                                                                                                                                                                                                                                                                                             |

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## Detailed Description

The MAX6427-MAX6438 family is available with several monitoring options. The MAX6427/MAX6428/MAX6429 offer factory-trimmed battery-monitor thresholds, with a single low-battery output (see Figure 1). The MAX6430/MAX6431/MAX6432 also feature factory-trimmed thresholds, but have two low-battery outputs (see Figure 2). The factory-trimmed thresholds of the MAX6427-MAX6432 eliminate the requirement for external components.

The user sets the threshold voltages for the MAX6433-MAX6438, which permit the user to select the hysteresis range, and consequently the sensitivity of the system to noise. A wide hysteresis range prevents chattering that can result during battery recovery or load removal. The MAX6433/MAX6434/MAX6435 have single low-battery outputs and the MAX6436/MAX6437/MAX6438 have dual low-battery outputs (see Figures 3 and 4).

The MAX6427-MAX6438 combine a 615mV reference with two comparators, logic, and timing circuitry to provide the user with information about the charge state of the power-supply batteries. The MAX6427-MAX6438 monitor separate high-voltage and low-voltage thresholds to determine battery status. The output(s) can be used to signal when the battery is charged, when the battery is low, and when the battery is empty. Factory-

trimmed thresholds are ideal for monitoring single-cell Li+ or multicell alkaline/NiCd/NiMH power supplies. User-programmable versions are also available with thresholds determined using an external resistor-divider (see *Resistor-Value Selection*). The adjustable versions can monitor down to 0.62V, making them suitable for monitoring single-cell alkaline, NiMH, and NiCd applications ( $V_{DD} \geq 1.6V$ ).

When the power-supply voltage drops below the specified low threshold, the low-battery output asserts (see *Low-Battery Output*). When the voltage rises above the specified high threshold following a 140ms (min) time-out period, the low-battery output is deasserted (see *Threshold Monitoring*). This ensures the supply voltage has stabilized before power-converter or microprocessor activity is enabled.

## Low-Battery Output

The low-battery outputs are available in active-low ( $\overline{LBO}$ ,  $\overline{LBOH}$ ,  $\overline{LBOL}$ , push-pull and open-drain) and active-high ( $LBO$ ,  $LBOH$ ,  $LBOH$ , open-drain) configurations. Push-pull outputs are referenced to BATT (for factory-trimmed versions) or  $V_{DD}$  (for adjustable threshold versions).

The open-drain devices can be pulled to a voltage independent of  $V_{DD}$  or BATT, up to 5.5V. This allows the

