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 ±8V
- 5th Order Filter
- Maximally Flat Response
- Internal or External Clock
- Cascadable for Faster Rolloff
- 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 ±2.5V to ±9V.

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

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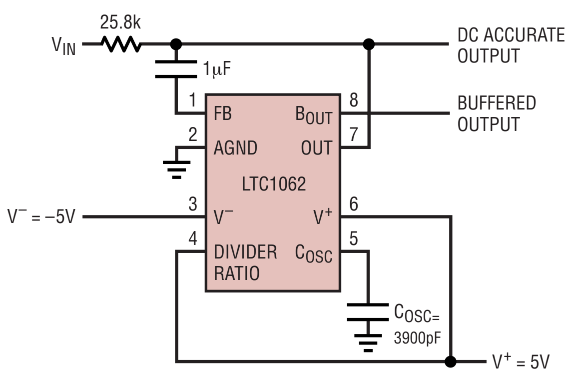
LTCMOS is a trademark of Linear Technology Corporation.

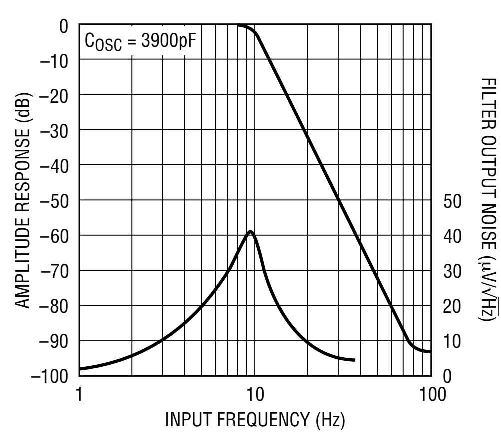
TYPICAL APPLICATION

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



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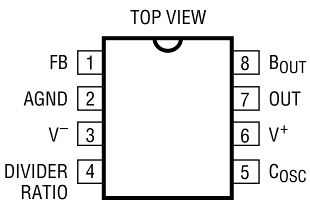
ABSOLUTE MAXIMUM RATINGS (Note 1)

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

PACKAGE/ORDER INFORMATION



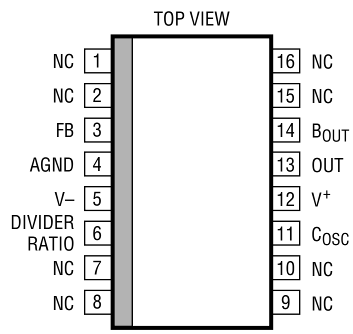
N8 PACKAGE
8-LEAD PDIP
$T_{J\,MAX} = 100°C$, $\theta_{JA} = 130°C/W$

ORDER PART NUMBER
LTC1062CN8

J8 PACKAGE 8-LEAD CERDIP
$T_{J\,MAX} = 150°C$, $\theta_{JA} = 100°C/W$

LTC1062MJ8
LTC1062CJ8

OBSOLETE PACKAGE
Consider the N8 Package as an Alternate Source



SW PACKAGE
16-LEAD PLASTIC SO
$T_{J\,MAX} = 150°C$, $\theta_{JA} = 90°C/W$

ORDER PART NUMBER
LTC1062CSW

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 $T_A = 25°C$. $V^+ = 5V$, $V^- = -5V$, 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	mA
		●			10	mA
Input Frequency Range				0 to 20		kHz
Filter Gain at $f_{IN} = 0$	$f_{CLK} = 100kHz$, Pin 4 (Pin 6 in SW16) at V^+,			0.00		dB
$f_{IN} = 0.5f_C$ (Note 2)	C = 0.01µF, R = 25.78k			–0.02	–0.3	dB
$f_{IN} = f_C$		●	–2	–3.00		dB
$f_{IN} = 2f_C$		●	–28	–30.00		dB
$f_{IN} = 4f_C$		●	–52	–60.00		dB
Clock-to-Cutoff Frequency Ratio, f_{CLK}/f_C	$f_{CLK} = 100kHz$, Pin 4 (Pin 6 in SW16) at V^+, C = 0.01µF, R = 25.78k			100 ±1		%
Filter Gain at $f_{IN} = 16kHz$	$f_{CLK} = 400kHz$, Pin 4 at V^+, C = 0.01µF, R = 6.5k	●	–43	–52		dB
f_{CLK}/f_C Tempco	$f_{CLK} = 400kHz$, Pin 4 at V^+, C = 0.01µF, R = 6.5k			10		ppm/°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}

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ELECTRICAL CHARACTERISTICS

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

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Internal Buffer						
Bias Current				2	50	pA
		●		170	1000	pA
Offset Voltage				2	20	mV
Voltage Swing	R_{LOAD} = 20k	●	±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	32	50	kHz
		●	15		65	kHz
Max Clock Frequency				4		MHz
Pin 5 (Pin 11 in SW16) Source or Sink Current		●		40	80	µA

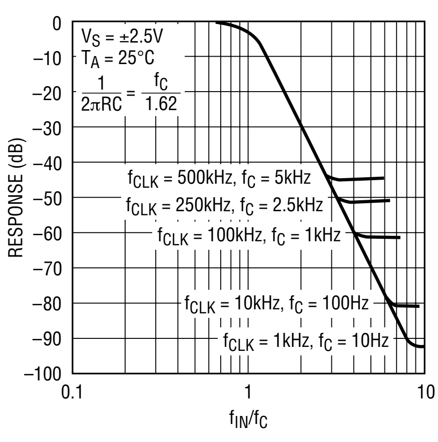
Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

