6-Input Supervisors Offer Accurate Monitoring and 125°C Operation

by Shuley Nakamura and Al Hinckley

Introduction

The latest trio of power supply supervisors from Linear Technology is ideal for today's multi-voltage systems that require accurate supply monitoring. The LTC2930, LTC2931, and LTC2932 are 6-input voltage monitors capable of maintaining 1.5% threshold accuracy from –40°C to 125°C. The combination of monitored supply voltages is set by a single pin. Each part offers 16 threshold voltage combinations, thus meeting the needs of almost any multi-voltage system. This programmability eliminates the need to qualify, source and stock unique part numbers for different threshold voltage combinations.

The overall architecture and operating specifications of these three devices are similar, but each has unique features (see Table 1). The LTC2930 generates a reset after any undervoltage event or when the manual reset input ($\overline{MR}$) pulls low. It is ideal for space-constrained applications as it comes in a compact 3mm × 3mm 12-lead DFN package. The LTC2931 includes a watchdog input (WDI), a watchdog output ($\overline{WDO}$) and user-adjustable watchdog periods to enable microprocessor monitoring and control. The LTC2932 can vary its monitor thresholds from 5% to 12.5%, and a reset disable pin provides margining capability. Both the LTC2931 and LTC2932 are packaged in 20-pin TSSOP packages and have separate comparator outputs, enabling individual supply monitoring and/or sequencing.

Table 1. LTC2930, LTC2931, LTC2932 feature summary

Feature	LTC2930	LTC2931	LTC2932
Configurable Input Threshold Combinations	16	16	16
Threshold Accuracy	1.5%	1.5%	1.5%
Adjustable Reset Time	✓	✓	✓
Buffered Reference	✓	✓	✓
Individual Comparator Outputs		✓	✓
Manual Reset	✓		
Independent Watchdog Circuitry		✓	
Reset Disable			✓
Supply Tolerance	Fixed, 5%	Fixed, 5%	User Selectable 5%, 7.5%, 10%, 12.5%
Package	12-lead 3mm × 3mm DFN	20-lead F Package	20-lead F Package

Single Pin Configuration Makes Life Easy

These supervisors offer an elegant method of configuring the input voltage thresholds. Figure 1 shows how a single resistive divider at the VPG pin sets the supervisor into one of the 16 threshold options shown in Table 2. See the data sheet for suggested mode-setting resistor values.

The actual thresholds are set by integrated precision dividers for 5V, 3.3V, 3V, 2.5V, 1.8V, and 1.5V supply monitoring. For other supply values, uncommitted comparators with 0.5V thresholds allow virtually any positive supply to be monitored using a resistive divider, as shown in Figure 2a. The V4 input also monitors negative voltages—with the same 1.5% accuracy—using the integrated buffered reference for offset (see Figure 2b).

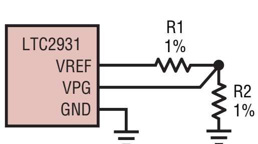
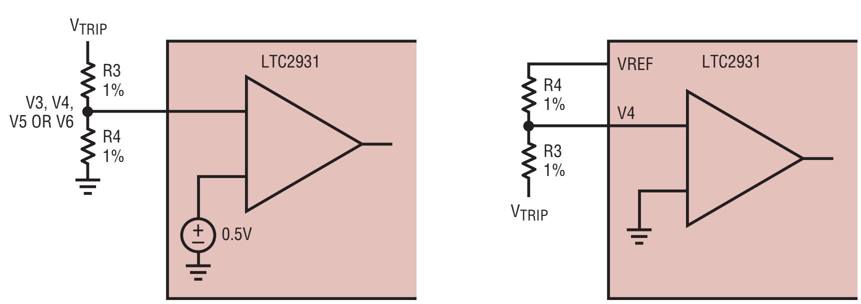


Figure 1. Mode selection



2a.

2b.

Figure 2. Using a resistive divider to set the voltage trip point

What Does Threshold Accuracy Mean?

Consider a 5V system with ±5% supply tolerance. The 5V supply may vary between 4.75V to 5.25V. System ICs powered by this supply must operate reliably within this band (and a little more, as explained below). A perfectly accurate supervisor for this supply generates a reset at exactly 4.75V. However, no supervisor is this perfect. The actual reset threshold of a supervisor fluctuates over a specified band; the LTC2930, LTC2931 and LTC2932 vary ±1.5% around their nominal threshold voltage over temperature (Figure 3). The reset threshold band and the power supply tolerance bands should not overlap. This prevents false or nuisance resets when the power supply is actually within its specified tolerance band.