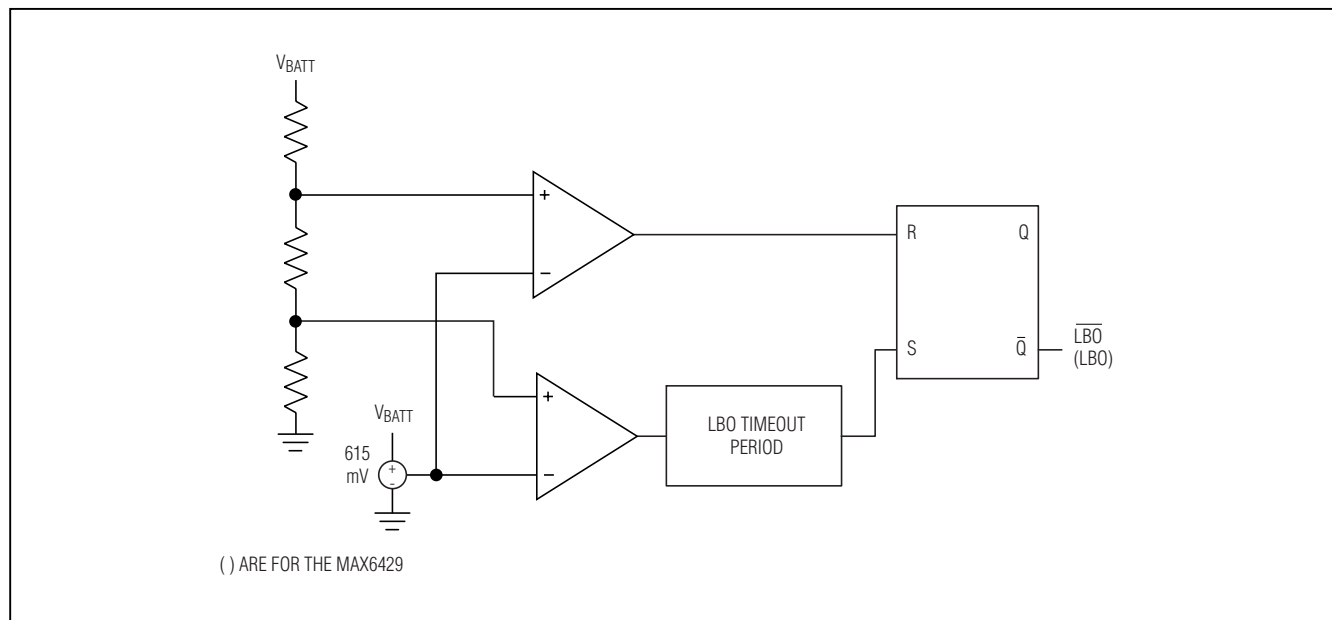


Figure 1. MAX6427/MAX6428/MAX6429 Functional Diagram

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis



Figure 2. MAX6430/MAX6431/MAX6432 Functional Diagram

device to monitor and operate from direct battery voltage while interfacing to higher voltage microprocessors.

The MAX6427/MAX6428/MAX6429/MAX6433/MAX6434/MAX6435 single-output voltage monitors provide a single low-battery output, LBO/LBO. The MAX6427/MAX6428/MAX6429 fixed-threshold parts assert LBO/LBO when BATT drops below  $V_{LTH}$ . The MAX6433/MAX6434/MAX6435 adjustable-threshold parts assert LBO/LBO when the LTHIN input drops below the  $V_{LTHIN}$  threshold (615mV) (see Figure 5).

The MAX6430/MAX6431/MAX6432/MAX6436/MAX6437/MAX6438 dual-output voltage monitors provide two low-battery outputs, LBOH/LBOH and LBOL/LBOL. The MAX6430/MAX6431/MAX6432 fixed-threshold parts assert LBOH/LBOH when BATT drops below  $V_{HTH-}$ , and assert LBOL/LBOL when BATT drops below  $V_{LTH-}$ . The MAX6436/MAX6437/MAX6438 adjustable-threshold parts assert LBOH/LBOH when HTHIN drops below  $V_{HTHIN-}$ , and assert LBOL/LBOL when LTHIN drops below  $V_{LTHIN-}$  (see Figure 6).

## Threshold Monitoring

The MAX6433-MAX6438 HTHIN and LTHIN inputs are high-impedance inputs to comparators. An external resistor-divider network is required between the monitored voltage, HTHIN, LTHIN, and GND to select the desired thresholds (see *Resistor-Value Selection*). The MAX6433/MAX6434/MAX6435 single-output voltage monitors assert LBO/LBO when LTHIN drops below the internal LTHIN reference (615mV). LBO/LBO is deasserted when HTHIN rises above the internal HTHIN reference level (615mV) for at least 140ms (see Figure 6).

The MAX6436/MAX6437/MAX6438 dual-output voltage monitors assert LBOL/LBOL when LTHIN drops below the LTHIN- threshold and deassert LBOL/LBOL when LTHIN rises above the LTHIN+ threshold for at least 140ms. LBOH/LBOH is asserted when HTHIN drops below the HTHIN- threshold and is deasserted when HTHIN rises above the HTHIN+ threshold for at least 140ms (see Figure 7).

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis



Figure 3. MAX6433/MAX6434/MAX6435 Functional Diagram

## Hysteresis

Hysteresis increases the comparator's noise margin by increasing the upper threshold or decreasing the lower threshold (see Figure 8). The hysteresis prevents the output from oscillating (chattering) when BATT or  $V_{DD}$  is near the low-battery threshold. This is especially important for applications where the load on the battery creates significant fluctuations in battery voltages.

### Fixed Hysteresis (MAX6427–MAX6432)

The MAX6427/MAX6428/MAX6429 total hysteresis is the difference between the factory-trimmed  $V_{LTH}$  and  $V_{HTH}$ . For the MAX6430/MAX6431/MAX6432, the total hysteresis is the difference between the factory-trimmed  $V_{HTH-}$  and  $V_{HTH+}$  or  $V_{LTH-}$  and  $V_{LTH+}$  values, approximately 5%.

### Adjustable Hysteresis (MAX6433–MAX6438)

Figure 7 shows the correct connections for the external resistor-dividers. To adjust the low-battery threshold and hysteresis connect resistor R1 between  $V_{DD}$  and LTHIN, resistor R2 between LTHIN and HTHIN, and R3 between HTHIN and GND. The hysteresis for the MAX6433–MAX6438 is determined by an external resistor-divider network (see *Resistor-Value Selection* section of Applications Information). The hysteresis for the MAX6436/MAX6437/MAX6438 is the differences between  $V_{HTH-}$  and  $V_{HTH+}$  (~5%) or  $V_{LTH-}$  and  $V_{LTH+}$  (~5%).

