Analog Engineer's Circuit

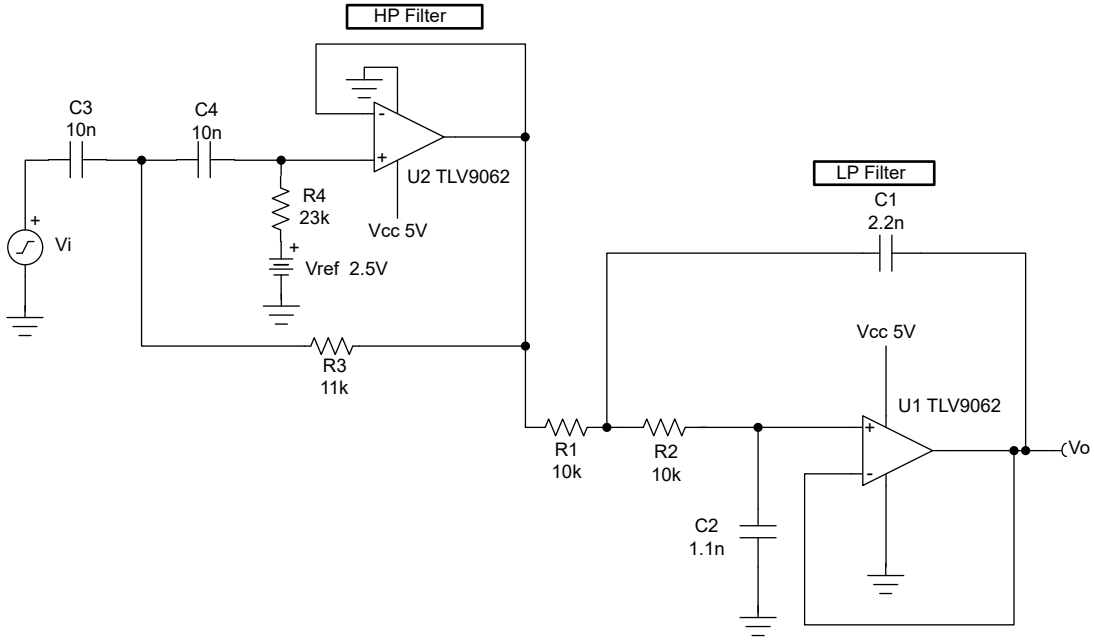
Single-Supply, 2nd-Order, Sallen-Key Band-Pass Filter Circuit

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. Vref 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.

   $R_1 = 10k\Omega$,
   $R_2 = 10k\Omega$

2. Use SK low-pass filter design to determine C_1 and C_2.

   $C_1 = 2.2nF$ (Standard Value),
   $C_2 = 1.1nF$ (Standard Value)

