



LTC1062

5th Order Lowpass Filter

FEATURES

- Lowpass Filter with No DC Error
- Low Passband Noise
- Operates DC to 20kHz
- Operates On a Single 5V Supply or Up to $\pm 8V$
- 5th Order Filter
- Maximally Flat Response
- Internal or External Clock
- Cascadable for Faster Roll-off
- Buffer Available

APPLICATIONS

- 60Hz Lowpass Filters
- Antialiasing Filter
- Low Level Filtering
- Rolling Off AC Signals from High DC Voltages
- Digital Voltmeters
- Scales
- Strain Gauges

DESCRIPTION

The LTC[®]1062 is a 5th order all pole maximally flat lowpass filter with no DC error. Its unusual architecture puts the filter outside the DC path so DC offset and low frequency noise problems are eliminated. This makes the LTC1062 very useful for lowpass filters where DC accuracy is important.

The filter input and output are simultaneously taken across an external resistor. The LTC1062 is coupled to the signal through an external capacitor. This RC reacts with the internal switched capacitor network to form a 5th order rolloff at the output.

The filter cutoff frequency is set by an internal clock that can be externally driven. The clock-to-cutoff frequency ratio is typically 100:1, allowing the clock ripple to be easily removed.

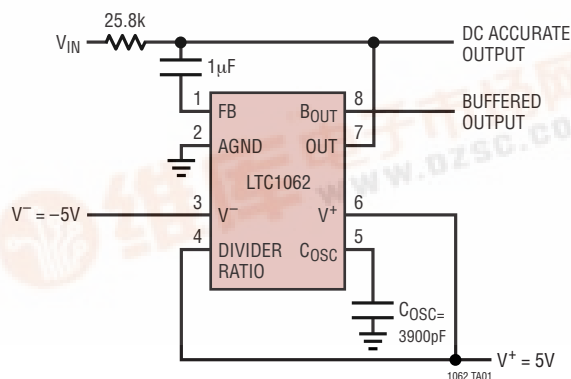
Two LTC1062s can be cascaded to form a 10th order quasi max flat lowpass filter. The device can be operated with single or dual supplies ranging from $\pm 2.5V$ to $\pm 9V$.

The LTC1062 is manufactured using Linear Technology's enhanced LTCMOS[™] silicon gate process.

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LTCMOS is a trademark of Linear Technology Corporation.

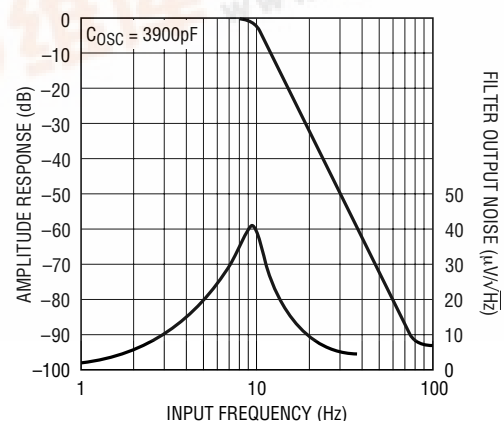
TYPICAL APPLICATION

10Hz 5th Order Butterworth Lowpass Filter



NOTE: TO ADJUST OSCILLATOR FREQUENCY, USE A 6800pF CAPACITOR IN SERIES WITH A 50k POT FROM PIN 5 TO GROUND

Filter Amplitude Response and Noise



LTC1062

ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-)	18V	Storage Temperature Range	-65°C to 150°C
Input Voltage at Any Pin $V^- - 0.3\text{V} \leq V_{\text{IN}} \leq V^+ + 0.3\text{V}$		Lead Temperature (Soldering, 10 sec)	300°C
Operating Temperature Range			
LTC1062M (OBSOLETE)	$-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$		
LTC1062C	$-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$		

PACKAGE/ORDER INFORMATION

<p>TOP VIEW</p> <p>N8 PACKAGE 8-LEAD PDIP</p> <p>$T_J \text{ MAX} = 100^{\circ}\text{C}, \theta_{JA} = 130^{\circ}\text{C/W}$</p> <p>J8 PACKAGE 8-LEAD Cerdip $T_J \text{ MAX} = 150^{\circ}\text{C}, \theta_{JA} = 100^{\circ}\text{C/W}$</p> <p>OBSOLETE PACKAGE Consider the N8 Package as an Alternate Source</p>	<p>ORDER PART NUMBER</p> <p>LTC1062CN8</p> <p>LTC1062MJ8 LTC1062CJ8</p>	<p>TOP VIEW</p> <p>SW PACKAGE 16-LEAD PLASTIC SO</p> <p>$T_J \text{ MAX} = 150^{\circ}\text{C}, \theta_{JA} = 90^{\circ}\text{C/W}$</p>	<p>ORDER PART NUMBER</p> <p>LTC1062CSW</p>
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Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^{\circ}\text{C}$. $V^+ = 5\text{V}$, $V^- = -5\text{V}$, unless otherwise specified. AC output measured at Pin 7, Figure 1.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply Current	C_{OSC} (Pin 5 to V^- , Pin 11 in SW16) = 100pF	●	4.5	7 10	mA mA
Input Frequency Range			0 to 20		kHz
Filter Gain at $f_{\text{IN}} = 0$	$f_{\text{CLK}} = 100\text{kHz}$, Pin 4 (Pin 6 in SW16) at V^+ , $C = 0.01\mu\text{F}$, $R = 25.78\text{k}$		0.00		dB
$f_{\text{IN}} = 0.5f_c$ (Note 2)		●	-0.02	-0.3	dB
$f_{\text{IN}} = f_c$		●	-2	-3.00	dB
$f_{\text{IN}} = 2f_c$		●	-28	-30.00	dB
$f_{\text{IN}} = 4f_c$		●	-52	-60.00	dB
Clock-to-Cutoff Frequency Ratio, f_{CLK}/f_c	$f_{\text{CLK}} = 100\text{kHz}$, Pin 4 (Pin 6 in SW16) at V^+ , $C = 0.01\mu\text{F}$, $R = 25.78\text{k}$		100 \pm 1		%
Filter Gain at $f_{\text{IN}} = 16\text{kHz}$	$f_{\text{CLK}} = 400\text{kHz}$, Pin 4 at V^+ , $C = 0.01\mu\text{F}$, $R = 6.5\text{k}$	●	-43	-52	dB
f_{CLK}/f_c Tempco	$f_{\text{CLK}} = 400\text{kHz}$, Pin 4 at V^+ , $C = 0.01\mu\text{F}$, $R = 6.5\text{k}$		10		ppm/ $^{\circ}\text{C}$
Filter Output (Pin 7, Pin 13 in SW16) DC Swing	Pin 7/Pin13 (SW16) Buffered with an External Op Amp	●	± 3.5	± 3.8	V
Clock Feedthrough			1		mV _{P-P}