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

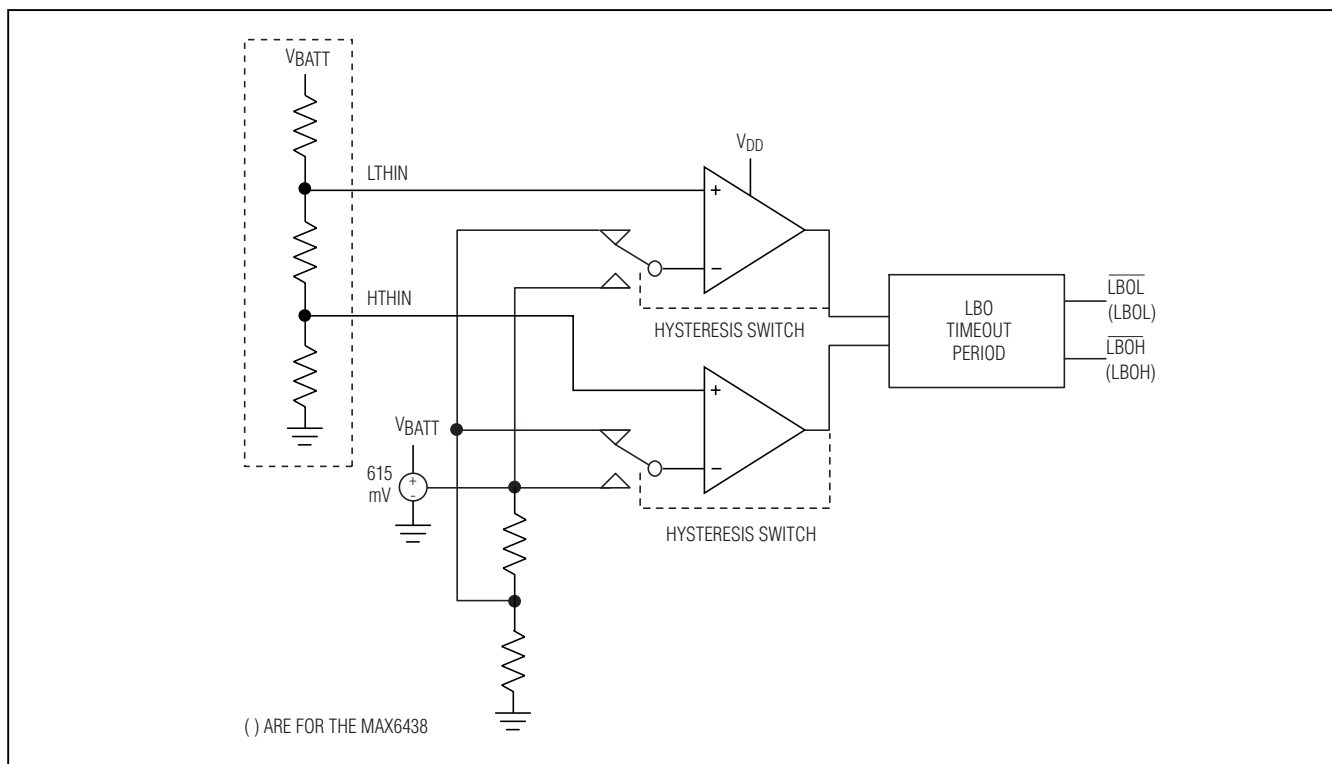


Figure 4. MAX6436/MAX6437/MAX6438 Functional Diagram

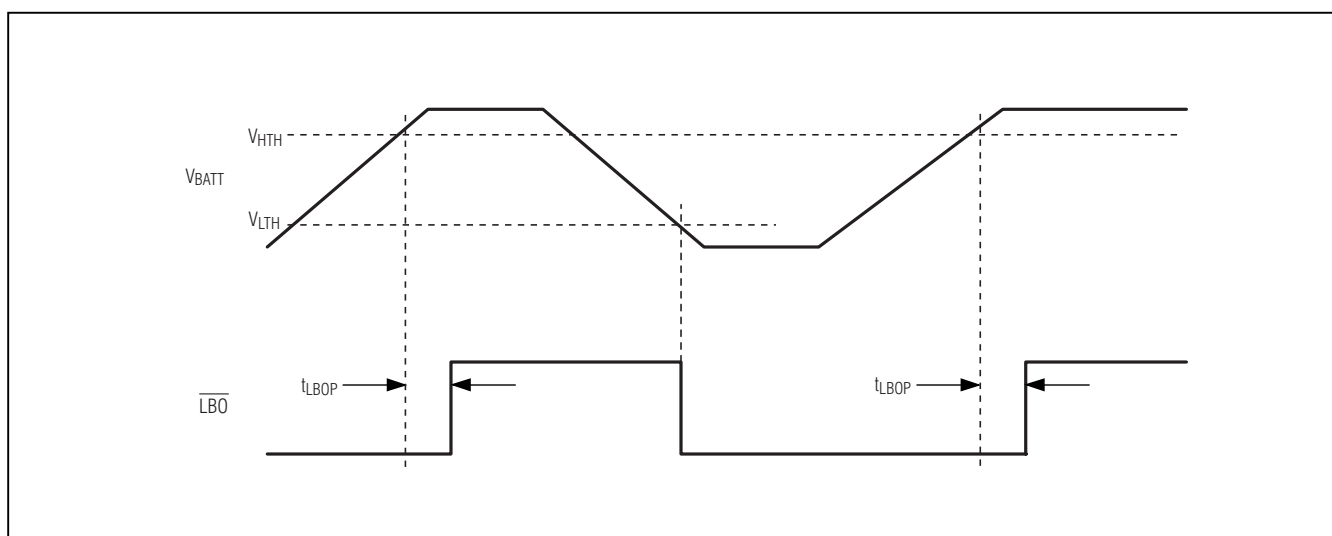


Figure 5. Single Low-Battery Output Timing

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

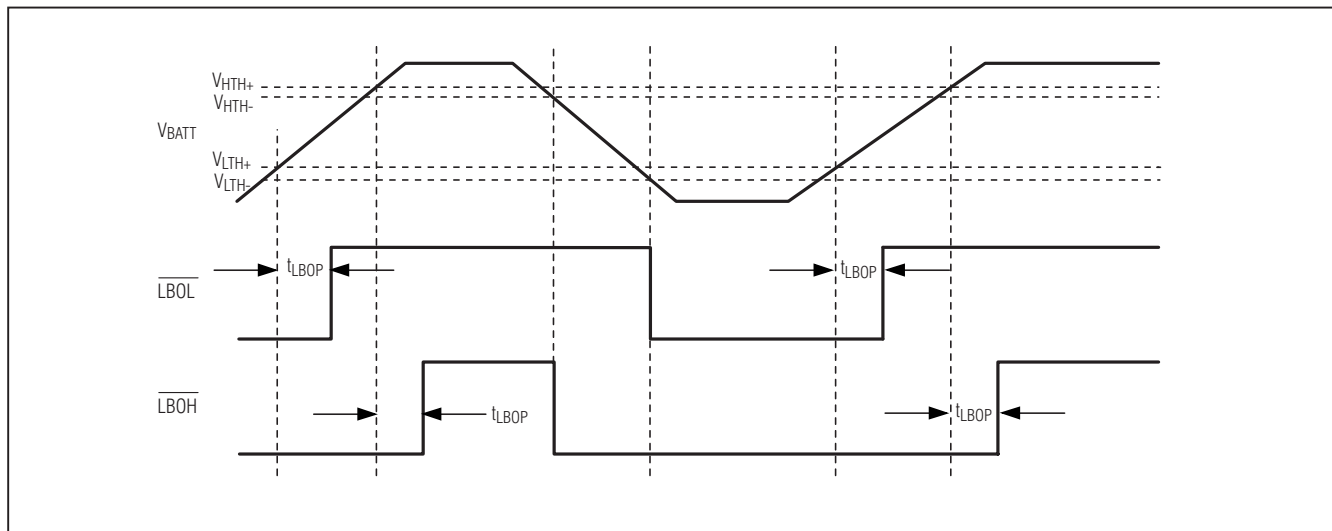


Figure 6. Dual Low-Battery Output Timing



Figure 7. Adjustable Threshold Selection



Figure 8. Hysteresis

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## Applications Information

### Resistor-Value Selection (Programming the Adjustable Thresholds)

#### MAX6433/MAX6434/MAX6435

(See Figure 5)

$$V_{REF} = V_{LTHIN} = V_{HTHIN} = 615\text{mV}$$

$$V_{TRIPLOW} = V_{LTH} = V_{REF} \left( \frac{R1 + R2 + R3}{R2 + R3} \right)$$

$$V_{TRIPHIGH} = V_{HTL} = V_{REF} \left( \frac{R1 + R2 + R3}{R3} \right)$$

$$R_{TOTAL} = R1 + R2 + R3$$

Use the following steps to determine values for R1, R2, and R3 of Figure 8.

- 1) Choose a value for  $R_{TOTAL}$ , the sum of R1, R2, and R3. Because the MAX6433/MAX6434/MAX6435 have very high input impedances,  $R_{TOTAL}$  can be up to  $5\text{M}\Omega$ .
- 2) Calculate R3 based on  $R_{TOTAL}$  and the desired upper trip point:

$$R3 = \frac{V_{REF} \times R_{TOTAL}}{V_{TRIPHIGH}} = \frac{585\text{mV} \times R_{TOTAL}}{V_{TRIPHIGH}}$$