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

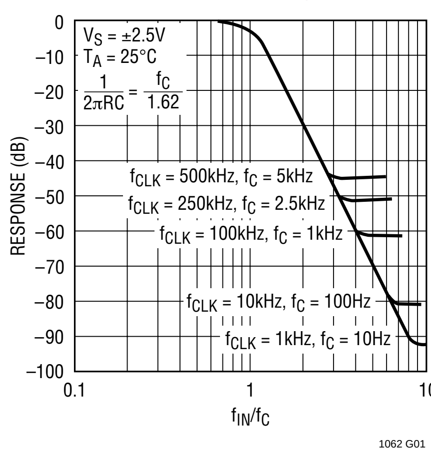
Note 3: The external or driven clock frequency is divided by either 1, 2 or 4 depending upon the voltage at Pin 4. For the N8 package, when Pin 4 = V^+, ratio = 1; when Pin 4 = GND, ratio = 2; when Pin 4 = V^-, ratio = 4.

TYPICAL PERFORMANCE CHARACTERISTICS

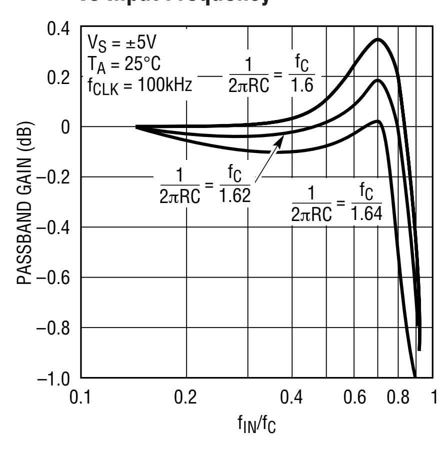
Amplitude Response Normalized to the Cutoff Frequency



Amplitude Response Normalized to the Cutoff Frequency



Passband Gain vs Input Frequency



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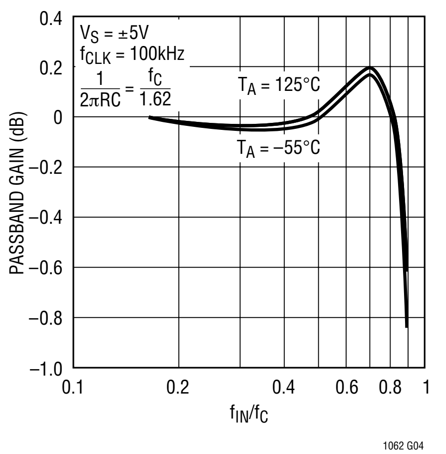
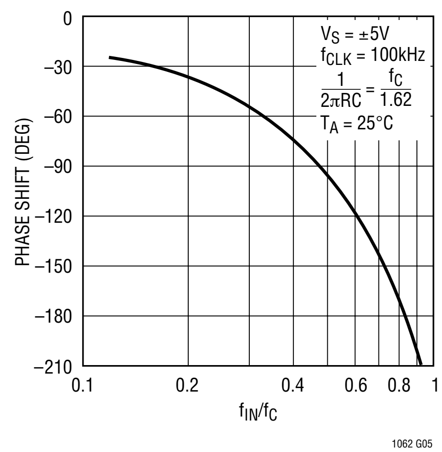
TYPICAL PERFORMANCE CHARACTERISTICS

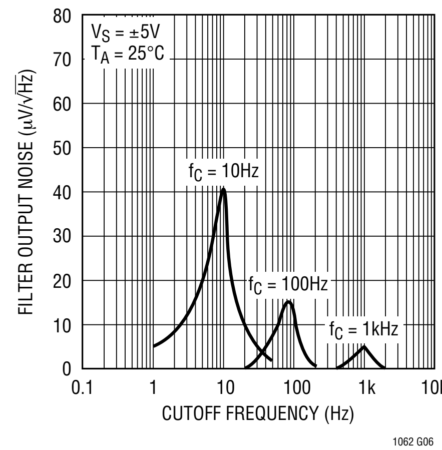
Passband Gain vs Input Frequency and Temperature



