

# DC Accurate, Clock-Tunable 5th Order Butterworth Lowpass Filter

## FEATURES

- Clock-Tunable Cutoff Frequency
- 1mV DC Offset (Typical)
- 80dB CMRR (Typical)
- Internal or External Clock
- 50 $\mu$ V<sub>RMS</sub> Clock Feedthrough
- 100:1 Clock-to-Cutoff Frequency Ratio
- 95 $\mu$ V<sub>RMS</sub> Total Wideband Noise
- 0.01% THD at 2V<sub>RMS</sub> Output Level
- 50kHz Maximum Cutoff Frequency
- Cascadable for Faster Roll-Off
- Operates from  $\pm 2.375$  to  $\pm 8$ V Power Supplies
- Self-Clocking with 1 RC

## APPLICATIONS

- Audio
- Strain Gauge Amplifiers
- Anti-Aliasing Filters
- Low Level Filtering
- Digital Voltmeters
- 60Hz Lowpass Filters
- Smoothing Filters
- Reconstruction Filters

## DESCRIPTION

The LTC1063 is the first monolithic filter providing both clock-tunability, low DC output offset and over 12-bit DC accuracy. The frequency response of the LTC1063 closely approximates a 5th order Butterworth polynomial. With appropriate PCB layout techniques the output DC offset is typically 1mV and is constant over a wide range of clock frequencies. With  $\pm 5$ V supplies and  $\pm 4$ V input voltage range, the CMR of the device is 80dB.

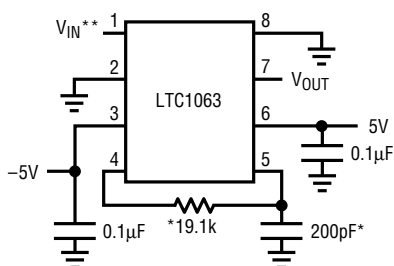
The filter cutoff frequency is controlled either by an internal or external clock. The clock-to-cutoff frequency ratio is 100:1. The on-board clock is power supply independent, and it is programmed via an external RC. The 50 $\mu$ V<sub>RMS</sub> clock feedthrough is considerably reduced over existing monolithic filters.

The LTC1063 wideband noise is 95 $\mu$ V<sub>RMS</sub>, and it can process large AC input signals with low distortion. With  $\pm 7.5$ V supplies, for instance, the filter handles up to 4V<sub>RMS</sub> (92dB S/N ratio) while the standard 1kHz THD is below 0.02%; 80dB dynamic ranges (S/N +THD) is obtained with input levels between 1V<sub>RMS</sub> and 2.3V<sub>RMS</sub>.

The LTC1063 is available in 8-pin miniDIP and 16-pin SOL. For a linear phase response, see LTC1065 data sheet.

## TYPICAL APPLICATION

2.5kHz 5th Order Lowpass Filter

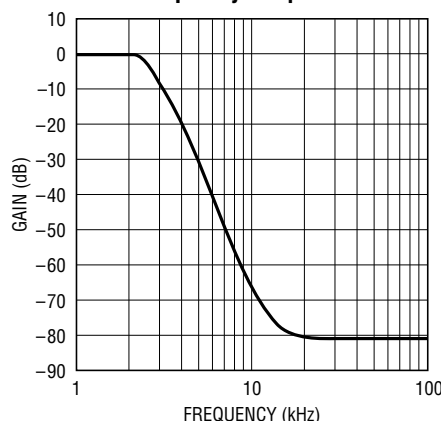


\* SELF-CLOCKING SCHEME

\*\* IF THE INPUT VOLTAGE CAN EXCEED V<sup>+</sup>,  
CONNECT A SIGNAL DIODE BETWEEN PIN 1 AND V<sup>+</sup>.

1063 TA01

Frequency Response



1063 TA02

## ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage ( $V^+$  to  $V^-$ ) ..... 16.5V  
 Power Dissipation ..... 400mW  
 Voltage at Any Input .... ( $V^- - 0.3V$ )  $\leq V_{IN} \leq (V^+ + 0.3V)$   
 Burn-In Voltage ..... 16V

Operating Temperature Range .....  $-40^\circ\text{C}$  to  $85^\circ\text{C}$   
 Storage Temperature Range .....  $-65^\circ\text{C}$  to  $150^\circ\text{C}$   
 Lead Temperature (Soldering, 10 sec) .....  $300^\circ\text{C}$

## PACKAGE/ORDER INFORMATION

|                                                                                                                                                                                                                                                                                                           |                                                                          |                                                                                                                                                          |                                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| <p>TOP VIEW</p> <p>J8 PACKAGE<br/>8-LEAD CERAMIC DIP</p> <p>N8 PACKAGE<br/>8-LEAD PLASTIC DIP</p> <p><math>T_{JMAX} = 150^\circ\text{C}</math>, <math>\theta_{JA} = 100^\circ\text{C/W}</math> (J)<br/> <math>T_{JMAX} = 100^\circ\text{C}</math>, <math>\theta_{JA} = 110^\circ\text{C/W}</math> (N)</p> | <p>ORDER PART NUMBER</p> <p>LTC1063CN8<br/>LTC1063CJ8<br/>LTC1063MJ8</p> | <p>TOP VIEW</p> <p>S PACKAGE<br/>16-LEAD PLASTIC SOL</p> <p><math>T_{JMAX} = 100^\circ\text{C}</math>, <math>\theta_{JA} = 85^\circ\text{C/W}</math></p> | <p>ORDER PART NUMBER</p> <p>LTC1063CS</p> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|

## ELECTRICAL CHARACTERISTICS

$V_S = \pm 5V$ ,  $f_{CLK} = 500\text{kHz}$ ,  $f_C = 5\text{kHz}$ ,  $R_L = 10k$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified.

