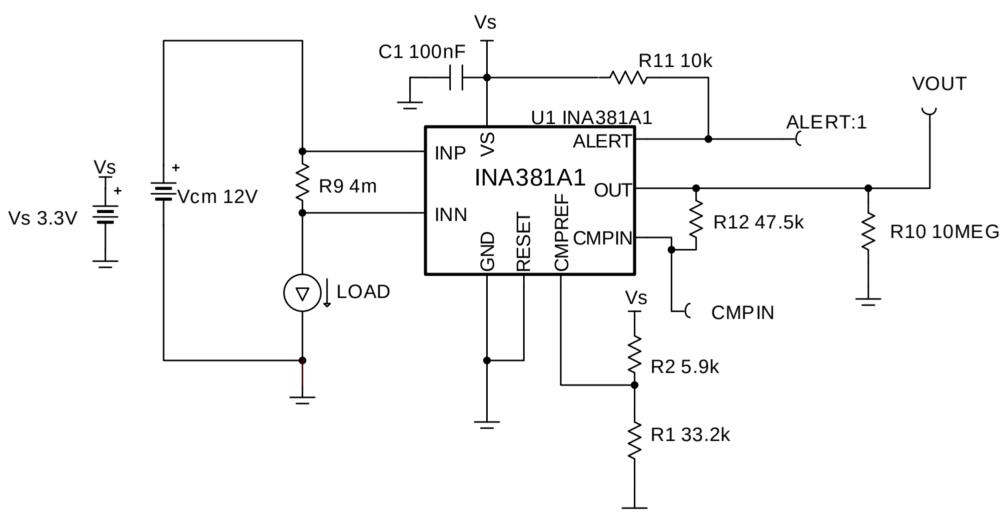
Overcurrent Event Detection Circuit

Design Goals

Input		Overcurrent Conditions		Output		Supply	
$I_{load\ Min}$	$I_{load\ Max}$	I_{OC_TH}	$I_{Release\_TH}$	V_{out_OC}	$V_{out\_release}$	V_S	V_{REF}
1.5A	40A	35A	32A	2.8V	2.61V	3.3V	2.8V

Design Description

This is a unidirectional current sensing solution generally referred to as overcurrent protection (OCP) that can provide an overcurrent alert signal to shut off a system for a threshold current and re-engage the system once the output drops below a desired voltage ($V_{out\_release}$) lower than the overcurrent output threshold voltage (V_{out_OC}). In this particular setup, the sensing range is from 1.5A to 40A, with the overcurrent threshold defined at 35A (I_{OC_TH}). The system re-asserts the ALERT to high once the current has dropped below 32A ($I_{Release\_TH}$). The current shunt monitor is powered from a 3.3-V supply rail. OCP can be applied to both high-side and low-side topologies. The solution presented in this article is a high-side implementation.



Design Notes

1. Use low-tolerance, high-precision resistors if using a voltage divider for CMPREF and consider buffering the voltage. Otherwise consider using a low-dropout regulator (LDO), reference or buffered reference voltage circuit to supply the CMPREF.
2. Use decoupling capacitors to ensure the device supply is stable, such as C1. Also place the decoupling capacitor as close to the device supply pin as possible.

Design Steps

1. Calculate the R_{shunt} value given 20V/V gain. Use the nearest standard value shunt, preferably lower than the calculated shunt to avoid railing the output prematurely .

$$R_{shunt} = \frac{V_{out\ max}}{gain \times I_{max}} = \frac{V_S - 0.02V}{gain \times I_{max}} = \frac{3.3V - 0.02V}{20V/V \times 40A} = 0.0041\Omega$$

$$R_{standard\ \ shunt} = 4m\Omega \text{ (standard 1\% value)}$$

2. Determine the voltage at the current shunt monitor output for the overcurrent threshold.

$$V_{out\_35A} = I_{OC\_TH} \times R_{standard\ \ shunt} \times gain = 35A \times 4m\Omega \times 20V/V = 2.8V$$

