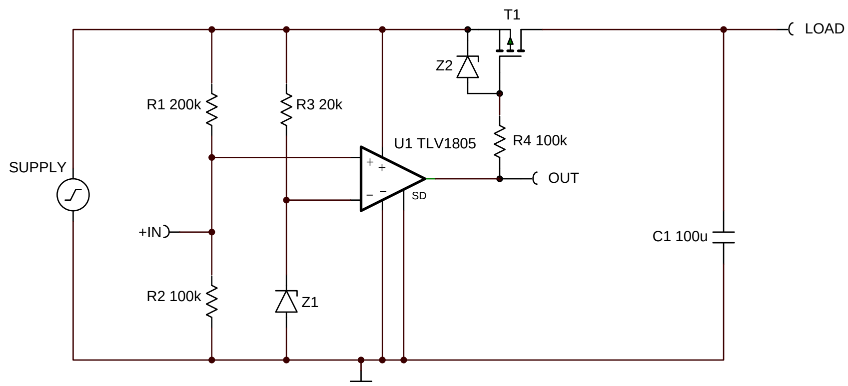
Overvoltage protection with comparator circuit

Design Goals

Supply	Load	Comparator Output Status (OUT)	
Operating Voltage Range	MAX Operating Voltage (V_{OVER})	SUPPLY < V_{OVER}	SUPPLY ≥ V_{OVER}
12V to 36V	30V	V_{OL} < 0.4V	V_{OH} = SUPPLY

Design Description

This overvoltage protection circuit uses a high-voltage comparator with a push-pull output stage to control a P-Channel MOSFET that connects the SUPPLY to the LOAD. When the SUPPLY voltage exceeds the overvoltage threshold (V_{OVER}), the output of the comparator goes HIGH and disconnects the LOAD from the SUPPLY by opening the P-Channel MOSFET. Likewise, when the SUPPLY voltage is below V_{OVER}, the output of the comparator is LOW and connects the LOAD to the SUPPLY.



Design Notes

1. Select a high-voltage comparator with a push-pull output stage.
2. Select a reference voltage that is below the lowest operating voltage range for the SUPPLY.
3. Calculate values for the resistor divider so the critical overvoltage level occurs when the input to the comparator (+IN) reaches the comparator's reference voltage.
4. Limit the source-gate voltage of the P-Channel MOSFET so that it remains below the device's maximum allowable value.

Design Steps

1. Select a high-voltage comparator with a push-pull output stage that can operate at the highest possible SUPPLY voltage. In this application, the highest SUPPLY voltage is 36V.
2. Determine an appropriate reference level for the overvoltage detection circuit. Since the lowest operating voltage for the SUPPLY is 12V, a 10V zener diode (Z_1) is selected for the reference (V_{REF}).
3. Calculate value of R3 by considering the minimum bias current to keep the Z_1 regulating at 10V. A minimum bias current of 100uA is used along with the minimum SUPPLY voltage of 12V.

   $$R_3 = \frac{SUPPLY\ (min) - V_{ZENER}}{I_{BIAS}\ (min)} = \frac{12V - 10V}{100\mu A} = 20\ k\Omega$$

4. Calculate the resistor divider ratio needed so the input to the comparator (+IN) crosses the reference voltage (10V) when the SUPPLY rises to the target overvoltage level (V_{OVER}) of 30V.

   $$V_{REF} = V_{OVER} \times \left(\frac{R_2}{R_1 + R_2}\right)$$

   $$\left(\frac{R_2}{R_1 + R_2}\right) = \frac{V_{REF}}{V_{OVER}} = \frac{10V}{30V} = 0.333$$

5. Select values for R_1 and R_2 that yield the resistor divider ratio of 0.333V by using the following equation or using the online "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 100k-ohm range and calculate for R_1. In this example, a value of 100k was chosen for R_2.

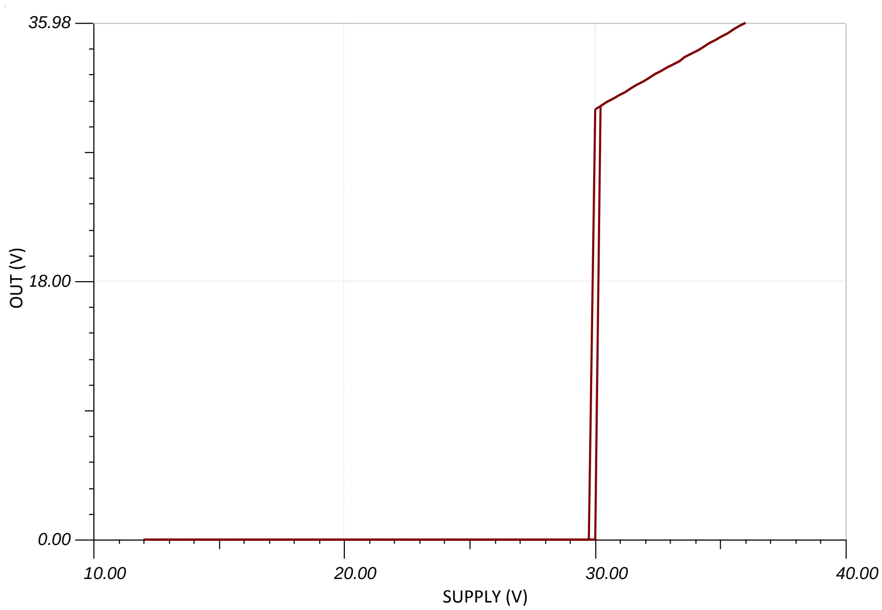
   $$R_1 = R_2\left(\frac{V_{OVER}}{V_{REF}} - 1\right) = 100\ k\Omega\ \left(\frac{30V}{10V} - 1\right) = 200\ k\Omega$$