| PARAMETER                                         | CONDITIONS                                                                                  | MIN             | TYP            | MAX            | UNITS    |
|---------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------|----------------|----------------|----------|
| Clock-to-Cutoff Frequency Ratio ( $f_{CLK}/f_C$ ) | $\pm 2.375V \leq V_S \leq \pm 7.5V$                                                         |                 | 100 $\pm$ 0.5  |                |          |
| Maximum Clock Frequency (Note 1)                  | $V_S = \pm 7.5V$                                                                            |                 | 5              |                | MHz      |
|                                                   | $V_S = \pm 5V$                                                                              |                 | 4              |                | MHz      |
|                                                   | $V_S = \pm 2.5V$                                                                            |                 | 3              |                | MHz      |
| Minimum Clock Frequency (Note 2)                  | $\pm 2.5V \leq V_S \leq \pm 7.5V$ , $T_A < 85^\circ\text{C}$                                |                 | 30             |                | Hz       |
| Input Frequency Range                             |                                                                                             | 0               |                | $0.9f_{CLK}$   |          |
| Filter Gain                                       | $V_S = \pm 5V$ , $f_{CLK} = 25\text{kHz}$ , $f_C = 250\text{Hz}$<br>$f_{IN} = 250\text{Hz}$ | -3.5<br>-3.6    | -3.0<br>-3.0   | -2.5<br>-2.4   | dB<br>dB |
|                                                   | $V_S = \pm 5V$ , $f_{CLK} = 500\text{kHz}$ , $f_C = 5\text{kHz}$<br>$f_{IN} = 100\text{Hz}$ |                 | 0              |                | dB       |
|                                                   | $f_{IN} = 1\text{kHz} = 0.2f_C$                                                             | -0.06<br>-0.075 | -0.01<br>-0.01 | 0.04<br>0.055  | dB<br>dB |
|                                                   | $f_{IN} = 2.5\text{kHz} = 0.5f_C$                                                           | -0.09<br>-0.14  | 0.16<br>0.16   | 0.41<br>0.46   | dB<br>dB |
|                                                   | $f_{IN} = 4\text{kHz} = 0.8f_C$                                                             | -0.5<br>-0.6    | -0.2<br>-0.2   | 0.1<br>0.2     | dB<br>dB |
|                                                   | $f_{IN} = 5\text{kHz} = f_C$                                                                | -3.5<br>-3.6    | -3.0<br>-3.0   | -2.5<br>-2.4   | dB<br>dB |
|                                                   | $f_{IN} = 20\text{kHz} = 4f_C$                                                              | -57.5<br>-57.0  | -60.0<br>-60.0 | -62.0<br>-62.5 | dB<br>dB |
|                                                   |                                                                                             |                 |                |                |          |
|                                                   |                                                                                             |                 |                |                |          |
|                                                   |                                                                                             |                 |                |                |          |

**ELECTRICAL CHARACTERISTICS** $V_S = \pm 5V$ ,  $f_{CLK} = 500kHz$ ,  $f_C = 5kHz$ ,  $R_L = 10k$ ,  $T_A = 25^\circ C$ , unless otherwise specified.

| PARAMETER                             | CONDITIONS                                                                                     |   | MIN                  | TYP            | MAX            | UNITS            |
|---------------------------------------|------------------------------------------------------------------------------------------------|---|----------------------|----------------|----------------|------------------|
| Filter Gain                           | $V_S = \pm 2.375V$ , $f_{CLK} = 500kHz$ , $f_C = 5kHz$<br>$f_{IN} = 1kHz$                      | ● | -0.066<br>-0.081     | 0.004<br>0.004 | 0.074<br>0.089 | dB<br>dB         |
|                                       | $f_{IN} = 2.5kHz$                                                                              | ● | -0.24<br>-0.29       | 0.16<br>0.16   | 0.56<br>0.61   | dB<br>dB         |
|                                       | $f_{IN} = 4kHz$                                                                                | ● | -0.6<br>-0.7         | -0.2<br>-0.2   | 0.2<br>0.3     | dB<br>dB         |
|                                       | $f_{IN} = 5kHz$                                                                                | ● | -3.5<br>-3.6         | -3.0<br>-3.0   | -2.5<br>-2.4   | dB<br>dB         |
|                                       |                                                                                                |   |                      |                |                |                  |
|                                       |                                                                                                |   |                      |                |                |                  |
| Clock Feedthrough                     | $\pm 2.375 \leq V_S \leq \pm 7.5V$                                                             |   |                      | 50             |                | $\mu V_{RMS}$    |
| Wideband Noise (Note 3)               | $\pm 2.375 \leq V_S \leq \pm 7.5V$ , $1Hz < f < f_{CLK}$                                       |   |                      | 100            |                | $\mu V_{RMS}$    |
| THD + Wideband Noise (Note 4)         | $V_S = \pm 7.5V$ , $f_C = 20kHz$ , $f_{IN} = 1kHz$ ,<br>$1V_{RMS} \leq V_{IN} \leq 2.3V_{RMS}$ |   |                      | -80            |                | dB               |
| Filter Output $\pm$ DC Swing          | $V_S = \pm 2.375V$                                                                             | ● | 1.6/-2.0<br>1.4/-1.8 | 1.7/-2.2       |                | V<br>V           |
|                                       | $V_S = \pm 5V$                                                                                 | ● | 4.0/-4.5<br>3.8/-4.3 | 4.3/-4.8       |                | V<br>V           |
|                                       | $V_S = \pm 7.5V$                                                                               | ● | 6.5/-7.0<br>6.3/-6.8 | 6.8/-7.3       |                | V<br>V           |
|                                       |                                                                                                |   |                      |                |                |                  |
|                                       |                                                                                                |   |                      |                |                |                  |
|                                       |                                                                                                |   |                      |                |                |                  |
| Input Bias Current                    |                                                                                                |   |                      | 10             |                | nA               |
| Dynamic Input Impedance               |                                                                                                |   |                      | 800            |                | M $\Omega$       |
| Output DC Offset (Note 5)             | $V_S = \pm 2.375V$                                                                             |   |                      | 2              |                | mV               |
|                                       | $V_S = \pm 5V$                                                                                 |   |                      | 0              | $\pm 5$        | mV               |
|                                       | $V_S = \pm 7.5V$                                                                               |   |                      | -4             |                | mV               |
| Output DC Offset Drift                | $V_S = \pm 2.375V$                                                                             |   |                      | 10             |                | $\mu V/^\circ C$ |
|                                       | $V_S = \pm 5V$                                                                                 |   |                      | 20             |                | $\mu V/^\circ C$ |
|                                       | $V_S = \pm 7.5V$                                                                               |   |                      | 25             |                | $\mu V/^\circ C$ |
|                                       |                                                                                                |   |                      |                |                |                  |
| Self-Clocking Frequency ( $f_{osc}$ ) | $R$ (Pin 4 to 5) = 20k, $C$ (Pin 5 to GND) = 470pF<br>$V_S = \pm 2.375V$                       |   |                      |                |                |                  |
|                                       | LTC1063CN, CS, CJ                                                                              | ● | 99                   | 105            | 112            | kHz              |
|                                       | LTC1063MJ                                                                                      | ● | 95                   | 103            | 111            | kHz              |
|                                       |                                                                                                |   | 92                   | 100            | 108            | kHz              |
|                                       | $V_S = \pm 5V$                                                                                 |   |                      |                |                |                  |
|                                       | LTC1063CN, CS, CJ                                                                              | ● | 102                  | 108            | 114            | kHz              |
|                                       | LTC1063MJ                                                                                      | ● | 98                   | 106            | 114            | kHz              |
|                                       |                                                                                                | ● | 97                   | 105            | 114            | kHz              |
|                                       | $V_S = \pm 7.5V$                                                                               |   |                      |                |                |                  |
|                                       | LTC1063CN, CS, CJ                                                                              | ● | 104                  | 110            | 116            | kHz              |
| External CLK Pin Logic Thresholds     | $V_S = \pm 2.375V$                                                                             |   |                      | 1.43           |                | V                |
|                                       | Min Logical "1"                                                                                |   |                      | 0.47           |                | V                |
|                                       | $V_S = \pm 5V$                                                                                 |   |                      | 3              |                | V                |
|                                       | Min Logical "1"                                                                                |   |                      | 1              |                | V                |
|                                       | $V_S = \pm 7.5V$                                                                               |   |                      | 4.5            |                | V                |
|                                       | Min Logical "1"                                                                                |   |                      | 1.5            |                | V                |
| Power Supply Current                  | $V_S = \pm 2.375V$ , $f_{CLK} = 500kHz$                                                        |   |                      | 2.7            | 4.0            | mA               |
|                                       | LTC1063CN, CS, CJ                                                                              | ● |                      |                | 5.5            | mA               |
|                                       | LTC1063MJ                                                                                      | ● |                      |                | 6.0            | mA               |
|                                       | $V_S = \pm 5V$ , $f_{CLK} = 500kHz$                                                            |   |                      | 5.5            | 8              | mA               |
|                                       | LTC1063CN, CS, CJ                                                                              | ● |                      |                | 11             | mA               |
|                                       | LTC1063MJ                                                                                      | ● |                      |                | 12             | mA               |
|                                       | $V_S = \pm 7.5V$ , $f_{CLK} = 500kHz$                                                          |   |                      | 7.0            | 11             | mA               |
|                                       | LTC1063CN, CS, CJ                                                                              | ● |                      |                | 14.5           | mA               |
|                                       | LTC1063MJ                                                                                      | ● |                      |                | 16.0           | mA               |