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$. $V^+ = 5\text{V}$, $V^- = -5\text{V}$, unless otherwise specified, AC output measured at Pin 7, Figure 1.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Internal Buffer					
Bias Current		●	2 170	50 1000	pA pA
Offset Voltage			2	20	mV
Voltage Swing	$R_{\text{LOAD}} = 20\text{k}$	●	± 3.5	± 3.8	V
Short-Circuit Current Source/Sink			40/3		mA
Clock (Note 3)					
Internal Oscillator Frequency	C_{OSC} (Pin 5 to V^- , Pin 11 in SW16) = 100pF	●	25 15	32 65	kHz kHz
Max Clock Frequency			4		MHz
Pin 5 (Pin 11 in SW16) Source or Sink Current		●	40	80	μA

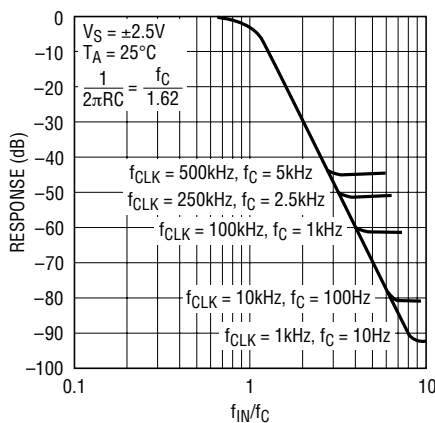
Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: f_C is the frequency where the gain is -3dB with respect to the input signal.

Note 3: The external or driven clock frequency is divided by either 1, 2 or 4 depending upon the voltage at Pin 4. For the N8 package, when Pin 4 = V^+ , ratio = 1; when Pin 4 = GND, ratio = 2; when Pin 4 = V^- , ratio = 4.

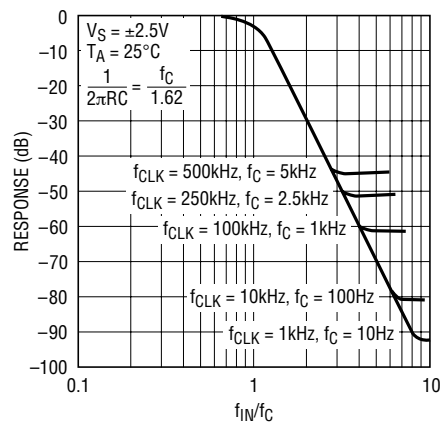
TYPICAL PERFORMANCE CHARACTERISTICS

Amplitude Response Normalized to the Cutoff Frequency



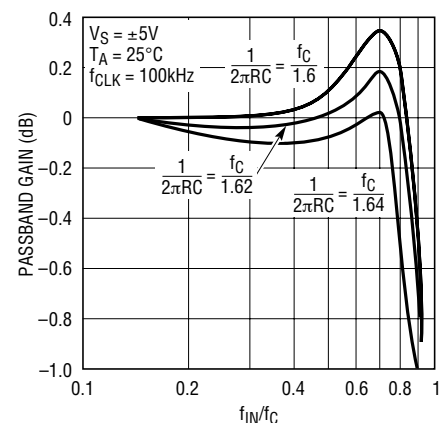
1062 G01

Amplitude Response Normalized to the Cutoff Frequency



1062 G01

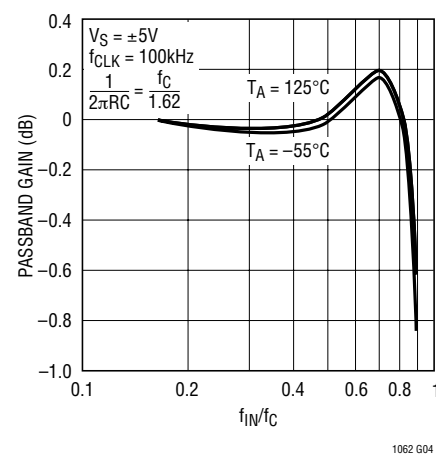
Passband Gain vs Input Frequency



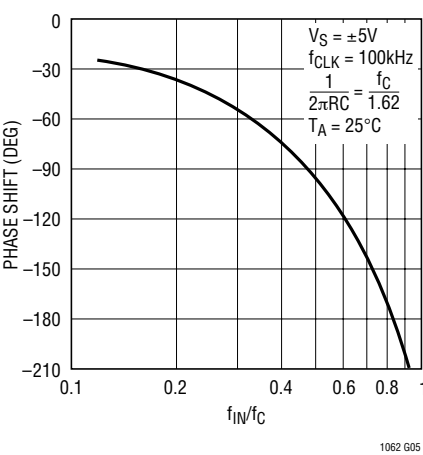
1062 G03

TYPICAL PERFORMANCE CHARACTERISTICS

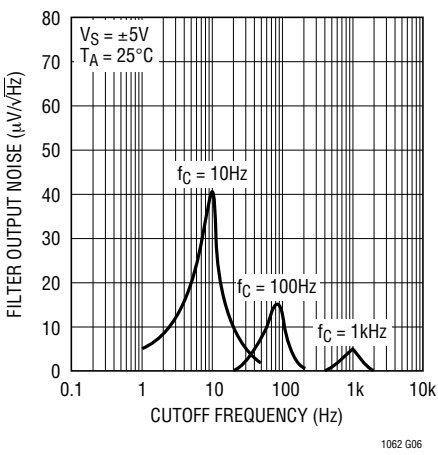
Passband Gain vs Input Frequency and Temperature



