

# Low Noise, Fast, Quad Universal Filter Building Block

## FEATURES

- **Four Filters in a 0.3-Inch Wide Package**
- One Half the Noise of the LTC1059/LTC1060/ LTC1061 Devices
- **Maximum Center Frequency: 140kHz**
- Maximum Clock Frequency: 7MHz
- Clock-to-Center Frequency Ratio of 50:1 and 100:1 Simultaneously Available
- Power Supplies:  $\pm 2.375V$  to  $\pm 8V$
- Low Offsets
- Low Harmonic Distortion
- **Customized Version with Internal Resistors Available**

## APPLICATIONS

- Anti-Aliasing Filters
- Wide Frequency Range Tracking Filters
- Spectral Analysis
- Loop Filters

## DESCRIPTION

The LTC<sup>®</sup>1064 consists of four high speed, low noise switched-capacitor filter building blocks. Each filter building block, together with an external clock and three to five resistors, can provide various 2nd order functions like lowpass, highpass, bandpass and notch. The center frequency of each 2nd order function can be tuned with an external clock, or a clock and resistor ratio. For  $Q \leq 5$ , the center frequency range is from 0.1Hz to 100kHz. For  $Q \leq 3$ , the center frequency range can be extended to 140kHz. Up to 8th order filters can be realized by cascading all four 2nd order sections. Any classical filter realization (such as Butterworth, Cauer, Bessel and Chebyshev) can be formed.

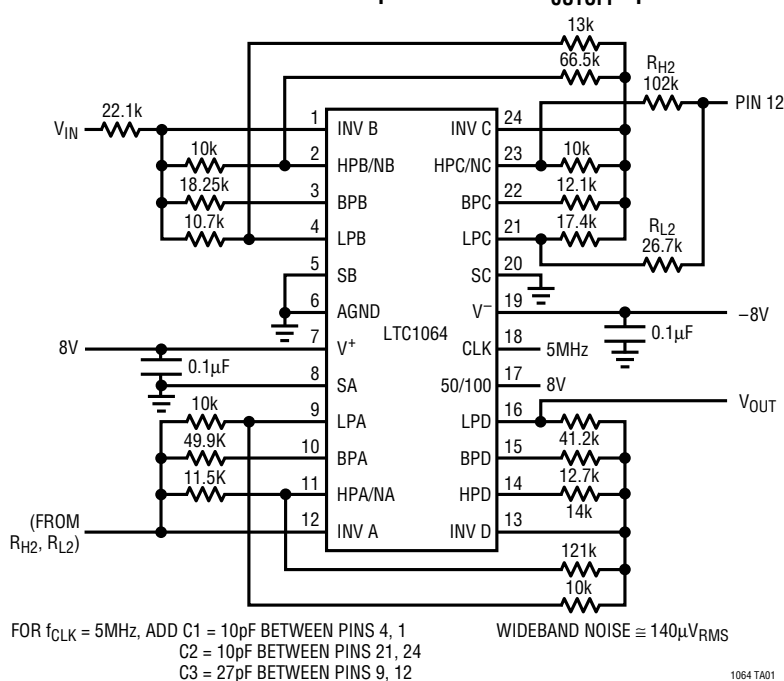
A customized monolithic version of the LTC1064 including internal thin film resistors can be obtained for high volume applications. Consult LTC Marketing for details.

The LTC1064 is manufactured using Linear Technology's enhanced LTCMOS<sup>™</sup> silicon gate process.

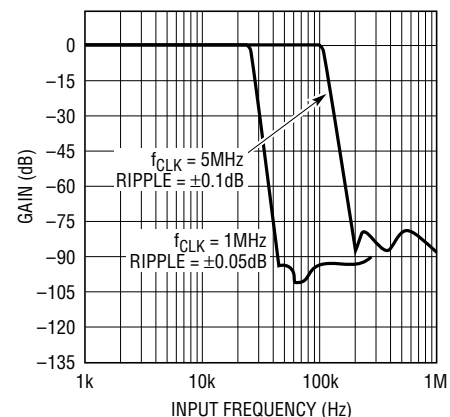
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 LTCMOS is a trademark of Linear Technology Corporation.

## TYPICAL APPLICATION

**Clock-Tunable 8th Order Cauer Lowpass Filter with  $f_{CUTOFF}$  up to 100kHz**



**Gain vs Frequency**



1064 TA02

# LTC1064

## ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage ( $V^+$ to $V^-$ )	16V	Storage Temperature Range	-65°C to 150°C
Power Dissipation	500mW	Lead Temperature (Soldering, 10 sec)	300°C
Operating Temperature Range			
LTC1064AC/LTC1064C	-40°C to 85°C		
LTC1064AM/LTC1064M	-55°C to 125°C		

## PACKAGE/ORDER INFORMATION

TOP VIEW	ORDER PART NUMBER	TOP VIEW	ORDER PART NUMBER
<p>J PACKAGE 24-LEAD CERAMIC DIP</p> <p>N PACKAGE 24-LEAD PLASTIC DIP</p> <p><math>T_{JMAX} = 150^{\circ}C</math>, <math>\theta_{JA} = 100^{\circ}C/W</math> (J) <math>T_{JMAX} = 110^{\circ}C</math>, <math>\theta_{JA} = 65^{\circ}C/W</math> (N)</p>	LTC1064ACJ LTC1064CJ LTC1064AMJ LTC1064MJ LTC1064ACN LTC1064CN	<p>SW PACKAGE 24-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 100^{\circ}C</math>, <math>\theta_{JA} = 85^{\circ}C/W</math></p>	LTC1064CS

Consult factory for Industrial grade parts.

## ELECTRICAL CHARACTERISTICS

(Internal Op Amps)  $T_A = 25^{\circ}C$ , unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage Range		$\pm 2.375$		$\pm 8$	V
Voltage Swings	$V_S = \pm 5V$ , $R_L = 5k$	$\pm 3.2$ $\pm 3.1$	$\pm 3.6$		V V
Output Short-Circuit Current (Source/Sink)	$V_S = \pm 5V$		3		mA
DC Open-Loop Gain	$V_S = \pm 5V$ , $R_L = 5k$		80		dB
GBW Product	$V_S = \pm 5V$		7		MHz
Slew Rate	$V_S = \pm 5V$		10		V/ $\mu s$

# ELECTRICAL CHARACTERISTICS

(Complete Filter)  $V_S = \pm 5V$ ,  $T_A = 25^\circ C$ , TTL clock input level, unless otherwise specified.

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
Center Frequency Range, $f_0$		$V_S = \pm 8V$ , $Q \leq 3$		0.1 to 140		kHz
Input Frequency Range				0 to 1		MHz
Clock-to-Center Frequency Ratio, $f_{CLK}/f_0$	LTC1064 LTC1064A (Note 1)	$f_{CLK} = 1MHz$ , $f_0 = 20kHz$ , Pin 17 High Sides A, B, C: Mode 1, $R1 = R3 = 5k$ , $R2 = 5k$ , $Q = 10$ , Sides D: Mode 3, $R1 = R3 = 50k$ $R2 = R4 = 5k$	●	$50 \pm 0.3$	$50 \pm 0.8$	%
					$50 \pm 0.9$	%
	LTC1064 LTC1064A (Note 1)	Same as Above, Pin 17 Low, $f_{CLK} = 1MHz$ $f_0 = 10kHz$ Sides A, B, C Side D	●	$100 \pm 0.3$	$100 \pm 0.8$	%
					$100 \pm 0.9$	%
Clock-to-Center Frequency Ratio, Side-to-Side Matching	LTC1064 LTC1064A (Note 1)	$f_{CLK} = 1MHz$	●	0.4	1	%
						%
Clock-to-Center Frequency Ratio, $f_{CLK}/f_0$ (Note 2)	LTC1064 LTC1064A (Note 1)	$f_{CLK} = 4MHz$ , $f_0 = 80kHz$ , Pin 17 High Sides A, B, C: Mode 1, $V_S = \pm 7.5V$ $R1 = R3 = 50k$ , $R2 = 5k$ , $Q = 5$ Side D: Mode 3, $R1 = R3 = 50k$ $R2 = R4 = 5k$ , $f_{CLK} = 4MHz$		$50 \pm 0.6$	$50 \pm 1.3$	%
						%
Q Accuracy		Sides A, B, C: Mode 1, $Q = 10$ Side D: Mode 3, $f_{CLK} = 1MHz$	●	$\pm 2$	6	%
				$\pm 3$	8	%
$f_0$ Temperature Coefficient		Mode 1, 50:1, $f_{CLK} < 2MHz$		$\pm 1$		ppm/ $^\circ C$
Q Temperature Coefficient		Mode 1, 100:1, $f_{CLK} < 2MHz$ Mode 3, $f_{CLK} < 2MHz$		$\pm 5$		ppm/ $^\circ C$
				$\pm 5$		ppm/ $^\circ C$
DC Offset Voltage	$V_{OS1}$ (Table 1)	$f_{CLK} = 1MHz$ , 50:1 or 100:1	●	2	15	mV
	$V_{OS2}$ (Table 1)	$f_{CLK} = 1MHz$ , 50:1 or 100:1	●	3	45	mV
	$V_{OS3}$ (Table 1)	$f_{CLK} = 1MHz$ , 50:1 or 100:1	●	3	45	mV
Clock Feedthrough		$f_{CLK} < 1MHz$		0.2		mV <sub>RMS</sub>
Maximum Clock Frequency		Mode 1, $Q < 5$ , $V_S \geq \pm 5V$		7		MHz
Power Supply Current			●	9	12	mA
					23 26	mA

The ● denotes specifications which apply over the full operating temperature range.

