Analog Engineer's Circuit

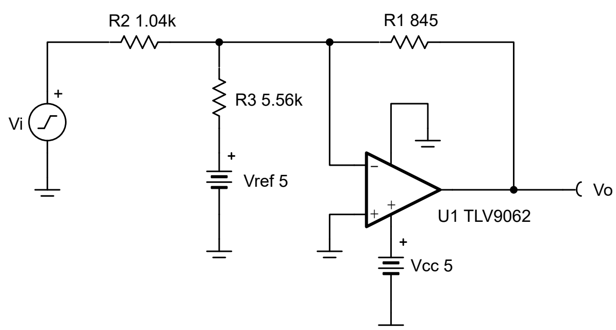
Inverting Op Amp with Inverting Positive Reference Voltage Circuit

Design Goals

Input		Output		Supply		
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}	V_{ref}
–5 V	–1 V	0.05 V	3.3 V	5 V	0 V	5 V

Design Description

This design uses an inverting amplifier with an inverting positive reference to translate an input signal of –5 V to –1 V to an output voltage of 3.3 V to 0.05 V. This circuit can be used to translate a negative sensor output voltage 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. Common mode range must extend down to or below ground.
3. V_{ref} output must be low impedance.
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

$$V_o = -V_i \times \left(\frac{R_1}{R_2}\right) - V_{ref} \times \left(\frac{R_1}{R_3}\right)$$

1. Calculate the gain of the input signal.

$$G_{input} = \frac{V_{o\_max} - V_{o\_min}}{V_{i\_max} - V_{i\_min}} = \frac{3.3V - 0.05V}{-1V - (-5\ \ V)} = 0.8125\frac{V}{V}$$

2. Calculate R_1 and R_2.

$$\text{Choose}\quad R_1 = 845\Omega$$

$$R_2 = \frac{R_1}{G_{input}} = \frac{R_1}{0.8125\frac{V}{V}} = 1.04\ \ k\Omega$$

3. Calculate the gain of the reference voltage required to offset the output.

$$G_{ref} = \frac{R_1}{R_3}$$

$$-V_{i\_min} \times \left(\frac{R_1}{R_2}\right) - V_{ref} \times \left(\frac{R_1}{R_3}\right) = V_{o\_min}$$

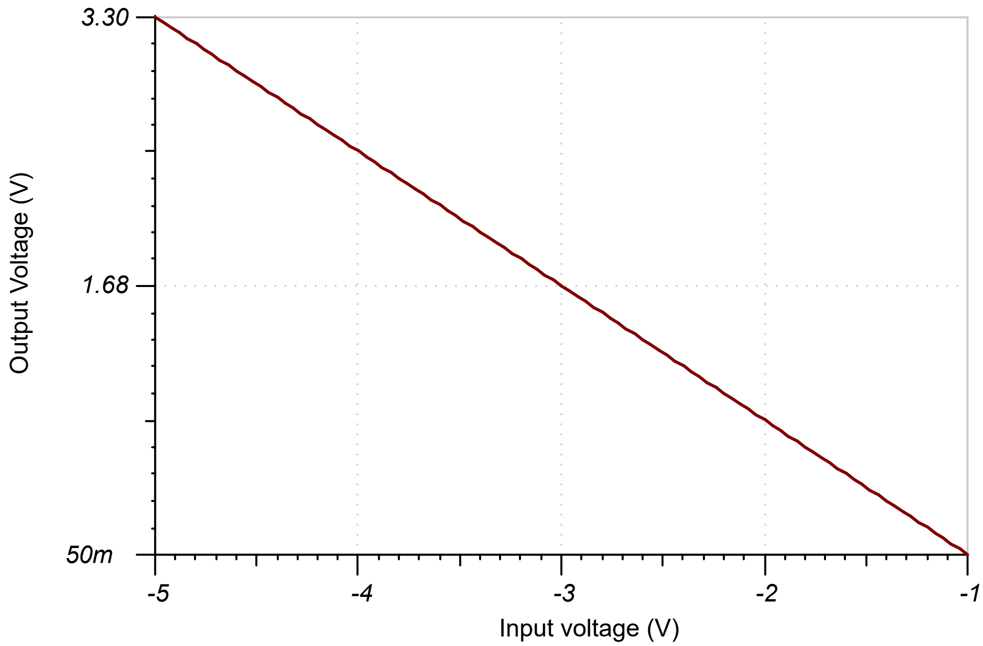
$$\frac{R_1}{R_3} = \frac{V_{o\_min} + V_{i\_min} \times \left(\frac{R_1}{R_2}\right)}{-V_{ref}} = \frac{0.05V + (-1\ \ V)\left(\frac{845\Omega}{1.04k\Omega}\right)}{-5} = 0.1525\frac{V}{V}$$

