

Single-supply, 2nd-order, Sallen-Key band-pass filter circuit



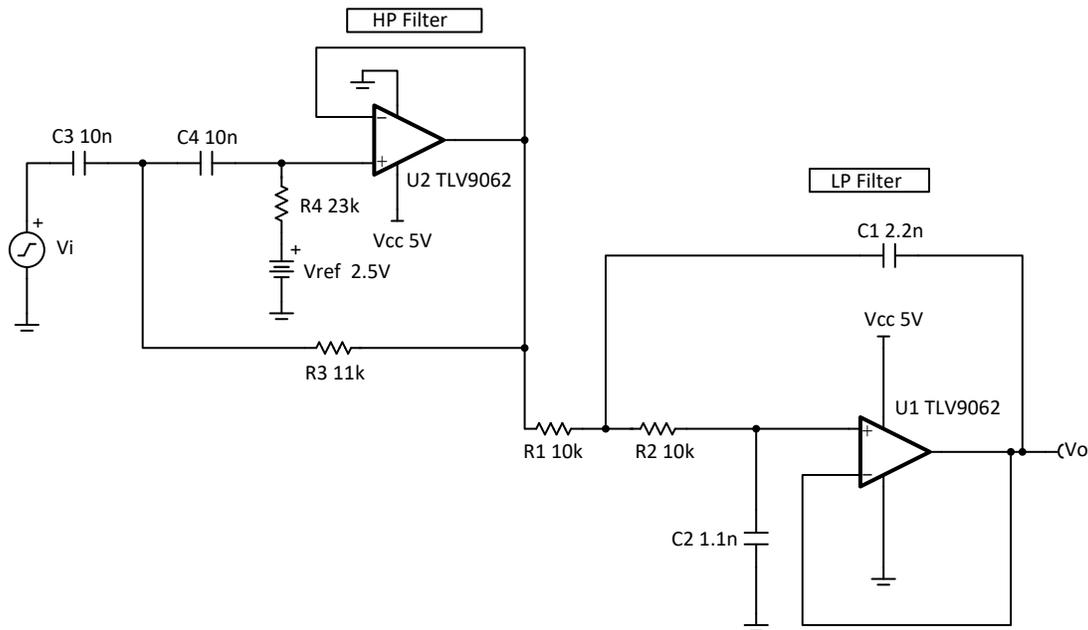
Amplifiers

| Input | | Output | | Supply | |
|------------|------------|------------|------------|----------|----------|
| V_{iMin} | V_{iMax} | V_{oMin} | V_{oMax} | V_{cc} | V_{ee} |
| -2.45V | +2.45V | 0.05V | 4.95V | 5V | 0V |

| Gain | Low Cutoff Frequency (f_l) | High Cutoff Frequency (f_h) | V_{ref} |
|------|--------------------------------|---------------------------------|-----------|
| 1V/V | 1kHz | 10kHz | 2.5V |

Design Description

This circuit is a single-supply, 2nd-order Sallen-Key (SK) band-pass (BP) filter. It is designed by cascading an SK low-pass filter and an SK high-pass filter. V_{ref} provides a DC offset to accommodate for a single supply.



Design Notes

1. Select an op amp with sufficient input common-mode range and output voltage swing.
2. Add V_{ref} to bias the input signal to meet the input common-mode range and output voltage swing.
3. Select the capacitor values first since standard capacitor values are more coarsely subdivided than the resistor values. Use high-precision, low-drift capacitor values to avoid errors in f_l and f_h .
4. To minimize the amount of slew-induced distortion, select an op amp with sufficient slew rate (SR).
5. For HP filters, the maximum frequency is set by the gain bandwidth (GBW) of the op amp. Therefore, be sure to select an op amp with sufficient GBW.

Design Steps

This BP filter design involves two cascaded filters, a low-pass (LP) filter and a high-pass (HP) filter. The lower cutoff frequency (f_l) of the BP filter is 1kHz and the higher cutoff frequency (f_h) is 10kHz. The design steps show an LP filter design with f_h of 10kHz and an HP filter design with f_l of 1kHz. See the SK LP filter design and SK HP filter design in the circuit cookbook for details on transfer function equations and calculations.