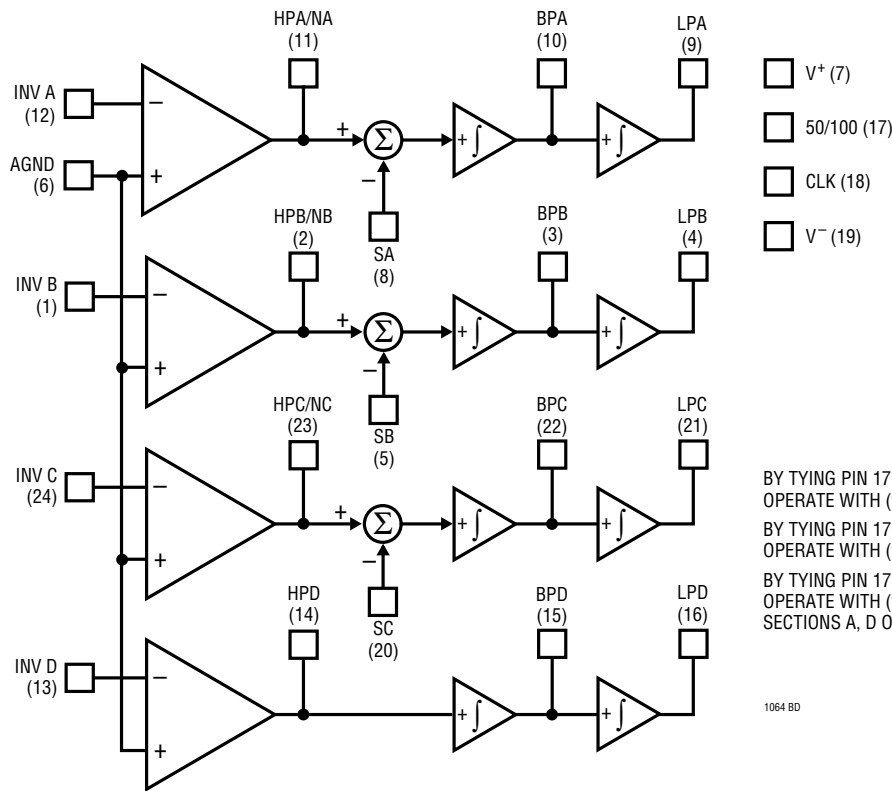
**Note 1:** Contact LTC Marketing.

**Note 2:** Not tested, guaranteed by Design.

**Table 1. Output DC Offsets, One 2nd Order Section**

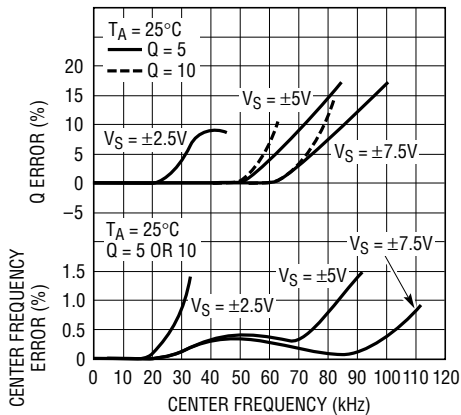
MODE	$V_{OSN}$ PINS 2, 11, 14, 23	$V_{OSBP}$ PINS 3, 10, 15, 22	$V_{OSLP}$ PINS 4, 9, 16, 21
1	$V_{OS1} [(1/Q) + 1 +   H_{OLP}  ] - V_{OS3}/Q$	$V_{OS3}$	$V_{OSN} - V_{OS2}$
1b	$V_{OS1} [(1/Q) + 1 + (R2/R1)] - V_{OS3}/Q$	$V_{OS3}$	$\sim (V_{OSN} - V_{OS2})[1 + (R5/R6)]$
2	$V_{OS1} [(1 + (R2/R1) + (R2/R3) + (R2/R4) - V_{OS3}(R2/R3)) \times [R4/(R2 + R4)] + V_{OS2}[R2/(R2 + R4)]$	$V_{OS3}$	$V_{OSN} - V_{OS2}$
3	$V_{OS2}$	$V_{OS3}$	$V_{OS1}[1 + (R4/R1) + (R4/R2) + (R4/R3)] - V_{OS2}(R4/R2) - V_{OS3}(R4/R3)$

## BLOCK DIAGRAM

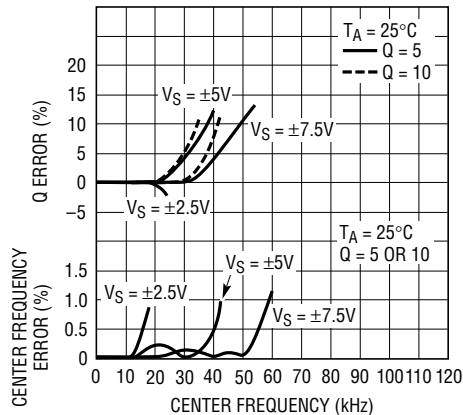


## TYPICAL PERFORMANCE CHARACTERISTICS

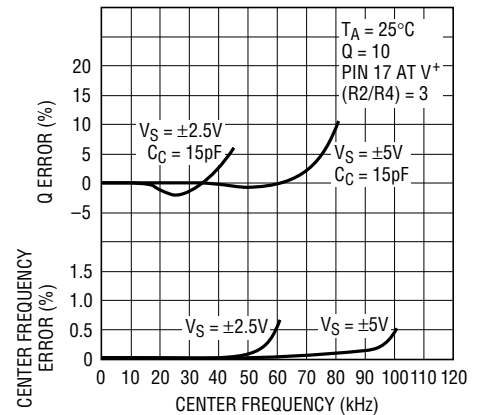
Mode 1,  $(f_{CLK}/f_0) = 50:1$



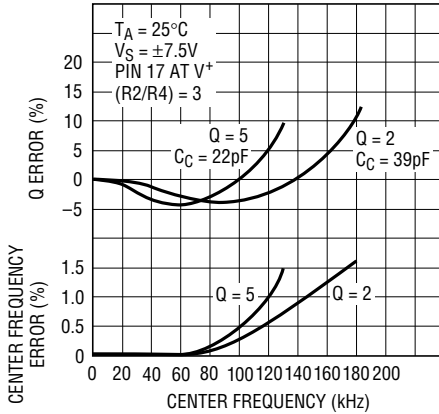
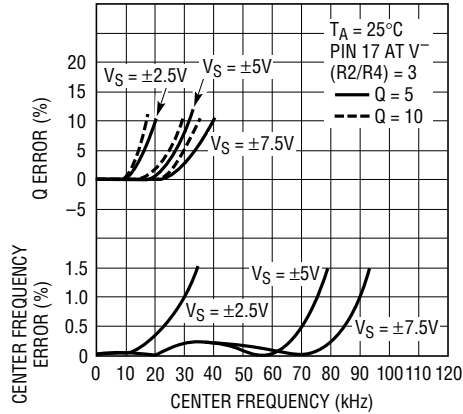
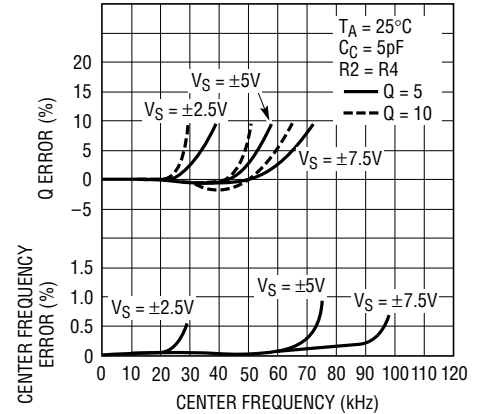
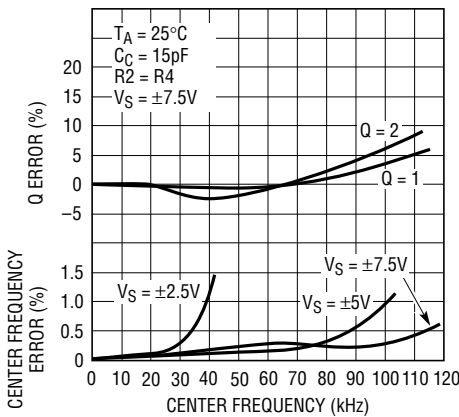
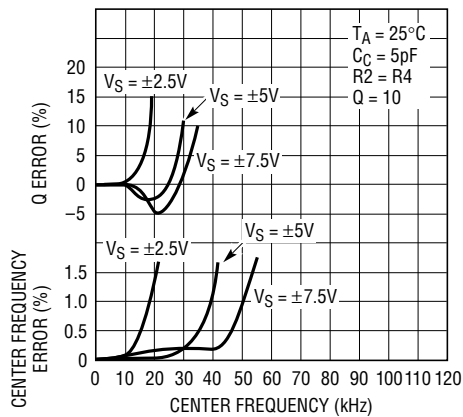
Mode 1,  $(f_{CLK}/f_0) = 100:1$



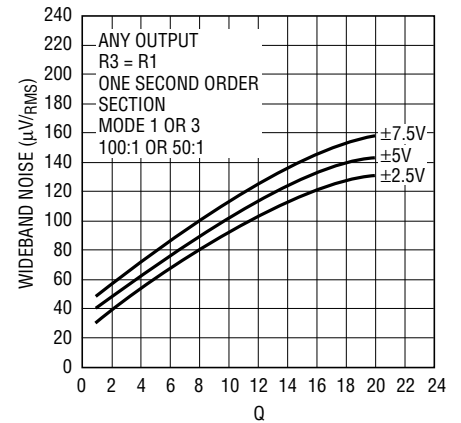
Mode 2,  $(f_{CLK}/f_0) = 25:1$



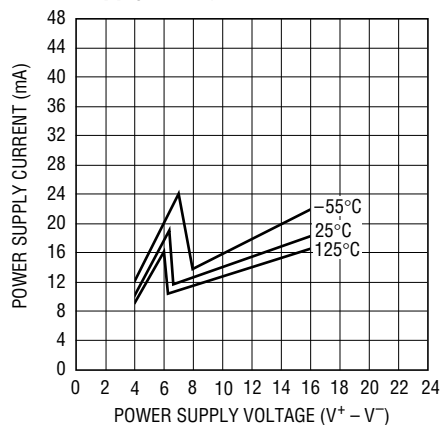
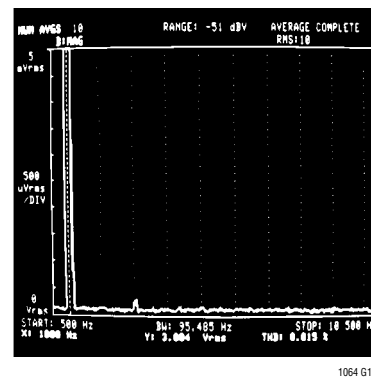
## TYPICAL PERFORMANCE CHARACTERISTICS

Mode 2, ( $f_{CLK}/f_0$ ) = 25:1Mode 2, ( $f_{CLK}/f_0$ ) = 50:1Mode 3, ( $f_{CLK}/f_0$ ) = 50:1Mode 3, ( $f_{CLK}/f_0$ ) = 50:1Mode 3, ( $f_{CLK}/f_0$ ) = 100:1

Wideband Noise vs Q



Power Supply Current vs Supply Voltage

Harmonic Distortion, 8th Order  
LP Butterworth,  $f_c = 20\text{kHz}$ ,  
THD = 0.015% for  $3V_{RMS}$  Input

## PIN FUNCTIONS

**V<sup>+</sup>, V<sup>-</sup> (Pins 7, 19):** Power Supplies. They should be bypassed with a 0.1 $\mu$ F ceramic capacitor. Low noise, nonswitching power supplies are recommended. The device operates with a single 5V supply and with dual supplies. The absolute maximum operating power supply voltage is  $\pm 8$ V.

