

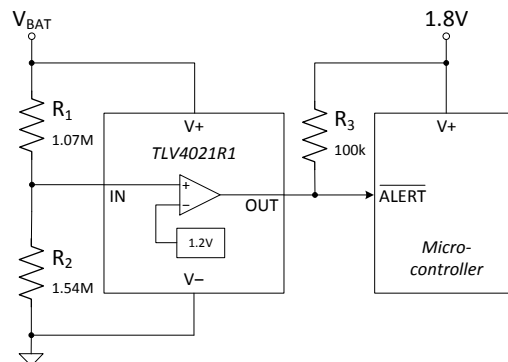
Undervoltage protection with comparator circuit

Design Goals

Battery Voltage Levels (V_{BAT})		Comparator Output Status (OUT)	
Undervoltage (V_{LOW})	Start-Up Operating Voltage (V_{HIGH})	Low Battery	Normal Operation
< 2.000V	> 2.034V	$V_{OL} < 0.4V$	$V_{OH} = V_{PU} = 1.8V$

Design Description

This undervoltage, protection circuit uses one comparator with a precision, integrated reference to create an alert signal at the comparator output (OUT) if the battery voltage sags below 2.0 V. The undervoltage alert in this implementation is ACTIVE LOW. So when the battery voltage drops below 2.0 V, the comparator output goes low, providing as an alert signal to whatever device is monitoring the output. Hysteresis is integrated in the comparator such that the comparator output will return to a logic high state when the battery voltage rises above 2.034 V. This circuit utilizes an open-drain output comparator in order to level shift the output high logic level for controlling a digital logic input pin. For applications needing to drive the gate of a MOSFET switch, a comparator with a push-pull output is preferred.



Design Notes

1. Select a comparator with a precision, integrated reference.
2. Select a comparator with an open-drain output stage for level-shifting.
3. Select values for the resistor divider so the critical undervoltage level occurs when the input to the comparator (IN) reaches the comparator's negative-going input threshold voltage (V_{IT}).

Design Steps

1. Calculate the resistor divider ratio needed so the input to the comparator crosses V_{IT-} when V_{BAT} sags to the target undervoltage level (V_{LOW}) of 2.0V. V_{IT-} from the TLV4021R1 data sheet is 1.18V.

$$V_{IT-} = \frac{R_2}{(R_1 + R_2)} \times V_{LOW}$$

$$\frac{R_2}{(R_1 + R_2)} = \frac{V_{IT-}}{V_{LOW}} = \frac{1.18 \text{ V}}{2.00 \text{ V}} = 0.59$$

2. Confirm that the value of V_{LOW} , the voltage level where the undervoltage alert signal is asserted, is 2.0 V.

$$V_{LOW} = \frac{R_1 + R_2}{R_2} \times V_{IT-} = \frac{1}{0.59} \times 1.18 \text{ V} = 2.0 \text{ V}$$

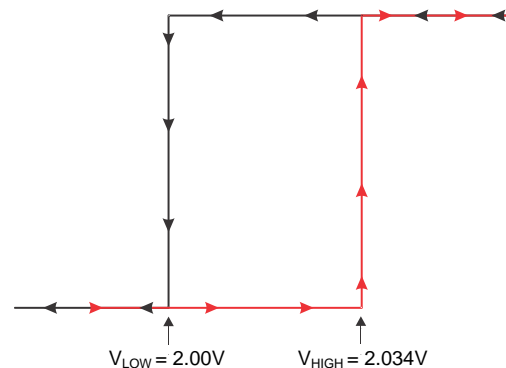
3. Select values for R_1 and R_2 that yield the resistor divider ratio of 0.59 by using the following equation or using the online tool "Voltage Divider Calculator" at http://www.ti.com/download/kbase/volt/volt_div3.htm.

If using the following equation, choose a value for R_2 in the Mega-ohm range and calculate for R_1 . In this example, a value of 1.54 M was chosen for R_2 .

$$R_1 = R_2 \left(\frac{V_{LOW}}{V_{IT-}} - 1 \right) = 1.54 \text{ M}\Omega \left(\frac{2 \text{ V}}{1.18 \text{ V}} - 1 \right) = 1.07 \text{ M}\Omega$$

