



# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## General Description

The MAX4373/MAX4374/MAX4375 low-cost, micropower, high-side current-sense supervisors contain a high-side current-sense amplifier, bandgap reference, and comparator with latching output. They feature a voltage output that eliminates the need for gain-setting resistors, making them ideal for today's notebook computers, cell phones, and other systems where battery/DC current monitoring is critical. High-side current monitoring is especially useful in battery-powered systems since it does not interfere with the ground path of the battery charger. The 0 to +28V input common-mode range is independent of the supply voltage, which ensures that the current-sense feedback remains viable even when connected to a battery pack in deep discharge.

The comparator output of the MAX4373/MAX4374/MAX4375 is latched to provide a turn-off flag that doesn't oscillate. In addition, the MAX4374/MAX4375 contain a second comparator for use in window-detection functions. The MAX4373/MAX4374/MAX4375 are available in three different gain versions (T = +20V/V, F = +50V/V, H = +100V/V) and use an external sense resistor to set the sensitivity of the input voltage to the load current. These features offer a high level of integration, resulting in a simple and compact current-sense solution.

The MAX4373/MAX4374/MAX4375 operate from a single +2.7V to +28V supply and consume 50 $\mu$ A. They are specified for the extended operating temperature range (-40°C to +85°C) and are available in 8-pin and 10-pin  $\mu$ MAX packages.

## Applications

Notebook Computers  
 Portable/Battery-Powered Systems  
 Smart Battery Packs/Chargers  
 Cell Phones  
 Power-Management Systems  
 General-System/Board-Level Current Monitoring  
 Precision Current Sources

Pin Configurations appear at end of data sheet.

## Features

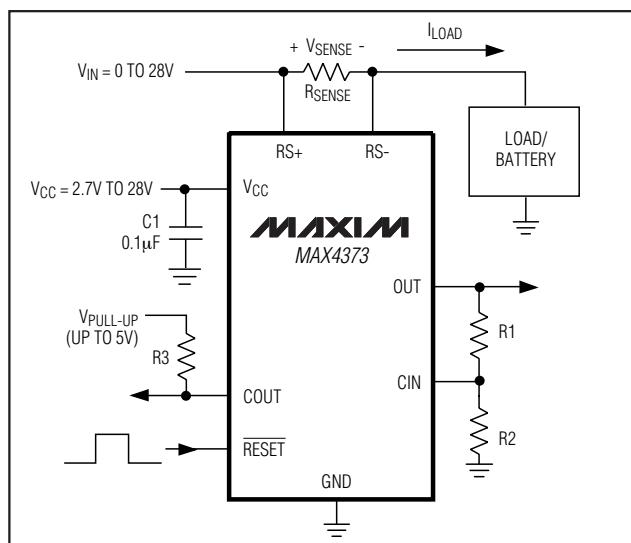
- ◆ Current-Sense Amplifier plus Internal Comparator and Bandgap Reference with Improved Accuracy
- ◆ 50 $\mu$ A Supply Current
- ◆ Single +2.7V to +28V Operating Supply
- ◆ 1mV (max) Input Offset Voltage
- ◆ 2% (max) Full-Scale Accuracy
- ◆ Internal Bandgap Reference ( $\pm 1.6\%$  Accuracy)
- ◆ Latching Comparator Output
- ◆ Three Gain Versions Available (+20V/V, +50V/V, +100V/V)
- ◆ Wide 0 to +28V Common-Mode Range, Independent of Supply Voltage

## Ordering Information

| PART        | TEMP RANGE     | PIN-PACKAGE | GAIN (V/V) |
|-------------|----------------|-------------|------------|
| MAX4373TEUA | -40°C to +85°C | 8 $\mu$ MAX | +20        |
| MAX4373TESA | -40°C to +85°C | 8 SO        | +20        |
| MAX4373FEUA | -40°C to +85°C | 8 $\mu$ MAX | +50        |
| MAX4373FESA | -40°C to +85°C | 8 SO        | +50        |
| MAX4373HEUA | -40°C to +85°C | 8 $\mu$ MAX | +100       |
| MAX4373HESA | -40°C to +85°C | 8 SO        | +100       |

Ordering Information continued at end of data sheet.

## Typical Operating Circuit



## ***Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs***

## ABSOLUTE MAXIMUM RATINGS

|                                                                         |                                                            |
|-------------------------------------------------------------------------|------------------------------------------------------------|
| V <sub>CC</sub> , RS+, RS- to GND .....                                 | -0.3V to +30V                                              |
| OUT to GND .....                                                        | -0.3V to the lesser of<br>(V <sub>CC</sub> + 0.3V) or +15V |
| CIN1, CIN2, RESET to GND .....                                          | -0.3V to the lesser of<br>(V <sub>CC</sub> + 0.3V) or +12V |
| Differential Input Voltage (V <sub>RS+</sub> - V <sub>RS-</sub> ) ..... | ±0.3V                                                      |
| COUT1, COUT2 to GND .....                                               | -0.3V to +6.0V                                             |
| Current into Any Pin .....                                              | ±10mA                                                      |

|                                                       |                 |
|-------------------------------------------------------|-----------------|
| Continuous Power Dissipation (T <sub>A</sub> = +70°C) |                 |
| 8-Pin $\mu$ MAX (derate 4.1mW/°C above +70°C) .....   | 330mW           |
| 8-Pin SO (derate 5.9mW/°C above +70°C) .....          | 471mW           |
| 10-Pin $\mu$ MAX (derate 5.6mW/°C above +70°C) .....  | 444mW           |
| 14-Pin SO (derate 8.3mW/°C above +70°C) .....         | 667mW           |
| 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