**CLK (Pin 18):** Clock. For  $\pm 5$ V supplies the logic threshold level is 1.4V. For  $\pm 8$ V and 0V to 5V supplies the logic threshold levels are 2.2V and 3V respectively. The logic threshold levels vary  $\pm 100$ mV over the full military temperature range. The recommended duty cycle of the input clock is 50%, although for clock frequencies below 500kHz, the clock “on” time can be as low as 200ns. The maximum clock frequency for  $\pm 5$ V supplies is 4MHz. For  $\pm 7$ V supplies and above, the maximum clock frequency is 7MHz.

**AGND (Pin 6):** Analog Ground. When the LTC1064 operates with dual supplies, Pin 6 should be tied to system ground. When the LTC1064 operates with a single positive supply, the analog ground pin should be tied to 1/2 supply and it should be bypassed with a 1 $\mu$ F solid tantalum in parallel with a 0.1 $\mu$ F ceramic capacitor, Figure 1. The positive input of all the internal op amps, as well as the common reference of all the internal switches, are internally tied to the analog ground pin. Because of this, a very “clean” ground is recommended.

**50/100 (Pin 17):** By tying Pin 17 to V<sup>+</sup>, all filter sections operate with a clock-to-center frequency ratio internally set at 50:1. When Pin 17 is at mid-supplies, sections B and C operate with  $(f_{CLK}/f_0) = 50:1$  and sections A and D operate at 100:1. When Pin 17 is shorted to the negative supply pin, all filter sections operate with  $(f_{CLK}/f_0) = 100:1$ .

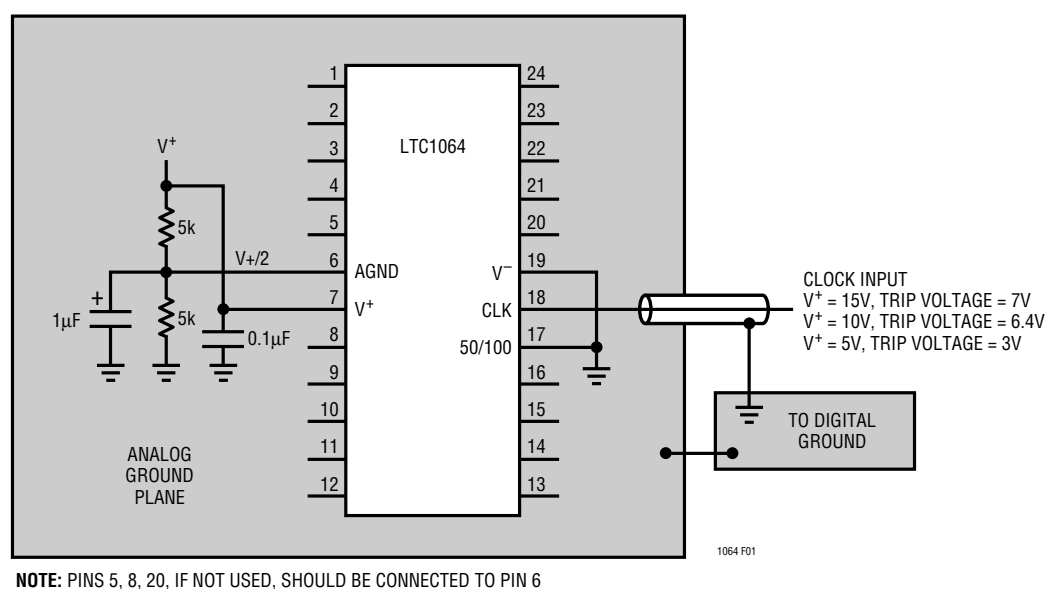


Figure 1. Single Supply Operation

## APPLICATIONS INFORMATION

### ANALOG CONSIDERATIONS

#### Grounding and Bypassing

The LTC1064 should be used with separated analog and digital ground planes and single point grounding techniques.

Pin 6 (AGND) should be tied directly to the analog ground plane.

Pin 7 ( $V^+$ ) should be bypassed to the ground plane with a  $0.1\mu\text{F}$  ceramic capacitor with leads as short as possible. Pin 19 ( $V^-$ ) should be bypassed with a  $0.1\mu\text{F}$  ceramic capacitor. For single supply applications,  $V^-$  can be tied to the analog ground plane.

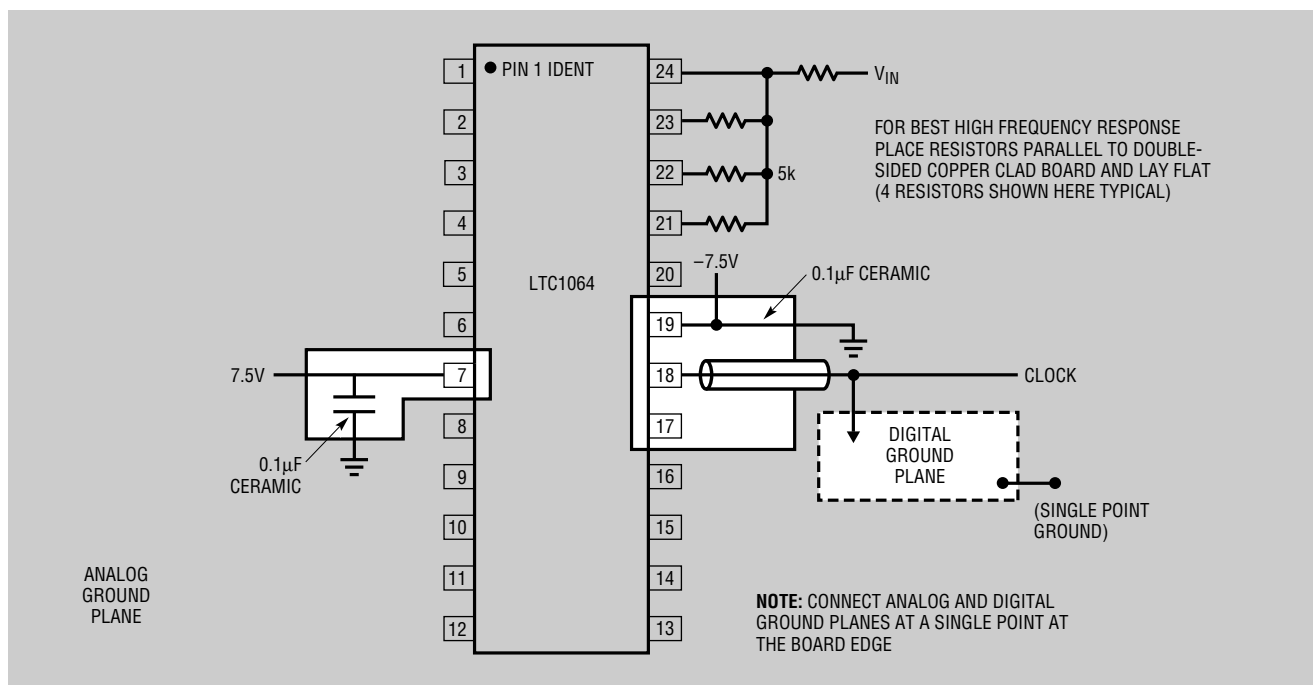
For good noise performance,  $V^+$  and  $V^-$  must be free of noise and ripple.

All analog inputs should be referenced directly to the single point ground. The clock inputs should be shielded from and/or routed away from the analog circuitry and a separate digital ground plane used.

Figure 2 shows an example of an ideal ground plane design for a two-sided board. Of course this much ground plane will not always be possible, but users should strive to get as close to this as possible. Protoboards are not recommended.

#### Buffering the Filter Output

When driving coaxial cables and  $1\times$  scope probes, the filter output should be buffered. This is important especially when high  $Q$ s are used to design a specific filter. *Inadequate buffering may cause errors in noise, distortion,  $Q$  and gain measurements.* When  $10\times$  probes are used, buffering is usually not required. An inverting buffer is recommended especially when THD tests are performed. As shown in Figure 3, the buffer should be adequately bypassed to minimize clock feedthrough.



1064 F02

Figure 2. Example Ground Plane Breadboard Technique for LTC1064

## APPLICATIONS INFORMATION

### Offset Nulling

Lowpass filters may have too much DC offset for some users. A servo circuit may be used to actively null the offsets of the LTC1064 or any LTC switched-capacitor filter. The circuit shown in Figure 4 will null offsets to better than 300 $\mu$ V. This circuit takes seconds to settle because of the integrator pole frequency.

### Noise

All the noise performance mentioned excludes the clock feedthrough. Noise measurements will degrade if the already described grounding bypassing and buffering techniques are not practiced. The graph Wideband Noise vs Q in the Typical Performance Characteristics section is a very good representation of the noise performance of this device.