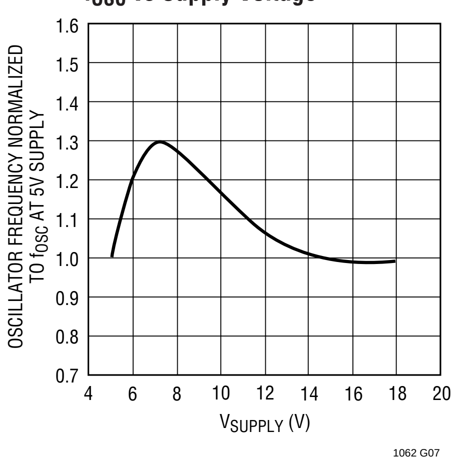
Passband Phase Shift vs Input Frequency



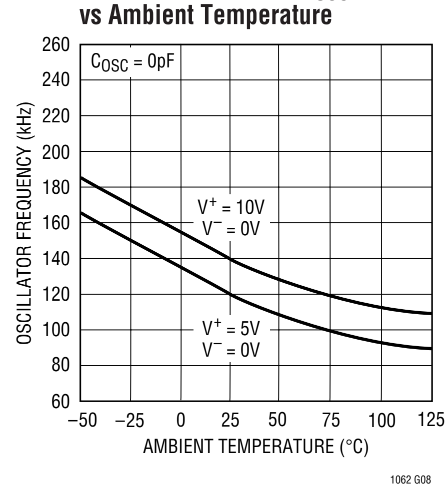
Filter Noise Spectral Density



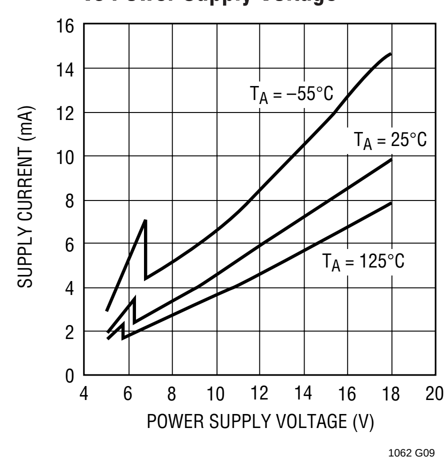
Normalized Oscillator Frequency, f_{OSC} vs Supply Voltage



Oscillator Frequency, f_{OSC} vs Ambient Temperature



Power Supply Current vs Power Supply Voltage



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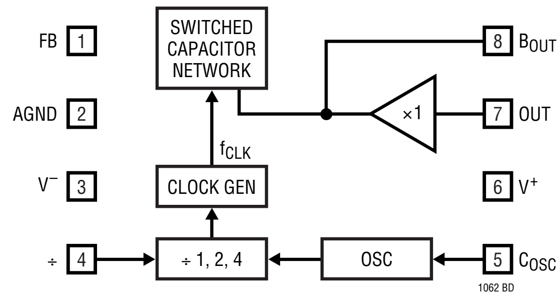
BLOCK DIAGRAM

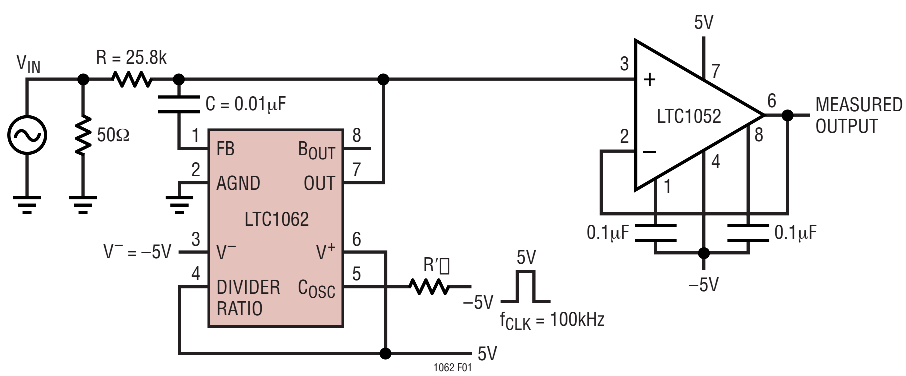
For Adjusting Oscillator Frequency, Insert a 50k Pot in Series with C_{OSC}. Use Two Times Calculated C_{OSC}



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 ±5V SUPPLIES, THE INTERNAL OSCILLATOR FREQUENCY IS:

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

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

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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 $0.8 \bullet f_C$, the gain is 1.7V/V and, with ±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.

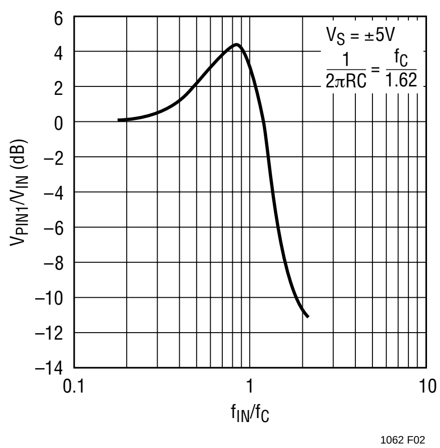

Figure 2. Amplitude Response of Pin 1

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 1μV/°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 ±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

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APPLICATIONS INFORMATION

Divide By 1, 2, 4 (Pin 4)

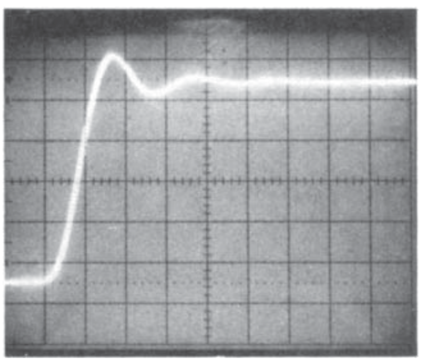
By connecting Pin 4 to V^+, to mid supplies or to V^-, the clock frequency driving the internal switched capacitor network is the oscillator frequency divided by 1, 2, 4 respectively. Note that the f_{CLK}/f_C ratio of 100:1 is with respect to the internal clock generator output frequency. The internal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

Transient Response

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

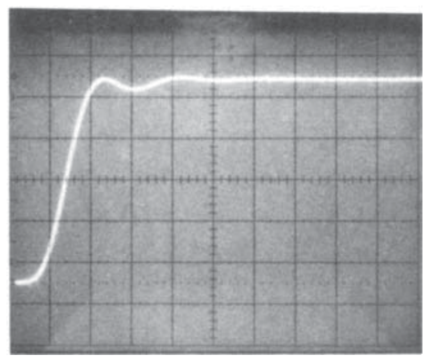
Filter Noise

The filter wideband RMS noise is typically $100\mu V_{RMS}$ for ±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 • f_C. This is shown in the Typical Performance Characteristics section. Table 2 shows the LTC1062 RMS noise for different noise bandwidths.

