

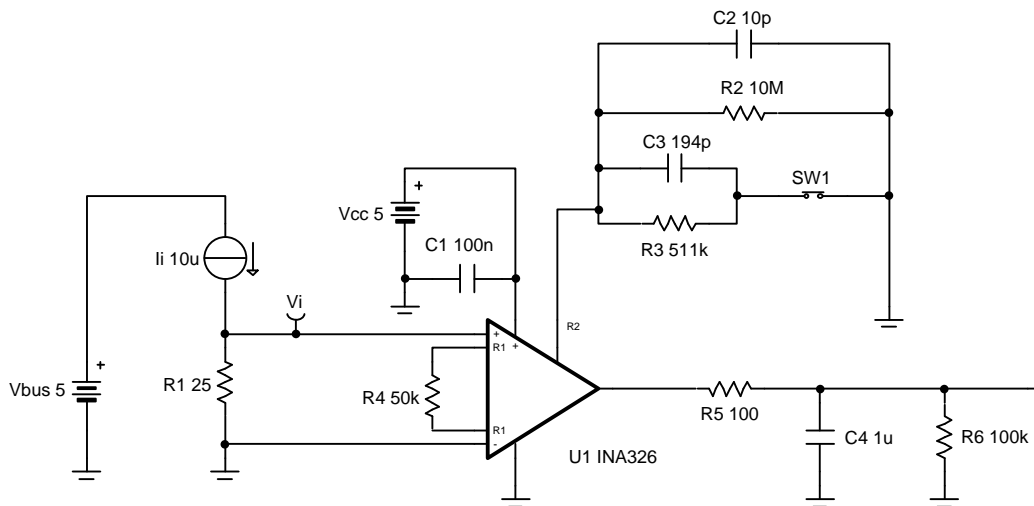
## 3-decade, load-current sensing circuit

### Design Goals

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

### Design Description

This single-supply, low-side, current-sensing solution accurately detects load current between 10 $\mu$ A and 10mA. 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.

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

2. Select gain resistors to set output range.

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

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

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

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

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

3. Select a capacitor for the output filter.

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

4. Select a capacitor for gain and filtering network.

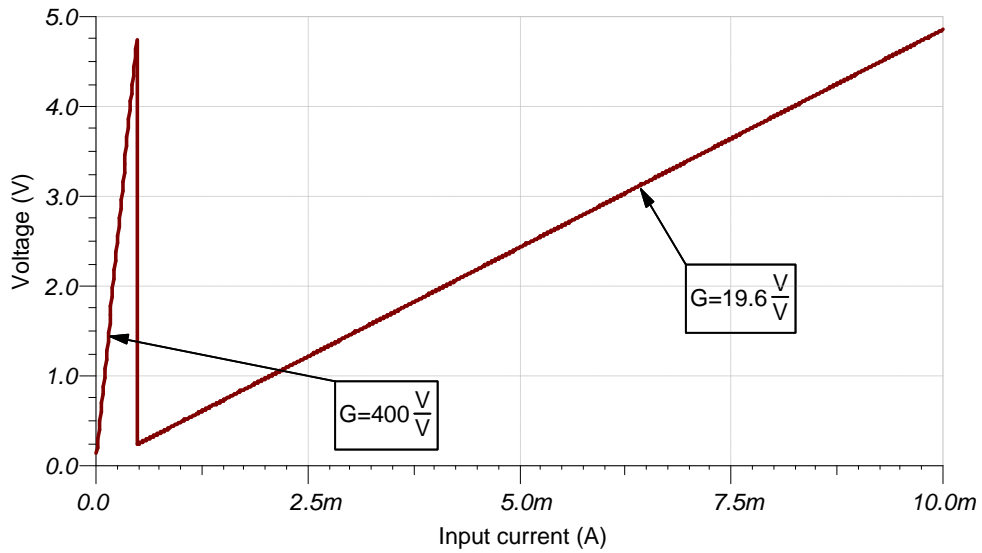
$$C_2 = \frac{1}{2 \times \pi \times R_2 \times f_p} = \frac{1}{2 \times \pi \times 10M\Omega \times 1.59kHz} = 10pF$$

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

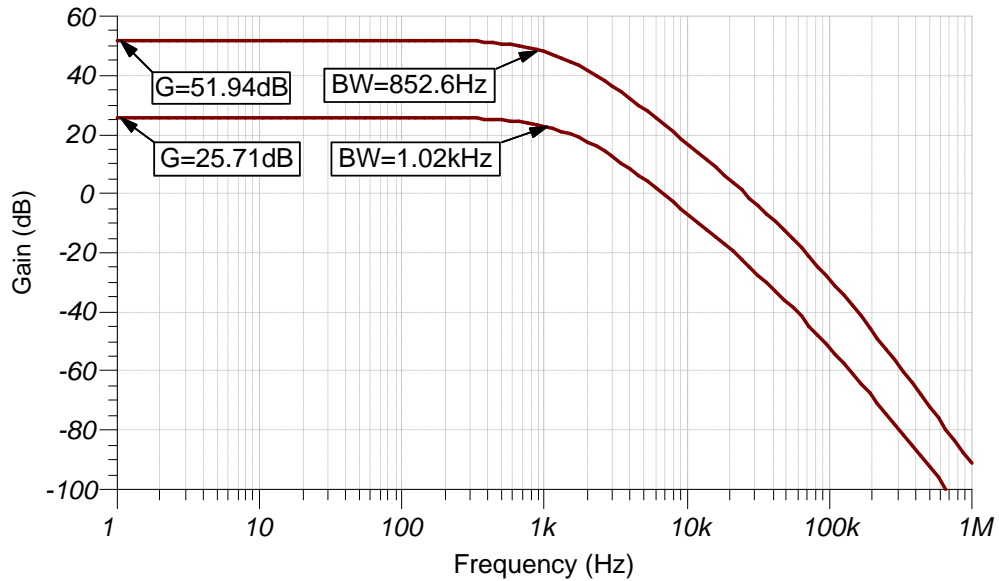
$$C_3 = 196pF \approx 194pF \text{ (Standard Value)}$$

**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, [www.ti.com/tool/tipd104](http://www.ti.com/tool/tipd104).

## Design Featured Op Amp

INA326	
$V_{SS}$	1.8V to 5.5V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	0.1mV
$I_q$	3.4mA
$I_b$	2nA
UGBW	1kHz
SR	Filter limited
#Channels	1
<a href="http://www.ti.com/product/ina326">www.ti.com/product/ina326</a>	

## Revision History

Revision	Date	Change
A	January 2019	Downscale the title and changed title role to 'Amplifiers'. Added link to circuit cookbook landing page.

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