

Fast-Response Overcurrent Event Detection Circuit

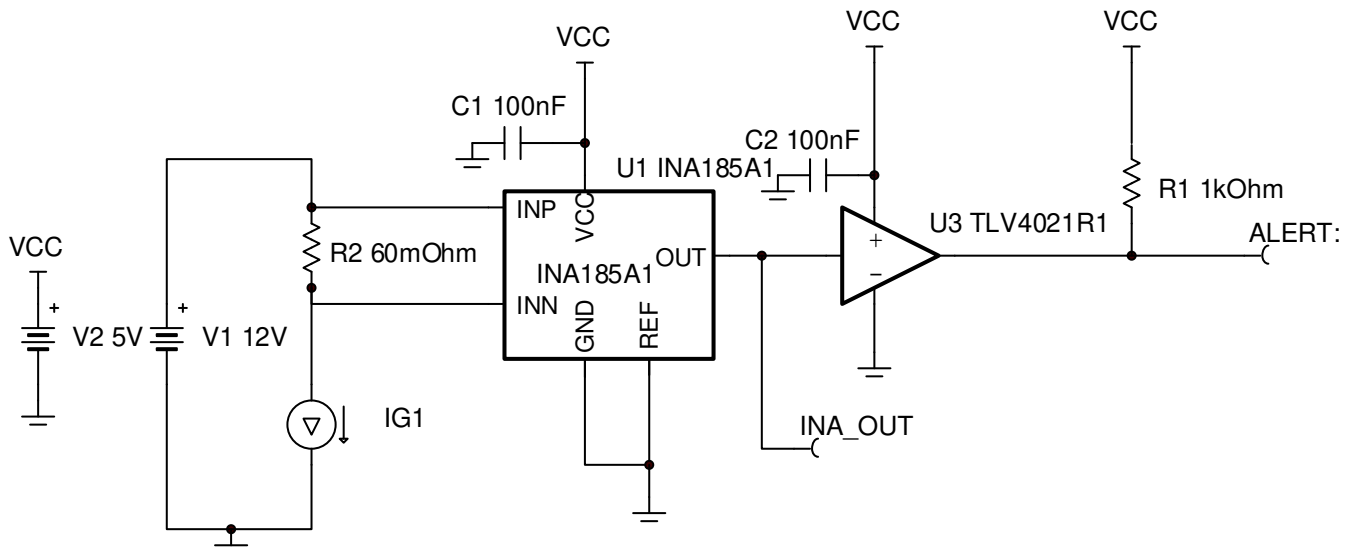


Design Goals

Input		Overcurrent Conditions		Output		Supply	
$I_{load\ Min}$	$I_{load\ Max}$	I_{OC_TH}	t_{resp}	V_{out_OC}	$V_{out_release}$	V_S	V_{REF}
80 mA	900 mA	1 A	< 2 μs	1.2 V	1.18 V	5 V	0 V

Design Description

This is a fast-response unidirectional current-sensing solution, generally referred to as overcurrent protection (OCP), that can provide a < 2 μs time response, t_{resp} , overcurrent alert signal to power off a system exceeding a threshold current. In this particular setup, the normal operating load is from 80 mA to 900 mA, with the overcurrent threshold defined at 1 A (I_{OC_TH}). The current shunt monitor is powered from a 5 V supply rail. OCP can be applied to both high-side and low-side topologies. The solution presented in this circuit is a high-side implementation. This circuit is useful in [smart speakers](#) and [docking stations](#).



Design Notes

1. Use decoupling capacitors C1 and C2 to ensure the device supply is stable. Place the decoupling capacitor as close to the device supply pin as possible.
2. If a larger dynamic current measurement range is required with a higher trip point, a voltage divider from the INA185 OUT pin to ground can be incorporated with the divider output going to the TLV4021R1 input.

Design Steps

1. Determine the slew rate, SR, needed to facilitate a fast enough response when paired with the propagation delay of a comparator. In this example, the TLV4021 device is selected as the external comparator due to its quick propagation delay ($t_p = 450$ ns) and its quick fall time ($t_f = 4$ ns). The worst case occurs when the load ramps from 0 A to 1 A ($\Delta V_{out} = V_{trip} - 0$ V). Device offset ($V_{OS} \times \text{gain}$) can be subtracted from V_{trip} in the numerator for less aggressive slew rates.

$$SR = \frac{\Delta V_{out}}{t_{resp} - t_p - t_f} = \frac{1.2V}{2\mu s - 450ns - 4ns} = 0.78V/\mu s$$