(V<sub>CC</sub> = +2.7V to +28V, V<sub>RS+</sub> = 0 to +28V, V<sub>SENSE</sub> = 0, V<sub>RESET</sub> = 0, R<sub>LOAD</sub> = 1MΩ, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                         | SYMBOL                              | CONDITIONS                                                                          |                                                       | MIN                                                   | TYP   | MAX  | UNITS |   |
|-----------------------------------|-------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------|------|-------|---|
| Operating Voltage Range (Note 2)  | V <sub>CC</sub>                     |                                                                                     |                                                       | 2.7                                                   |       | 28   | V     |   |
| Common-Mode Input Range (Note 3)  | V <sub>CMR</sub>                    |                                                                                     |                                                       | 0                                                     |       | 28   | V     |   |
| Common-Mode Rejection             | CMR                                 | V <sub>RS+</sub> > 2V                                                               |                                                       | 85                                                    |       |      | dB    |   |
| Supply Current                    | I <sub>CC</sub>                     | V <sub>RS+</sub> > 2V, V <sub>SENSE</sub> = 5mV                                     |                                                       | 50                                                    |       | 100  | μA    |   |
| Leakage Current                   | I <sub>RS+</sub> , I <sub>RS-</sub> | V <sub>CC</sub> = 0                                                                 |                                                       | ±0.015                                                |       | ±0.5 | μA    |   |
| Input Bias Current                | I <sub>RS+</sub>                    | V <sub>RS+</sub> > 2V                                                               |                                                       | 0                                                     |       | 2.5  | μA    |   |
|                                   |                                     | V <sub>RS+</sub> ≤ 2V                                                               |                                                       | -25                                                   |       | 2.0  |       |   |
|                                   | I <sub>RS-</sub>                    | V <sub>RS+</sub> > 2V                                                               |                                                       | 0                                                     |       | 4    |       |   |
|                                   |                                     | V <sub>RS+</sub> ≤ 2V                                                               |                                                       | -50                                                   |       | 4    |       |   |
| Full-Scale Sense Voltage (Note 4) | V <sub>SENSE</sub>                  | Gain = +20V/V, +50V/V                                                               |                                                       | 150                                                   | 170   |      | mV    |   |
|                                   |                                     | Gain = +100V/V                                                                      |                                                       | 100                                                   | 120   |      |       |   |
| Input Offset Voltage              | V <sub>OS</sub>                     | V <sub>CC</sub> = V <sub>RS+</sub> = 12V (Note 11)                                  | T <sub>A</sub> = +25°C                                | 0.1                                                   |       | 1    | mV    |   |
|                                   |                                     |                                                                                     | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | 2                                                     |       |      |       |   |
| Total OUT Voltage Error (Note 5)  | V <sub>OUT</sub>                    | V <sub>SENSE</sub> = 100mV (Note 6)                                                 | V <sub>CC</sub> = 12V, V <sub>RS+</sub> = 12V         | T <sub>A</sub> = +25°C                                | ±0.30 |      | ±2    | % |
|                                   |                                     |                                                                                     |                                                       | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | ±3    |      |       |   |
|                                   |                                     |                                                                                     | V <sub>CC</sub> = 28V, V <sub>RS+</sub> = 28V         | T <sub>A</sub> = +25°C                                | ±0.35 |      | ±2    |   |
|                                   |                                     |                                                                                     |                                                       | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | ±3    |      |       |   |
|                                   |                                     |                                                                                     | V <sub>CC</sub> = 12V, V <sub>RS+</sub> = 0.1V        |                                                       | ±5.0  |      |       |   |
|                                   |                                     | V <sub>SENSE</sub> = 6.25mV, V <sub>CC</sub> = 12V, V <sub>RS+</sub> = 12V (Note 7) |                                                       | ±5.0                                                  |       |      |       |   |
| OUT Voltage Low                   | V <sub>OUT</sub>                    | V <sub>CC</sub> = 2.7V                                                              | I <sub>OUT</sub> = 10μA                               | 2.5                                                   |       |      | mV    |   |
|                                   |                                     |                                                                                     | I <sub>OUT</sub> = 100μA                              | 8.5                                                   |       | 65   |       |   |
| OUT Voltage High                  | V <sub>CC</sub> - V <sub>OH</sub>   | V <sub>CC</sub> = 2.7V, I <sub>OUT</sub> = -500μA                                   |                                                       |                                                       |       | 0.25 | V     |   |

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

MAX4373/MAX4374/MAX4375

## ELECTRICAL CHARACTERISTICS (continued)

(V<sub>CC</sub> = +2.7V to +28V, V<sub>RS+</sub> = 0 to +28V, V<sub>SENSE</sub> = 0, V<sub>RESET</sub> = 0, R<sub>LOAD</sub> = 1M $\Omega$ , T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER                                 | SYMBOL           | CONDITIONS                                                                                                |                                               | MIN  | TYP  | MAX | UNITS |
|-------------------------------------------|------------------|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------|------|------|-----|-------|
| -3dB Bandwidth                            | BW               | V <sub>RS+</sub> = 12V,<br>V <sub>CC</sub> = 12V,<br>C <sub>LOAD</sub> = 10pF                             | V <sub>SENSE</sub> = 100mV,<br>Gain = +20V/V  | 200  |      | kHz |       |
|                                           |                  |                                                                                                           | V <sub>SENSE</sub> = 100mV,<br>Gain = +50V/V  | 120  |      |     |       |
|                                           |                  |                                                                                                           | V <sub>SENSE</sub> = 100mV,<br>Gain = +100V/V | 110  |      |     |       |
|                                           |                  |                                                                                                           | V <sub>SENSE</sub> = 6.25mV                   | 50   |      |     |       |
| Gain                                      | A <sub>V</sub>   | MAX437_T                                                                                                  |                                               | +20  |      | V/V |       |
|                                           |                  | MAX437_F                                                                                                  |                                               | +50  |      |     |       |
|                                           |                  | MAX437_H                                                                                                  |                                               | +100 |      |     |       |
| Gain Accuracy                             | ΔA <sub>V</sub>  | V <sub>SENSE</sub> =<br>20mV to 150mV;<br>V <sub>CC</sub> = 12V; V <sub>RS+</sub> =<br>12V; Gain = 20, 50 | T <sub>A</sub> = +25°C                        | ±0.3 | ±1.7 | %   |       |
|                                           |                  |                                                                                                           | T <sub>A</sub> = -40°C to +85°C               | ±2.7 |      |     |       |
|                                           |                  | V <sub>SENSE</sub> =<br>20mV to 100mV,<br>V <sub>CC</sub> = 12V, V <sub>RS+</sub> =<br>12V, Gain = 100    | T <sub>A</sub> = +25°C                        | ±0.3 | ±1.7 |     |       |
|                                           |                  |                                                                                                           | T <sub>A</sub> = -40°C to +85°C               | ±2.7 |      |     |       |
| OUT Settling Time to 1% of<br>Final Value |                  | Gain = +20V/V,<br>V <sub>CC</sub> = 12V,<br>V <sub>RS+</sub> = 12V,<br>C <sub>LOAD</sub> = 10pF           | V <sub>SENSE</sub> = 6.25mV to<br>100mV       | 20   |      | μs  |       |
|                                           |                  |                                                                                                           | V <sub>SENSE</sub> = 100mV to<br>6.25mV       | 20   |      |     |       |
| Capacitive Load Stability                 |                  | No sustained oscillations                                                                                 |                                               | 1000 |      | pF  |       |
| OUT Output Resistance                     | R <sub>OUT</sub> | V <sub>SENSE</sub> = 100mV                                                                                |                                               | 1.5  |      | Ω   |       |
| Power-Supply Rejection                    | PSR              | V <sub>OUT</sub> = 2V, V <sub>RS+</sub> > 2V                                                              |                                               | 72   | 87   | dB  |       |
| Power-Up Time to 1% of Final<br>Value     |                  | V <sub>SENSE</sub> = 100mV, C <sub>LOAD</sub> = 10pF,<br>V <sub>CC</sub> = 12V, V <sub>RS+</sub> = 12V    |                                               | 0.5  |      | ms  |       |
| Saturation Recovery Time<br>(Note 8)      |                  | V <sub>CC</sub> = 12V, V <sub>RS+</sub> = 12V, C <sub>LOAD</sub> = 10pF                                   |                                               | 0.1  |      | ms  |       |
| COMPARATOR (Note 9)                       |                  |                                                                                                           |                                               |      |      |     |       |
| Comparator Threshold                      | V <sub>TH</sub>  | T <sub>A</sub> = +25°C                                                                                    |                                               | 590  | 600  | 610 | mV    |
|                                           |                  | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                     |                                               | 586  | 614  |     |       |
| Comparator Hysteresis                     |                  |                                                                                                           |                                               | -9   |      | mV  |       |
| Input Bias Current                        | I <sub>B</sub>   |                                                                                                           |                                               | ±2.2 | ±15  | nA  |       |
| Propagation Delay                         |                  | C <sub>L</sub> = 10pF, R <sub>L</sub> = 10kΩ pull-up to 5V,<br>5mV of overdrive                           |                                               | 4    |      | μs  |       |
| Output Low Voltage                        | V <sub>OL</sub>  | I <sub>SINK</sub> = 1mA                                                                                   |                                               | 0.6  |      | V   |       |

