Analog Engineer's Circuit

Inverting attenuator circuit

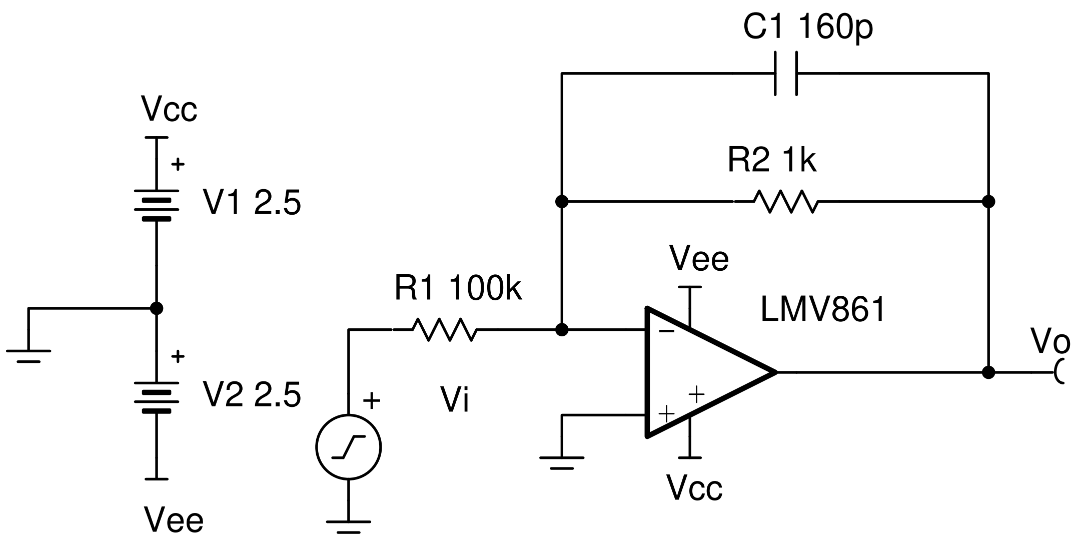
Amplifiers

Design Goals

Input		Output		BW	Gain	Supply	
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	f_p	G	V_{cc}	V_{ee}
–200V	200V	–2V	2V	1MHz	–40dB	2.5V	–2.5V

Design Description

This circuit inverts the input signal, V_i, and applies a signal gain of –40dB. The common-mode voltage of an inverting amplifier is equal to the voltage applied to the non-inverting input, which is ground in this design.



Design Notes

1. The common-mode voltage in this circuit does not vary with input voltage.
2. The input impedance is determined by the input resistor. Make sure this value is large when compared to the output impedance of the source.
3. Using high-value resistors can degrade the phase margin of the circuit and introduce additional noise in the circuit. The capacitor in parallel with R_2 provides filtering and improves stability of the circuit if high-value resistors are used for both the input and feedback resistances.
4. Avoid placing capacitive loads directly on the output of the amplifier to minimize stability issues.
5. Small-signal bandwidth is determined by the noise gain (or non-inverting gain) and op amp gain-bandwidth product (GBP).
6. 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.
7. For more information on op amp linear operating region, stability, slew-induced distortion, capacitive load drive, driving ADCs, and bandwidth see the *Design References* section.
8. Note that higher input voltage levels may require the use of multiple resistors in series to help reduce the voltage drop across the individual resistors. For more information, see the *Design References* section.

Design Steps

The transfer function of this circuit follows:

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

1. Calculate the gain required for the circuit.

$$G = \frac{V_{oMax} - V_{oMin}}{V_{iMax} - V_{iMin}} = \frac{2V - (-2V)}{200V - (-200V)} = 0.01 \frac{V}{V} = -40dB$$

2. Choose the starting value of R_1.

$$R_1 = 100k\Omega$$

3. Calculate for a desired signal attenuation of 0.01 V/V.

$$G = \frac{R_2}{R_1} \rightarrow R_2 = R_1 \times G = 0.01 \frac{V}{V} \times 100k\Omega = 1k\Omega$$

4. Select the feedback capacitor, C_1, to meet the circuit bandwidth.

$$C_1 \le \frac{1}{2\pi \times R_2 \times f_p} \rightarrow C_1 \le \frac{1}{2\pi \times 1k\Omega \times 1MHz} \le 159.15pF \approx 160pF \text{ (Standard Value)}$$

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

$$V_p < \frac{SR}{2\pi \times f_p} \rightarrow SR > 2\pi \times f \times V_p \rightarrow SR > 2\pi \times 1\ MHz \times 2\ V = 12.6 \frac{V}{\mu S}$$

   - SR_{LMV861} = 18V/µs; therefore, it meets this requirement.

