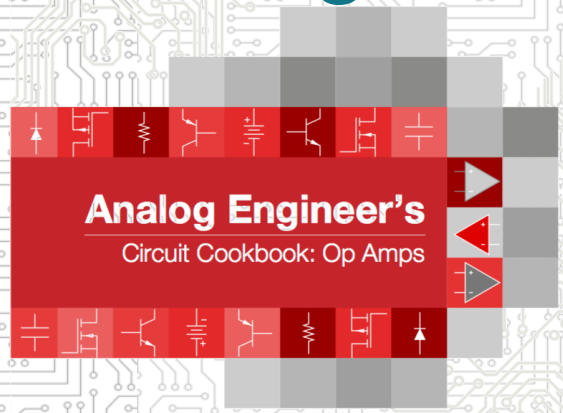
How to Design
Low-side, bidirectional current sensing circuit



General Purpose Amplifiers

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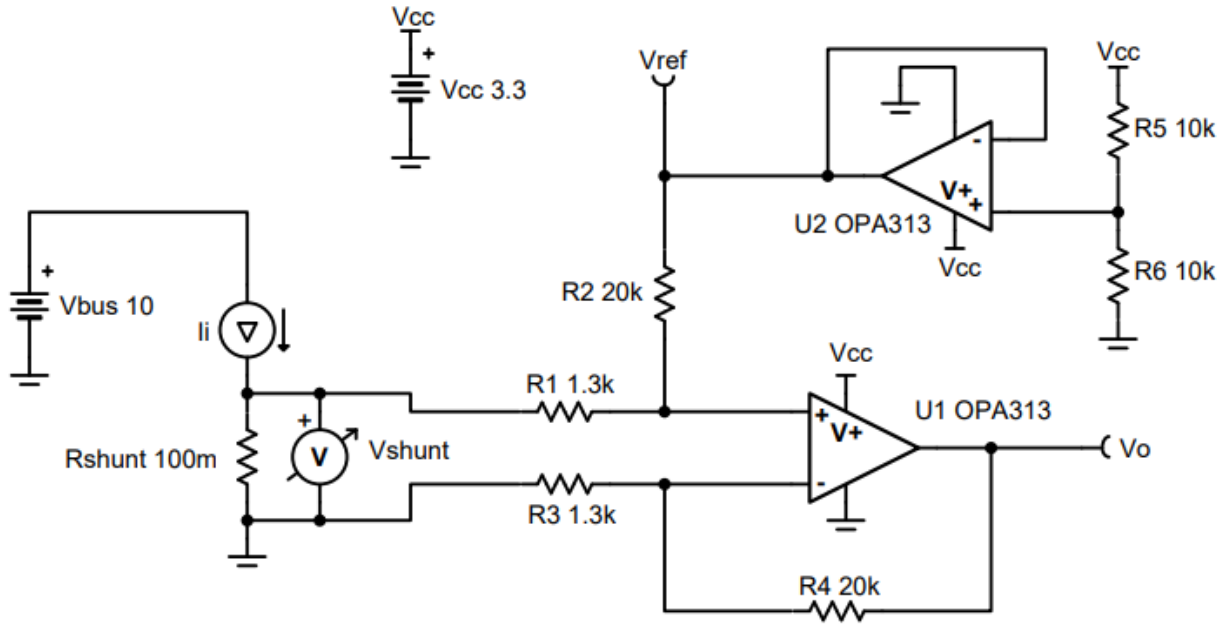
Circuit Description



$$Vo = \left(Ii \times Rshunt \times \frac{R4}{R3}\right) + Vref$$

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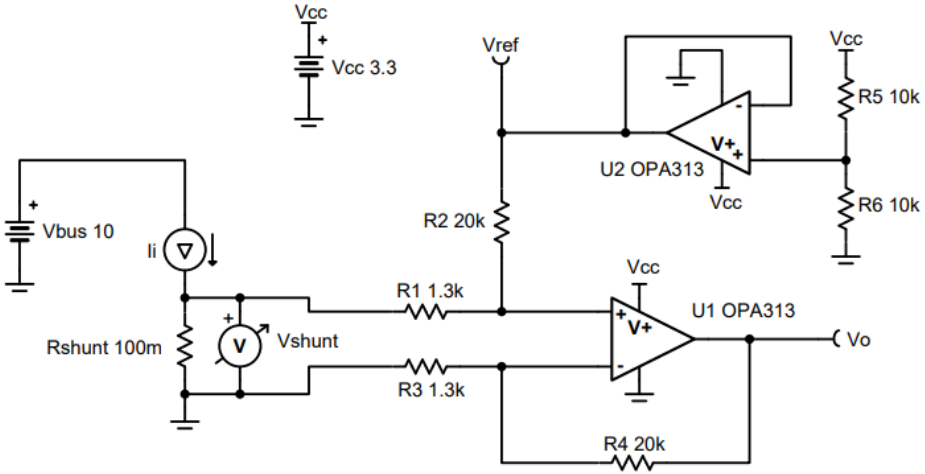
Design Goal

