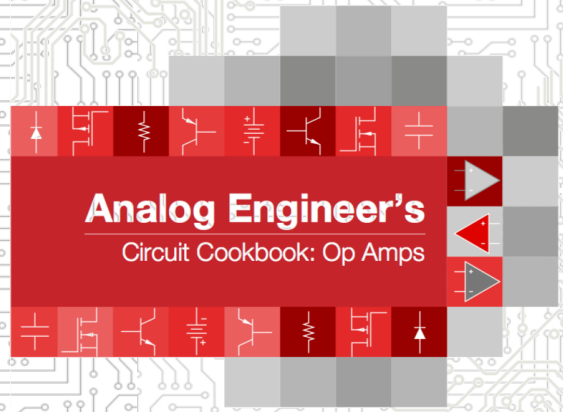
CIRCUIT060001

How to Design
Single-supply, low-side, unidirectional current sensing circuit



General Purpose Amplifiers

www.ti.com/general-amps

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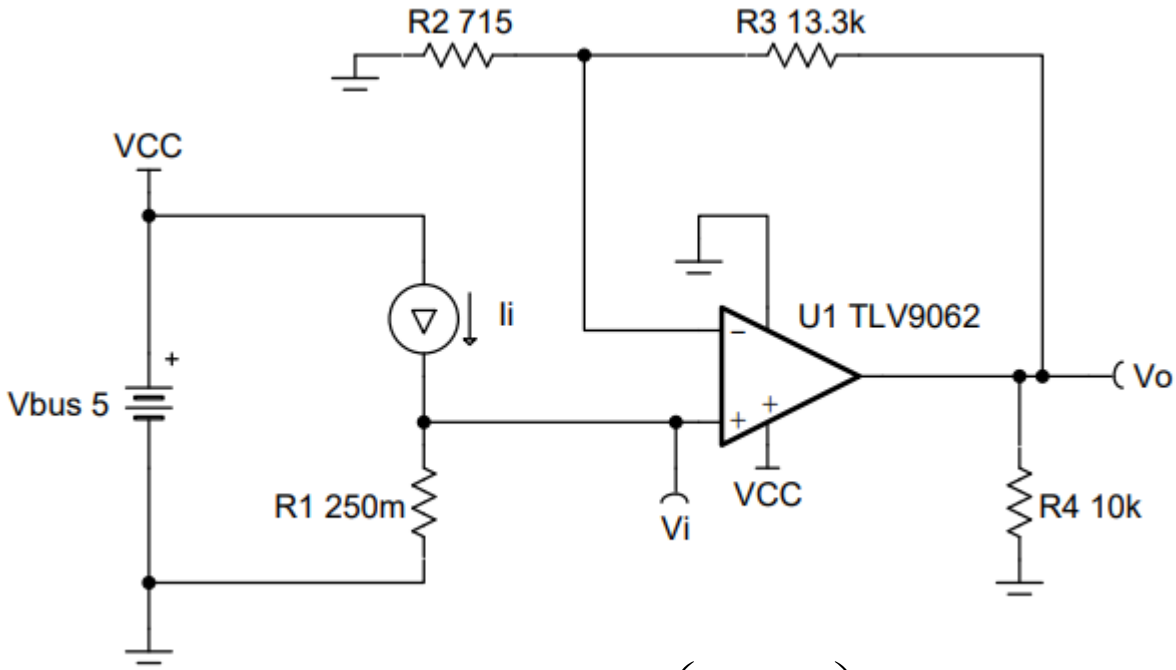
Circuit Description



