

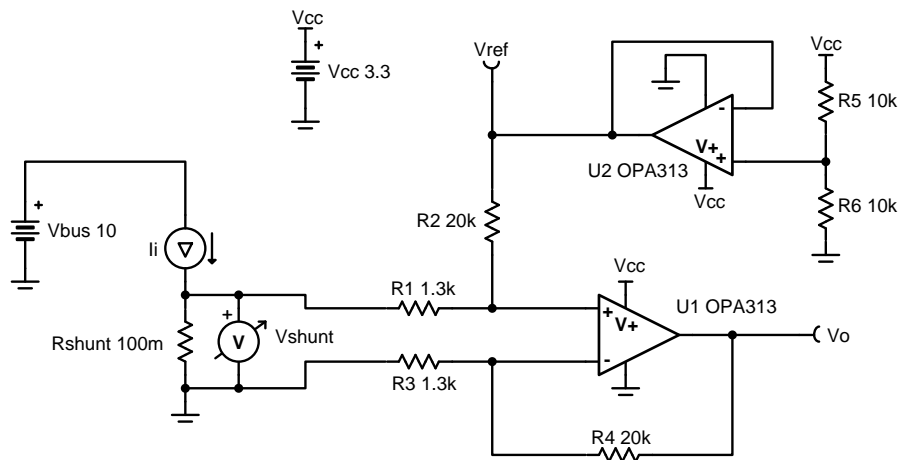
## Low-side, bidirectional current sensing circuit

### 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

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

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

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

- Determine the maximum shunt resistance.

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

- Set reference voltage.

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

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

- 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.

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

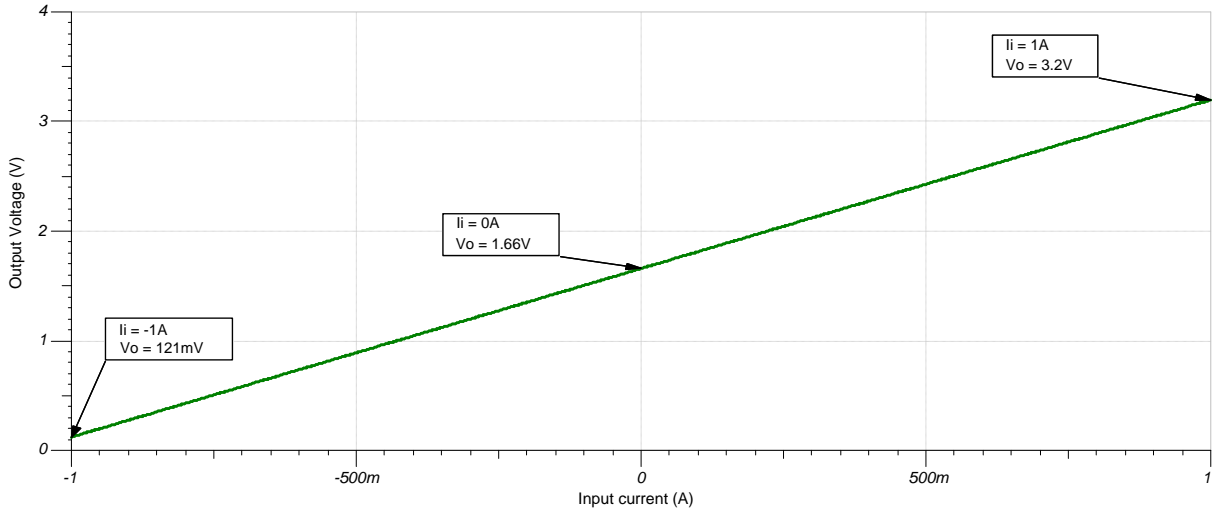
$$\text{Gain} = \frac{R_4}{R_3} = 15.5 \frac{\text{V}}{\text{V}}$$