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



Current to Voltage

Reference Voltage

$$Vo = \left(Ii \times Rshunt \times \frac{R4}{R3}\right) + Vref$$

Diff Amp Gain

$$Vref = Vcc \times \frac{R6}{R5 + R6}$$

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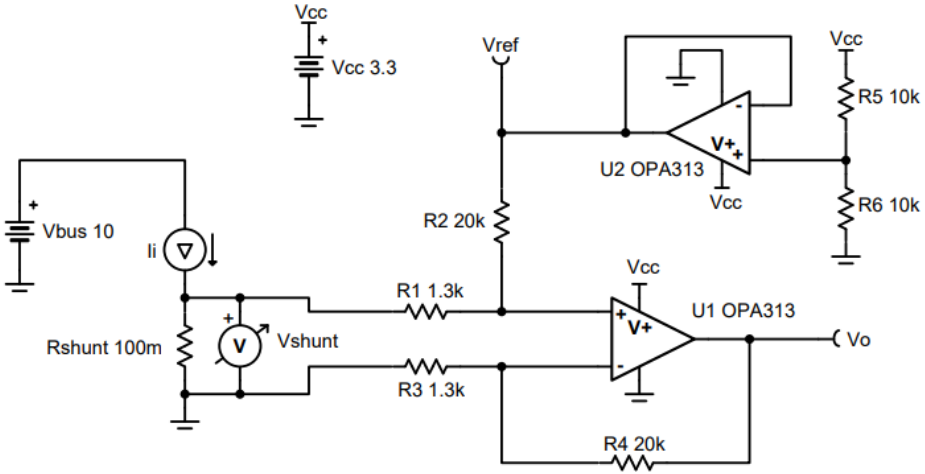
Design Steps

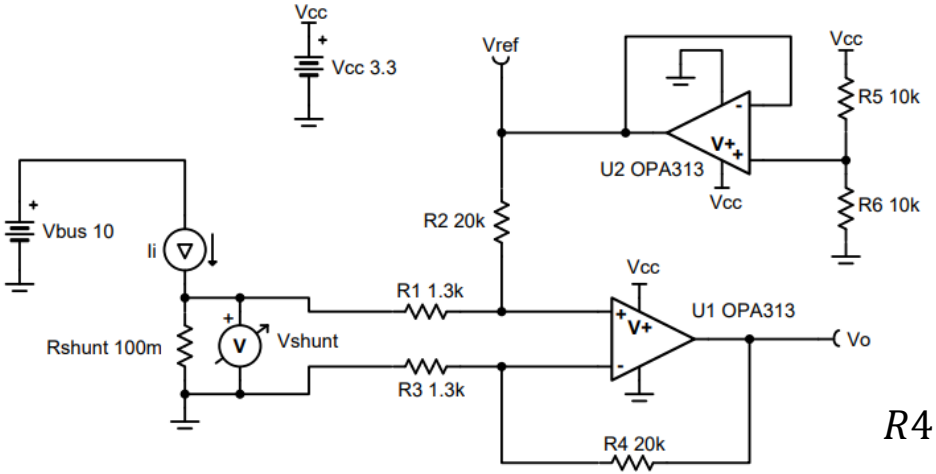
Input		Output		Supply		
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	V_{dd}	V_{ee}	V_{ref}
-1 A	1 A	110mV	3.19V	3.3V	0V	1.65V



$$Rshunt = \frac{Vshunt\_max}{IiMax} = \frac{100mV}{1A} = 100\ m\Omega$$

Design Steps

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



$$Gain = \frac{VoMax - VoMin}{Rshunt \times (IiMax - IiMin)} = 15.5\ V/V$$

$$Gain = \frac{R4}{R3}$$

$$R3 = R1 = 1.3\ k\Omega$$

$$R4 = R2 = Gain \times R3 = 15.5\frac{V}{V} \times 1.3\ k\Omega = 20.15\ k\Omega$$

