Analog Engineer's Circuit

Low-pass, filtered, non-inverting amplifier circuit

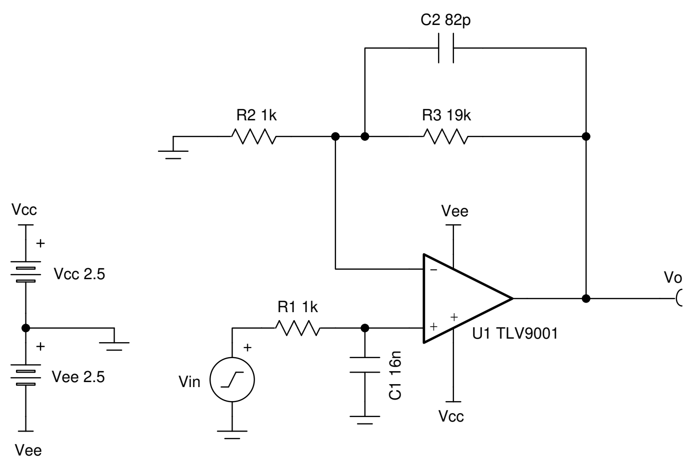
Amplifiers

Design Goals

Input		Output		BW	Supply	
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	f_c	V_{cc}	V_{ee}
–0.1V	0.1V	–2V	2V	10kHz	2.5V	–2.5V

Design Description

This low-pass non-inverting circuit amplifies the signal level by 20V/V (26dB) and filters the signal by setting the pole at 10kHz. Components R_1 and C_1 create a low-pass filter on the non-inverting pin. The frequency response of this circuit is the same as that of a passive RC filter, except that the output is amplified by the pass-band gain of the amplifier. Components C_2 and R_3 are used to set the cutoff frequency, $f_{c,}$ of the non-inverting amplifier.



Design Notes

1. The common-mode voltage is equal to the input voltage applied to the non-inverting input of the op amp.
2. Using high-value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit.
3. Set the pole frequency created by R_3 / C_2 to be ten times higher than the pole created by R_1 / C_1 to achieve a single poll roll-off that is dominated by R_1 / C_1. If the filter pairs R_1 / C_1 and R_3 / C_2 have the same pole frequency, the gain will be reduced by 6dB at the cutoff frequency. Also the gain decreases at a rate of –40dB/dec until the response reaches 0dB, after which the slope changes to –20dB/dec until the op amp runs out of bandwidth.
4. C_2 limits the bandwidth of the non-inverting gain stage.
5. Avoid placing capacitive loads directly on the output of the amplifier to minimize stability issues.
6. Large signal performance may be limited by slew rate. Therefore, check the maximum output swing versus frequency plot in the data sheet to minimize slew-induced distortion.
7. For more information on an op amp linear operating region, stability, slew-induced distortion, capacitive load drive, driving ADCs, and bandwidth, see the *Design References* section.

Design Steps

The DC transfer function of this circuit follows:

$$V_o = V_{in} \times \left(1 + \frac{R_3}{R_2}\right)$$

1. Calculate the gain.

$$\text{Gain} = \frac{V_{oMax} - V_{oMin}}{V_{iMax} - V_{iMin}} = \frac{2V - (-2V)}{0.1V - (-0.1V)} = 20\frac{V}{V}$$

2. Calculate values for R_2 and R_3.

$$\text{Gain} = 1 + \frac{R_3}{R_2} = 20\frac{V}{V} \rightarrow (26dB)$$

Choose $R_2 = 1k\Omega$:

$$R_3 = (\text{Gain} - 1) \times R_2 = 19k\Omega$$

3. Calculate the component values R_1 and C_1 to set the cutoff frequency, f_c. Pick the value of R_1 and then calculate C_1 to set the location of f_c.