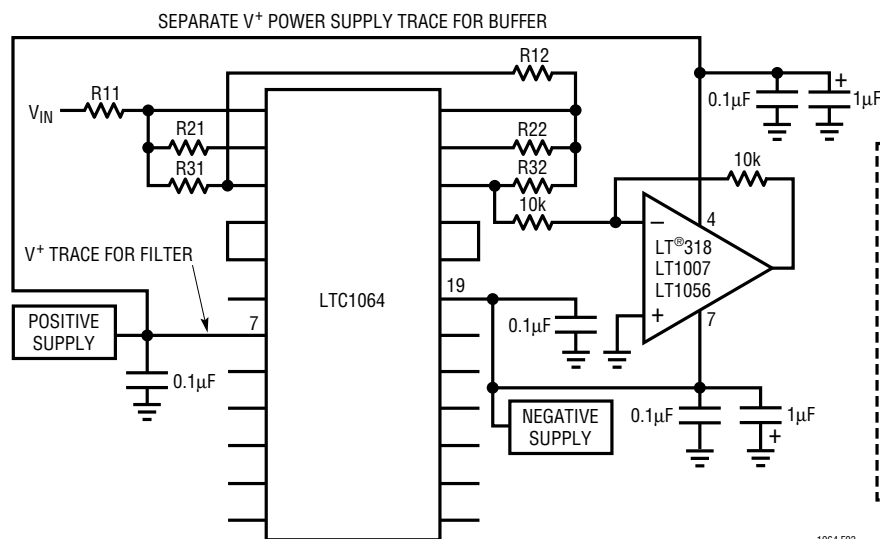


Figure 3. Buffering the Output of a 4th Order Bandpass Realization

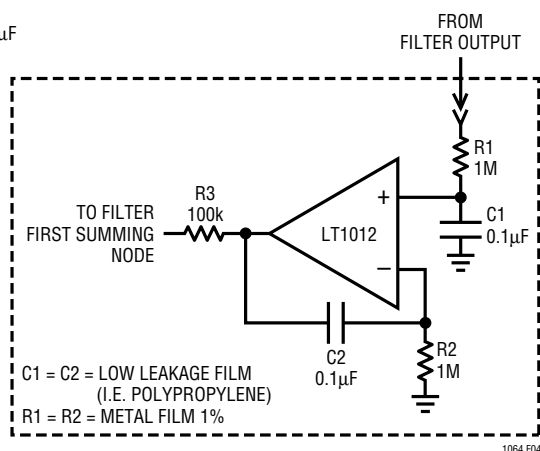


Figure 4. Servo Amplifier

## MODES OF OPERATION

### PRIMARY MODES

#### Mode 1

In Mode 1, the ratio of the external clock frequency to the center frequency of each 2nd order section is internally fixed at 50:1 or 100:1. Figure 5 illustrates Mode 1 providing 2nd order notch, lowpass and bandpass outputs. Mode 1 can be used to make high order Butterworth lowpass filters; it can also be used to make low Q notches and for cascading 2nd order bandpass functions tuned at the same center frequency with unity gain. Mode 1 is faster than Mode 3. Note that Mode 1 can only be implemented with three of the four LTC1064 sections because Section D has no externally available summing node. Section D, however, can be internally connected in Mode 1 upon special request.

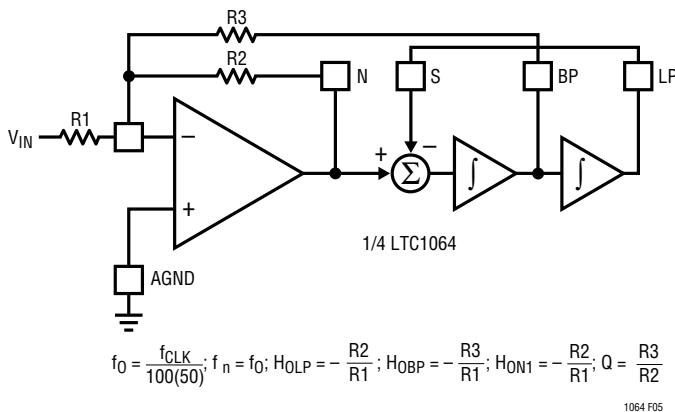


Figure 5. Mode 1: 2nd Order Filter Providing Notch, Bandpass and Lowpass

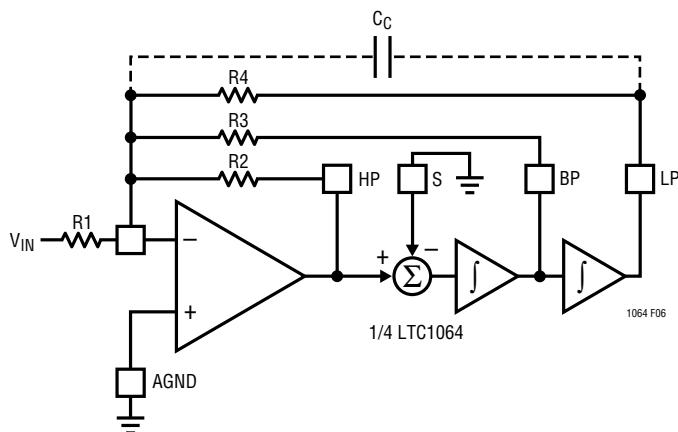


## MODES OF OPERATION

### Mode 3

Mode 3 is the second of the primary modes. In Mode 3, the ratio of the external clock frequency to the center frequency of each 2nd order section can be adjusted above or below 50:1 or 100:1. Side D of the LTC1064 can only be connected in Mode 3. Figure 6 illustrates Mode 3, the classical state variable configuration, providing highpass, bandpass and lowpass 2nd order filter functions. Mode 3 is slower than Mode 1. Mode 3 can be used to make high order all-pole bandpass, lowpass, highpass and notch filters.

When the internal clock-to-center frequency ratio is set at 50:1, the design equations for  $Q$  and bandpass gain are different from the 100:1 case. This was done to provide speed without penalizing the noise performance.



$$\text{MODE 3 (100:1): } f_0 = \frac{f_{\text{CLK}}}{100} \sqrt{\frac{R_2}{R_4}}; Q = \frac{R_3}{R_2} \sqrt{\frac{R_2}{R_4}}; H_{\text{OHP}} = -\frac{R_2}{R_1};$$

$$H_{\text{OBP}} = -\frac{R_3}{R_1}; H_{\text{OLP}} = -\frac{R_4}{R_1}$$

$$\text{MODE 3 (50:1): } f_0 = \frac{f_{\text{CLK}}}{50} \sqrt{\frac{R_2}{R_4}}; Q = \frac{1.005 \sqrt{\frac{R_2}{R_4}}}{\frac{R_2}{R_3} - \frac{16R_4}{R_3}}$$

$$H_{\text{OHP}} = -\frac{R_2}{R_1}; H_{\text{OBP}} = -\frac{\frac{R_3}{R_1}}{1 - \frac{R_3}{16R_4}}; H_{\text{OLP}} = -\frac{R_4}{R_1}$$

**NOTE:** THE 50:1 EQUATIONS FOR MODE 3 ARE DIFFERENT FROM THE EQUATIONS FOR MODE 3 OPERATIONS OF THE LTC1059, LTC1060 AND LTC1061. START WITH  $f_0$ , CALCULATE  $R_2/R_4$ , SET  $R_4$ ; FROM THE  $Q$  VALUE, CALCULATE  $R_3$ :

$$R_3 = \frac{R_2}{\frac{1.005 \sqrt{\frac{R_2}{R_4}}}{Q} + \frac{R_2}{16R_4}}; \text{ THEN CALCULATE } R_1 \text{ TO SET THE DESIRED GAIN.}$$

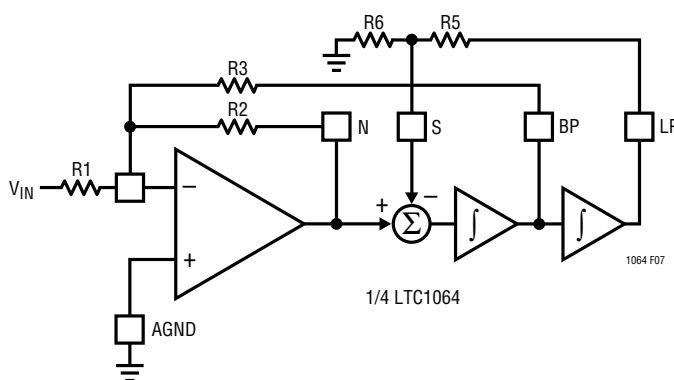
1064 F06 Eq

**Figure 6. Mode 3: 2nd Order Filter Providing Highpass, Bandpass and Lowpass**

### SECONDARY MODES

#### Mode 1b

Mode 1b is derived from Mode 1. In Mode 1b, Figure 7, two additional resistors  $R_5$  and  $R_6$  are added to alternate the amount of voltage fed back from the lowpass output into the input of the SA (or SB or SC) switched-capacitor summer. This allows the filter's clock-to-center frequency ratio to be adjusted beyond 50:1 or 100:1. Mode 1b maintains the speed advantages of Mode 1.



$$f_0 = \frac{f_{\text{CLK}}}{100(50)} \sqrt{\frac{R_6}{R_5 + R_6}}; f_n = f_0; Q = \frac{R_3}{R_2} \sqrt{\frac{R_6}{R_5 + R_6}};$$

$$H_{\text{ON1}}(f \rightarrow 0) = H_{\text{ON2}}\left(f \rightarrow \frac{f_{\text{CLK}}}{2}\right) = -\frac{R_2}{R_1}; H_{\text{OLP}} = -\frac{\frac{R_2}{R_1}}{\frac{R_6}{R_5 + R_6}};$$

$$H_{\text{OBP}} = -\frac{R_3}{R_1}; R_5 || R_6 \leq 5k$$

1064 F07 Eq

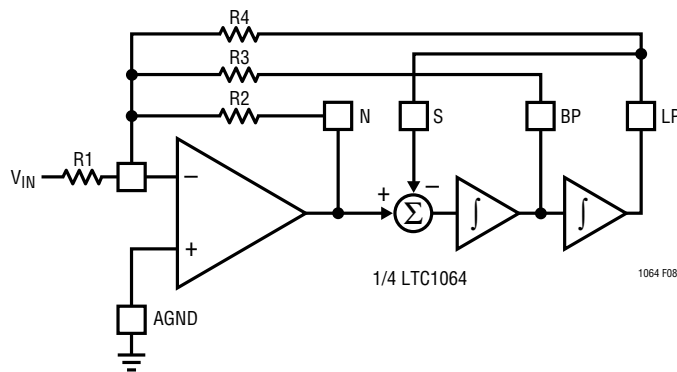
**Figure 7. Mode 1b: 2nd Order Filter Providing Notch, Bandpass and Lowpass**

#### Mode 2

Mode 2 is a combination of Mode 1 and Mode 3, as shown in Figure 8. With Mode 2, the clock-to-center frequency ratio  $f_{\text{CLK}}/f_0$  is always less than 50:1 or 100:1. The advantage of Mode 2 is that it provides less sensitivity to resistor tolerances than does Mode 3. As in Mode 1, Mode 2 has a notch output which depends on the clock frequency and the notch frequency is therefore less than the center frequency  $f_0$ .