$$Gain_{actual} = 15.38\frac{V}{V}$$

Design Steps

Input		Output		Supply		
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	V_{dd}	V_{ee}	V_{ref}
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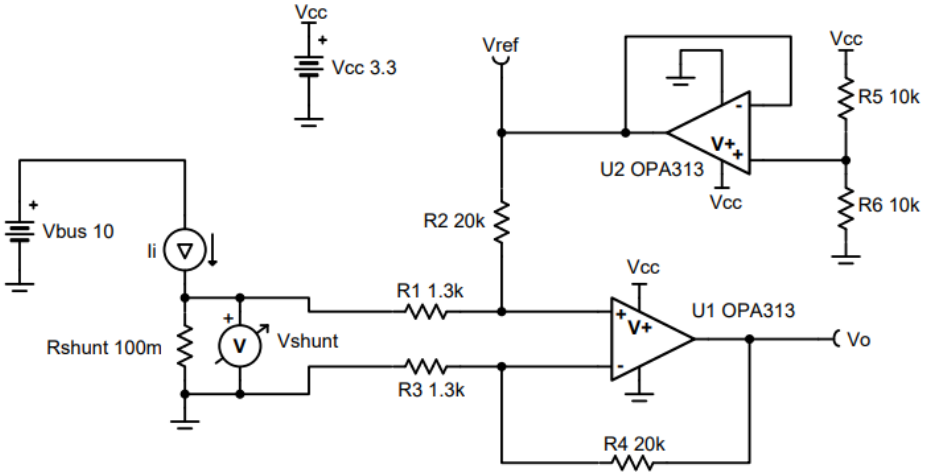


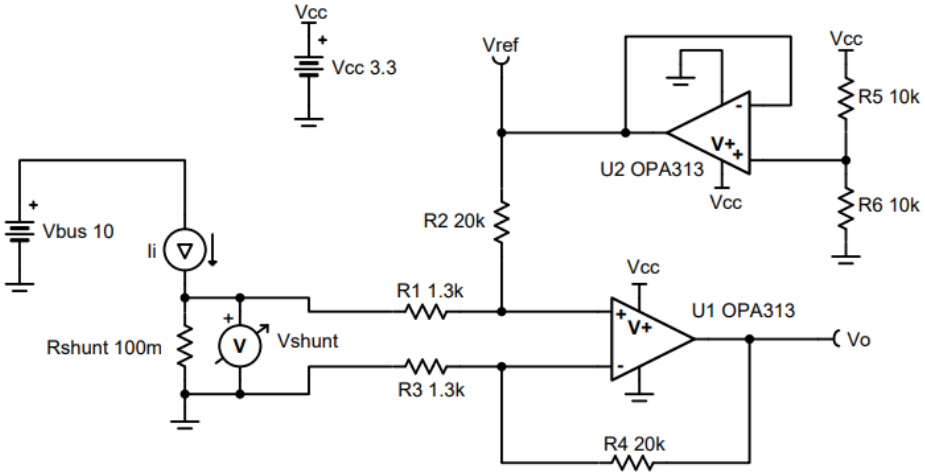
$$Vref = Vcc \times \frac{R6}{R5 + R6}$$