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +2.7V$  to  $+28V$ ,  $V_{RS+} = 0$  to  $+28V$ ,  $V_{SENSE} = 0$ ,  $V_{RESET} = 0$ ,  $R_{LOAD} = 1M\Omega$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                              | SYMBOL              | CONDITIONS                                      | MIN  | TYP | MAX | UNITS   |
|----------------------------------------|---------------------|-------------------------------------------------|------|-----|-----|---------|
| Output High Leakage Current            |                     | $V_{CC} = 28V$ , $V_{PULL-UP} = 5V$ (Note 10)   |      |     | 1   | $\mu A$ |
| $\overline{RESET}$ Input High Voltage  | $V_{IH}$            |                                                 | 2.0  |     |     | V       |
| $\overline{RESET}$ Input Low Voltage   | $V_{IL}$            |                                                 |      |     | 0.8 | V       |
| Logic Input Current                    | $I_{IL}$ , $I_{IH}$ | $V_{IL} = 0$ , $V_{IH} = 5.5V$ , $V_{CC} = 28V$ | -0.5 |     | 0.5 | $\mu A$ |
| Minimum $\overline{RESET}$ Pulse Width | $t_{RPW}$           |                                                 |      | 1.5 |     | $\mu s$ |
| $\overline{RESET}$ Propagation Delay   | $t_{RPD}$           |                                                 |      | 3   |     | $\mu s$ |

**Note 1:** All devices are 100% production tested at  $T_A = +25^\circ C$ . All temperature limits are guaranteed by design.

**Note 2:** Guaranteed by PSR test.

**Note 3:** Guaranteed by OUT Voltage Error test.

**Note 4:** Guaranteed by Gain Accuracy test. Output voltage is internally clamped not to exceed 12V.

**Note 5:** Total OUT Voltage Error and Full-Scale Accuracy are the sum of gain and offset voltage errors.

**Note 6:** Measured at  $I_{OUT} = -500\mu A$  ( $R_{LOAD} = 4k\Omega$  for gain of  $+20V/V$ ,  $R_{LOAD} = 10k\Omega$  for gain of  $+50V/V$ ,  $R_{LOAD} = 20k\Omega$  for gain of  $+100V/V$ ).

**Note 7:**  $+6.25mV = 1/16$  of  $+100mV$  full-scale voltage.

**Note 8:** The device will not experience phase reversal when overdriven.

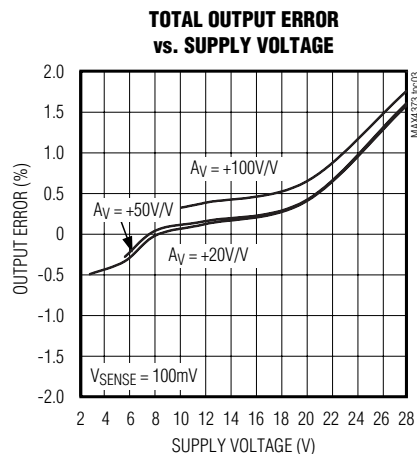
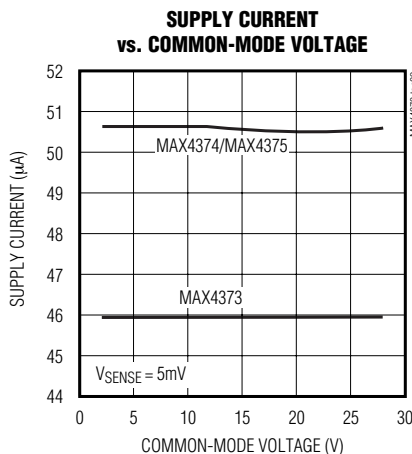
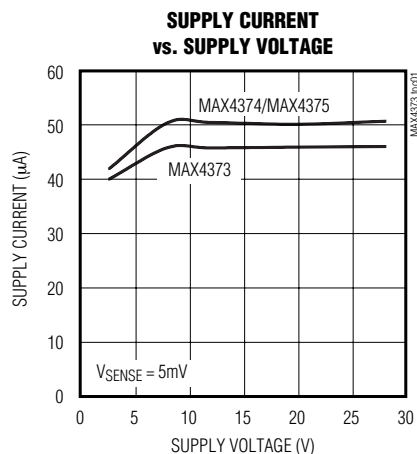
**Note 9:** All comparator tests are done with  $V_{RS+} = +12V$ .

**Note 10:**  $V_{PULL-UP}$  is defined as an externally applied voltage through a resistor to pull up the comparator output.

