



# Battery-Backup Circuits with Regulated Output Voltage

## General Description

The MAX16023/MAX16024 low-power battery-backup circuits with a regulated output are capable of delivering up to 100mA output current. The MAX16023/MAX16024 include a low-dropout regulator, a microprocessor ( $\mu$ P) reset circuit, and a battery switchover circuit. Additional available features include a manual reset, a power-fail comparator, and a battery-on indicator. These devices reduce the number of external components to minimize board space and improve reliability.

The MAX16023/MAX16024 are ideally suited for providing power for backing up critical memory such as static random-access memory (SRAM) or real-time clocks (RTCs). The regulated output is powered by  $V_{CC}$  when it is present and switches over to the backup power during brownout. The MAX16023/MAX16024 accept an input voltage from 1.53V to 5.5V and provide fixed standard output voltages of 1.2V, 1.8V, 2.5V, 3.0V, and 3.3V. The MAX16024 offers the ability to externally set the output voltage using a resistive divider. All outputs are available with push-pull or open-drain configurations.

The MAX16023 offers a power-fail comparator for monitoring an additional voltage or for providing an early power-fail warning. Another feature includes a manual-reset input (MAX16023/MAX16024). The MAX16024 also features a battery-on indicator and chip-enable gating function.

The MAX16023/MAX16024 are offered in 8- and 10-pin TDFN packages and are fully specified from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range.

## Applications

Main/Backup Power for RTCs/SRAM  
Industrial Controls  
GPS Systems  
Set-Top Boxes  
Point-of-Sale Equipment  
Portable/Battery Equipment

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## Features

- ◆ System Monitoring for 5V, 3.3V, 3V, 2.5V, or 1.8V Power-Supply Voltages
- ◆ 100mA Low-Dropout Regulator
- ◆ Factory-Trimmed and Adjustable Output Voltages
- ◆ 1.53V to 5.5V Operating Voltage Range
- ◆ Low-Power Consumption: 4 $\mu$ A (typ)
- ◆ Power-Fail Comparators for Monitoring Voltages Down to 0.6V
- ◆ Battery-On Indicator
- ◆ Battery Freshness Seal
- ◆ On-Board Gating of CE Signals, 1.5ns Propagation Delay (MAX16024)
- ◆ Debounced Manual-Reset Input
- ◆ 145ms (min) Reset Timeout Period
- ◆ Tiny 8-Pin and 10-Pin TDFN Packages
- ◆ UL<sup>®</sup> Certified to Conform to IEC 60950-1

## Ordering Information

| PART            | TEMP RANGE                                     | PIN-PACKAGE |
|-----------------|------------------------------------------------|-------------|
| MAX16023_TA__+T | $-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$ | 8 TDFN-EP*  |
| MAX16024_TB__+T | $-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$ | 10 TDFN-EP* |

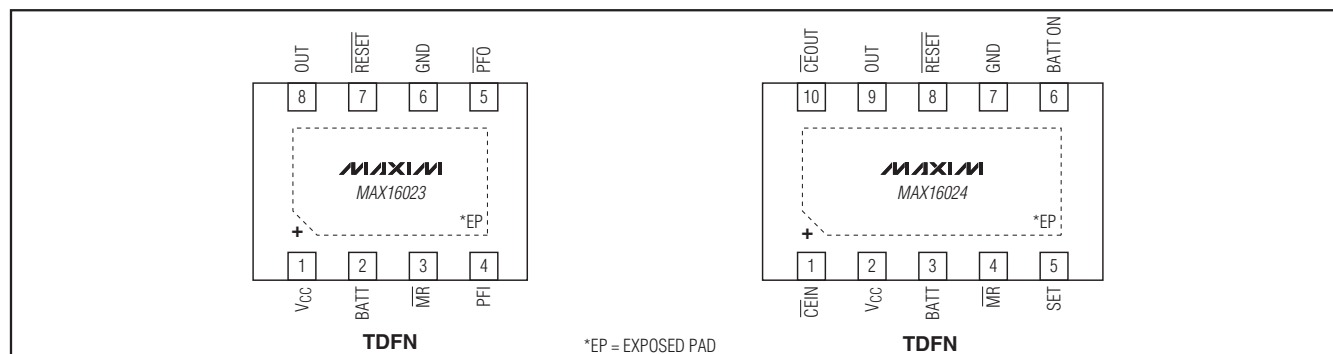
The first placeholder “\_” designates reset output options. A letter “L” in this placeholder indicates a push-pull output and letter “P” indicates an open-drain output. The next placeholder “\_” designates the reset threshold (Table 1). The last two placeholders “\_” designate output voltage (Table 2). For the MAX16024 with adjustable output voltage version, there are no last two placeholders.

+Denotes a lead-free/RoHS-compliant package.

T = Tape and reel.

\*EP = Exposed pad.

## Pin Configurations



# Battery-Backup Circuits with Regulated Output Voltage

## ABSOLUTE MAXIMUM RATINGS

|                                             |                                    |
|---------------------------------------------|------------------------------------|
| V <sub>CC</sub> , BATT, OUT to GND          | -0.3V to +6V                       |
| RESET, PFO, BATT ON (all open drain) to GND | -0.3V to +6V                       |
| RESET, PFO, BATT ON (all push-pull) to GND  | -0.3V to (V <sub>OUT</sub> + 0.3V) |
| PFI, CEIN, CEOUT to GND                     | -0.3V to (V <sub>OUT</sub> + 0.3V) |
| MR to GND                                   | -0.3V to (V <sub>CC</sub> + 0.3V)  |
| Input Current                               |                                    |
| V <sub>CC</sub> Peak Current                | 1A                                 |
| V <sub>CC</sub> Continuous Current          | 250mA                              |
| BATT Peak Current                           | 500mA                              |
| BATT Continuous Current                     | 70mA                               |

|                                                       |                 |
|-------------------------------------------------------|-----------------|
| Output Current                                        |                 |
| OUT Short Circuit to GND Duration                     | 10s             |
| RESET, BATT ON, CEOUT                                 | 20mA            |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C) |                 |
| 8-Pin TDFN (derate 24.4mW/°C above +70°C)             | 1951mW          |
| 10-Pin TDFN (derate 24.4mW/°C above +70°C)            | 1951mW          |
| Thermal Resistance (Note 1)                           |                 |
| θ <sub>JA</sub> (8-Pin and 10-Pin TDFN)               | 41°C/W          |
| 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          |

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maxim-ic.com/thermal-tutorial](http://www.maxim-ic.com/thermal-tutorial).

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> = 1.53V to 5.5V, V<sub>BATT</sub> = 3V, reset not asserted, T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, C<sub>OUT</sub> = 10μF, unless otherwise noted. Typical values are at T<sub>A</sub> = T<sub>J</sub> = +25°C.) (Note 2)

| PARAMETER                             | SYMBOL                              | CONDITIONS                                                          |            | MIN   | TYP | MAX   | UNITS |
|---------------------------------------|-------------------------------------|---------------------------------------------------------------------|------------|-------|-----|-------|-------|
| Operating Voltage Range               | V <sub>CC</sub> , V <sub>BATT</sub> | (Note 3)                                                            |            | 1.53  |     | 5.5   | V     |
| Supply Current                        | I <sub>CC</sub>                     | V <sub>CC</sub> = LDO + 0.5V,<br>no load                            | LDO = 1.2V |       | 4.3 | 6     | μA    |
|                                       |                                     |                                                                     | LDO = 1.8V |       | 4.7 | 7     |       |
|                                       |                                     |                                                                     | LDO = 2.5V |       | 5.2 | 7.5   |       |
|                                       |                                     |                                                                     | LDO = 3V   |       | 5.5 | 8     |       |
|                                       |                                     |                                                                     | LDO = 3.3V |       | 5.7 | 8     |       |
|                                       |                                     | V <sub>CC</sub> = LDO + 0.5V,<br>I <sub>OUT</sub> = 20mA            | LDO = 1.2V |       | 16  | 20    |       |
|                                       |                                     |                                                                     | LDO = 1.8V |       | 16  | 21    |       |
|                                       |                                     |                                                                     | LDO = 2.5V |       | 16  | 18.1  |       |
|                                       |                                     |                                                                     | LDO = 3V   |       | 17  | 18.6  |       |
|                                       |                                     |                                                                     | LDO = 3.3V |       | 17  | 19    |       |
| Supply Current in Battery-Backup Mode | I <sub>BATT</sub>                   | V <sub>CC</sub> = 0, V <sub>BATT</sub> = 3V,<br>no dropout, no load |            |       | 3.5 | 5.26  | μA    |
| BATT Standby Current                  |                                     | V <sub>CC</sub> > V <sub>BATT</sub> + 0.2V                          |            | -0.01 |     | +0.01 | μA    |
| SET Reference Voltage                 | V <sub>SET</sub>                    | MAX16024_TB_, V <sub>CC</sub> = 2.2V                                |            | 1.144 | 1.2 | 1.272 | V     |
| SET Input Leakage Current             |                                     | MAX16024_TB_, SET = 1.2V                                            |            | -20   |     | +20   | nA    |
| Output Voltage Range                  | V <sub>OUT</sub>                    | MAX16024_TB_, V <sub>CC</sub> > V <sub>OUT</sub>                    |            | 1.8   |     | 5.25  | V     |
| Output Voltage Accuracy               |                                     | I <sub>OUT</sub> = 1mA                                              | LDO = 1.2V | 1.145 | 1.2 | 1.270 | V     |
|                                       |                                     |                                                                     | LDO = 1.8V | 1.704 | 1.8 | 1.900 |       |
|                                       |                                     |                                                                     | LDO = 2.5V | 2.368 | 2.5 | 2.634 |       |
|                                       |                                     |                                                                     | LDO = 3V   | 2.837 | 3   | 3.165 |       |
|                                       |                                     |                                                                     | LDO = 3.3V | 3.114 | 3.3 | 3.482 |       |