When the internal clock-to-center frequency ratio is set at 50:1, the design equations for  $Q$  and bandpass gain are different from the 100:1 case.

## MODES OF OPERATION



$$\text{MODE 2 (100:1): } f_0 = \frac{f_{\text{CLK}}}{100} \sqrt{1 + \frac{R_2}{R_4}}; f_n = \frac{f_{\text{CLK}}}{50}; Q = \frac{R_3}{R_2} \sqrt{1 + \frac{R_2}{R_4}}; H_{\text{OLP}} = -\frac{\frac{R_2}{R_1}}{1 + \frac{R_2}{R_4}};$$

$$H_{\text{OBP}} = -\frac{R_3}{R_1}; H_{\text{ON1}}(f \rightarrow 0) = -\frac{\frac{R_1}{R_2}}{1 + \frac{R_2}{R_4}}; H_{\text{ON2}}\left(f \rightarrow \frac{f_{\text{CLK}}}{2}\right) = -\frac{R_2}{R_1}$$

$$\text{MODE 2 (50:1): } f_0 = \frac{f_{\text{CLK}}}{50} \sqrt{1 + \frac{R_2}{R_4}}; f_n = \frac{f_{\text{CLK}}}{50}; Q = \frac{1.005 \sqrt{1 + \frac{R_2}{R_4}}}{\frac{R_2}{R_3} - \frac{R_2}{16R_4}}; H_{\text{OLP}} = -\frac{\frac{R_2}{R_1}}{1 + \frac{R_2}{R_4}};$$

$$H_{\text{OBP}} = -\frac{\frac{R_3}{R_1}}{1 - \frac{R_3}{16R_4}}; H_{\text{ON1}}(f \rightarrow 0) = -\frac{\frac{R_1}{R_2}}{1 + \frac{R_2}{R_4}}; H_{\text{ON2}} = \left(f \rightarrow \frac{f_{\text{CLK}}}{2}\right) = -\frac{R_2}{R_1}$$

**NOTE:** THE 50:1 EQUATIONS FOR MODE 2 ARE DIFFERENT FROM THE EQUATIONS FOR MODE 2 OPERATION OF THE LTC1059, LTC1060 AND LTC1061. START WITH  $f_0$ , CALCULATE  $R_2/R_4$ , SET  $R_4$ ; FROM THE  $Q$  VALUE, CALCULATE  $R_3$ :

$$R_3 = \frac{R_2}{\frac{1.005}{Q} \sqrt{1 + \frac{R_2}{R_4}} + \frac{R_2}{16R_4}}; \text{ THEN CALCULATE } R_1 \text{ TO SET THE DESIRED GAIN.}$$

1064 F08Eq

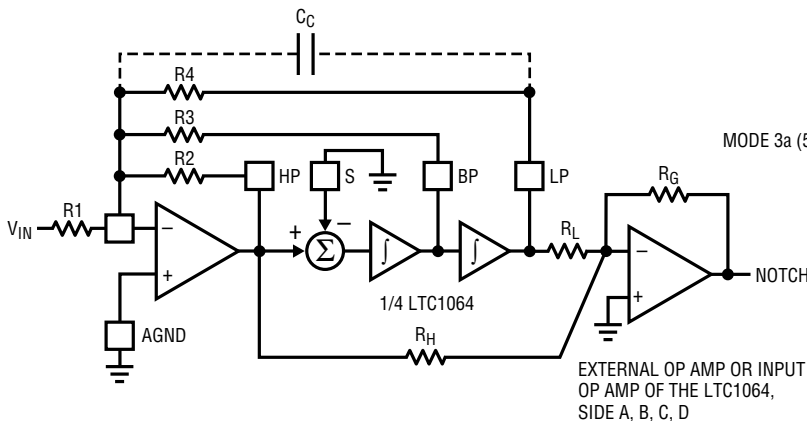
Figure 8. Mode 2: 2nd Order Filter Providing Notch, Bandpass and Lowpass

### Mode 3a

This is an extension of Mode 3 where the highpass and lowpass outputs are summed through two external resistors  $R_H$  and  $R_L$  to create a notch. This is shown in Figure 9. Mode 3a is more versatile than Mode 2 because the notch frequency can be higher or lower than the center frequency of the 2nd order section. The external op amp of Figure 9 is not always required. When cascading the sections of the LTC1064, the highpass and lowpass out-

puts can be summed directly into the inverting input of the next section. The topology of Mode 3a is useful for elliptic highpass and notch filters with clock-to-cutoff frequency ratios higher than 100:1. This is often required to extend the allowed input signal frequency range and to avoid premature aliasing.

*When the internal clock-to-center frequency ratio is set at 50:1, the design equations for  $Q$  and bandpass gain are different from the 100:1 case.*



$$\text{MODE 3a (100:1): } f_0 = \frac{f_{\text{CLK}}}{100} \sqrt{\frac{R_2}{R_4}}; f_n = \frac{f_{\text{CLK}}}{100} \sqrt{\frac{R_H}{R_L}}; H_{\text{OHP}} = -\frac{R_2}{R_1}; H_{\text{OBP}} = -\frac{R_3}{R_1};$$

$$H_{\text{OLP}} = -\frac{R_4}{R_1}; H_{\text{ON1}}(f \rightarrow 0) = \left(\frac{R_G}{R_L}\right) \left(\frac{R_4}{R_1}\right); H_{\text{ON2}}\left(f \rightarrow \frac{f_{\text{CLK}}}{2}\right) = \left(\frac{R_G}{R_H}\right) \left(\frac{R_2}{R_1}\right);$$

$$H_{\text{ON}}(f = f_0) = Q \left(\frac{R_G}{R_L} H_{\text{OLP}} - \frac{R_G}{R_H} H_{\text{OHP}}\right); Q = \frac{R_3}{R_2} \sqrt{\frac{R_2}{R_4}}$$

$$\text{MODE 3a (50:1): } f_0 = \frac{f_{\text{CLK}}}{50} \sqrt{1 + \frac{R_2}{R_4}}; f_n = \frac{f_{\text{CLK}}}{50} \sqrt{\frac{R_H}{R_L}}; H_{\text{OHP}}\left(f \rightarrow \frac{f_{\text{CLK}}}{2}\right) = -\frac{R_2}{R_1};$$

$$H_{\text{OBP}} = -\frac{\frac{R_3}{R_1}}{1 - \frac{R_3}{16R_4}}; H_{\text{OLP}}(f = 0) = -\frac{R_4}{R_1}; Q = \frac{1.005 \sqrt{\frac{R_2}{R_4}}}{\frac{R_2}{R_3} - \frac{R_2}{16R_4}}$$

**NOTE:** THE 50:1 EQUATIONS FOR MODE 3a ARE DIFFERENT FROM THE EQUATIONS FOR MODE 3a OPERATION OF THE LTC1059, LTC1060 AND LTC1061. START WITH  $f_0$ , CALCULATE  $R_2/R_4$ , SET  $R_4$ ; FROM THE  $Q$  VALUE, CALCULATE  $R_3$ :

$$R_3 = \frac{R_2}{\frac{1.005}{Q} \sqrt{\frac{R_2}{R_4}} + \frac{R_2}{16R_4}}; \text{ THEN CALCULATE } R_1 \text{ TO SET THE DESIRED GAIN.}$$

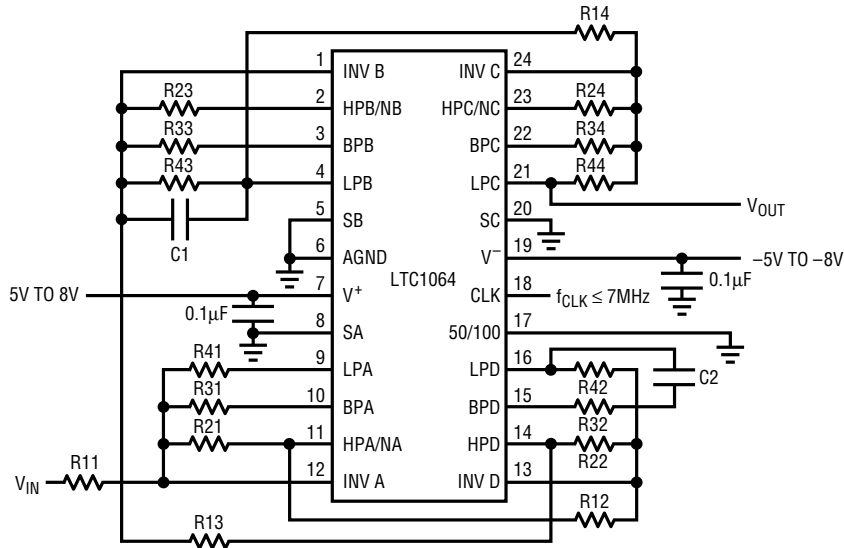
1064 F09Eq

Figure 9. Mode 3a: 2nd Order Filter Providing Highpass, Bandpass, Lowpass and Notch

## TYPICAL APPLICATIONS

## Wideband Bandpass: Ratio of High to Low Corner Frequency Equal to 2

## Amplitude Response

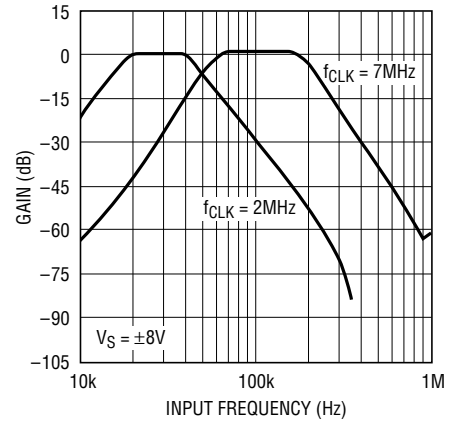


## RESISTOR VALUES:

R11 = 16k R21 = 16k R31 = 7.32k R41 = 10k  
 R12 = 10k R22 = 10k R32 = 22.6k R42 = 13.3k  
 R13 = 23.2k R23 = 13.3k R33 = 21.5k R43 = 10k  
 R14 = 6.8k R24 = 20k R34 = 15.4k R44 = 32.4k

