

## FEATURES

- *Guaranteed* Reset Assertion at  $V_{CC} = 1V$
- 1.5mA Maximum Supply Current
- Fast (35ns Max.) Onboard Gating of RAM Chip Enable Signals
- Conditional Battery Backup Extends Battery Life
- 4.65V Precision Voltage Monitor
- Power OK/Reset Time Delay: 200ms
- External Reset Control
- Minimum External Component Count
- 1 $\mu$ A Maximum Standby Current
- Voltage Monitor for Power Fail or Low Battery Warning
- Thermal Limiting
- Performance Specified Over Temperature
- All the LTC695 Features Plus Conditional Battery Backup and External Reset Control

## APPLICATIONS

- Critical  $\mu$ P Power Monitoring
- Intelligent Instruments
- Battery-Powered Computers and Controllers
- Automotive Systems

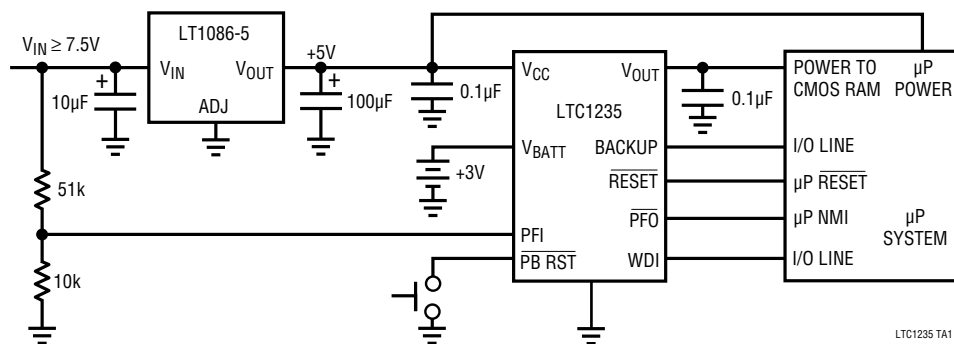
## DESCRIPTION

The LTC1235 provides complete power supply monitoring and battery control functions for microprocessor reset, battery backup, RAM write protection, power failure warning and watchdog timing. The LTC1235 has all the LTC695 features plus conditional battery backup and external reset control. When an out-of-tolerance power supply condition occurs, the reset outputs are forced to active states and the Chip Enable output write-protects external memory. The RESET output is guaranteed to remain logic low with  $V_{CC}$  as low as 1V. External reset control is provided by a debounced push-button reset input.

The LTC1235 powers the active CMOS RAMs with a charge pumped NMOS power switch to achieve low dropout and low supply current. When primary power is lost, auxiliary power, connected to the battery input pin, provides backup power to the RAMs. The LTC1235 can be programmed by a  $\mu$ P signal to either back up the RAMs or not. This extends the battery life in situations where RAM data need not always be saved when power goes down.

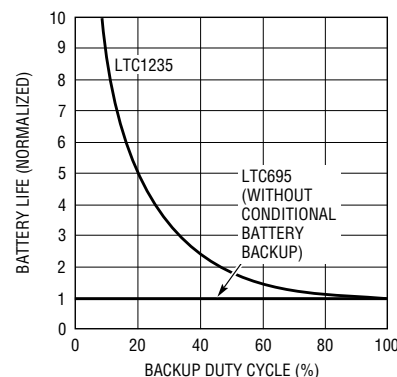
For an early warning of impending power failure, the LTC1235 provides an internal comparator with a user-defined threshold. An internal watchdog timer is also available, which forces the reset pins to active states when the watchdog input is not toggled prior to the time-out period.

## TYPICAL APPLICATION



THE LTC1235 EXTENDS BATTERY LIFE BY PROVIDING BATTERY POWER ONLY WHEN REQUIRED TO BACK UP RAM DATA. IT SAVES THE BATTERY WHEN NO DATA BACKUP IS NEEDED. THE  $\mu$ P REQUESTS BACKUP WITH THE BACKUP PIN.

Battery Life vs  
Backup Duty Cycle



# LTC1235

## ABSOLUTE MAXIMUM RATINGS (Notes 1 and 2)

Terminal Voltage	$V_{CC}$ ..... -0.3V to 6.0V	$V_{OUT}$ Output Current ..... Short Circuit Protected
	$V_{BATT}$ ..... -0.3V to 6.0V	Power Dissipation ..... 500mW
	All Other Inputs ..... -0.3V to ( $V_{CC} + 0.3V$ )	Operating Temperature Range
Input Current	$V_{CC}$ ..... 200mA	LTC1235C ..... 0°C to 70°C
	$V_{BATT}$ ..... 50mA	Storage Temperature Range ..... -65°C to 150°C
		Lead Temperature (Soldering, 10 sec.) ..... 300°C

## PACKAGE/ORDER INFORMATION (Note 3)

<p>N PACKAGE 16-LEAD PLASTIC DIP <math>T_{JMAX} = 110^{\circ}C, \theta_{JA} = 130^{\circ}C/W</math></p>	ORDER PART NUMBER	<p>S PACKAGE 16-LEAD PLASTIC SOL <math>T_{JMAX} = 110^{\circ}C, \theta_{JA} = 130^{\circ}C/W</math> CONDITIONS: PCB MOUNT ON FR4 MATERIAL, STILL AIR AT 25°C, COPPER TRACE</p>	ORDER PART NUMBER
	LTC1235CN		LTC1235CS

## PRODUCT SELECTION GUIDE

	PINS	RESET	WATCHDOG TIMER	BATTERY BACKUP	POWER FAIL WARNING	RAM WRITE PROTECT	PUSH-BUTTON RESET	CONDITIONAL BATTERY BACKUP
LTC1235	16	X	X	X	X	X	X	X
LTC690	8	X	X	X	X			
LTC691	16	X	X	X	X	X		
LTC694	8	X	X	X	X			
LTC695	16	X	X	X	X	X		
LTC699	8	X	X					
LTC1232	8	X	X				X	

## ELECTRICAL CHARACTERISTICS

$V_{CC}$  = Full Operating Range,  $V_{BATT} = 2.8V$ , Backup = No Connection,  $T_A = 25^\circ C$ , unless otherwise noted.