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

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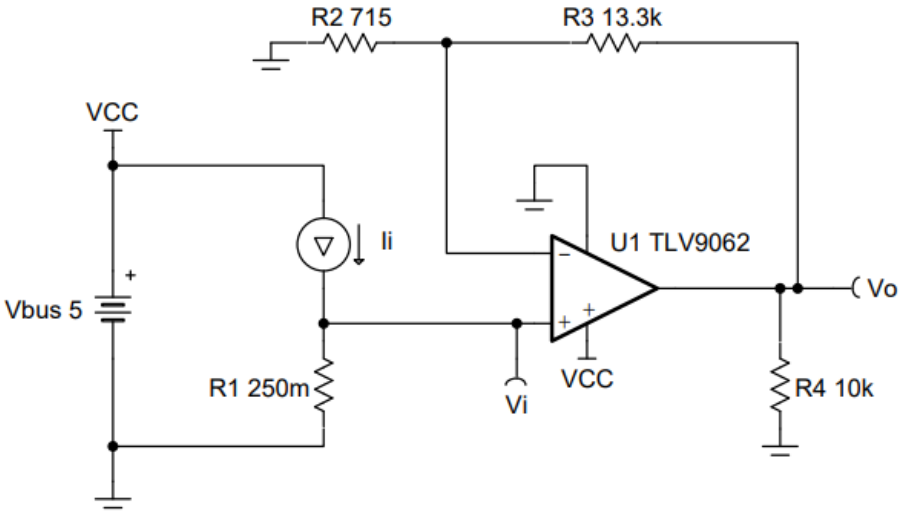
Design Goals

Input		Output		Full-Scale Range Error	Supply	
I_{iMax}	V_{iMax}	V_{oMin}	V_{oMax}	FSR_{Error}	V_{cc}	V_{ee}
1A	250mV	50mV	4.9V	0.2%	5V	0V



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

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Design Steps

Input		Output		Full-Scale Range Error	Supply	
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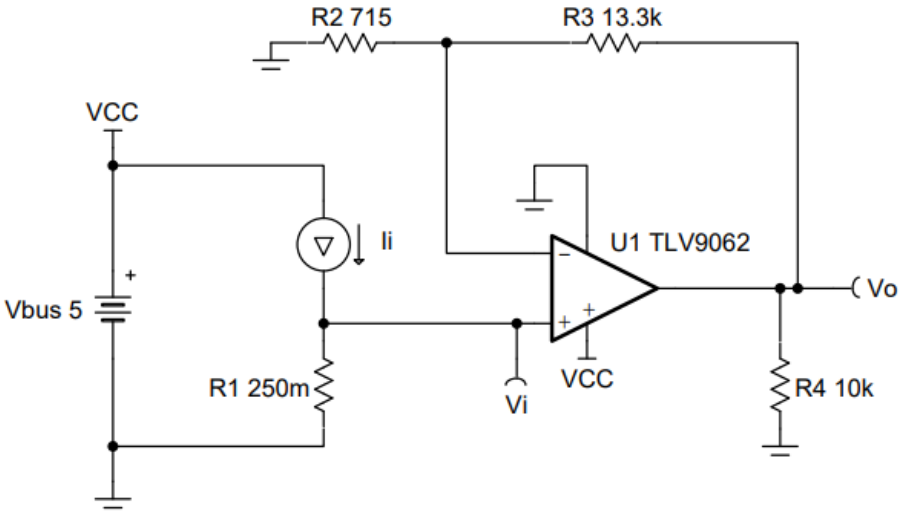
1A	250mV	50mV	4.9V	0.2%	5V	0V



$$R_1 = \frac{V_{iMax}}{I_{iMax}} = \frac{250mV}{1A} = 250m\Omega$$

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Design Steps

Input		Output		Full-Scale Range Error	Supply	
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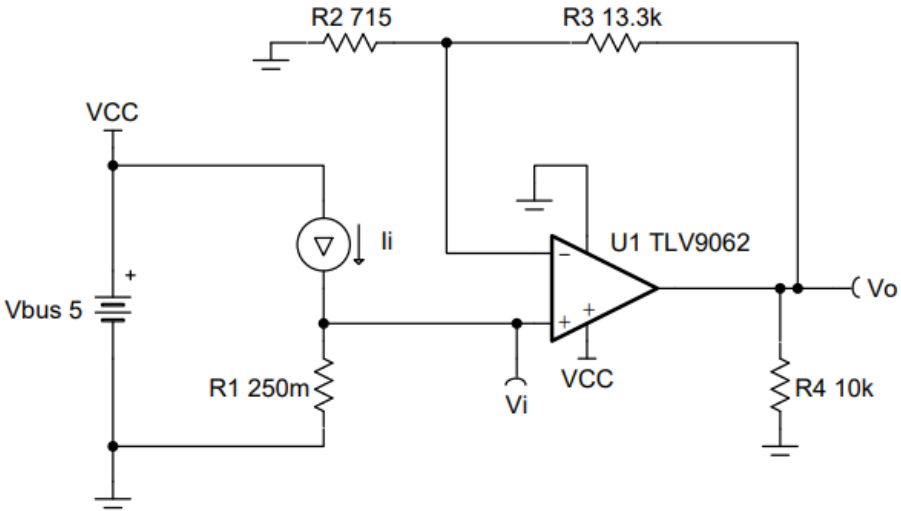

