Analog Engineer's Circuit

Transimpedance amplifier with T-network circuit

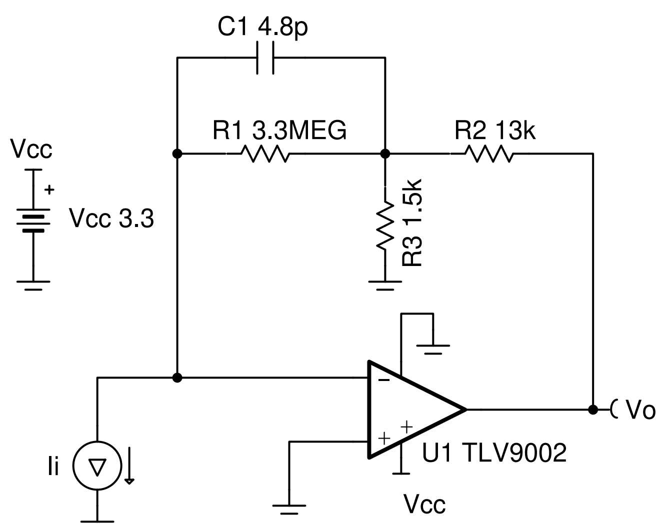
Amplifiers

Design Goals

Input		Output		BW	Supply	
I_{iMin}	I_{iMax}	V_{oMin}	V_{oMax}	f_p	V_{cc}	V_{ee}
0A	100nA	0V	3.2V	10kHz	3.3V	0V

Design Description

This transimpedance amplifier with a T-network feedback configuration converts an input current into an output voltage. The current-to-voltage gain is based on the T-network equivalent resistance which is larger than any of the resistors used in the circuit. Therefore, the T-network feedback configuration circuit allows for very high gain without the use of large resistors in the feedback or a second gain stage, reducing noise, stability issues, and errors in the system.



Design Notes

1. C_1 and R_1 set the input signal cutoff frequency, f_p.
2. Capacitor C_1 in parallel with R_1 helps limit the bandwidth, reduce noise, and also improve the stability of the circuit if high-value resistors are used.
3. The common-mode voltage is the voltage at the non-inverting input and does not vary with input current.
4. A bias voltage can be added to the non-inverting input to bias the output voltage above the minimum output swing for 0A input current.
5. Using high-value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit.
6. Avoid placing capacitive loads directly on the output of the amplifier to minimize stability issues.
7. For more information on op amp linear operating region, stability, slew-induced distortion, capacitive load drive, driving ADCs, and bandwidth see the *Design References* section.

Design Steps

The transfer function of this circuit follows:

$$V_o = I_i \times \left(\frac{R_2 \times R_1}{R_3} + R_1 + R_2 \right)$$

1. Calculate the required gain:

$$\text{Gain} = \frac{V_{oMax}}{I_{oMax}} = \frac{3.2V}{100nA} = 3.2 \times 10^7 \frac{V}{A}$$

2. Choose the resistor values to set the pass-band gain:

$$\text{Gain} = \left(\frac{R_2 \times R_1}{R_3} + R_1 + R_2 \right)$$

Since R_1 will be the largest resistor value in the system choose this value first then choose R_2 and calculate R_3. Select R_1 = 3.3MΩ and R_2 = 13kΩ. R_1 is very large due to the large transimpedance gain of the circuit. R_2 is in the ~10k ohm range so the op amp can drive it easily.

$$R_3 = \left(\frac{R_2 \times R_1}{\text{Gain} - R_1 - R_2} \right) = \left(\frac{13k\Omega \times 3.3M\Omega}{3.2 \times 10^7 \frac{V}{A} - 3.3M\Omega - 13k\Omega} \right) = 1.5k\Omega$$