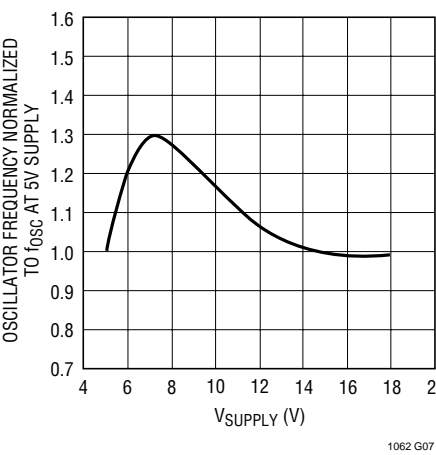
Passband Phase Shift vs Input Frequency



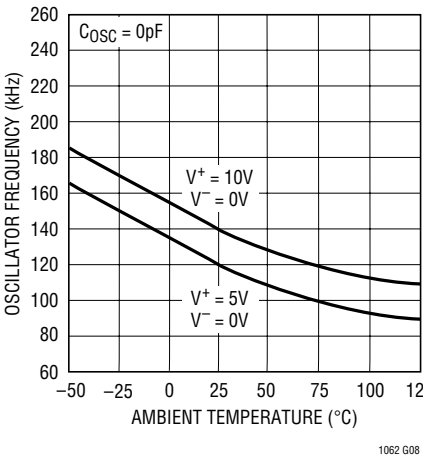
Filter Noise Spectral Density



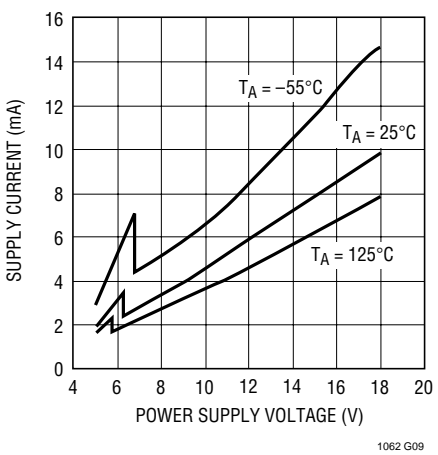
Normalized Oscillator Frequency, f_{OSC} vs Supply Voltage



Oscillator Frequency, f_{OSC} vs Ambient Temperature

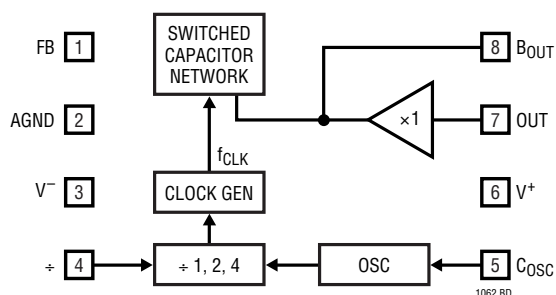


Power Supply Current vs Power Supply Voltage



BLOCK DIAGRAM

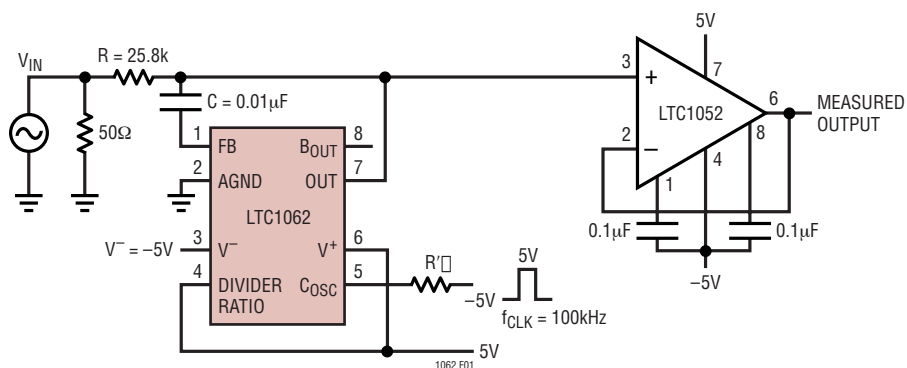
For Adjusting Oscillator Frequency, Insert a 50k Pot in Series with C_{OSC} . Use Two Times Calculated C_{OSC}



BY CONNECTING PIN 4 TO V^+ , AGND OR V^- , THE OUTPUT FREQUENCY OF THE INTERNAL CLOCK GENERATOR IS THE OSCILLATOR FREQUENCY DIVIDED BY 1, 2, 4. THE (f_{CLK}/f_C) RATIO OF 100:1 IS WITH RESPECT TO THE INTERNAL CLOCK GENERATOR OUTPUT FREQUENCY. PIN 5 CAN BE DRIVEN WITH AN EXTERNAL CMOS LEVEL CLOCK. THE LTC1062 CAN ALSO BE SELF-CLOCKED BY CONNECTING AN EXTERNAL CAPACITOR (C_{OSC}) TO GROUND (OR TO V^- IF C_{OSC} IS POLARIZED). UNDER THIS CONDITION AND WITH $\pm 5V$ SUPPLIES, THE INTERNAL OSCILLATOR FREQUENCY IS:

$$f_{OSC} \approx 140\text{kHz} [33\text{pF}/(33\text{pF} + C_{OSC})]$$

AC TEST CIRCUIT



FOR BEST MAX FLAT APPROXIMATION, THE INPUT RC SHOULD BE SUCH AS:

$$\frac{1}{2\pi RC} = \frac{f_{CLK}}{100} \cdot \frac{1}{1.63}$$

A 0.5k RESISTOR, R' , SHOULD BE USED IF THE BIPOLAR EXTERNAL CLOCK IS APPLIED BEFORE THE POWER SUPPLIES TURN ON

Figure 1

APPLICATIONS INFORMATION

Filter Input Voltage Range

Every node of the LTC1062 typically swings within 1V of either voltage supply, positive or negative. With the appropriate external (RC) values, the amplitude response of all the internal or external nodes does not exceed a gain of 0dB with the exception of Pin 1. The amplitude response of the feedback node (Pin 1) is shown in Figure 2. For an input frequency around $0.8 \cdot f_C$, the gain is 1.7V/V and, with $\pm 5V$ supplies, the peak-to-peak input voltage should not exceed 4.7V. If the input voltage goes beyond this value, clipping and distortion of the output waveform occur, but the filter will not get damaged nor will it oscillate. Also, the absolute maximum input voltage should not exceed the power supplies.

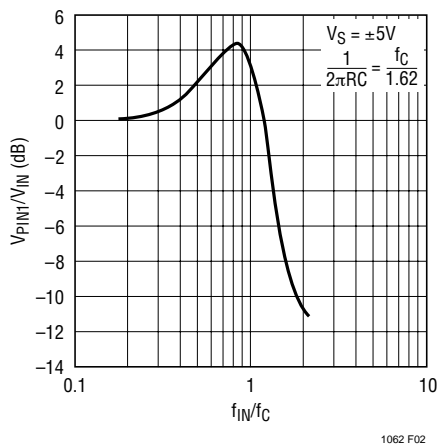


Figure 2. Amplitude Response of Pin 1

Internal Buffer

The internal buffer out (Pin 8) and Pin 1 are part of the signal AC path. Excessive capacitive loading will cause gain errors in the passband, especially around the cutoff frequency. The internal buffer gain at DC is typically 0.006dB. The internal buffer output can be used as a filter output, however, it has a few millivolts of DC offset. The temperature coefficient of the internal buffer is typically $1\mu V/^\circ C$.