# Battery-Backup Circuits with Regulated Output Voltage

MAX16023/MAX16024

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = 1.53V$  to  $5.5V$ ,  $V_{BATT} = 3V$ , reset not asserted,  $T_A = T_J = -40^{\circ}C$  to  $+85^{\circ}C$ ,  $C_{OUT} = 10\mu F$ , unless otherwise noted. Typical values are at  $T_A = T_J = +25^{\circ}C$ .) (Note 2)

| PARAMETER                                           | SYMBOL               | CONDITIONS                                                                                      |            | MIN                     | TYP   | MAX   | UNITS |
|-----------------------------------------------------|----------------------|-------------------------------------------------------------------------------------------------|------------|-------------------------|-------|-------|-------|
| Line Regulation                                     |                      | V <sub>CC</sub> = (V <sub>OUT</sub> + 1V) to (V <sub>OUT</sub> + 2V),<br>I <sub>OUT</sub> = 1mA |            |                         | 0.2   | 1.0   | %/V   |
| Load Regulation                                     |                      | V <sub>CC</sub> = V <sub>OUT</sub> + 1V, I <sub>OUT</sub> = 1mA to 2mA                          |            |                         | 0.15  | 1.0   | %     |
| Dropout Voltage                                     |                      | I <sub>OUT</sub> = 50mA<br>(Note 4)                                                             | LDO = 1.2V |                         | 500   |       | mV    |
|                                                     |                      |                                                                                                 | LDO = 1.8V |                         | 200   |       |       |
|                                                     |                      |                                                                                                 | LDO = 2.5V |                         | 180   |       |       |
|                                                     |                      |                                                                                                 | LDO = 3V   |                         | 150   |       |       |
|                                                     |                      |                                                                                                 | LDO = 3.3V |                         | 150   |       |       |
| Output Current Limit                                |                      | V <sub>CC</sub> = 1.6V                                                                          |            |                         | 75    |       | mA    |
|                                                     |                      | V <sub>CC</sub> ≥ 2V                                                                            |            |                         | 150   |       |       |
| Battery Freshness Leakage Current                   |                      | V <sub>BATT</sub> = 5.5V                                                                        |            |                         |       | 10    | nA    |
| RESET OUTPUT (RESET)                                |                      |                                                                                                 |            |                         |       |       |       |
| Reset Threshold                                     | V <sub>TH</sub>      |                                                                                                 |            | (See Table 1)           |       |       | V     |
| V <sub>CC</sub> Falling to Reset Delay              | t <sub>RD</sub>      | V <sub>CC</sub> falling at 10V/ms                                                               |            | 20                      |       |       | μs    |
| Reset Timeout Period                                | t <sub>RP</sub>      | V <sub>CC</sub> rising                                                                          |            | 145                     | 215   | 285   | ms    |
| RESET Output Low Voltage                            | V <sub>OL</sub>      | V <sub>OUT</sub> = 3.3V, I <sub>SINK</sub> = 3.2mA, RESET asserted                              |            | 0.3                     |       |       | V     |
|                                                     |                      | V <sub>OUT</sub> = 1.8V, I <sub>SINK</sub> = 1mA, RESET asserted                                |            | 0.3                     |       |       |       |
|                                                     |                      | V <sub>OUT</sub> = 1.2V, I <sub>SINK</sub> = 100μA, RESET asserted                              |            | 0.3                     |       |       |       |
| RESET Output High Voltage<br>(Push-Pull Output)     | V <sub>OH</sub>      | V <sub>CC</sub> ≥ 1.1 × V <sub>TH</sub> , I <sub>SOURCE</sub> = 100μA,<br>RESET deasserted      |            | V <sub>OUT</sub> - 0.3V |       |       | V     |
| RESET Output Leakage Current<br>(Open-Drain Output) |                      | V <sub>RESET</sub> = 5.5V, reset deasserted                                                     |            | 1                       |       |       | μA    |
| POWER-FAIL COMPARATOR (PFI, PFO)                    |                      |                                                                                                 |            |                         |       |       |       |
| PFI Input Threshold                                 | V <sub>PFT</sub>     | V <sub>PFI</sub> falling, 1.6V ≤ V <sub>CC</sub> ≤ 5.5V                                         |            | 0.570                   | 0.590 | 0.611 | V     |
| PFI Input Hysteresis                                | V <sub>PFI-HYS</sub> |                                                                                                 |            | 30                      |       |       | mV    |
| PFI Input Current                                   | I <sub>PFI</sub>     |                                                                                                 |            | -1                      |       | +1    | μA    |
| PFO Output Low Voltage                              |                      | V <sub>OUT</sub> = 1.8V, I <sub>SINK</sub> = 1mA, PFO asserted                                  |            | 0.3                     |       |       | V     |
|                                                     |                      | V <sub>OUT</sub> = 1.2V, I <sub>SINK</sub> = 100μA, PFO asserted                                |            | 0.3                     |       |       |       |
| PFO Output High Voltage<br>(Push-Pull Output)       |                      | I <sub>SOURCE</sub> = 100μA, PFO deasserted                                                     |            | V <sub>OUT</sub> - 0.3V |       |       | V     |
| PFO Leakage Current<br>(Open-Drain Output)          |                      | V <sub>PFO</sub> = 5.5V, PFO deasserted                                                         |            | 1                       |       |       | μA    |
| PFO Delay Time                                      |                      | (V <sub>PFI</sub> + 100mV) to (V <sub>PFI</sub> - 100mV)                                        |            | 20                      |       |       | μs    |
| MANUAL RESET (MR)                                   |                      |                                                                                                 |            |                         |       |       |       |
| Input Low Voltage                                   | V <sub>IL</sub>      |                                                                                                 |            | 0.3 × V <sub>CC</sub>   |       |       | V     |
| Input High Voltage                                  | V <sub>IH</sub>      |                                                                                                 |            | 0.7 × V <sub>CC</sub>   |       |       |       |
| Pullup Resistance                                   |                      | Pullup resistance to V <sub>CC</sub>                                                            |            | 20                      | 30    |       | kΩ    |
| Glitch Immunity                                     |                      |                                                                                                 |            | 100                     |       |       | ns    |
| MR to Reset Delay                                   |                      |                                                                                                 |            | 120                     |       |       | ns    |

# Battery-Backup Circuits with Regulated Output Voltage

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = 1.53V$  to  $5.5V$ ,  $V_{BATT} = 3V$ , reset not asserted,  $T_A = T_J = -40^{\circ}C$  to  $+85^{\circ}C$ ,  $C_{OUT} = 10\mu F$ , unless otherwise noted. Typical values are at  $T_A = T_J = +25^{\circ}C$ .) (Note 2)

| PARAMETER                                                                      | SYMBOL   | CONDITIONS                                                    | MIN              | TYP  | MAX | UNITS    |
|--------------------------------------------------------------------------------|----------|---------------------------------------------------------------|------------------|------|-----|----------|
| <b>BATTERY-ON INDICATOR (BATT ON)</b>                                          |          |                                                               |                  |      |     |          |
| Output Low Voltage                                                             | $V_{OL}$ | $V_{OUT} = 1.2V$ , $I_{SINK} = 100\mu A$ , BATT ON deasserted |                  |      | 0.3 | V        |
|                                                                                |          | $V_{OUT} = 1.8V$ , $I_{SINK} = 1mA$ , BATT ON deasserted      |                  |      | 0.3 |          |
|                                                                                |          | $V_{OUT} = 3.3V$ , $I_{SINK} = 3.2mA$ , BATT ON deasserted    |                  |      | 0.3 |          |
| Output High Voltage (Push-Pull Output)                                         | $V_{OH}$ | $I_{SOURCE} = 100\mu A$ , BATT ON asserted                    | $V_{OUT} - 0.3V$ |      |     | V        |
| Output Leakage Current (Open-Drain Output)                                     |          | $V_{CC} = 5.5V$                                               |                  |      | 1   | $\mu A$  |
| Output Short-Circuit Current                                                   |          | Sink current, $V_{CC} = 5V$ (Note 6)                          |                  | 60   |     | mA       |
| <b>CE GATING (<math>\overline{CEIN}</math>, <math>\overline{CEOUT}</math>)</b> |          |                                                               |                  |      |     |          |
| $\overline{CEIN}$ Leakage Current                                              |          | Reset asserted, $V_{CC} = 0.9 \times V_{TH}$ or 0             | -1               |      | +1  | $\mu A$  |
| $\overline{CEIN}$ to $\overline{CEOUT}$ Resistance                             |          | $V_{CC} = 5V$ , reset deasserted                              |                  | 8    | 50  | $\Omega$ |
| $\overline{CEOUT}$ Short-Circuit Current                                       |          | Reset asserted, $\overline{CEOUT} = 0$                        |                  | 0.75 | 2   | mA       |
| $\overline{CEIN}$ to $\overline{CEOUT}$ Propagation Delay                      |          | $50\Omega$ source, $C_{LOAD} = 50pF$ , $V_{CC} = 4.75V$       |                  | 1.5  | 7   | ns       |
| Output High Voltage                                                            | $V_{OH}$ | $I_{SOURCE} = 100\mu A$ , reset asserted                      | $V_{OUT} - 0.3V$ |      |     | V        |
| Reset to $\overline{CEOUT}$ Delay                                              |          |                                                               |                  | 12   |     | $\mu s$  |

**Note 2:** All devices are 100% production tested at  $T_A = +25^{\circ}C$  and  $T_A = +85^{\circ}C$ . Limits over temperature are guaranteed by design.

**Note 3:**  $V_{BATT}$  can be 0 anytime or  $V_{CC}$  can go down to 0 if  $V_{BATT}$  is active (except at startup).

**Note 4:** Dropout voltage is defined as  $(V_{IN} - V_{OUT})$  when  $V_{OUT}$  is 2% below the value of  $V_{OUT}$  when  $V_{IN} = V_{OUT} + 1V$ .