## ELECTRICAL CHARACTERISTICS

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

**Note 1:** The maximum clock frequency criterion is arbitrarily defined as: The frequency at which the filter AC response exhibits  $\geq 1$ dB of gain peaking.

**Note 2:** At limited temperature ranges (i.e.,  $T_A \leq 50^\circ\text{C}$ ) the minimum clock frequency can be as low as 10Hz. The minimum clock frequency is arbitrarily defined as: the clock frequency at which the output DC offset changes by more than 1mV.

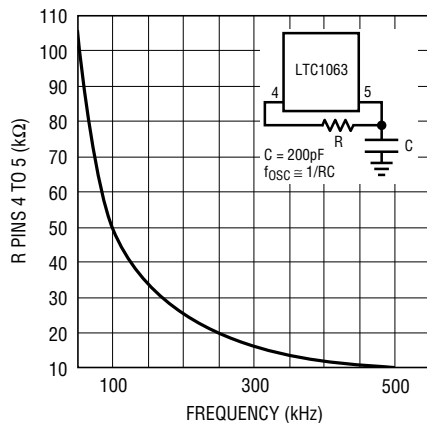
**Note 3:** The wideband noise specification does not include the clock feedthrough.

**Note 4:** To properly evaluate the filter's harmonic distortion an inverting output buffer is recommended as shown in the Test Circuit. An output buffer is not necessarily needed when measuring output DC offset or wideband noise.

**Note 5:** The output DC offset is optimized for  $\pm 5\text{V}$  supply. The output DC offset shifts when the power supplies change; however this phenomenon is repeatable and predictable.

