

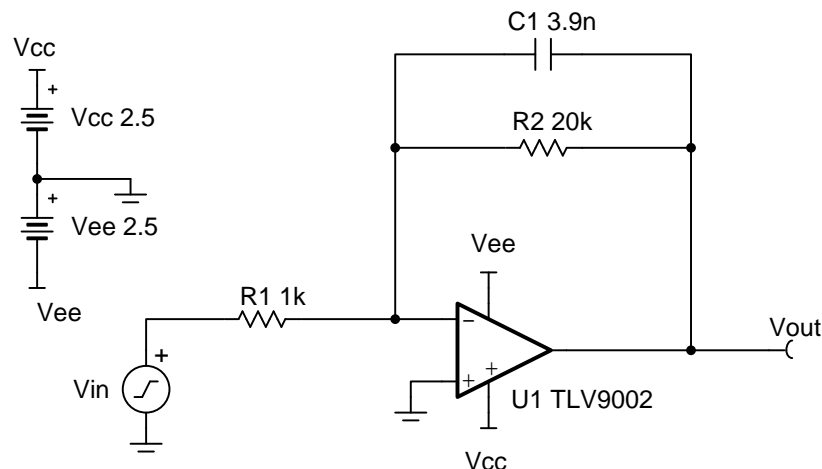
## **Low-pass filtered, inverting amplifier circuit**

### 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.

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

$$R_1 = 1 \text{ k}\Omega$$

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

2. Select low-pass filter pole frequency  $f_p$

$$f_p = 2 \text{ kHz}$$

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

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

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

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

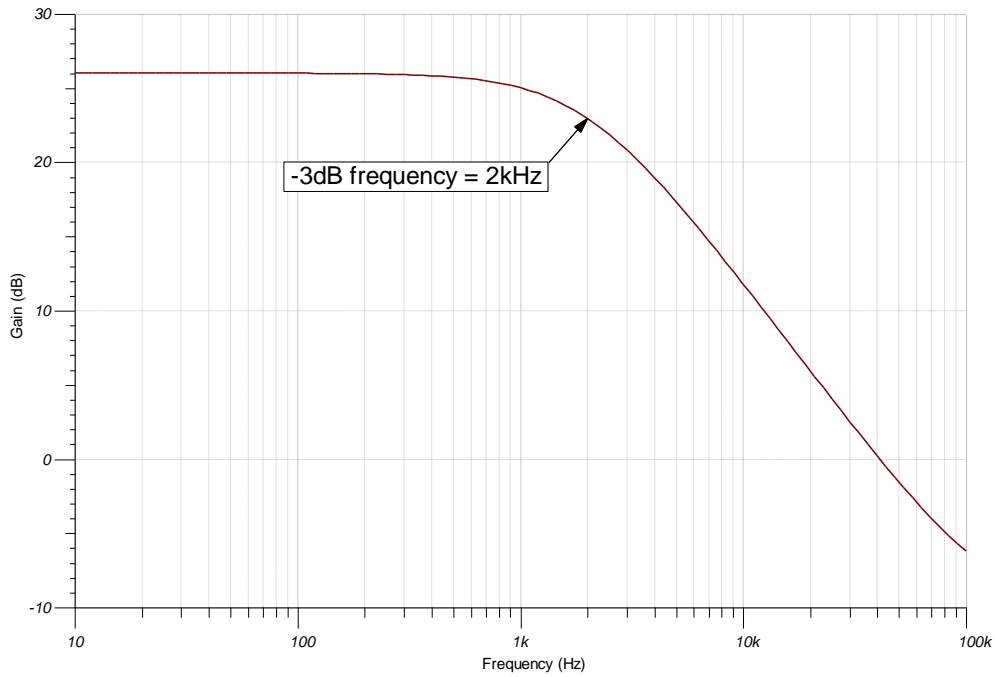
$$V_p = \frac{SR}{2 \times \pi \times f} \rightarrow SR > 2 \times \pi \times f \times V_p$$