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

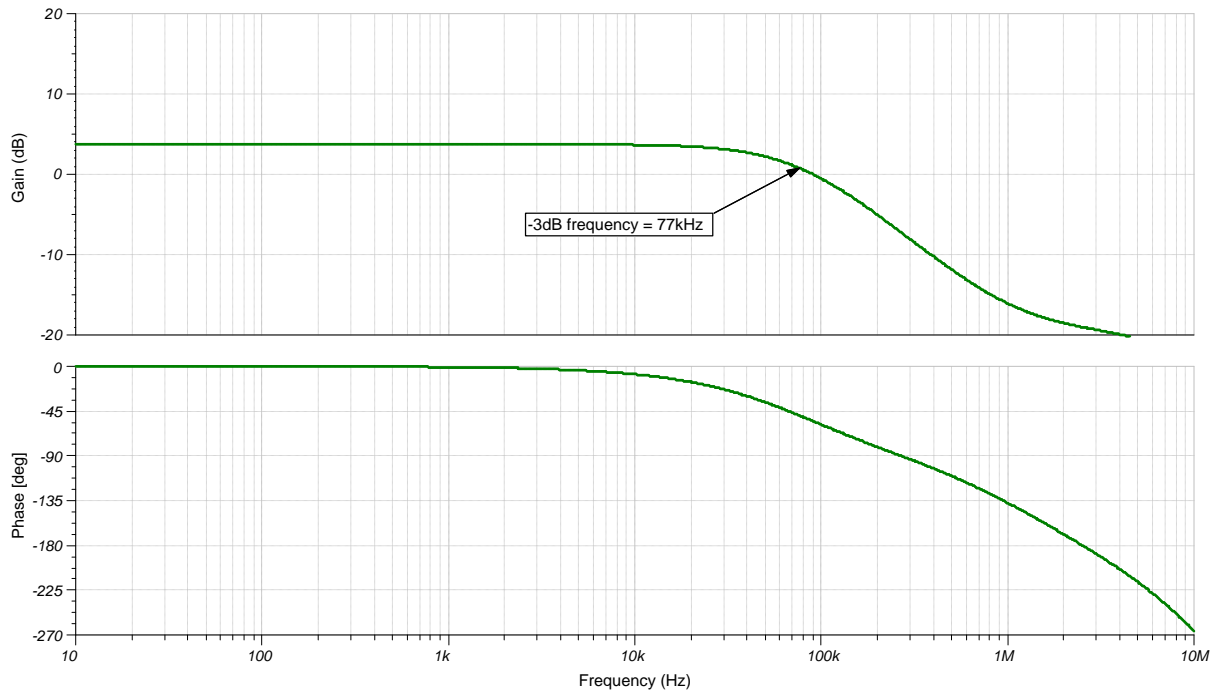
$$R_2 = R_4 = 15.5 \frac{\text{V}}{\text{V}} \times 1.3\text{k}\Omega = 20.15 \text{ k}\Omega \approx 20\text{k}\Omega \text{ (Standard Value)}$$

**Design Simulations**

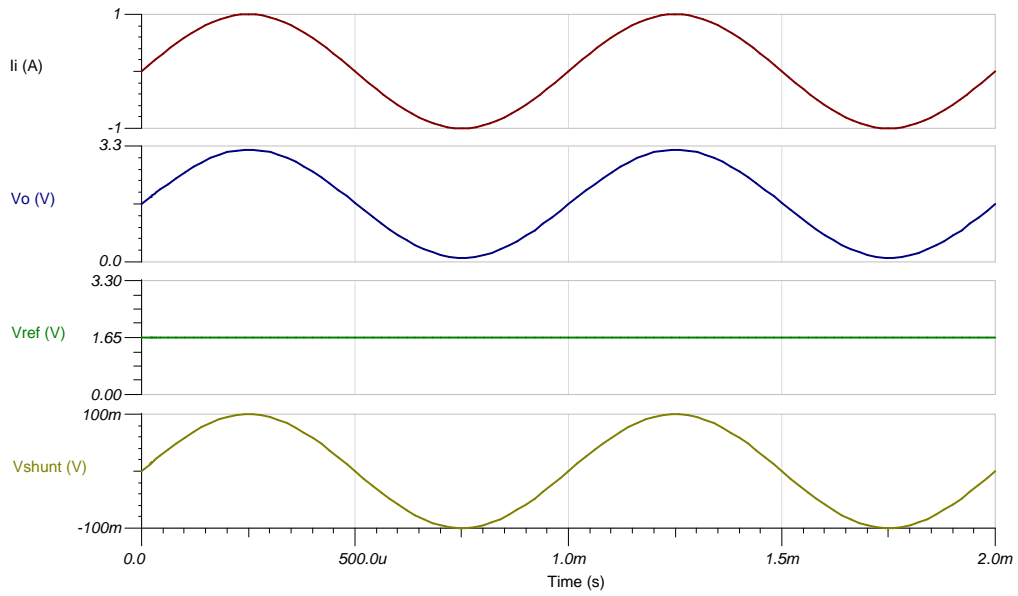
**DC Simulation Results**



**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](http://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 $\mu$ V
$I_q$	50 $\mu$ A/Ch
$I_b$	0.2pA
UGBW	1MHz
SR	0.5V/ $\mu$ s
#Channels	1, 2, 4
<a href="http://www.ti.com/product/opa313">www.ti.com/product/opa313</a>	

## 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 $\mu$ V	5 $\mu$ V
$I_q$	538 $\mu$ A/Ch	760 $\mu$ A/Ch
$I_b$	0.5pA	0.2pA
UGBW	10MHz	5.5MHz
SR	6.5V/ $\mu$ s	2V/ $\mu$ s
#Channels	1, 2, 4	1, 2, 4
<a href="http://www.ti.com/product/tlv9062">www.ti.com/product/tlv9062</a>		<a href="http://www.ti.com/product/opa376">www.ti.com/product/opa376</a>

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 $\mu$ V
$I_q$	650nA/Ch
$I_b$	7pA
UGBW	8KHz
SR	3.3V/ms
#Channels	1
<a href="http://www.ti.com/product/lpv821">www.ti.com/product/lpv821</a>	

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**Revision History**

Revision	Date	Change
B	January 2019	Downscale the title. Added link to circuit cookbook landing page.
A	May 2018	Changed title role to 'Amplifiers'. Added SPICE simulation file link. Added LPV821 as a <i>Design Alternate Op Amp</i> for battery-operated or power-conscious designs.

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