$$\text{Gain} = \frac{V_{oMax}}{V_{iMax}} = \frac{4.9V}{250mV} = 19.6\frac{V}{V}$$

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Design Steps

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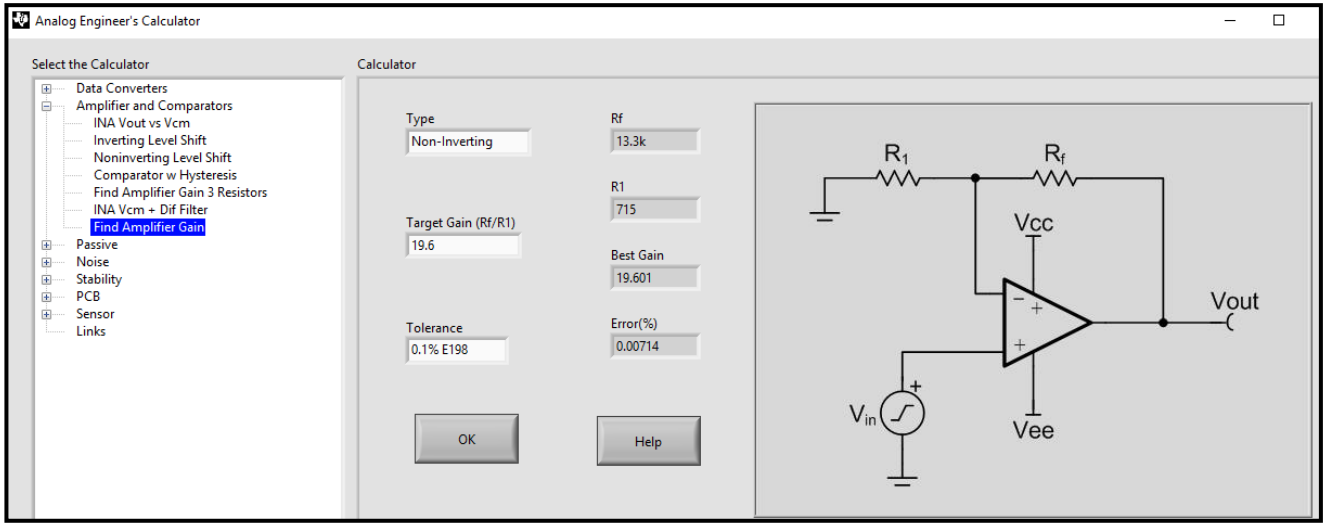

$$R_3 = 13.3k\Omega$$

$$R_2 = 715\Omega$$

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Design Steps

Input		Output		Full-Scale Range Error	Supply	
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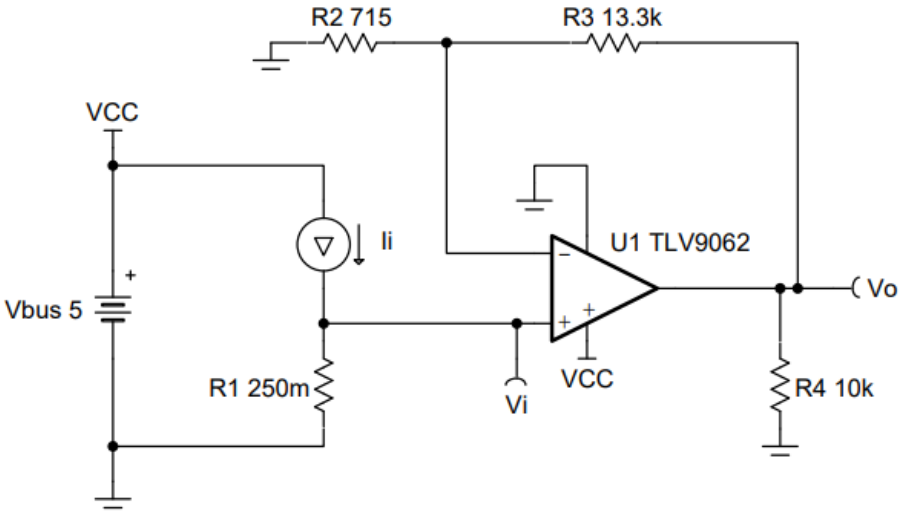
1A	250mV	50mV	4.9V	0.2%	5V	0V



