Analog Engineer's Circuit

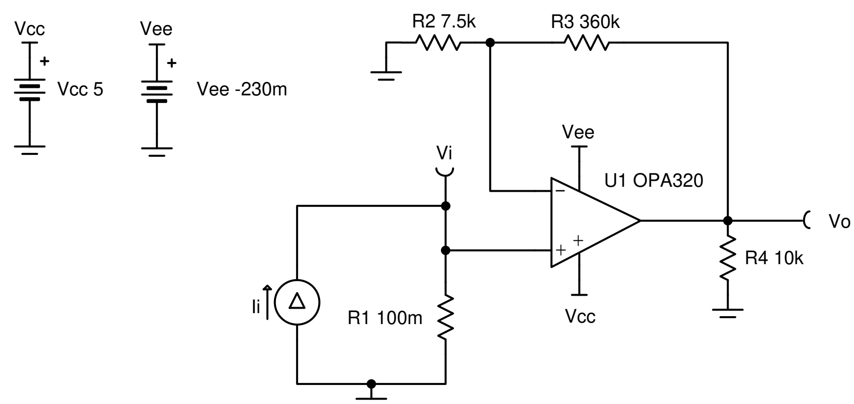
Single-Supply, Low-Side, Unidirectional Current-Sensing Solution With Output Swing to GND Circuit

Design Goals

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

Design Description

This single-supply, low-side, current sensing solution accurately detects load current between 0 A to 1 A and converts it to a voltage between 0 V to 4.9 V. 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 0 V.



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.

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

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

3. Select gain resistors to set the output range.

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

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

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

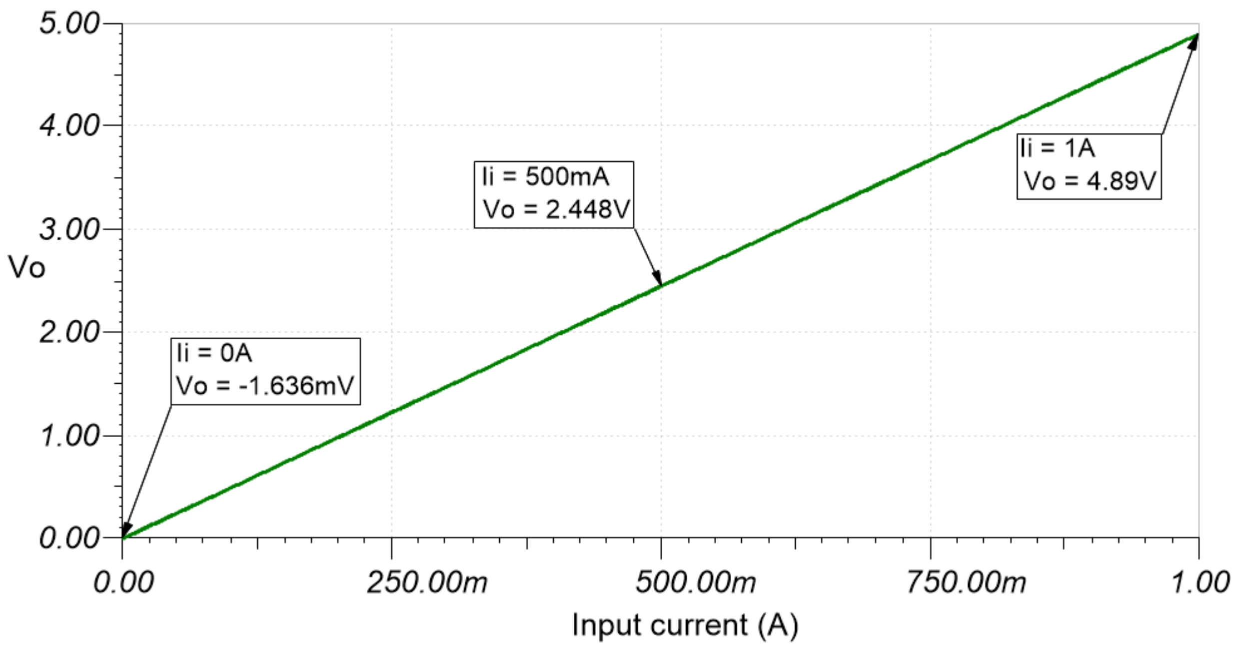
4. Select a standard value for R_2 and R_3.

