Inverting Amplifier With T-Network Feedback Circuit

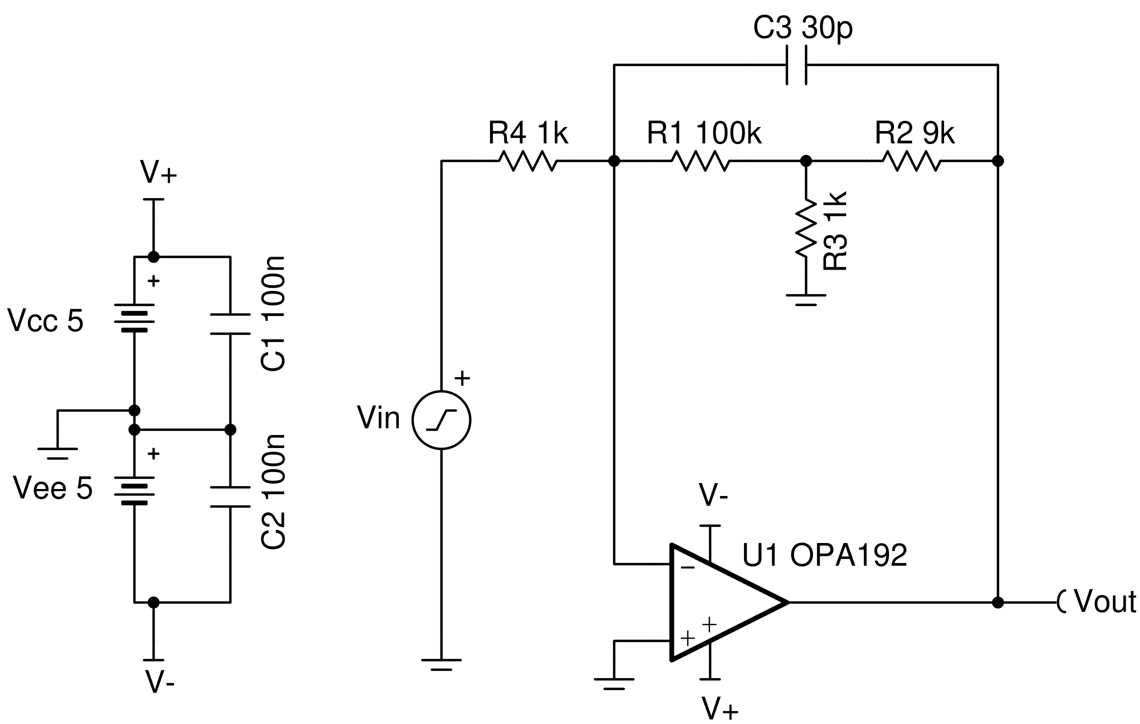
Amplifiers

Design Goals

Input		Output		BW	Supply	
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	f_p	V_{cc}	V_{ee}
–2.5mV	2.5mV	–2.5V	2.5V	5kHz	5V	–5V

Design Description

This design inverts the input signal, V_{in}, and applies a signal gain of 1000V/V or 60dB. The inverting amplifier with T-feedback network can be used to obtain a high gain without a small value for R_4 or very large values for the feedback resistors.



Design Notes

1. C_3 and the equivalent resistance of feedback resistors set the cutoff frequency, f_p.
2. The common-mode voltage in this circuit does not vary with input voltage.
3. Using high-value resistors can degrade the phase margin and increase noise.
4. Avoid placing capacitive loads directly on the output of the amplifier to minimize stability issues.
5. Due to the high gain of the circuit, be sure to use an op amp with sufficient gain bandwidth product. Remember to use the noise gain when calculating bandwidth. Use precision, or low offset, devices due to the high gain of the circuit.
6. 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

1. Calculate required gain.

$$\text{Gain} = \frac{V_{oMax} - V_{oMin}}{V_{iMax} - V_{iMin}} = \frac{2.5V - (-2.5V)}{2.5mV - (-2.5mV)} = 1000\frac{V}{V} = 60dB$$

2. Calculate resistor values to set the required gain.

$$\text{Gain} = \left(\frac{\frac{R_2 \times R_1}{R_3} + R_1 + R_2}{R_4}\right)$$

Choose the input resistor R_4 to be 1kΩ. To obtain a gain of 1000V/V, normally a 1-MΩ resistor would be required. A T-network allows us to use smaller resistor values in the feedback loop. Selecting R_1 to be 100kΩ and R_2 to be 9kΩ allows calculation of the value for R_3. R_2 is in the 10kΩ range so the op amp can easily drive the feedback network.