The LTC2930, LTC2931 and LTC2932 boast a ±1.5% reset threshold accuracy, so a "5%" threshold is usually set to 6.5% below the nominal input voltage. Therefore, a typical 5V, "5%" threshold is 4.675V. The threshold is guaranteed to lie in the band between 4.750V and 4.600V over temperature. The powered system must work reliably down to the low end of the threshold band, or risk malfunction before a reset signal is properly issued.

A less accurate supervisor increases the required system voltage margin and increases the probability of system malfunction. The tight ±1.5% accuracy specification of the LTC2930, LTC2931 and LTC2932 improves the reliability of the system over supervisors with wider threshold specifications.

Table 2. Voltage threshold modes

V1 (V)	V2 (V)	V3 (V)	V4 (V)	V5 (V)	V6 (V)
5.0	3.3	2.5	1.8	ADJ	ADJ
5.0	3.3	2.5	1.5	ADJ	ADJ
5.0	3.3	2.5	ADJ	ADJ	ADJ
5.0	3.3	1.8	ADJ	ADJ	ADJ
5.0	3.3	1.8	–ADJ	ADJ	ADJ
5.0	3.3	ADJ	ADJ	ADJ	ADJ
5.0	3.3	ADJ	–ADJ	ADJ	ADJ
5.0	3.0	2.5	ADJ	ADJ	ADJ
5.0	3.0	1.8	ADJ	ADJ	ADJ
5.0	3.0	ADJ	ADJ	ADJ	ADJ
3.3	2.5	1.8	1.5	ADJ	ADJ
3.3	2.5	1.8	ADJ	ADJ	ADJ
3.3	2.5	1.8	–ADJ	ADJ	ADJ
3.3	2.5	1.5	ADJ	ADJ	ADJ
3.3	2.5	ADJ	ADJ	ADJ	ADJ
3.3	2.5	ADJ	–ADJ	ADJ	ADJ

Glitch Immunity = No Spurious Resets!

Monitored supply voltages are far from being ideal, perfectly flat DC signals. Riding on top of these supplies are high frequency components caused by a number of sources such as the output ripple of the power supply or coupling from other signals. If the monitored voltage is near or at the reset threshold voltage, this noise could cause spurious resets. Fortunately, the LTC2930, LTC2931 and LTC2932 have been designed with this potential issue in mind, so spurious resets are of little to no concern.

Some supply monitors overcome spurious resets by adding hysteresis to the input comparator. The amount of applied hysteresis is stated as a percentage of the trip threshold. Unfortunately, this degrades monitor accuracy because the true accuracy of the trip threshold is now the percentage of added hysteresis plus the advertised accuracy of the part. The LTC2930, LTC2931 and LTC2932 do not use hysteresis, but instead use an integration scheme that requires transients to possess enough magnitude and duration to switch the comparators. This suppresses spurious resets without degrading the monitor accuracy.

The COMP5 comparator output response to a "noisy" input on the LTC2931 is demonstrated in Figure 4.

