

# Single-Supply, Low-Side, Unidirectional Current-Sensing Solution With Output Swing to GND Circuit



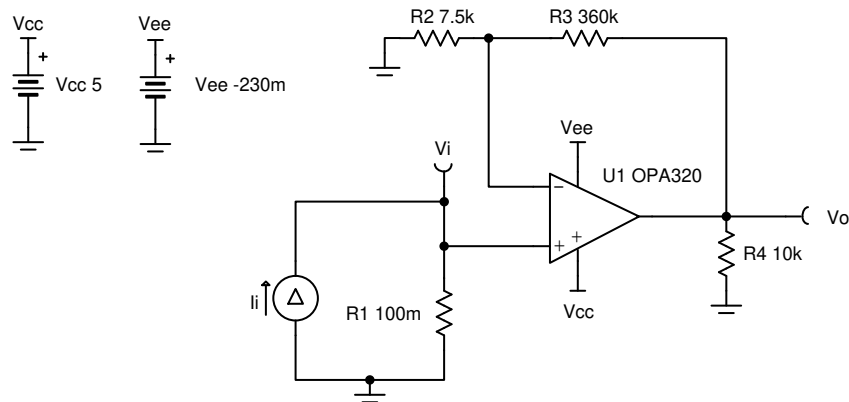
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## Design Goals

Input		Output		Supply		
$I_{iMin}$	$I_{iMax}$	$V_{oMin}$	$V_{oMax}$	$V_{cc}$	$V_{ee}$	$V_{ref}$
0A	1A	0V	4.9V	5V	0V	0V

## Design Description

This single-supply, low-side, current sensing solution accurately detects load current between 0A to 1A and converts it to a voltage between 0V to 4.9V. The input current range and output voltage range can be scaled as necessary and larger supplies can be used to accommodate larger swings. A negative charge pump (such as the LM7705) is used as the negative supply in this design to maintain linearity for output signals near 0V.



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## Design Notes

1. Use precision resistors to minimize gain error.
2. For light load accuracy, the negative supply should extend slightly below ground.
3. A capacitor placed in parallel with the feedback resistor will limit bandwidth and help reduce noise.

## Design Steps

1. Determine the transfer function.

$$V_o = I_i \times R_1 \times \left(1 + \frac{R_3}{R_2}\right)$$

2. Define the full-scale shunt voltage and shunt resistance.

$$V_{iMax} = 100\text{mV at } I_{iMax} = 1\text{A}$$

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

3. Select gain resistors to set the output range.

$$V_{iMax} = 100\text{mV and } V_{oMax} = 4.9\text{V}$$

$$\text{Gain} = \frac{V_{oMax}}{V_{iMax}} = \frac{4.9\text{V}}{100\text{mV}} = 49\frac{\text{V}}{\text{V}}$$

$$\text{Gain} = 1 + \frac{R_3}{R_2} = 49\frac{\text{V}}{\text{V}}$$

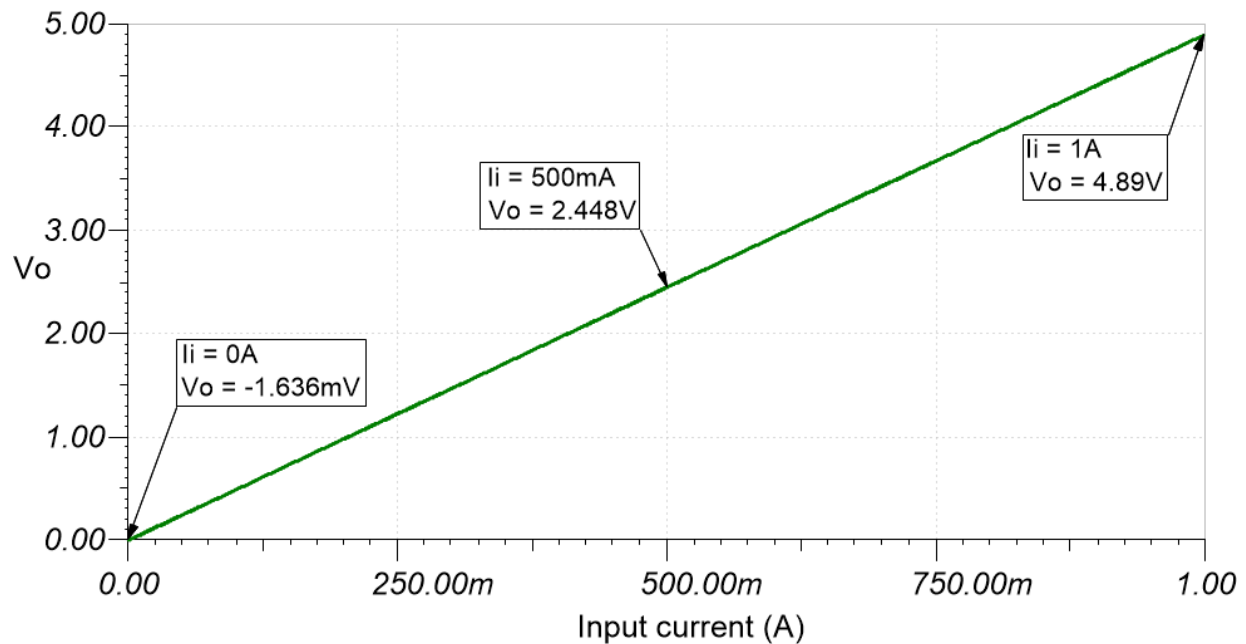
4. Select a standard value for  $R_2$  and  $R_3$ .