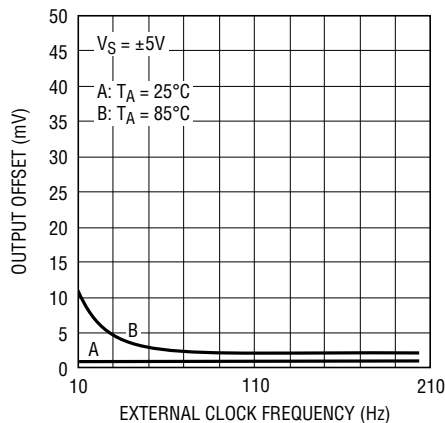
## TYPICAL PERFORMANCE CHARACTERISTICS

Self-Clocking Frequency vs R



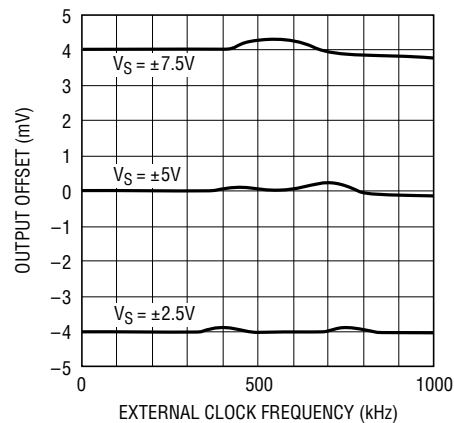
1063 G01

Output Offset vs Clock, Low Clock Rates



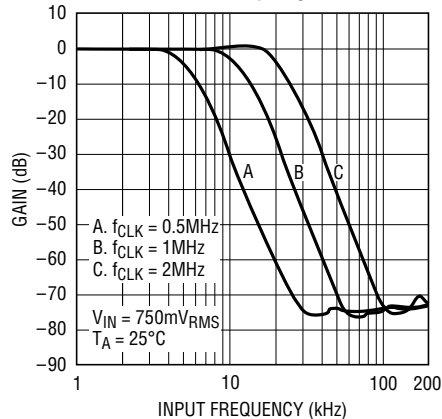
1063 G02

Output Offset vs Clock, Medium Clock Rates



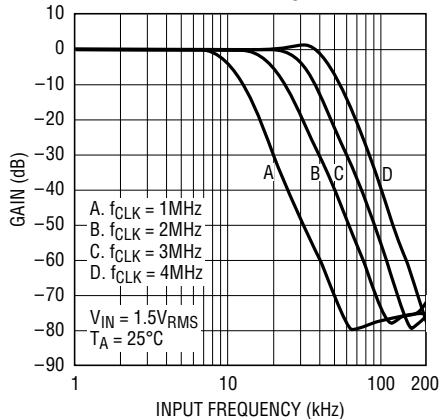
1063 G03

Gain vs Frequency;  $V_S = \pm 2.5\text{V}$



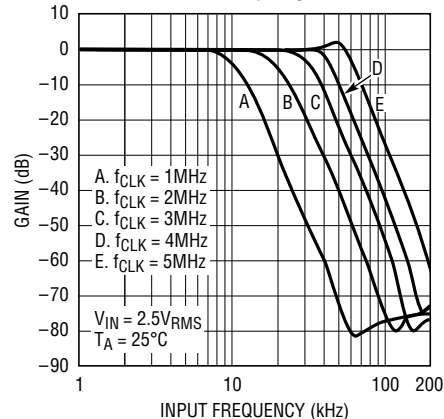
1063 G04

Gain vs Frequency;  $V_S = \pm 5\text{V}$



1063 G05

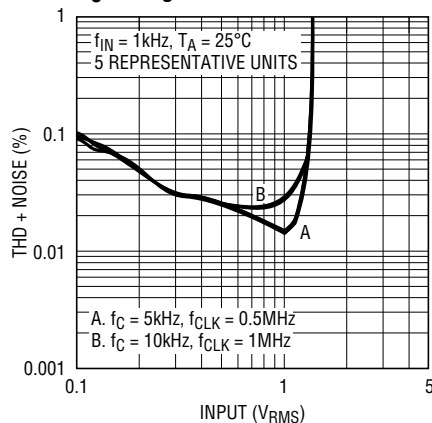
Gain vs Frequency;  $V_S = \pm 7.5\text{V}$