**Note 11:**  $V_{OS}$  is extrapolated from the gain accuracy test.

## Typical Operating Characteristics

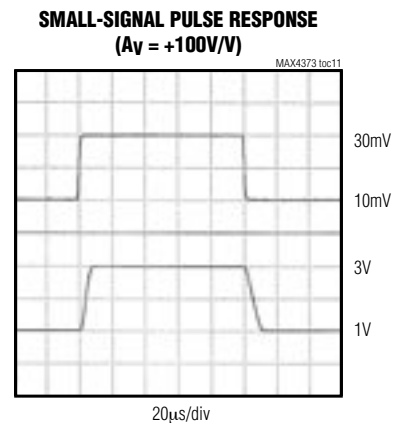
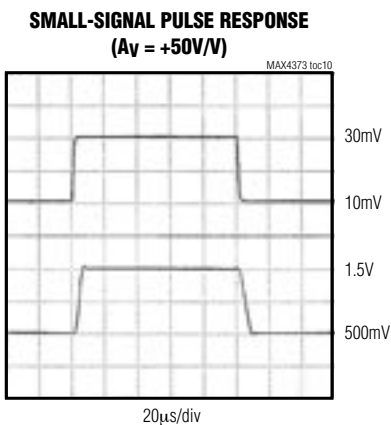
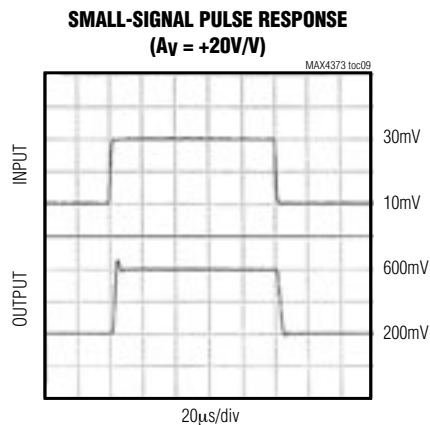
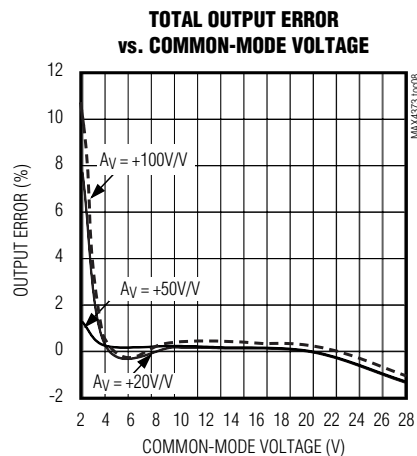
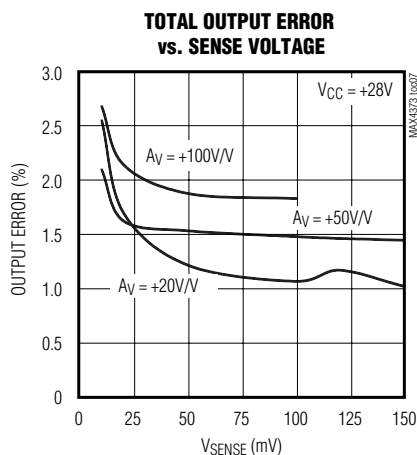
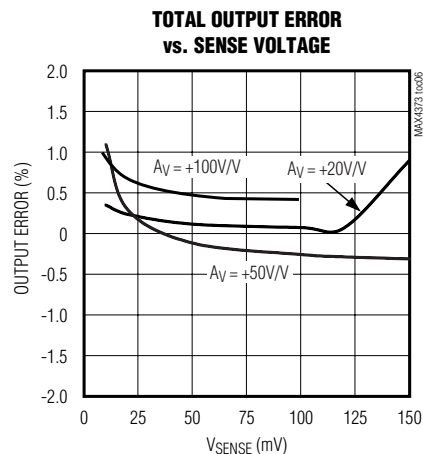
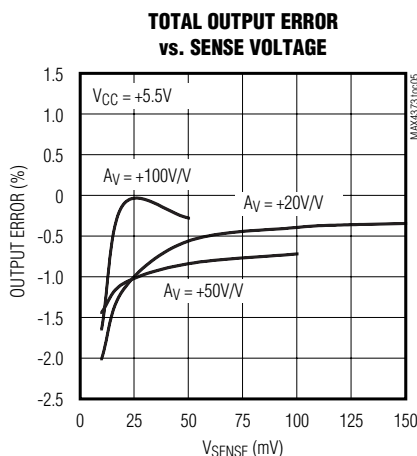
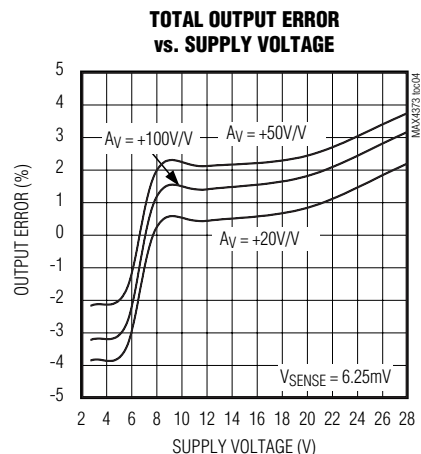
( $V_{RS+} = +12V$ ,  $V_{CC} = +12V$ ,  $R_{LOAD} = 1M\Omega$ ,  $V_{RESET} = 0$ ,  $V_{SENSE} = 100mV$ ,  $V_{PULL-UP} = +5V$ ,  $R_{PULL-UP} = 10k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## Typical Operating Characteristics (continued)

( $V_{RS+} = +12V$ ,  $V_{CC} = +12V$ ,  $R_{LOAD} = 1M\Omega$ ,  $V_{RESET} = 0$ ,  $V_{SENSE} = 100mV$ ,  $V_{PULL-UP} = +5V$ ,  $R_{PULL-UP} = 10k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

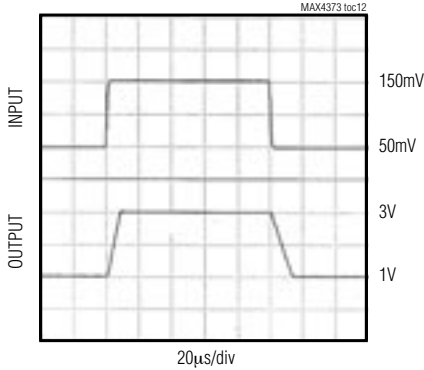


# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

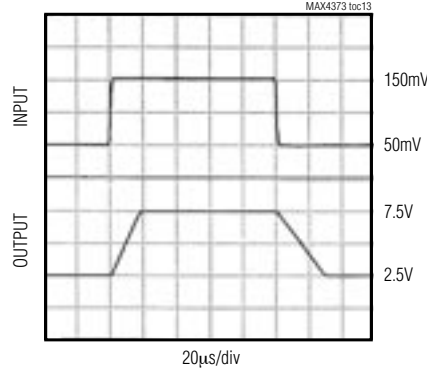
## Typical Operating Characteristics (continued)

( $V_{RS+} = +12V$ ,  $V_{CC} = +12V$ ,  $R_{LOAD} = 1M\Omega$ ,  $V_{RESET} = 0$ ,  $V_{SENSE} = 100mV$ ,  $V_{PULL-UP} = +5V$ ,  $R_{PULL-UP} = 10k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

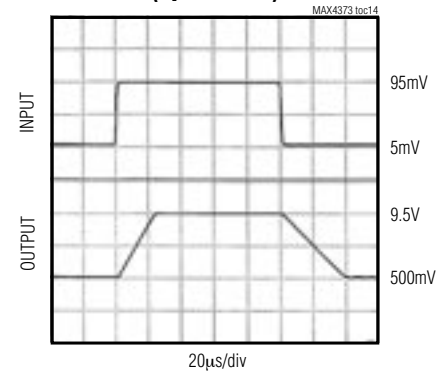
**LARGE-SIGNAL PULSE RESPONSE**  
( $A_V = +20V/V$ )



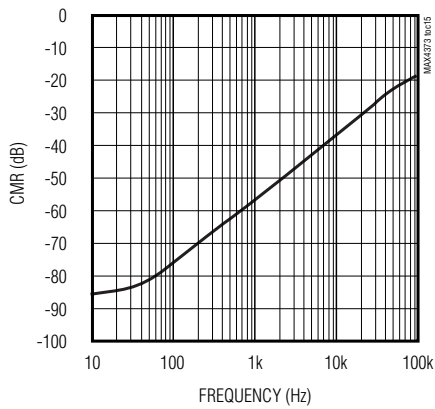
**LARGE-SIGNAL PULSE RESPONSE**  
( $A_V = +50V/V$ )



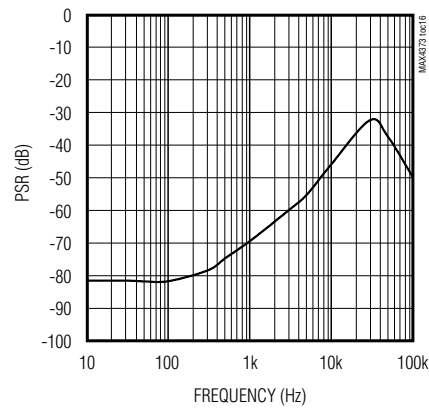
**LARGE-SIGNAL PULSE RESPONSE**  
( $A_V = +100V/V$ )



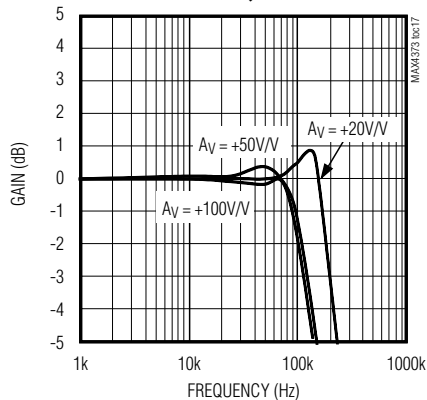
**COMMON-MODE REJECTION**  
**vs. FREQUENCY**