$$R_3 = \left(\frac{R_2 \times R_1}{(\text{Gain} \times R_4) - R_1 - R_2}\right) = \left(\frac{9k\Omega \times 100k\Omega}{(1000 \times 1k\Omega) - 100k\Omega - 9k\Omega}\right) = 1k\Omega$$

3. Calculate C_3 using the equivalent resistance of the feedback resistors, R_{eq}, to set the location of f_p.

$$R_{eq} = \left(\frac{R_2 \times R_1}{R_3} + R_1 + R_2\right) = \left(\frac{9k\Omega \times 100k\Omega}{1k\Omega} + 100k\Omega + 9k\Omega\right) = 1.009M\Omega$$

$$f_p = \frac{1}{2\pi \times R_{eq} \times C_3} = 5kHz$$

$$C_3 = \frac{1}{2\pi \times R_{eq} \times f_p} = \frac{1}{2\pi \times 1.009M\Omega \times 5kHz} = 31.55pF \approx 30pF \text{ (Standard Value)}$$

4. Calculate the small signal circuit bandwidth to ensure it meets the 5 kHz requirement. Be sure to use the noise gain, NG, or non-inverting gain of the circuit.

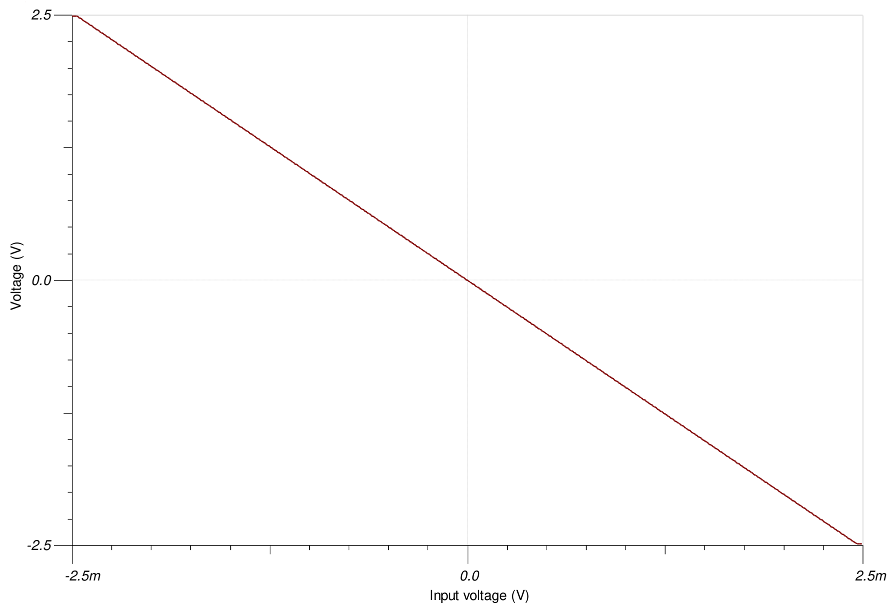
$$NG = 1 + \frac{R_{eq}}{R_4} = 1 + 1009 = 1010\frac{V}{V}$$

$$BW = \frac{GBP}{NG} = \frac{10MHz}{1010\ V/V} = 9.9kHz$$

- BW_{OPA192} = 10MHz; therefore this requirement is met.