4. Calculate R_3.

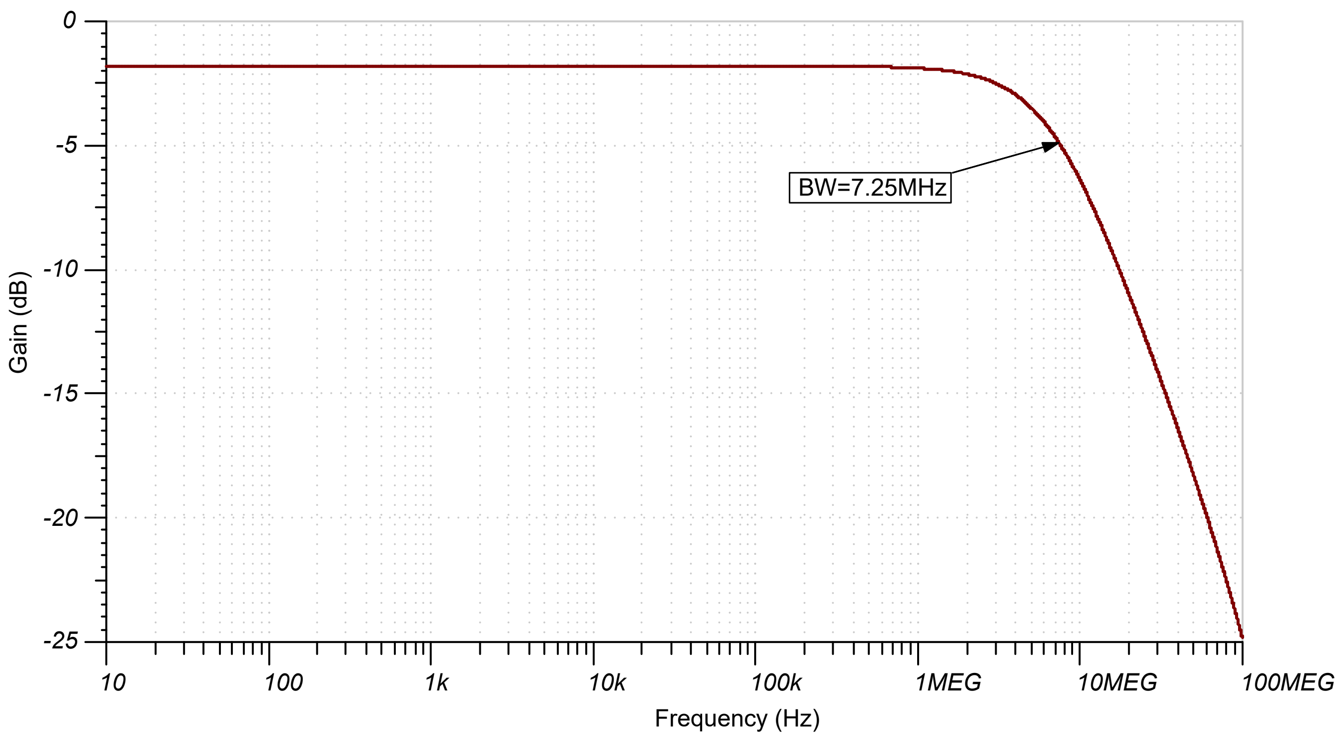
$$R_3 = \frac{R_1}{G_{ref}} = \frac{845\Omega}{0.1525\frac{V}{V}} = 5.54\ \ k\Omega \approx 5.56\ \ k\Omega$$

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 SBOC511.

See *Designing Gain and Offset in Thirty Seconds*.

Design Featured Op Amp

TLV9062	
V_{ss}	1.8 V to 5.5 V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	0.3 mV
I_q	538 µA
I_b	0.5 pA
UGBW	10 MHz
SR	6.5 V/µs
#Channels	1, 2, and 4
TLV9062	

Design Alternate Op Amp

OPA197	
V_{ss}	4.5 V to 36 V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	25 µV
I_q	1 mA
I_b	5 pA
UGBW	10 MHz
SR	20 V/µs
#Channels	1, 2, and 4
OPA197	

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