LP Filter Design

1. Use [SK low-pass filter design](#) to determine R_1 and R_2 .

$$R_1 = 10\text{k}\Omega,$$

$$R_2 = 10\text{k}\Omega$$

2. Use [SK low-pass filter design](#) to determine C_1 and C_2 .

$$C_1 = 2.2\text{nF} \text{ (Standard Value)},$$

$$C_2 = 1.1\text{nF} \text{ (Standard Value)}$$

HP Filter Design

1. Use [SK high-pass filter design](#) to determine C_3 and C_4 .

$$C_3 = 10\text{nF},$$

$$C_4 = 10\text{nF}$$

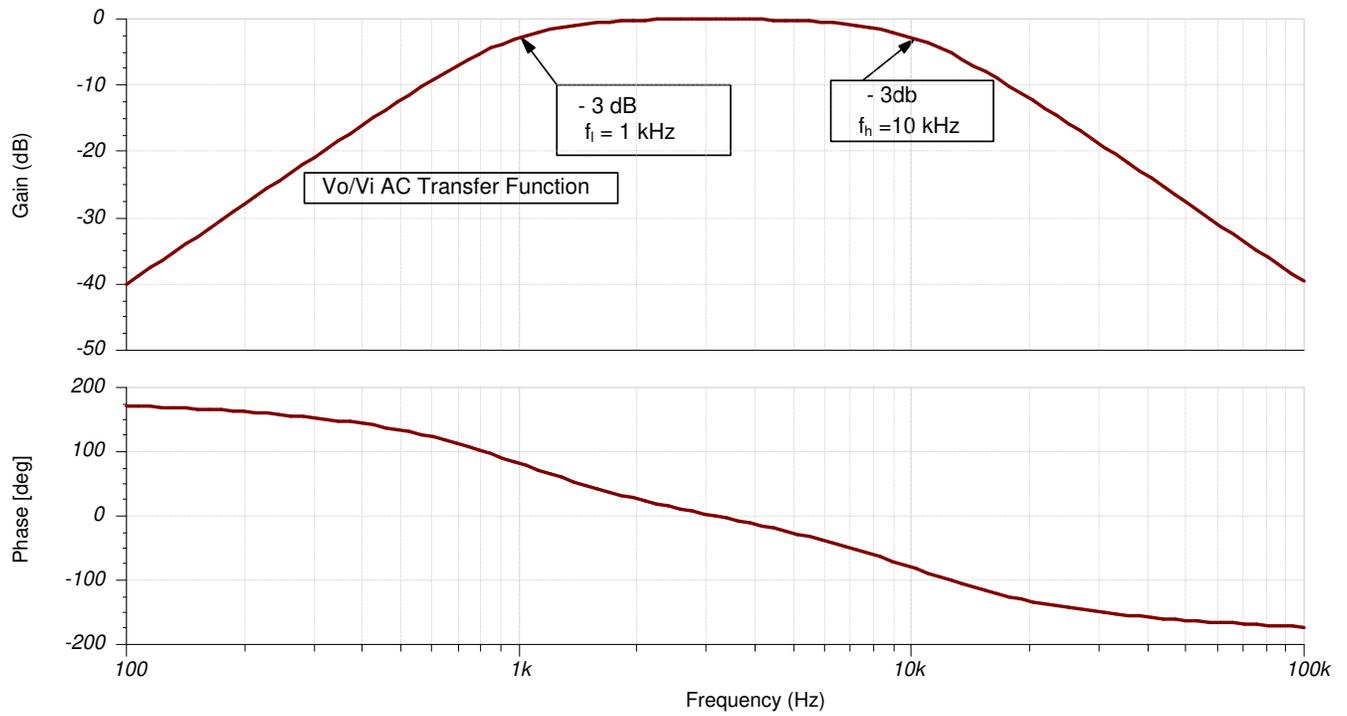
2. Use [SK high-pass filter design](#) to determine R_3 and R_4 .

