

# Inverting Op Amp with Non-Inverting Positive Reference Voltage Circuit

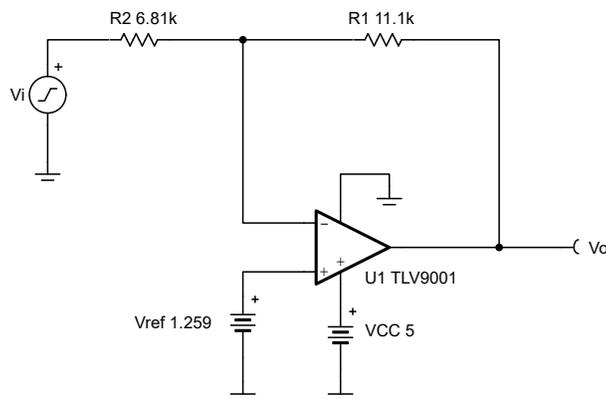


## Design Goals

Input		Output		Supply		
$V_{iMin}$	$V_{iMax}$	$V_{oMin}$	$V_{oMax}$	$V_{cc}$	$V_{ee}$	$V_{ref}$
-1 V	2 V	0.05 V	4.95 V	5 V	0 V	1.259 V

## Design Description

This design uses an inverting amplifier with a non-inverting positive reference voltage to translate an input signal of -1 V to 2 V to an output voltage of 0.05 V to 4.95 V. This circuit can be used to translate a sensor output voltage with a positive slope and negative offset to a usable ADC input voltage range.



## Design Notes

1. Use op amp linear output operating range. Usually specified under  $A_{OL}$  test conditions.
2. Amplifier common mode voltage is equal to the reference voltage.
3.  $V_{ref}$  can be created with a voltage divider.
4. Input impedance of the circuit is equal to  $R_2$ .
5. Choose low-value resistors to use in the feedback. It is recommended to use resistor values less than 100 k $\Omega$ . Using high-value resistors can degrade the phase margin of the amplifier and introduce additional noise in the circuit.
6. The cutoff frequency of the circuit is dependent on the gain bandwidth product (GBP) of the amplifier. Additional filtering can be accomplished by adding a capacitor in parallel to  $R_1$ . Adding a capacitor in parallel with  $R_1$  will also improve stability of the circuit, if high-value resistors are used.

## Design Steps

$$V_o = -V_i \times \left(\frac{R_1}{R_2}\right) + V_{\text{ref}} \times \left(1 + \frac{R_1}{R_2}\right)$$

1. Calculate the gain of the input signal.

$$G_{\text{input}} = -\frac{R_1}{R_2}$$

$$V_{o_{\text{max}}} - V_{o_{\text{min}}} = (V_{i_{\text{max}}} - V_{i_{\text{min}}}) \left(-\frac{R_1}{R_2}\right)$$

$$-\frac{R_1}{R_2} = -\frac{V_{o_{\text{max}}} - V_{o_{\text{min}}}}{V_{i_{\text{max}}} - V_{i_{\text{min}}}} = -\frac{4.95\text{V} - 0.05\text{V}}{2\text{V} - (-1\text{V})} = -1.633\frac{\text{V}}{\text{V}}$$

2. Select  $R_2$  and calculate  $R_1$ .

$$R_2 = 6.81 \text{ k}\Omega$$

$$R_1 = G_{\text{input}} \times R_2 = 1.633\frac{\text{V}}{\text{V}} \times 6.81 \text{ k}\Omega = 11.123\text{k}\Omega \approx 11.1 \text{ k}\Omega \text{ (Standard Value)}$$

3. Calculate the reference voltage.

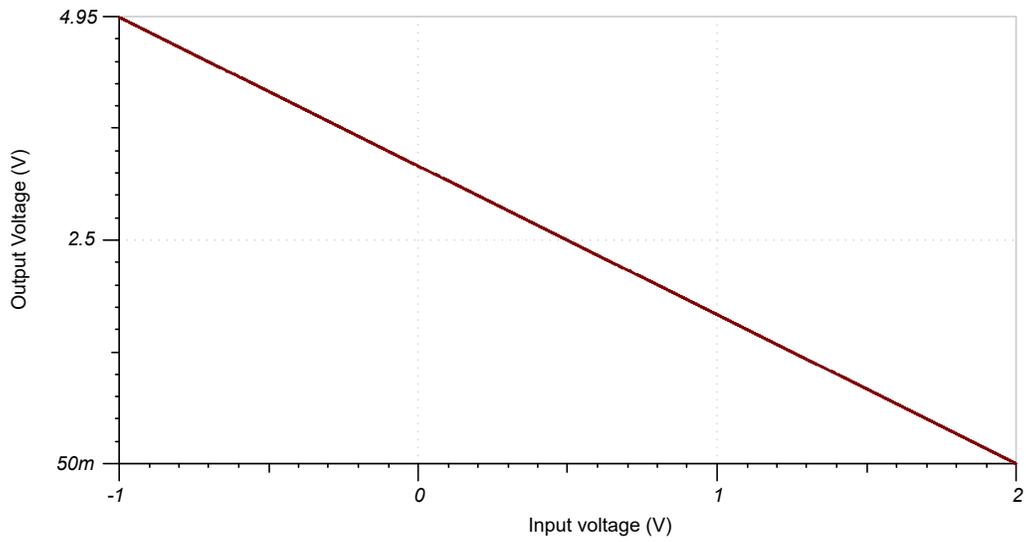
$$V_{o_{\text{min}}} = -V_{i_{\text{max}}} \times \left(\frac{R_1}{R_2}\right) + V_{\text{ref}} \times \left(1 + \frac{R_1}{R_2}\right)$$

