Analog Engineer's Circuit

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

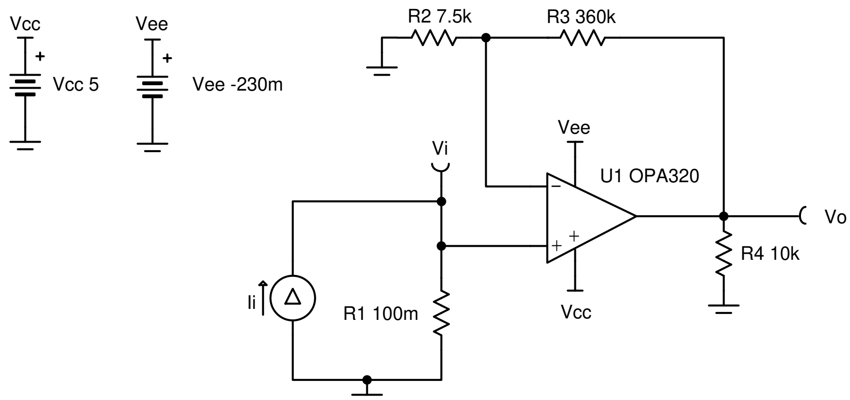
Caelan (Zak) Kaye

Design Goals

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

Design Description

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



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.

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

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

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

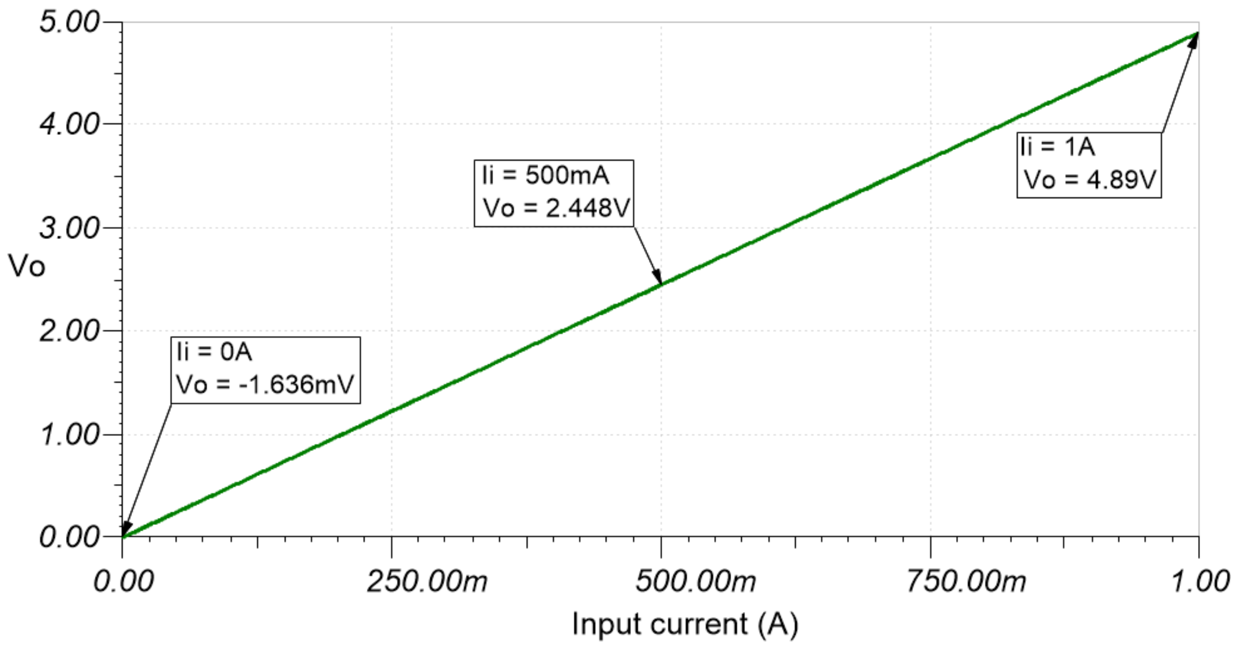
4. Select a standard value for R_2 and R_3.

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

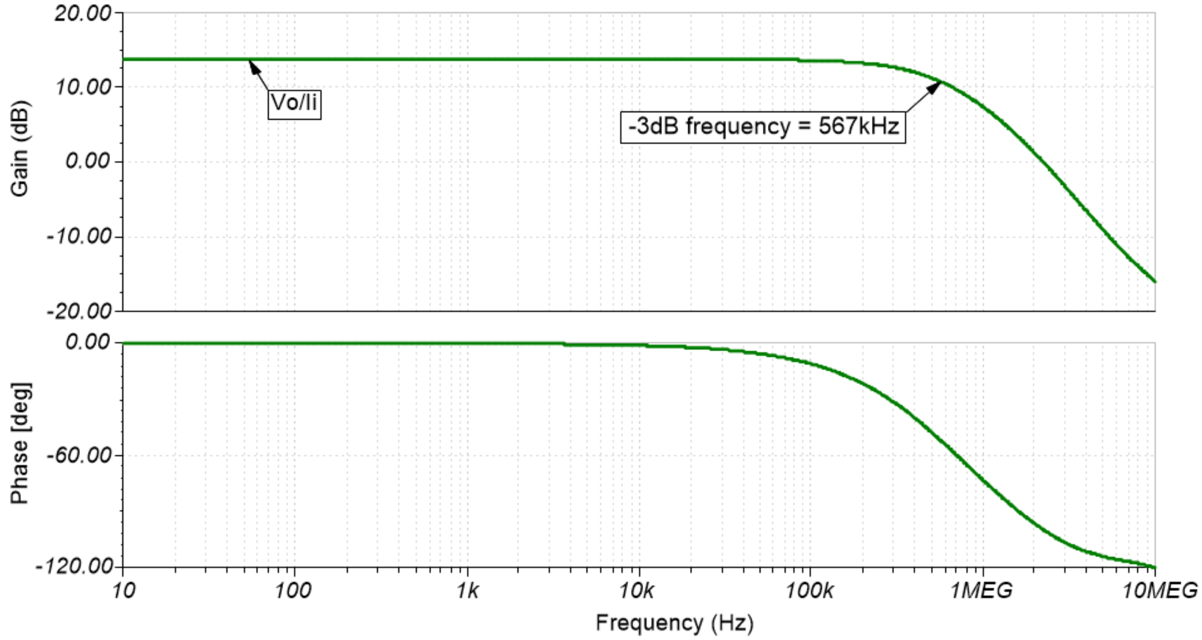
$$R_3 = 48 \times R_2 = 360\text{k}\Omega \text{ (0.05\% Standard Value)}$$

Design Simulations

DC Simulation Results



AC Simulation Results



Design References

Texas Instruments, *Simulation for Unidirectional Current Sense with Output Swing to GND*, circuit SPICE simulation file

Texas Instruments, *0-1A, Single-Supply, Low-Side, Current Sensing Solution*, reference design

Design Featured Op Amp

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

Design Alternate Op Amp

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

Trademarks

All trademarks are the property of their respective owners.

Revision History

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

Changes from Revision A (February 2019) to Revision B (October 2024) **Page**

- Updated the format for tables, figures, and cross-references throughout the document................................. 1

Changes from Revision * (February 2018) to Revision A (February 2019) **Page**

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