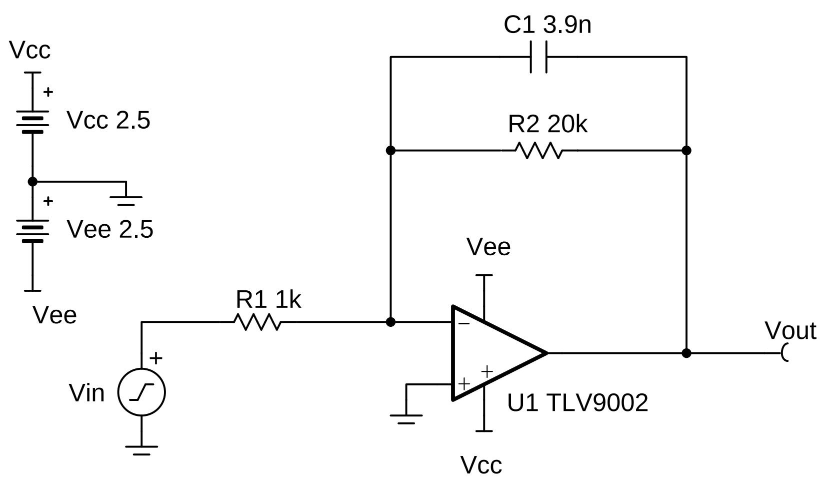
Low–pass filtered, inverting amplifier circuit

Design Goals

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

Design Description

This tunable low–pass inverting amplifier circuit amplifies the signal level by 26dB or 20V/V. R_2 and C_1 set the cutoff frequency for this circuit. 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. Low–pass filters are often used in audio signal chains and are sometimes called bass–boost filters.



Design Notes

1. C_1 and R_2 set the low–pass filter cutoff frequency
2. The common-mode voltage is set by the non–inverting input of the op amp, which in this case is mid–supply.
3. Using high value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit.
4. R_2 and R_1 set the gain of the circuit.
5. The pole frequency f_p of 2kHz is selected for an audio bass–boost application.
6. Avoid placing capacitive loads directly on the output of the amplifier to minimize stability issues.
7. 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.
8. For more information on op amp linear operation region, stability, slew–induced distortion, capacitive load drive, driving ADCs and bandwidth please see the design references section.

Design Steps

The DC transfer function of this circuit is given below.

$$V_o = V_i \times \left(-\frac{R_2}{R_1}\right)$$

1. Pick resistor values for given passband gain.

$$Gain = \frac{R_2}{R_1} = 20\ \frac{V}{V}\ (26\ dB)$$

$$R_1 = 1\ k\Omega$$

$$R_2 = Gain \times (R_1) = 20\ \frac{V}{V} \times 1\ k\Omega = 20\ k\Omega$$

2. Select low–pass filter pole frequency f_p

$$f_p = 2\ kHz$$

3. Calculate C_1 using R_2 to set the location of f_p.

$$f_p = \frac{1}{2\pi \times R_2 \times C_1} = 2\ kHz$$

$$C_1 = \frac{1}{2\pi \times R_2 \times f_p} = \frac{1}{2\pi \times 20\ k\Omega \times 2\ kHz} = 3.98nF \approx 3.9nF\ (Standard\ \ Value)$$

4. Calculate the minimum slew rate required to minimize slew–induced distortion.

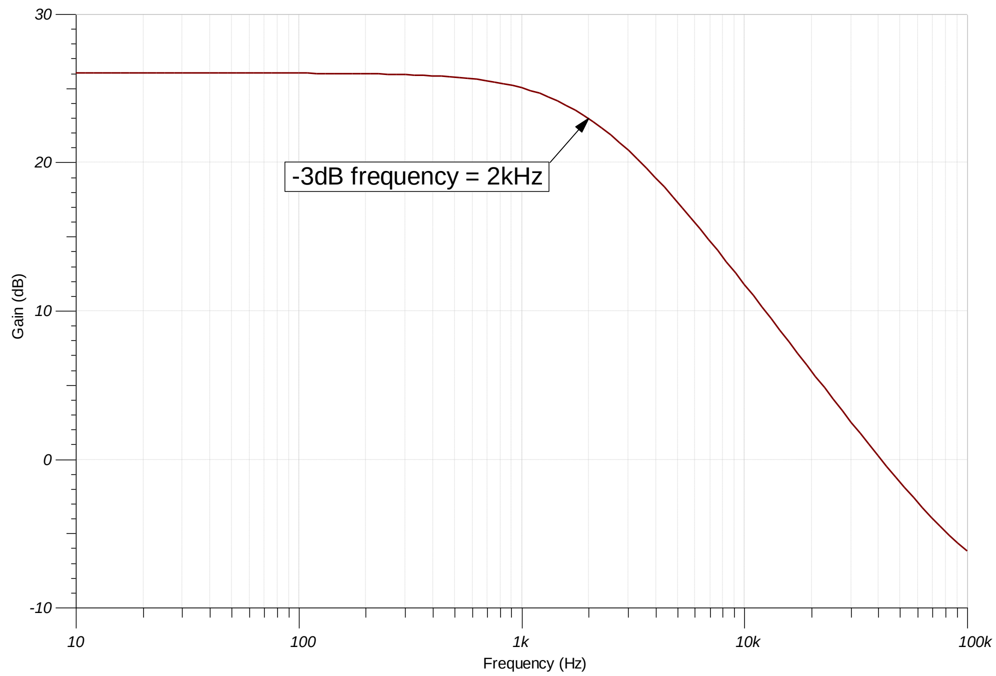
$$V_p = \frac{SR}{2 \times \pi \times f} \rightarrow SR > 2 \times \pi \times f \times V_p$$