PARAMETER	CONDITONS	MIN	TYP	MAX	UNITS	
<b>Battery Backup Switching</b>						
Operating Voltage Range $V_{CC}$ $V_{BATT}$		4.75 2.00		5.50 4.25	V	
$V_{OUT}$ Output Voltage	$I_{OUT} = 1mA$	$V_{CC} - 0.05$ $V_{CC} - 0.1$	$V_{CC} - 0.005$ $V_{CC} - 0.005$		V	
	$I_{OUT} = 50mA$	$V_{CC} - 0.5$	$V_{CC} - 0.25$			
BACKUP Input Threshold	$V_{CC} >$ Reset Voltage Threshold Logic Low Logic High	2.0		0.8	V	
BACKUP Pullup Current (Note 4)			3		$\mu A$	
$V_{OUT}$ in Battery Backup Mode (Note 5)	$I_{OUT} = 250\mu A$ , $V_{CC} < V_{BATT}$	$V_{BATT} - 0.1$	$V_{BATT} - 0.02$		V	
$V_{OUT}$ in Battery Saving Mode (Note 5)	$V_{CC} < V_{BATT}$ 1M $\Omega$ Pulldown on $V_{OUT}$		0		V	
$V_{CC}$ Supply Current (excluding $I_{OUT}$ )	$I_{OUT} \leq 50mA$		0.6 0.6	1.5 2.5	mA	
Battery Supply Current in Battery Backup Mode and Battery Saving Mode (Note 5)	$V_{CC} = 0V$ , $V_{BATT} = 2.8V$		0.04 0.04	1 5	$\mu A$	
Battery Standby Current (+ = Discharge, - = Charge)	$5.5 > V_{CC} > V_{BATT} + 0.2V$	-0.1 -1.0		+0.02 +0.10	$\mu A$	
Battery Switchover Threshold $V_{CC} - V_{BATT}$	Power Up		70		mV	
	Power Down		50			
Battery Switchover Hysteresis			20		mV	
BATT ON Output Voltage (Note 6)	$I_{SINK} = 3.2mA$			0.4	V	
BATT ON Output Short Circuit Current (Note 6)	BATT ON = $V_{OUT}$ Sink Current BATT ON = 0V Source Current		35		mA	
		0.5	1	25	$\mu A$	
<b>Push-Button Reset</b>						
PB RST Input Threshold	Logic Low Logic High	2.0		0.8	V	
PB RST Input Low Time (Notes 4, 7)		40			ms	
<b>Reset and Watchdog Timer</b>						
Reset Voltage Threshold		4.5	4.65	4.75	V	
Reset Threshold Hysteresis			40		mV	
Reset Active Time	$V_{CC} = 5V$		160 140	200 200	240 280	ms
Watchdog Time-out Period	$V_{CC} = 5V$		1.2 1.0	1.6 1.6	2.00 2.25	sec
Reset Active Time PSRR			1		ms/V	
Watchdog Time-out Period PSRR			8		ms/V	
Minimum WDI Input Pulse Width	$V_{IL} = 0.4V$ , $V_{IH} = 3.5V$	200			ns	
RESET Output Voltage At $V_{CC} = 1V$	$I_{SINK} = 10\mu A$ , $V_{CC} = 1V$		4	200	mV	
RESET and LOW LINE Output Voltage (Note 6)	$I_{SINK} = 1.6mA$ , $V_{CC} = 4.25V$ $I_{SOURCE} = 1\mu A$ , $V_{CC} = 5V$	3.5		0.4	V	

## ELECTRICAL CHARACTERISTICS

$V_{CC}$  = Full Operating Range,  $V_{BATT} = 2.8V$ , Backup = No Connection,  $T_A = 25^\circ C$ , unless otherwise noted.

PARAMETER	CONDITONS		MIN	TYP	MAX	UNITS
RESET and $\overline{WDO}$ Output Voltage (Note 6)	$I_{SINK} = 1.6mA$ , $V_{CC} = 5V$ $I_{SOURCE} = 1\mu A$ , $V_{CC} = 4.25V$		3.5		0.4	V
RESET, $\overline{RESET}$ , $\overline{WDO}$ , LOW LINE Output Short Circuit Current (Note 6)	Output Source Current Output Sink Current		1	3 25	25	$\mu A$ mA
WDI Input Threshold	Logic Low Logic High		2.0		0.8	V
WDI Input Current	$WDI = V_{OUT}$ $WDI = 0V$	● ●	-50	4 -8	50	$\mu A$
<b>Power Fail Detector</b>						
PFI Input Threshold	$V_{CC} = 5V$	●	1.25	1.3	1.35	V
PFI Input Threshold PSRR				0.3		mV/V
PFI Input Current				$\pm 0.01$	$\pm 25$	nA
$\overline{PFO}$ Output Voltage (Note 6)	$I_{SINK} = 3.2mA$ $I_{SOURCE} = 1\mu A$		3.5		0.4	V
$\overline{PFO}$ Short Circuit Source Current (Note 6)	PFI = HIGH, $\overline{PFO} = 0V$ PFI = LOW, $\overline{PFO} = V_{OUT}$		1	3 30	25	$\mu A$ mA
PFI Comparator Response Time (falling)	$\Delta V_{IN} = -20mV$ , $V_{OD} = 15mV$			2		$\mu s$
PFI Comparator Response Time (rising) (Note 6)	$\Delta V_{IN} = 20mV$ , $V_{OD} = 15mV$ with $10k\Omega$ Pullup			40 8		$\mu s$
<b>Chip Enable Gating</b>						
$\overline{CE}$ IN Threshold	$V_{IL}$ $V_{IH}$		2.0		0.8	V
$\overline{CE}$ IN Pullup Current (Note 4)				3		$\mu A$
$\overline{CE}$ OUT Output Voltage	$I_{SINK} = 3.2mA$ $I_{SOURCE} = 3.0mA$ $I_{SOURCE} = 1\mu A$ , $V_{CC} = 0V$		$V_{OUT} - 1.50$ $V_{OUT} - 0.05$		0.4	V
$\overline{CE}$ Propagation Delay	$V_{CC} = 5V$ , $C_L = 20pF$	●		20 20	35 45	ns
$\overline{CE}$ OUT Output Short Circuit Current	Output Source Current Output Sink Current			30 35		mA

The ● denotes specifications which apply over the operating temperature range.

**Note 1:** Absolute maximum ratings are those values beyond which the life of device may be impaired.

**Note 2:** All voltage values are with respect to GND.

**Note 3:** For military temperature range parts, consult the factory.

**Note 4:** The input pins of  $\overline{PB}$  RST, BACKUP and  $\overline{CE}$  IN, have weak internal pullups which pull to the supply when the input pins are floating.

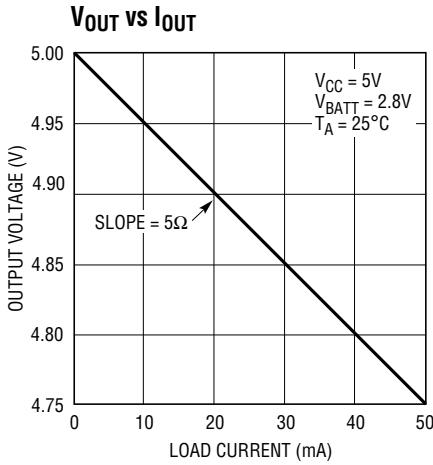
**Note 5:** The LTC1235 can be programmed either to provide or not to provide battery backup power to the  $V_{OUT}$  pin during power failure. The power down condition of  $V_{OUT}$  is selected by the logic level of the BACKUP pin which is latched internally when  $V_{CC}$  falls through the reset voltage threshold. If the latched logic level of the BACKUP pin is high,  $V_{OUT}$  will be

in Battery Backup Mode and will be switched to  $V_{BATT}$  when  $V_{CC}$  falls below  $V_{BATT}$ . If the latched logic level of the BACKUP pin is low,  $V_{OUT}$  will be in Battery Saving Mode when  $V_{CC}$  falls below  $V_{BATT}$ .

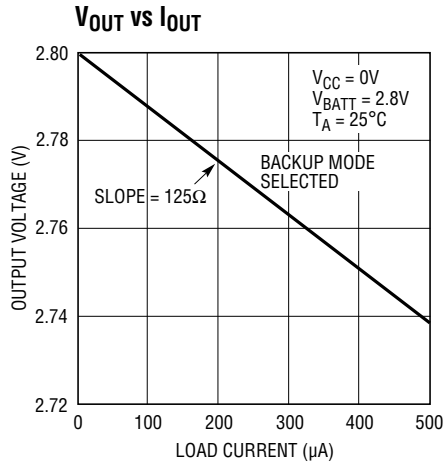
**Note 6:** The output pins of BATT ON, LOW LINE,  $\overline{PFO}$ ,  $\overline{WDO}$ ,  $\overline{RESET}$  and  $\overline{RESET}$  have weak internal pullups of typically  $3\mu A$ . However, external pullup resistors may be used when higher speed is required.

**Note 7:** The push-button reset input requires an active low signal. Internally, this input signal is debounced and timed for a minimum of 40ms. When this condition is satisfied, the reset outputs go to the active states. The reset outputs will remain in active states for a minimum of 140ms from the moment the push-button reset input is released from logic low level.