Filter Attenuation

The LTC1062 rolloff is typically 30dB/octave. When the clock and the cutoff frequencies increase, the filter's maximum attenuation decreases. This is shown in the

Typical Performance Characteristics. The decrease of the maximum attenuation is due to the rolloff at higher frequencies of the loop gains of the various internal feedback paths and not to the increase of the noise floor. For instance, for a 100kHz clock and 1kHz cutoff frequency, the maximum attenuation is about 64dB. A 4kHz, $1V_{RMS}$ input signal will be predictably attenuated by 60dB at the output. A 6kHz, $1V_{RMS}$ input signal will be attenuated by 64dB and not by 77dB as an ideal 5th order maximum flat filter would have dictated. The LTC1062 output at 6kHz will be about $630\mu V_{RMS}$. The measured RMS noise from DC to 17kHz was $100\mu V_{RMS}$ which is 16dB below the filter output.

C_{OSC}, Pin 5

The C_{OSC}, Pin 5, can be used with an external capacitor, C_{OSC}, connected from Pin 5 to ground. If C_{OSC} is polarized it should be connected from Pin 5 to the negative supply, Pin 3. C_{OSC} lowers the internal oscillator frequency. If Pin 5 is floating, an internal 33pF capacitor plus the external interpin capacitance set the oscillator frequency around 140kHz with $\pm 5V$ supply. An external C_{OSC} will bring the oscillator frequency down by the ratio $(33pF)/(33pF + C_{OSC})$. The Typical Performance Characteristics curves provide the necessary information to get the internal oscillator frequency for various power supply ranges. Pin 5 can also be driven with an external CMOS clock to override the internal oscillator. Although standard 7400 series CMOS gates do not guarantee CMOS levels with the current source and sink requirements of Pin 5, they will, in reality, drive the C_{OSC} pin. CMOS gates conforming to standard B series output drive have the appropriate voltage levels and more than enough output current to simultaneously drive several LTC1062 C_{OSC} pins. The typical trip levels of the internal Schmitt trigger which input is Pin 5, are given in Table 1.

Table 1

V _{SUPPLY}	V _{TH} ⁺	V _{TH} ⁻
±2.5V	0.9V	-1V
±5V	1.3V	-2.1V
±6V	1.7V	-2.5V
±7V	1.75V	-2.9V

APPLICATIONS INFORMATION

Divide By 1, 2, 4 (Pin 4)

By connecting Pin 4 to V^+ , to mid supplies or to V^- , the clock frequency driving the internal switched capacitor network is the oscillator frequency divided by 1, 2, 4 respectively. Note that the f_{CLK}/f_C ratio of 100:1 is with respect to the internal clock generator output frequency. The internal divider is useful for applications where octave tuning is required. The ± 2 threshold is typically $\pm 1V$ from the mid supply voltage.

Transient Response

Figure 3 shows the LTC1062 response to a 1V input step.

Filter Noise

The filter wideband RMS noise is typically $100\mu V_{RMS}$ for $\pm 5V$ supply and it is nearly independent from the value of the cutoff frequency. For single 5V supply the RMS noise is $80\mu V_{RMS}$. Sixty-two percent of the wideband noise is in the passband, that is from DC to f_C . The noise spectral density, unlike conventional active filters, is nearly zero for frequencies below $0.1 \cdot f_C$. This is shown in the Typical Performance Characteristics section. Table 2 shows the LTC1062 RMS noise for different noise bandwidths.

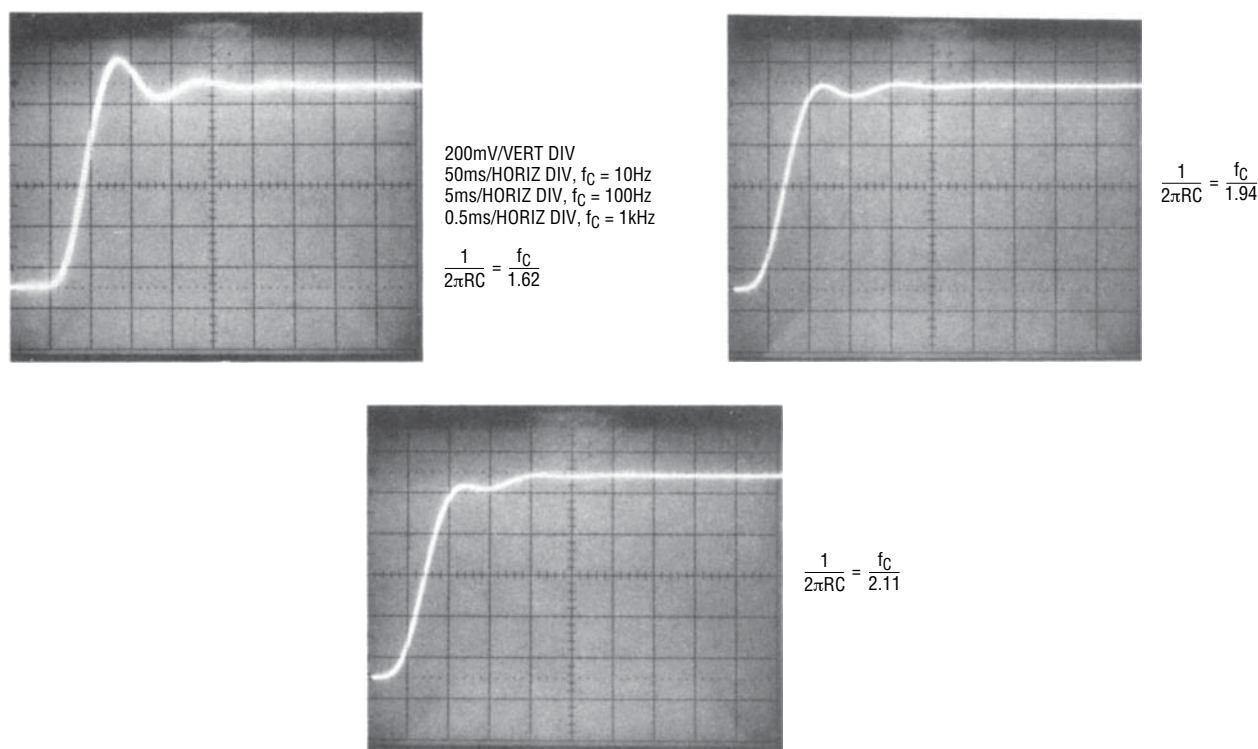


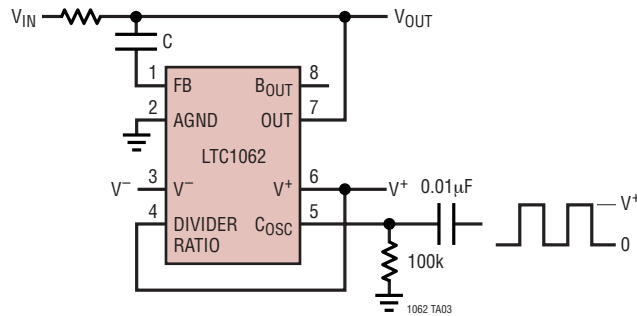
Figure 3. Step Response to a 1V Peak Input Step