1063 G06

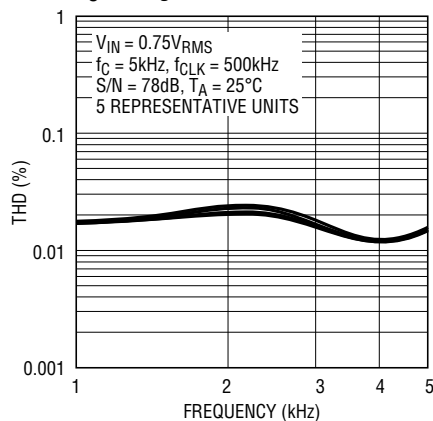
# TYPICAL PERFORMANCE CHARACTERISTICS

**THD + Noise vs Input Voltage;  
 $V_S$  = Single 5V**



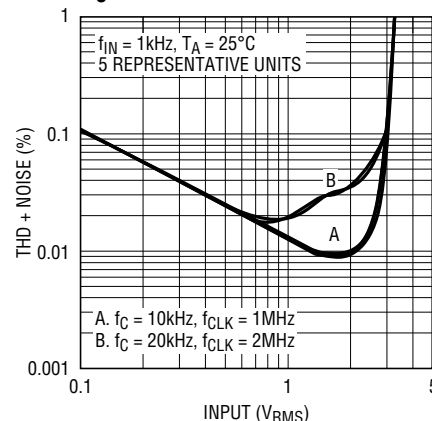
1063 G07

**THD vs Frequency;  
 $V_S$  = Single 5V**



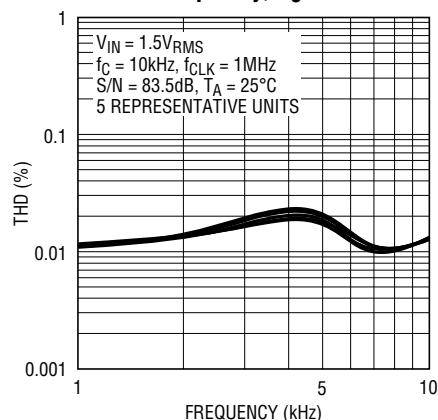
1063 G08

**THD + Noise vs Input Voltage;  
 $V_S = \pm 5V$**



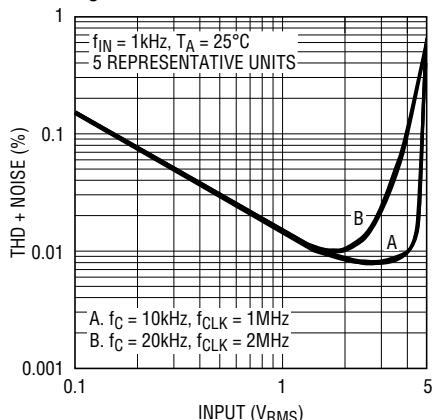
1063 G09

**THD vs Frequency;  $V_S = \pm 5V$**



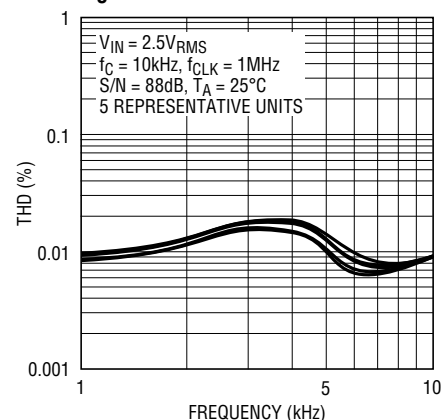
1063 G10

**THD + Noise vs Input Voltage;  
 $V_S = \pm 7.5V$**



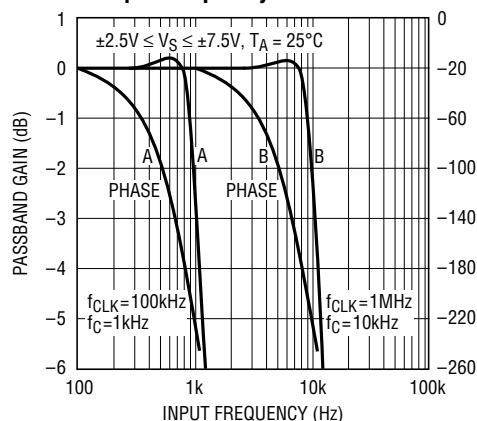
1063 G11

**THD vs Frequency;  
 $V_S = \pm 7.5V$**



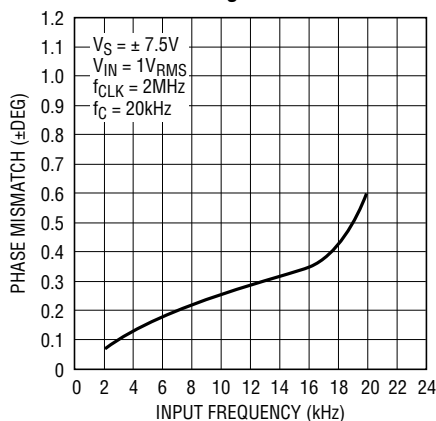
1063 G12

**Passband Gain and Phase  
vs Input Frequency**



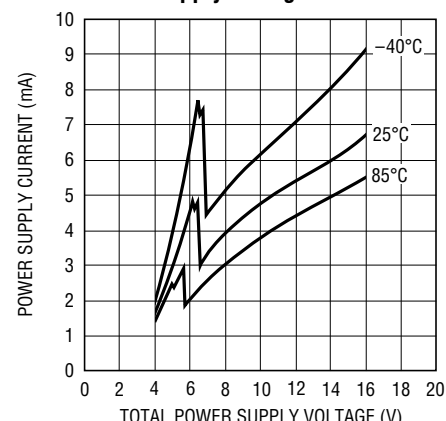
1063 G13

**Phase Matching**



1063 G14

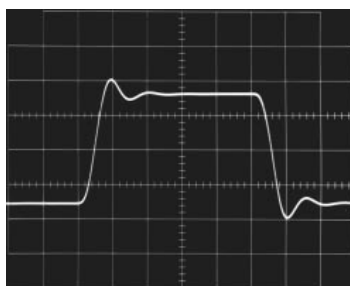
**Power Supply Current vs  
Power Supply Voltage**



1063 G15

## TYPICAL PERFORMANCE CHARACTERISTICS

Transient Response



HORIZONTAL: 0.1ms/DIV, VERTICAL: 2V/DIV  
 $V_S = \pm 5V$ ,  $f_C = 10kHz$ ,  $V_{IN} = 1kHz \pm 3V_P$   
 SQUARE WAVE

1063 G16

## PIN FUNCTIONS

### Power Supply Pins (Pins 6, 3, N Package)

The positive and negative supply pin should be bypassed with a high quality 0.1 $\mu$ F ceramic capacitor. In applications where the clock pin (5) is externally swept to provide several cutoff frequencies, the output DC offset variation is minimized by connecting an additional 1 $\mu$ F solid tantalum capacitor in parallel with the 0.1 $\mu$ F disc ceramic. This technique was used to generate the graphs of the output DC offset variation versus clock; they are illustrated in the Typical Performance Characteristics section.

When the power supply voltage exceeds  $\pm 7V$ , and when  $V^-$  is applied before  $V^+$ , if  $V^+$  is allowed to go below ground, connect a signal diode between the positive supply pin and ground to prevent latch-up (see Typical Applications).

### Ground Pin (Pin 2, N Package)

The ground pin merges the internal analog and digital ground paths. The potential of the ground pin is the reference for the internal switched-capacitor resistors, and the reference for the external clock. The positive input of the internal op amp is also tied to the ground pin.

For dual supply operation, the ground pin should be connected to a high quality AC and DC ground. A ground plane, if possible, should be used. A poor ground will degrade DC offset and it will increase clock feedthrough, noise and distortion.

A small amount of AC current flows out of the ground pin whether or not the internal oscillator is used. The fre-

quency of the ground current equals the frequency of the internal or external clock. The average value of this current is approximately 55 $\mu$ A, 110 $\mu$ A, 170 $\mu$ A for  $\pm 2.5V$ ,  $\pm 5V$  and  $\pm 7.5V$  supplies respectively.

For single supply operation, the ground pin should be preferably biased at half supply (see Typical Applications).

### $V_{OS}$ Adjust Pin (Pin 8, N Package)

The  $V_{OS}$  adjust pin can be used to trim any small amount of output DC offset voltage or to introduce a desired output DC level. The DC gain from the  $V_{OS}$  adjust pin to the filter output pin equals two.

Any DC voltage applied to this pin will reflect at the output pin of the filter multiplied by two.

If the  $V_{OS}$  adjust pin is not used, it should be shorted to the ground pin. The DC bias current flowing into the  $V_{OS}$  adjust pin is typically 10pA.

Pin 8 should always be connected to an AC ground; AC signals applied to this pin will degrade the filter response.

### Input Pin (Pin 1, N Package)

Pin 1 is the filter input and it is connected to an internal switched-capacitor resistor. If the input pin is left floating, the filter output will saturate. The DC input impedance of pin 1 is very high; with  $\pm 5V$  supplies and 1MHz clock, the DC input impedance is typically 1G $\Omega$ . A resistor,  $R_{IN}$ , in series, with the input pin will not alter the value of the

## PIN FUNCTIONS

filter's DC output offset (Figure 1).  $R_{IN}$  should, however, be limited to a maximum value (Table 1), otherwise the filter's passband flatness will be affected. Refer to the Applications Information section for more details.