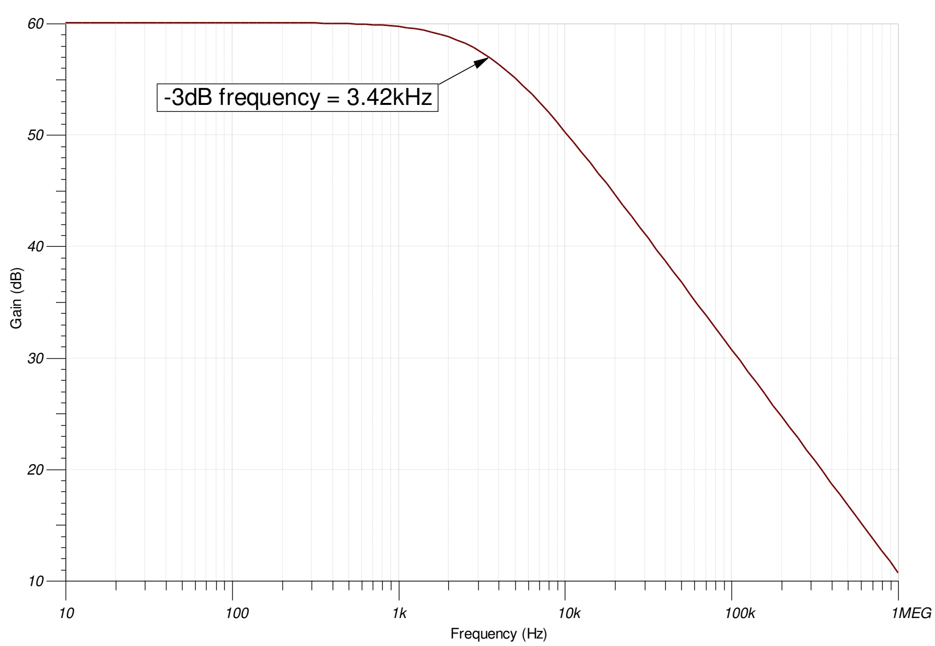
Design Simulations

DC Simulation Results

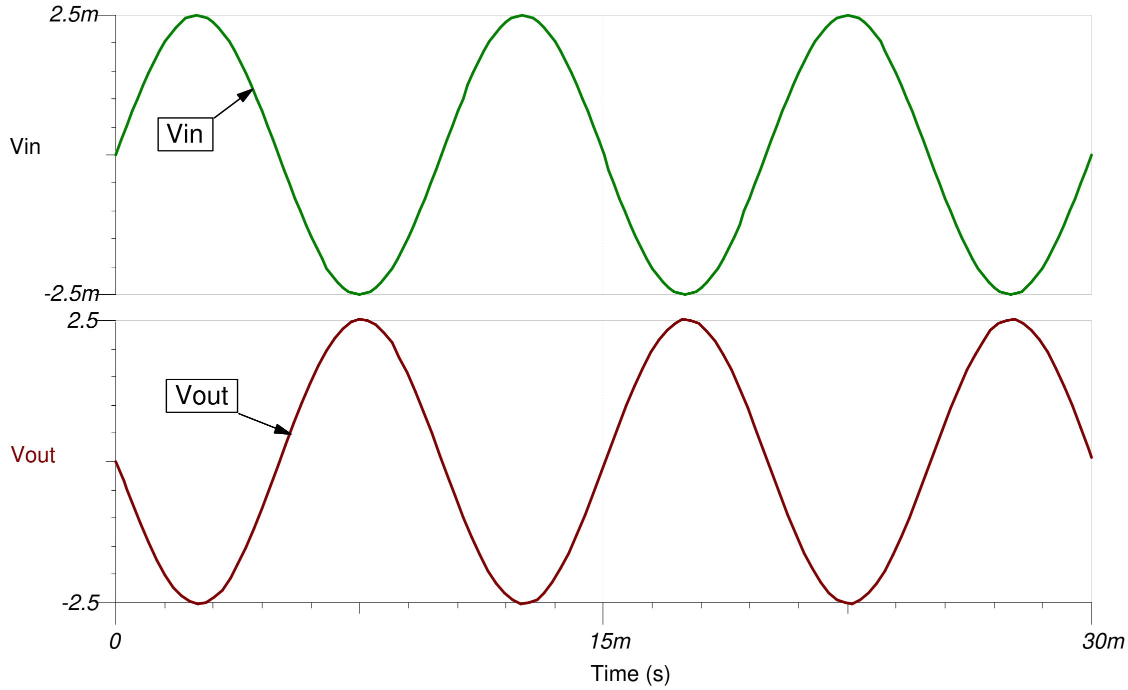


AC Simulation Results

The simulation is very close to the calculation.



Transient Simulation Results



Design References

1. See *Analog Engineer's Circuit Cookbooks* for the comprehensive TI circuit library.
2. TI Precision Labs
3. See the *1 MHz, Single-Supply, Photodiode Amplifier Reference Design*.

Design Featured Op Amp

OPA192	
V_{ss}	±2.25V to ±18V
V_{inCM}	Rail-to-Rail
V_{out}	Rail-to-Rail
V_{os}	5µV
I_q	1mA
I_b	5pA
UGBW	10MHz
SR	20V/µs
#Channels	1, 2, 4
www.ti.com/product/OPA192	

Design Alternate Op Amp

TLV9062	
V_{ss}	1.8V to 5.5V
V_{inCM}	Rail-to-Rail
V_{out}	Rail-to-Rail
V_{os}	0.3mV
I_q	538µA
I_b	0.5pA
UGBW	10MHz
SR	6.5V/µs
#Channels	1,2,4
www.ti.com/product/TLV9062	

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