Table 2

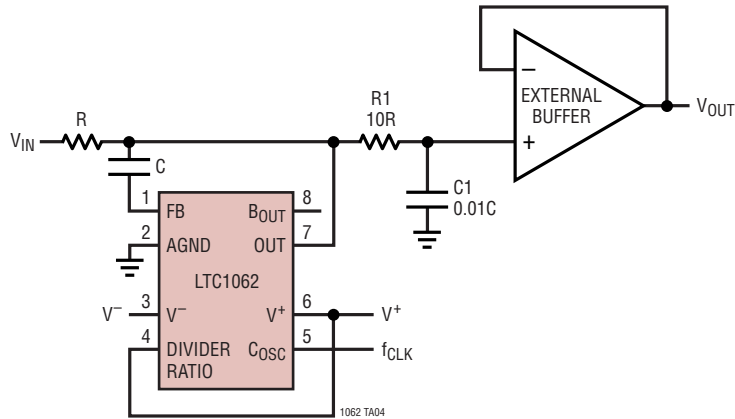
NOISE BW	RMS NOISE ($V_S = \pm 5V$)
DC – $0.1 \cdot f_C$	$2\mu V$
DC – $0.25 \cdot f_C$	$8\mu V$
DC – $0.5 \cdot f_C$	$20\mu V$
DC – $1 \cdot f_C$	$62\mu V$
DC – $2 \cdot f_C$	$100\mu V$

TYPICAL APPLICATIONS

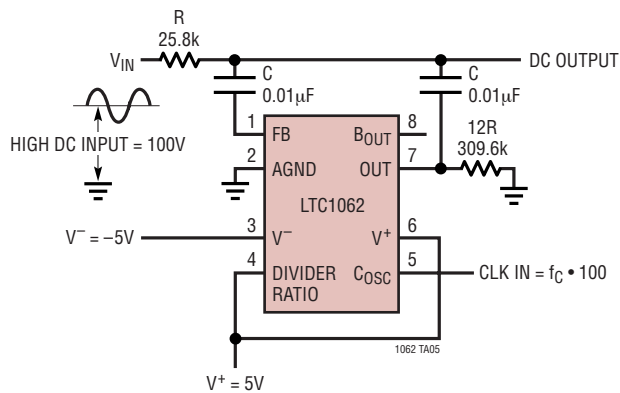
AC Coupling an External CMOS Clock Powered from a Single Positive Supply, V^+



Adding an External (R_1 , C_1) to Eliminate the Clock Feedthrough and to Improve the High Frequency Attenuation Floor

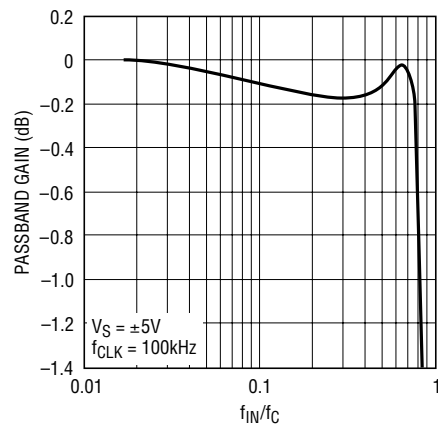


Filtering AC Signals from High DC Voltages



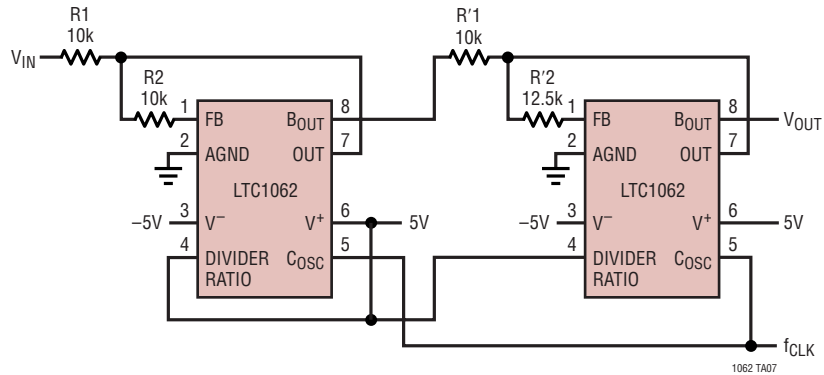
EXAMPLE:
 $f_{CLK} = 100\text{kHz}$, $f_C = 1\text{kHz}$. THE FILTER ACCURATELY PASSES THE HIGH DC INPUT AND ACTS AS 5TH ORDER LP FILTER FOR THE AC SIGNALS RIDING ON THE DC

Passband Amplitude Response for the High DC Accurate 5th Order Filter



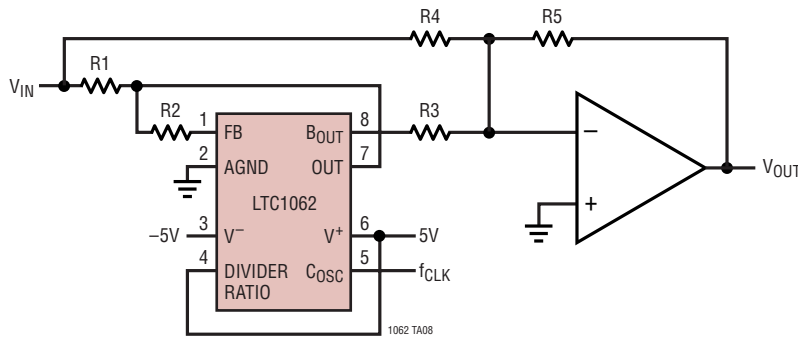
TYPICAL APPLICATIONS

Cascading Two LTC1062s to Form a Very Selective Clock Sweepable Bandpass Filter

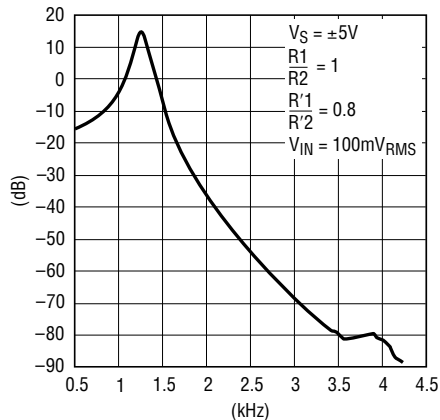


Clock Tunable Notch Filter
For Simplicity Use $R_3 = R_4 = R_5 = 10k$;