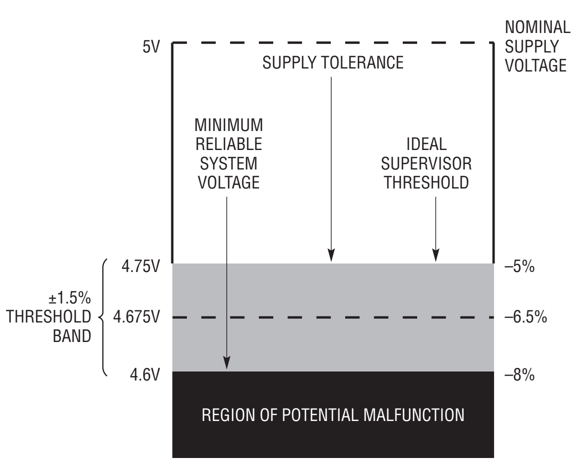


Figure 3. Tight 1.5% threshold accuracy yields high system reliability

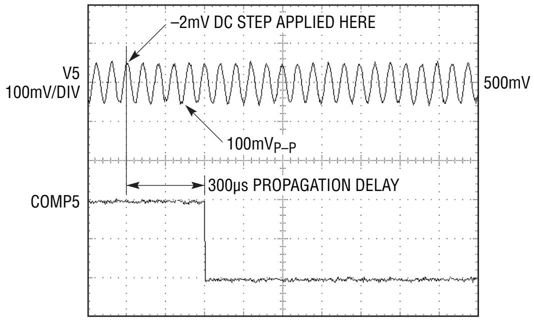


Figure 4. Comparator output is resistant to noisy input voltage

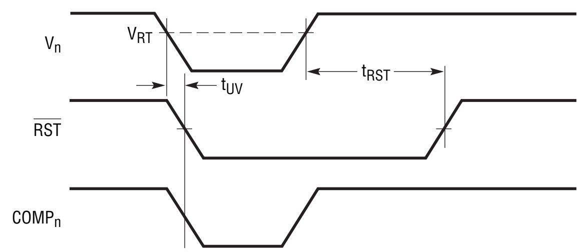


Figure 5. $\overline{RST}$ timing diagram

In the example shown, a 500kHz, $100mV_{P-P}$ sine wave centered at 500mV is applied to the V5 input. The threshold voltage of the adjustable input, V5, is 500mV. Even though the signal amplitude goes as low as 450mV, COMP5 remains high. Next, the DC level of the input is dropped 2mV. In response, COMP5 pulls low and remains low. As mentioned earlier, only transients of long enough duration and magnitude trigger the comparator output to pull high or low.

Adjustable Reset Timeout Period for Varied Application Needs

Each of the supervisors includes an adjustable reset timeout period, t_{RST}. Once all the inputs are above their threshold values, the reset timer is started (Figure 5). $\overline{RST}$ stays low for the duration of t_{RST} and remains low as long as the time between transients is less than the reset timeout. In other words, the reset timeout prevents supply transients with frequencies greater than $1/t_{RST}$ from causing undesired toggling at the $\overline{RST}$ output. Keeping $\overline{RST}$ low during these supply transients suppresses spurious resets.

The reset timeout period is adjustable to accommodate a variety of microprocessor applications. Configure the reset timeout period, t_{RST}, by connecting a capacitor, C_{RT}, between the CRT pin and GND. The value of this capacitor is determined by

$$C_{RT} = \frac{t_{RST}}{2M\Omega} = 500(pF/ms) \bullet t_{RST}$$

Leaving the CRT pin unconnected generates a minimum reset timeout of approximately 25µs. Maximum reset timeout is limited by the largest available low leakage capacitor.

Additional Glitch Filtering

Even though all six comparators have built-in glitch filtering, adding bypass capacitors on the V1 and V2 inputs is recommended, because of these two, the input with the higher voltage functions as V_{CC} for the entire chip. Additional filter capacitors may be added to the V3, V4, V5 and V6 inputs if needed to suppress troublesome noise.

Open-Drain Reset

The $\overline{RST}$ outputs on the LTC2930, LTC2931 and LTC2932 are open-drain and contain weak pull-up current sources to the V2 voltage.