$$SR > 2 \times \pi \times 2\ kHz \times 2\ V = 0.25\ \frac{V}{\mu s}$$

5. $SR_{TLV9002}$ = 2V/µs, therefore it meets this requirement

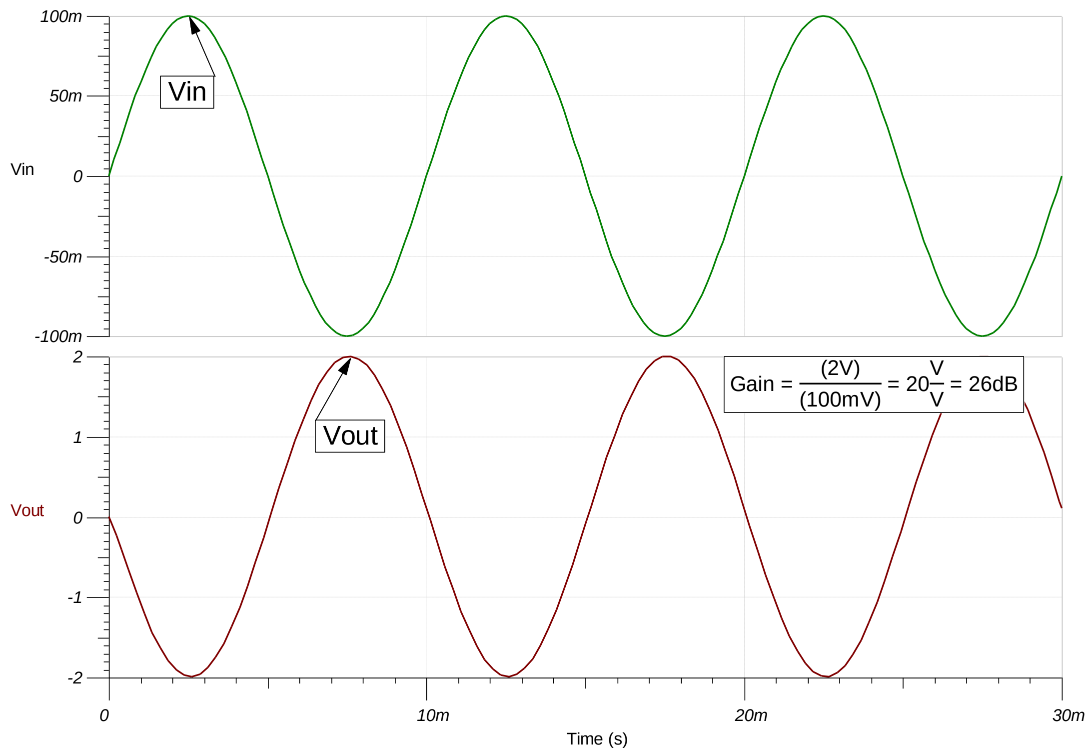
Design Simulations

AC Simulation Results

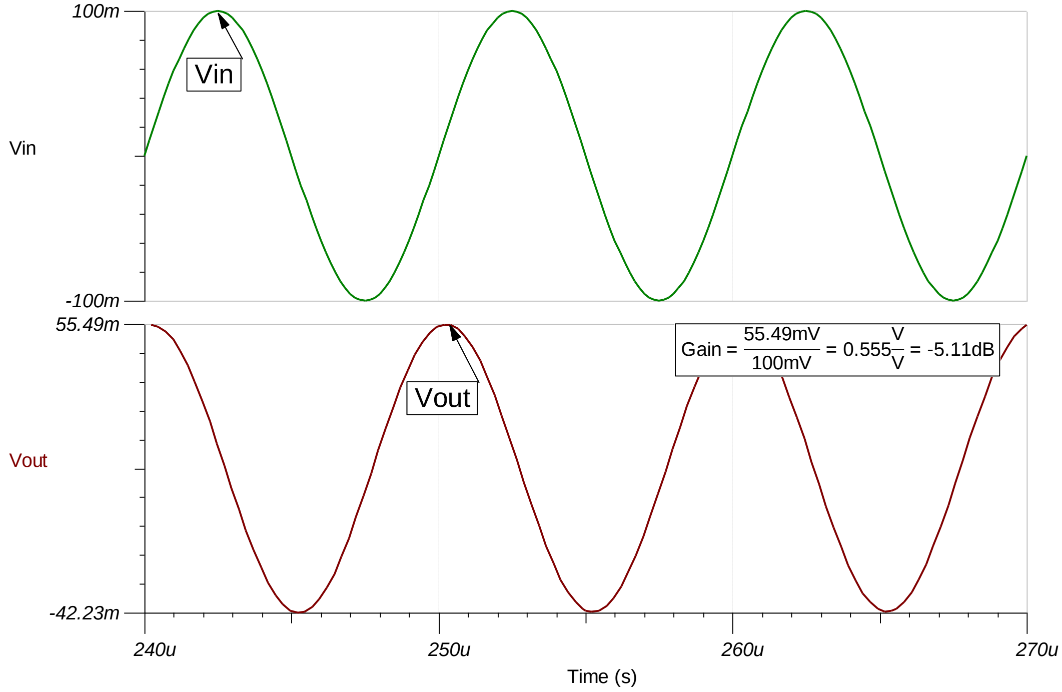


Transient Simulation Results

A 100 Hz, 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 0.1 V_{pp} output sine wave.



References:

1. Analog Engineer's Circuit Cookbooks
2. SPICE Simulation File SBOC523
3. TI Precision Designs TIPD185
4. TI Precision Labs

Design Featured Op Amp

TLV9002	
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/tlv9002	

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
www.ti.com/product/opa375	