$$I_{iMin} = \frac{V_{oMin}}{R_1 \times \text{Gain}} = \frac{50mV}{250m\Omega \times 19\frac{V}{V}} = 10.2mA$$

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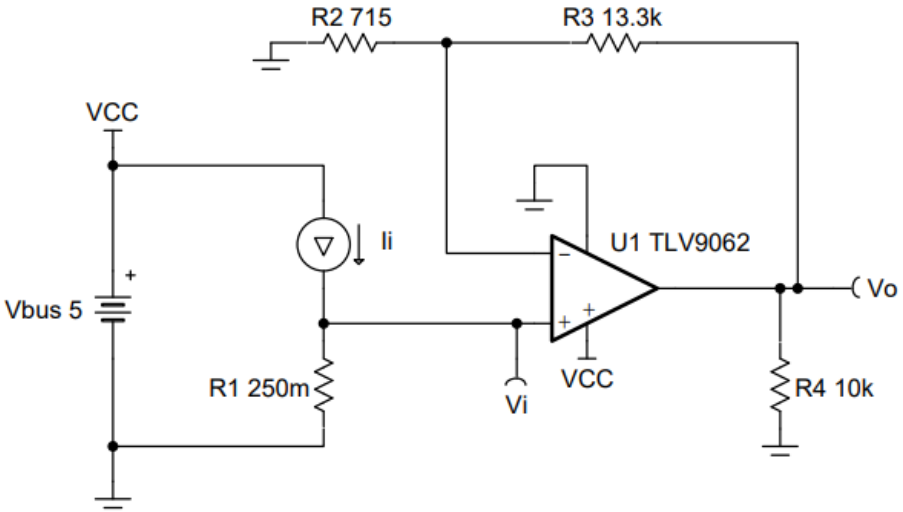
Design Steps

Input		Output		Full-Scale Range Error	Supply	
I_{iMax}	V_{iMax}	V_{oMin}	V_{oMax}	FSR_{Error}	V_{cc}	V_{ee}
1A	250mV	50mV	4.9V	0.2%	5V	0V