**Note 5:**  $\overline{CEIN}$  to  $\overline{CEOUT}$  resistance is tested with  $V_{CC} = 5V$  and  $V_{\overline{CEIN}} = 0$  or  $5V$ .

**Note 6:** Use external current-limiting resistor to limit current to 20mA (max).

# Battery-Backup Circuits with Regulated Output Voltage

Table 1. Reset Threshold Ranges

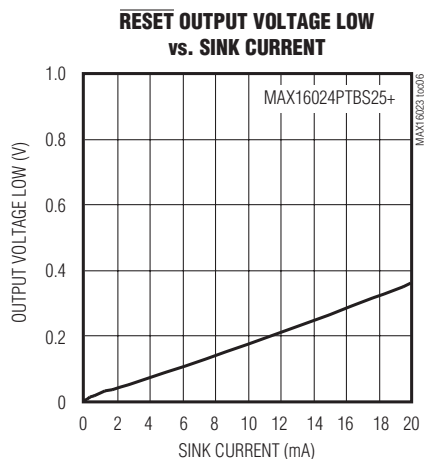
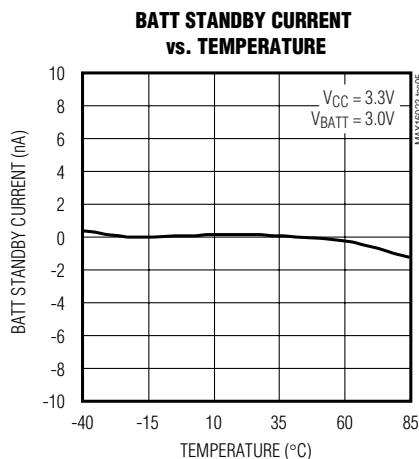
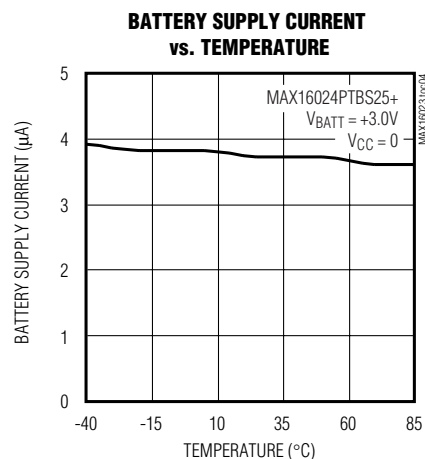
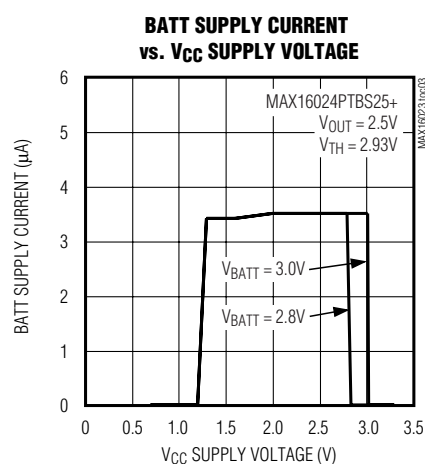
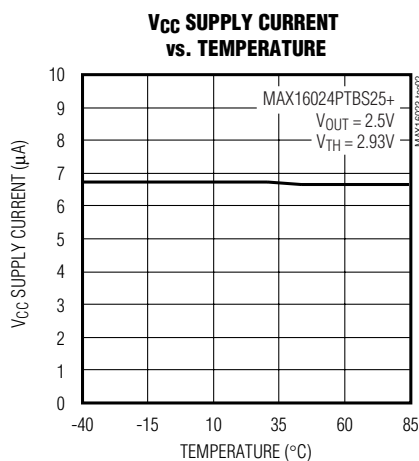
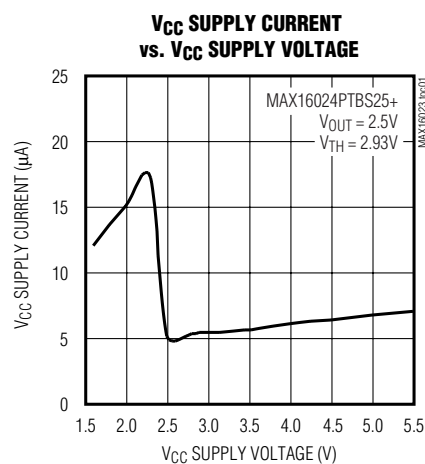
| SUFFIX | RESET THRESHOLD RANGES (V) |       |       |
|--------|----------------------------|-------|-------|
|        | MIN                        | TYP   | MAX   |
| L      | 4.508                      | 4.63  | 4.906 |
| M      | 4.264                      | 4.38  | 4.635 |
| T      | 2.991                      | 3.08  | 3.239 |
| S      | 2.845                      | 2.93  | 3.080 |
| R      | 2.549                      | 2.63  | 2.755 |
| Z      | 2.243                      | 2.32  | 2.425 |
| Y      | 2.117                      | 2.19  | 2.288 |
| W      | 1.603                      | 1.67  | 1.733 |
| V      | 1.514                      | 1.575 | 1.639 |

Table 2. Fixed Output Voltage

| SUFFIX | NOMINAL OUTPUT VOLTAGE (V) |
|--------|----------------------------|
| 33     | 3.3                        |
| 30     | 3.0                        |
| 25     | 2.5                        |
| 18     | 1.8                        |
| 12     | 1.2                        |

## Typical Operating Characteristics

( $V_{CC} = 5V$ ,  $V_{BATT} = 0$ ,  $I_{OUT} = 0$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

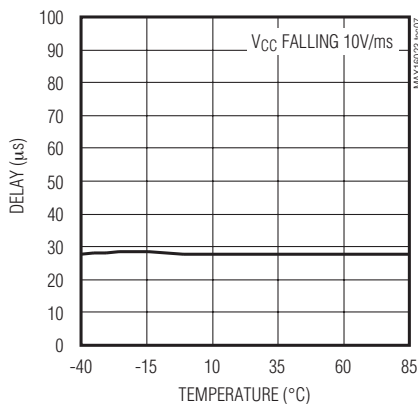


# Battery-Backup Circuits with Regulated Output Voltage

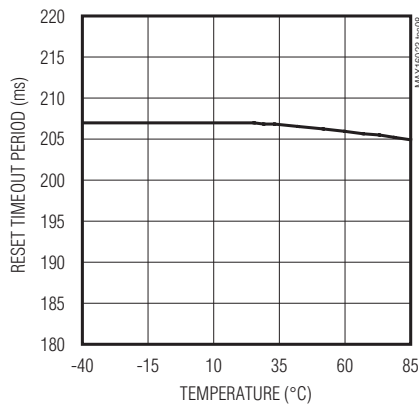
## Typical Operating Characteristics (continued)

( $V_{CC} = 5V$ ,  $V_{BATT} = 0$ ,  $I_{OUT} = 0$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

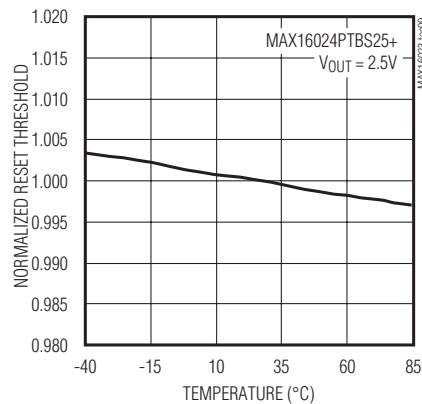
**$V_{CC}$  FALLING TO RESET DELAY  
vs. TEMPERATURE**



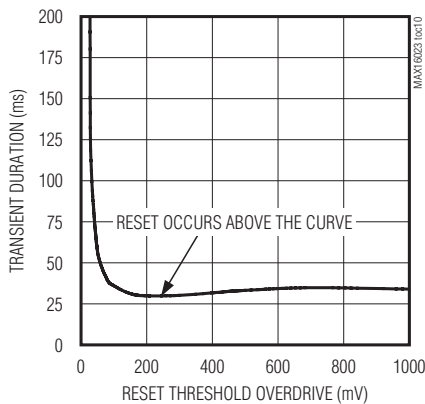
**RESET TIMEOUT PERIOD  
vs. TEMPERATURE**



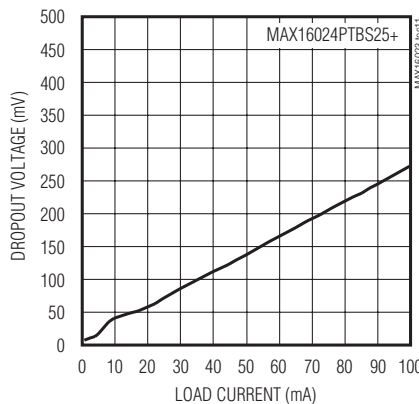
**NORMALIZED RESET THRESHOLD  
vs. TEMPERATURE**



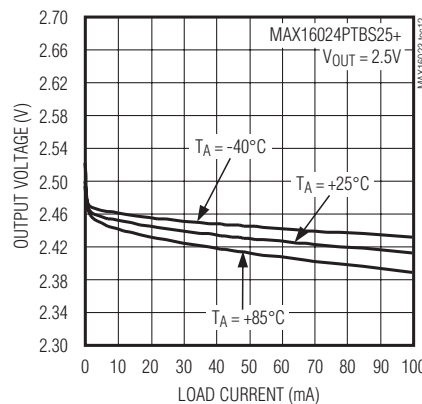
**MAXIMUM TRANSIENT DURATION  
vs. RESET THRESHOLD OVERDRIVE**



