

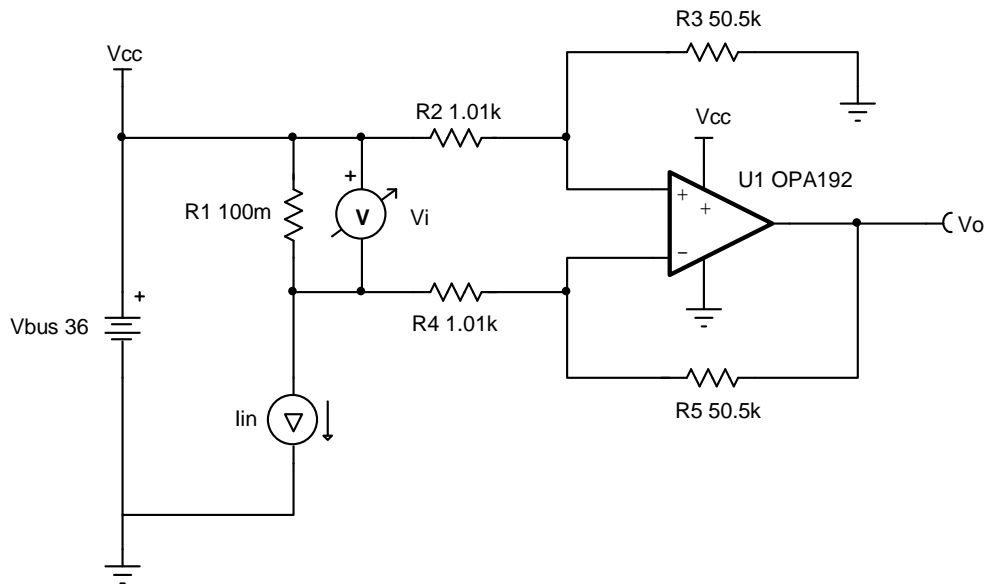
## High-side current-sensing circuit design

### 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 solution 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.
- Ensure 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 will limit 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

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

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

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

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

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

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

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

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

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

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

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

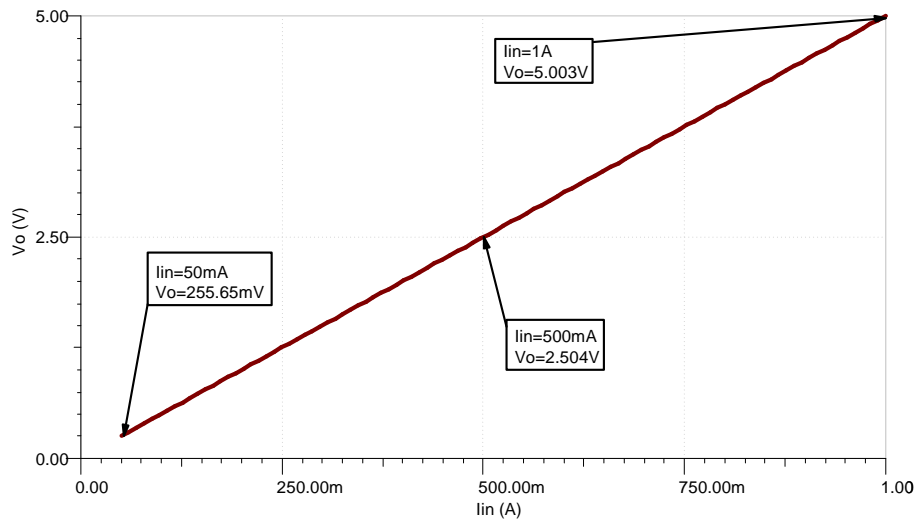
$$V_{cm} = V_{CC} \times \frac{R_3}{R_2 + R_3} = 36V \times \frac{50.5k}{1.01k + 50.5k} = 35.294V$$

6. 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.

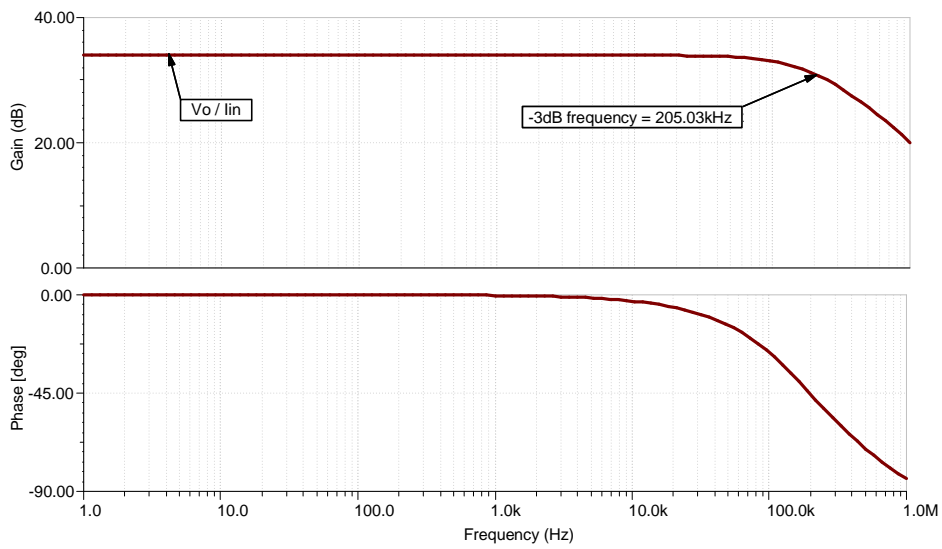
$$f_H = \frac{GBW}{\text{Noise Gain}} = \frac{10MHz}{51 \frac{V}{V}} = 196.1 \text{ kHz}$$

## Design Simulations

### DC Simulation Results



### AC Simulation Results



**References:**

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBOMAV4](#)
3. [TI Precision Labs](#)

**Design Featured Op Amp**

<b>OPA192</b>	
$V_{cc}$	4.5V to 36V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	5 $\mu$ V
$I_q$	1mA
$I_b$	5pA
<b>UGBW</b>	10MHz
<b>SR</b>	20V/ $\mu$ s
<b>#Channels</b>	1, 2, 4
<a href="http://www.ti.com/product/OPA192">www.ti.com/product/OPA192</a>	

**Design Alternate Op Amp**

<b>OPA2990</b>	
$V_{cc}$	2.7V to 40V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	250 $\mu$ V
$I_q$	120 $\mu$ A
$I_b$	10pA
<b>UGBW</b>	1.25MHz
<b>SR</b>	5V/ $\mu$ s
<b>#Channels</b>	2
<a href="http://www.ti.com/product/OPA2990">www.ti.com/product/OPA2990</a>	

**Revision History**

Revision	Date	Change
A	February 2019	Downstyle title. Added <i>Design Alternate Op Amp</i> table.

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