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

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

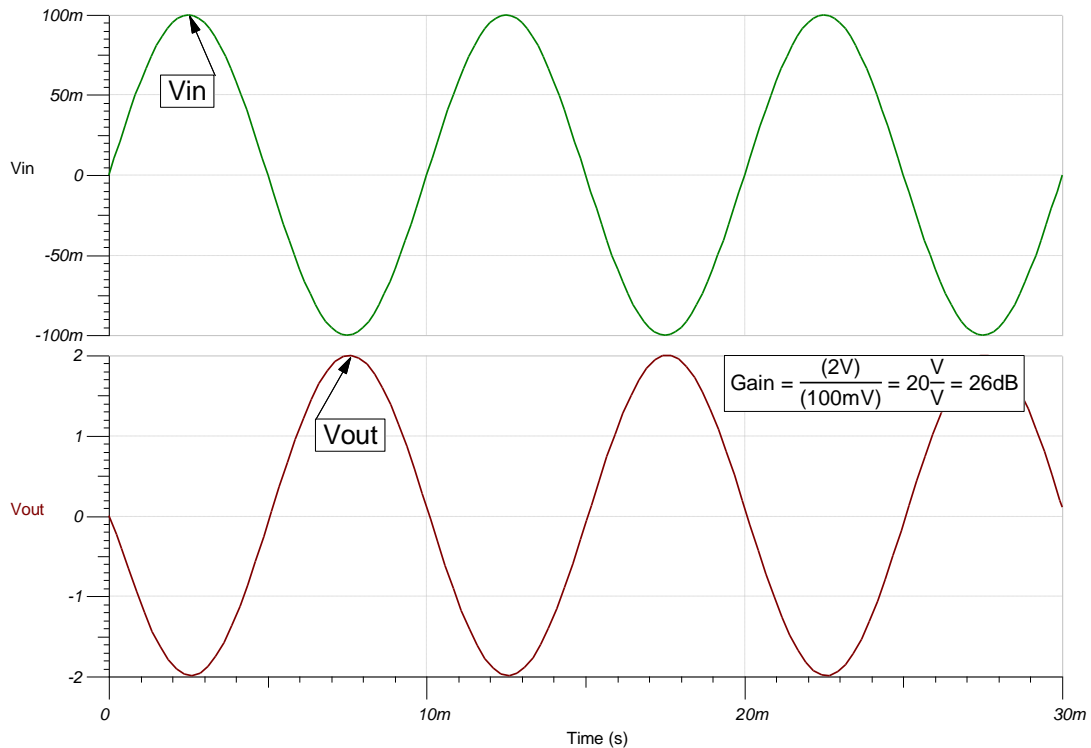
Design Simulations

AC Simulation Results

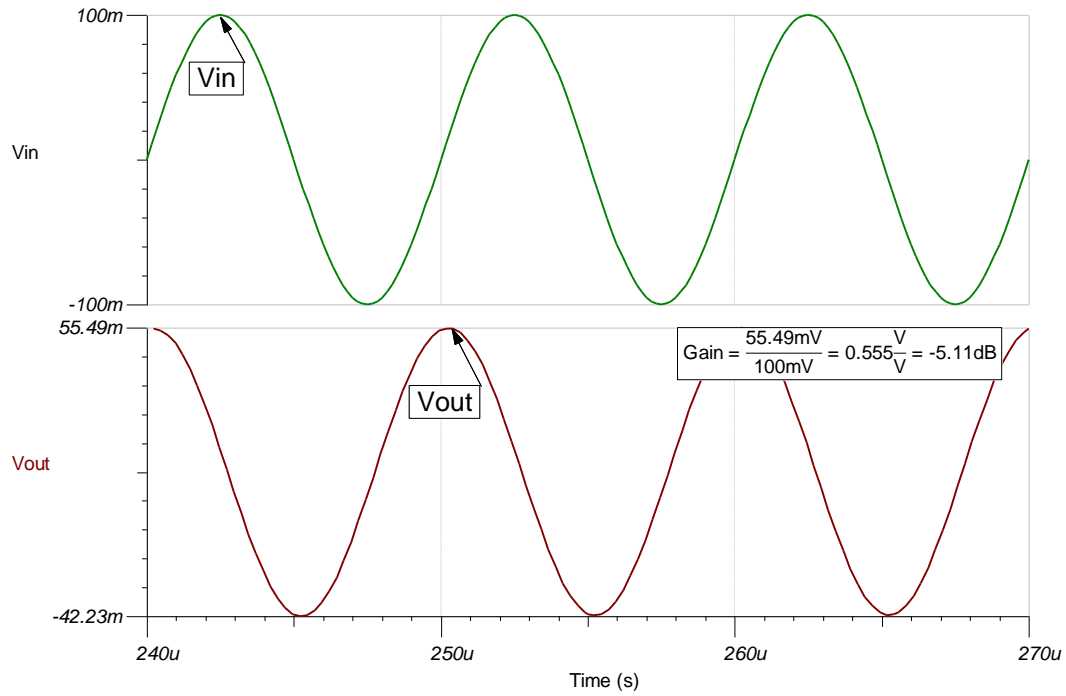


Transient Simulation Results

A 100 Hz, 0.2 V<sub>pp</sub> sine wave yields a 4 V<sub>pp</sub> output sine wave.



A 100 kHz, 0.2 V<sub>pp</sub> sine wave yields a 0.1 V<sub>pp</sub> 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**

<b>TLV9002</b>	
$V_{ss}$	1.8V to 5.5V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	0.4mV
$I_q$	60 $\mu$ A
$I_b$	5pA
<b>UGBW</b>	1MHz
<b>SR</b>	2V/ $\mu$ s
<b>#Channels</b>	1,2,4
<a href="http://www.ti.com/product/tlv9002">www.ti.com/product/tlv9002</a>	

**Design Alternate Op Amp**

<b>OPA375</b>	
$V_{ss}$	2.25V to 5.5V
$V_{inCM}$	$V_{ee}$ to $V_{cc} - 1.2V$
$V_{out}$	Rail-to-rail
$V_{os}$	0.15mV
$I_q$	890 $\mu$ A
$I_b$	10pA
<b>UGBW</b>	10MHz
<b>SR</b>	4.75V/ $\mu$ s
<b>#Channels</b>	1
<a href="http://www.ti.com/product/opa375">www.ti.com/product/opa375</a>	

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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
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