$$\frac{R_5}{R_2} = 1.234, \frac{f_{CLK}}{f_{NOTCH}} = \frac{79.3}{1}$$

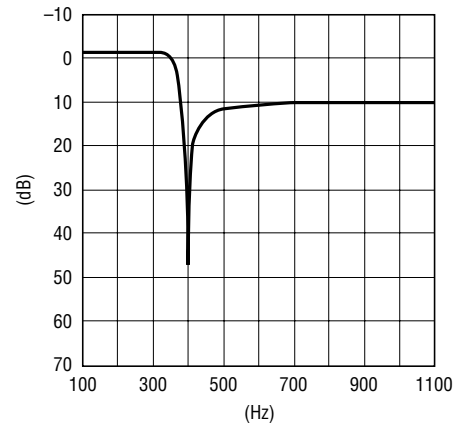


Frequency Response of the Bandpass Filter



1062 TA09

Frequency Response of the Notch Filter



1062 TA10

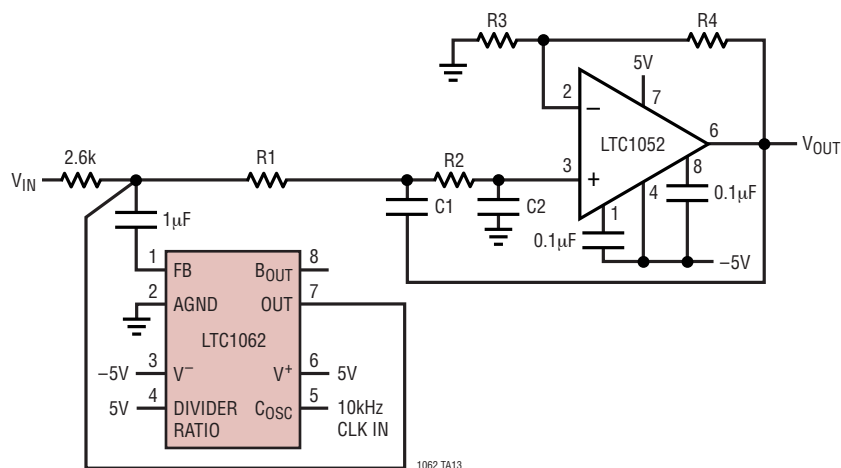
TYPICAL APPLICATIONS

The circuit diagram shows a multi-stage filter. It begins with an input voltage V_{IN} passing through a 25.8k resistor and a 1μF capacitor to the first LTC1062 op-amp. This op-amp is configured with its feedback (FB) to the output (BOUT), its inverting input (V-) to ground, and its non-inverting input (V+) to the output of the second LTC1062. The second LTC1062 has its feedback (FB) to the output (BOUT), its inverting input (V-) to ground, and its non-inverting input (V+) to the output of the LTC1052. The LTC1052 is configured as a voltage follower with its output (6) connected to its inverting input (2). Its non-inverting input (3) receives the signal from the second LTC1062. Both LTC1062 op-amps have their divider ratio (DIVIDER RATIO) set to 10 and their clock input (COSC) to 10kHz. The LTC1052 is powered by a 5V supply (pin 7) and has its output (pin 6) connected to the DC accurate output. The circuit is powered by a -5V supply and a 5V supply. A 412k resistor and a 0.1μF capacitor are used in the signal path between the two LTC1062 op-amps. The LTC1052 has two 0.1μF capacitors connected to its pins 1 and 4, which are both connected to ground. The output of the LTC1052 is labeled 'DC ACCURATE OUTPUT'.

10Hz, 10TH ORDER DC ACCURATE LOWPASS FILTER
 60dB/OCTAVE ROLLOFF
 0.5dB PASSBAND ERROR, 0dB DC GAIN
 MAXIMUM ATTENUATION 110dB ($f_{CLK} = 10\text{kHz}$)
 100dB ($f_{CLK} = 1\text{kHz}$)
 95dB ($f_{CLK} = 1\text{MHz}$)

TYPICAL APPLICATIONS

7th Order 100Hz Lowpass Filter with Continuous Output Filtering, Output Buffering and Gain Adjustment

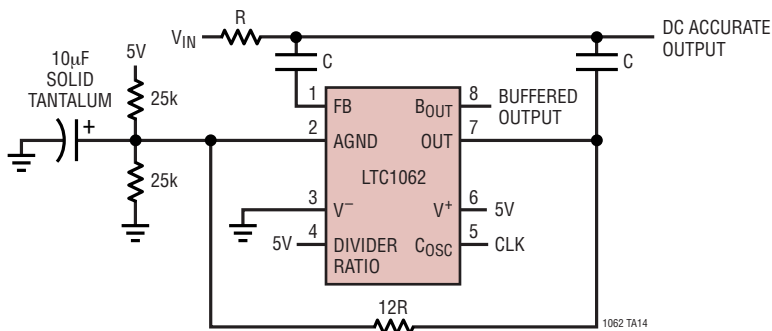


THE LTC1052 IS CONNECTED AS A 2ND ORDER SALLEN AND KEY LOWPASS FILTER WITH A CUTOFF FREQUENCY EQUAL TO THE CUTOFF FREQUENCY OF THE LTC1062. THE ADDITIONAL FILTERING ELIMINATES ANY 10kHz CLOCK FEEDTHROUGH PLUS DECREASES THE WIDEBAND NOISE OF THE FILTER
 DC OUTPUT OFFSET (REFERRED TO A DC GAIN OF UNITY) = 5μV MAX
 WIDEBAND NOISE (REFERRED TO A DC GAIN OF UNITY) = 60μVRMS

OUTPUT FILTER COMPONENT VALUES

DC GAIN	R3	R4	R1	R2	C1	C2
1	∞	0	14.3k	53.6k	0.1μF	0.033μF
10	3.57k	32.4k	46k	274k	0.01μF	0.02μF