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

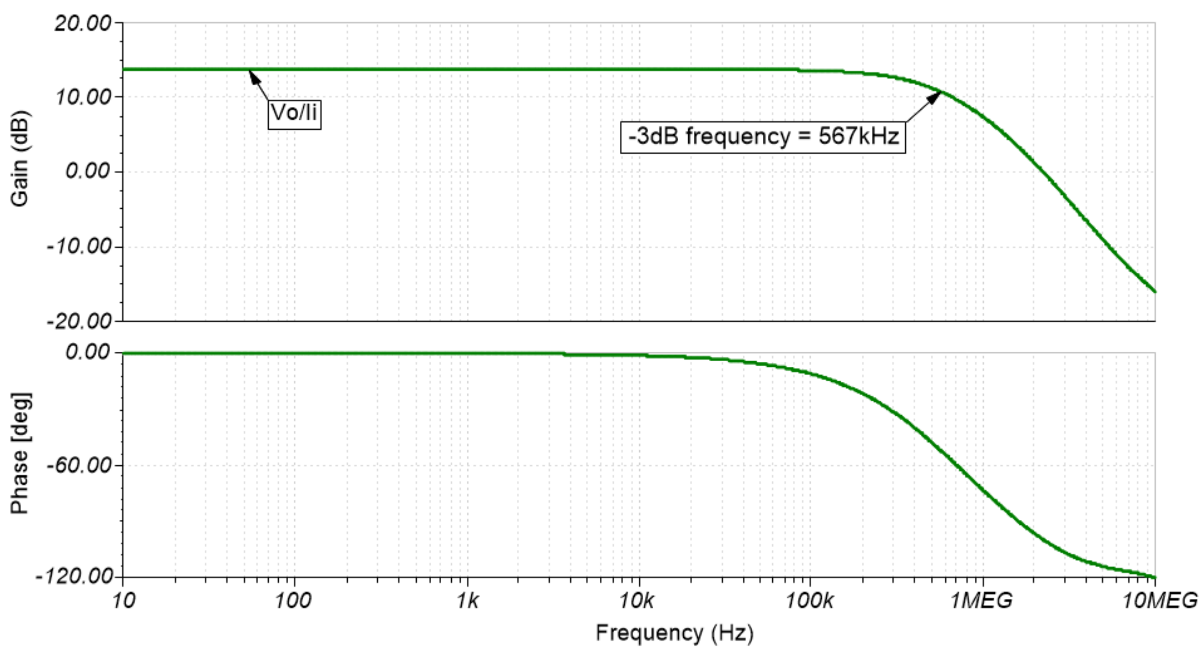
$$R_3 = 48 \times R_2 = 360\text{k}\Omega \text{ (0.05\% Standard Value)}$$

Design Simulations

DC Simulation Results



AC Simulation Results



Design References

See *Analog Engineer's Circuit Cookbooks* for TI's comprehensive circuit library.

See circuit SPICE simulation file SBOC499.

See TIPD129.

Design Featured Op Amp

OPA320	
V_{cc}	1.8 V to 5.5 V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	40 µV
I_q	1.5 mA/Ch
I_b	0.2 pA
UGBW	10 MHz
SR	10 V/µs
#Channels	1 and 2
OPA320	

Design Alternate Op Amp

TLV9002	
V_{cc}	1.8 V to 5.5 V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	400 µV
I_q	60 µA
I_b	5 pA
UGBW	1 MHz
SR	2 V/µs
#Channels	1, 2, and 4
TLV9002	

Revision History

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

Changes from February 1, 2018 to February 1, 2019 — **Page**

- Downscale the title and changed title role to *Amplifiers*. Added link to circuit cookbook landing page.............. 1