Analog Engineer's Circuit

High-Speed Overcurrent Detection Circuit

Jaskaran Atwal

Design Goal

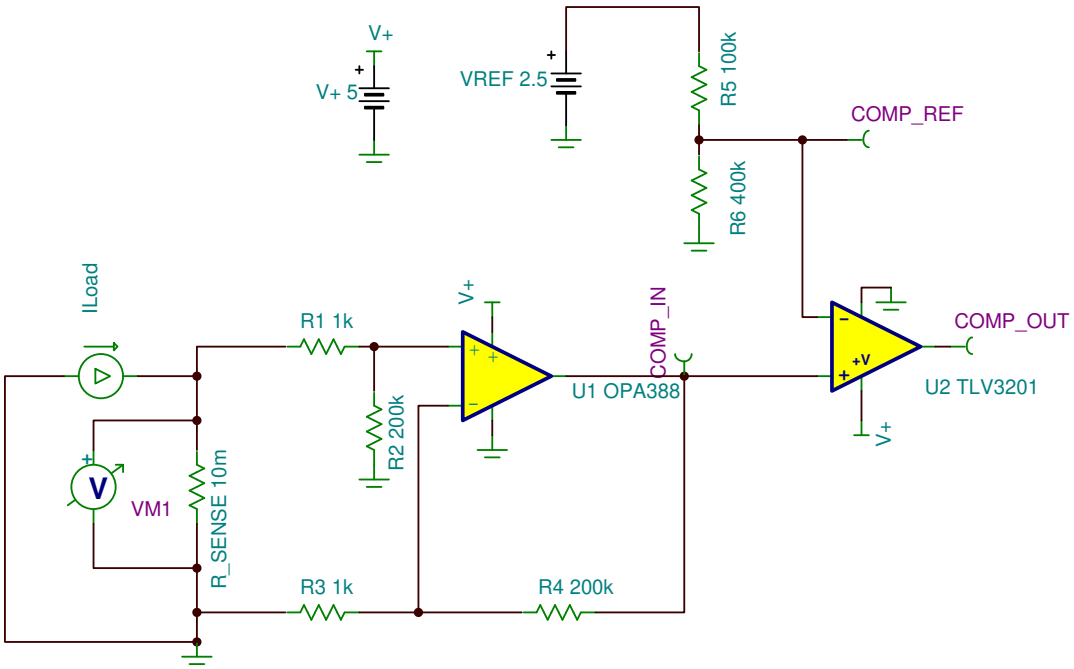
Overcurrent Levels		Supply		Transient Response Time
I_{IN} (min)	I_{IN} (max)	V+	V–	t
0A	1.0A	5V	0V	< 10µs

Design Description

This high-speed, low-side overcurrent detection option is implemented with a single zero-drift fast-settling amplifier (OPA388) and one high-speed comparator (TLV3201). This circuit is designed for applications that monitor fast current signals and overcurrent events, such as current detection in motors and power supply units.

The OPA388 is selected for wide bandwidth with ultra-low offset and fast slew rate. The TLV3201 is selected for the fast response due to a small propagation delay of 40ns and rise time of 4.8ns. This allows the comparator to quickly respond and alert the system of an overcurrent event all within the transient response time requirement. The push-pull output stage also allows the comparator to directly interface with the logic levels of the microcontroller. The TLV3201 also has low power consumption with a quiescent current of 40µA.

Typically for low-side current detection, the amplifier across the sense resistor can be used in a noninverting configuration. The application circuit shown, however, uses the OPA388 as a differential amplifier across the sense resistor. This provides a true differential measurement across the shunt resistor and can be beneficial in cases where the supply ground and load ground are not necessarily the same.



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Design Notes

1. To minimize errors, choose precision resistors and set $R_1 = R_3$, and $R_2 = R_4$.
2. Select R_{SENSE} to minimize the voltage drop across the resistor at the max current of 1A.
3. Due to the ultra-low offset of the OPA388 (0.25µV), the effect of any offset error from the amplifier is minimal on the mV range measurement across R_{SENSE} .
4. Select the amplifier gain so COMP_IN reaches 2V when the system crosses its critical overcurrent value of 1A.
5. Traditional bypass capacitors are omitted to simplify the application circuit.

Design Steps

1. Determine the transfer equation where $R_1 = R_3$ and $R_2 = R_4$.

$$COMP_IN = (R_{SENSE} \times I_{LOAD}) \times \left(\frac{R_2}{R_1 + R_2}\right) \times \left(1 + \frac{R_4}{R_3}\right)$$

2. Select the SENSE resistor value assuming a maximum voltage drop of 10mV with a load current of 1A to minimize the voltage drop across the resistor.

$$R_{SENSE} = \frac{V_{SENSE}(max)}{I_{LOAD}(critical)} = \frac{10mV}{1A} = 10m\Omega$$

3. Select the amplifier gain such that COMP_IN reaches 2V when the load current reaches the critical threshold of 1A.

$$Gain = \frac{VREF}{R_{SENSE} \times I_{LOAD}(critical)} = \frac{2V}{0.01V} = \frac{R_2}{R_1 + R_2} \times 1 + \frac{R_4}{R_3} = 200$$