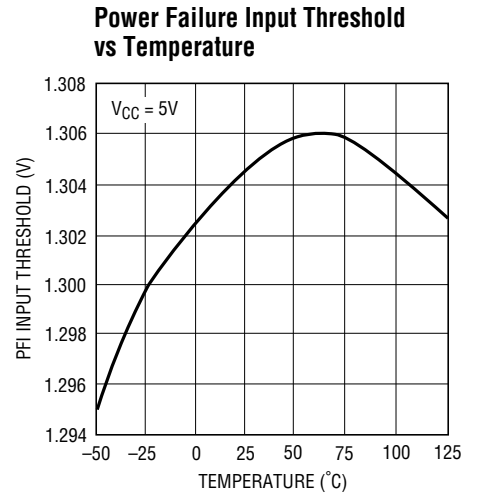
# TYPICAL PERFORMANCE CHARACTERISTICS



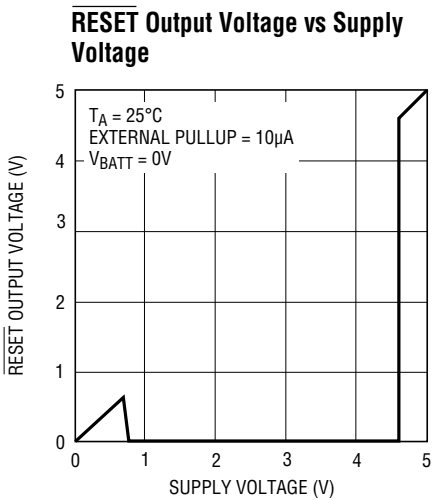
LTC1235 G01



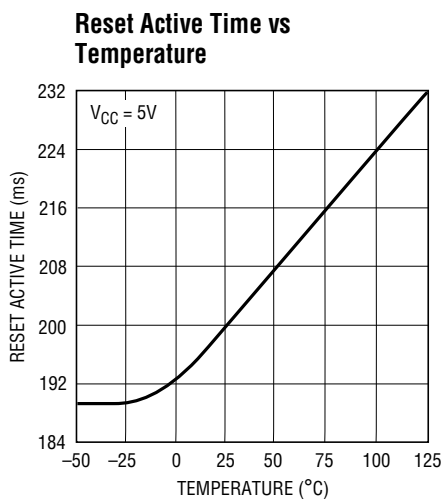
LTC1235 G02



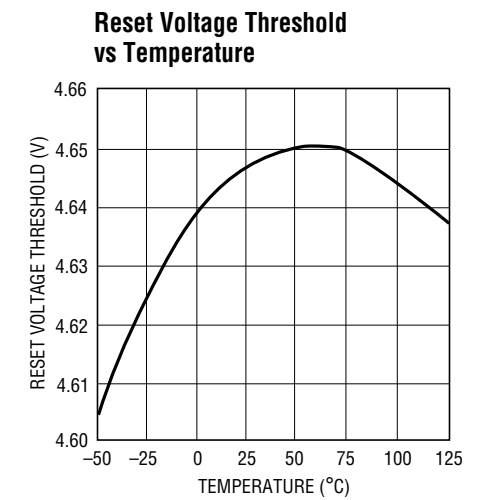
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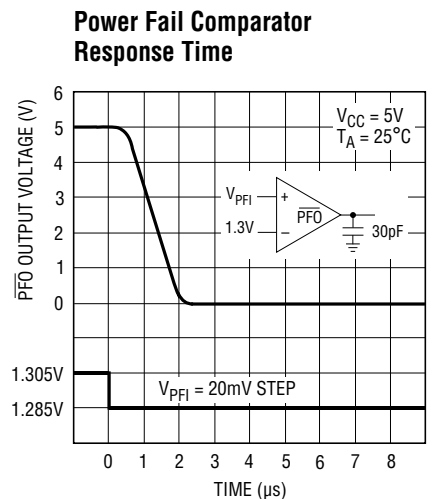
LTC1235 G04



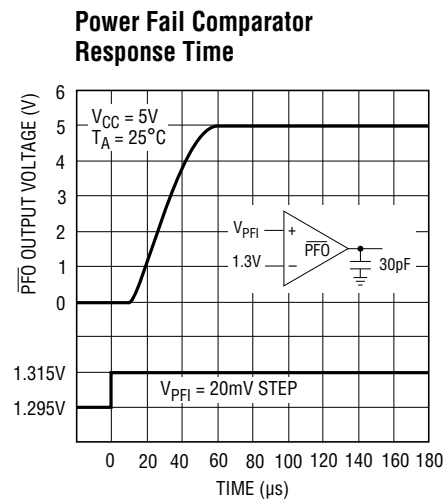
LTC1235 G05



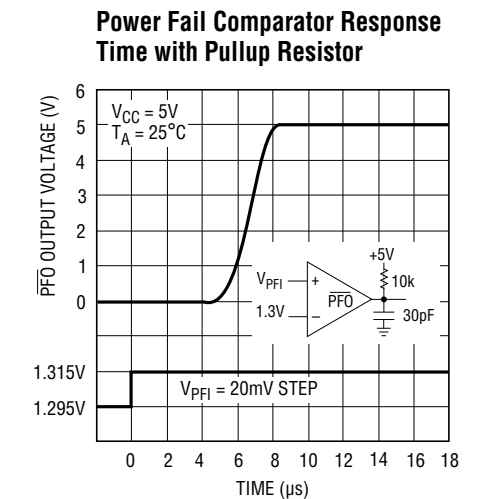
LTC1235 G06



LTC1235 G07



LTC1235 G08



LTC1235 G09

## PIN FUNCTIONS

**V<sub>CC</sub>**: +5V supply input. The V<sub>CC</sub> pin should be bypassed with a 0.1μF capacitor.

**Backup**: Logic input to control the PMOS switch, M2, when V<sub>CC</sub> is lower than V<sub>BATT</sub>. While V<sub>CC</sub> is falling through the reset voltage threshold, the status of the BACKUP pin (logic low or logic high) is latched in Memory Logic and used to turn on or off M2 when V<sub>CC</sub> is below V<sub>BATT</sub>. If the latched status of the BACKUP pin is high, the Memory Logic turns on M2 when V<sub>CC</sub> falls to 50mV greater than V<sub>BATT</sub>. If the latched status of the BACKUP pin is low, the Memory Logic keeps M2 off even after V<sub>CC</sub> falls below V<sub>BATT</sub>. If the BACKUP pin is left floating it will be pulled high by an internal pullup and the LTC1235 will provide battery backup when V<sub>CC</sub> falls.

**V<sub>OUT</sub>**: Voltage output for backed up memory. Bypass with a capacitor of 0.1μF or greater. During normal operation, V<sub>OUT</sub> obtains power from V<sub>CC</sub> through an NMOS power switch, M1, which can deliver up to 50mA and has a typical on resistance of 5Ω. When V<sub>CC</sub> is lower than V<sub>BATT</sub>, the status of the BACKUP pin stored in Memory Logic controls M2. If the status is high, the Memory Logic turns on M2 and V<sub>OUT</sub> is internally switched to V<sub>BATT</sub> through M2. If the status is low, the Memory Logic keeps M2 off and V<sub>OUT</sub> is in Battery Saving Mode. If V<sub>OUT</sub> and V<sub>BATT</sub> are not used, connect V<sub>OUT</sub> to V<sub>CC</sub>.