$$R_3 = 11\text{k}\Omega,$$

$$R_4 = 23\text{k}\Omega$$

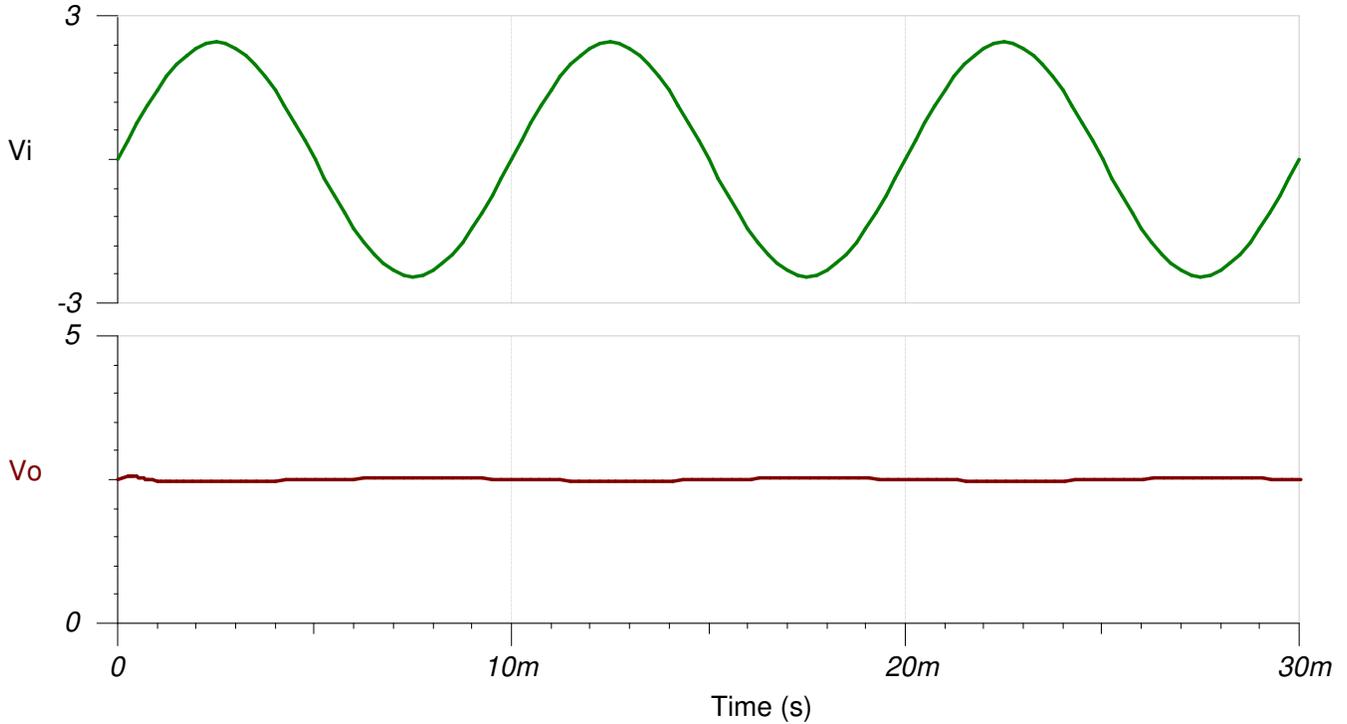
Design Simulations

AC Simulation Results

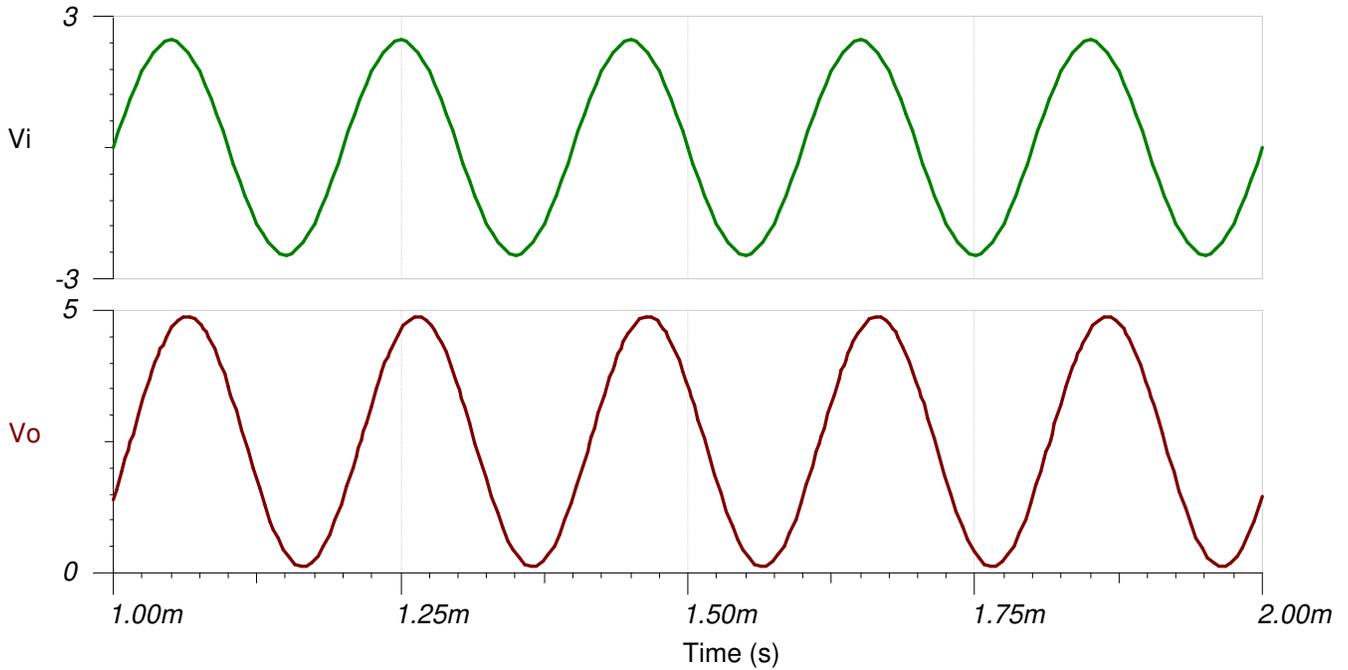


Transient Simulation Results

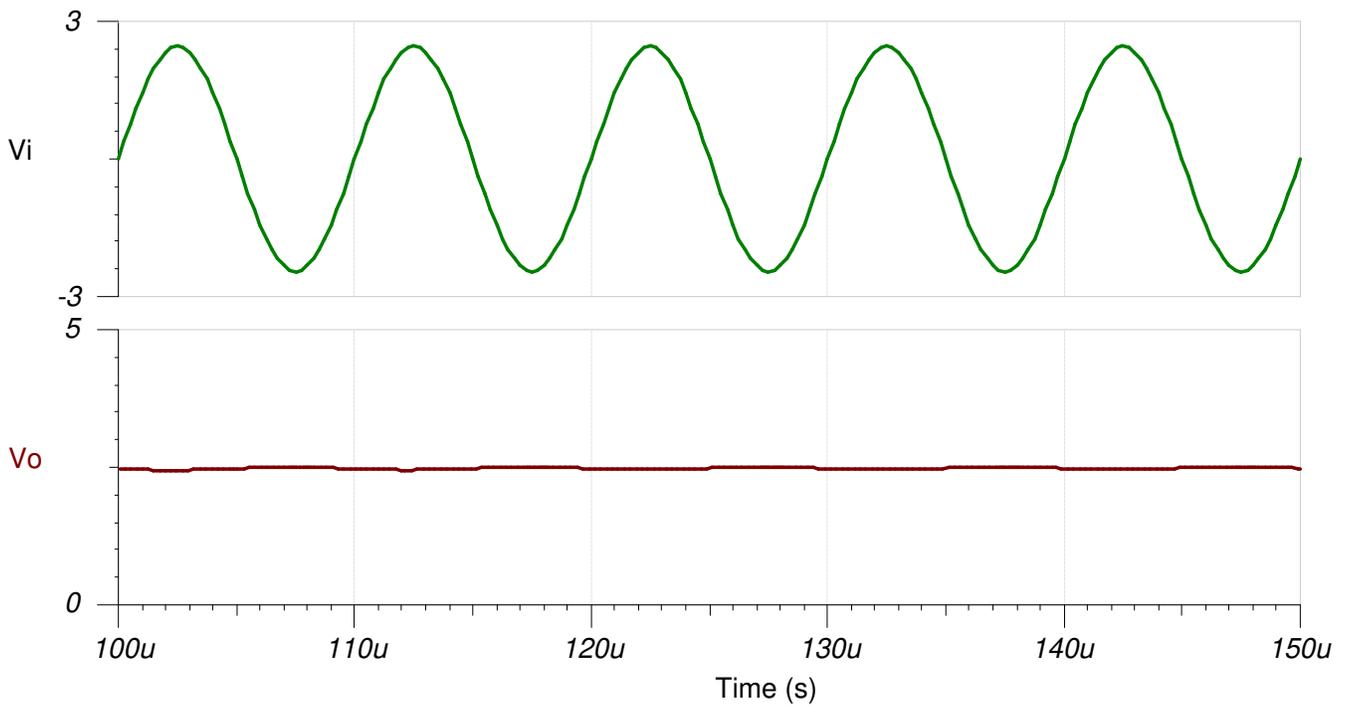
The following image shows a filter output in response to a 5-V_{pp}, 100-Hz input signal (gain = 0.01 V/V).



The following transient simulation result shows a filter output in response to a 5- V_{pp} , 5-kHz input signal (gain = 1V/V).



The following image shows a filter output in response to a 5- V_{pp} , 100-kHz input signal (gain = 0.01V/V).



Design References

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

Design Featured Op Amp

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

Design Alternate Op Amp

| | TLV316 | OPA325 |
|-------------------------|--|--|
| 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} | 0.75mV | 0.150mV |
| I_q | 400μA | 650μA |
| I_b | 10pA | 0.2pA |
| UGBW | 10MHz | 10MHz |
| SR | 6V/μs | 5V/μs |
| #Channels | 1, 2, 4 | 1, 2, 4 |
| | www.ti.com/product/TLV316 | www.ti.com/product/OPA325 |

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