6. Calculate the circuit bandwidth to ensure it meets the 1-MHz requirement. Be sure to use the noise gain, NG, or non-inverting gain, of the circuit.

$$NG = 1 + \frac{R_2}{R_1} = 1.01 \frac{V}{V} \rightarrow BW = \frac{GBP}{NG} = \frac{30MHz}{1.01 \frac{V}{V}} = 29.7MHz$$

   - BW_{LMV861} = 30MHz; therefore, it meets this requirement.

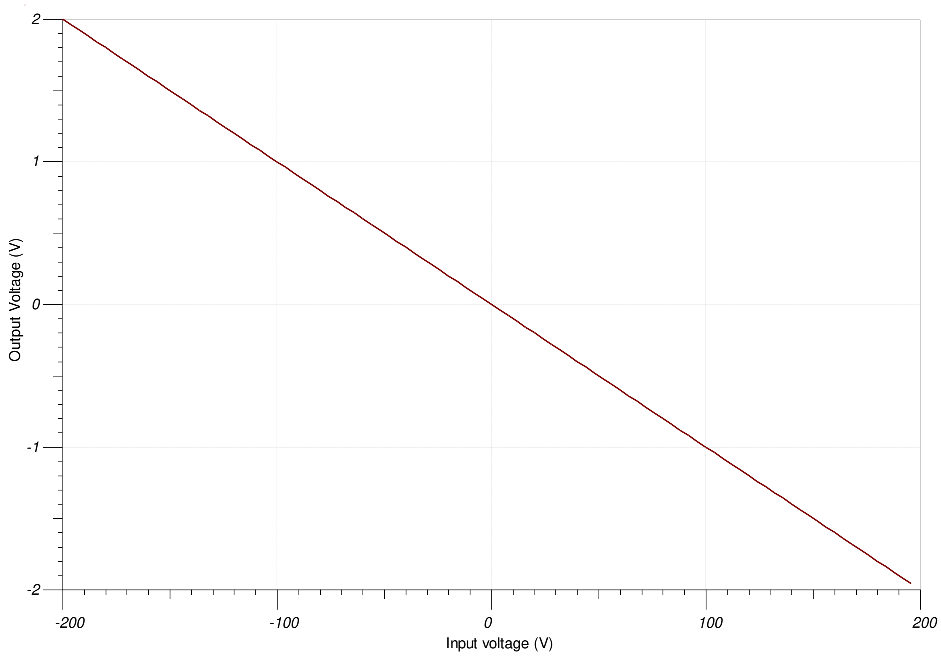
7. If C_1 is not used to limit the circuit bandwidth, to avoid stability issues ensure that the zero created by the gain setting resistors and input capacitance of the device is greater than the bandwidth of the circuit.

$$\frac{1}{2\pi \times (C_{cm} + C_{diff}) \times (R_2 \parallel R_1)} > \frac{GBP_{LMV861}}{NG}$$

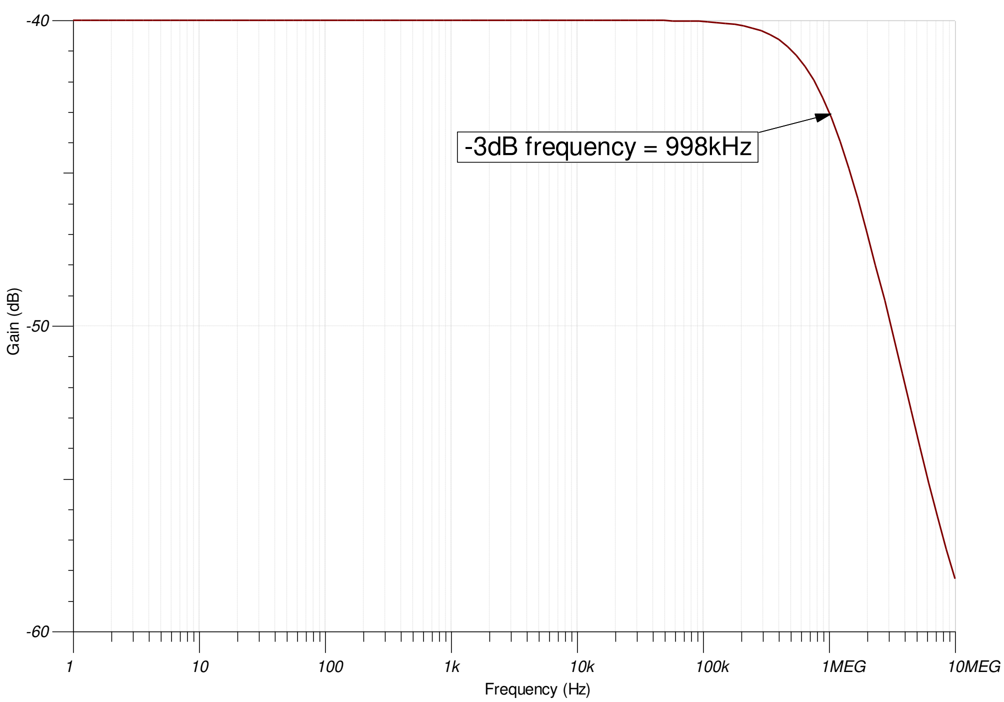
   - C_{cm} and C_{diff} are the common-mode and differential input capacitance of the LMV861, respectively.