**V<sub>BATT</sub>**: Backup battery input. When V<sub>CC</sub> falls below V<sub>BATT</sub>, the status of the BACKUP pin stored in the Memory Logic controls M2. If the status is high, auxiliary power, connected to V<sub>BATT</sub> is delivered to V<sub>OUT</sub> through M2. If the status is low, the Memory Logic keeps M2 off and V<sub>OUT</sub> is in Battery Saving Mode. If backup battery or auxiliary power is not used, V<sub>BATT</sub> should be connected to GND.

**GND**: Ground pin.

**BATT ON**: Battery on logic output from comparator C2. BATT ON goes low when V<sub>OUT</sub> is internally connected to V<sub>CC</sub>. The output typically sinks 35mA and can provide base drive for an external PNP transistor to increase the output current above the 50mA rating of V<sub>OUT</sub>. BATT ON goes high when V<sub>CC</sub> falls below V<sub>BATT</sub>, if the status of the BACKUP pin stored in Memory Logic is high and V<sub>OUT</sub> is switched to V<sub>BATT</sub>.

**PFI**: Power Failure Input. PFI is the noninverting input to the Power Fail Comparator, C3. The inverting input is internally connected to a 1.3V reference. The Power Failure Output remains high when PFI is above 1.3V and goes low when PFI is below 1.3V. Connect PFI to GND or V<sub>OUT</sub> when C3 is not used.

**PFO**: Power Failure Output from C3. PFO remains high when PFI is above 1.3V and goes low when PFI is below 1.3V. When V<sub>CC</sub> is lower than V<sub>BATT</sub>, C3 is shut down and PFO is forced low.

**PB RST**: Logic input for direct connection to a push-button. The push-button reset input requires an active low signal. Internally, this input signal is debounced and timed for a minimum of 40ms. When this condition is satisfied, the reset pulse generator forces  $\overline{\text{RESET}}$  to active low. The  $\overline{\text{RESET}}$  signal will remain active low for a minimum of 140ms from the moment the push-button reset input is released from logic low level.

**RESET**: Logic output for μP reset control. The LTC1235 provides three ways to generate μP reset. First, whenever V<sub>CC</sub> falls below either the reset voltage threshold (4.65V, typically) or V<sub>BATT</sub>,  $\overline{\text{RESET}}$  goes active low. After V<sub>CC</sub> returns to 5V, the reset pulse generator forces  $\overline{\text{RESET}}$  to remain active low for a minimum of 140ms. Second, when the watchdog timer is enabled but not serviced prior to the time-out period, the reset pulse generator also forces  $\overline{\text{RESET}}$  to active low for a minimum of 140ms for every time-out period (see Figure 11). Third, when the PB RST pin stays active low for a minimum of 40ms,  $\overline{\text{RESET}}$  is forced low by reset pulse generator. The  $\overline{\text{RESET}}$  signal will remain active low for a minimum of 140ms from the moment the push-button reset input is released from logic low level.

**RESET**: RESET is an active high logic output. It is the inverse of  $\overline{\text{RESET}}$ .

**LOW LINE**: Logic output from comparator C1.  $\overline{\text{LOW LINE}}$  indicates a low line condition at the V<sub>CC</sub> input. When V<sub>CC</sub> falls below the reset voltage threshold (4.65V typically),  $\overline{\text{LOW LINE}}$  goes low. As soon as V<sub>CC</sub> rises above the reset voltage threshold,  $\overline{\text{LOW LINE}}$  returns high (see Figure 1).  $\overline{\text{LOW LINE}}$  goes low when V<sub>CC</sub> drops below V<sub>BATT</sub> (see Table 1).

## PIN FUNCTIONS

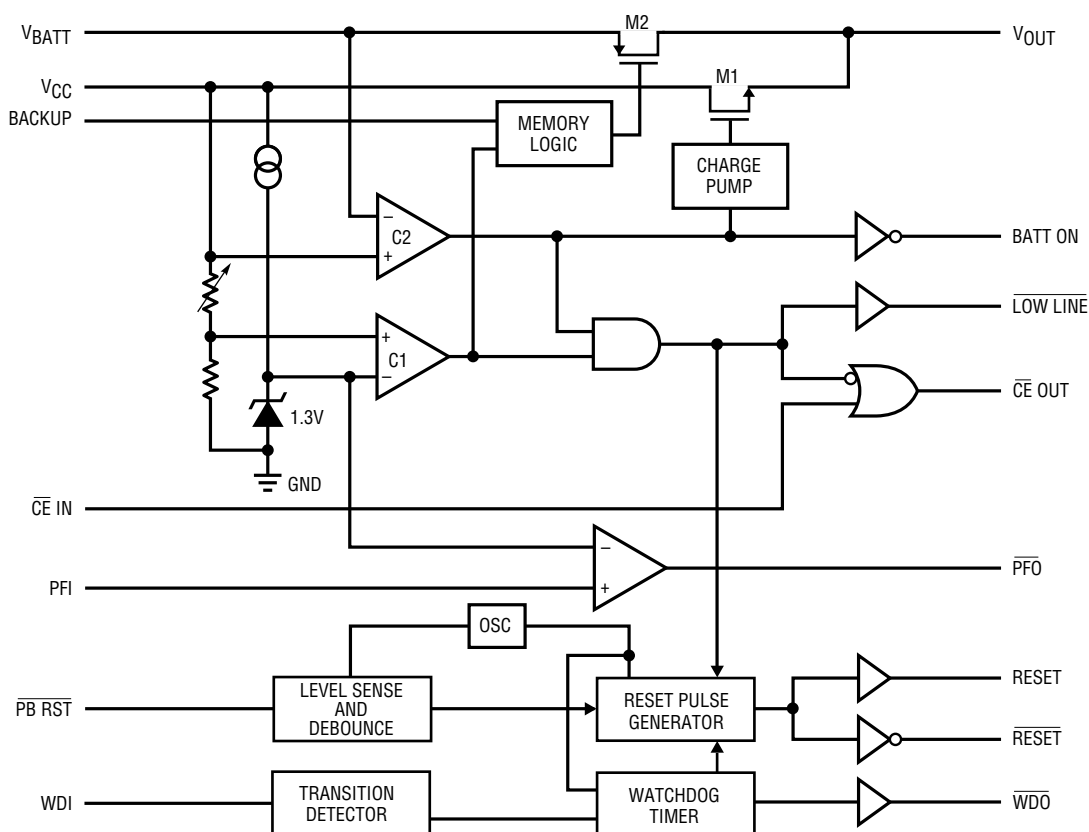
**WDI:** Watchdog Input, WDI, is a three level input. Driving WDI either high or low for longer than the watchdog time-out period, forces both  $\overline{\text{RESET}}$  and  $\overline{\text{WDO}}$  low. Floating WDI disables the Watchdog Timer. The timer resets itself with each transition of the Watchdog Input (see Figure 11).

**WDO:** Watchdog logic output. When the watchdog input remains either high or low for longer than the watchdog time-out period,  $\overline{\text{WDO}}$  goes low.  $\overline{\text{WDO}}$  is set high whenever there is a transition on the WDI pin, or  $\overline{\text{LOW LINE}}$  goes low. The watchdog timer can be disabled by floating WDI (see Figure 11).

**$\overline{\text{CE IN}}$ :** Logic input to the  $\overline{\text{Chip Enable}}$  gating circuit.  $\overline{\text{CE IN}}$  can be derived from microprocessor's address line and/or decoder output. See Applications Information Section and Figure 6 for additional information.

**$\overline{\text{CE OUT}}$ :** Logic output from the  $\overline{\text{Chip Enable}}$  gating circuit. When  $V_{\text{CC}}$  is above the reset voltage threshold,  $\overline{\text{CE OUT}}$  is a buffered replica of  $\overline{\text{CE IN}}$ . When  $V_{\text{CC}}$  is below the reset voltage threshold  $\overline{\text{CE OUT}}$  is forced high (see Figure 6).