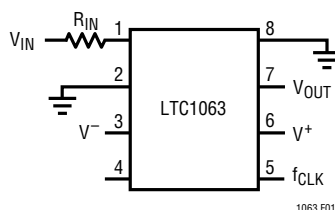


Figure 1.

Table 1.  $R_{IN(MAX)}$  vs Clock and Power Supply

|                    | $R_{IN(MAX)}$    |                |                  |
|--------------------|------------------|----------------|------------------|
|                    | $V_S = \pm 7.5V$ | $V_S = \pm 5V$ | $V_S = \pm 2.5V$ |
| $f_{CLK} = 4MHz$   | 2.2k             | —              | —                |
| $f_{CLK} = 3MHz$   | 3.4k             | 2.9k           | —                |
| $f_{CLK} = 2MHz$   | 5.5k             | 5k             | 2.7k             |
| $f_{CLK} = 1MHz$   | 11k              | 11k            | 9.2k             |
| $f_{CLK} = 500kHz$ | 24k              | 23k            | 21k              |
| $f_{CLK} = 100kHz$ | 120k             | 120k           | 110k             |

### Output Pin (Pin 7, N Package)

Pin 7 is the filter output. This pin can typically source over 20mA and sink 2mA. Pin 7 should not drive long coax cables, otherwise the filter's total harmonic distortion will degrade.

### Clock Input Pin (Pin 5, N Package)

An external clock when applied to pin 5 tunes the filter cutoff frequency. The clock-to-cutoff frequency ratio is 100:1. The high ( $V_{HIGH}$ ) and low ( $V_{LOW}$ ) clock logic threshold levels are illustrated in Table 2. Square wave clocks with duty cycles between 30% and 50% are strongly recommended. Sinewave clocks are not recommended.

Table 2. Clock Pin Threshold Levels

| POWER SUPPLY     | $V_{HIGH}$ | $V_{LOW}$ |
|------------------|------------|-----------|
| $V_S = \pm 2.5V$ | 1.5V       | 0.5V      |
| $V_S = \pm 5V$   | 3V         | 1V        |
| $V_S = \pm 7.5V$ | 4.5V       | 1.5V      |
| $V_S = \pm 8V$   | 4.8V       | 1.6V      |
| $V_S = 5V, 0V$   | 4V         | 3V        |
| $V_S = 12V, 0V$  | 9.6V       | 7.2V      |
| $V_S = 15V, 0V$  | 12V        | 9V        |

### Clock Output Pin (Pin 4, N Package)

Any external clock applied to the clock input pin appears at the clock output pin. The duty cycle of the clock output equals the duty cycle of the external clock applied to the clock input pin. The clock output pin swings to the power supply rails. When the LTC1063 is used in a self-clocking mode, the clock of the internal oscillator appears at the clock output pin with a 30% duty cycle. The clock output pin can be used to drive other LTC1063s or other ICs. The maximum capacitance,  $C_{L(MAX)}$ , the clock output pin can drive is illustrated in Figure 3.

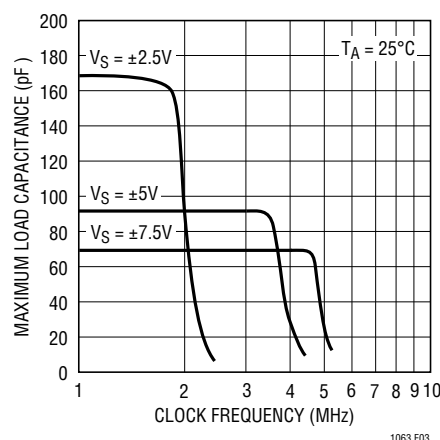


Figure 3. Maximum Load Capacitance at the Clock Output Pin

## TEST CIRCUIT

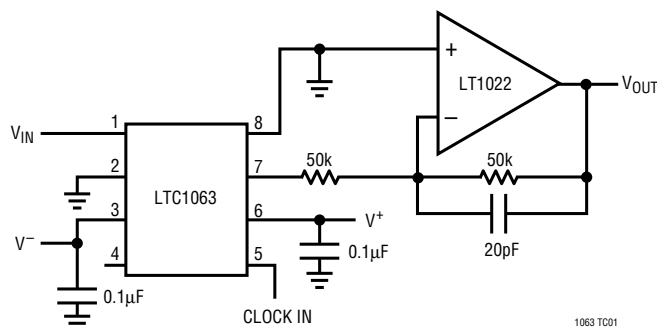


Figure 2. Test Circuit for THD

## APPLICATIONS INFORMATION

### Self-Clocking Operation

The LTC1063 features an internal oscillator which can be tuned via an external RC. The LTC1063's internal oscillator is primarily intended for generation of clock frequencies below 500kHz. The first curve of the Typical Performance Characteristics section shows how to quickly choose the value of the RC for a given frequency. More precisely, the frequency of the internal oscillator is equal to:

$$f_{CLK} = K/RC$$

For clock frequencies ( $f_{CLK}$ ) below 100kHz, K equals 1.07. Figure 4b shows the variation of the parameter K versus clock frequency and power supply. First choose the desired clock frequency, ( $f_{CLK} < 500\text{kHz}$ ), then through Figure 4b pick the right value of K, set  $C = 200\text{pF}$  and solve for R.

Example 1:  $f_{CUTOFF} = 2\text{kHz}$ ,  $f_{CLK} = 200\text{kHz}$ ,  $V_S = \pm 5\text{V}$ ,  
 $T_A = 25^\circ\text{C}$ ,  $K = 1.0$ ,  $C = 200\text{pF}$

then,  $R = (1.0)/(200\text{kHz} \times 204\text{pF}) = 24.5\text{k}$ .

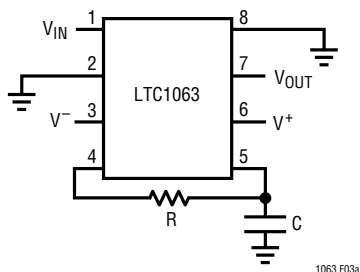


Figure 4a.

