

Low-side, bidirectional current sensing circuit

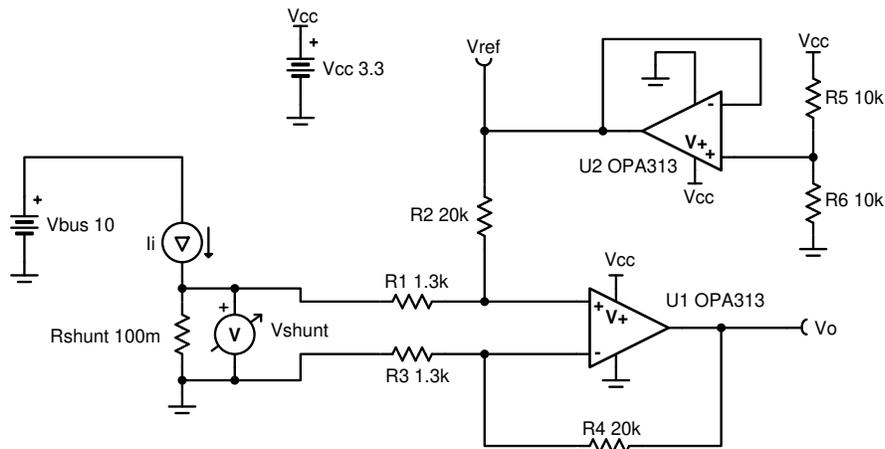


Design Goals

Input		Output		Supply		
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}	V_{ref}
-1A	1A	110mV	3.19V	3.3V	0V	1.65V

Design Description

This single-supply low-side, bidirectional current sensing solution can accurately detect load currents from -1A to 1A. The linear range of the output is from 110mV to 3.19V. Low-side current sensing keeps the common-mode voltage near ground, and is thus most useful in applications with large bus voltages.



Design Notes

1. To minimize errors, set $R_3 = R_1$ and $R_4 = R_2$.
2. Use precision resistors for higher accuracy.
3. Set output range based on linear output swing (see A_{ol} specification).
4. Low-side sensing should not be used in applications where the system load cannot withstand small ground disturbances or in applications that need to detect load shorts.

Design Steps

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

$$V_o = \left(I_i \times R_{\text{shunt}} \times \frac{R_4}{R_3} \right) + V_{\text{ref}}$$

$$V_{\text{ref}} = V_{\text{cc}} \times \left(\frac{R_6}{R_5 + R_6} \right)$$

2. Determine the maximum shunt resistance.

$$R_{\text{shunt}} = \frac{V_{\text{shunt}}}{I_{\text{imax}}} = \frac{100\text{mV}}{1 \text{ A}} = 100\text{m}\Omega$$

3. Set reference voltage.

- a. Since the input current range is symmetric, the reference should be set to mid supply. Therefore, make R_5 and R_6 equal.

$$R_5 = R_6 = 10\text{k}\Omega$$

4. Set the difference amplifier gain based on the op amp output swing. The op amp output can swing from 100mV to 3.2V, given a 3.3-V supply.

$$\text{Gain} = \frac{V_{\text{oMax}} - V_{\text{oMin}}}{R_{\text{shunt}} \times (I_{\text{iMax}} - I_{\text{iMin}})} = \frac{3.2 \text{ V} - 100\text{mV}}{100\text{m}\Omega \times (1 \text{ A} - (-1 \text{ A}))} = 15.5 \frac{\text{V}}{\text{V}}$$