## BLOCK DIAGRAM



LTC1235 BD

## APPLICATIONS INFORMATION

### Power Monitoring

The LTC1235 uses a bandgap voltage reference and a precision voltage comparator C1 to monitor the 5V supply input on  $V_{CC}$  (see BLOCK DIAGRAM). When  $V_{CC}$  falls below the reset voltage threshold, the reset outputs are forced to active states. The reset voltage threshold accounts for a 5% variation on  $V_{CC}$ , so the reset outputs become active when  $V_{CC}$  falls below 4.75V (4.65V typical). On power-up, the reset signals are held active states for a minimum of 140ms after the reset voltage threshold is reached to allow the power supply and microprocessor to stabilize. On power-down, the  $\overline{\text{RESET}}$  signal remains active low even with  $V_{CC}$  as low as 1V. This capability helps hold the microprocessor in stable shutdown condition. Figure 1 shows the timing diagram of the  $\overline{\text{RESET}}$  signal.

The precision voltage comparator, C1, typically has 40mV of hysteresis which ensures that glitches at  $V_{CC}$  pin do not activate the reset outputs. Response time is typically 10 $\mu$ s.

To help prevent mistriggering due to transient loads,  $V_{CC}$  pin should be bypassed with a 0.1 $\mu$ F capacitor with the leads trimmed as short as possible.

$\overline{\text{LOW LINE}}$  is the output of the precision voltage comparator C1. When  $V_{CC}$  falls below the reset voltage threshold,  $\overline{\text{LOW LINE}}$  goes low.  $\overline{\text{LOW LINE}}$  returns high as soon as  $V_{CC}$  rises above the reset voltage threshold.

### Push-Button Reset

The LTC1235 provides an logic input pin for direct connection to a push-button. The push-button reset input,  $\overline{\text{PB RST}}$ , requires an active low signal. Internally, this input signal is debounced and timed for a minimum of 40ms. When this condition is satisfied, the reset pulse generator forces the reset outputs to active states. The reset signals will remain in active states for a minimum of 140ms from the moment the push-button reset input is released from logic low level (Figure 2).

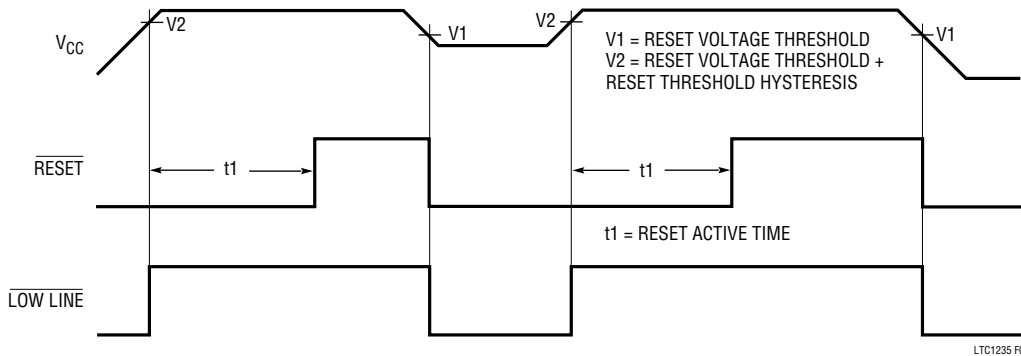


Figure 1. Reset Active Time

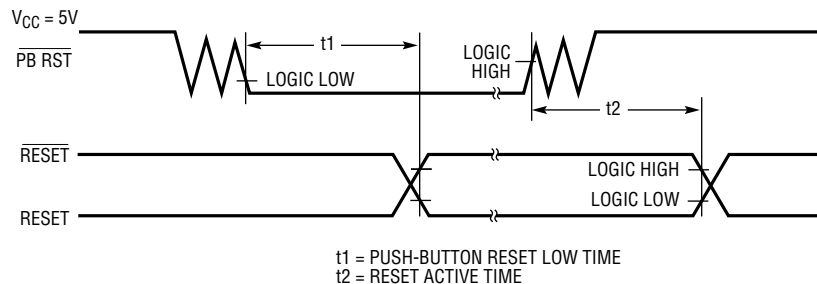


Figure 2. Push-Button Reset



## APPLICATIONS INFORMATION

### Voltage Output

During normal operation, the LTC1235 uses a charge pumped NMOS power switch to achieve low dropout and low supply current. This power switch can deliver up to 50mA to  $V_{OUT}$  from  $V_{CC}$  and has a typical on resistance of  $5\Omega$ . The  $V_{OUT}$  pin should be bypassed with a capacitor of  $0.1\mu\text{F}$  or greater to ensure stability. Use of a larger bypass capacitor is advantageous for supplying current to heavy transient loads.

When operating currents larger than 50mA are required from  $V_{OUT}$ , or a lower dropout ( $V_{CC} - V_{OUT}$  voltage differential) is desired, the LTC1235 provides BATT ON output to drive the base of external PNP transistor (Figure 3). Another alternative to provide higher current is to connect a high current Schottky diode from the  $V_{CC}$  pin to the  $V_{OUT}$  pin to supply the extra current.

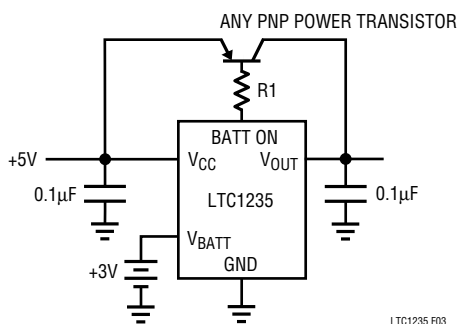


Figure 3. Using BATT ON to Drive External PNP Transistor

The LTC1235 is protected for safe area operation with short circuit limit. Output current is limited to approximately 200mA. If the device is overloaded for a long period of time, thermal shutdown turns the power switch off until the device cools down. The threshold temperature for thermal shutdown is approximately  $155^{\circ}\text{C}$  with about  $10^{\circ}\text{C}$  of hysteresis which prevents the device from oscillating in and out of shutdown.

The PNP switch was not chosen for the internal power switch because it injects unwanted current into the substrate. This current is collected by the  $V_{BATT}$  pin in competitive devices and adds to the charging current of the battery which can damage lithium batteries. LTC1235

uses a charge pumped NMOS power switch to eliminate unwanted charging current while achieving low dropout and low supply current. Since no current goes to the substrate, the current collected by  $V_{BATT}$  pin is strictly junction leakage.

### Conditional Battery Backup

LTC1235 provides an unique feature to either allow  $V_{OUT}$  to be switched to  $V_{BATT}$  or to disable the CMOS RAM battery backup function when primary power is lost. Disabling the battery backup function is useful in conserving the backup battery's life when the SRAM doesn't need battery backup during long term storage of a computer system, or delivery of the computer system to the end user.

The BACKUP pin (Pin 8) is used to serve this feature on power-down. When  $V_{CC}$  is falling through the reset voltage threshold, the status of the BACKUP pin (logic low or logic high) is stored in the Memory Logic (see BLOCK DIAGRAM). If the stored status is logic high and  $V_{CC}$  fall to 50mV greater than  $V_{BATT}$ , a  $125\Omega$  PMOS switch, M2, connects the  $V_{BATT}$  input to  $V_{OUT}$  and the battery switchover comparator, C2, shuts off the NMOS power switch, M1. M2 is designed for very low dropout voltage (input-to-output differential). This feature is advantageous for low current applications such as battery backup in CMOS RAM and other low power CMOS circuitry. If the stored status is logic low and  $V_{CC}$  falls to 50mV greater than  $V_{BATT}$ , the Memory Logic keeps M2 off and C2 shuts off M1.  $V_{OUT}$  is in Battery Saving Mode (see Figure 4). The supply current in both mode is  $1\mu\text{A}$  maximum.