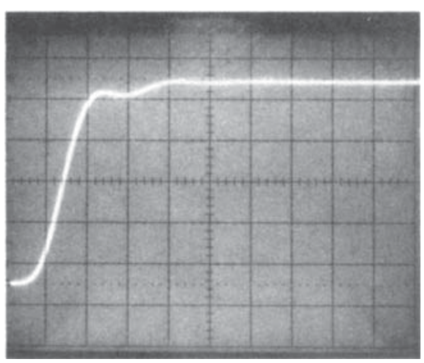


200mV/VERT DIV
50ms/HORIZ DIV, f_C = 10Hz
5ms/HORIZ DIV, f_C = 100Hz
0.5ms/HORIZ DIV, f_C = 1kHz

$$\frac{1}{2\pi RC} = \frac{f_C}{1.62}$$



$$\frac{1}{2\pi RC} = \frac{f_C}{1.94}$$



$$\frac{1}{2\pi RC} = \frac{f_C}{2.11}$$

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

Table 2

NOISE BW	RMS NOISE (V_S = ±5V)
DC – 0.1 • f_C	2μV
DC – 0.25 • f_C	8μV
DC – 0.5 • f_C	20μV
DC – 1 • f_C	62μV
DC – 2 • f_C	100μV

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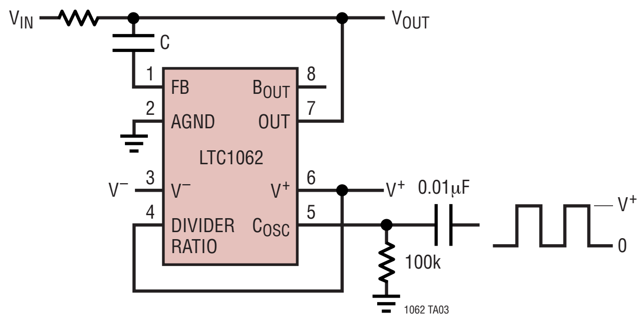
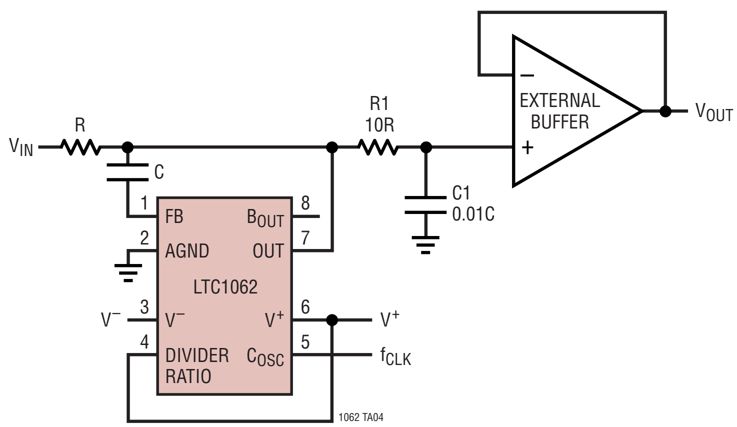
TYPICAL APPLICATIONS

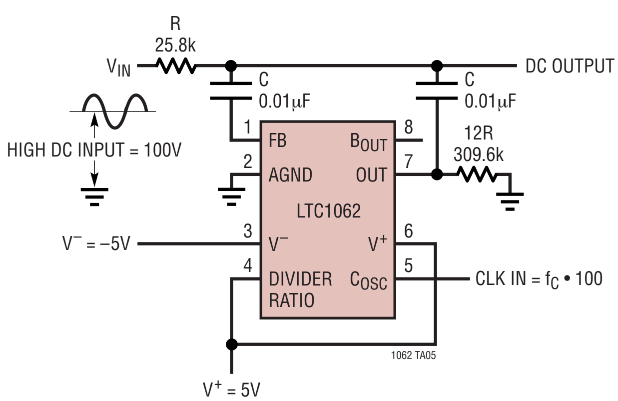
AC Coupling an External CMOS Clock Powered from a Single Positive Supply, V+



Adding an External (R1, C1) to Eliminate the Clock Feedthrough and to Improve the High Frequency Attenuation Floor

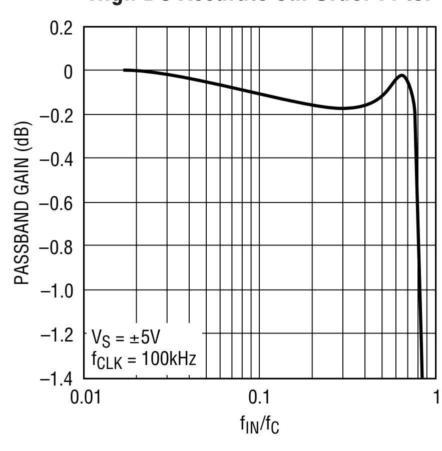


Filtering AC Signals from High DC Voltages



EXAMPLE:
f_{CLK} = 100KHz, f_C = 1kHz. 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



