

Analog Engineer's Circuit

High-Speed Overcurrent Detection Circuit



Design Goal

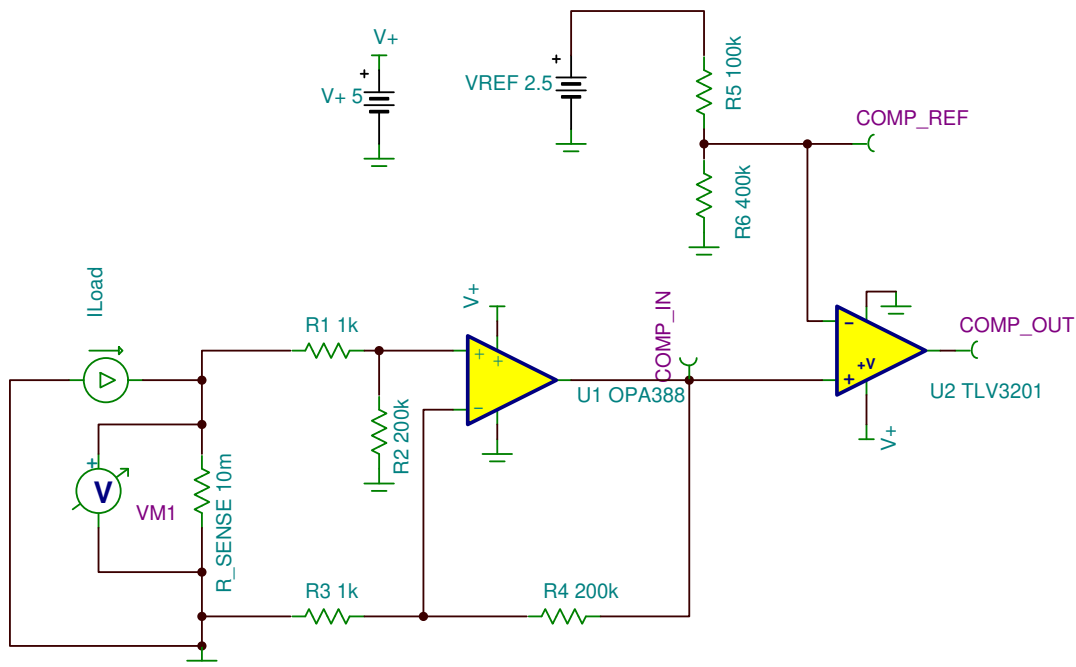
| Overcurrent Levels | | Supply | | Transient Response Time |
|--------------------|----------------|--------|-----|-------------------------|
| I_{IN} (min) | I_{IN} (max) | V+ | V- | t |
| 0 A | 1.0 A | 5 V | 0 V | < 10 μ s |

Design Description

This high-speed, low-side overcurrent detection solution 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 its widest bandwidth with ultra-low offset and fast slew rate. The TLV3201 is selected for its fast response due to its small propagation delay of 40 ns and rise time of 4.8 ns. 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 40 μ A.

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.



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 1 A.
3. Due to the ultra-low offset of the OPA388 (0.25 μV), 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 2 V when the system crosses its critical overcurrent value of 1 A.
5. Traditional bypass capacitors are omitted to simplify the application circuit.

Design Steps

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

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

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

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

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

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

Set:

$$R_1 = R_3 = 1\text{k}\Omega$$

$$R_2 = R_4 = 200\text{k}\Omega$$

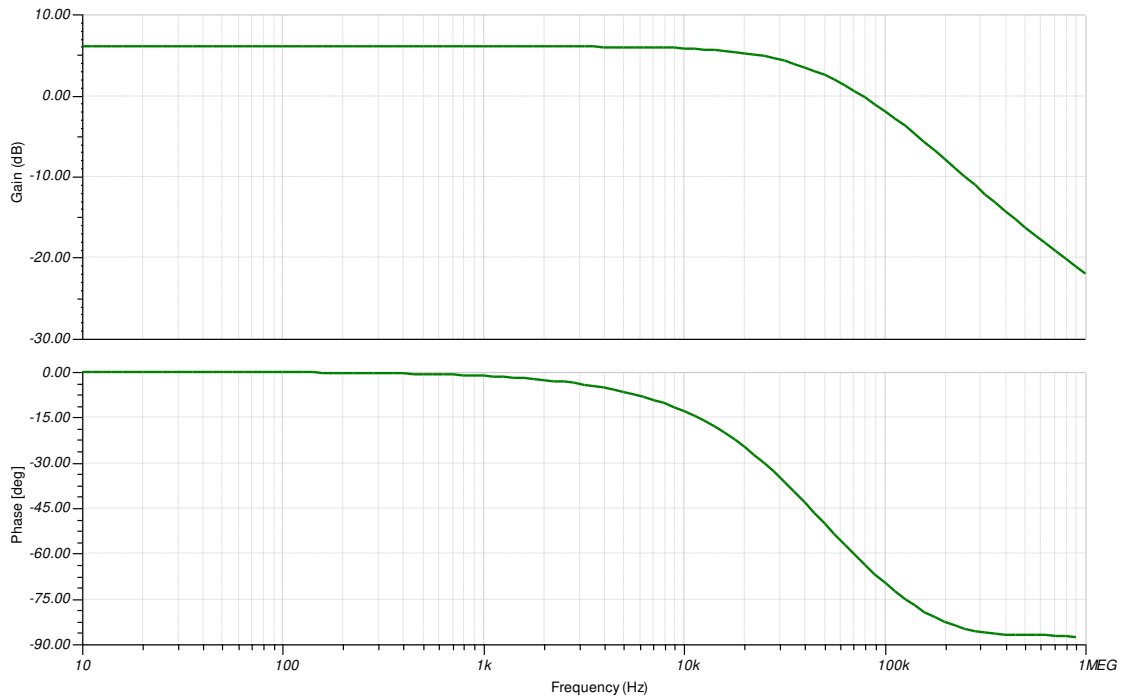
4. Calculate the transimpedance gain of the amplifier in order to verify the following AC simulation results:

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

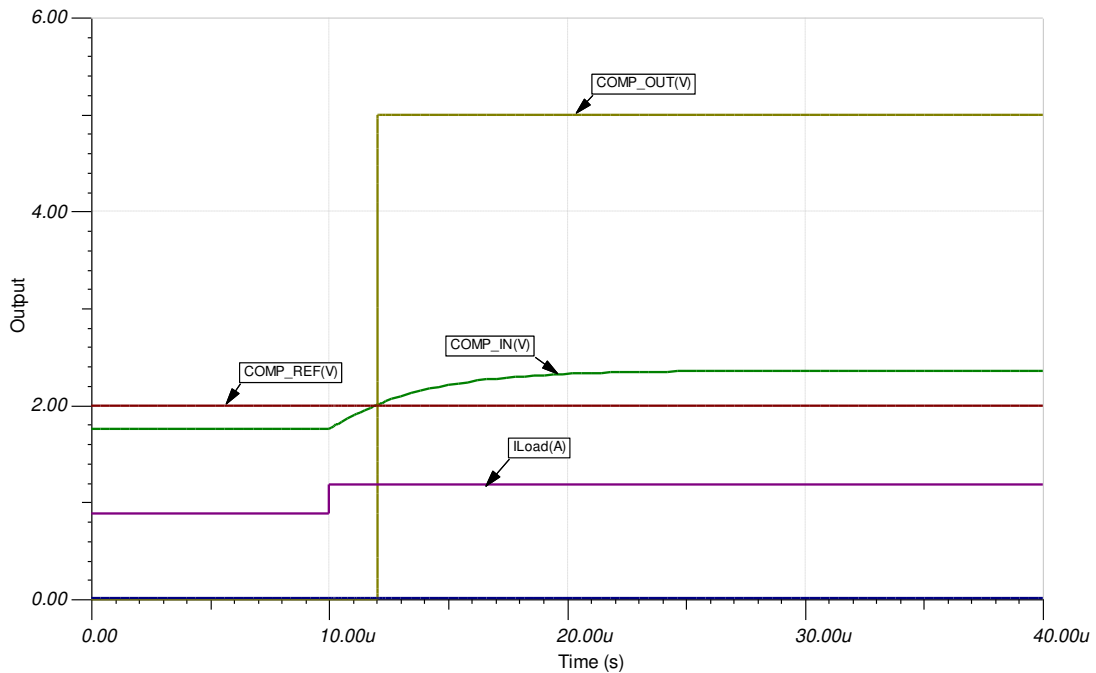
$$\frac{V_{\text{OUT}}}{I_{\text{LOAD}}} = 10\text{m}\Omega \cdot 200 = 2$$

Design Simulations

COMP_IN Transimpedance AC Simulation Results



Transient Response Simulation Results



Design References

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

See the [Current sensing using nanopower op amps](#) blog.

References

1. Texas Instruments, [Advantages of using nanopower, zero drift amplifiers for battery voltage and current monitoring in portable applications TI tech note](#)
2. Texas Instruments, [Current sensing in no-neutral light switches TI tech note](#)
3. Texas Instruments, [GPIO Pins power signal chain in personal electronics running on Li-Ion batteries TI tech note](#)

Design Featured Comparator

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

Design Alternate Comparator

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

Design Featured Op Amp

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

Design Alternate Op Amp

| THS4521 | |
|-----------------------------|-----------------------|
| V_S | 2.5 V to 5.5 V |
| Input V_{CM} | Rail-to-rail |
| V_{out} | Rail-to-rail |
| V_{os} | 20 μ V |
| V_{os} Drift | μ V/ $^{\circ}$ C |
| I_q | 1 mA/Ch |
| I_b | 0.6 μ A |
| UGBW | 145 MHz |
| THS4521 | |

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