**DROPOUT VOLTAGE  
vs. LOAD CURRENT**



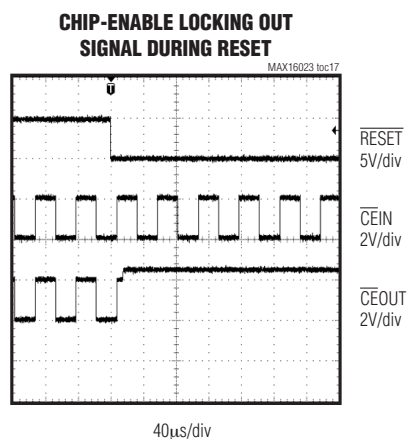
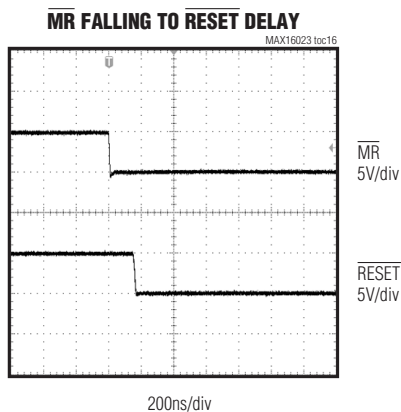
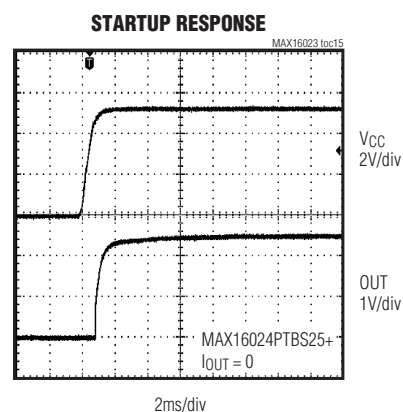
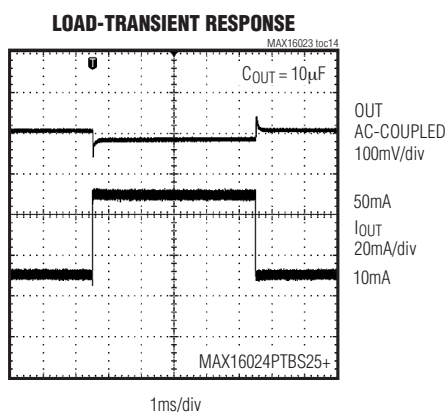
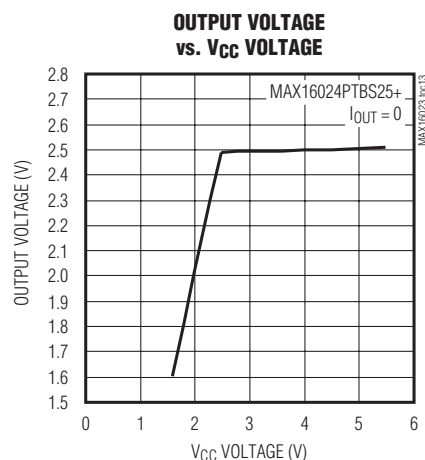
**OUTPUT VOLTAGE  
vs. LOAD CURRENT**



# Battery-Backup Circuits with Regulated Output Voltage

## Typical Operating Characteristics (continued)

( $V_{CC} = 5V$ ,  $V_{BATT} = 0$ ,  $I_{OUT} = 0$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# Battery-Backup Circuits with Regulated Output Voltage

## Pin Description

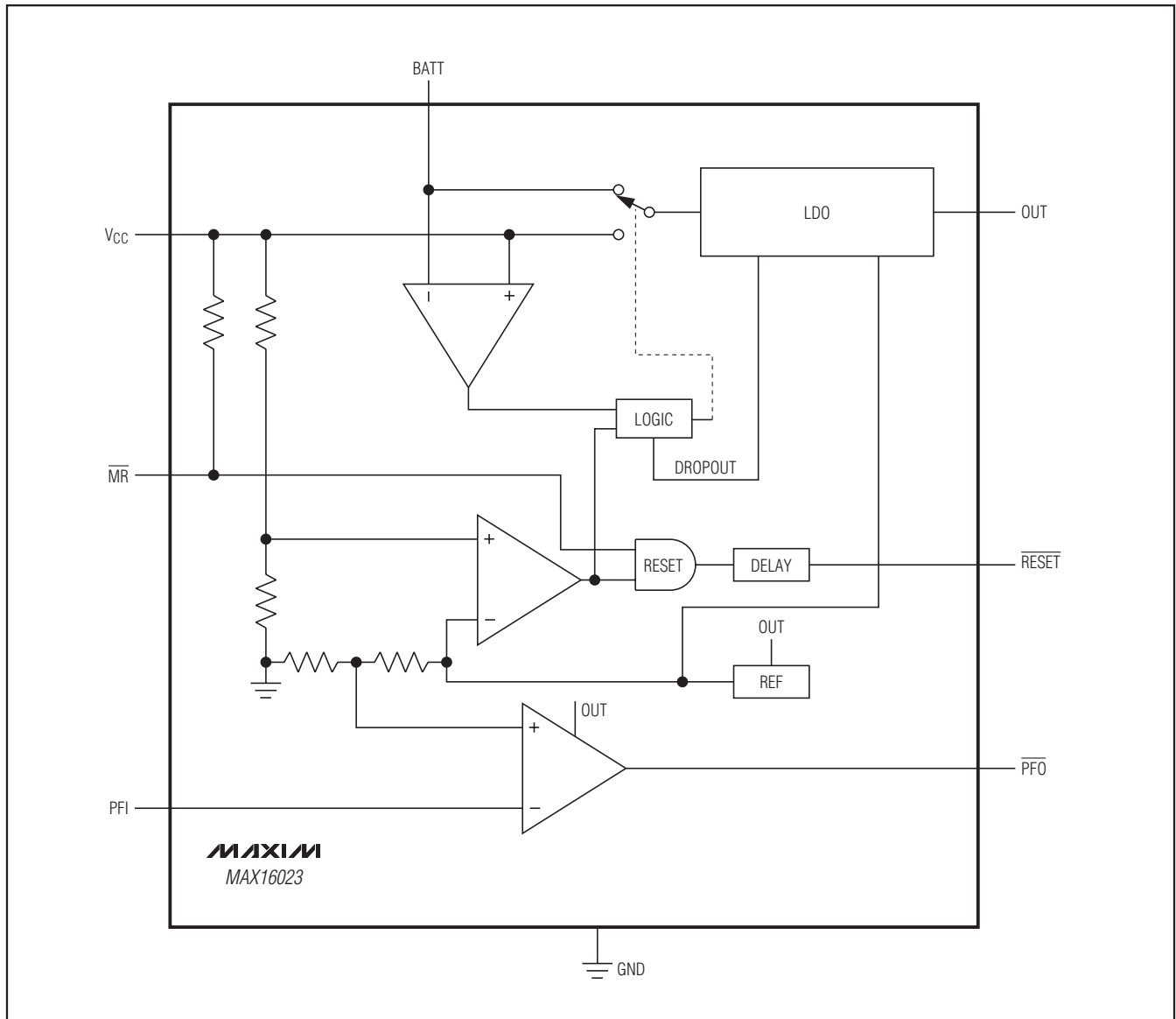
| PIN      |          | NAME                      | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----------|----------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX16023 | MAX16024 |                           |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 1        | 2        | V <sub>CC</sub>           | Supply Voltage Input. Bypass V <sub>CC</sub> to GND with a 0.1μF capacitor.                                                                                                                                                                                                                                                                                                                                                      |
| 2        | 3        | BATT                      | Backup Battery Input. If V <sub>CC</sub> falls below its reset threshold (V <sub>TH</sub> ), V <sub>BATT</sub> ≥ V <sub>CC</sub> , and if the regulator enters dropout, the regulator is powered from BATT. If V <sub>BATT</sub> < V <sub>CC</sub> , the regulator is powered from V <sub>CC</sub> . Bypass BATT to GND with a 0.1μF capacitor.                                                                                  |
| 3        | 4        | $\overline{\text{MR}}$    | Active-Low, Manual-Reset Input. $\overline{\text{RESET}}$ asserts when $\overline{\text{MR}}$ is pulled low. $\overline{\text{RESET}}$ remains low for the duration of reset timeout period after $\overline{\text{MR}}$ transitions from low to high. Connect $\overline{\text{MR}}$ to OUT or leave unconnected if not used. $\overline{\text{MR}}$ is internally connected to V <sub>CC</sub> through a 30kΩ pullup resistor. |
| 4        | —        | PFI                       | Power-Fail Comparator Input. Connect PFI to a resistive divider to set the desired PFI threshold. The PFI input is referenced to an internal V <sub>PFT</sub> threshold. A V <sub>PFI-HYS</sub> internal hysteresis provides noise immunity. The power-fail comparator is powered from OUT.                                                                                                                                      |
| 5        | —        | $\overline{\text{PFO}}$   | Active-Low, Power-Fail Comparator Output. $\overline{\text{PFO}}$ goes low when V <sub>PFI</sub> falls below the internal V <sub>PFT</sub> threshold and goes high when V <sub>PFI</sub> rises above V <sub>PFT</sub> + V <sub>PFI-HYS</sub> hysteresis.                                                                                                                                                                         |
| 6        | 7        | GND                       | Ground                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 7        | 8        | $\overline{\text{RESET}}$ | Active-Low Reset Output. $\overline{\text{RESET}}$ asserts when V <sub>CC</sub> falls below the reset threshold or $\overline{\text{MR}}$ is pulled low. $\overline{\text{RESET}}$ remains low for the duration of the reset timeout period after V <sub>CC</sub> rises above the reset threshold and $\overline{\text{MR}}$ goes high. $\overline{\text{RESET}}$ is available in push-pull and open-drain options.              |
| 8        | 9        | OUT                       | Linear Regulator Output Voltage. Available in the following factory-fixed voltages of 1.2V, 1.8V, 2.5V, 3.0V, or 3.3V for all devices. The MAX16024 is also available with an adjustable output voltage (1.8V to 5.25V). Bypass OUT to GND with a 10μF capacitor.                                                                                                                                                                |
| —        | 1        | $\overline{\text{CEIN}}$  | Chip-Enable Input. The input to CE gating circuitry. Connect to GND or OUT if not used.                                                                                                                                                                                                                                                                                                                                          |
| —        | 5        | SET                       | Set Output Voltage Input. For the fixed output voltage versions (MAX16024_TB_ _ _), SET is not used. Connect SET to GND. For MAX16024_TB_ _ _ , connect SET to an external resistive divider to set the desired output voltage between 1.8V and 5.25V.                                                                                                                                                                           |
| —        | 6        | BATT ON                   | Active-High, Battery-On Output. BATT ON goes high when in the battery backup mode.                                                                                                                                                                                                                                                                                                                                               |
| —        | 10       | $\overline{\text{CEOUT}}$ | Active-Low, Chip-Enable Output. $\overline{\text{CEOUT}}$ goes low only when $\overline{\text{CEIN}}$ is low and reset is not asserted. If $\overline{\text{CEIN}}$ is low when reset is asserted, $\overline{\text{CEOUT}}$ stays low for 12μs (typ) or until $\overline{\text{CEIN}}$ goes high, whichever occurs first.                                                                                                       |
| —        | —        | EP                        | Exposed Pad. Internally connected to GND. Connect EP to a large ground plane to aid heat dissipation. Do not use EP as the only ground connection for the device.                                                                                                                                                                                                                                                                |