$$FSR_{ERROR} = \left(\frac{V_{OS}}{V_{iMax} - V_{iMin}} \right) \times 100$$

$$FSR_{ERROR} = \left(\frac{300\mu V(typ)}{250mV - 2.55mV} \right) \times 100$$

$$FSR_{ERROR} = 0.12\%$$

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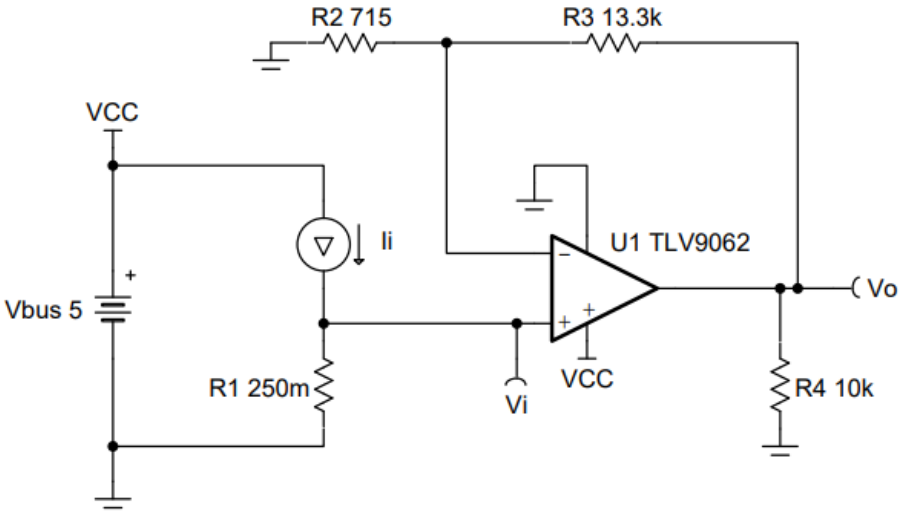
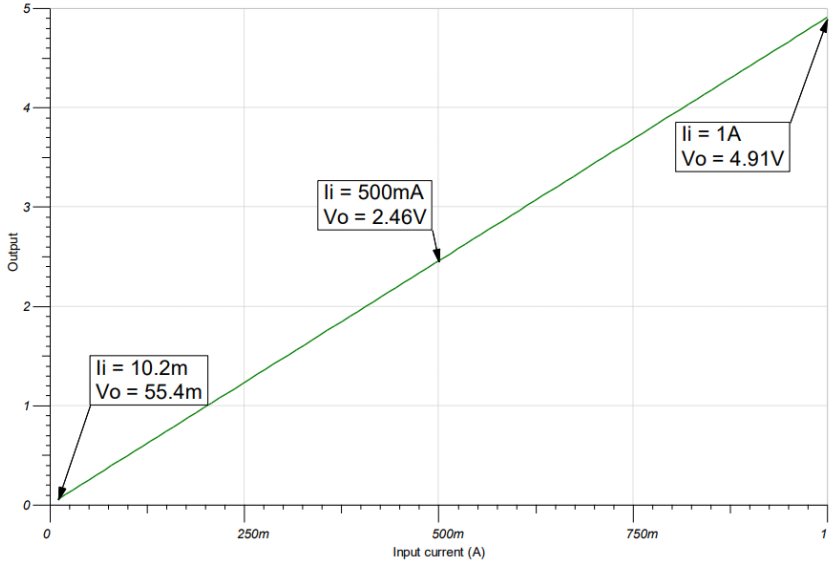
DC Results

Input		Output		Full-Scale Range Error	Supply	
I_{iMax}	V_{iMax}	V_{oMin}	V_{oMax}	FSR_{Error}	V_{cc}	V_{ee}
1A	250mV	50mV	4.9V	0.2%	5V	0V





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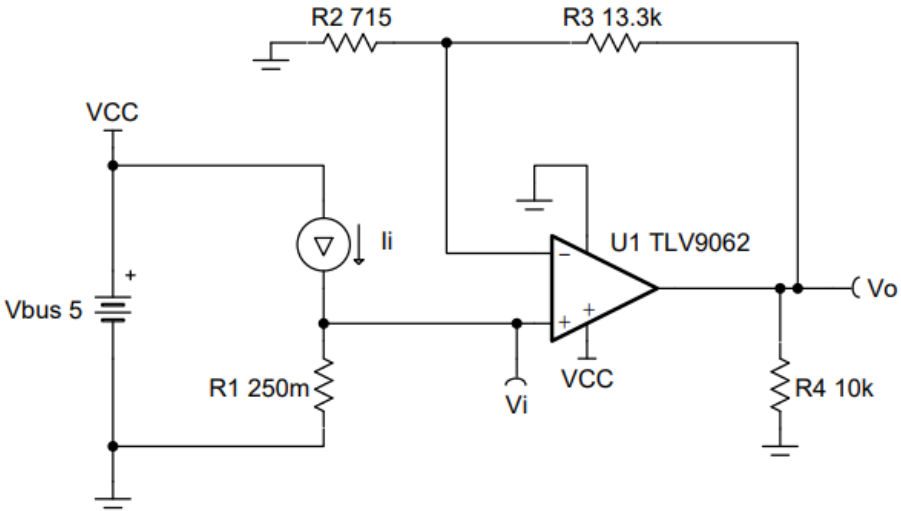
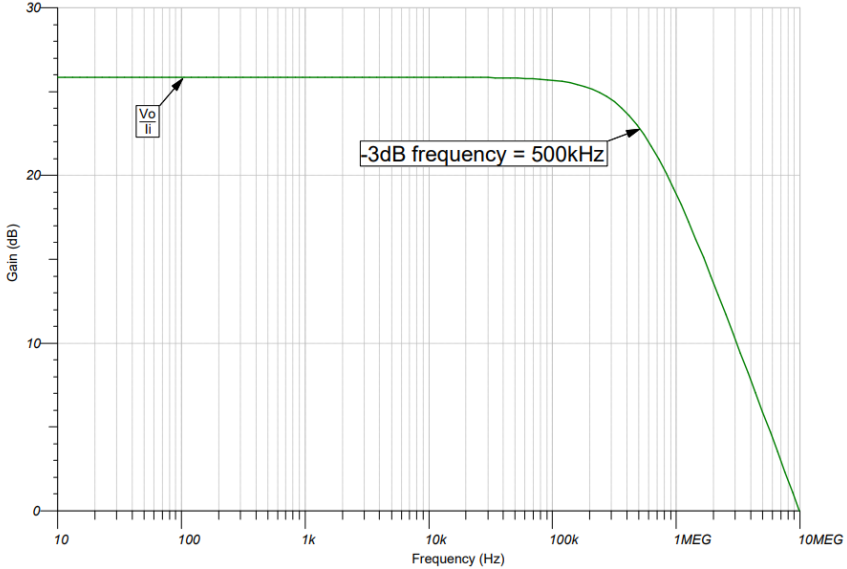
AC Results