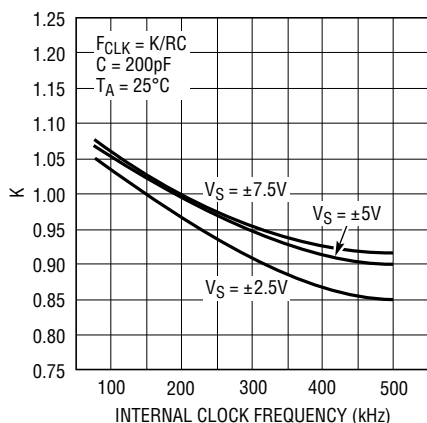


Figure 4b.  $f_{CLK}$  vs K

Note a 4pF parasitic capacitance is assumed in parallel with the external 200pF timing capacitor. Figure 5 shows the clock frequency variation from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ . The 200kHz clock of Example 1 will change by  $-1.75\%$  at  $85^\circ\text{C}$ .

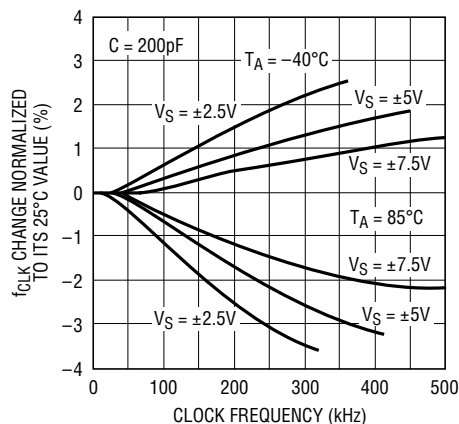


Figure 5.  $f_{CLK}$  vs Temperature

For a very limited temperature range, the internal oscillator of the LTC1063 can be used to generate clock frequencies above 500kHz (Figures 6 and 7). The data of Figure 6 is derived from several devices. For a given external (RC) value, the observed device-to-device clock frequency variation was  $\pm 1\%$  ( $V_S = \pm 5\text{V}$ ), and  $\pm 1.25\%$  for  $V_S = \pm 2.5\text{V}$ .

Example 2:  $f_{CUTOFF} = 20\text{kHz}$ ,  $f_{CLK} = 2\text{MHz}$ ,  $V_S = \pm 7.5\text{V}$ ,  
 $T_A = 25^\circ\text{C}$ ,  $C = 10\text{pF}$

from Figure 6,  $K = 0.575$ ,  
 and,  $R = (0.575)/(2\text{MHz} \times 14\text{pF}) = 20.5\text{k}$ .

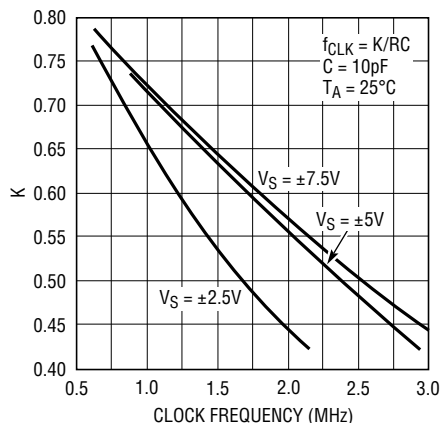


Figure 6.  $f_{CLK}$  vs K



## APPLICATIONS INFORMATION

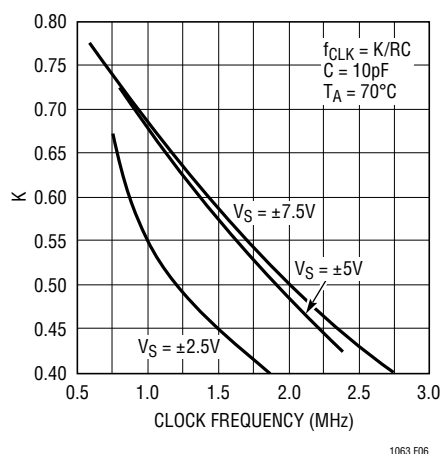


Figure 7.  $f_{CLK}$  vs K

A 4pF parasitic capacitance is assumed in parallel with the external 10pF capacitor. A  $\pm 1\%$  clock frequency variation from device to device can be expected. The 2MHz clock frequency designed above will typically drift to 1.74MHz at 70°C (Figure 7).

The internal clock of the LTC1063 can be overridden by an external clock provided that the external clock source can drive the timing capacitor, C, which is connected from the clock input pin to ground.

### Output Offset

The DC output offset of the LTC1063 is trimmed to typically less than  $\pm 1\text{mV}$ . The trimming is done at  $V_S = \pm 5\text{V}$ . To obtain optimum DC offset performance, appropriate PC layout techniques should be used and the filter IC should be soldered to the PC board. A socket will degrade the output DC offset by typically 1mV. The output DC offset is sensitive to the coupling of the clock output pin 4 (N package) to the negative power supply pin 3 (N package). The negative supply pin should be well decoupled. When the surface mount package is used, all the unused pins should be grounded.

When the power supplies are fixed, the output DC offset should not change by more than  $\pm 100\mu\text{V}$  over 10Hz to 1MHz clock frequency variation. When the filter clock frequency is fixed, the output DC offset will typically change by  $-4\text{mV}$  (2mV) when the power supply varies from  $\pm 5\text{V}$  to  $\pm 7.5\text{V}$  ( $\pm 2.5\text{V}$ ). See Typical Performance Characteristics.

### Common-Mode Rejection Ratio

The common-mode rejection ratio is defined as the change of the output DC offset with respect to the DC change of the input voltage applied to the filter.

$$\text{CMRR} = 20\log(\Delta V_{OS\text{ OUT}}/\Delta V_{IN})(\text{dB})$$

Table 3 illustrates the common-mode rejection for three power supplies and three temperatures. The common-mode rejection improves if the output offset is adjusted to approximately 0V. The output offset can be adjusted via pin 8 (N package) (see Typical Applications).