# Battery-Backup Circuits with Regulated Output Voltage

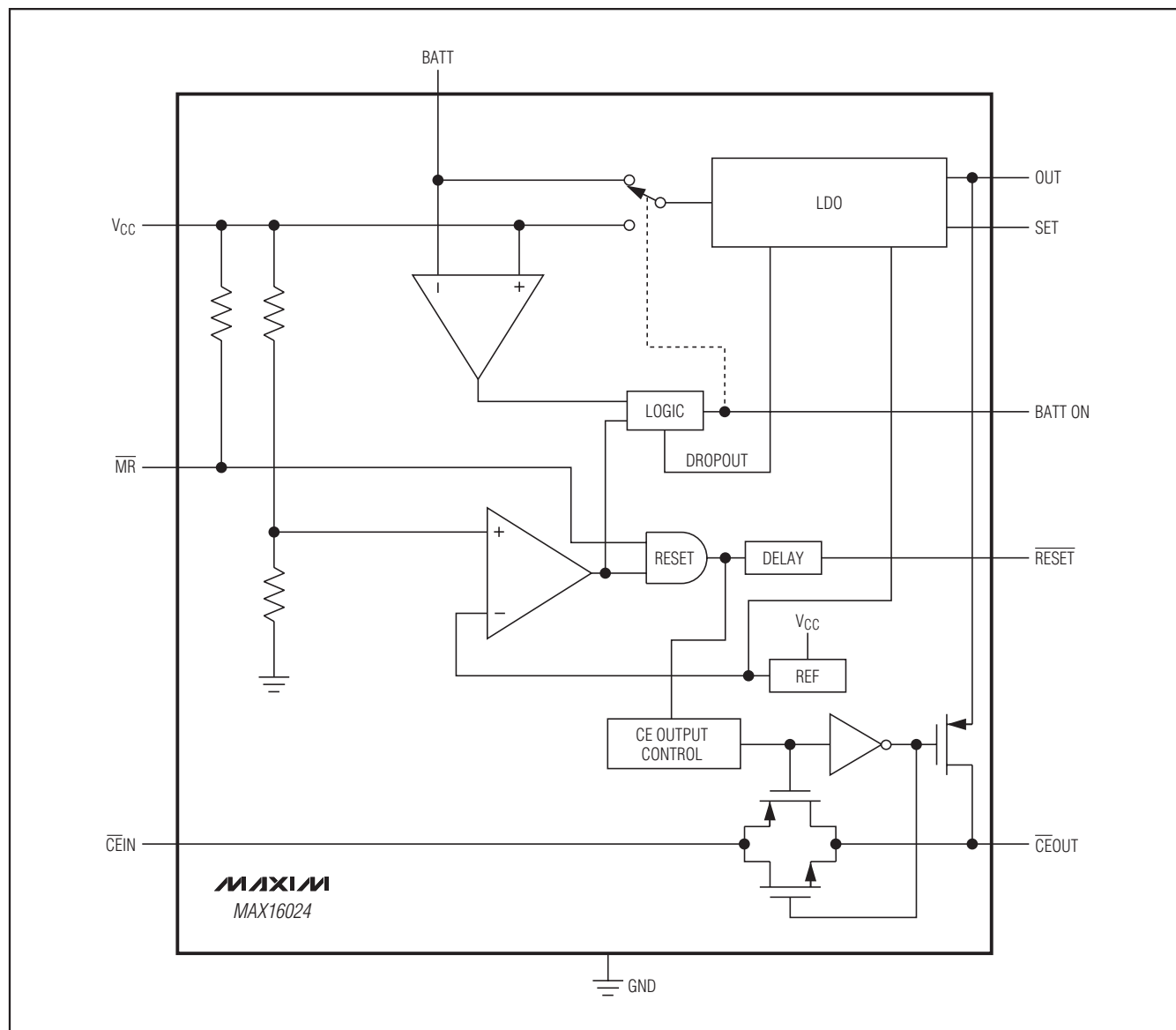
## Functional Diagrams

MAX16023/MAX16024



# Battery-Backup Circuits with Regulated Output Voltage

## Functional Diagrams (continued)



# Battery-Backup Circuits with Regulated Output Voltage

## Detailed Description

The *Typical Applications Circuit* shows a typical connection using the MAX16024. OUT powers the SRAM. If  $V_{CC}$  is higher than the reset threshold ( $V_{TH}$ ), or if  $V_{CC}$  is lower than  $V_{TH}$  but higher than  $V_{BATT}$ , the regulator is powered from  $V_{CC}$ . If  $V_{CC} < V_{TH}$ ,  $V_{CC} < V_{BATT}$ , and the regulator is in dropout, the regulator is powered from BATT (see the *Functional Diagrams*). OUT supplies up to 100mA from  $V_{CC}$ .

## Backup-Battery Switchover

In a brownout or power failure, it may be necessary to preserve the contents of the RAM. With a backup-battery installed at BATT, the MAX16023/MAX16024 automatically switch the RAM to backup power when  $V_{CC}$  falls. The MAX16024 has a BATT ON output that goes high when in battery-backup mode. Three conditions must be met for these devices to switch to battery backup mode:

- 1)  $V_{CC}$  is lower than the reset threshold.
- 2)  $V_{CC}$  is lower than  $V_{BATT}$ .
- 3) The regulator is in dropout (except for the 1.2V output version).

## Chip-Enable Signal Gating (MAX16024)

The MAX16024 provides internal gating of CE signals to prevent erroneous data from being written to CMOS RAM in the event of a power failure or brownout. During normal operation, the CE gate enables and passes all CE transitions. When the reset output asserts, this path becomes disabled, preventing erroneous data from corrupting the CMOS RAM and  $\overline{CEOUT}$  is pulled up to OUT through an internal current source. The 1.5ns propagation delay from  $\overline{CEIN}$  to  $\overline{CEOUT}$  allows the devices to be used with most  $\mu$ Ps and high-speed DSPs.

During normal operation (reset not asserted),  $\overline{CEIN}$  is connected to  $\overline{CEOUT}$  through a low on-resistance transmission gate. If  $\overline{CEIN}$  is high when a reset asserts,  $\overline{CEOUT}$  remains high regardless of any subsequent transition on  $\overline{CEIN}$  during the reset event.

If  $\overline{CEIN}$  is low when reset asserts,  $\overline{CEOUT}$  is held low for 12 $\mu$ s to allow completion of the read/write operation. After the 12 $\mu$ s delay expires,  $\overline{CEOUT}$  goes high and stays high regardless of any subsequent transitions on  $\overline{CEIN}$  during the reset event. When  $\overline{CEOUT}$  is disconnected from  $\overline{CEIN}$ ,  $\overline{CEOUT}$  is actively pulled up to OUT.

The propagation delay through the chip-enable circuitry depends on both the source impedance of the drive to  $\overline{CEIN}$  and the capacitive loading at  $\overline{CEOUT}$ . Minimize the capacitive load at  $\overline{CEOUT}$  to minimize propagation delay, and use a low-output-impedance driver.