Set:

$$R_1 = R_3 = 1k\Omega$$

$$R_2 = R_4 = 200k\Omega$$

4. Calculate the transimpedance gain of the amplifier to verify the following AC simulation results:

$$\frac{V_{OUT}}{I_{LOAD}} = 10m\Omega \times 200 = 2$$

$$V_{OUT} = I_{LOAD} \times 10m\Omega \times 200$$

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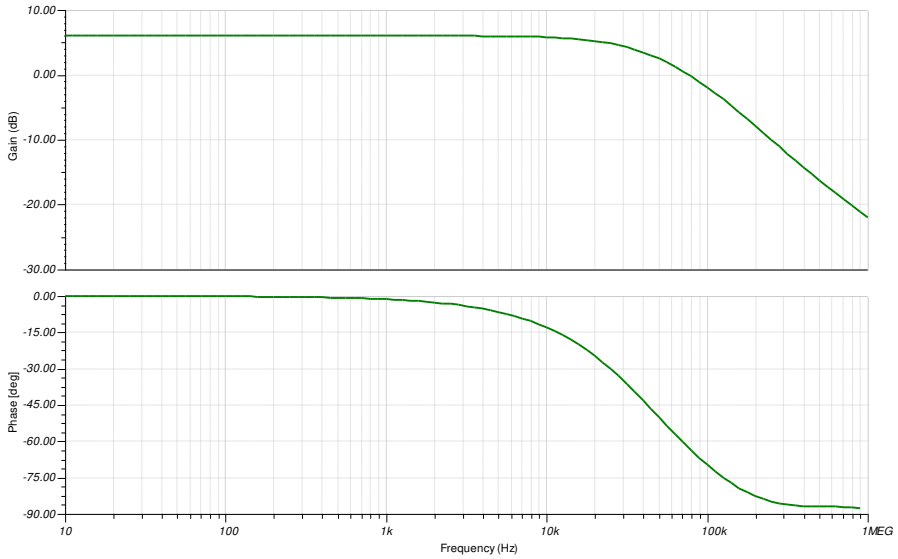
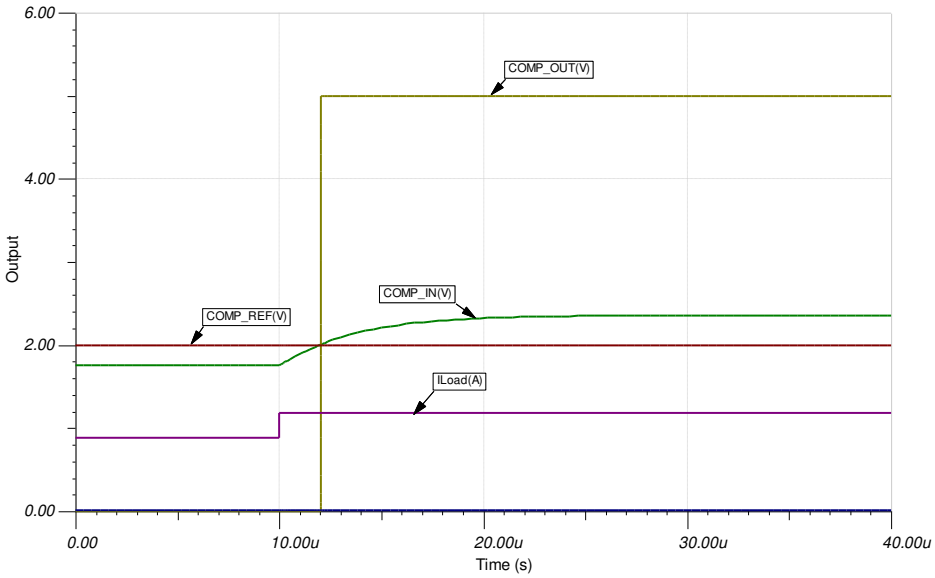
Design Simulations

COMP_IN Transimpedance AC Simulation Results



Transient Response Simulation Results



References

1. Texas Instruments, *Advantages of Using Nanopower, Zero Drift Amplifiers for Battery Voltage and Current Monitoring in Portable Applications*, application note
2. Texas Instruments, *Current Sensing in No-Neutral Light Switches*, technology brief
3. Texas Instruments, *GPIO Pins Power Signal Chain in Personal Electronics Running on Li-Ion Batteries*, application brief

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Design Featured Comparator

TLV3201	
V_S	2.7V to 5.5V
t_{PD}	40ns
Input V_{CM}	Rail-to-rail
V_{os}	1mV
I_q	40µA
TLV3201	

Design Alternate Comparator

TLV7021	
V_S	1.6V to 5.5V
t_{PD}	260ns
Input V_{CM}	Rail-to-rail
V_{os}	0.5mV
I_q	5µA
TLV7021	

Design Featured Op Amp

OPA388	
V_S	2.5V to 5.5V
Input V_{CM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	0.25µV
V_{os} Drift	.005µV/°C
I_q	1.7mA/Ch
I_b	30pA
UGBW	10MHz
OPA388	

Design Alternate Op Amp

THS4521	
V_S	2.5V to 5.5V
Input V_{CM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	20µV
V_{os} Drift	µV/°C
I_q	1mA/Ch
I_b	0.6µA
UGBW	145MHz
THS4521	

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