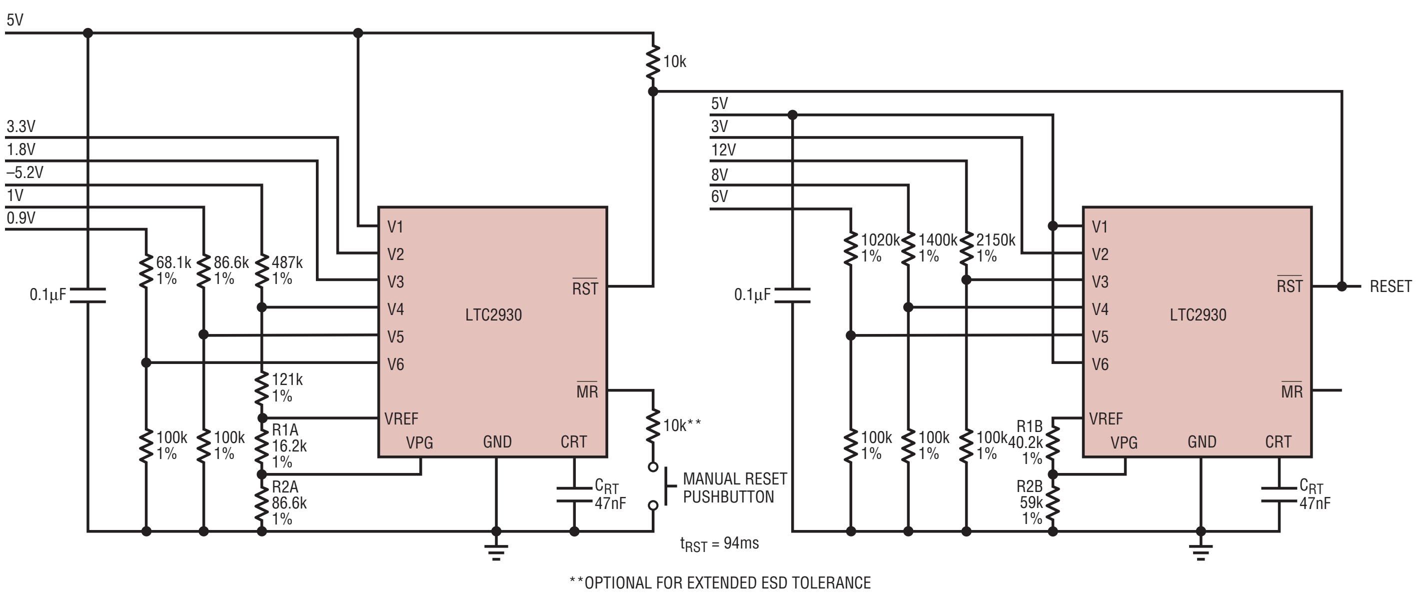


Figure 6. Wired-OR system reset

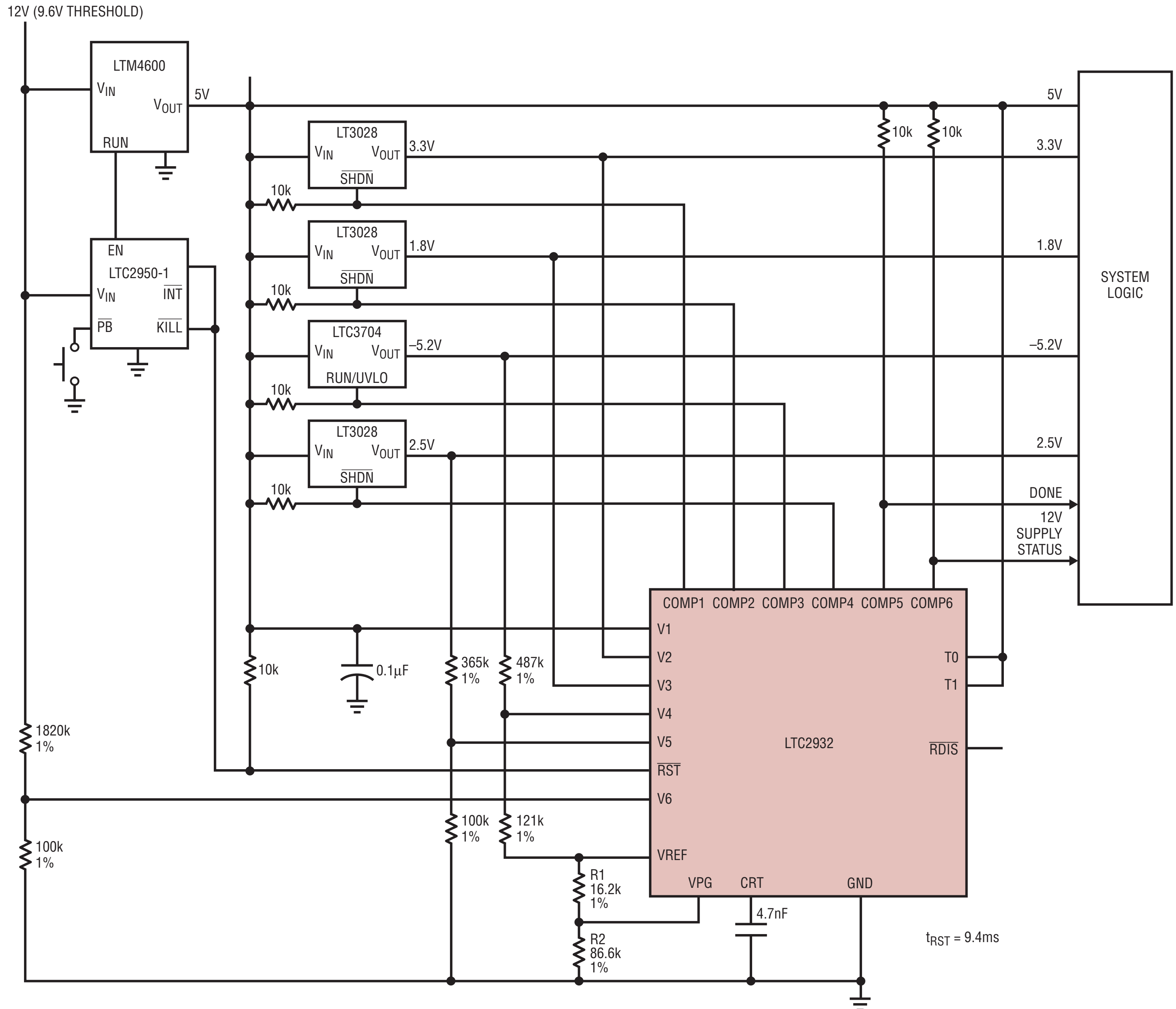


Figure 7. Five supply 12.5% tolerance power-up sequencer with pushbutton

The open-drain structure provides many advantages. For instance, each of these outputs can be externally pulled-up to voltages higher than V2 using a pull-up resistor. This facilitates the use of multiple devices operating under different I/O voltages. In addition, multiple open-drain outputs can be configured in a "wired-OR" format where the outputs are tied together. Figure 6 showcases two LTC2930 supervisors, whose open-drain $\overline{\text{RST}}$ outputs are tied together and pulled-up to 5V via a 10k pull-up resistor. If one $\overline{\text{RST}}$ output pulls low due to a reset event, it sinks current and pulls the other output low.

Comparator Outputs Enable Individual Supply Monitoring and Sequencing Support

Real-time comparator outputs on both the LTC2931 and LTC2932 indicate the status of the individual inputs. Similar to the $\overline{\text{RST}}$ output, the comparator outputs are also open-drain and have weak pull-up current sources to the V2 voltage.

While $\overline{\text{RST}}$ pulls low when an undervoltage event occurs on any of the monitored supplies, a comparator output pulls low only when its counterpart input is below its threshold voltage. The ability to monitor the status of each supply is useful in multi-voltage systems where it is important to know which particular supply has failed.

The individual comparator outputs also allow power supply sequencing. Figure 7 shows the LTC2932 in a 5-supply power-up sequencer. As an input reaches its threshold, the respective comparator output pulls high and enables the next DC/DC converter.