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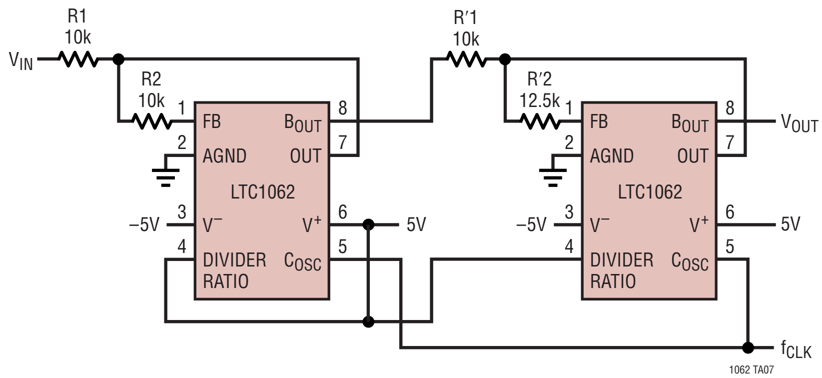
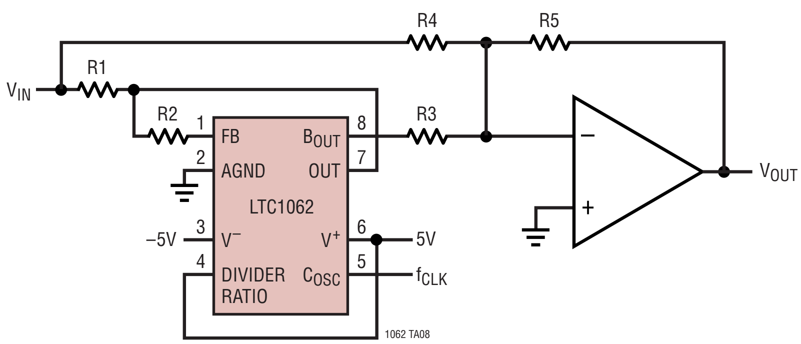
TYPICAL APPLICATIONS

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

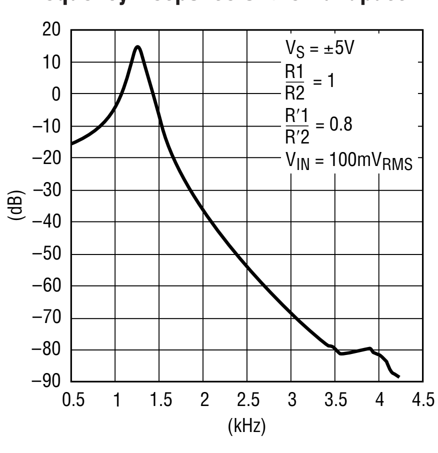


Clock Tunable Notch Filter
For Simplicity Use R3 = R4 = R5 = 10k;

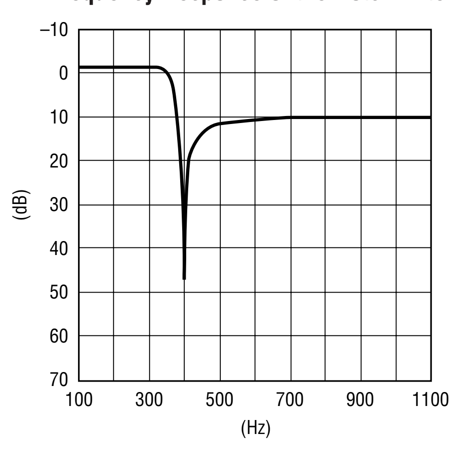
$$\frac{R5}{R2} = 1.234, \frac{f_{CLK}}{f_{NOTCH}} = \frac{79.3}{1}$$