$$R_2 = 7.5\text{k}\Omega \text{ (0.05\% Standard Value)}$$

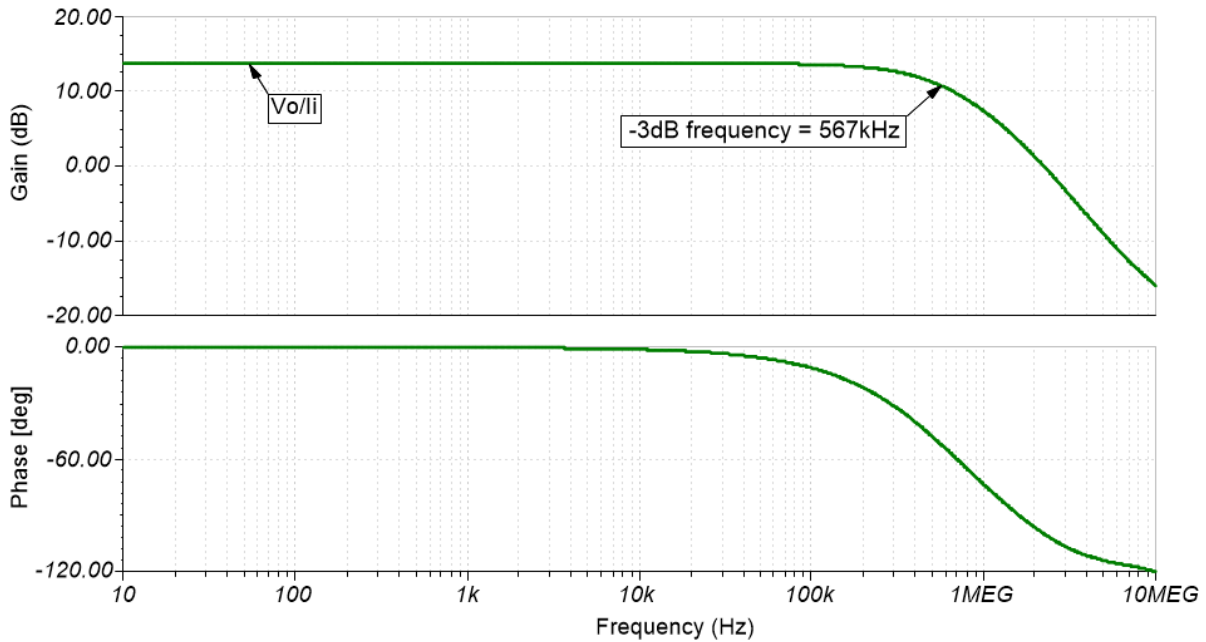
$$R_3 = 48 \times R_2 = 360\text{k}\Omega \text{ (0.05\% Standard Value)}$$

## Design Simulations

### DC Simulation Results



## AC Simulation Results



## Design References

Texas Instruments, [Simulation for Unidirectional Current Sense with Output Swing to GND](#), circuit SPICE simulation file

Texas Instruments, [0-1A, Single-Supply, Low-Side, Current Sensing Solution](#), reference design

## Design Featured Op Amp

OPA320	
$V_{CC}$	1.8V to 5.5V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	40 $\mu$ V
$I_q$	1.5 mA/Ch
$I_b$	0.2pA
UGBW	10MHz
SR	10V/ $\mu$ s
#Channels	1 and 2
<a href="#">OPA320</a>	

## Design Alternate Op Amp

TLV9002	
$V_{cc}$	1.8V to 5.5V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	400 $\mu$ V
$I_q$	60 $\mu$ A
$I_b$	5pA
UGBW	1MHz
SR	2V/ $\mu$ s
#Channels	1, 2, and 4
<a href="#">TLV9002</a>	

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## Revision History

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

<b>Changes from Revision A (February 2019) to Revision B (October 2024)</b>	<b>Page</b>
• Updated the format for tables, figures, and cross-references throughout the document.....	1

<b>Changes from Revision * (February 2018) to Revision A (February 2019)</b>	<b>Page</b>
• Downscale the title and changed title role to <i>Amplifiers</i> . Added link to circuit cookbook landing page.....	1

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