HP Filter Design

1. Use SK high-pass filter design to determine C_3 and C_4.

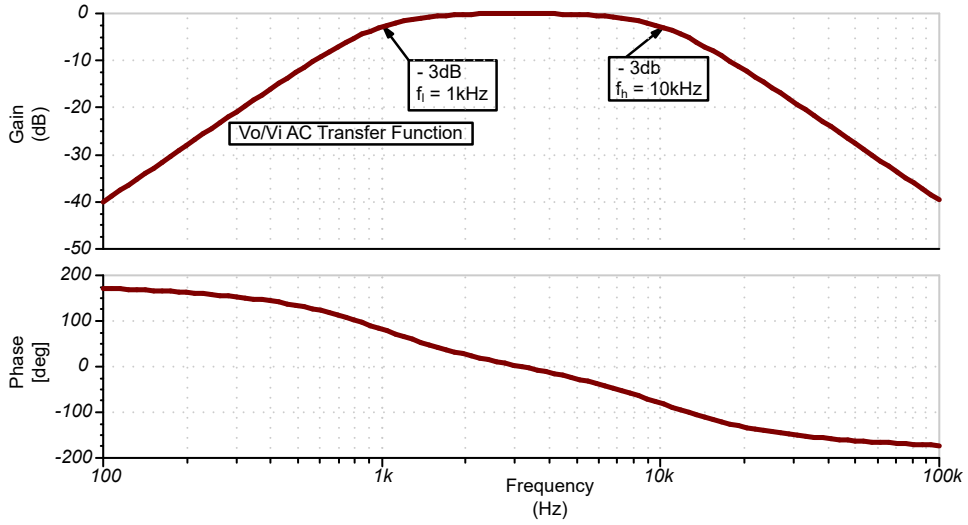
   $C_3 = 10nF$,
   $C_4 = 10nF$

2. Use SK high-pass filter design to determine R_3 and R_4.

   $R_3 = 11k\Omega$,
   $R_4 = 23k\Omega$

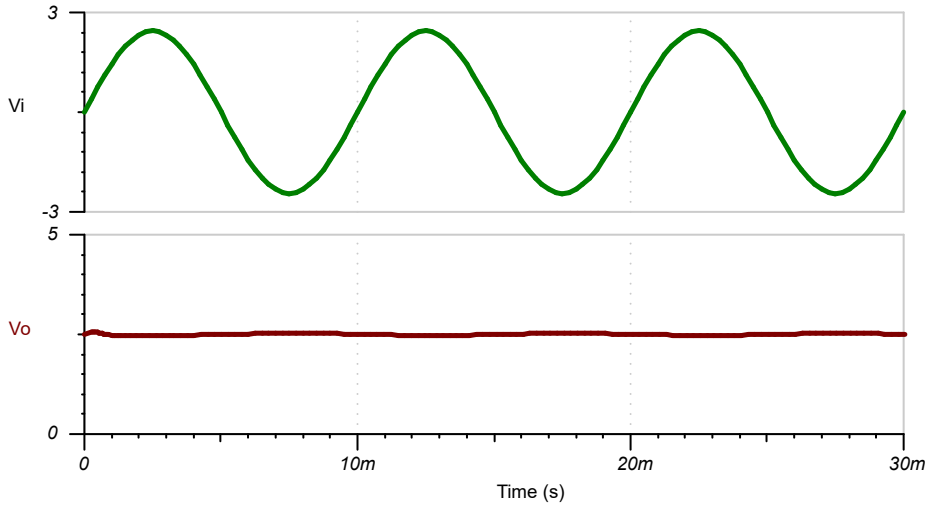
Design Simulations

AC Simulation Results

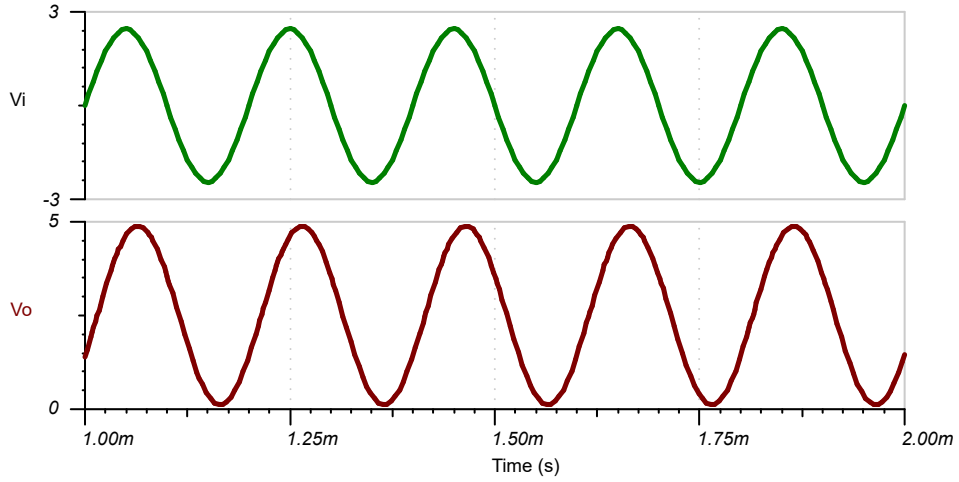


Transient Simulation Results

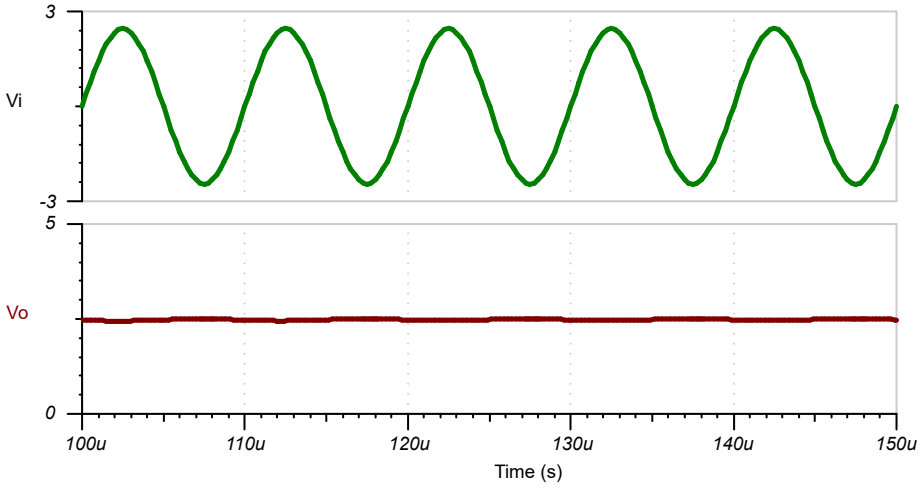
The following image shows a filter output in response to a $5V_{pp}$, 100Hz input signal (gain = 0.01V/V).



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



The following image shows a filter output in response to a $5V_{pp}$, 100kHz 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
3. SPICE Simulation File

Design Featured Op Amp

TLV9062	
Vss	1.8V to 5.5V
V_{inCM}	Rail-to-Rail
Vout	Rail-to-Rail
Vos	0.3mV
Iq	538µA
Ib	0.5pA
UGBW	10MHz
SR	6.5V/µs
# of Channels	1, 2, 4
www.ti.com/product/TLV9062	

Design Alternate Op Amp

	Parametric Search
V_{ss}	5V
V_{inCM}	Rail-to-Rail
Vout	Rail-to-Rail
UGBW	1MHz
SR	> 5V/µS
# of Channels	2
	www.ti.com/parametricsearch

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