2. Choose a current shunt monitor with a slew rate greater than or equal 0.78 V/ μ s. The INA185 device satisfies the requirement with a typical slew of 2 V/ μ s.
3. For maximum headroom between the lowest measured current level and the overcurrent level, select the smallest gain variant of the chosen current shunt monitor. A 20 V/V current shunt monitor paired with 1.2 V comparator reference is adequate in this case.
4. Calculate the R_{shunt} value given 20 V/V gain. Use the nearest standard value shunt, preferably lower than the calculated shunt to avoid railing the output prematurely.

$$R_{shunt} = \frac{V_{trip}}{\text{gain} \times I_{trip}} = \frac{1.2V}{20V/V \times 1A} = 0.06\Omega$$

$$R_{standard\ shunt} = 60m\Omega \text{ (standard 1\% value)}$$

5. Check that the minimum meaningful current measurement is significantly higher than the current shunt monitor input offset voltage. The recommended maximum error from offset, $\text{error}_{V_{OS}}$ is 10%.

$$I_{Device_min} = \frac{V_{OS}}{\frac{\text{error}_{V_{OS}}}{100} \times R_{shunt}} = \frac{450\mu V}{\frac{10}{100} \times 0.06\Omega} = 75mA$$

6. Check that $I_{Load\ Max}$ is below the hysteresis threshold, $I_{Release_TH}$, to ensure that the ALERT signal is cleared after the system has taken corrective action to bring the load back under the upper limit of the normal operating range. In this case there is 83mA of margin between the 900 mA normal operating region maximum and the hysteresis level imposed by the comparator.

$$I_{Release_TH} = \frac{V_{trip} - 20mV}{\text{gain} \times R_{shunt}} = \frac{1.2V - 20mV}{20V/V \times 0.06\Omega} = 0.983A$$

Design Simulations

DC Simulation Results

The DC transfer characteristic curve confirms that the OCP trigger occurs from a 1 A load.

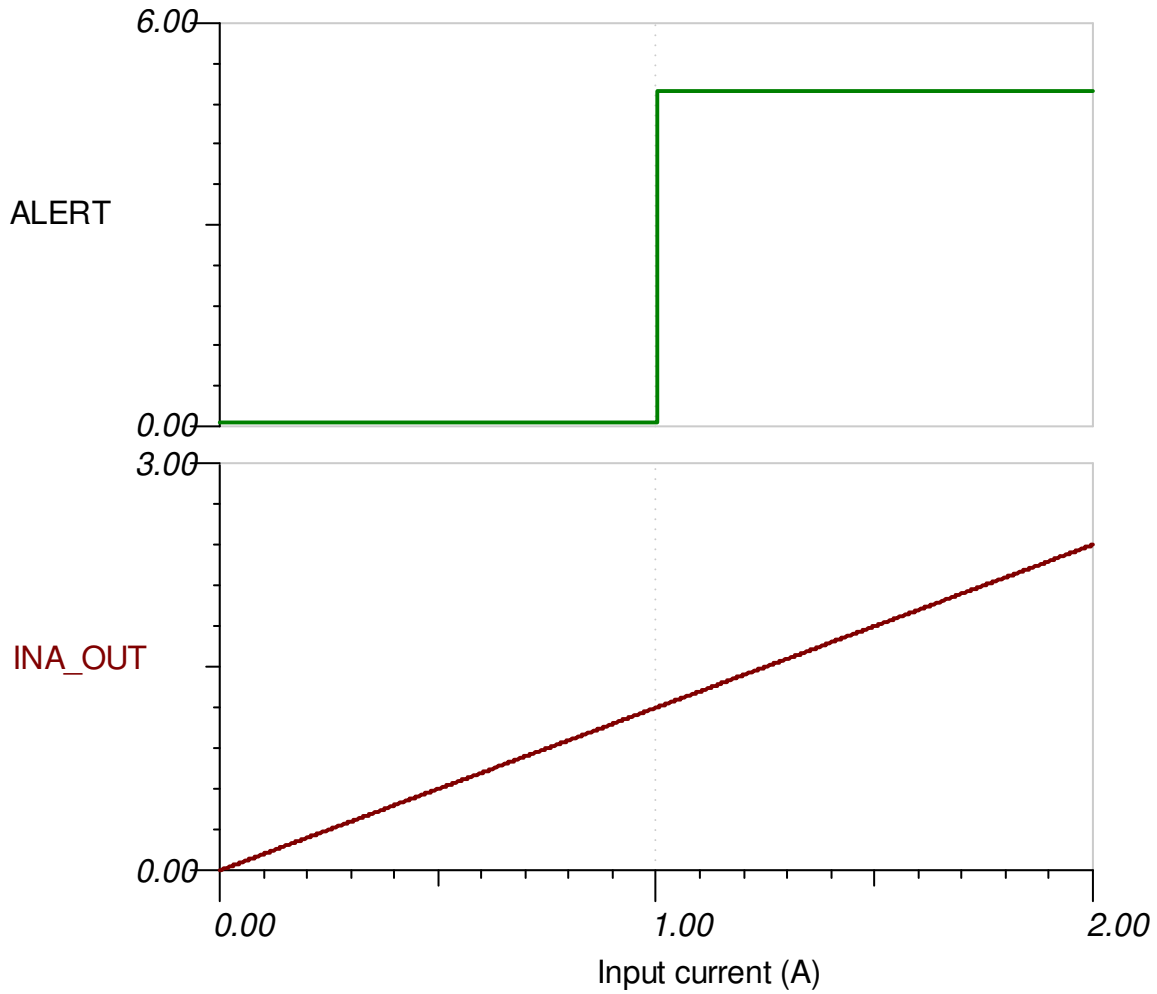
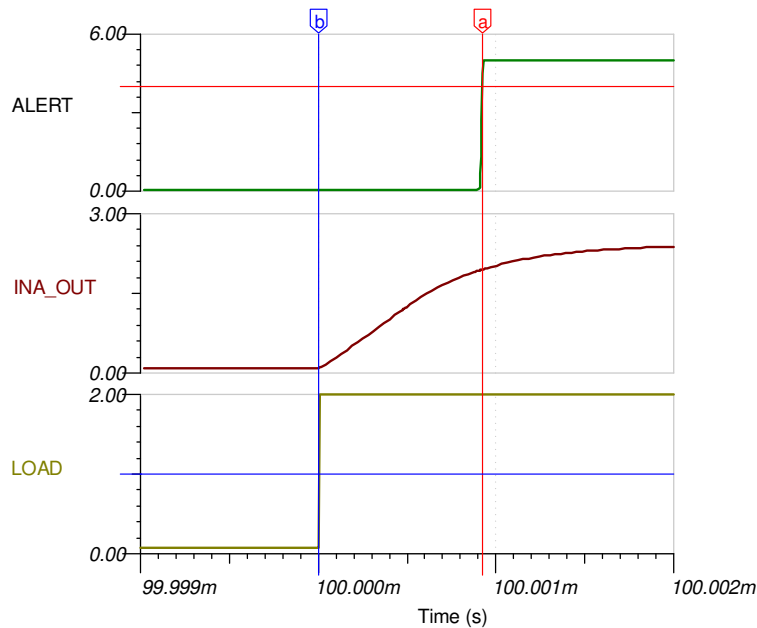


