

Analog Engineer's Circuit

High-Side Current-Sensing Circuit Design



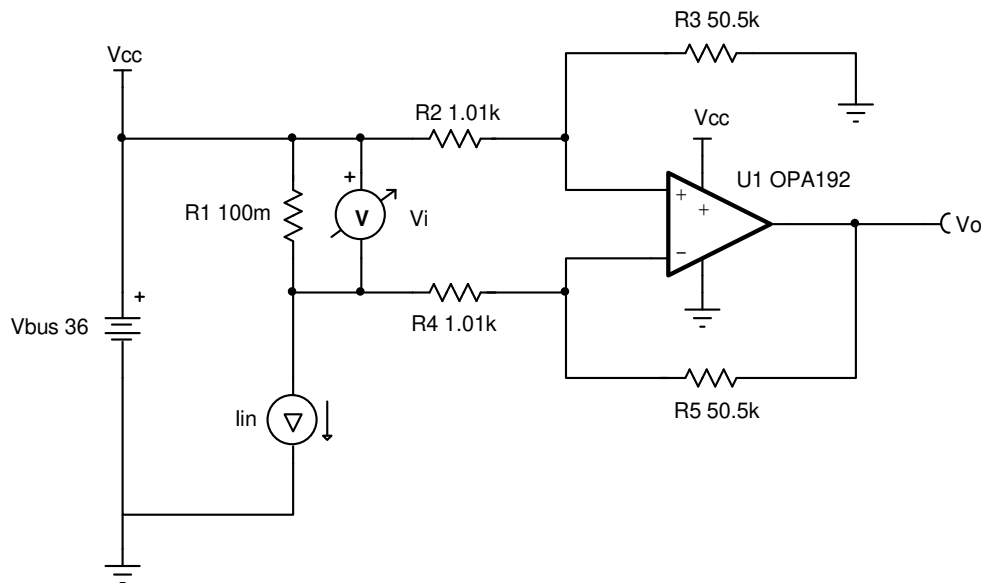
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Design Goals

Input		Output		Supply	
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}
50mA	1A	0.25V	5V	36V	0V

Design Description

This single-supply, high-side, low-cost current sensing method detects load current between 50mA and 1A and converts it to an output voltage from 0.25V to 5V. High-side sensing allows for the system to identify ground shorts and does not create a ground disturbance on the load.



Design Notes

- DC common mode rejection ratio (CMRR) performance is dependent on the matching of the gain setting resistors, R_2 - R_5 .
- Increasing the shunt resistor increases power dissipation.
- Verify that the common-mode voltage is within the linear input operating region of the amplifier. The common mode voltage is set by the resistor divider formed by R_2 , R_3 , and the bus voltage. Depending on the common-mode voltage determined by the resistor divider a rail-to-rail input (RRI) amplifier may not be required for this application.
- An op amp that does not have a common-mode voltage range that extends to V_{cc} may be used in low-gain or an attenuating configuration.
- A capacitor placed in parallel with the feedback resistor limits bandwidth, improve stability, and help reduce noise.
- Use the op amp in a linear output operating region. Linear output swing is usually specified under the A_{OL} test conditions.

Design Steps

- The full transfer function of the circuit is provided below.

$$V_o = I_{in} \times R_1 \times \frac{R_5}{R_4}$$

$$\text{Given } R_2 = R_4 \text{ and } R_3 = R_5$$

- Calculate the maximum shunt resistance. Set the maximum voltage across the shunt to 100mV.

$$R_1 = \frac{V_{iMax}}{I_{iMax}} = \frac{100mV}{1A} = 100m\Omega$$

- Calculate the gain to set the maximum output swing range.

$$\text{Gain} = \frac{V_{oMax} - V_{oMin}}{(I_{iMax} - I_{iMin}) \times R_1} = \frac{5V - 0.25V}{(1A - 0.05A) \times 100m\Omega} = 50 \frac{V}{V}$$

- Calculate the gain setting resistors to set the gain calculated in step 3.

$$\text{Choose } R_2 = R_4 = 1.01k\ \Omega \text{ (Standard value)}$$

$$R_3 = R_5 = R_2 \times \text{Gain} = 1.01k\ \Omega \times 50 \frac{V}{V} = 50.5k\ \Omega \text{ (Standard value)}$$