$$0.05\text{V} = -2\text{V} \times \left(\frac{11.11 \text{ k}\Omega}{6.81 \text{ k}\Omega}\right) + V_{\text{ref}} \times \left(1 + \frac{11.11 \text{ k}\Omega}{6.81 \text{ k}\Omega}\right)$$

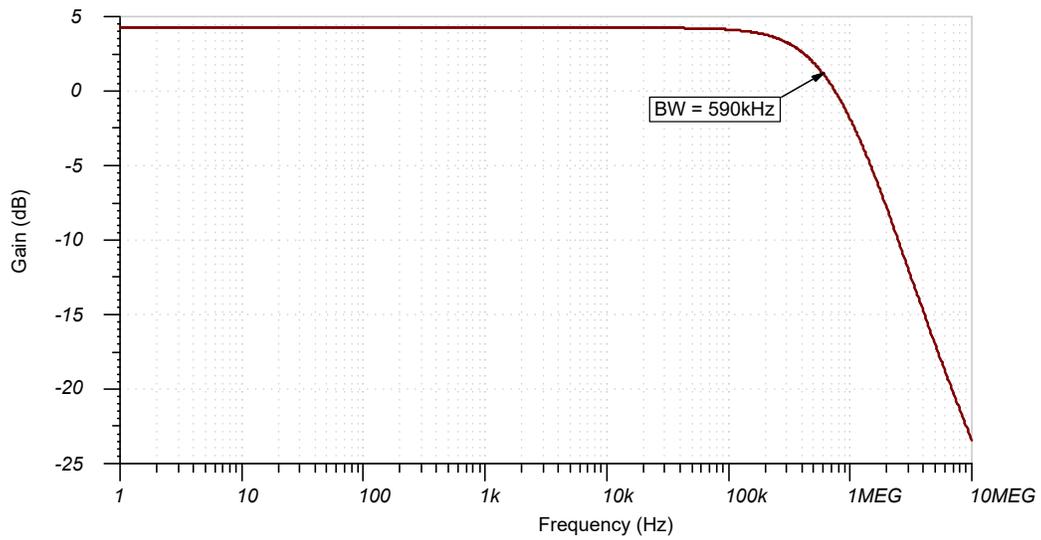
$$V_{\text{ref}} = \frac{V_{o_{\text{min}}} + V_{i_{\text{max}}} \times \left(\frac{R_1}{R_2}\right)}{\left(1 + \frac{R_1}{R_2}\right)} = \frac{0.05\text{V} + 2\text{V} \times \left(\frac{11.11 \text{ k}\Omega}{6.81 \text{ k}\Omega}\right)}{\left(1 + \frac{11.11 \text{ k}\Omega}{6.81 \text{ k}\Omega}\right)} = 1.259\text{V}$$

## Design Simulations

### DC Simulation Results



### AC Simulation Results



## Design References

See [Analog Engineer's Circuit Cookbooks](#) for TI's comprehensive circuit library.

See the circuit SPICE simulation file [SBOC514](#).

See [Designing Gain and Offset in Thirty Seconds](#).

## Design Featured Op Amp

TLV9001	
$V_{SS}$	1.8 V to 5.5 V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	0.4 mV
$I_q$	60 $\mu$ A
$I_b$	5 pA
UGBW	1 MHz
SR	2 V/ $\mu$ s
#Channels	1, 2, and 4
<a href="#">TLV9001</a>	

## Design Alternate Op Amp

OPA376	
$V_{SS}$	2.2 V to 5.5 V
$V_{inCM}$	Rail-to-rail
$V_{out}$	Rail-to-rail
$V_{os}$	5 $\mu$ V
$I_q$	760 $\mu$ A
$I_b$	0.2 pA
UGBW	5.5 MHz
SR	2 V/ $\mu$ s
#Channels	1, 2, and 4
<a href="#">OPA376</a>	

## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

### Changes from February 1, 2018 to February 4, 2019

**Page**

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>Downscale the title and changed title role to 'Amplifiers'. Added links to circuit cookbook landing page and SPICE simulation file.....</li> </ul> | 1 |
|---|---|

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