Single 5V Supply 5th Order LP Filter

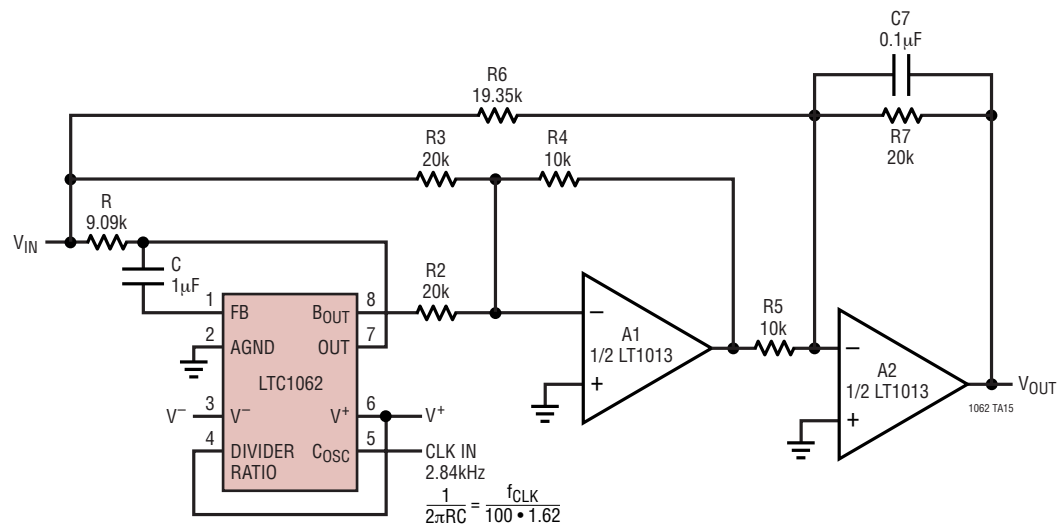


FOR A 10Hz FILTER: $R = 29.4k$, $C = 1\mu F$, $f_{CLK} = 1kHz$

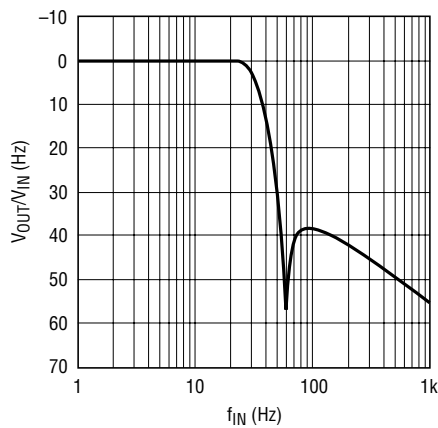
THE FILTER IS MAXIMALLY FLAT FOR $\frac{1}{2\pi RC} = \frac{f_c}{1.84}$

TYPICAL APPLICATIONS

A Lowpass Filter with a 60Hz Notch



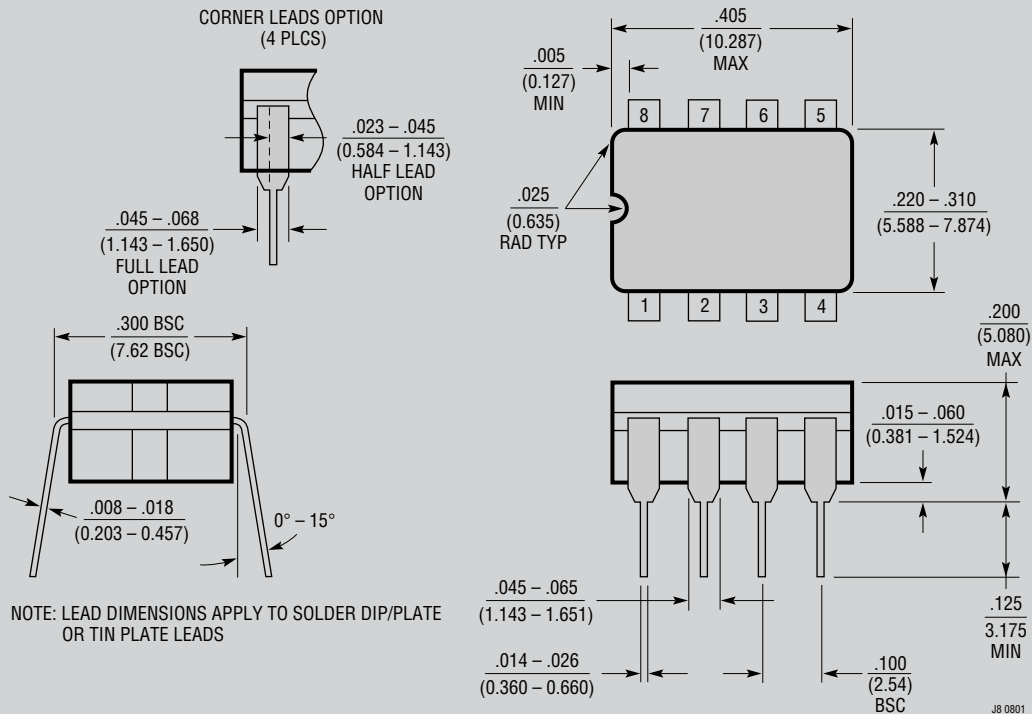
Frequency Response of the Above Lowpass Filter
with the Notch $f_{NOTCH} = f_{CLK}/47.3$



