Analog Engineer's Circuit

3-Decade, Load-Current Sensing Circuit

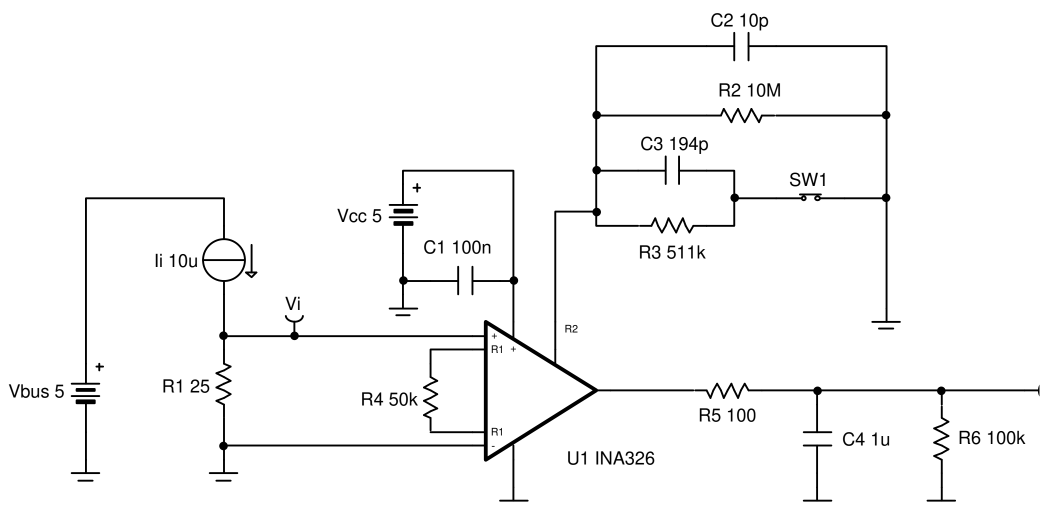
TEXAS INSTRUMENTS

Design Goals

Input		Output		Supply		
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}	V_{ref}
10 µA	10 mA	100 mV	4.9 V	5.0 V	0 V	0 V

Design Description

This single-supply, low-side, current-sensing solution accurately detects load current between 10 µA and 10 mA. A unique yet simple gain switching network was implemented to accurately measure the three-decade load current range.



Design Notes

1. Use a maximum shunt resistance to minimize relative error at minimum load current.
2. Select 0.1% tolerance resistors for R_1, R_2, R_3, and R_4 in order to achieve approximately 0.1% FSR gain error.
3. Use a switch with low on-resistance (R_{on}) to minimize interaction with feedback resistances, preserving gain accuracy.
4. Minimize capacitance on INA326 gain setting pins.
5. Scale the linear output swing based on the gain error specification.

Design Steps

1. Define full-scale shunt resistance.

$$R_1 = \frac{V_{iMax}}{I_{iMax}} = \frac{250\text{mV}}{10\text{mA}} = 25\Omega$$

2. Select gain resistors to set output range.

$$G_{IiMax} = \frac{V_{oMax}}{V_{iMax}} = \frac{V_{oMax}}{R_1 \times I_{iMax}} = \frac{4.9\text{V}}{25\Omega \times 10\text{mA}} = 19.6\frac{\text{V}}{\text{V}}$$

$$G_{IiMin} = \frac{V_{oMin}}{V_{iMin}} = \frac{V_{oMin}}{R_1 \times I_{iMin}} = \frac{100\text{mV}}{25\Omega \times 10\mu\text{A}} = 400\frac{\text{V}}{\text{V}}$$

$$R_2 = \frac{R_4 \times G_{IiMin}}{2} = \frac{50\text{k}\Omega \times 400\frac{\text{V}}{\text{V}}}{2} = 10\text{M}\Omega$$

$$R_2 \parallel R_3 = \frac{R_4 \times G_{IiMax}}{2} = \frac{50\text{k}\Omega \times 19.6\frac{\text{V}}{\text{V}}}{2} = 490\text{k}\Omega$$

$$R_3 = \frac{490\text{k}\Omega \times R_2}{R_2 - 490\text{k}\Omega} = 515.25\text{k}\Omega \approx 511\text{k}\Omega \text{ (Standard Value)}$$

3. Select a capacitor for the output filter.

$$f_p = \frac{1}{2 \times \pi \times R_5 \times C_4} = \frac{1}{2 \times \pi \times 100\Omega \times 1\ \ \mu\text{F}} = 1.59\text{kHz}$$