NOTE: FOR  $f_{CLK} \geq 3\text{MHz}$ , USE  $C1 = C2 = 22\text{pF}$

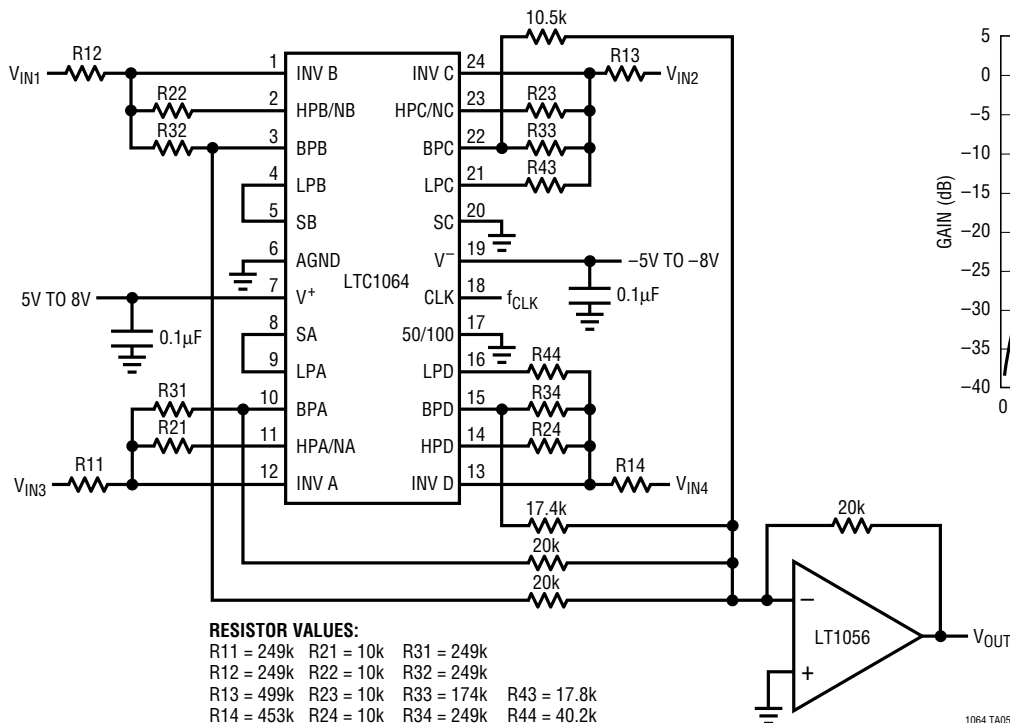
1064 TA03



1064 TA04

Quad Bandpass Filter with Center Frequency Equal to  $f_0$ ,  $2f_0$ ,  $3f_0$ , and  $4f_0$ 

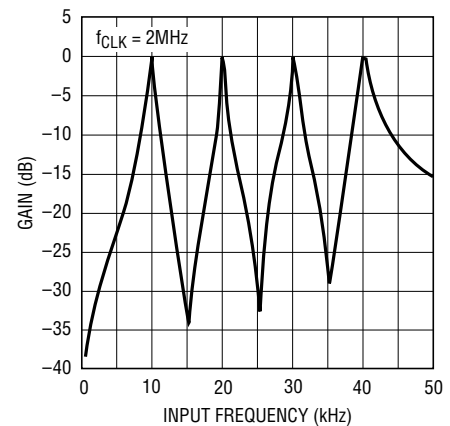
## Amplitude Response



## RESISTOR VALUES:

R11 = 249k R21 = 10k R31 = 249k  
 R12 = 249k R22 = 10k R32 = 249k  
 R13 = 499k R23 = 10k R33 = 174k R43 = 17.8k  
 R14 = 453k R24 = 10k R34 = 249k R44 = 40.2k

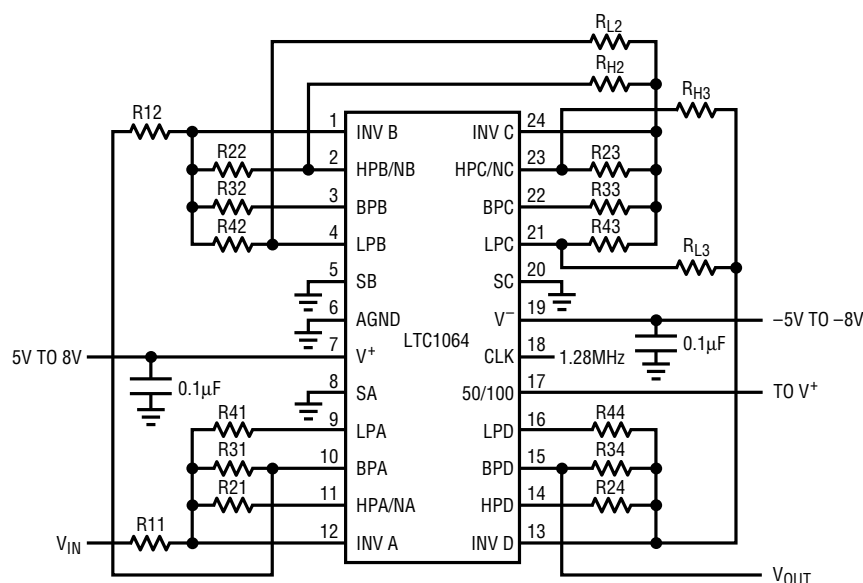
1064 TA05



1064 TA06

## TYPICAL APPLICATIONS

## 8th Order Bandpass Filter with 2 Stopband Notches



## RESISTOR VALUES:

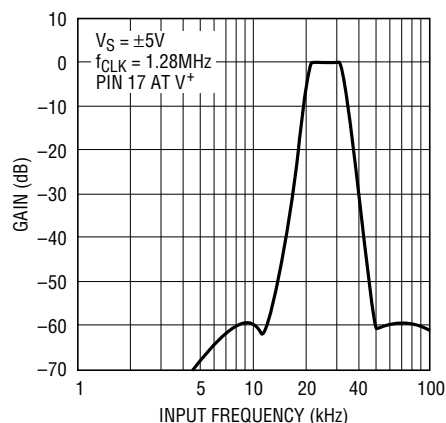
$R_{11} = 46.95k$   $R_{21} = 10k$   $R_{31} = 38.25k$   $R_{41} = 11.81k$   
 $R_{12} = 93.93k$   $R_{22} = 10k$   $R_{32} = 81.5k$   $R_{42} = 14.72k$   $R_{L2} = 27.46k$   $R_{H2} = 6.9k$   
 $R_{23} = 16.3k$   $R_{33} = 70.3k$   $R_{43} = 10k$   $R_{L3} = 17.9k$   $R_{H3} = 69.7k$   
 $R_{24} = 13.19k$   $R_{34} = 39.42k$   $R_{44} = 10.5k$

**NOTE1:** THE  $V^+$ ,  $V^-$  PINS SHOULD BE BYPASSED WITH A  $0.1\mu F$  TO  $0.22\mu F$  CERAMIC CAPACITOR, RIGHT AT THE PINS.

**NOTE 2:** THE RATIOS OF ALL ( $R_2/R_4$ ) RESISTORS SHOULD BE MATCHED TO BETTER THAN 0.25%. THE REMAINING RESISTORS SHOULD BE BETTER THAN 0.5% ACCURATE.

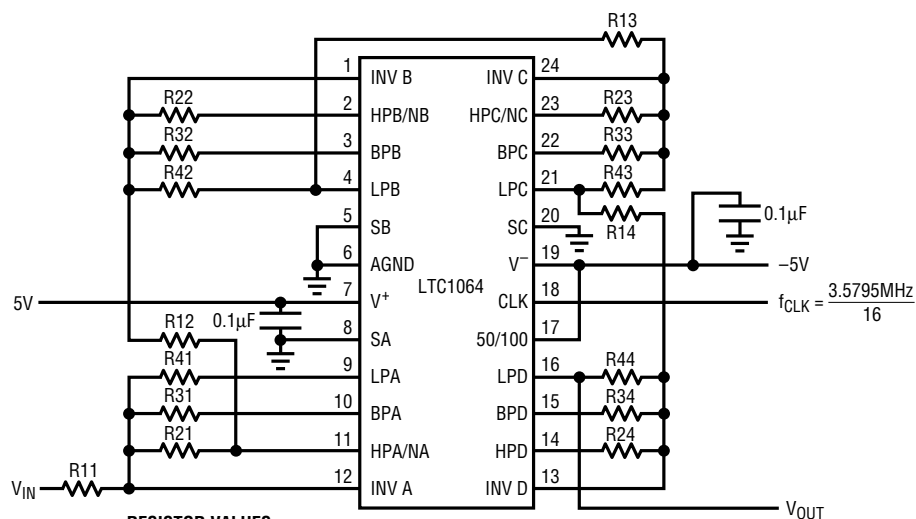
1064 TA07

## Amplitude Response



1064 TA08

## C-Message Filter

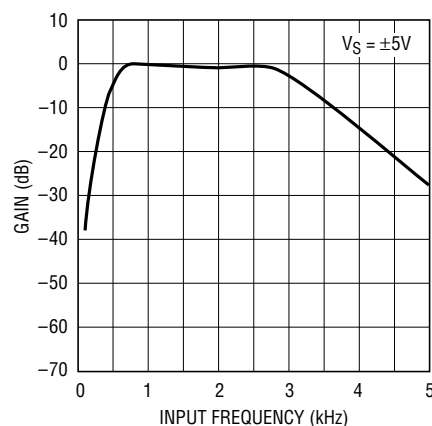


## RESISTOR VALUES:

$R_{11} = 88.7k$   $R_{21} = 10k$   $R_{31} = 35.7k$   $R_{41} = 88.7k$   
 $R_{12} = 10k$   $R_{22} = 44.8k$   $R_{32} = 33.2k$   $R_{42} = 24.9k$   
 $R_{13} = 15.8k$   $R_{23} = 48.9k$   $R_{33} = 63.5k$   $R_{43} = 25.5k$   
 $R_{14} = 15.8k$   $R_{24} = 44.8k$   $R_{34} = 16.5k$   $R_{44} = 24.9k$