1062 TA16

PACKAGE DESCRIPTION

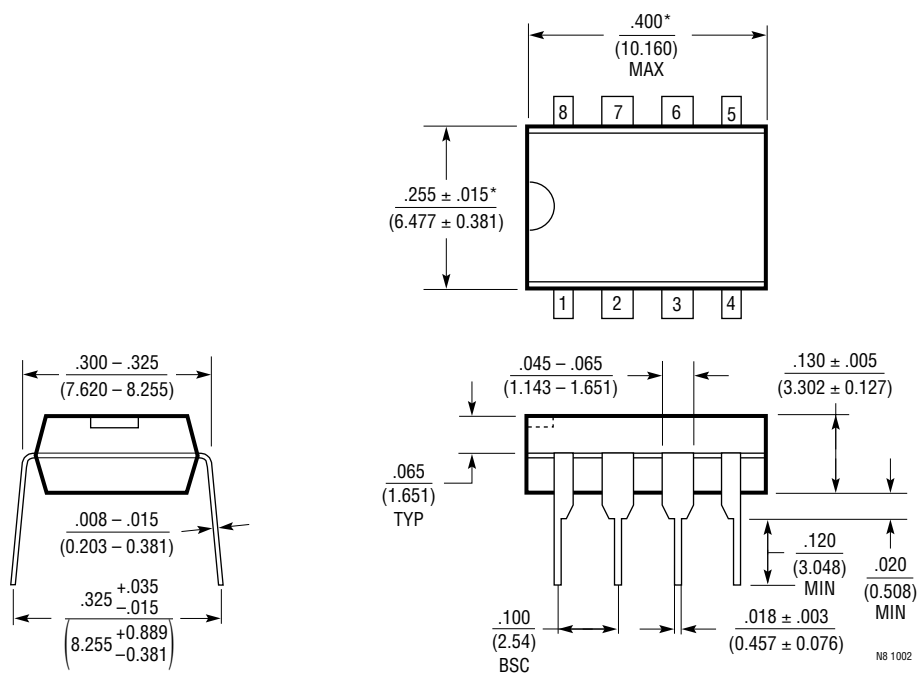
J8 Package 8-Lead Cerdip (Narrow .300 Inch, Hermetic) (Reference LTC DWG # 05-08-1110)



OBsolete PACKAGE

PACKAGE DESCRIPTION

N8 Package
8-Lead PDIP (Narrow .300 Inch)
 (Reference LTC DWG # 05-08-1510)



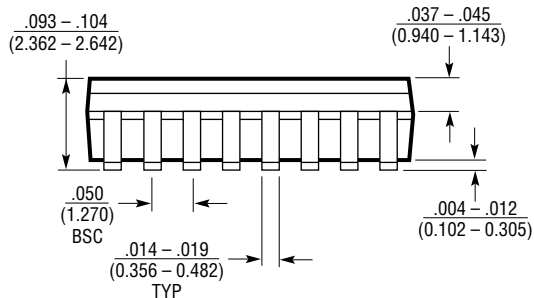
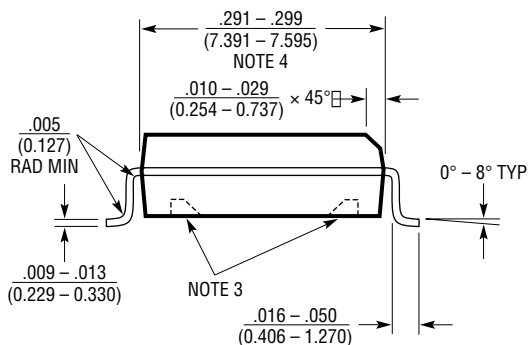
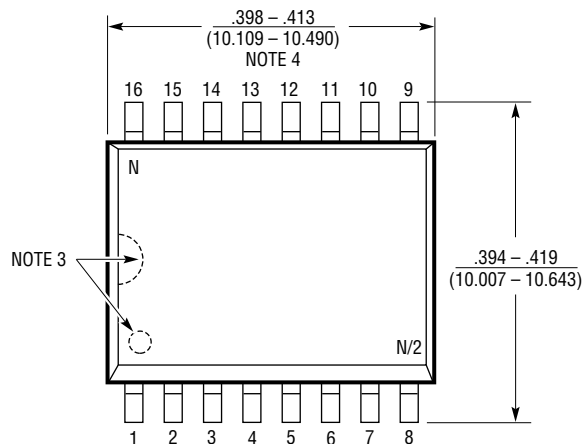
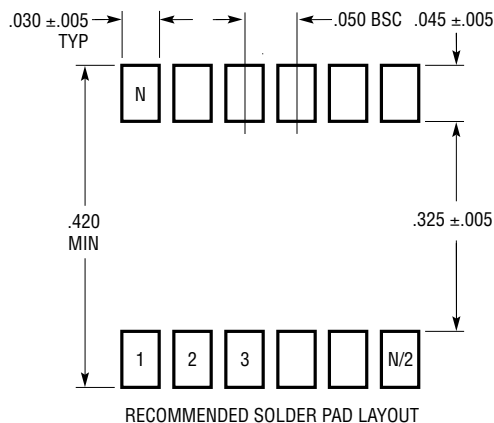
NOTE:

1. DIMENSIONS ARE $\frac{\text{INCHES}}{\text{MILLIMETERS}}$

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

PACKAGE DESCRIPTION

SW Package 16-Lead Plastic Small Outline (Wide .300 Inch) (Reference LTC DWG # 05-08-1620)



NOTE:

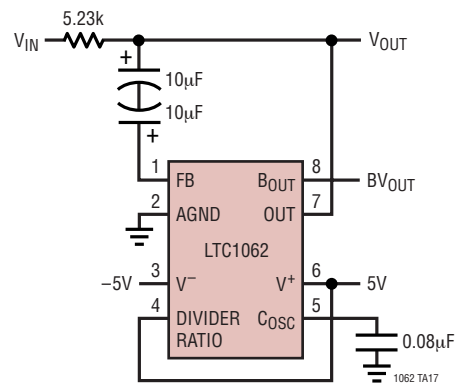
1. DIMENSIONS IN $\frac{\text{INCHES}}{\text{MILLIMETERS}}$
2. DRAWING NOT TO SCALE
3. PIN 1 IDENT. NOTCH ON TOP AND CAVITIES ON THE BOTTOM OF PACKAGES ARE THE MANUFACTURING OPTIONS. THE PART MAY BE SUPPLIED WITH OR WITHOUT ANY OF THE OPTIONS
4. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

S16 (WIDE) 0502

LTC1062

TYPICAL APPLICATION

A Low Frequency, 5Hz Filter Using Back-to-Back Solid Tantalum Capacitors



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1063	5th Order Butterworth Lowpass, DC Accurate	Clock Tunable, No External Components
LTC1065	5th Order Bessel Lowpass, DC Accurate	Clock Tunable, No External Components
LTC1066-1	8th Order Elliptic or Linear Phase, DC Accurate	Clock Tunable, $f_c \leq 120\text{kHz}$
LTC1563-2/ LTC1563-3	Active RC, 4th Order Lowpass	Very Low Noise, $256\text{Hz} \leq f_c \leq 256\text{kHz}$
LTC1564	10kHz to 150kHz Digitally Controlled Lowpass and PGA	Continuous Time, Very High Dynamic Range, PGA Included
LTC1569-6	Linear Phase, DC Accurate, 10th Order	No External Clock Required, $f_c \leq 64\text{kHz}$, S08
LTC1569-7	Linear Phase, DC Accurate, 10th Order	No External Clock Required, $f_c \leq 300\text{kHz}$, S08