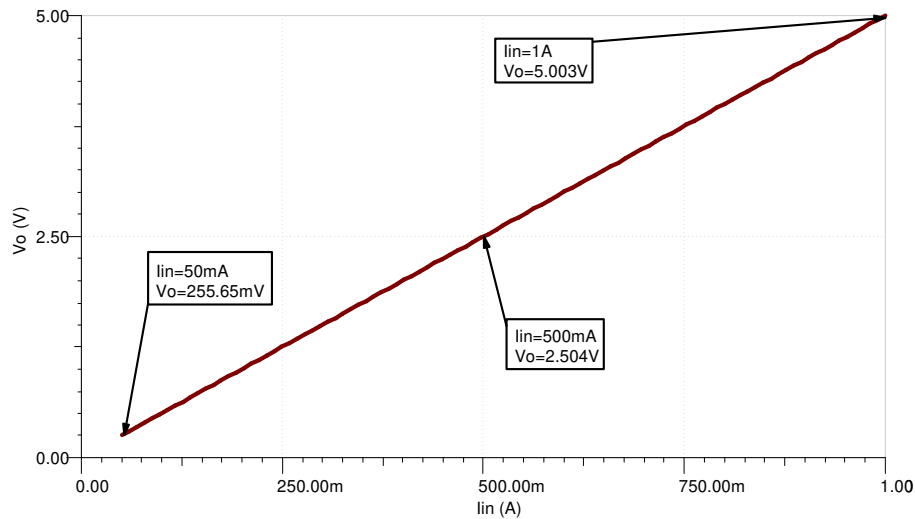
- Calculate the common-mode voltage of the amplifier to establish linear operation.

$$V_{cm} = V_{CC} \times \frac{R_3}{R_2 + R_3} = 36V \times \frac{50.5k}{1.01k + 50.5k} = 35.294\ V$$

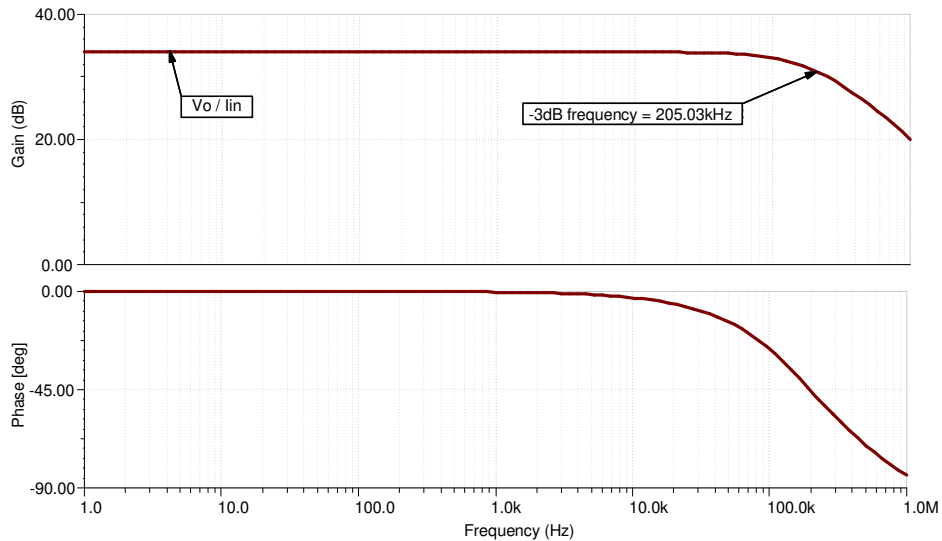
- The upper cutoff frequency (f_H) is set by the non-inverting gain (noise gain) of the circuit and the gain bandwidth (GBW) of the op amp.

$$f_H = \frac{GBW}{\text{Noise Gain}} = \frac{10MHz}{51 \frac{V}{V}} = 196.1\ \text{kHz}$$

Design Simulations



DC Simulation Results



AC Simulation Results

References:

Texas Instruments, [SBOMAV4 simulation file](#), software support

Design Featured Op Amp

OPA192	
V_{CC}	4.5V to 36V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	5 μ V
I_q	1mA
I_b	5pA
UGBW	10MHz
SR	20V/ μ s
#Channels	1, 2, and 4
OPA192	

Design Alternate Op Amp

OPA2990	
V_{CC}	2.7V to 40V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	250 μ V
I_q	120 μ A
I_b	10pA
UGBW	1.25MHz
SR	5V/ μ s
#Channels	2
OPA2990	

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (February 2019) to Revision B (September 2024)	Page
• Updated the format for tables, figures, and cross-references throughout the document	1

Changes from Revision * (December 2018) to Revision A (February 2019)	Page
• Downstyle title. Added <i>Design Alternate Op Amp</i> table.....	1

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