Frequency Response of the Bandpass Filter



Frequency Response of the Notch Filter



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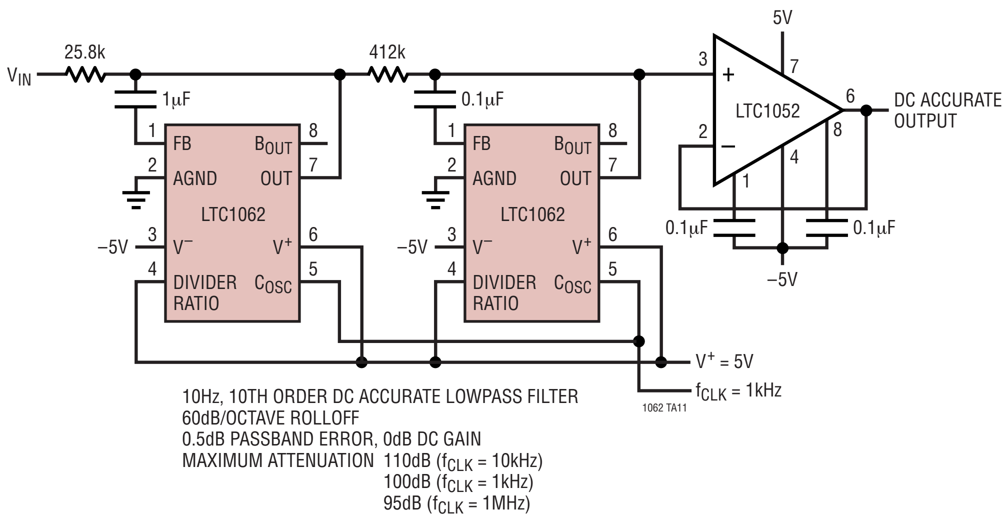
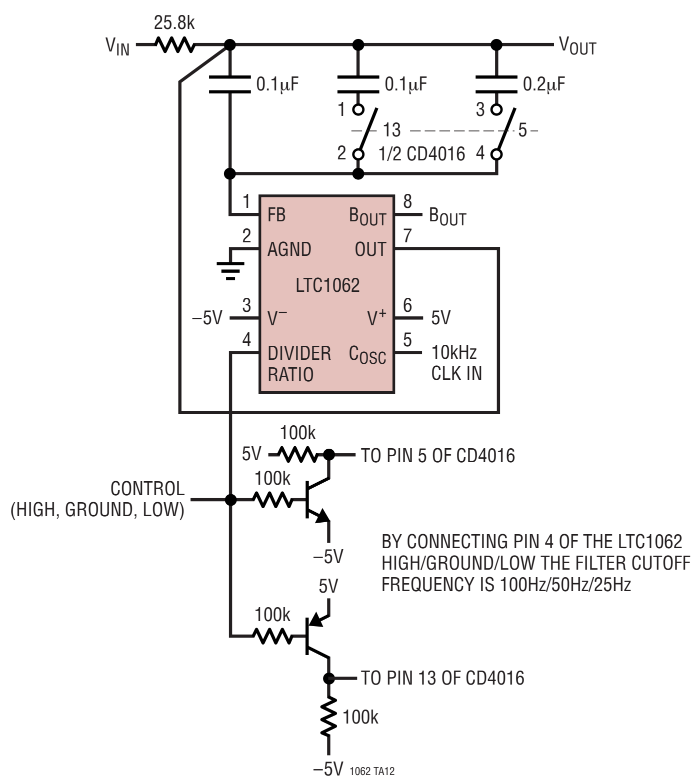
TYPICAL APPLICATIONS

Simple Cascading Technique



100Hz, 50Hz, 25Hz 5th Order DC Accurate LP Filter



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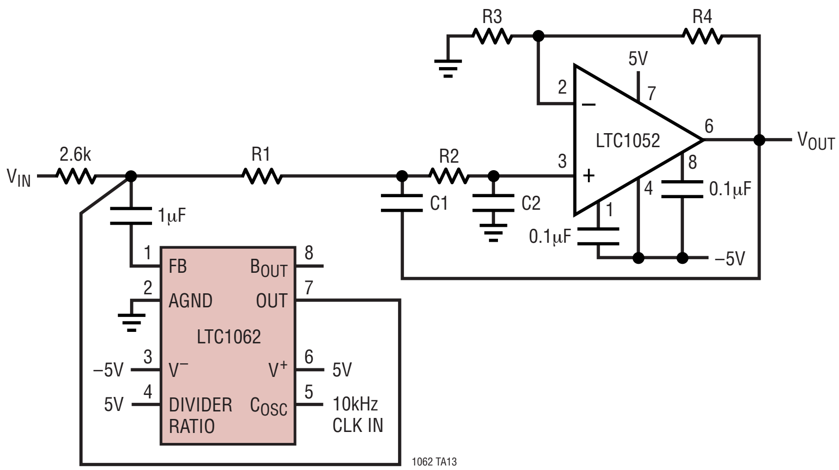
TYPICAL APPLICATIONS

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

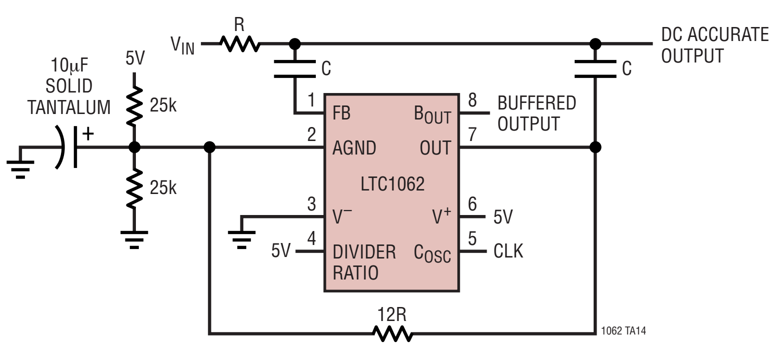
DC OUTPUT OFFSET (REFERRED TO A DC GAIN OF UNITY) = 5µV MAX