6. Note that the TLV1805 which is used in application circuit has 15mV of hysteresis. This means that the actualy switching threshold will be 7.5mV higher than the switching threshold (VREF) when the SUPPLY is rising and 7.5mV lower when the SUPPLY is falling. The result of the hysteresis is most easily seen in the DC Simulation curve. Since SUPPLY is resistor divided down by a factor of 3, the net impact to the SUPPLY switching threshold is 3 times this amount.
7. 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.
8. Select a zener diode (Z_2) to limit the source-gate voltage (V_{SG}) of the P-Channel MOSFET so that it remains below the device's maximum allowable value. It is common for P-Channel, power MOSFETs to have a V_{SG} max value of 20V, so a 16V zener is placed from source to gate.
9. Calculate a value for the current limiting resistor (R_4). When SUPPLY rises above 16V and Z_2 begins to conduct, R_4 limits the amount of current that the comparator output will sink when its output is LOW. With a nominal SUPPLY voltage of 24V, the sink current is limited to 80µA.

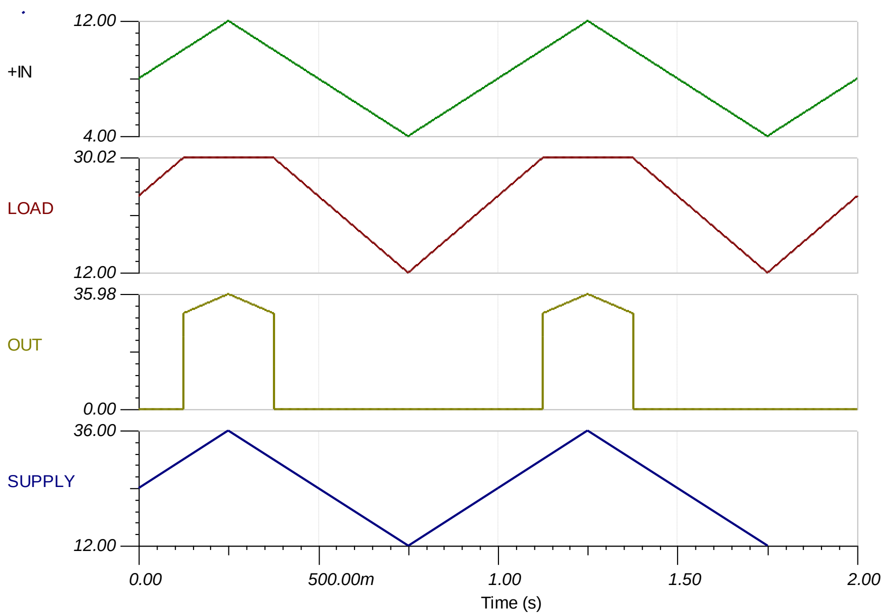
   $$I_{SINK} = \left(\frac{SUPPLY - V_{Z2}}{R_4}\right) = \left(\frac{24V - 16V}{100\ k\Omega}\right) = 80\ \mu A$$

Design Simulations

DC Simulation Results



Transient Simulation Results



References:

1. Analog Engineer's Circuit Cookbooks
2. SPICE Simulation File SNOAA20
3. TI Precision Labs

Design Featured Comparator

TLV1805-Q1 / TLV1805	
V_S	3.3 V to 40 V
V_{inCM}	Rail-to-rail
V_{OUT}	Push-Pull
V_{OS}	500 µV
Hysteresis	15 mV
I_Q	135 µA
$t_{PD(HL)}$	250 ns
www.ti.com/product/tlv1805	

Design Alternate Comparator

	TLV3701 / TLV370x-Q1	TLC3702 / TLC3702-Q1
V_S	2.5 V to 16 V	4V to 16 V
V_{inCM}	Rail-to-rail	-1 V from VDD
V_{OUT}	Push-Pull	Push-Pull
V_{OS}	250 µV	1.2 mV
Hysteresis	n/a	n/a
I_Q	0.56 µA	9.5 µA/Ch
$t_{PD(HL)}$	36 µs	0.65 µs
	www.ti.com/product/tlv3701	www.ti.com/product/tlc3702