- 3) Calculate R2 based on  $R_{TOTAL}$ , R3, and the desired lower trip point:

$$R2 = \frac{615\text{mV} \times R_{TOTAL}}{V_{TRIPLOW}} - R3$$

- 4) Calculate R1 based on  $R_{TOTAL}$ , R3, and R2:

$$R1 = R_{TOTAL} - R2 - R3$$

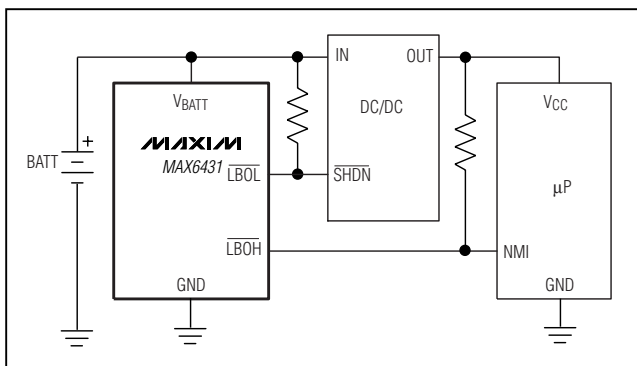


Figure 9. DC-to-DC Converter Application

#### MAX6436/MAX6437/MAX6438

(See Figure 6)

$$V_{REF} = V_{LTHIN-} = V_{HTHIN-} = 585\text{mV}$$

$\overline{\text{LBOL}}$  /LBOL OUTPUT:

$$V_{TRIPLOW} = V_{LTH-} = V_{REF} \left( \frac{R1 + R2 + R3}{R2 + R3} \right)$$

$\overline{\text{LBOH}}$  /LBOH OUTPUT:

$$V_{TRIPHIGH} = V_{HTL-} = V_{REF} \left( \frac{R1 + R2 + R3}{R3} \right)$$

$$R_{TOTAL} = R1 + R2 + R3$$

Use the following steps to determine values for R1, R2, and R3 of Figure 8.

- 1) Choose a value for  $R_{TOTAL}$ , the sum of R1, R2, and R3. Because the MAX6436/MAX6437/MAX6438 have very high input impedances,  $R_{TOTAL}$  can be up to  $5\text{M}\Omega$ .
- 2) Calculate R3 based on  $R_{TOTAL}$  and the desired upper trip point:

$$R3 = \frac{V_{REF} \times R_{TOTAL}}{V_{TRIPHIGH}} = \frac{585\text{mV} \times R_{TOTAL}}{V_{TRIPHIGH}}$$

- 3) Calculate R2 based on  $R_{TOTAL}$ , R3, and the desired lower trip point:

$$\frac{585\text{mV} \times R_{TOTAL}}{V_{TRIPLOW}} - R3$$

- 4) Calculate R1 based on  $R_{TOTAL}$ , R3, and R2:

$$R1 = R_{TOTAL} - R2 - R3$$

$$V_{HTH+} = V_{HTH-} \times 1.05, V_{LTH+} = V_{LTH-} \times 1.05$$

### DC-to-DC Converter Application

The MAX6430/MAX6431/MAX6432 and MAX6436/MAX6437/MAX6438 dual-output battery monitors can be used in conjunction with a step-up DC-to-DC converter to power 5V microprocessor systems using a single Li+ cell or two to three alkaline/NiCd/NiMH cells (Figure 9). The  $\overline{\text{LBOH}}$  output indicates that the battery voltage is weak, and is used to warn the microprocessor of potential problems. Armed with this information the microprocessor can reduce system power consumption. The  $\overline{\text{LBOL}}$  output indicates the battery is empty, and system power should be disabled. By connecting  $\overline{\text{LBOL}}$  to the SHDN pin of the DC-to-DC converter, power to the microprocessor is removed.

## Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

Microprocessor power will not return until the battery has recharged to a voltage greater than HTH+ (Figure 6).

### Li+ Battery Charger Application

The MAX6430/MAX6431/MAX6432 and MAX6436/MAX6437/MAX6438 dual-output battery monitors can be used in conjunction with a battery charger to provide a system with additional information about the battery charge state (Figure 10). Many battery chargers, such as the MAX1879, provide the user with a CHG output, which tells the system that the battery is charged. The MAX6430/MAX6431/MAX6432 and MAX6436/MAX6437/MAX6438 dual-output battery mon-

itors provide two outputs, which can be used to relay the battery condition to the system. This information is useful in determining which system resources can be powered by the battery at the current charge state.



