Application Report
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Voltage Monitoring in eCall Telematics Control Unit

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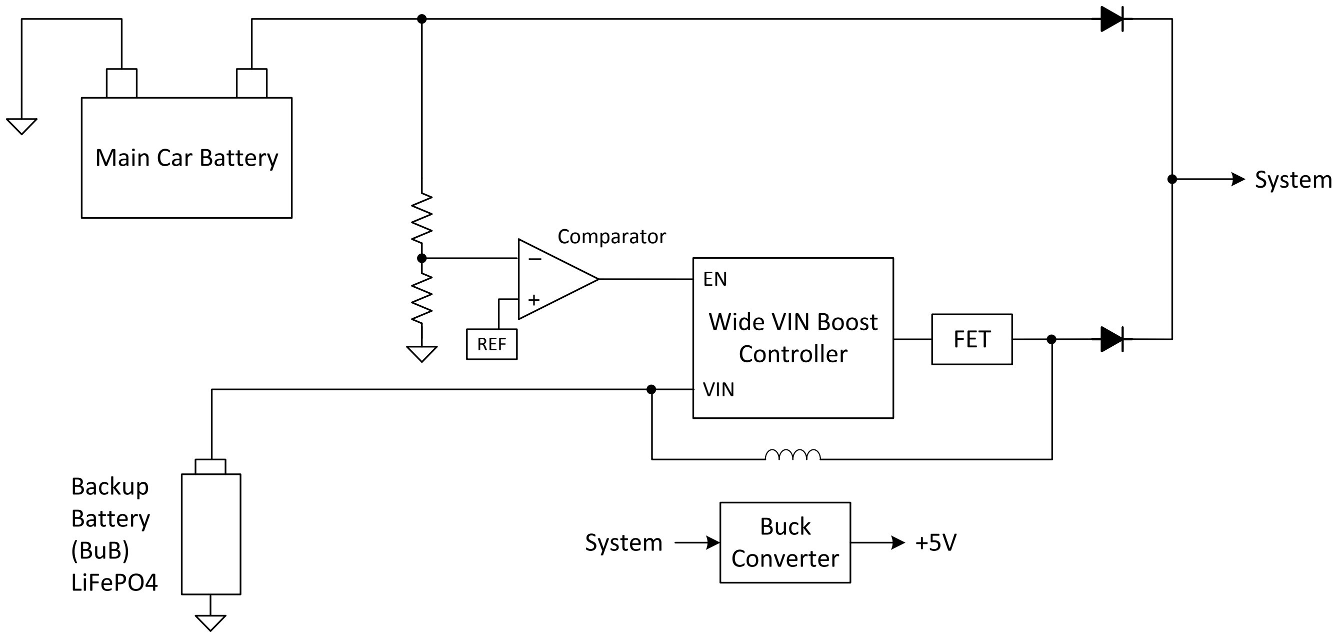
How to Design Undervoltage Protection with Comparators

Application Summary

When you are involved in a crash or your car breaks down on the road, an emergency call (eCall) device in your car's infotainment system allows you to alert emergency services. In order to maintain your safety and security on the road, eCall devices need to be powered reliably during the complete phase of an emergency call. In an emergency situation, the car may have been severely damaged including the disconnection or a breakdown of the car battery supply. For this reason, automobile manufacturers have integrated a backup power source to maintain the operation of an eCall device.

This design shows how the eCall system switches seamlessly from the main car battery to the backup power while minimizing power consumption during normal car operation. Here is a block diagram of the circuit.



In this circuit, a simple, low-power comparator is used to monitor the main car battery. When the car battery drops below a certain operating level, the comparator will enable a wide input voltage boost controller that is powered by a backup battery. Since the car battery voltage is eroding at the same time that the wide VIN boost controller is rising, two diodes are used to connect the sources together. The diodes are configured in what is referred to as an "OR-ing" configuration. In this configuration, the path with the higher voltage source will forward bias its diode and power the system load, while the path with the lower voltage source will reverse bias its diode and isolate itself from the system.

Listed below are the design requirements of the comparator circuit that is monitoring the main car battery.

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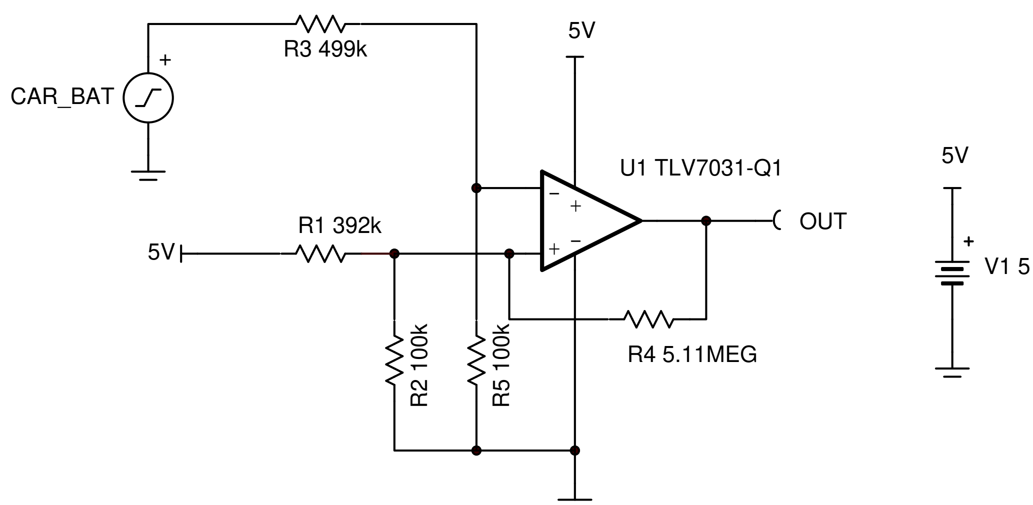
Design Goals