Design Simulations

DC Simulation Results

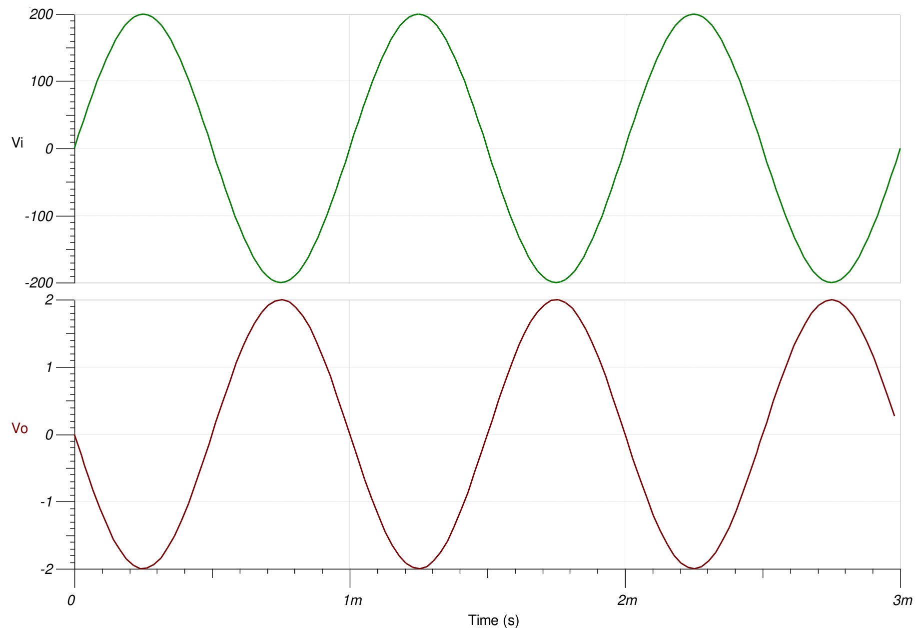


AC Simulation Results



Transient Simulation Results

A 1-kHz, 400-Vpp input sine wave yields a 4-Vpp output sine wave.



Design References

1. See *Analog Engineer's Circuit Cookbooks* for the comprehensive TI circuit library.
2. SPICE Simulation File SBOC522.
3. TI Precision Labs
4. For more information on circuits with larger input voltages, see *Considerations for High-Voltage Measurements*.

Design Featured Op Amp

LMV861	
V_{ss}	2.7V to 5.5V
V_{inCM}	(Vee – 0.1V) to (Vcc – 1.1V)
V_{out}	Rail-to-rail
V_{os}	0.273mV
I_q	2.25mA
I_b	0.1pA
UGBW	30MHz
SR	18V/µs
#Channels	1, 2
www.ti.com/product/LMV861	

Design Alternate Op Amp

	TLV9002	OPA377
V_{ss}	1.8V to 5.5V	2.2V to 5.5V
V_{inCM}	Rail-to-rail	Rail-to-rail
V_{out}	Rail-to-rail	Rail-to-rail
V_{os}	0.4mV	0.25mV
I_q	0.06mA	0.76mA
I_b	5pA	0.2pA
UGBW	1MHz	5.5MHz
SR	2V/µs	2V/µs
#Channels	1, 2, 4	1, 2, 4
	www.ti.com/product/TLV9002	www.ti.com/product/OPA377