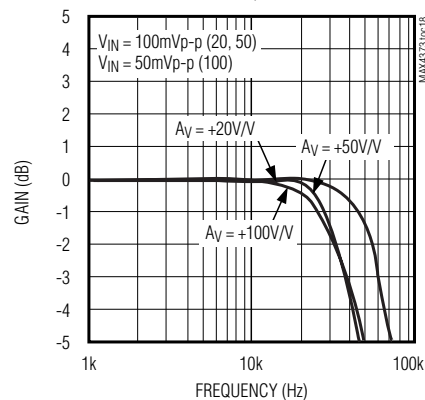
**POWER-SUPPLY REJECTION**  
**vs. FREQUENCY**



**SMALL-SIGNAL GAIN**  
**vs. FREQUENCY**



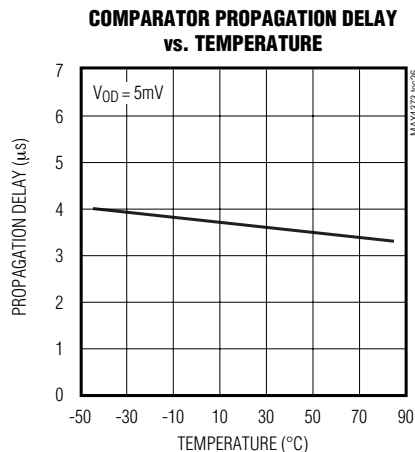
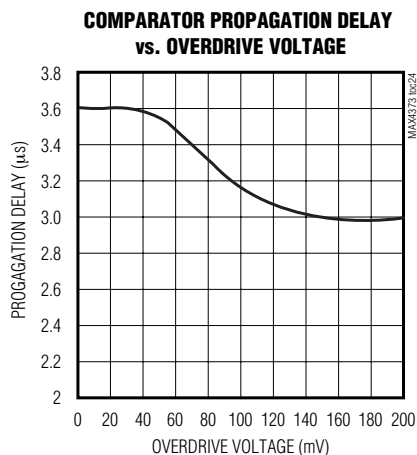
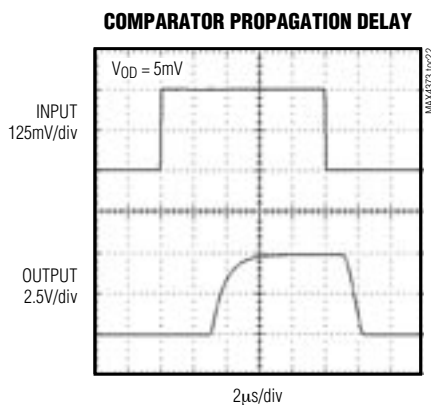
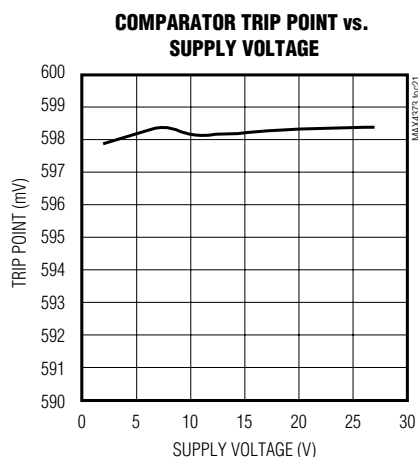
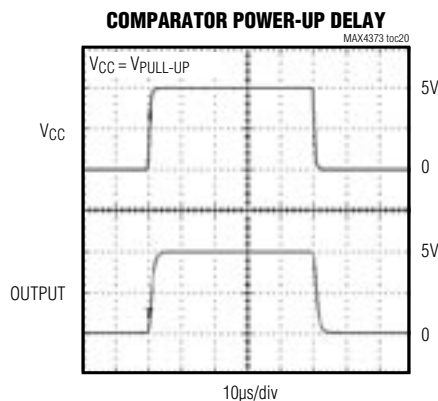
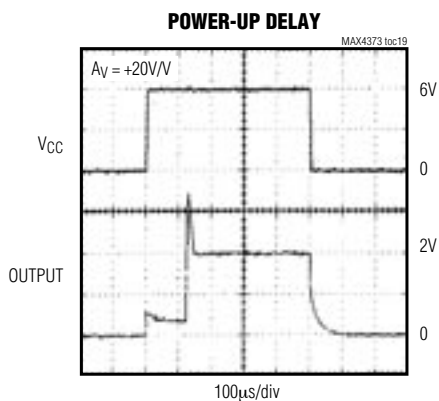
**LARGE-SIGNAL GAIN**  
**vs. FREQUENCY**



# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## Typical Operating Characteristics (continued)

( $V_{RS+} = +12V$ ,  $V_{CC} = +12V$ ,  $R_{LOAD} = 1M\Omega$ ,  $V_{RESET} = 0$ ,  $V_{SENSE} = 100mV$ ,  $V_{PULL-UP} = +5V$ ,  $R_{PULL-UP} = 10k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



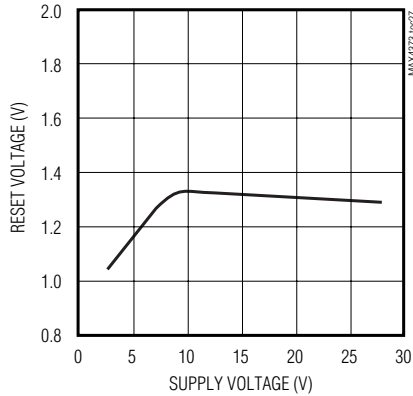
MAX4373/MAX4374/MAX4375

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

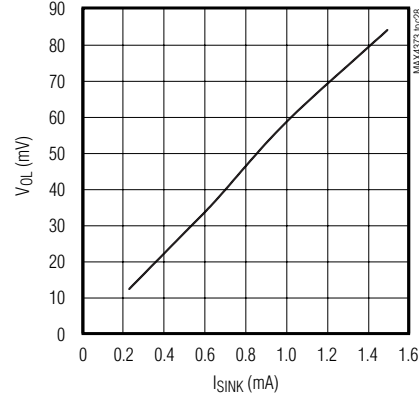
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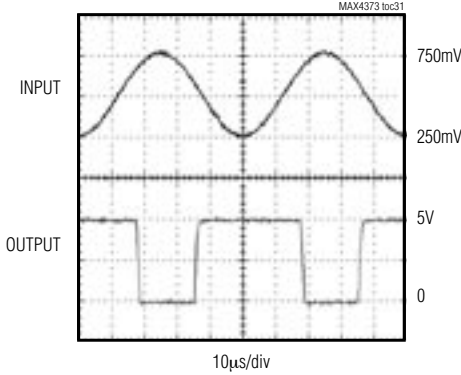
**COMPARATOR RESET VOLTAGE  
vs. SUPPLY VOLTAGE**



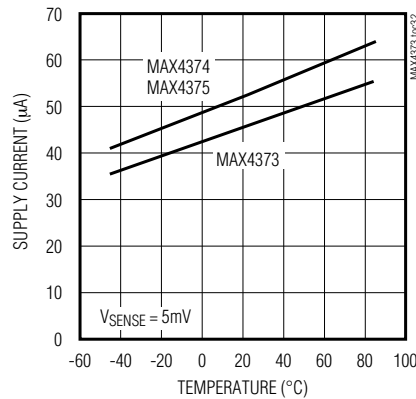
**COMPARATOR  $V_{OL}$  vs.  $I_{SINK}$**