1064 TA09

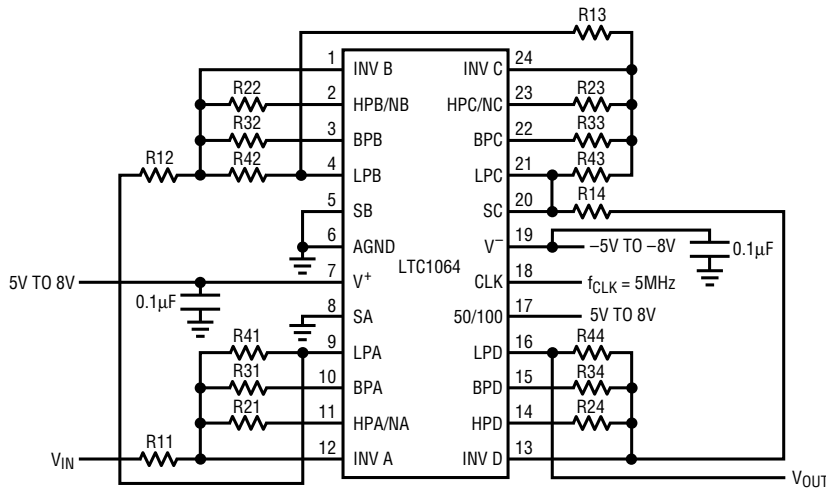
## Amplitude Response



1064 TA10

## TYPICAL APPLICATIONS

## 8th Order Chebyshev Lowpass Filter with a Passband Ripple of 0.1dB and Cutoff Frequency up to 100kHz



## RESISTOR VALUES:

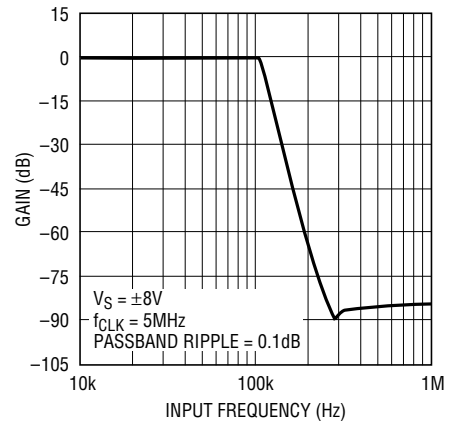
R11 = 100.86k R21 = 16.75k R31 = 23.6k R41 = 99.73k  
 R12 = 25.72k R22 = 20.93k R32 = 45.2k R42 = 25.52k  
 R13 = 16.61k R23 = 10.18k R33 = 68.15k R43 = 99.83k  
 R14 = 13.84k R24 = 11.52k R34 = 17.72k R44 = 25.42k

FOR  $f_{CLK} > 3\text{MHz}$ , ADD C2 = 10pF ACROSS R42  
 C3 = 10pF ACROSS R43  
 C4 = 10pF ACROSS R44

WIDEBAND NOISE =  $170\mu\text{VRMS}$

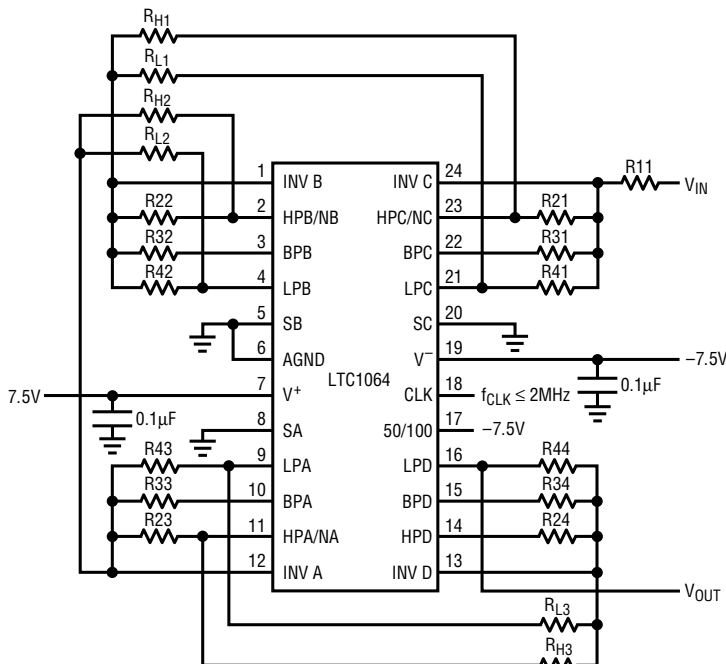
1064 TA11

## Amplitude Response



1064 TA12

## 8th Order Clock-Sweepable Lowpass Elliptic Antialiasing Filter



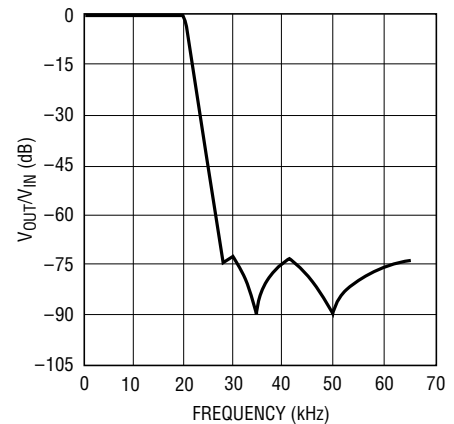
## RESISTOR VALUES:

R11 = 19.1k R21 = 10k R31 = 13.7k R41 = 15.4k R L1 = 14k R H1 = 30.9k  
 R22 = 10k R32 = 23.7k R42 = 10.2k R L2 = 26.7k R H2 = 76.8k  
 R23 = 11.3k R33 = 84.5k R43 = 10k R L3 = 10k R H3 = 60.2k  
 R24 = 15.4k R34 = 15.2k R44 = 42.7k

NOTE: FOR  $f_{CUTOFF} > 15\text{kHz}$ , ADD A 5pF CAPACITOR ACROSS R41 AND R43

1064 TA13

## Amplitude Response



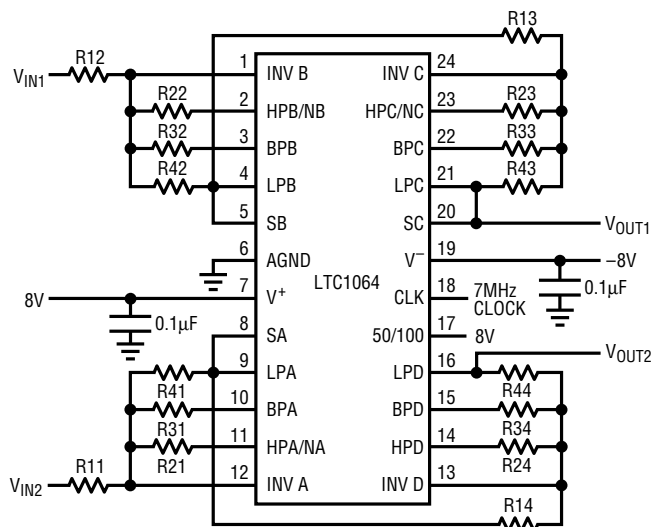
8TH ORDER CLOCK-SWEEPABLE LOWPASS ELLIPTIC ANTIALIASING FILTER MAINTAINS, FOR  $0.1\text{Hz} \leq f_{CUTOFF} \leq 20\text{kHz}$ ,  $A \pm 0.1\text{dB}$  MAX PASSBAND ERROR AND 72dB MIN STOPBAND ATTENUATION AT  $1.5 \times f_{CUTOFF}$ .

TOTAL WIDEBAND NOISE =  $150\mu\text{VRMS}$ , THD = 70dB (0.03%) FOR  $V_{IN} = 3\text{VRMS}$ ,  $f_{CLK}/f_{CUTOFF} = 100:1$ . THIS FILTER AVAILABLE AS LTC1064-1 WITH INTERNAL THIN FILM RESISTORS.

1064 TA14

## TYPICAL APPLICATIONS

Dual 4th Order Bessel Filter with 140kHz Cutoff Frequency



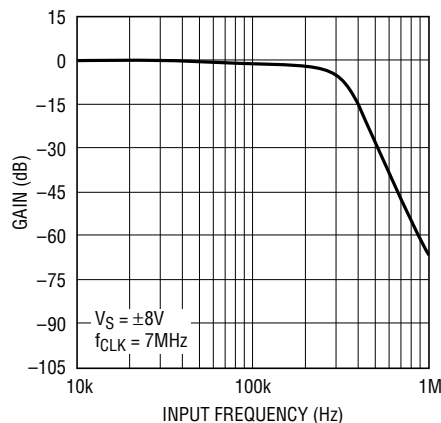
## RESISTOR VALUES:

R11 = 14.3k	R21 = 13k	R31 = 7.5k	R41 = 10k
R12 = 15.4k	R22 = 15.4k	R32 = 7.5k	R42 = 10k
R13 = 3.92k	R23 = 20k	R33 = 27.4k	R43 = 40k
R14 = 3.92k	R24 = 20k	R34 = 6.8k	R44 = 10k

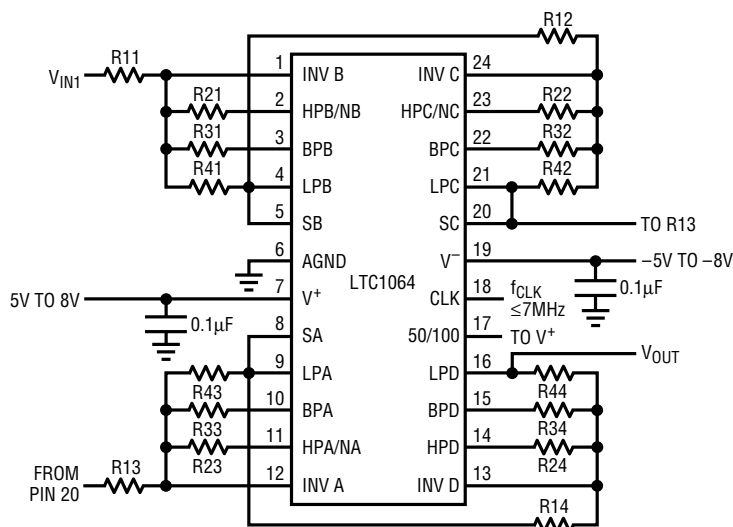
WIDEBAND NOISE =  $64\mu\text{VRMS}$ 

1064 TA15

Amplitude Response



1064 TA16

8th Order Linear Phase (Bessel) Filter with  $\frac{f_{\text{CLK}}}{f_{-3\text{dB}}} = \frac{65}{1}$ 