The LTC2950-1 is used to provide pushbutton control for the sequencer. After the pushbutton is pressed, the LTC2950-1 pulls the RUN pin of the LTM4600 high. Subsequently, the LTM4600 generates a 5V output which supplies power to each of the four DC/DC converters.

Three Supervisor Flavors

LTC2930: Manual Reset ($\overline{MR}$) Forces $\overline{RST}$ Low

Use the manual reset input ($\overline{MR}$) on the LTC2930 to issue a forced reset, independent of input voltage levels. A 10µA (typical) internal current source pulls the $\overline{MR}$ pin to V_{CC}. A logic low on this pin pulls $\overline{RST}$ low. When the $\overline{MR}$ pin returns high, $\overline{RST}$ returns high after the selected reset timeout period has elapsed, assuming all six voltage inputs are above their thresholds (Figure 8). The input-high threshold on the $\overline{MR}$ pin is 1.6V (max), allowing the pin to be driven by low voltage logic as well.

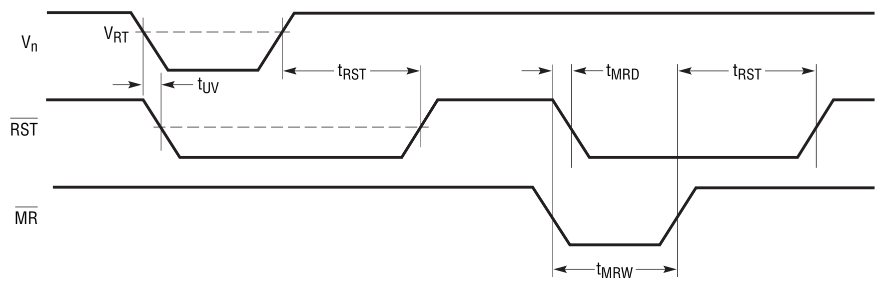


Figure 8. $\overline{MR}$ timing diagram

LTC2931: Monitor a Microprocessor with the Watchdog Function

The LTC2931's independent watchdog circuitry monitors a microprocessor's activity. The microprocessor is required to change the logic state of the WDI pin on a periodic basis in order to clear the watchdog timer. The LTC2931 consists of a watchdog input (WDI), a watchdog output ($\overline{WDO}$) and a timing pin (CWT), which allows for a user adjustable watchdog timeout period. Figure 9 illustrates the watchdog timer and its relationship to the reset timer and WDI.