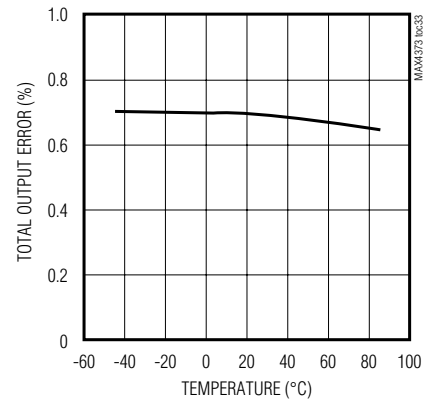
**COMPARATOR AC RESPONSE**



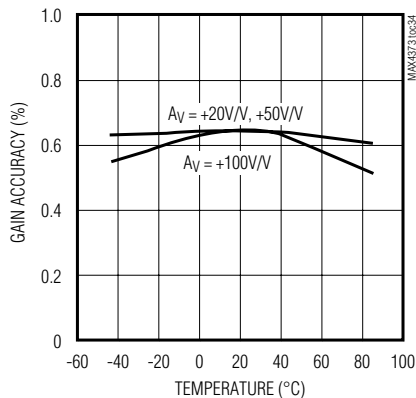
**SUPPLY CURRENT  
vs. TEMPERATURE**



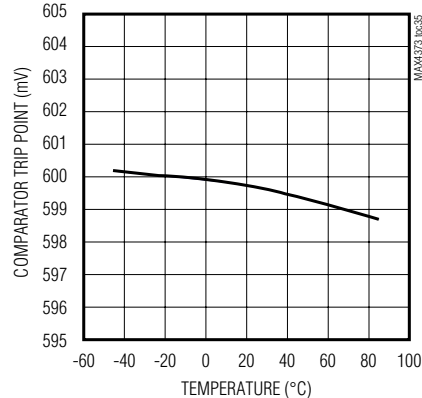
**TOTAL OUTPUT ERROR  
vs. TEMPERATURE**



**GAIN ACCURACY  
vs. TEMPERATURE**



**COMPARATOR TRIP POINT  
vs. TEMPERATURE**





# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## Pin Description

| PIN          |                 |             | NAME                      | FUNCTION                                                                                                                                                                                                     |
|--------------|-----------------|-------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX4373      | MAX4374/MAX4375 |             |                           |                                                                                                                                                                                                              |
| $\mu$ MAX/SO | $\mu$ MAX       | SO          |                           |                                                                                                                                                                                                              |
| 1            | 1               | 1           | V <sub>CC</sub>           | Supply Voltage Input                                                                                                                                                                                         |
| 2            | 2               | 2           | OUT                       | Voltage Output. V <sub>OUT</sub> is proportional to V <sub>SENSE</sub> (V <sub>RS+</sub> - V <sub>RS-</sub> ).                                                                                               |
| 3            | 3               | 4           | CIN1                      | Comparator Input 1. Positive input of an internal comparator. The negative terminal is connected to a 0.6V internal reference.                                                                               |
| —            | 4               | 5           | CIN2                      | Comparator Input 2. Terminal of a second internal comparator. The positive terminal for the MAX4374 and the negative terminal for the MAX4375. The other terminal is connected to a 0.6V internal reference. |
| 4            | 5               | 7           | GND                       | Ground                                                                                                                                                                                                       |
| 5            | 6               | 8           | $\overline{\text{RESET}}$ | Reset Input. Resets the output latch of the comparator at CIN1.                                                                                                                                              |
| 6            | 8               | 11          | COUT1                     | Open-Drain Comparator Output. Latching output of the comparator controlled by CIN1. Connect $\overline{\text{RESET}}$ to GND to disable the latch.                                                           |
| —            | 7               | 10          | COUT2                     | Open-Drain Comparator Output. Output of the second unlatched internal comparator.                                                                                                                            |
| 7            | 9               | 13          | RS-                       | Load-Side Connection for the External Sense Resistor                                                                                                                                                         |
| 8            | 10              | 14          | RS+                       | Power Connection to the External Sense Resistor                                                                                                                                                              |
| —            | —               | 3, 6, 9, 12 | N.C.                      | No Connection. Not internally connected.                                                                                                                                                                     |

MAX4373/MAX4374/MAX4375

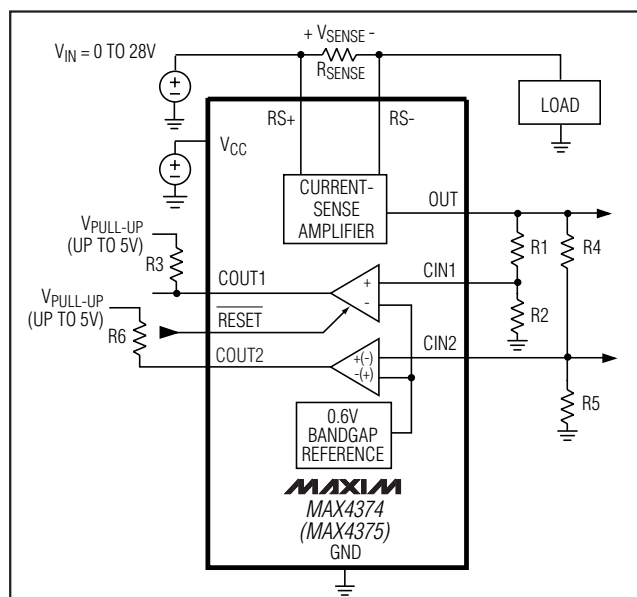


Figure 1. Functional Diagram

## Detailed Description

The MAX4373 high-side current-sense supervisor features a high-side current-sense amplifier, bandgap reference, and comparator with latching output to monitor a supply for an overcurrent condition (Figure 1). The latching output allows the comparator to shut down a power supply without oscillations. The MAX4374/MAX4375 offer an additional comparator to allow window detection of the current.

### Current-Sense Amplifier

The internal current-sense amplifier features a 0V to +28V input common-mode range that is independent of the supply voltage. With this feature, the device can monitor the output current of a battery in deep discharge and also high-side current-sensing voltages exceeding VCC.

The current-sense amplifier is also suitable for low-side current sensing. However, the total output voltage error will increase when  $V_{RS+}$  falls below 2V, as shown in the *Electrical Characteristics* and *Typical Operating Characteristics*.

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## Internal Comparator(s)

The MAX4373/MAX4374/MAX4375 contain an open-drain output comparator for current limiting. The comparator's negative terminal is connected to the internal 600mV reference. The positive terminal is accessible at CIN1. When RESET is high, the internal latch is active, and once CIN1 rises above 600mV, the output latches into the open state. Pulsing RESET low for 1.5μs resets the latch, and holding RESET low makes the latch transparent. See *RESET at Power-Up* section.

The MAX4374/MAX4375 contain an additional open-drain comparator. The negative terminal of the MAX4374's additional comparator and the positive terminal of the MAX4375's additional comparator are connected to the internal 600mV reference as shown in Figure 1. The positive terminal of the MAX4374's additional comparator and the negative terminal of the MAX4375's additional comparator are accessible at CIN2.