On power-ups, C2 keeps M1 off before  $V_{CC}$  reaches 70mV higher than  $V_{BATT}$ . On the first power-up after the battery is replaced (with power off), the status stored in the Memory Logic is undetermined.  $V_{OUT}$  could be either in Battery Backup Mode or in Battery Saving Mode. When  $V_{CC}$  is 70mV greater than  $V_{BATT}$ , M1 connects  $V_{OUT}$  to  $V_{CC}$ . C2 has typically 20mV of hysteresis to prevent spurious switching when  $V_{CC}$  remains nearly equal to  $V_{BATT}$  and the status stored in the Memory Logic is high. The response time of C2 is approximately  $20\mu\text{s}$ .

## APPLICATIONS INFORMATION

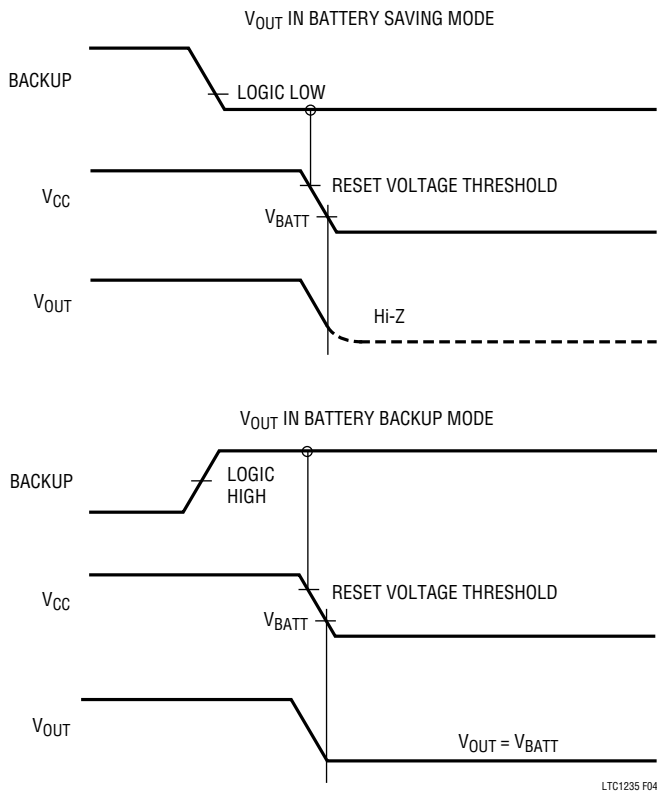


Figure 4. Conditional Battery Backup Operation

The operating voltage at the  $V_{BATT}$  pin ranges from 2.0V to 4.25V. High value capacitors, such as electrolytic or farad-size double layer capacitors, can be used for short term memory backup instead of a battery. For capacitor backup, see Typical Applications. The charging resistor for recharging rechargeable batteries should be connected to  $V_{OUT}$  through a diode since this eliminates the discharge path that exists when  $V_{CC}$  collapses and RAM is not backed up (Figure 5).

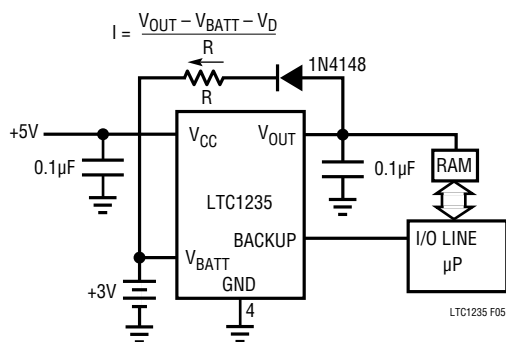


Figure 5. Charging External Battery Through  $V_{OUT}$

### Replacing the Backup Battery with Power On

When changing the backup battery with system power on, spurious resets can occur while battery is removed due to battery standby current. Although battery standby current is only a tiny leakage current, it can still charge up the stray capacitance on the  $V_{BATT}$  pin. The oscillation cycle is as follows: When  $V_{BATT}$  reaches within 50mV of  $V_{CC}$ , the LTC1235 switches to battery backup or battery saving mode. In either case, the battery supply current pulls  $V_{BATT}$  low and the device goes back to normal operation. The leakage current then charges up the  $V_{BATT}$  pin again and the cycle repeats.

If spurious resets during battery replacement pose no problems, then no action is required. Otherwise, two methods can be used to eliminate this problem. First, a capacitor from  $V_{BATT}$  to GND will allow time for battery replacement by slowing the charge rate. For example, the battery standby current is  $1\mu A$  maximum over temperature and the external capacitor required to slow the charge rate is:

$$C_{EXT} \geq T_{REQ'D} \left( \frac{1\mu A}{V_{CC} - V_{BATT}} \right)$$

where  $T_{REQ'D}$  is the maximum time required to replace the backup battery. With  $V_{CC} = 4.5V$ ,  $V_{BATT} = 3V$  and  $T_{REQ'D} = 3$  sec, the value for external capacitor is  $2\mu F$ . Second, a resistor from  $V_{BATT}$  to GND will hold the pin low while changing the battery. For example, the battery standby current is  $1\mu A$  maximum over temperature and the external resistor required to hold  $V_{BATT}$  below  $V_{CC}$  is:

$$R \leq \frac{V_{CC} - 50mV}{1\mu A}$$

With  $V_{CC} = 4.5V$ , a  $4.3M\Omega$  resistor will work. With a 3V battery, this resistor will draw only  $0.7\mu A$  from the battery, which is negligible in most cases.

If the battery connections are made with long wires or PC traces, inductive spikes can be generated during battery replacement. Even if a resistor is used to prevent spurious resets as described above, these spikes can take the  $V_{BATT}$  pin below GND violating the LTC1235 absolute maximum ratings. A  $0.1\mu F$  capacitor from  $V_{BATT}$  to GND is recommended to eliminate these potential spikes when battery replacement is made through long wires.

## APPLICATIONS INFORMATION

Table 1 shows the state of each pin during battery backup. If the backup battery is not used, connect  $V_{BATT}$  to GND and  $V_{OUT}$  to  $V_{CC}$ .

**Table 1. Input and Output Status in Battery Backup Mode**

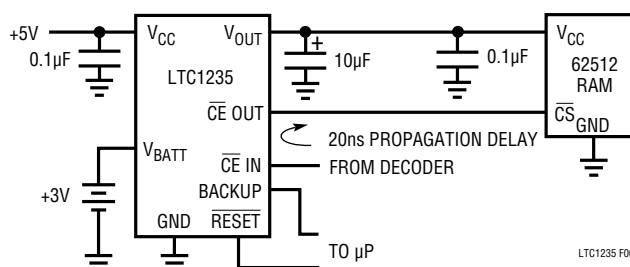
SIGNAL	STATUS
$V_{CC}$	C2 monitors $V_{CC}$ for active switchover.
BACKUP	BACKUP is ignored.
$V_{OUT}$	$V_{OUT}$ is connected to $V_{BATT}$ through an internal PMOS switch.
$V_{BATT}$	The supply current is 1 $\mu$ A maximum.
BATT ON	Logic high. The open circuit output voltage is equal to $V_{OUT}$ .
PFI	Power Failure Input is ignored.
$\overline{PFO}$	Logic low
$\overline{PB RST}$	$\overline{PB RST}$ is ignored.
$\overline{RESET}$	Logic low
RESET	Logic high. The open circuit output voltage is equal to $V_{OUT}$ .
$\overline{LOW LINE}$	Logic low
WDI	Watchdog Input is ignored.
$\overline{WDO}$	Logic high. The open circuit output voltage is equal to $V_{OUT}$ .
$\overline{CE IN}$	Chip Enable Input is ignored.
$\overline{CE OUT}$	Logic high. The open circuit output voltage is equal to $V_{OUT}$ .