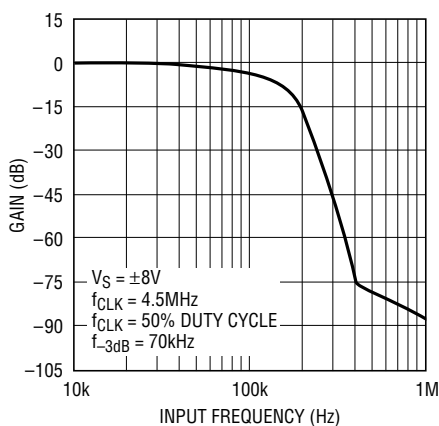
## RESISTOR VALUES:

R11 = 34.8k	R21 = 34.8k	R31 = 14.3k	R41 = 40.2k
R12 = 10.5k	R22 = 45.3k	R32 = 22.1k	R42 = 39.2k
R13 = 12.7k	R23 = 34.8k	R33 = 24.3k	R43 = 20k
R14 = 20k	R24 = 34.8k	R34 = 13.3k	R44 = 20k

WIDEBAND NOISE =  $70\mu\text{VRMS}$ 

1064 TA17

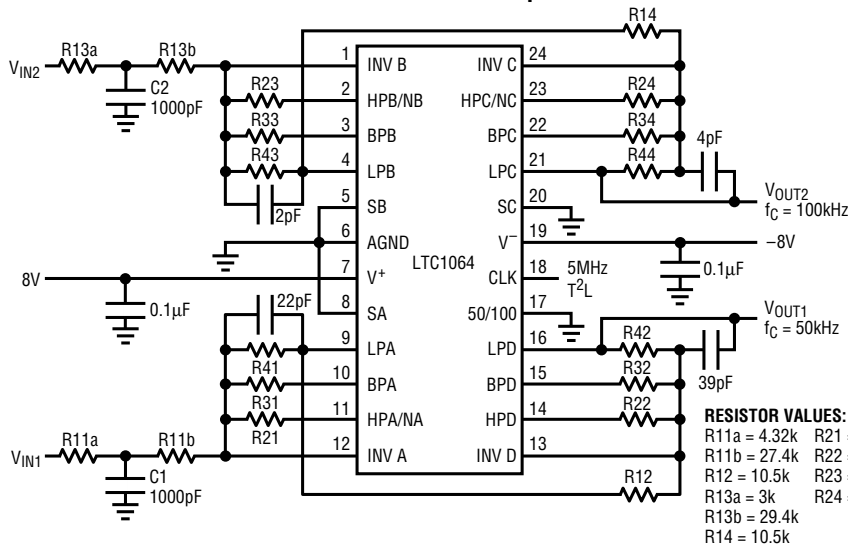
Amplitude Response



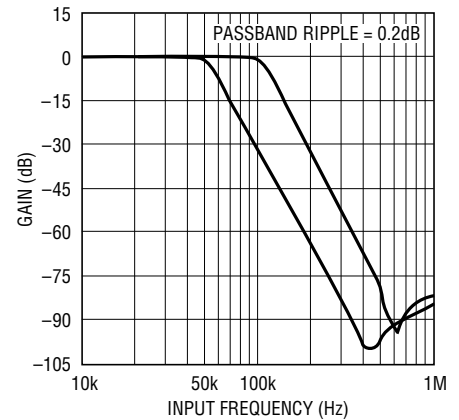
1064 TA18

## TYPICAL APPLICATIONS

Dual 5th Order Chebyshev Lowpass Filter with 50kHz and 100kHz Cutoff Frequencies



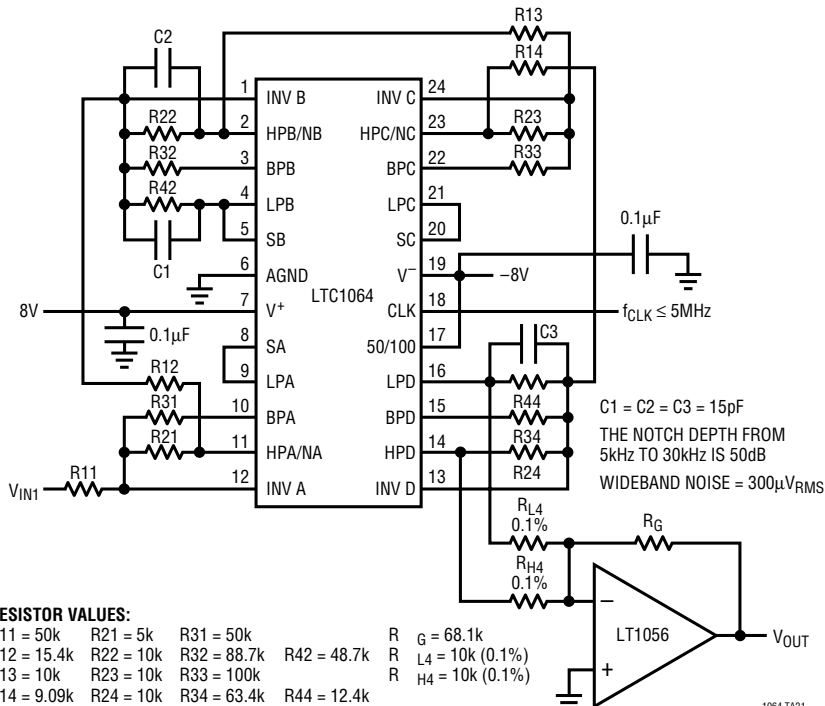
Amplitude Response



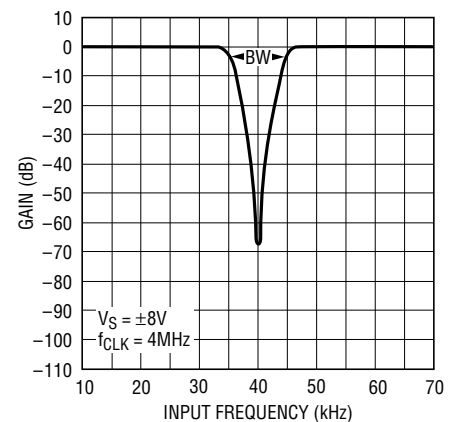
1064 TA20

1064 TA19

Clock-Tunable, 30kHz to 90kHz 8th Order Notch Filter Providing Notch Depth in Excess of 60dB



Amplitude Response



1064 TA22

1064 TA21

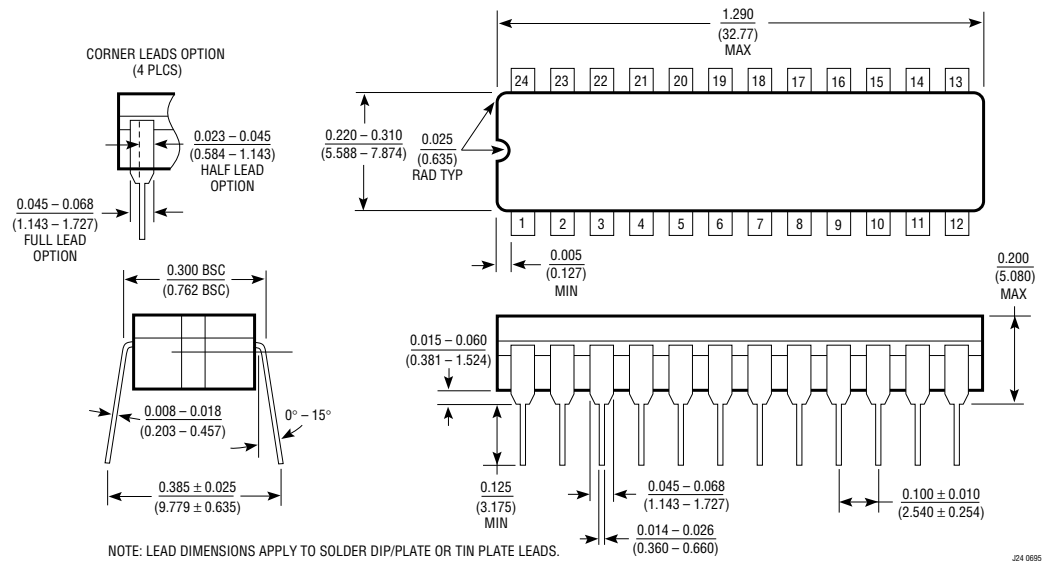
## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENT
LTC1061	Triple Universal Filter Building Block	Three Filter Building Blocks in a 20-Pin Package
LTC1164	Low Power, Quad Universal Filter Building Block	Low Noise, Low Power Pin-for-Pin LTC1064 Compatible
LTC1264	High Speed, Quad Universal Building Block	Up to 250kHz Center Frequency

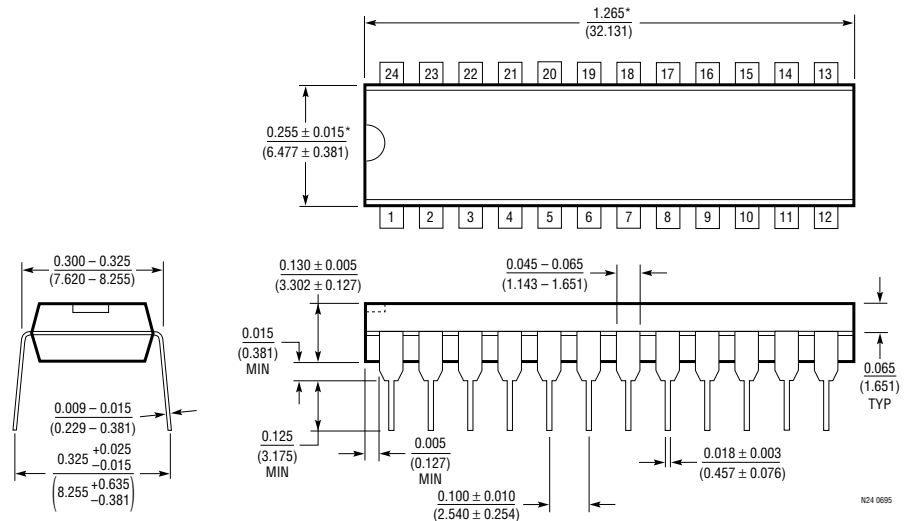
# PACKAGE DESCRIPTION

Dimension in inches (millimeters) unless otherwise noted.

## J Package 24-Lead Ceramic DIP



## N Package 24-Lead Plastic DIP



## SW Package 24-Lead Plastic SO