Choose $R_1 = 1k\Omega$:

$$C_1 = \frac{1}{2\pi \times R_1 \times f_c} = \frac{1}{2\pi \times 1k\Omega \times 10kHz} = 15.92nF \approx 16nF \text{ (Standard Value)}$$

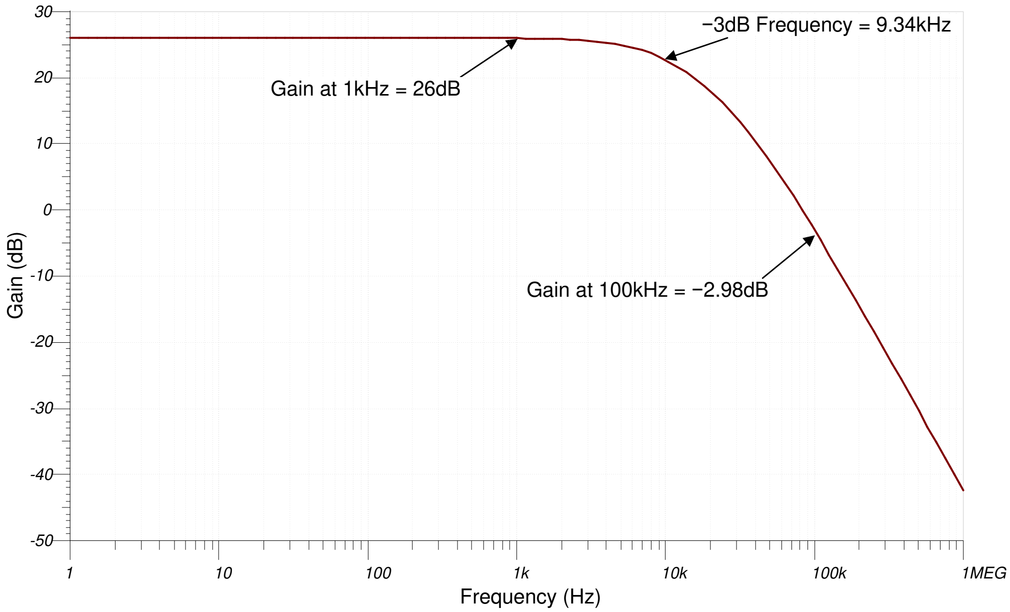
4. Calculate C_2 value to set the cutoff frequency (f_c) of the op amp. Select the corner frequency to be at least ten times larger than f_c.

$$f_c = 10kHz;\ 10 \times f_c = 100kHz$$

$$C_2 = \frac{1}{2\pi \times R_3 \times 100kHz} = \frac{1}{2\pi \times 19k\Omega \times 100kHz} = 83.77pF \approx 82pF \text{ (Standard Value)}$$