Comparator Voltages	Battery Voltage Levels (CAR_BAT)		
Supply (V_S)	Max Voltage	Undervoltage Threshold (V_L)	Recovery Threshold (V_H)
5 V	40 V	6 V	6.5 V

Design Description

This undervoltage, detection circuit uses a low-power comparator to create an enable signal at the comparator output (OUT) if the main car battery drops below 6V. The enable signal is active high to enable a wide VIN boost controller. To generate an active high signal from a battery voltage that is decreasing, an inverting comparator configuration is implemented. The supply voltage (V_S) and reference voltage (V_{REF}) for the comparator are derived from the regulated output of a 5V buck converter that is downstream of this circuitry in the system. The 5V buck converter output can be utilized since system power to the buck converter will never be interrupted. Power to the buck converter is uninterrupted because of the "OR-ing" diodes that provide continuous power to the system from either the car battery directly or from the boost controller. External hysteresis is implemented so that the boost controller is disabled once the car battery recovers to 6.5V.

Figure 1.



Design Notes

1. Select a low-power comparator with a push-pull output stage that operates at a quiescent current less than 1uA.
2. Select resistor values in the 100k ohm range to minimize power consumption.
3. Implement hysteresis in order to avoid chatter at the comparator output as the main battery voltage crosses the 6V threshold voltage.

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Design Steps

1. Calculate the resistor divider ratio of R3 and R5 so a car battery voltage of 40V does not cause the inverting input of the comparator (IN-) to exceed 7V (the abs max input voltage of the TLV7031-Q1). Voltage spikes as high as 40V can occur during the start of the car engine.

   $$IN- = CAR\_BAT \times \frac{R_5}{(R_3 + R_5)} \leq 7V \text{ when } CAR\_BAT = 40V$$

   $$\frac{R_5}{(R_3 + R_5)} \leq \frac{7}{40} = 0.175$$

2. To minimize power consumption, set R5 to 100k. Solving for R3, R3 needs to be greater than 471k. A value of 499k is arbitrarily selected for R3.
3. Confirm that the values of R3 = 499k and R5 = 100k limit the voltage at IN- to less than 7V.

   $$40V \times \frac{100}{100 + 499} = 6.68V \leq 7V$$

4. Calculate the voltage at (IN-) when the car battery reaches 6V because this is the critical voltage where the backup system switches from the car battery to the backup battery. This voltage will be used when setting the resistor divider for generating V_{REF} and feedback resistor for hysteresis in future steps. As a reminder, the equation for a voltage divider is:

$$V_{OUT} = \frac{V_S \times R2}{R1 + R2} \quad (1)$$

   $$\text{Undervoltage Threshold } (V_L) = \frac{6 \times 100}{(100 + 499)} = 1.002V$$

5. Repeat the previous step for when the car battery reaches 6.5V. This is when the backup system will switch back to the car battery.

$$\text{Recovery Threshold } (V_H) = \frac{6.5 \times 100}{(100 + 499)} = 1.085V \quad (2)$$

6. Derive values for R1, R2, and R4 using Analog Engineer's Circuit: Inverting Comparator with Hysteresis Circuit at www.ti.com/lit/an/snoa997a/snoa997a.pdf.
7. In reference to snoa997a.pdf, a value of 100k was arbitrarily selected for R2 (a large value was selected to minimize power consumption). From step 3, set V_L=1.002V and V_H=1.085V.
8. Likewise, after using the equations from snoa997a, the the following results are obtained: R1 = 389.92k (select closest 1% resistor value of 392k) and R4 = 5.12M (select closest 1% resistor value is 5.11M).