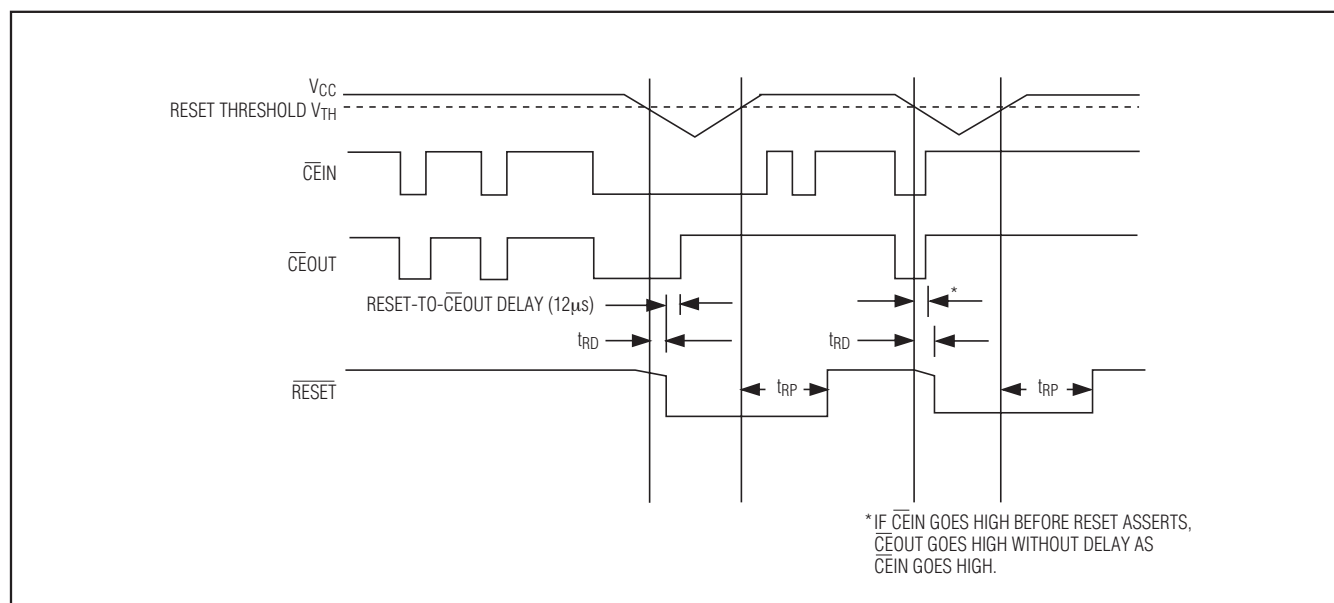


Figure 1. Reset and Chip-Enable Timing

# Battery-Backup Circuits with Regulated Output Voltage

## Manual-Reset Input (MAX16023/MAX16024)

Many  $\mu$ P-based products require manual-reset capability, allowing the operator, a test technician, or external logic circuitry to initiate a reset. For the MAX16023/MAX16024, a logic-low on  $\overline{\text{MR}}$  asserts  $\overline{\text{RESET}}$ .  $\overline{\text{RESET}}$  remains asserted while  $\overline{\text{MR}}$  is low. When  $\overline{\text{MR}}$  goes high,  $\overline{\text{RESET}}$  deasserts after a minimum of 145ms ( $t_{\text{RP}}$ ).  $\overline{\text{MR}}$  has an internal 30k $\Omega$  pullup resistor to  $V_{\text{CC}}$ .  $\overline{\text{MR}}$  can be driven with TTL/CMOS logic levels or with open-drain/collector outputs. Connect a normally open momentary switch from  $\overline{\text{MR}}$  to GND to create a manual-reset function; external debounce circuitry is not required. If  $\overline{\text{MR}}$  is driven from a long cable or the device is used in a noisy environment, connect a 0.1 $\mu$ F capacitor from  $\overline{\text{MR}}$  to GND to provide additional noise immunity.

## Battery-On Indicator (MAX16024)

The MAX16024's BATT ON output goes high when in battery-backup mode. Use BATT ON to indicate battery-switchover status.

## Battery Freshness Seal

The MAX16023/MAX16024 battery freshness seal disconnects the backup battery from internal circuitry and OUT until  $V_{\text{CC}}$  is applied. This ensures the backup battery connected to BATT is fresh when the final product is used for the first time.

The internal freshness seal latch prevents BATT from powering OUT until  $V_{\text{CC}}$  has come up for the first time, setting the latch. When  $V_{\text{CC}}$  subsequently turns off, BATT begins to power OUT.

To reenoble the freshness seal (MAX16023/MAX16024):

- 1) Connect a battery to BATT.
- 2) Bring  $V_{\text{CC}}$  to 0.
- 3) Drive  $\overline{\text{MR}}$  higher than  $V_{\text{BATT}} + 1.2\text{V}$  for at least 3 $\mu$ s.
- 4) Pull OUT to 0.

## Reset Output (MAX16023/MAX16024)

A  $\mu$ P's reset input starts the  $\mu$ P in a known state. The MAX16023/MAX16024  $\mu$ P supervisory circuits assert a reset to prevent code-execution errors during power-up, power-down, and brownout conditions.  $\overline{\text{RESET}}$  asserts when  $V_{\text{CC}}$  is below the reset threshold and remains low for at least 145ms ( $t_{\text{RP}}$ ) after  $V_{\text{CC}}$  rises

above the reset threshold.  $\overline{\text{RESET}}$  also asserts when  $\overline{\text{MR}}$  is low.  $\overline{\text{RESET}}$  is available in both push-pull and open-drain configurations.

## Power-Fail Comparator (MAX16023)

The MAX16023 offers an additional undervoltage comparator. The output  $\overline{\text{PFO}}$  goes low when the voltage at PFI falls below its  $V_{\text{PFT}}$  threshold. Common uses for the power-fail comparator include monitoring the input of the power supply (such as a battery) before any voltage regulation to provide an early power-fail warning, so software can conduct an orderly system shutdown. The power-fail comparator has a typical input hysteresis of  $V_{\text{PFI-HYS}}$  and is powered from OUT, making it independent of the reset circuit. Connect PFI to GND, if not used.

## Regulator Output

Fixed output voltages of 1.2V, 1.8V, 2.5V, 3.0V, and 3.3V are available for all devices. The regulator output delivers up to 100mA of load current.

The MAX16024 is available with both fixed and adjustable output-voltage options. Use an external resistive divider network connected between OUT, SET, and GND (Figure 2) to set the adjustable output voltage from 1.8V to 5.25V. Connect SET to GND for parts with fixed output voltage option.

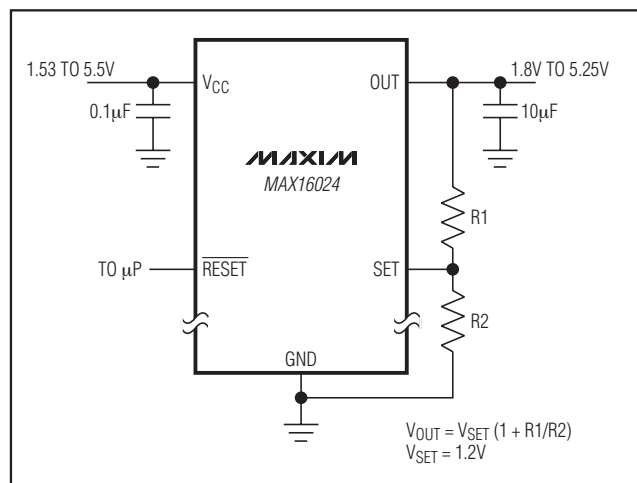


Figure 2. Setting the Adjustable Output Voltage (MAX16024 Only)

# Battery-Backup Circuits with Regulated Output Voltage

## Applications Information

The MAX16023/MAX16024 are protected for typical short-circuit conditions of 10s or less. Shorting OUT to ground for longer than 10s might damage the device. Bypass  $V_{CC}$  and BATT to GND with a 0.1 $\mu$ F capacitor each. Connect a 10 $\mu$ F low-ESR capacitor from OUT to GND. All capacitors should be mounted as close as possible to the device.

### Monitoring an Additional Supply

The MAX16023 power-fail comparator can monitor either positive or negative supplies using a resistive divider to PFI (Figures 3 and 4). PFO can be used to generate an interrupt to the  $\mu$ P or to trigger a reset. To monitor a negative supply, connect the top of the resistive divider to  $V_{CC}$ . Connect the bottom of the resistive divider to the negative voltage to be monitored.

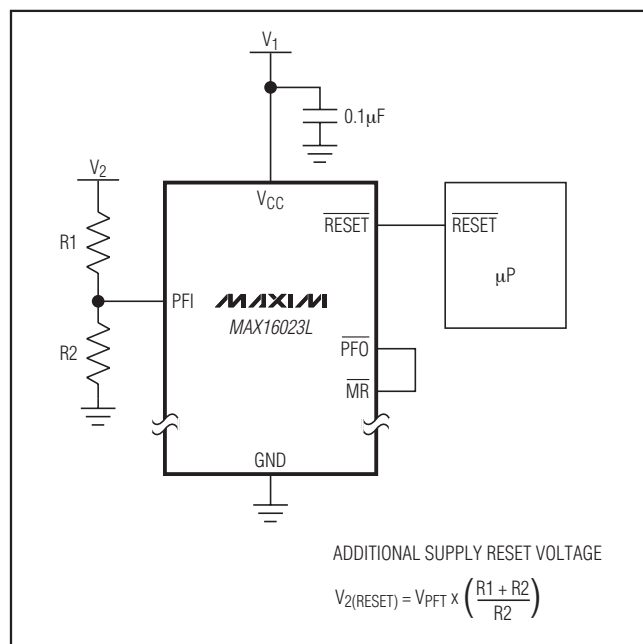


Figure 3. Monitoring an Additional Supply by Connecting  $\overline{\text{PFO}}$  to  $\overline{\text{MR}}$

### Adding Hysteresis to PFI

The power-fail comparators have a typical input hysteresis of  $V_{PFI-HYS}$ . This is sufficient for most applications where a power-supply line is being monitored through an external voltage-divider (see the *Monitoring an Additional Supply* section). Figure 5 shows how to add hysteresis to the power-fail comparator. Select the ratio of R1 and R2 such that PFI sees  $V_{PFT}$  when  $V_{IN}$  falls to the desired trip point ( $V_{TRIP}$ ). Resistor R3 adds hysteresis. R3 is typically an order of magnitude greater than R1 or R2. The current through R1 and R2 should be at least 100 $\mu$ A to ensure that the 1 $\mu$ A (max) PFI input current does not shift the trip point. R3 should be larger than 50k $\Omega$  to prevent it from loading down  $\overline{\text{PFO}}$ . Capacitor C1 adds additional noise rejection.