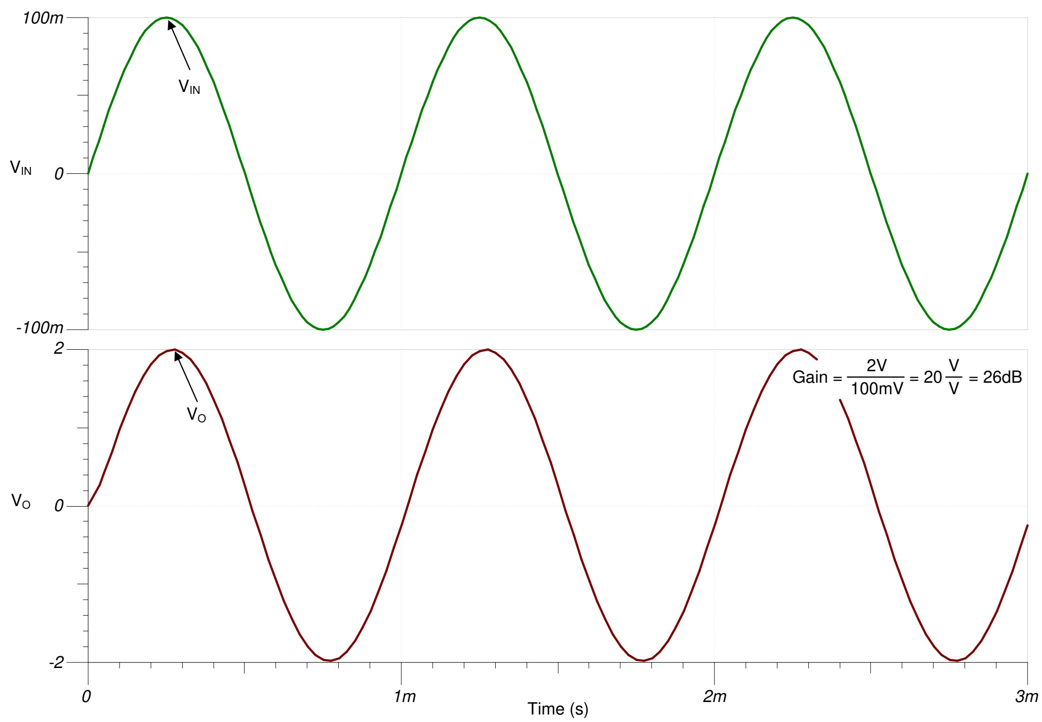
Design Simulations

AC Simulation Results

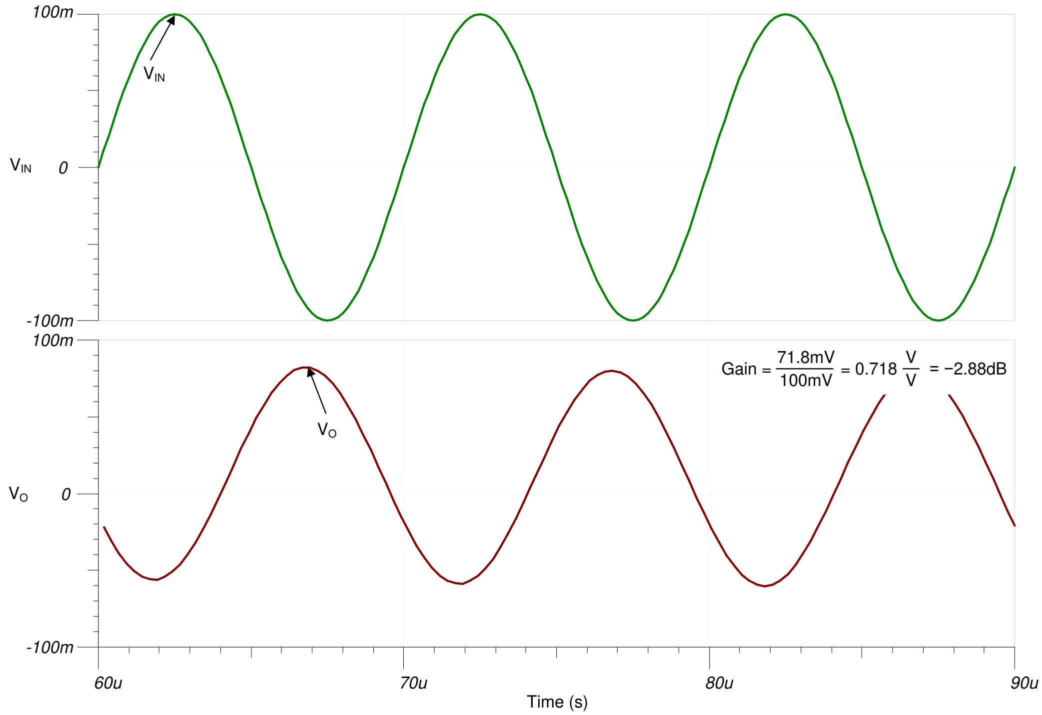


Transient Simulation Results

A 1-kHz, 0.2-V_{PP} sine wave yields a 4-V_{PP} output sine wave.



A 100-kHz, 0.2-V_{PP} sine wave yields a 0.071-V_{PP} output sine wave.



Design References

1. See Analog Engineer's Circuit Cookbooks for the comprehensive TI circuit library.
2. SPICE Simulation File SBOC528.
3. *TI Precision Labs*
4. See the *AC Coupled, Single-Supply, Inverting and Non-inverting Amplifier Reference Design*.

Design Featured Op Amp

TLV9001	
V_{ss}	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/TLV9001	

Design Alternate Op Amp

OPA375	
V_{ss}	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	1,2,4
www.ti.com/product/OPA375	