Figure 1-1.

Transient Simulation Results

The following result confirms that the INA185 device paired with the TLV4021 device can trigger an ALERT within 2 μs of the overcurrent threshold being exceeded. In this case, a typical value of almost 1 μs is achieved. Please keep in mind that models used in these simulations are designed around typical device characteristics. Real-world performance may vary based on normal device variations.



A	x: 100.0009289184ms	y: 4 V
B	x: 100.00001ms	y: 1 A
A-B	x: 918.9184ns	y:

Design References

See [Analog Engineer's Circuit Cookbooks](#) for TI's comprehensive circuit library.

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

[Getting started with current sense amplifiers](#)

Design Featured Current Sense Amplifier

INA185	
V_S	2.7 V to 5.5 V
V_{CM}	GND-0.2 V to 26 V
V_{OUT}	GND + 500 μ V to $V_S - 0.02$ V
Gain	20 V/V, 50 V/V, 100 V/V, 200 V/V
V_{OS}	± 100 μ V typical
SR	2 V/ μ s typical
I_q	200 μ A typical
I_B	75 μ A typical
INA185	

Design Alternate Current Sense Monitor

	INA181	INA180
V_S	2.7 V to 5.5 V	2.7 V to 5.5 V
V_{CM}	GND-0.2 V to 26 V	GND-0.2 V to 26 V
V_{OUT}	GND + 500 μ V to $V_S - 0.02$ V	GND + 500 μ V to $V_S - 0.02$ V
Gain	20 V/V, 50 V/V, 100 V/V, 200 V/V	20 V/V, 50 V/V, 100 V/V, 200 V/V
V_{OS}	± 100 μ V typical	± 100 μ V typical
SR	2 V/ μ s typical	2 V/ μ s typical
I_q	195 μ A typical	197 μ A typical
I_B	75 μ A typical	80 μ A typical
	INA181	INA180

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](https://www.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 © 2023, Texas Instruments Incorporated