## Applications Information

### Recommended Component Values

Ideally, the maximum load current will develop the full-scale sense voltage across the current-sense resistor. Choose the gain version needed to yield the maximum output voltage required for the application:

$$V_{OUT} = V_{SENSE} \times A_V$$

where  $V_{SENSE}$  is the full-scale sense voltage, 150mV for gains of +20V/V and +50V/V or 100mV for a gain of +100V/V.  $A_V$  is the gain of the device. The minimum supply voltage is  $V_{OUT} + 0.25V$ . Note that the output for the gain of +100V/V is internally clamped at 12V. Calculate the maximum value for  $R_{SENSE}$  so that the differential voltage across RS+ and RS- does not exceed the full-scale sense voltage:

$$R_{SENSE(MAX)} = \frac{V_{SENSE(MAX)}}{I_{LOAD}}$$

Choose the highest value resistance possible to maximize  $V_{SENSE}$  and thus minimize total output error.

In applications monitoring high current, ensure that  $R_{SENSE}$  is able to dissipate its own  $I^2R$  loss. If the resistor's power dissipation is exceeded, its value may drift or it may fail altogether, causing a differential voltage across the terminals in excess of the absolute maximum ratings. Use resistors specified for current-sensing applications.

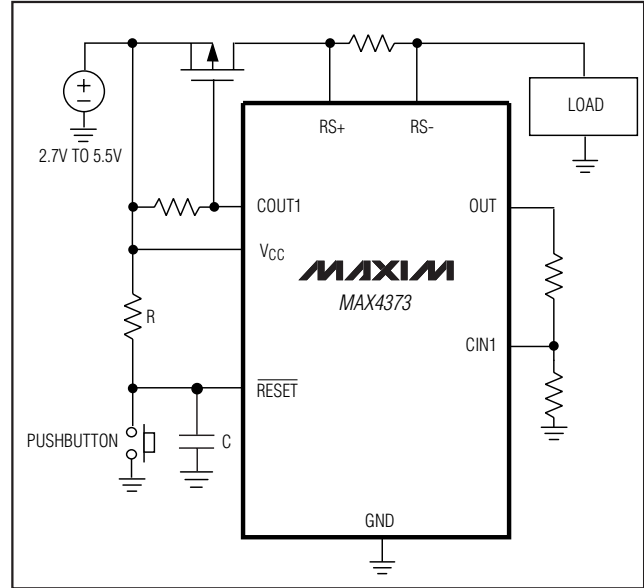


Figure 2. MAX4373 Overcurrent Protection Circuit

### Overcurrent Protection Circuit

The overcurrent protection circuit, shown in Figure 2, uses the MAX4373 to control an external P-channel MOSFET. The MOSFET controlled by the MAX4373 opens the current path under overload conditions. The latched output of the MAX4373's comparator prevents the circuit from oscillating, and the pushbutton resets the current path after an overcurrent condition.

### Window Detection Circuit

Figure 3 shows a simple circuit suitable for window detection. Let  $I_{OVER}$  be the minimum load current

$$I_{UNDER} = \frac{V_{REF}}{R_{SENSE} \times A_V} \left( \frac{R4 + R5}{R5} \right)$$

and

$$I_{OVER} = \frac{V_{REF}}{R_{SENSE} \times A_V} \left( \frac{R1 + R2}{R2} \right)$$

( $I_{LOAD}$ ) required to cause a low state at COUT2, and let  $I_{UNDER}$  be the maximum load current required to cause a high state at COUT1:

where  $A_V$  is the gain of the device and  $V_{REF}$  is the internal reference voltage (0.6V typ).

Connect COUT1 and COUT2; the resulting comparator output will be high when the current is inside the current window and low when the current is outside the window. The window is defined as load currents less than  $I_{OVER}$  and greater than  $I_{UNDER}$ .

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

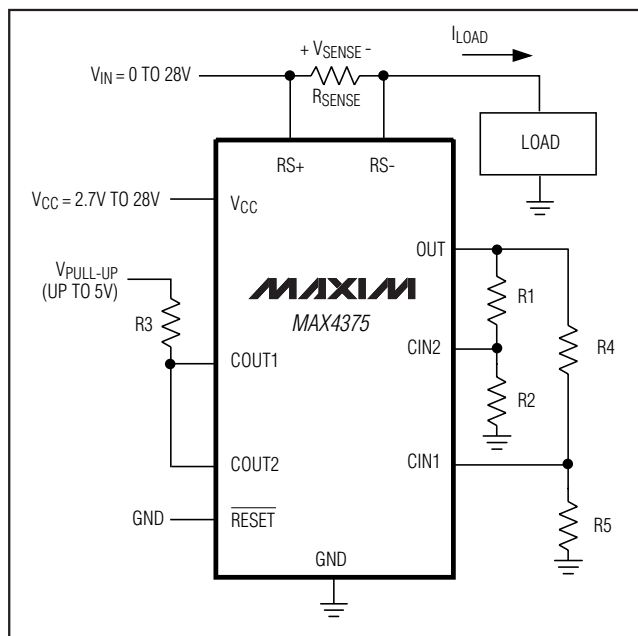


Figure 3. MAX4375 Window Detector

## Power-Supply Bypassing

It is recommended that  $V_{CC}$  be bypassed to GND with at least a 0.1 $\mu$ F ceramic capacitor to isolate the IC from supply voltage transients. It is possible that plugging in/out a battery or AC adapter/charger could cause large, fast line transients (>5V/ $\mu$ s) at  $V_{CC}$ . The simplest solution is to run  $V_{CC}$  from a better regulated supply (+5V for example), since  $V_{CC}$  and RS+ (or RS-) do not have to be connected together.

For high-speed  $V_{CC}$  transients, another solution is to add a resistor in series with the  $V_{CC}$  pin and a 0.1 $\mu$ F capacitor to create an RC time constant to slow the rise time of the transient. Since these current-sense amplifiers consume less than 100 $\mu$ A, even a 2.5k $\Omega$  resistor only drops an extra 250mV at  $V_{CC}$ . For most applications with fast transients, 1k $\Omega$  in conjunction with a 0.1 $\mu$ F bypass capacitor works well.

## RESET at Power-Up

The RESET pin is used to control the latch function of comparator 1. Holding RESET low (<0.8V) makes the latch transparent and COUT1 will respond to changes at CIN1, above and below the internal 600mV reference threshold voltage. When RESET is high (>2.0V), once CIN1 rises above 600mV, COUT1 latches into the open-drain OFF state and remains in this state even if CIN1 drops below 600mV. Pulsing RESET low for at least 1.5 $\mu$ s resets the latch.

There is no internal circuitry to control the reset function during power-up. To prevent false latching, RESET must be held low until the  $V_{CC}$  power has risen above the 2.7V minimum operating supply voltage. This is easily accomplished when RESET is driven under  $\mu$ C or logic gate control. However, if RESET is to be always connected high, add an RC between  $V_{CC}$ , RESET and GND (see Figure 2). Note that RESET cannot exceed  $V_{CC} + 0.3$ V or +12V, whichever is less.

The following formula can be used to determine the appropriate RC value.