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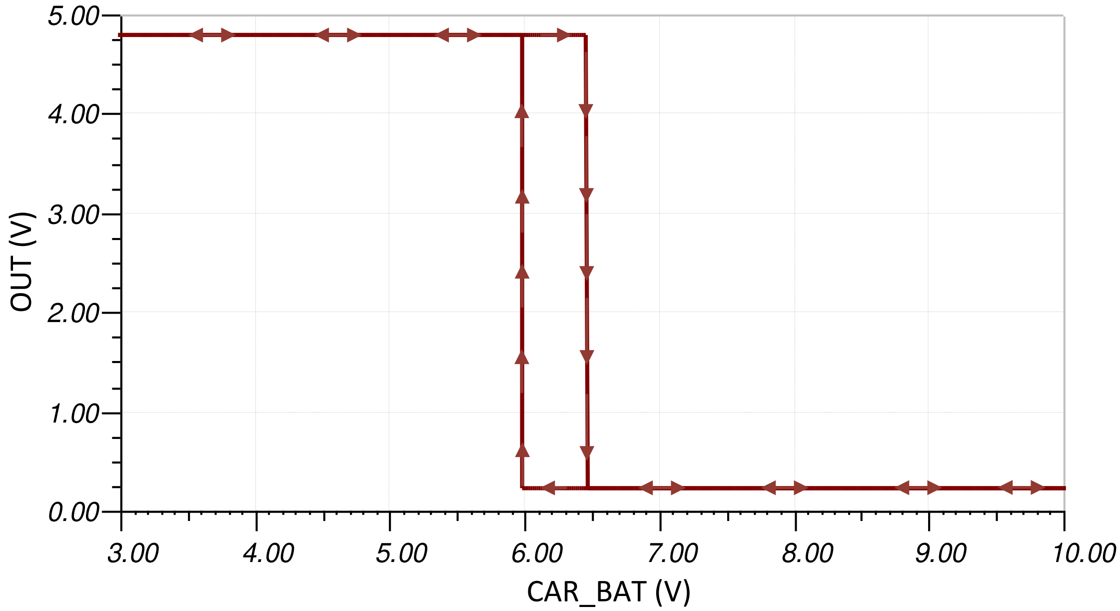
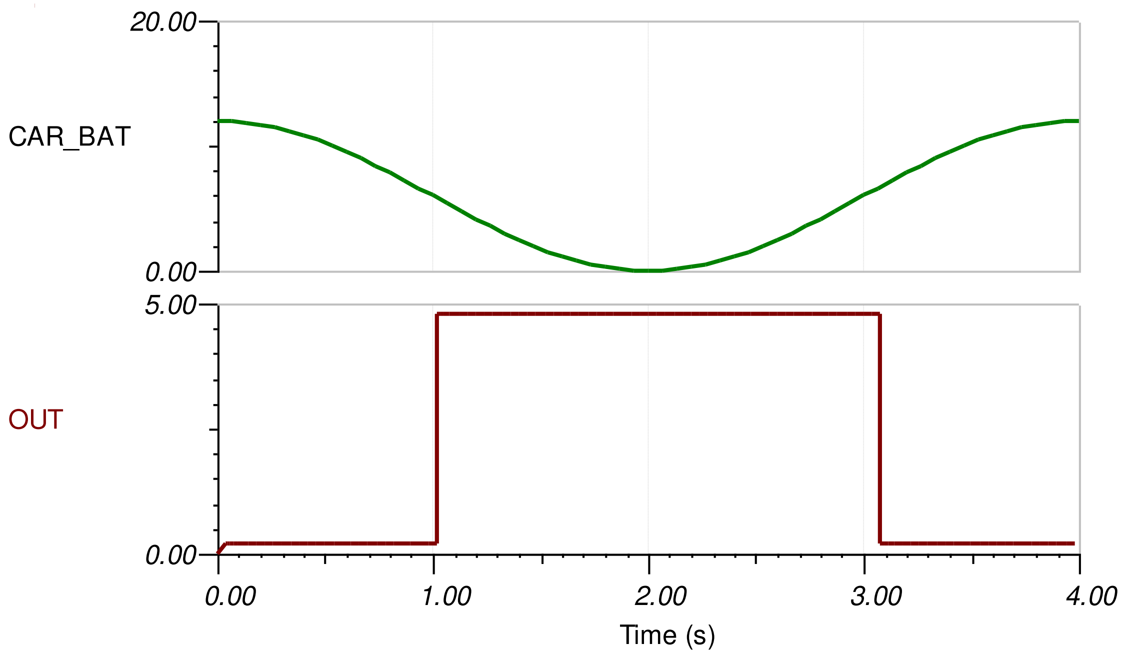
Design Simulations

DC Transfer Simulation Results



Transient Simulation Results



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References:

1. Analog Engineer's Circuit Cookbooks
2. SPICE Simulation File – SLVMD83
3. TI Precision Labs

Design Featured Comparator

TLV7031-Q1	
V_S	1.6V to 6.5V
V_{inCM}	Rail-to-rail
V_{OUT}	Push-pull
V_{OS}	± 0.1 mV
Hysteresis	7 mV
I_Q	335 nA
$t_{PD(HL)}$	3 µs
www.ti.com/product/tlv7031-q1	

Design Alternate Comparator

	TLV3701-Q1	TLV1805-Q1
V_S	2.7V to 16V	3.3V to 40V
V_{inCM}	Rail-to-rail	Rail-to-rail
V_{OUT}	Push-pull	Push-pull
V_{OS}	0.25 mV	0.5 mV
Hysteresis	External only	14 mV
I_Q	500 nA	135 µA
$t_{PD(HL)}$	36 µs	250 ns
	www.ti.com/lit/ds/symlink/tlv3701-q1.pdf	www.ti.com/lit/ds/symlink/tlv1805-q1.pdf

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