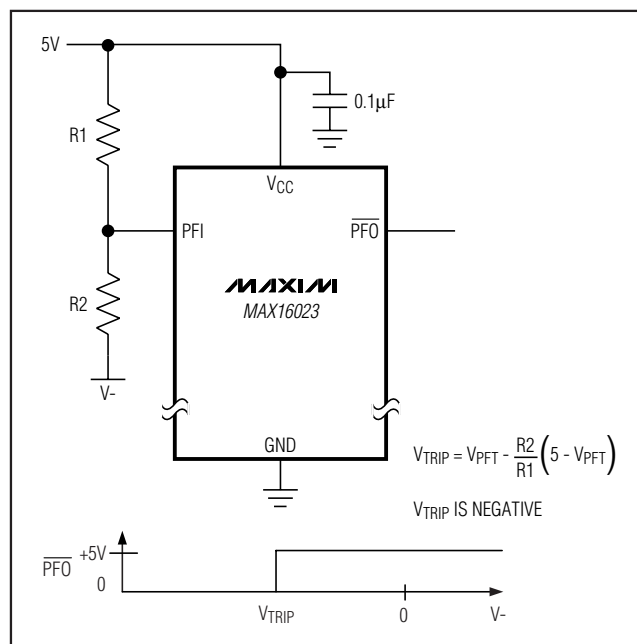


Figure 4. Monitoring a Negative Supply

# Battery-Backup Circuits with Regulated Output Voltage

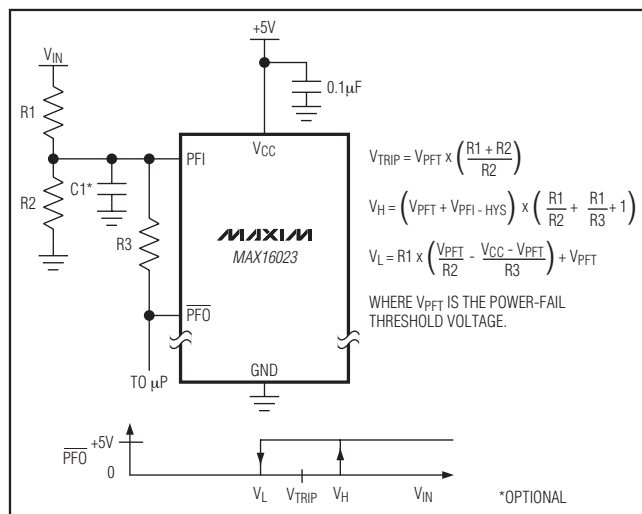


Figure 5. Adding Hysteresis to the Power-Fail Comparator

## Operation Without a Backup Power Source

The MAX16023/MAX16024 provide battery-backup functions. If a backup power source is not used, connect BATT to GND.

## Replacing the Backup Battery

When  $V_{CC}$  is above  $V_{TH}$ , the backup power source can be removed without danger of triggering a reset pulse. The device does not enter battery-backup mode when  $V_{CC}$  stays above the reset threshold voltage.

## Negative-Going $V_{CC}$ Transients

The MAX16023/MAX16024 are relatively immune to short duration, negative-going  $V_{CC}$  transients. Resetting the  $\mu P$  when  $V_{CC}$  experiences only small glitches is usually not desirable. A 0.1 $\mu F$  bypass capacitor mounted close to the  $V_{CC}$  pin provides additional transient immunity.

## Capacitor Selection and Regulator Stability

For stable operation, connect a low-ESR 10 $\mu F$  (min) output capacitor from OUT to GND. To reduce noise and improve load-transient response and power-supply rejection, use larger output capacitor values.

## Part Number Table

| PART                    | OUTPUT TYPE      | RESET THRESHOLD VOLTAGE (V) | REGULATED OUTPUT VOLTAGE (V) | PART             | OUTPUT TYPE | RESET THRESHOLD VOLTAGE (V) | REGULATED OUTPUT VOLTAGE (V) |
|-------------------------|------------------|-----------------------------|------------------------------|------------------|-------------|-----------------------------|------------------------------|
| MAX16023LTAL12+T        | Push-Pull        | 4.63                        | 1.2                          | MAX16024LTBL12+T | Push-Pull   | 4.63                        | 1.2                          |
| MAX16023LTAL18+T        | Push-Pull        | 4.63                        | 1.8                          | MAX16024LTBL18+T | Push-Pull   | 4.63                        | 1.8                          |
| MAX16023LTAL25+T        | Push-Pull        | 4.63                        | 2.5                          | MAX16024LTBL25+T | Push-Pull   | 4.63                        | 2.5                          |
| MAX16023LTAL33+T        | Push-Pull        | 4.63                        | 3.3                          | MAX16024LTBL33+T | Push-Pull   | 4.63                        | 3.3                          |
| MAX16023LTAM12+T        | Push-Pull        | 4.38                        | 1.2                          | MAX16024LTBM12+T | Push-Pull   | 4.38                        | 1.2                          |
| MAX16023LTAM18+T        | Push-Pull        | 4.38                        | 1.8                          | MAX16024LTBM18+T | Push-Pull   | 4.38                        | 1.8                          |
| MAX16023LTAM25+T        | Push-Pull        | 4.38                        | 2.5                          | MAX16024LTBM25+T | Push-Pull   | 4.38                        | 2.5                          |
| MAX16023LTAM33+T        | Push-Pull        | 4.38                        | 3.3                          | MAX16024LTBM33+T | Push-Pull   | 4.38                        | 3.3                          |
| MAX16023LTAT12+T        | Push-Pull        | 3.08                        | 1.2                          | MAX16024LTBT12+T | Push-Pull   | 3.08                        | 1.2                          |
| MAX16023LTAT18+T        | Push-Pull        | 3.08                        | 1.8                          | MAX16024LTBT18+T | Push-Pull   | 3.08                        | 1.8                          |
| MAX16023LTAT25+T        | Push-Pull        | 3.08                        | 2.5                          | MAX16024LTBT25+T | Push-Pull   | 3.08                        | 2.5                          |
| MAX16023LTAS12+T        | Push-Pull        | 2.93                        | 1.2                          | MAX16024LTBS12+T | Push-Pull   | 2.93                        | 1.2                          |
| <b>MAX16023LTAS18+T</b> | <b>Push-Pull</b> | <b>2.93</b>                 | <b>1.8</b>                   | MAX16024LTBS18+T | Push-Pull   | 2.93                        | 1.8                          |
| MAX16023LTAS25+T        | Push-Pull        | 2.93                        | 2.5                          | MAX16024LTBS25+T | Push-Pull   | 2.93                        | 2.5                          |
| MAX16023LTAR12+T        | Push-Pull        | 2.63                        | 1.2                          | MAX16024LTBR12+T | Push-Pull   | 2.63                        | 1.2                          |
| MAX16023LTAR18+T        | Push-Pull        | 2.63                        | 1.8                          | MAX16024LTBR18+T | Push-Pull   | 2.63                        | 1.8                          |
| MAX16023LTAR25+T        | Push-Pull        | 2.63                        | 2.5                          | MAX16024LTBR25+T | Push-Pull   | 2.63                        | 2.5                          |
| MAX16023LTAZ12+T        | Push-Pull        | 2.32                        | 1.2                          | MAX16024LTBZ12+T | Push-Pull   | 2.32                        | 1.2                          |