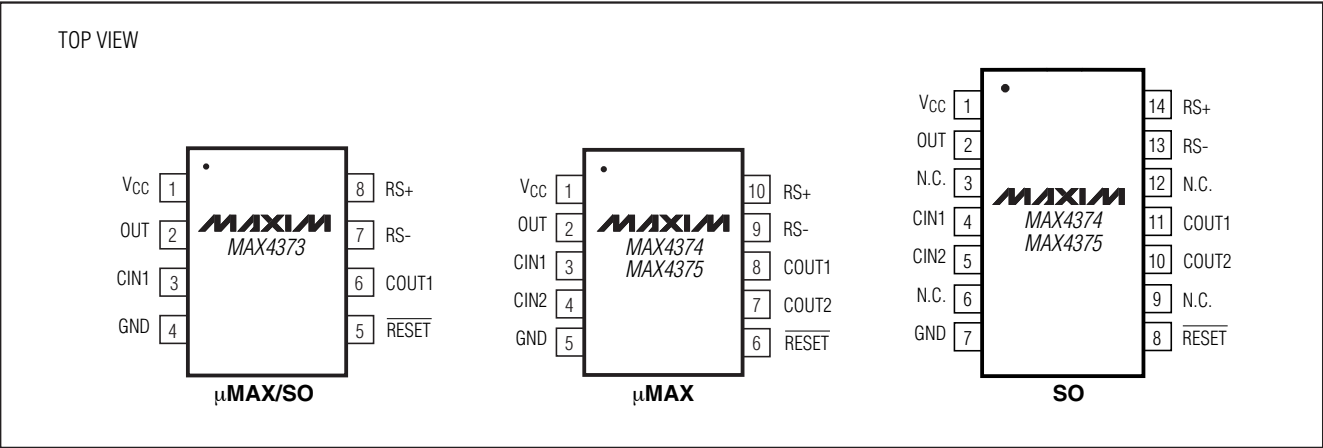
$$RC = \frac{T}{\ln(2.7V/(2.7V - 0.8V))} = \frac{T}{0.3514}$$

where T is the maximum time for  $V_{CC}$  to reach 2.7V and 0.8V is the maximum RESET logic low voltage. For example, a 470k $\Omega$  resistor and 0.22 $\mu$ F capacitor will keep RESET low during a power-up time of up to 36ms. A faster power-up time is also safe with the calculated R and C since the capacitor will have even less time to charge.

MAX4373/MAX4374/MAX4375

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## Pin Configurations



## Ordering Information (continued)

| PART                | TEMP RANGE     | PIN-PACKAGE | GAIN (V/V) |
|---------------------|----------------|-------------|------------|
| <b>MAX4374</b> TEUB | -40°C to +85°C | 10 μMAX     | +20        |
| MAX4374TESD         | -40°C to +85°C | 14 SO       | +20        |
| MAX4374FEUB         | -40°C to +85°C | 10 μMAX     | +50        |
| MAX4374FESD         | -40°C to +85°C | 14 SO       | +50        |
| MAX4374HEUB         | -40°C to +85°C | 10 μMAX     | +100       |
| MAX4374HESD         | -40°C to +85°C | 14 SO       | +100       |
| <b>MAX4375</b> TEUB | -40°C to +85°C | 10 μMAX     | +20        |
| MAX4375TESD         | -40°C to +85°C | 14 SO       | +20        |
| MAX4375FEUB         | -40°C to +85°C | 10 μMAX     | +50        |
| MAX4375FESD         | -40°C to +85°C | 14 SO       | +50        |
| MAX4375HEUB         | -40°C to +85°C | 10 μMAX     | +100       |
| MAX4375HESD         | -40°C to +85°C | 14 SO       | +100       |

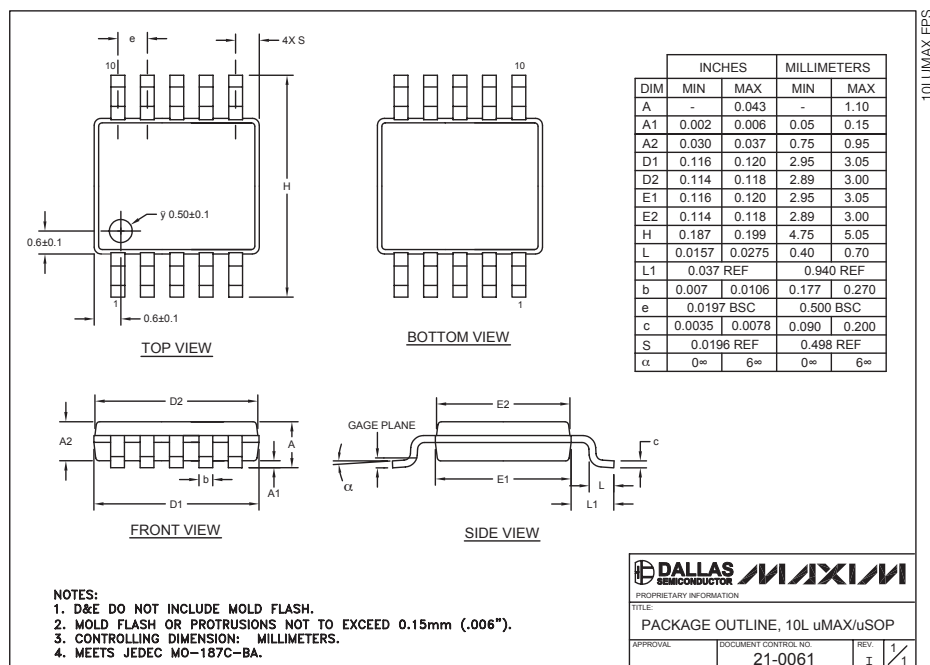
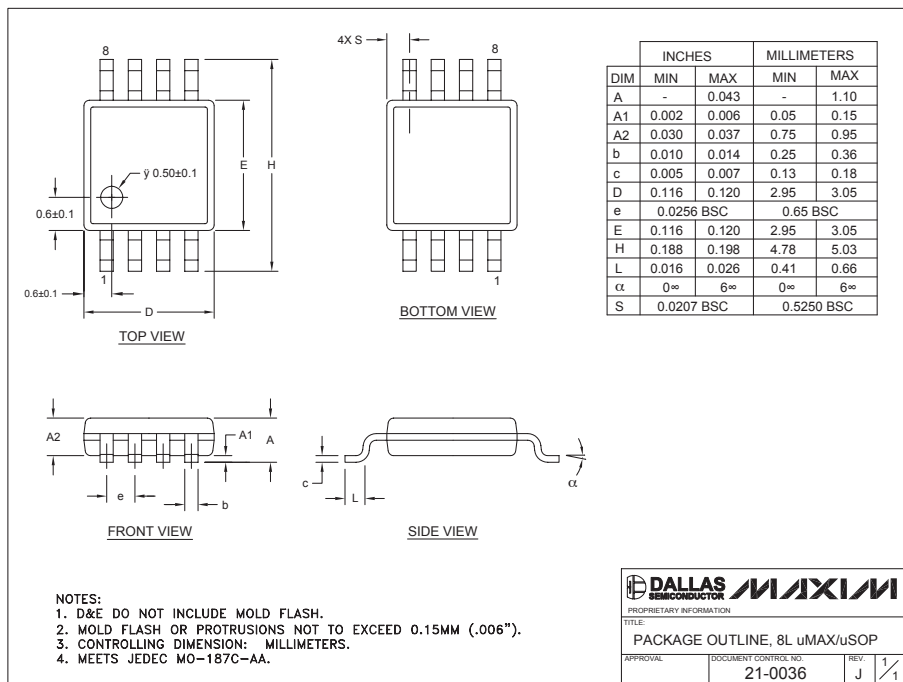
## Chip Information

TRANSISTOR COUNT: 390  
SUBSTRATE CONNECTED TO GND

# Low-Cost, Micropower, High-Side Current-Sense Amplifier + Comparator + Reference ICs

## 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).)



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