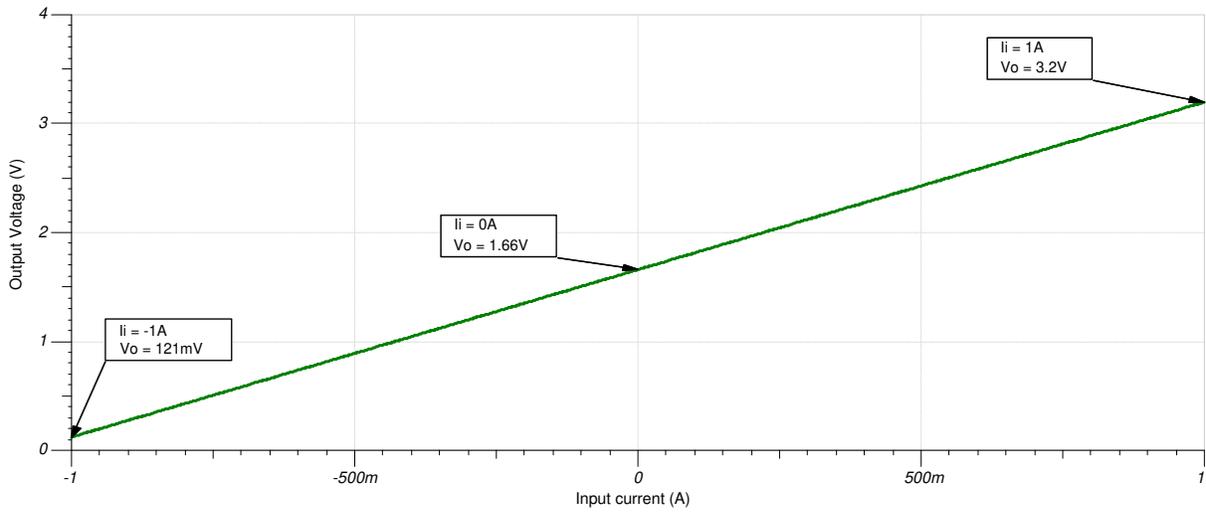
$$\text{Gain} = \frac{R_4}{R_3} = 15.5 \frac{\text{V}}{\text{V}}$$

Choose $R_1 = R_3 = 1.3\text{k}\Omega$ (Standard Value)

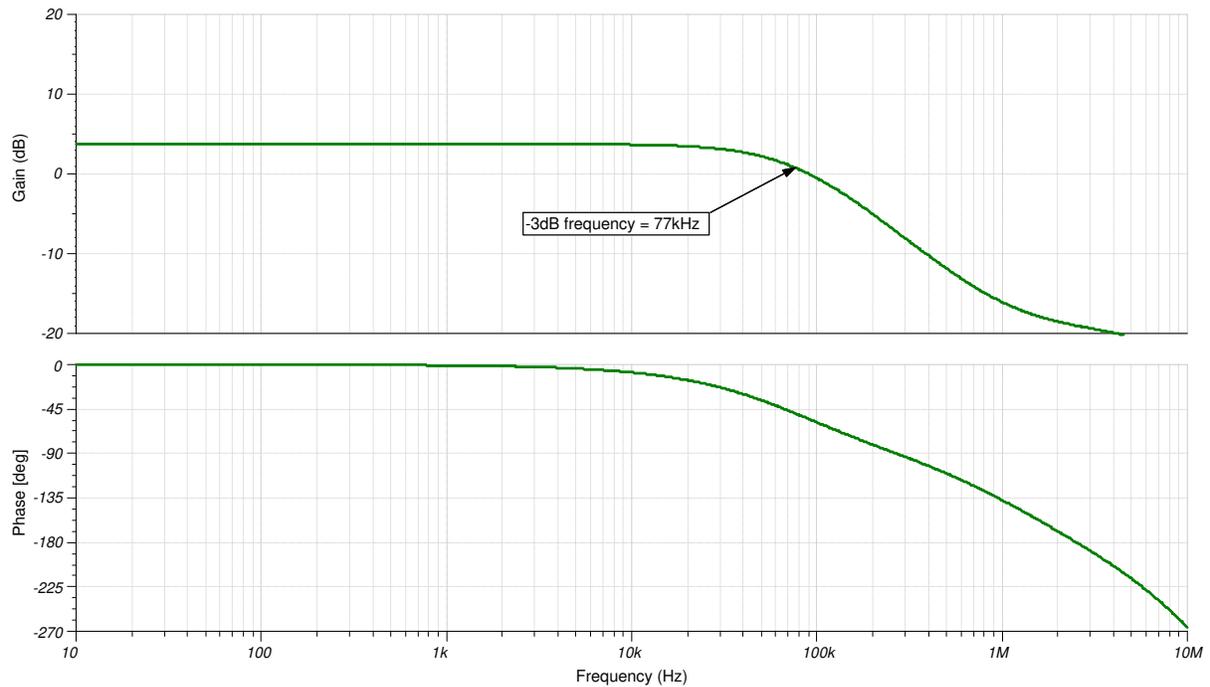
$$R_2 = R_4 = 15.5 \frac{\text{V}}{\text{V}} \times 1.3\text{k}\Omega = 20.15 \text{ k}\Omega \approx 20\text{k}\Omega \text{ (Standard Value)}$$