Figure 10. Lithium-Ion Cell Charger Application (using MAX1879)

### Typical Operating Circuit



# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## Ordering Information (continued)

| PART          | TEMP RANGE     | PIN-PACKAGE |
|---------------|----------------|-------------|
| MAX6428__UR-T | -40°C to +85°C | 3 SOT23-3   |
| MAX6429__UR-T | -40°C to +85°C | 3 SOT23-3   |
| MAX6430__US-T | -40°C to +85°C | 4 SOT143-4  |
| MAX6431__US-T | -40°C to +85°C | 4 SOT143-4  |
| MAX6432__US-T | -40°C to +85°C | 4 SOT143-4  |
| MAX6433UK-T   | -40°C to +85°C | 5 SOT23-5   |
| MAX6434UK-T   | -40°C to +85°C | 5 SOT23-5   |
| MAX6435UK-T   | -40°C to +85°C | 5 SOT23-5   |
| MAX6436UT-T   | -40°C to +85°C | 6 SOT23-6   |
| MAX6437UT-T   | -40°C to +85°C | 6 SOT23-6   |
| MAX6438UT-T   | -40°C to +85°C | 6 SOT23-6   |

†The MAX6427-MAX6432 are available with factory-trimmed battery-monitor thresholds. Select the desired thresholds using Tables 1 or 2 and enter the corresponding letters in the part number by replacing “\_\_”.

Devices are available in both leaded and lead-free packaging. Specify lead-free by replacing “-T” with “+T” when ordering.

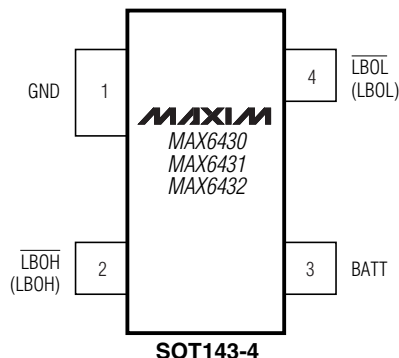
**Note:** There are 26 standard versions with a required order minimum of 2500 pieces. Sample stock is generally held on the standard versions only (see Standard Versions Table). Required order increment is 10,000 pieces for nonstandard versions. Contact factory for availability. All devices available in tape-and-reel only.

## Chip Information

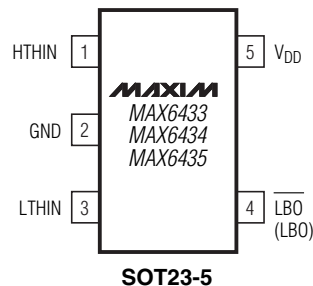
TRANSISTOR COUNT: 905

PROCESS TECHNOLOGY: BiCMOS

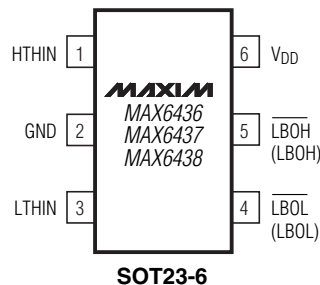
## Pin Configurations (continued)



( ) ARE FOR THE MAX6432



( ) ARE FOR THE MAX6435



( ) ARE FOR THE MAX6438

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

**Table 1. Factory-Trimmed Lower and Upper Threshold Combinations for Single-Cell Li+ or Three-Cell Alkaline/NiCd/NiMH Applications (MAX6427–MAX6432)**

| LOWER THRESHOLD<br>(LTH/LTH-) | VOLTAGES | UPPER THRESHOLD (HTH/HTH-) |      |      |      |
|-------------------------------|----------|----------------------------|------|------|------|
|                               |          | 3.3V                       | 3.4V | 3.5V | 3.6V |
|                               | 2.6V     | AG                         | AH   | AI   | AJ   |
|                               | 2.7V     | BG                         | BH   | BI   | BJ   |
|                               | 2.8V     | CG                         | CH   | CI   | CJ   |
|                               | 2.9V     | DG                         | DH   | DI   | DJ   |
|                               | 3.0V     | EG                         | EH   | EI   | EJ   |
|                               | 3.1V     | FG                         | FH   | FI   | FJ   |

**Table 2. Factory-Trimmed Lower and Upper Threshold Combinations for Two-Cell Alkaline/NiCd/NiMH Applications (MAX6427–MAX6432)**

| LOWER THRESHOLD<br>(LTH/LTH-) | VOLTAGES | UPPER THRESHOLD (HTH/HTH-) |      |      |      |
|-------------------------------|----------|----------------------------|------|------|------|
|                               |          | 2.3V                       | 2.4V | 2.5V | 2.6V |
|                               | 1.6V     | KQ                         | KR   | KS   | KT   |
|                               | 1.7V     | LQ                         | LR   | LS   | LT   |
|                               | 1.8V     | MQ                         | MR   | MS   | MT   |
|                               | 1.9V     | NQ                         | NR   | NS   | NT   |
|                               | 2.0V     | OQ                         | OR   | OS   | OT   |
|                               | 2.1V     | PQ                         | PR   | PS   | PT   |

