Analog Engineer's Circuit

Inverting Op Amp with Non-Inverting Positive Reference Voltage Circuit

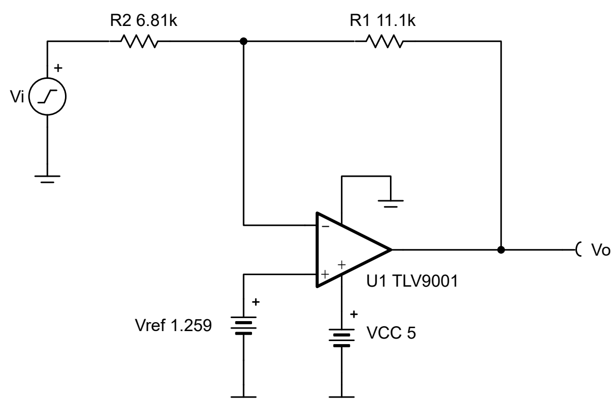
TEXAS INSTRUMENTS

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 kΩ. 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

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

1. Calculate the gain of the input signal.

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

$$V_{o\_max} - V_{o\_min} = \left(V_{i\_max} - V_{i\_min}\right)\left(-\frac{R_1}{R_2}\right)$$

$$-\frac{R_1}{R_2} = -\frac{V_{o\_max} - V_{o\_min}}{V_{i\_max} - V_{i\_min}} = -\frac{4.95V - 0.05V}{2V - (-1\ \ V)} = -1.633\frac{V}{V}$$

2. Select R_2 and calculate R_1.

$$R_2 = 6.81\ \ k\Omega$$

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

3. Calculate the reference voltage.

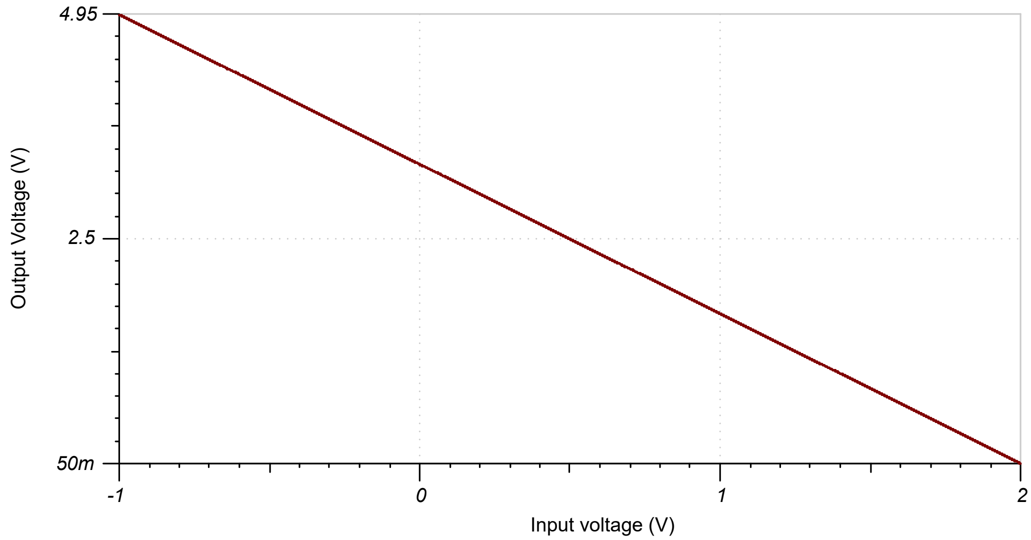
$$V_{o\_min} = -V_{i\_max} \times \left(\frac{R_1}{R_2}\right) + V_{ref} \times \left(1 + \frac{R_1}{R_2}\right)$$

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

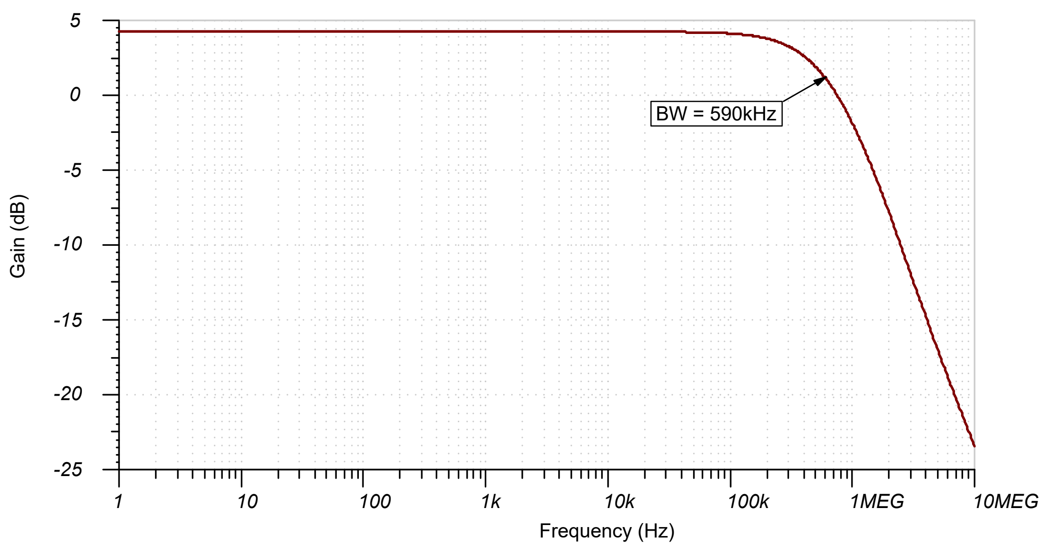
$$V_{ref} = \frac{V_{o\_min} + V_{i\_max} \times \left(\frac{R_1}{R_2}\right)}{\left(1 + \frac{R_1}{R_2}\right)} \frac{0.05V + 2V \times \left(\frac{11.11\ \ k\Omega}{6.81\ \ k\Omega}\right)}{\left(1 + \frac{11.11\ \ k\Omega}{6.81\ \ k\Omega}\right)} = 1.259V$$

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 µA
I_b	5 pA
UGBW	1 MHz
SR	2 V/µs
#Channels	1, 2, and 4
TLV9001	

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 µV
I_q	760 µA
I_b	0.2 pA
UGBW	5.5 MHz
SR	2 V/µs
#Channels	1, 2, and 4
OPA376	

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**

- Downscale the title and changed title role to 'Amplifiers'. Added links to circuit cookbook landing page and SPICE simulation file........ 1

IMPORTANT NOTICE AND DISCLAIMER