The watchdog timeout period is adjustable and can be optimized for software execution. The watchdog timeout period, t_{WD}, is adjusted by connecting a capacitor, C_{WT}, between the CWT pin and ground. The value of this capacitor is determined by

$$C_{WT} = \frac{t_{WD}}{20M\Omega} = 50\left(pF/ms\right) \bullet t_{WD}$$

Leaving the CWT pin unconnected generates a minimum watchdog timeout of approximately 200µs. Maximum watchdog timeout is limited by the largest available low leakage capacitor.

LTC2932: Margining Capabilities and Wider Threshold Tolerances

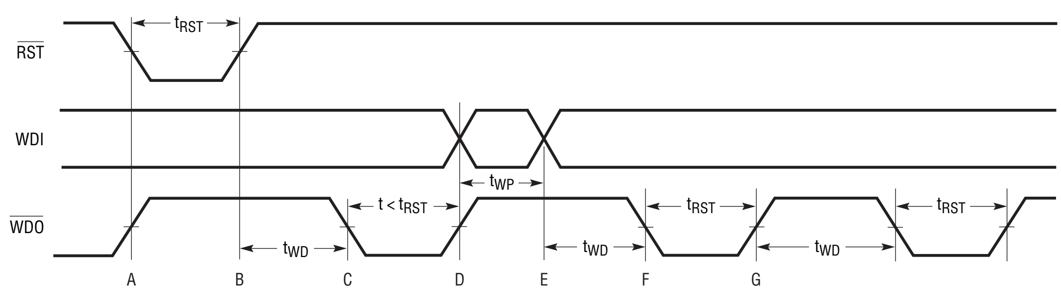
In high reliability system manufacturing and testing, it is important to verify that the components will continue to operate at or below the rated power supply tolerance. Verification usually involves margining the power supplies, running their outputs at or beyond rated tolerances. The LTC2932 is designed to complement such testing in two ways. First, the $\overline{RST}$ output can be disabled by pulling $\overline{RDIS}$ low. In this state, the $\overline{RST}$ output remains high despite any undervoltage events which may occur during margining tests. This does not affect the individual supply monitoring, which is independent of the logic state of $\overline{RDIS}$. Second, lowering the trip thresholds can increase supply headroom to match the margining ranges. This is simply a matter of changing the two tolerance selection inputs, T0 and T1, to adjust the global supply tolerance to 5%, 7.5%, 10%, or 12.5% (see Table 3).

Table 3. LTC2932 Tolerance Selection

T0	T1	TOLERANCE (%)	V_{REF} (V)
Low	Low	5	1.210
Low	High	7.5	1.175
High	Low	10	1.146
High	High	12.5	1.113

Automotive Application

The ease of implementation, wide operating temperature range, and low supply current requirements for the LTC2930, LTC2931 and LTC2932 supervisors make them ideal for automotive applications. Figure 10



A. UNDERVOLTAGE EVENT OCCURS, $\overline{RST}$ PULLS LOW, $\overline{WDO}$ PULLS HIGH, AND $\overline{RST}$ TIMER STARTS.
B. $\overline{RST}$ TIMES OUT (ALL INPUT VOLTAGES BECOME GOOD BEFORE $\overline{RST}$ TIMEOUT), t_{RST}, THEN WATCHDOG TIMER STARTS.
C. WATCHDOG TIMES OUT, t_{WD}, AND $\overline{WDO}$ PULLS LOW. $\overline{RST}$ TIMER STARTS.
D. WDI TRANSITION OCCURS BEFORE $\overline{RST}$ TIMEOUT. $\overline{WDO}$ PULLS HIGH AND $\overline{WDO}$ TIMER STARTS.
E. WDI TRANSITION OCCURS WHILE $\overline{WDO}$ IS HIGH. WATCHDOG TIMER CLEARS AND RESTARTS.
F. WATCHDOG TIMES OUT. $\overline{WDO}$ PULLS LOW AND $\overline{RST}$ TIMER STARTS.
G. $\overline{RST}$ TIMES OUT. $\overline{WDO}$ PULLS HIGH AND WATCHDOG TIMER STARTS.