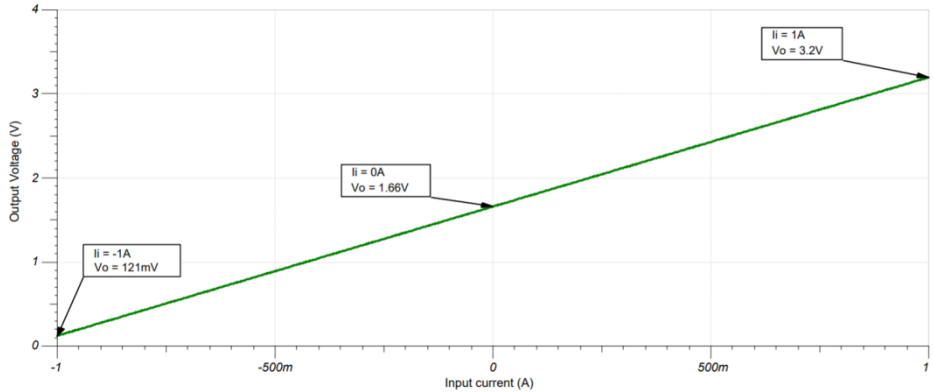
$$R5 = R6 = 10\ k\Omega$$

$$Vref = 3.3\ V \times \frac{10\ k\Omega}{10\ k\Omega + 10\ k\Omega} = 1.65V$$

DC Results

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





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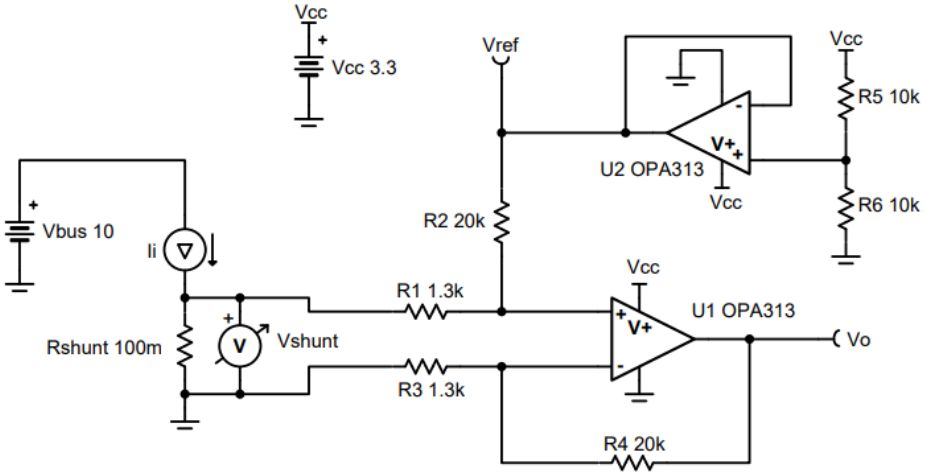
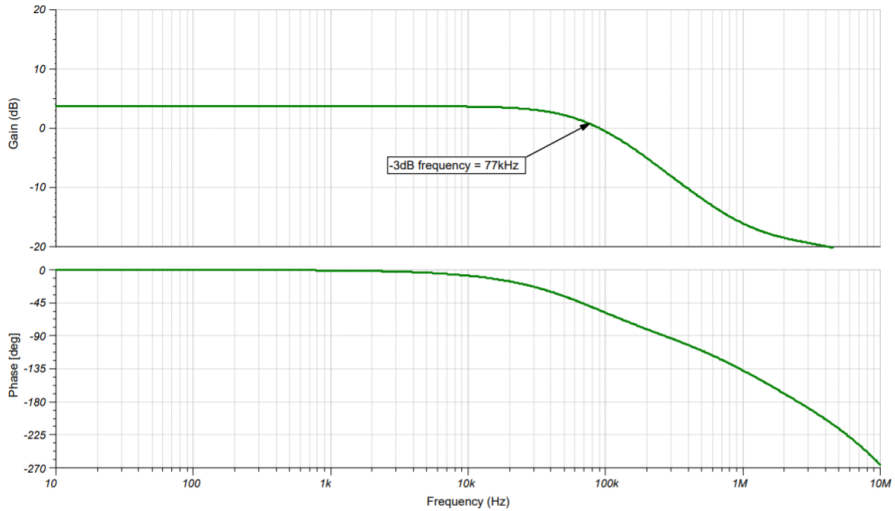
AC Results

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





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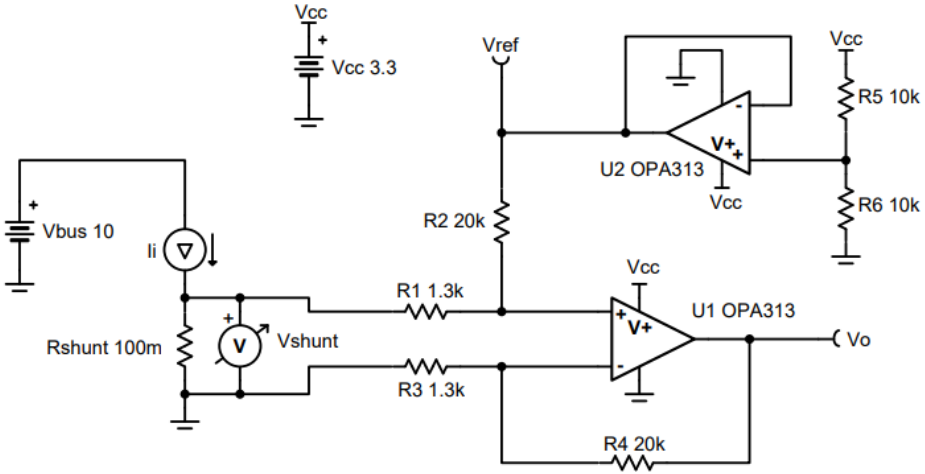
Design Notes

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



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. Buffer the voltage divider to provide a low impedance node to the reference voltage, Vref.

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
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Schematic entry and post-processor for waveform math

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

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