Design Simulations

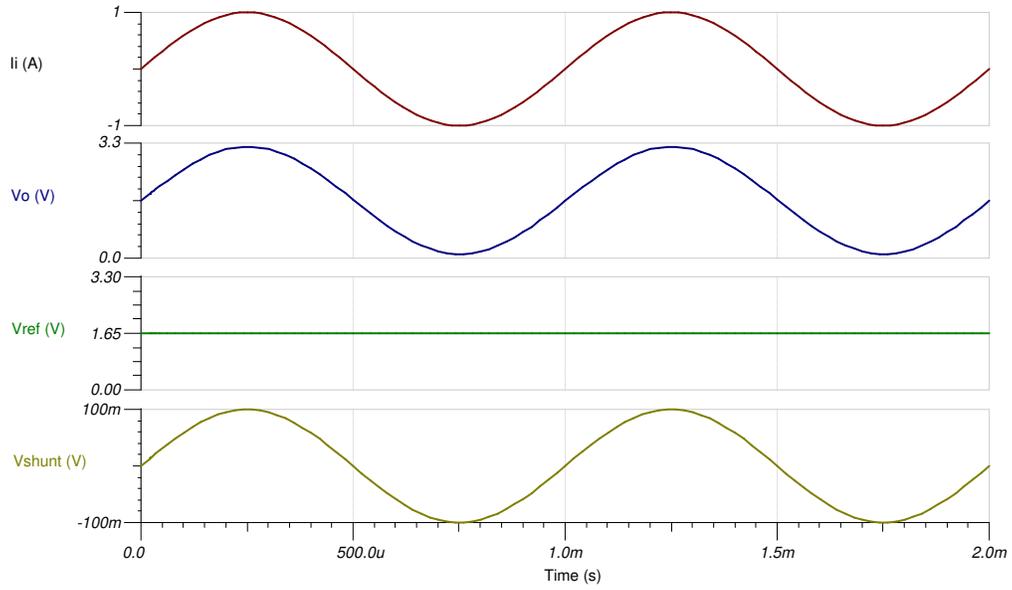
DC Simulation Results



Closed Loop AC Simulation Results



Transient Simulation Results



Design References

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

See circuit SPICE simulation file [SBOC500](#).

See TIPD175, www.ti.com/tipd175.

Design Featured Op Amp

OPA313	
V_{CC}	1.8V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	500 μ V
I_q	50 μ A/Ch
I_b	0.2pA
UGBW	1MHz
SR	0.5V/ μ s
#Channels	1, 2, 4
www.ti.com/product/opa313	

Design Alternate Op Amp

	TLV9062	OPA376
V_{CC}	1.8V to 5.5V	2.2V to 5.5V
V_{inCM}	Rail-to-rail	Rail-to-rail
V_{out}	Rail-to-rail	Rail-to-rail
V_{os}	300 μ V	5 μ V
I_q	538 μ A/Ch	760 μ A/Ch
I_b	0.5pA	0.2pA
UGBW	10MHz	5.5MHz
SR	6.5V/ μ s	2V/ μ s
#Channels	1, 2, 4	1, 2, 4
www.ti.com/product/tlv9062		www.ti.com/product/opa376

For battery-operated or power-conscious designs, outside of the original design goals described earlier, where lowering total system power is desired.

LPV821	
V_{CC}	1.7V to 3.6V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	1.5 μ V
I_q	650nA/Ch
I_b	7pA
UGBW	8KHz
SR	3.3V/ms
#Channels	1
www.ti.com/product/lpv821	

Revision History

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

Changes from Revision A (May 2018) to Revision B (January 2019)	Page
• Removed the title.cookbook landing page	1

Changes from Revision * (February 2018) to Revision A (May 2018)	Page
• Changed title role to 'Amplifiers'.....	1
• Added SPICE simulation file link.....	1
• Added LPV821 as a <i>Design Alternate Op Amp</i> for battery-operated or power-conscious designs.....	1

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