Figure 9. Watchdog timing diagram

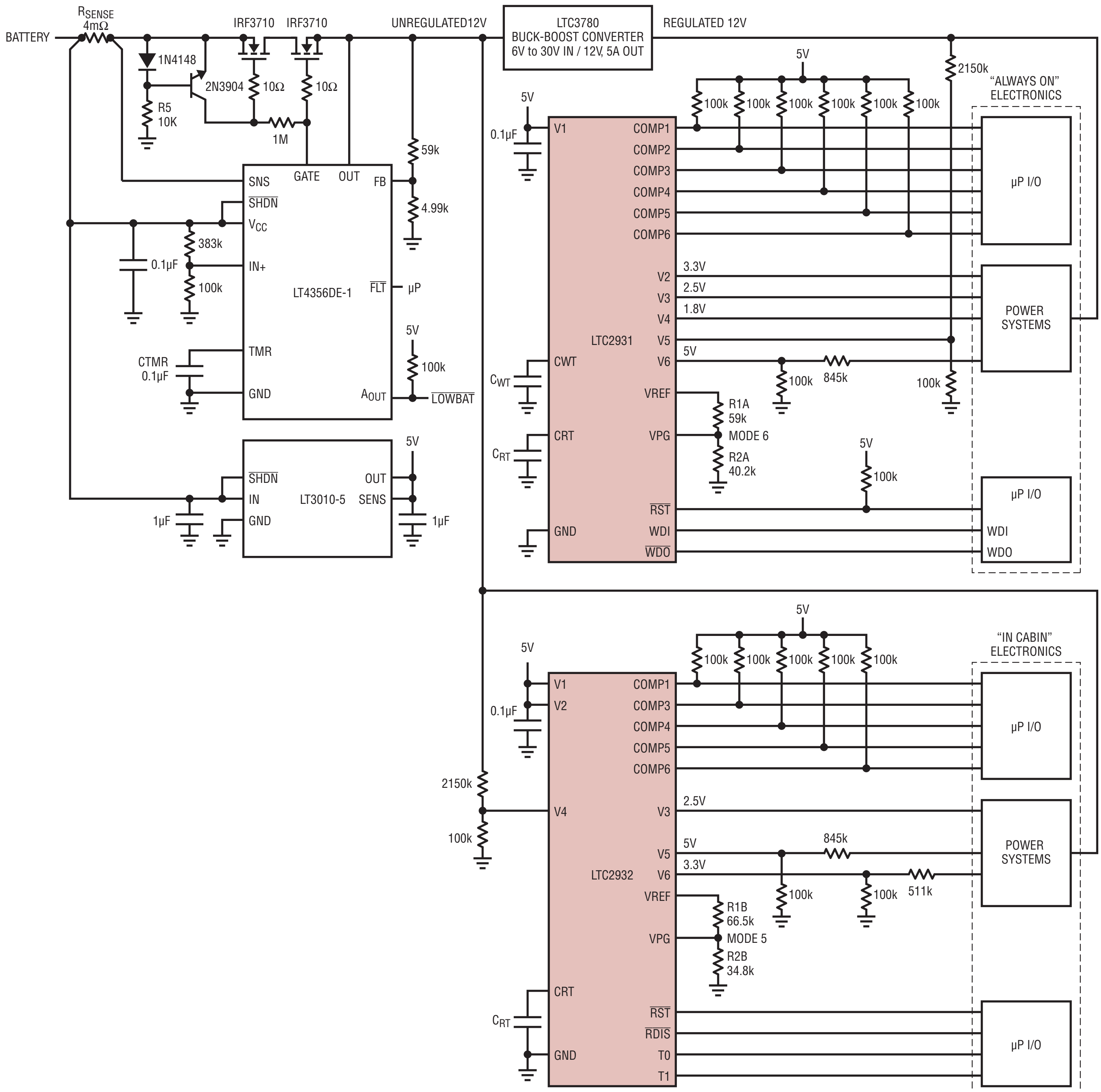


Figure 10. The LTC2931 and LTC2932 in an automotive application

is a block diagram schematic of an automotive application that uses the LTC2931 and LTC2932. It was designed to highlight and utilize the features of these parts beyond simple voltage monitoring. The voltage monitors are powered by the LT3010-5, a fixed 5V micropower linear regulator. Voltage transient protection is provided by the LT4356DE-1 overvoltage protection regulator and inrush limiter.

In a typical automotive power system, a distinction is made between "Always On" and "In Cabin" electronics. "Always On" systems include critical electronics that deal with the safety and security of an automobile and, as the name implies, are always on. "In Cabin" electronics pertain to comfort and entertainment accessories used in automobiles. In the event the battery is low, for instance, the in cabin electronics are turned off to preserve and siphon power to the critical path.

In this automotive application, power for the always on critical electronics is generated by the LTC3780 buck

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LTC4357 with a FDB3632 MOSFET to replace the Schottky diode.