WIDEBAND NOISE (REFERRED TO A DC GAIN OF UNITY) = 60µV_{RMS}

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 = 1µF, f_{CLK} = 1kHz

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

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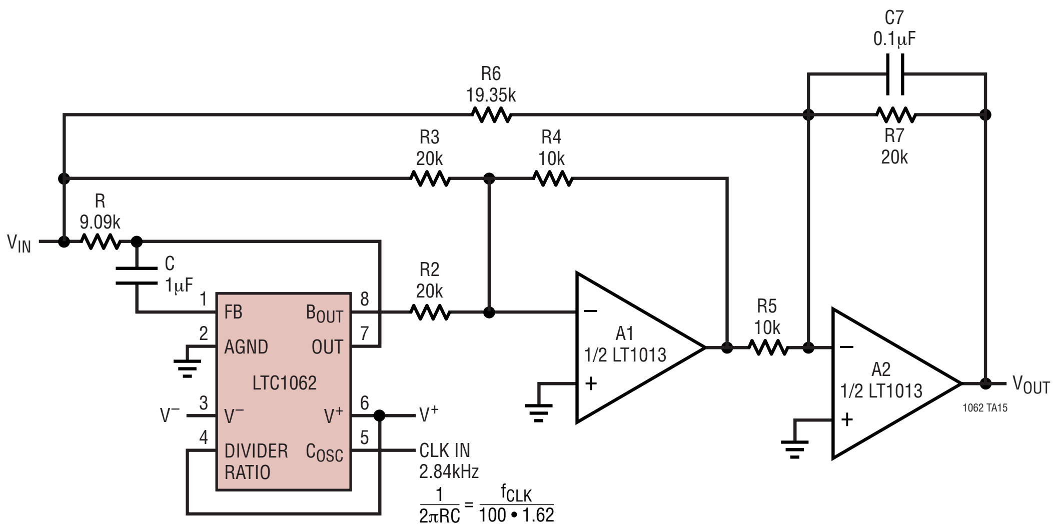
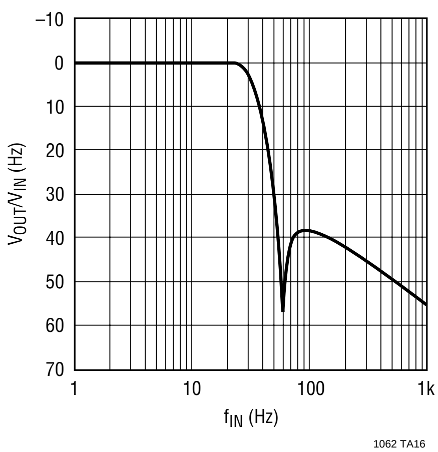
TYPICAL APPLICATIONS

A Lowpass Filter with a 60Hz Notch



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



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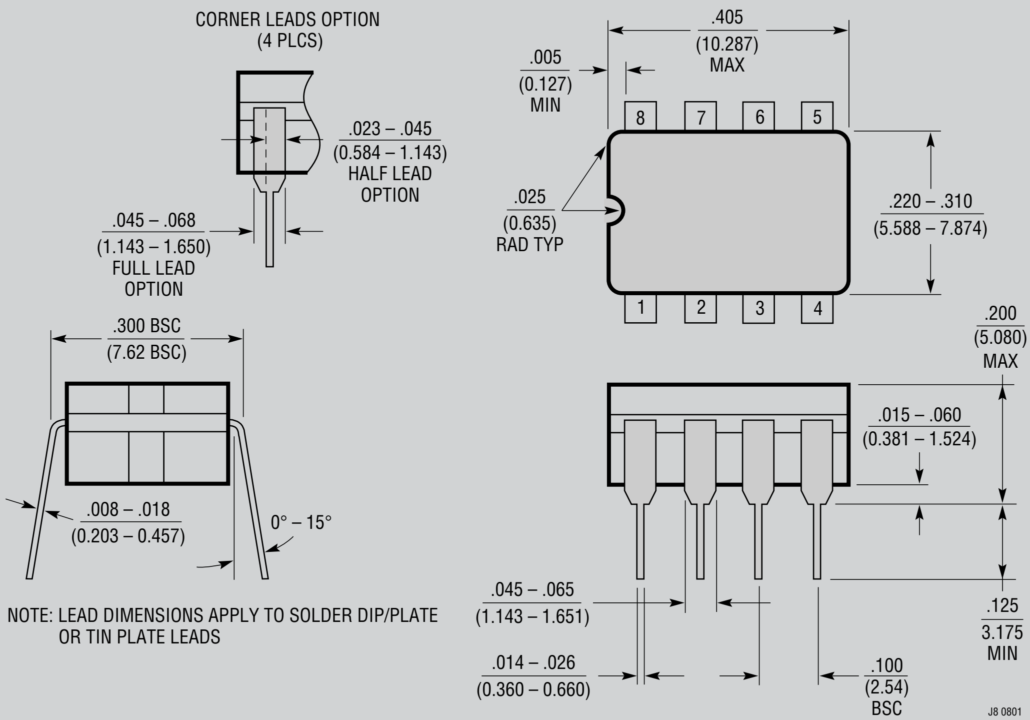
PACKAGE DESCRIPTION