3. Choose a standard resistor value for R_1 and solve for R_2.

   A resistor with kilo-ohm resistance or higher is desired to minimize power loss. Through calculation, 33.2kΩ and 5.9kΩ were chosen for resistances $R_1$and R_2.

$$R_2 = \left(\frac{V_S}{V_{out\_35A}} - 1\right) \times R_1 = \left(\frac{3.3V}{2.8V} - 1\right) \times 33.2k\Omega = 5.9k\Omega$$

4. Calculate the resistance (R_{Hyst}) required for the proper hysteresis.

$$R_{Hyst} = \frac{V_{out\_35A} - (I_{Release\ \_TH} \times R_{standard\ \ shunt} \times gain + V_{Hyst\_def})}{I_{Hyst}}$$

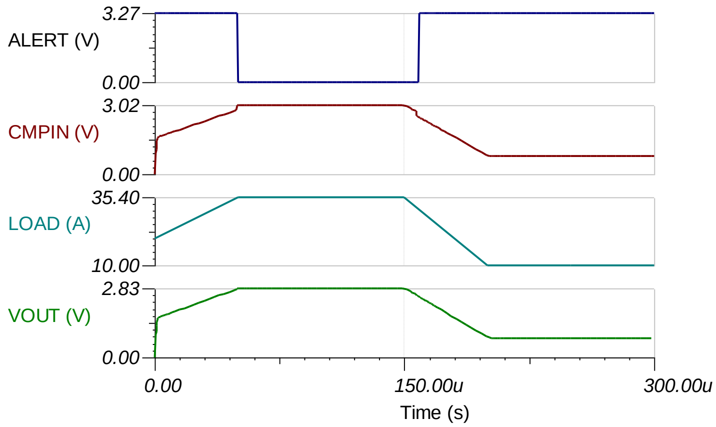
$$R_{Hyst} = \frac{2.8V - (32A \times 4m\Omega \times 20V/V + 50mV)}{4\mu A} = 47.5k\Omega$$

Design Simulations

Transient Simulation Results

Considering error, V_{out_OC} is expected to be approximately 2.8V, while $V_{out\_release}$ is expected to be approximately 2.61V.

High-Side OCP Simulation Results



The device exhibits an active low on the Alert pin when the load reaches 35A and re-asserts Alert to high when the load drops below 32A. If the user zooms in and looks at the VOUT voltage, and accounts for an expected propagation delay of 0.4µs, the device output is 2.69V at I_{OC_TH}, which only has an error of 0.39% with respect to the ideal output of 2.8V. At $I_{release\_TH}$, the alert re-asserts to high when the output dropped to 2.58V, which only has an error of 1.15% with respect to the ideal output of 2.61V.

Design References

Key files for Overcurrent Protection Circuit:

Source files for this design:
High-Side OCP Tina Model
Low-Side OCP Tina Model

Getting Started with Current Sense Amplifiers video series:

https://training.ti.com/getting-started-current-sense-amplifiers

Design Featured Current Sense Amplifier

INA381	
V_S	2.7V to 5.5V
V_{CM}	GND-0.3V to 26V
V_{OUT}	GND+5µV to V_S-0.02V
V_{OS}	±100 typical
I_q	250µA typical
I_B	80µA typical
http://www.ti.com/product/INA381	

Design Alternate Current Sense Monitor

	INA301	INA302	INA303
V_S	2.7V to 5.5V	2.7V to 5.5V	2.7V to 5.5V
V_{CM}	GND-0.3V to 40V	-0.1V to 36V	-0.1V to 36V
V_{OUT}	GND+0.02 to V_S-0.05V	GND+0.015 to V_S-0.05V	GND+0.015 to V_S-0.05V
V_{OS}	Gain Dependent	Gain Dependent	Gain Dependent
I_q	500µA typical	850µA typical	850µA typical
I_B	120µA typical	115µA typical	115µA typical
Comparator	Single Comparators	Dual Comparators	Window Comparators
	http://www.ti.com/product/INA301	http://www.ti.com/product/INA302	http://www.ti.com/product/INA303

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