When the solar panel is illuminated by full sunlight, it charges the battery. A shunt regulator absorbs any excess charging current to prevent overcharging. If the forward current is greater than $25mV/R_{DS(ON)}$, the MOSFET is fully enhanced and the voltage drop rises according to $R_{DS(ON)} \bullet (I_{BATTERY} + I_{LOAD})$. In darkness, or in the event of a short circuit across the solar panel or a component failure in the shunt regulator, the output voltage of the solar panel will be less than the battery voltage. In this case, the LTC4357 shuts off the MOSFET, so the battery will not discharge. The current drawn from the battery into the LTC4357's OUT pin is only 7µA at 12V.

Protecting Against Reverse Inputs

In automotive applications, the LTC4357 inputs can be reversed. An additional component, shown in Figure 3, prevents the MOSFET from turning on and protects the LTC4357.

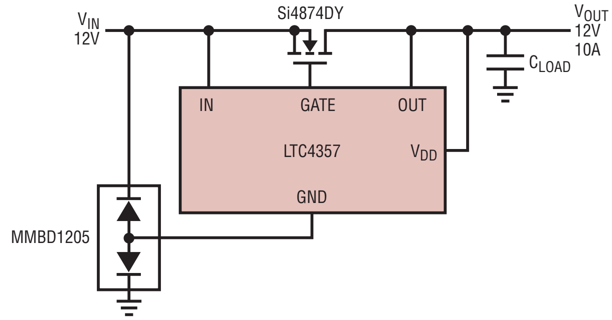

Figure 3. –12V Reverse input protection blocks reverse input voltage to the load

With a reverse input, the diode connected to system ground is reverse biased. The GND pin is pulled by the second diode to within 700mV of the reverse input voltage. Any loading or leakage current tends to hold the output near system ground, biasing the LTC4357 in the blocking condition. If the output is held up at +12V by a backup source or stored charge in the output capacitor, roughly double the input voltage appears across the MOSFET. The MOSFET is off and held in the blocking state.

Conclusion

The LTC4357 ideal diode controller can replace a Schottky diode in many applications. This simple solution reduces both voltage drop and power dissipation, thereby shrinking the thermal layout and reducing power loss. Its wide 9V to 80V supply operating range and 100V absolute maximum rating accommodate a broad range of input supply voltages and applications, including automotive, telecom and industrial. A dual version, the LTC4355, is available in 4mm × 3mm DFN-14 or SSOP-16 packages.

LTC293x, continued from page 15

boost regulator and monitored by the LTC2931. The LTC3780 is protected from transients by the LT4356DE-1 and is capable of delivering full power to the load with a supply voltage as low as 6V. The LTC2931 is configured to monitor four fixed and two adjustable voltages, including two independent 5V supplies. 1.5% voltage monitoring accuracy is guaranteed over the entire operating temperature range. Additionally, each voltage monitoring channel has its own comparator output that can be used by the microprocessor to identify a fault condition. The comparator outputs are pulled up to the 5V bus that powers both voltage monitoring devices. The LTC2931 has an adjustable watchdog timer, which allows the LTC2931 to report a malfunctioning microprocessor to the rest of the system.

The unregulated battery voltage and power supplies delivered to the in cabin electronics are monitored by the LTC2932. This application monitors the unregulated battery voltage, and the COMP4 output alerts the system to a low battery condition, allowing the system to enter a standby or power save mode.

The LTC2932 also provides a mechanism to override a reset or fault condition. This is accomplished by pulling the $\overline{RDIS}$ pin low. With $\overline{RDIS}$ pulled low, the $\overline{RST}$ output pulls up to the V2 input voltage. Since V2 is tied to V1, the reset high level is 5V. The $\overline{RDIS}$ function allows the system to have flexibility in controlling the power sources without generating system faults. Additionally, the LTC2932 allows real time setting of the voltage monitoring threshold. This could be useful when changes in loading or environment make for predictable supply variances.

Conclusion

The LTC2930, LTC2931 and LTC2932 can each monitor six supplies, saving valuable board area in space constrained applications. The LTC2930 is available in a 3mm × 3mm DFN, while the LTC2931 and LTC2932 are available in 20-pin TSSOP packages.

All include design-time saving features for multi-voltage applications. Voltage thresholds are accurate to ±1.5%, guaranteed over the entire –40°C to 125°C temperature range. This translates directly to simplified power supply design, as threshold accuracy must be accounted for in the entire power supply tolerance budget.

Comparator glitch immunity eliminates false resets, with no effect on the high accuracy of the monitor. These devices support a variety of voltage combinations, easily set with only a few external components. The reset timeout period is also adjustable with a single capacitor.

Lastly, the features which differentiate the LTC2930, LTC2931 and LTC2932 give users the flexibility to choose one for any application.