# Battery-Backup Circuits with Regulated Output Voltage

**Part Number Table (continued)**

| PART                    | OUTPUT TYPE       | RESET THRESHOLD VOLTAGE (V) | REGULATED OUTPUT VOLTAGE (V) | PART                    | OUTPUT TYPE       | RESET THRESHOLD VOLTAGE (V) | REGULATED OUTPUT VOLTAGE (V) |
|-------------------------|-------------------|-----------------------------|------------------------------|-------------------------|-------------------|-----------------------------|------------------------------|
| MAX16023LTAZ18+T        | Push-Pull         | 2.32                        | 1.8                          | <b>MAX16024LTBZ18+T</b> | <b>Push-Pull</b>  | <b>2.32</b>                 | <b>1.8</b>                   |
| MAX16023LTAY12+T        | Push-Pull         | 2.19                        | 1.2                          | MAX16024LTBY12+T        | Push-Pull         | 2.19                        | 1.2                          |
| MAX16023LTAY18+T        | Push-Pull         | 2.19                        | 1.8                          | MAX16024LTBY18+T        | Push-Pull         | 2.19                        | 1.8                          |
| MAX16023LTAW12+T        | Push-Pull         | 1.67                        | 1.2                          | MAX16024LTBW12+T        | Push-Pull         | 1.67                        | 1.2                          |
| MAX16023LTAV12+T        | Push-Pull         | 1.575                       | 1.2                          | MAX16024LTBV12+T        | Push-Pull         | 1.575                       | 1.2                          |
| MAX16023PTAL12+T        | Open-Drain        | 4.63                        | 1.2                          | MAX16024PTBL12+T        | Open-Drain        | 4.63                        | 1.2                          |
| MAX16023PTAL18+T        | Open-Drain        | 4.63                        | 1.8                          | MAX16024PTBL18+T        | Open-Drain        | 4.63                        | 1.8                          |
| MAX16023PTAL25+T        | Open-Drain        | 4.63                        | 2.5                          | MAX16024PTBL25+T        | Open-Drain        | 4.63                        | 2.5                          |
| MAX16023PTAL33+T        | Open-Drain        | 4.63                        | 3.3                          | MAX16024PTBL33+T        | Open-Drain        | 4.63                        | 3.3                          |
| MAX16023PTAM12+T        | Open-Drain        | 4.38                        | 1.2                          | MAX16024PTBM12+T        | Open-Drain        | 4.38                        | 1.2                          |
| MAX16023PTAM18+T        | Open-Drain        | 4.38                        | 1.8                          | MAX16024PTBM18+T        | Open-Drain        | 4.38                        | 1.8                          |
| MAX16023PTAM25+T        | Open-Drain        | 4.38                        | 2.5                          | MAX16024PTBM25+T        | Open-Drain        | 4.38                        | 2.5                          |
| MAX16023PTAM33+T        | Open-Drain        | 4.38                        | 3.3                          | MAX16024PTBM33+T        | Open-Drain        | 4.38                        | 3.3                          |
| MAX16023PTAT12+T        | Open-Drain        | 3.08                        | 1.2                          | MAX16024PTBS12+T        | Open-Drain        | 3.08                        | 1.2                          |
| MAX16023PTAT18+T        | Open-Drain        | 3.08                        | 1.8                          | MAX16024PTBS18+T        | Open-Drain        | 3.08                        | 1.8                          |
| MAX16023PTAT25+T        | Open-Drain        | 3.08                        | 2.5                          | <b>MAX16024PTBS25+T</b> | <b>Open-Drain</b> | <b>3.08</b>                 | <b>2.5</b>                   |
| MAX16023PTAS12+T        | Open-Drain        | 2.93                        | 1.2                          | MAX16024PTBT12+T        | Open-Drain        | 2.93                        | 1.2                          |
| MAX16023PTAS18+T        | Open-Drain        | 2.93                        | 1.8                          | MAX16024PTBT18+T        | Open-Drain        | 2.93                        | 1.8                          |
| <b>MAX16023PTAS25+T</b> | <b>Open-Drain</b> | <b>2.93</b>                 | <b>2.5</b>                   | MAX16024PTBT25+T        | Open-Drain        | 2.93                        | 2.5                          |
| MAX16023PTAR12+T        | Open-Drain        | 2.63                        | 1.2                          | MAX16024PTBR12+T        | Open-Drain        | 2.63                        | 1.2                          |
| MAX16023PTAR18+T        | Open-Drain        | 2.63                        | 1.8                          | MAX16024PTBR18+T        | Open-Drain        | 2.63                        | 1.8                          |
| MAX16023PTAR25+T        | Open-Drain        | 2.63                        | 2.5                          | MAX16024PTBR25+T        | Open-Drain        | 2.63                        | 2.5                          |
| MAX16023PTAZ12+T        | Open-Drain        | 2.32                        | 1.2                          | MAX16024PTBZ12+T        | Open-Drain        | 2.32                        | 1.2                          |
| MAX16023PTAZ18+T        | Open-Drain        | 2.32                        | 1.8                          | MAX16024PTBZ18+T        | Open-Drain        | 2.32                        | 1.8                          |
| MAX16023PTAY12+T        | Open-Drain        | 2.19                        | 1.2                          | MAX16024PTBY12+T        | Open-Drain        | 2.19                        | 1.2                          |
| MAX16023PTAY18+T        | Open-Drain        | 2.19                        | 1.8                          | MAX16024PTBY18+T        | Open-Drain        | 2.19                        | 1.8                          |
| MAX16023PTAW12+T        | Open-Drain        | 1.67                        | 1.2                          | MAX16024PTBW12+T        | Open-Drain        | 1.67                        | 1.2                          |
| MAX16023PTAV12+T        | Open-Drain        | 1.575                       | 1.2                          | MAX16024PTBV12+T        | Open-Drain        | 1.575                       | 1.2                          |
| MAX16024PTBL+T          | Open-Drain        | 4.63                        | Adjustable                   | MAX16024LTBL+T          | Push-Pull         | 4.63                        | Adjustable                   |
| MAX16024PTBM+T          | Open-Drain        | 4.38                        | Adjustable                   | MAX16024LTBM+T          | Push-Pull         | 4.38                        | Adjustable                   |
| MAX16024PTBT+T          | Open-Drain        | 3.08                        | Adjustable                   | MAX16024LTBT+T          | Push-Pull         | 3.08                        | Adjustable                   |
| MAX16024PTBS+T          | Open-Drain        | 2.93                        | Adjustable                   | MAX16024LTBS+T          | Push-Pull         | 2.93                        | Adjustable                   |
| MAX16024PTBR+T          | Open-Drain        | 2.63                        | Adjustable                   | MAX16024LTBR+T          | Push-Pull         | 2.63                        | Adjustable                   |
| MAX16024PTBZ+T          | Open-Drain        | 2.32                        | Adjustable                   | MAX16024LTBZ+T          | Push-Pull         | 2.32                        | Adjustable                   |
| MAX16024PTBY+T          | Open-Drain        | 2.19                        | Adjustable                   | MAX16024LTBY+T          | Push-Pull         | 2.19                        | Adjustable                   |
| MAX16024PTBW+T          | Open-Drain        | 1.67                        | Adjustable                   | MAX16024LTBW+T          | Push-Pull         | 1.67                        | Adjustable                   |
| MAX16024PTBV+T          | Open-Drain        | 1.575                       | Adjustable                   | MAX16024LTBV+T          | Push-Pull         | 1.575                       | Adjustable                   |

Bold parts denote standard versions. Samples are generally available on standard versions.  
Contact factory for availability of nonstandard versions.

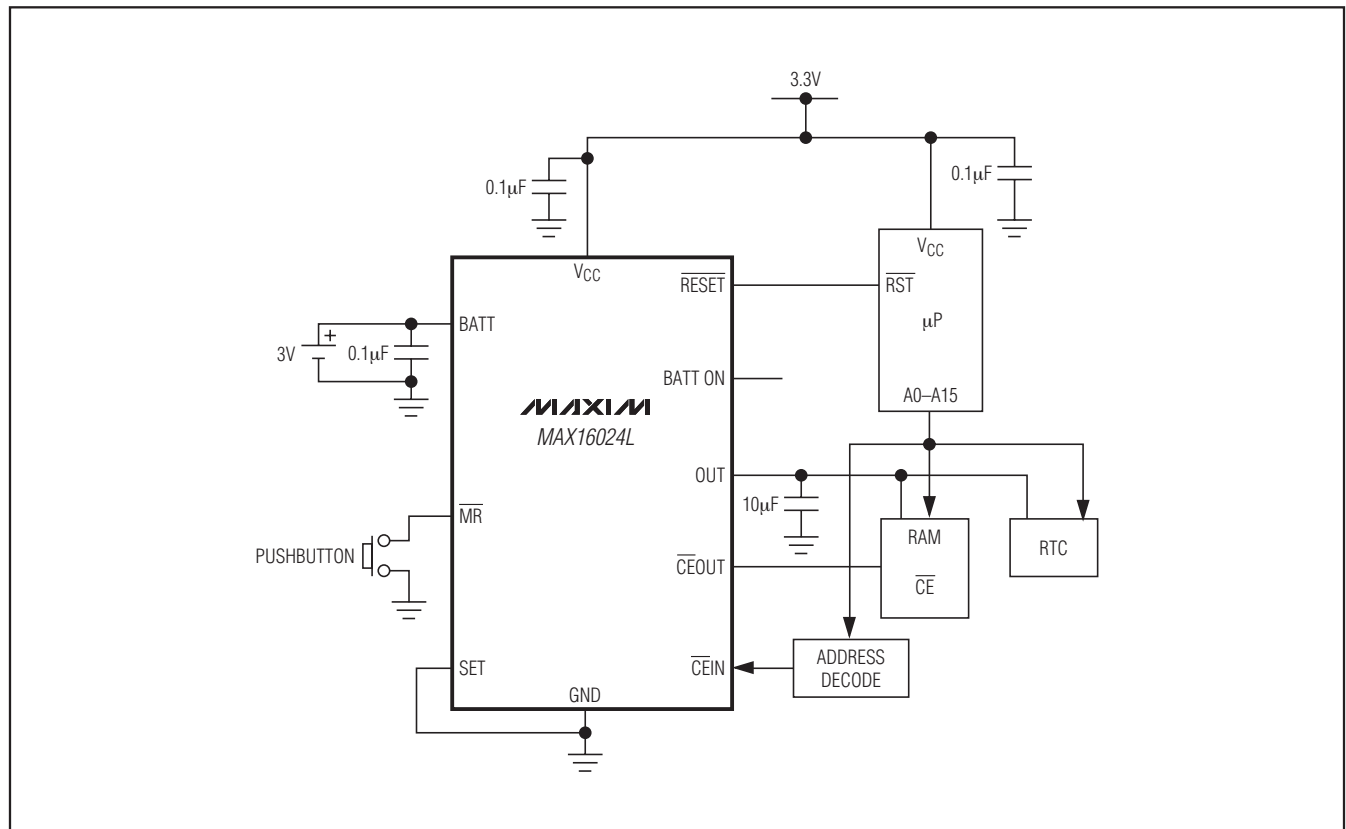
MAX16023/MAX16024

# Battery-Backup Circuits with Regulated Output Voltage

## Selector Guide

| PART      | OUTPUTS<br>(RESET, PFO,<br>BATT ON ) | RESET | MR | POWER-FAIL<br>COMPARATOR | CE<br>GATE | BATT ON | REGULATOR<br>OUTPUT VOLTAGE |
|-----------|--------------------------------------|-------|----|--------------------------|------------|---------|-----------------------------|
| MAX16023L | Push-Pull                            | √     | √  | √                        | —          | —       | Fixed                       |
| MAX16023P | Open Drain                           | √     | √  | √                        | —          | —       | Fixed                       |
| MAX16024L | Push-Pull                            | √     | √  | —                        | √          | √       | Fixed/adjustable            |
| MAX16024P | Open Drain                           | √     | √  | —                        | √          | √       | Fixed/adjustable            |

## Typical Applications Circuit





# Battery-Backup Circuits with Regulated Output Voltage

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO.            |
|--------------|--------------|-------------------------|
| 8 TDFN       | T833-2       | <a href="#">21-0137</a> |
| 10 TDFN      | T1033-1      | <a href="#">21-0137</a> |

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