4. Select a capacitor for gain and filtering network.

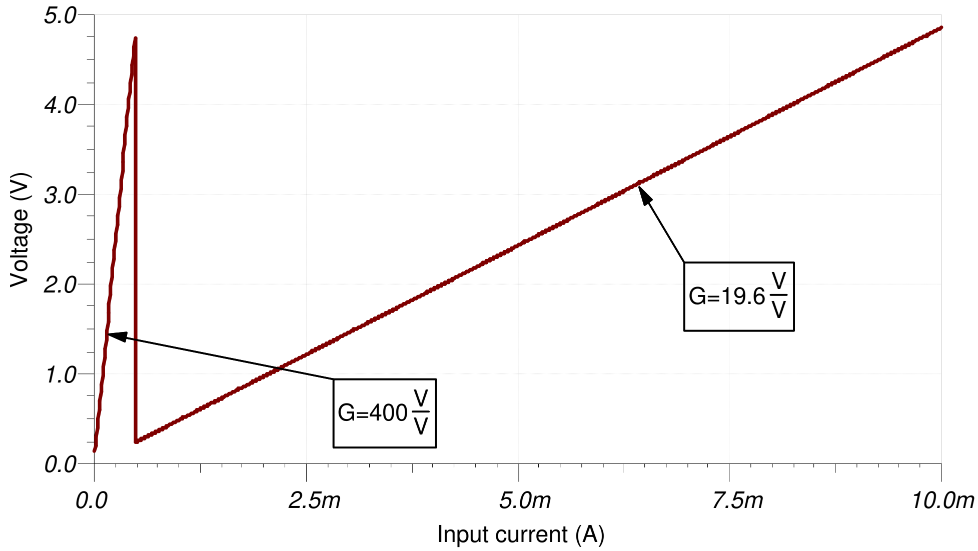
$$C_2 = \frac{1}{2 \times \pi \times R_2 \times f_p} = \frac{1}{2 \times \pi \times 10\text{M}\Omega \times 1.59\text{kHz}} = 10\text{pF}$$

$$C_3 = \frac{1}{2 \times \pi \times (R_2 || R_3) \times f_p} - C_2 = \frac{1}{2 \times \pi \times (10\text{M}\Omega || 511\text{k}\Omega) \times 1.59\text{kHz}} - 10\text{pF}$$

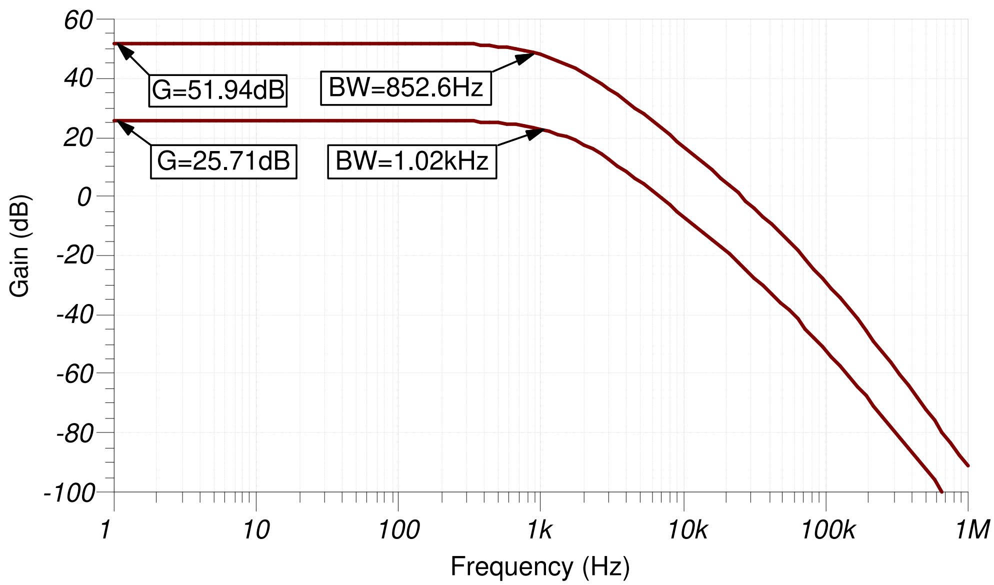
$$C_3 = 196\text{pF} \approx 194\text{pF (Standard Value)}$$

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 SBOC498.

See TIPD104, Current Sensing Solution, 10 µA-10 mA, Low-Side, Single Supply.

Design Featured Op Amp

INA326	
V_{ss}	1.8 V to 5.5 V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	0.1 mV
I_q	3.4 mA
I_b	2 nA
UGBW	1 kHz
SR	Filter limited
#Channels	1
INA326	

Revision History

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

Changes from January 28, 2018 to February 1, 2019	Page
• Downscale the title and changed title role to 'Amplifiers'. Added link to circuit cookbook landing page	1

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