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



NOTE: LEAD DIMENSIONS APPLY TO SOLDER DIP/PLATE OR TIN PLATE LEADS

OBSOLETE PACKAGE

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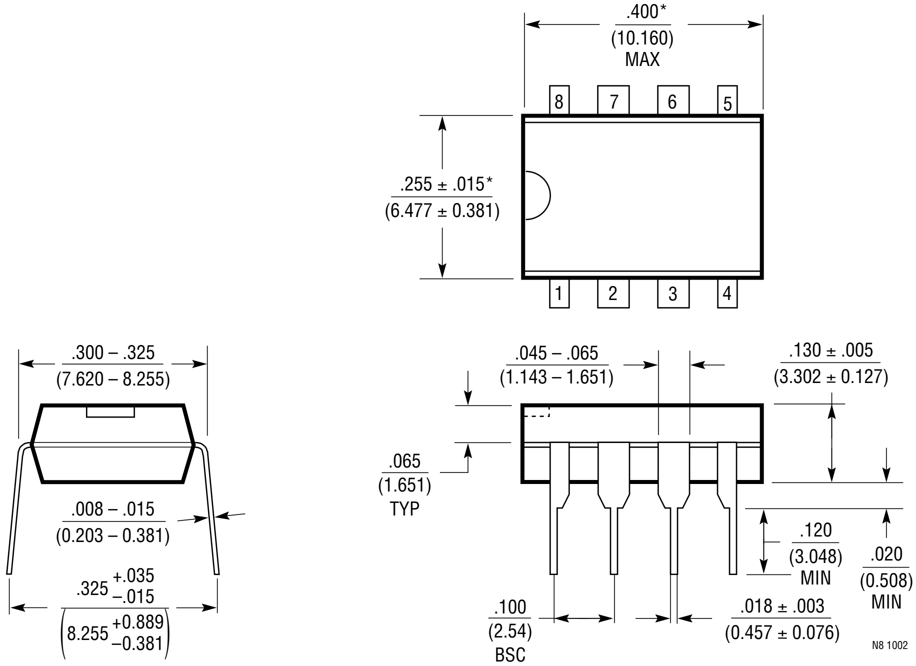
PACKAGE DESCRIPTION

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)

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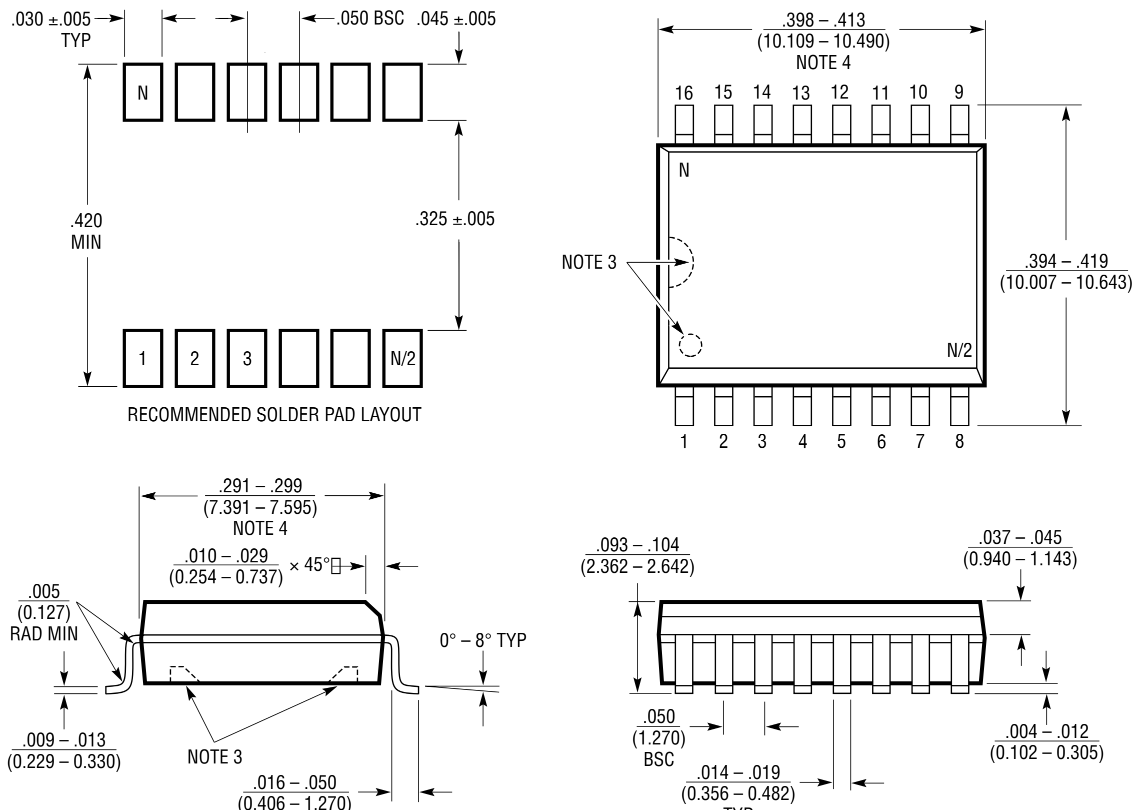
PACKAGE DESCRIPTION

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

LINEAR TECHNOLOGY

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

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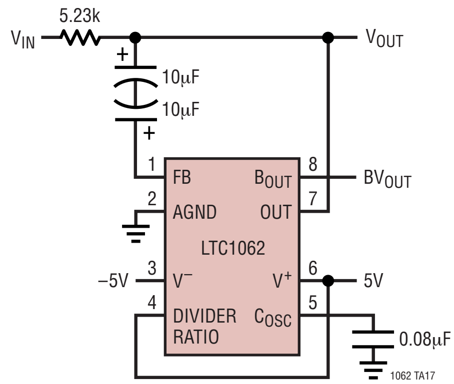
TYPICAL APPLICATION

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, fc ≤ 120kHz
LTC1563-2/ LTC1563-3	Active RC, 4th Order Lowpass	Very Low Noise, 256Hz ≤ fc ≤ 256kHz
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, fc ≤ 64kHz, S08
LTC1569-7	Linear Phase, DC Accurate, 10th Order	No External Clock Required, fc ≤ 300kHz, S08

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