Input		Output		Full-Scale Range Error	Supply	
I_{iMax}	V_{iMax}	V_{oMin}	V_{oMax}	FSR_{Error}	V_{cc}	V_{ee}
1A	250mV	50mV	4.9V	0.2%	5V	0V





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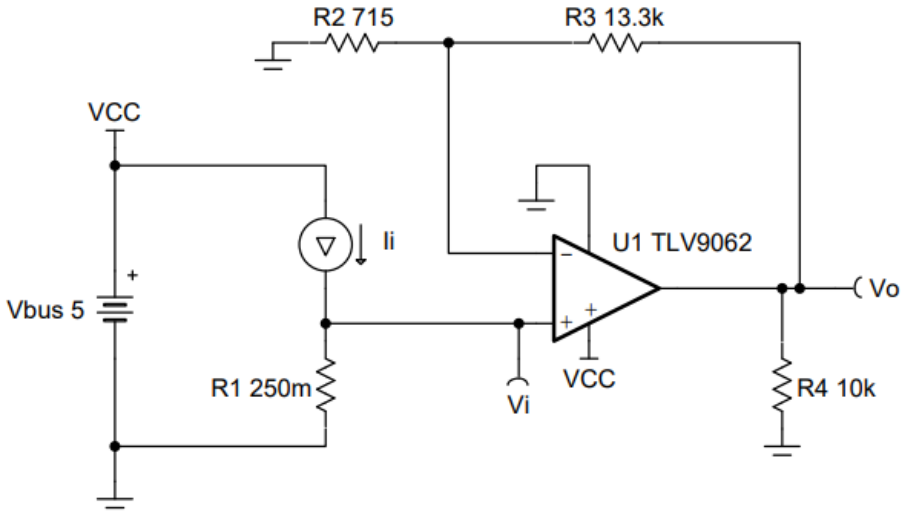
Design Notes

Input		Output		Full-Scale Range Error	Supply	
I_{iMax}	V_{iMax}	V_{oMin}	V_{oMax}	FSR_{Error}	V_{cc}	V_{ee}
1A	250mV	50mV	4.9V	0.2%	5V	0V



Design Notes:

1. For low-side sensing, use op amps whose Vcm includes ground
2. Operate within the linear output voltage swing (See A_{OL} specification) to minimize non-linearity errors.
3. If trying to detect zero load current, a negative charge pump such as LM7705 for the negative supply voltage.

Design Resources

EE Cookbook: Op Amp
www.ti.com/circuitcookbooks
Step-by-step circuit design of common op amp building block circuits.

TI Designs
www.TI.com/tidesigns
Ready-to-use reference designs with
theory, calculations, simulations
schematics, PCB files, bench test results

Analog Engineer's Pocket Reference
www.TI.com/analogrefguide
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Conversions, tables, equations

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The Signal
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PDF, iTunes app and hardcopy available
A compendium of blog posts on op amp design topics including offset voltage, input bias current, stability, noise and more

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Tips, tricks, and design techniques

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