### Memory Protection

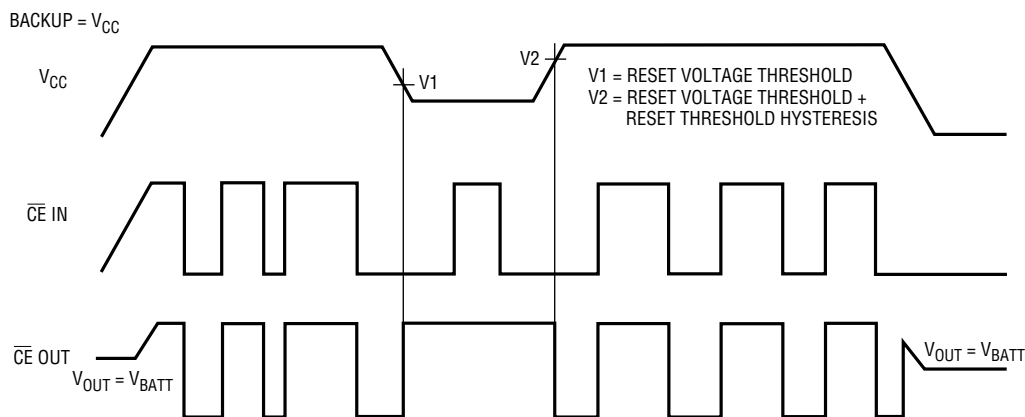
The LTC1235 includes memory protection circuitry which ensures the integrity of the data in memory by preventing write operations when  $V_{CC}$  is at invalid level. Two pins,  $\overline{CE}$

IN and  $\overline{CE OUT}$ , control the Chip Enable or Write inputs of CMOS RAM. When  $V_{CC}$  is +5V,  $\overline{CE OUT}$  follows  $\overline{CE IN}$  with a typical propagation delay of 20ns. When  $V_{CC}$  falls below the reset voltage threshold or  $V_{BATT}$ ,  $\overline{CE OUT}$  is forced high, independent of  $\overline{CE IN}$ .  $\overline{CE OUT}$  is an alternative signal to drive the  $\overline{CE}$ ,  $\overline{CS}$ , or Write input of battery-backed up CMOS RAM.  $\overline{CE OUT}$  can also be used to drive the Store or Write input of an EEPROM, EAROM or NOVRAM to achieve similar protection. Figure 6 shows the timing diagram of  $\overline{CE IN}$  and  $\overline{CE OUT}$ .

$\overline{CE IN}$  can be derived from the microprocessor's address decoder output. Figure 7 shows a typical nonvolatile CMOS RAM application.



**Figure 7. A Typical Nonvolatile CMOS RAM Application**



**Figure 6. Timing Diagram for  $\overline{CE IN}$  and  $\overline{CE OUT}$**

LTC1235 F06

## APPLICATIONS INFORMATION

### Power Fail Warning

The LTC1235 generates a Power Failure Output ( $\overline{\text{PFO}}$ ) for early warning of failure in the microprocessor's power supply. This is accomplished by comparing the Power Failure Input (PFI) with an internal 1.3V reference.  $\overline{\text{PFO}}$  goes low when the voltage at PFI pin is less than 1.3V. Typically PFI is driven by an external voltage divider (R1 and R2 in Figures 8 and 9) which senses either an unregulated DC input or a regulated 5V output. The voltage divider ratio can be chosen such that the voltage at PFI pin falls below 1.3V several milliseconds before the +5V supply falls below the maximum reset voltage threshold 4.75V.  $\overline{\text{PFO}}$  is normally used to interrupt the microprocessor to execute shut-down procedure between  $\overline{\text{PFO}}$  and  $\overline{\text{RESET}}$  or RESET.

The power fail comparator, C3, does not have hysteresis. Hysteresis can be added however, by connecting a resistor between the  $\overline{\text{PFO}}$  output and the noninverting PFI input pin as shown in Figures 8 and 9. The upper and lower trip points in the comparator are established as follows:

When  $\overline{\text{PFO}}$  output is low, R3 sinks current from the summing junction at the PFI pin.

$$V_H = 1.3V \left( 1 + \frac{R1}{R2} + \frac{R1}{R3} \right)$$

When  $\overline{\text{PFO}}$  output is high, the series combination of R3 and R4 source current into the PFI summing junction.

$$V_L = 1.3V \left( 1 + \frac{R1}{R2} - \frac{(5V - 1.3V)R1}{1.3V(R3 + R4)} \right)$$

Assuming  $R4 \ll R3$ ,  $V_{\text{HYSTERESIS}} = 5V \frac{R1}{R3}$

**Example 1:** The circuit in Figure 8 demonstrates the use of the power fail comparator to monitor the unregulated power supply input. Assuming the the rate of decay of the supply input  $V_{\text{IN}}$  is 100mV/ms and the total time to execute a shut-down procedure is 8ms. Also the noise of  $V_{\text{IN}}$  is 200mV. With these assumptions in mind, we can reasonably set  $V_L = 7.5V$  which 1.25V greater than the sum of maximum reset voltage threshold and the dropout voltage of LT1086-5 (4.75V + 1.5V) and  $V_{\text{HYSTERESIS}} = 850mV$ .

$$V_{\text{HYSTERESIS}} = 5V \frac{R1}{R3} = 850mV$$

$$R3 \approx 5.88 R1$$

Choose  $R3 = 300k\Omega$  and  $R1 = 51k\Omega$ . Also select  $R4 = 10k\Omega$  which is much smaller than  $R3$ .

$$7.5V = 1.3V \left( 1 + \frac{51k\Omega}{R2} - \frac{(5V - 1.3V)51k\Omega}{1.3V(310k\Omega)} \right)$$

$R2 = 9.7k\Omega$ , Choose nearest 5% resistor 10k and recalculate  $V_L$ ,

$$V_L = 1.3V \left( 1 + \frac{51k\Omega}{10k\Omega} - \frac{(5V - 1.3V)51k\Omega}{1.3V(310k\Omega)} \right) = 7.32V$$

$$V_H = 1.3V \left( 1 + \frac{51k\Omega}{10k\Omega} + \frac{51k\Omega}{300k\Omega} \right) = 8.151V$$

$$\frac{(7.32V - 6.25V)}{100mV/ms} = 10.7ms$$

$$V_{\text{HYSTERESIS}} = 8.151V - 7.32V = 831mV$$

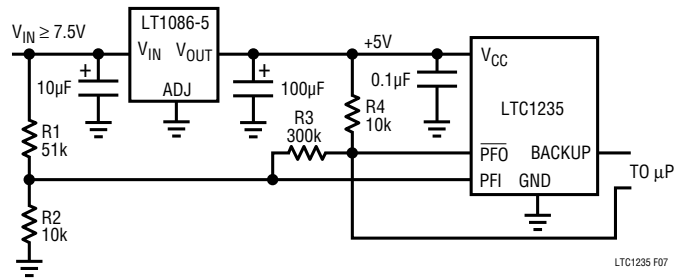


Figure 8. Monitoring *Unregulated* DC Supply with the LTC1235 Power Fail Comparator

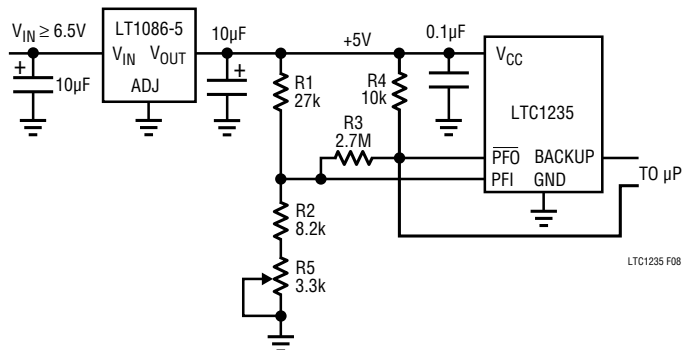


Figure 9. Monitoring *Regulated* DC Supply with the LTC1235 Power Fail Comparator

## APPLICATIONS INFORMATION

The 10.7ms allows enough time to execute shut-down procedure for microprocessor and 831mV of hysteresis would prevent PFO from going low due to the noise of  $V_{IN}$ .