## Standard Versions

| PART      | TOP MARK |
|-----------|----------|
| MAX6427DH | FZKZ     |
| MAX6427EH | FZLA     |
| MAX6427EI | FZLB     |
| MAX6427MR | FZLF     |
| MAX6427OR | FZLG     |
| MAX6428DH | FZLC     |
| MAX6428EH | FZLD     |
| MAX6428EI | FZLE     |
| MAX6428MR | FZLH     |
| MAX6428OR | FZLI     |
| MAX6430DH | KAEP     |
| MAX6430EH | KAEQ     |
| MAX6430EI | KAER     |

| PART      | TOP MARK |
|-----------|----------|
| MAX6430MR | KAEL     |
| MAX6430OR | KAEM     |
| MAX6431DH | KAES     |
| MAX6431EH | KAET     |
| MAX6431EI | KAEU     |
| MAX6431MR | KAEN     |
| MAX6431OR | KAEO     |
| MAX6433UK | ADVH     |
| MAX6434UK | ADVI     |
| MAX6435UK | ADVJ     |
| MAX6436UT | ABAB     |
| MAX6437UT | ABAC     |
| MAX6438UT | ABAD     |

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## Selector Guide

| PART    | FACTORY-FIXED THRESHOLDS | USER-ADJUSTABLE THRESHOLDS | ACTIVE-LOW PUSH-PULL OUTPUT | ACTIVE-LOW OPEN-DRAIN OUTPUT | ACTIVE-HIGH OPEN-DRAIN OUTPUT | SINGLE OUTPUT | DUAL OUTPUT |
|---------|--------------------------|----------------------------|-----------------------------|------------------------------|-------------------------------|---------------|-------------|
| MAX6427 | ✓                        | —                          | ✓                           | —                            | —                             | ✓             | —           |
| MAX6428 | ✓                        | —                          | —                           | ✓                            | —                             | ✓             | —           |
| MAX6429 | ✓                        | —                          | —                           | —                            | ✓                             | ✓             | —           |
| MAX6430 | ✓                        | —                          | ✓                           | —                            | —                             | —             | ✓           |
| MAX6431 | ✓                        | —                          | —                           | ✓                            | —                             | —             | ✓           |
| MAX6432 | ✓                        | —                          | —                           | —                            | ✓                             | —             | ✓           |
| MAX6433 | —                        | ✓                          | ✓                           | —                            | —                             | ✓             | —           |
| MAX6434 | —                        | ✓                          | —                           | ✓                            | —                             | ✓             | —           |
| MAX6435 | —                        | ✓                          | —                           | —                            | ✓                             | ✓             | —           |
| MAX6436 | —                        | ✓                          | ✓                           | —                            | —                             | —             | ✓           |
| MAX6437 | —                        | ✓                          | —                           | ✓                            | —                             | —             | ✓           |
| MAX6438 | —                        | ✓                          | —                           | —                            | ✓                             | —             | ✓           |

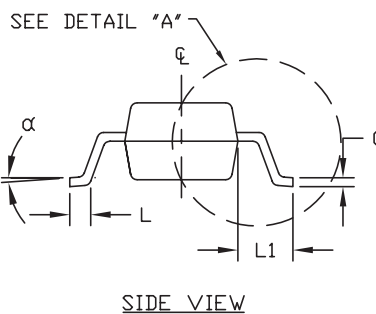
# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## 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).)

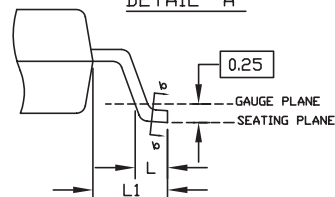
### NOTES:

1. D&E DO NOT INCLUDE MOLD FLASH.
  2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006").
  3. CONTROLLING DIMENSION: MILLIMETERS.
  4. REFERENCE JEDEC TD236-VARIATION AB.
  5. LEADS TO BE COPLANAR WITHIN 0.10mm.
- △ DIMENSIONS MEASURED AT FLAT SECTION OF LEAD BETWEEN 0.08mm AND 0.15mm FROM LEAD TIP.



| DIM | INCHES |       | MILLIMETERS |       |
|-----|--------|-------|-------------|-------|
|     | MIN    | MAX   | MIN         | MAX   |
| A   | 0.035  | 0.044 | 0.890       | 1.120 |
| A1  | 0.001  | 0.004 | 0.013       | 0.100 |
| B   | 0.015  | 0.020 | 0.370       | 0.500 |
| b1  | 0.012  | 0.018 | 0.300       | 0.450 |
| c   | 0.003  | 0.071 | 0.085       | 0.180 |
| c1  | 0.003  | 0.071 | 0.080       | 0.160 |
| D   | 0.110  | 0.120 | 2.800       | 3.040 |
| E   | 0.047  | 0.055 | 1.200       | 1.400 |
| e   | 0.037  | BSC.  | 0.950       | BSC.  |
| e1  | 0.075  | BSC.  | 1.900       | BSC.  |
| H   | 0.083  | 0.104 | 2.100       | 2.640 |
| L   | 0.015  | 0.023 | 0.400       | 0.600 |
| L1  | 0.021  | REF   | 0.54        | REF   |
| S   | 0.018  | 0.024 | 0.45        | 0.60  |
| α   | 0°     | 8°    | 0°          | 8°    |