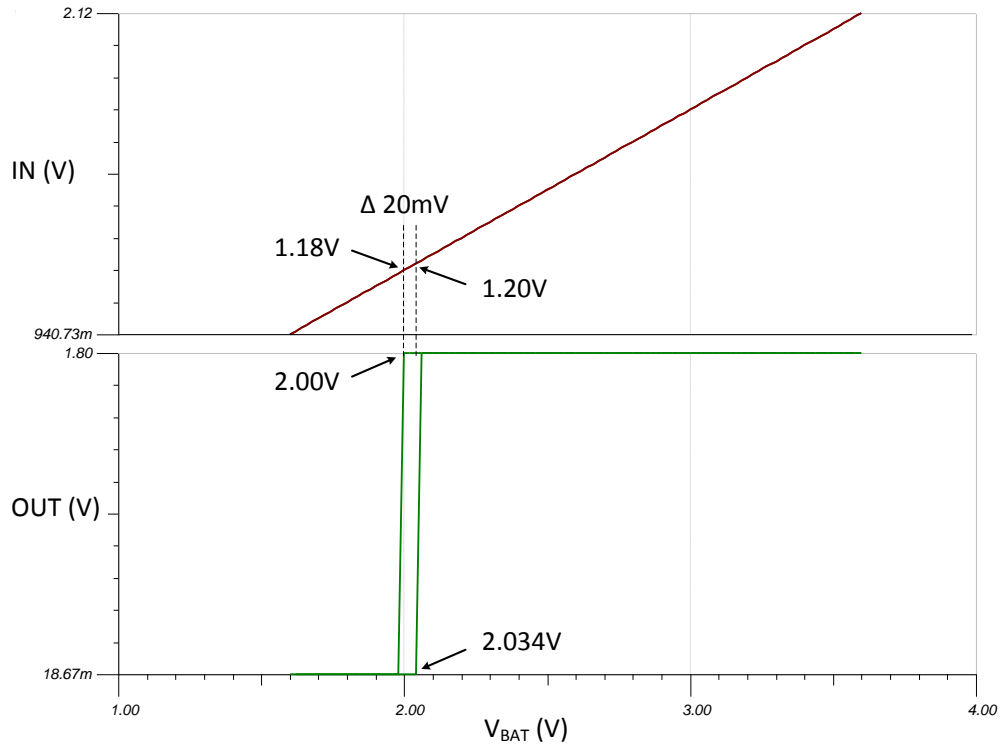
4. Verify that the current through the resistor divider is at least 100 times higher than the input bias current of the comparator. The resistors can have high values to minimize power consumption in the circuit without adding significant error to the resistor divider.
5. Calculate V_{HIGH} , the battery voltage where the undervoltage alert signal is de-asserted (returns to a logic high value). When the battery voltage reduces below the 2.0-V level or is ramping up at initial start-up, the comparator input needs to exceed (V_{IT+}), the positive-going input threshold voltage for the output to return to a logic high. V_{IT+} from the TLV4021R1 data sheet is 1.20V.

$$V_{HIGH} = \frac{R_1 + R_2}{R_2} \times V_{IT+} = \frac{1.07 \text{ M}\Omega + 1.54 \text{ M}\Omega}{1.54 \text{ M}\Omega} \times 1.20 \text{ V} = 2.034 \text{ V}$$

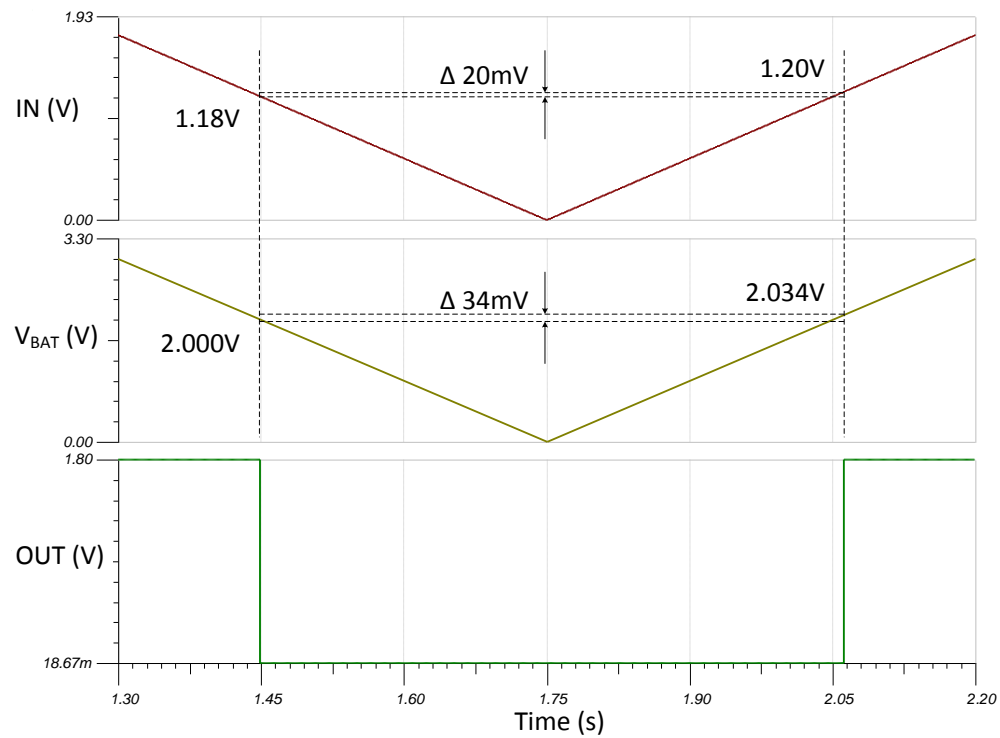


Design Simulations

DC Simulation Results



Transient Simulation Results



References:

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File – [SNOAA18](#)
3. [TI Precision Labs](#)

Design Featured Comparator

TLV4021R1	
V_S	1.6V to 5.5V
V_{inCM}	Rail-to-rail
V_{OUT}	Open Drain
Integrated Reference	1.2V \pm 1% over temperature
Hysteresis	20 mV
I_Q	2.5 μ A
$t_{PD(HL)}$	450 ns
www.ti.com/product/tlv4021	

Design Alternate Comparator

	TLV4041R1	TLV3011
V_S	1.6V to 5.5V	1.8V to 5.5V
V_{inCM}	Rail-to-rail	Rail-to-rail
V_{OUT}	Push-Pull	Open Drain
Integrated Reference	1.2 V \pm 1% over temperature	1.242 \pm 1% room temperature
Hysteresis	20mV	NA
I_Q	2.5 μ A	2.8 μ A
$t_{PD(HL)}$	450ns	6 μ s
	www.ti.com/product/tlv4041	www.ti.com/product/tlv3011

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2022, Texas Instruments Incorporated