**Example 2:** The circuit in Figure 9 can be used to measure the regulated 5V supply to provide early warning of power failure. Because of variations in the PFI threshold, this circuit requires adjustment to ensure that the PFI comparator trips before the reset threshold is reached. Adjust R5 such that the  $\overline{PFO}$  output goes low when the  $V_{CC}$  supply reaches the desired level (e.g., 4.85V).

### Monitoring the Status of the Battery

C3 can also monitor the status of the memory backup battery (Figure 10). If desired, the  $\overline{CE}$  OUT can be used to apply a test load to the battery. Since  $\overline{CE}$  OUT is forced high in battery backup mode, the test load will not be applied to the battery while it is in use, even if the microprocessor is not powered.

### Watchdog Timer

The LTC1235 provides a watchdog timer function to monitor the activity of the microprocessor. If the microprocessor does not toggle the Watchdog Input (WDI) within the time-out period, the reset outputs are forced to active states for a minimum of 140ms. The watchdog time-out period is fixed at 1.0 second minimum on the LTC1235. This time-out period provides adequate time for many systems to service the watchdog timer immediately after a reset. Figure 11 shows the timing diagram of

watchdog time-out period and reset active time. The watchdog time-out period is restarted as soon as the reset outputs are inactive. When either a high-to-low or low-to-high transition occurs at the WDI pin prior to time-out, the watchdog time is reset and begins to time out again. To ensure the watchdog time does not time out, either a high-to-low or low-to-high transition on the WDI pin must occur at or less than the minimum time-out period. If the input to the WDI pin remains either high or low, reset pulses will be issued every 1.6 seconds typically. The watchdog timer can be deactivated by floating the WDI pin. The timer is also disabled when  $V_{CC}$  falls below the reset voltage threshold or  $V_{BATT}$ .

The Watchdog Output,  $\overline{WDO}$ , goes low if the watchdog timer is allowed to time out and remains low until set high by the next transition on the WDI pin.  $\overline{WDO}$  is also set high when  $V_{CC}$  falls below the reset voltage threshold or  $V_{BATT}$ .

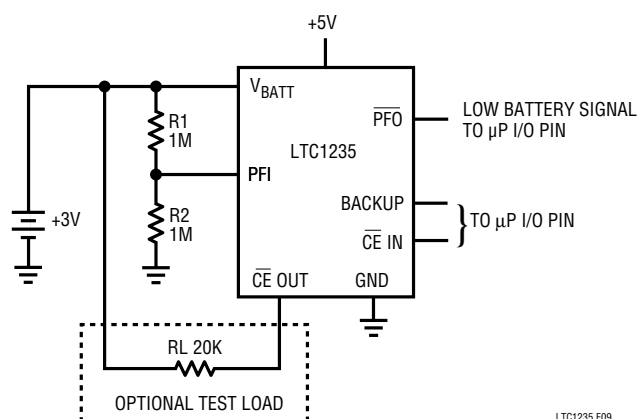


Figure 10. Backup Battery Monitor with Optional Test Load

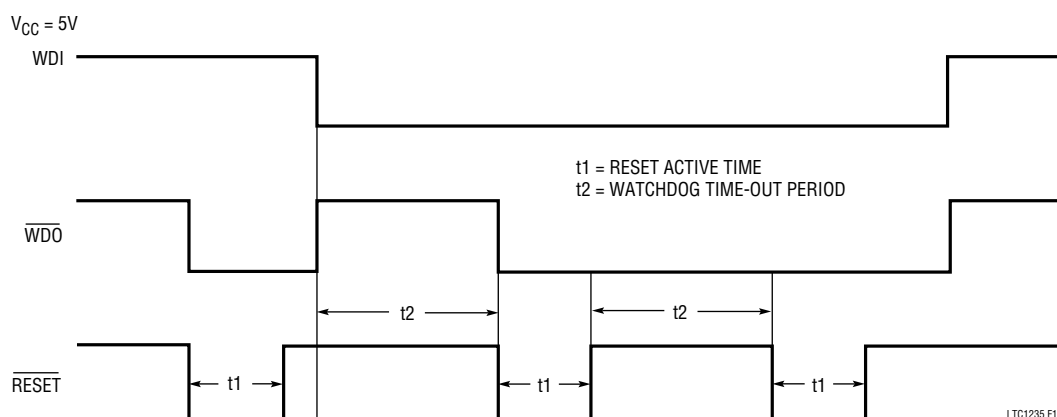
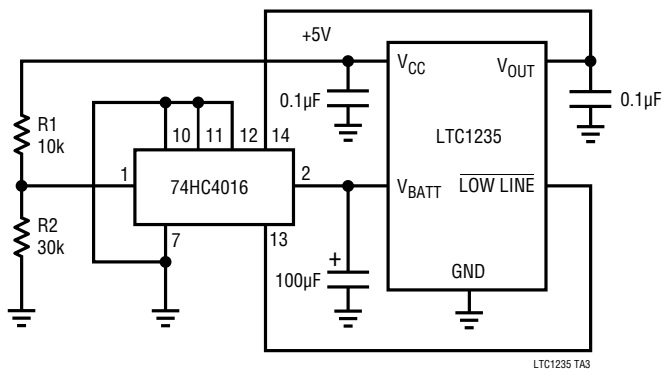


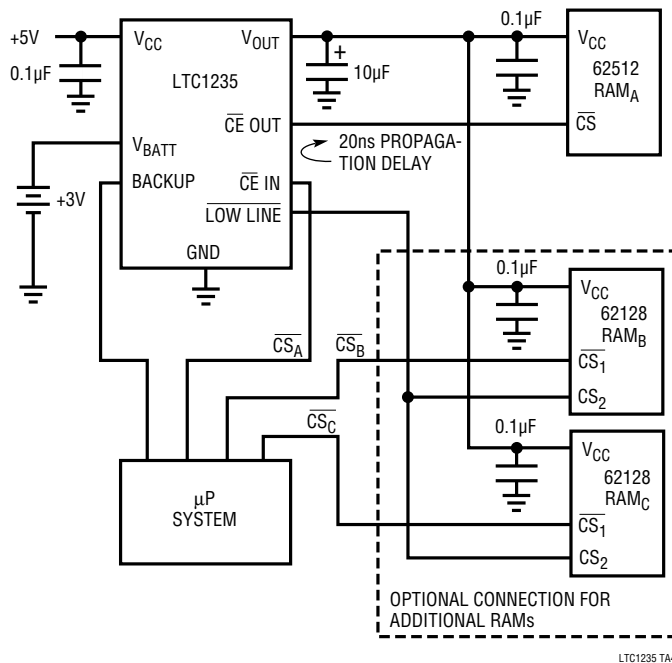
Figure 11. Watchdog Time-out Period and Reset Active Time

# TYPICAL APPLICATIONS

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