DETAIL "A"



|                                                                                                                      |                                 |                                                                                       |     |
|----------------------------------------------------------------------------------------------------------------------|---------------------------------|---------------------------------------------------------------------------------------|-----|
|  <b>DALLAS</b><br>SEMICONDUCTOR |                                 |  |     |
| PROPRIETARY INFORMATION                                                                                              |                                 |                                                                                       |     |
| TITLE:<br>PACKAGE OUTLINE, 3L SOT-23                                                                                 |                                 |                                                                                       |     |
| APPROVAL                                                                                                             | DOCUMENT CONTROL NO.<br>21-0051 | REV.<br>F                                                                             | 1/1 |

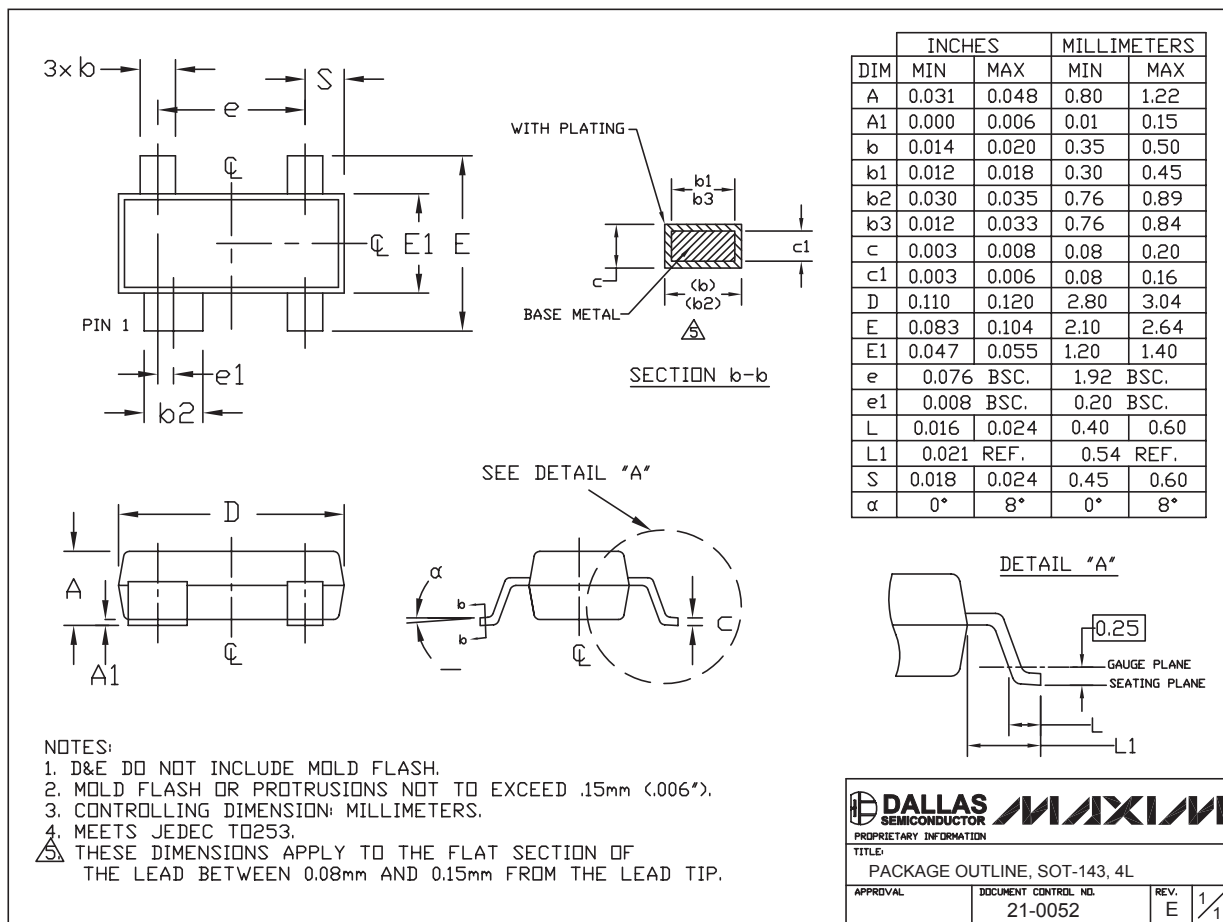
SOT23 LEPS

MAX6427-MAX6438

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## 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).)



SOT-143 4L EPS

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## 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).)



SOT-23 5L, EPS

MAX6427-MAX6438

# Low-Power, Single/Dual-Level Battery Monitors with Hysteresis

## 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).)



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