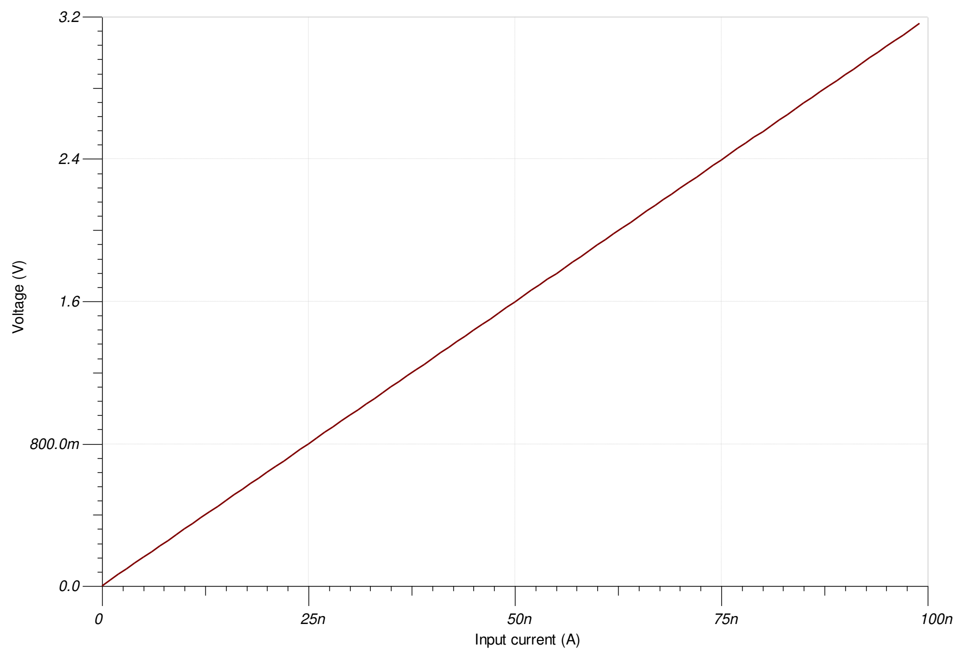
3. Calculate C_1 to set the location of f_p.

$$C_1 = \frac{1}{2\,\pi \times R_1 \times f_p} = \frac{1}{2\pi \times 3.3M\Omega \times 10kHz} = 4.82pF \approx 4.8pF \text{ (Standard Value)}$$

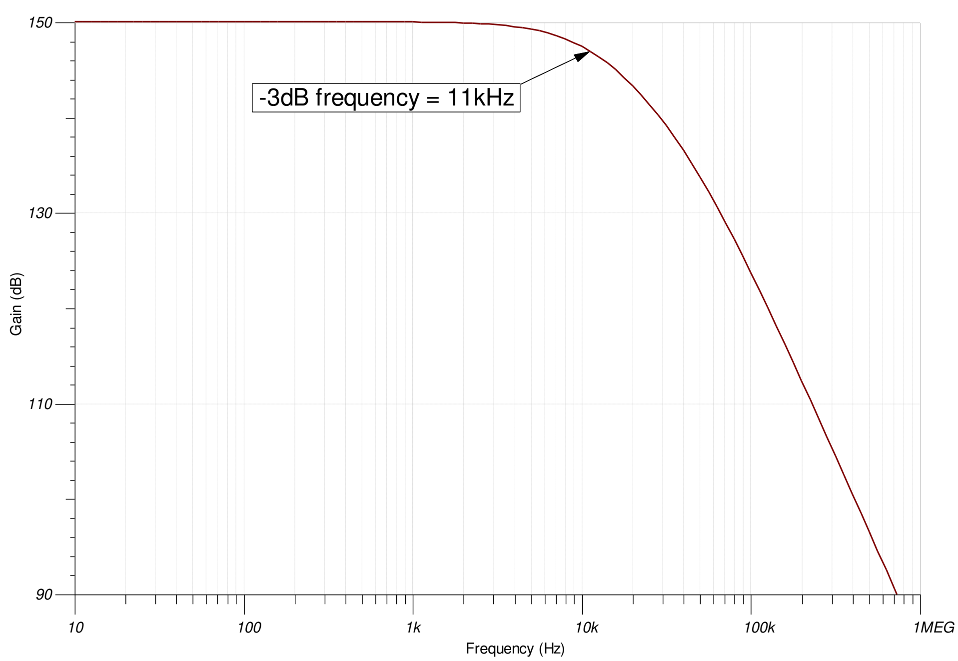
4. Run a stability analysis to make sure that the circuit is stable. For more information on how to run a stability analysis see the *TI Precision Labs - Op amp: Stability* video.

Design Simulations

DC Simulation Results



AC Simulation Results



Design References

1. See Analog Engineer's Circuit Cookbooks for TI's comprehensive circuit library.
2. See SPICE file, SBOMB39.
3. See TIPD176, www.ti.com/tool/tipd176.
4. For more information on many op amp topics including common-mode range, output swing, bandwidth, and how to drive an ADC please visit TI Precision Labs.

Design Featured Op Amp

TLV9002	
V_{cc}	1.8V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail–to–rail
V_{os}	0.4mV
I_q	60µA
I_b	5pA
UGBW	1MHz
SR	2V/µs
#Channels	1, 2, 4
www.ti.com/product/TLV9002	

Design Alternate Op Amp

OPA375	
V_{cc}	2.25V to 5.5V
V_{inCM}	V_{ee} to (V_{cc} –1.2V)
V_{out}	Rail–to–rail
V_{os}	0.15mV
I_q	890µA
I_b	10pA
UGBW	10MHz
SR	4.75V/µs
#Channels	1
www.ti.com/product/OPA375	

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