Table 3. CMRR Data,  $f_{CLK} = 100\text{kHz}$

| POWER SUPPLY      | $\Delta V_{IN}$   | $-40^\circ\text{C}$ | $25^\circ\text{C}$ | $85^\circ\text{C}$ | $25^\circ\text{C}$<br>( $V_{OS}$ Nulled) |
|-------------------|-------------------|---------------------|--------------------|--------------------|------------------------------------------|
| $\pm 2.5\text{V}$ | $\pm 1.8\text{V}$ | 76dB                | 78dB               | 76dB               | 85dB                                     |
| $\pm 5\text{V}$   | $\pm 4\text{V}$   | 74dB                | 79dB               | 75dB               | 82dB                                     |
| $\pm 7.5\text{V}$ | $\pm 6\text{V}$   | 70dB                | 72dB               | 74dB               | 76dB                                     |

The above data is valid for clock frequencies up to 800kHz, 900kHz, 1MHz, for  $V_S = \pm 2.5\text{V}$ ,  $\pm 5\text{V}$ ,  $\pm 7.5\text{V}$  respectively.

### Clock Feedthrough

Clock feedthrough is defined as the RMS value of the clock frequency and its harmonics which are present at the filter's output pin. The clock feedthrough is tested with the filter input grounded and it depends on the quality of the PC board layout and power supply decoupling. Any parasitic switching transients, during the rise and fall of the incoming clock, are not part of the clock feedthrough specifications; their amplitude strongly depends on scope probing techniques as well as ground quality and power supply bypassing. For a power supply  $V_S = \pm 5\text{V}$ , the clock feedthrough of the LTC1063 is  $50\mu\text{V}_{\text{RMS}}$ ; for  $V_S = \pm 7.5\text{V}$ , the clock feedthrough approaches  $75\mu\text{V}_{\text{RMS}}$ . Figure 8 shows a typical scope photo of the LTC1063 output pin when the input pin is grounded. The filter cutoff frequency was 1kHz, while scope bandwidth was chosen to be 1MHz such as switching transients above the 100kHz clock frequency will show.

### Wideband Noise

The wideband noise of the filter is the RMS value of the device's output noise spectral density. The wideband noise data is used to determine the operating signal-to-

## APPLICATIONS INFORMATION

noise ratio at a given distortion level. The wideband noise ( $\mu\text{V}_{\text{RMS}}$ ) is nearly independent of the value of the clock frequency and excludes the clock feedthrough. The LTC1063's typical wideband noise is  $95\mu\text{V}_{\text{RMS}}$ . Figure 9 shows the same scope photo as Figure 8 but with a more sensitive vertical scale: The clock feedthrough is imbedded in the filter's wideband noise. The peak-to-peak wideband noise of the filter can be clearly seen; it is approximately  $500\mu\text{V}_{\text{P-P}}$ . Note that  $500\mu\text{V}_{\text{P-P}}$  equals the  $95\mu\text{V}_{\text{RMS}}$  wideband noise of the part, multiplied by a crest factor of 5.25.

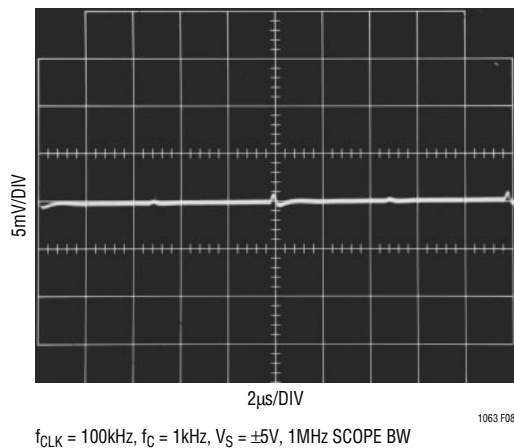


Figure 8. LTC1063 Output Clock Feedthrough + Noise

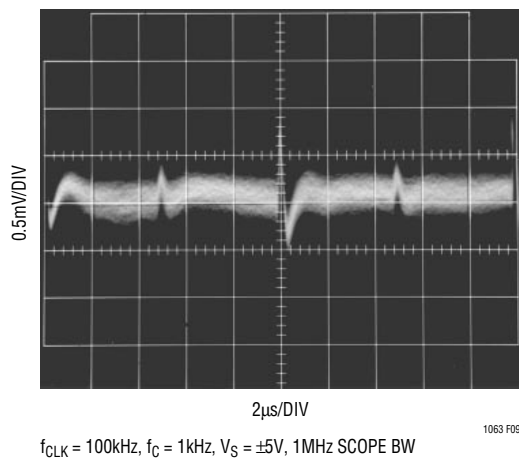


Figure 9. LTC1063 Output Clock Feedthrough + Noise

### Aliasing

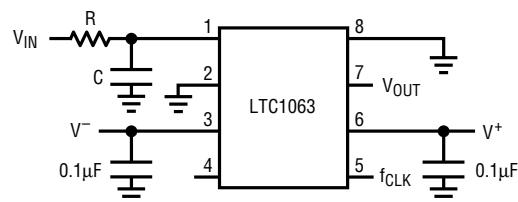
Aliasing is an inherent phenomenon of sampled data filters and it primarily occurs when the frequency of an input signal approaches the sampling frequency. For the LTC1063, an input signal whose frequency is in the range of  $f_{\text{CLK}} \pm 6\%$  will generate an alias signal into the filter's passband and stopband. Table 4 shows details.

Example: LTC1063,  $f_{\text{CLK}} = 20\text{kHz}$ ,  $f_{\text{C}} = 200\text{kHz}$ ,  
 $f_{\text{IN}} = (19.6\text{kHz}, 100\text{mV}_{\text{RMS}})$   
 $f_{\text{ALIAS}} = (400\text{Hz}, 3.16\text{mV}_{\text{RMS}})$

An input RC can be used to attenuate incoming signals close to the filter clock frequency (Figure 10). A Butterworth passband response will be maintained if the value of the input resistor follows Table 1.

Table 4. Aliasing Data

| INPUT FREQUENCY        | OUTPUT FREQUENCY       | OUTPUT AMPLITUDE<br>REFERENCED TO<br>INPUT SIGNAL |
|------------------------|------------------------|---------------------------------------------------|
| $0.9995f_{\text{CLK}}$ | $0.0005f_{\text{CLK}}$ | 0 dB                                              |
| $0.995f_{\text{CLK}}$  | $0.005f_{\text{CLK}}$  | 0 dB                                              |
| $0.99f_{\text{CLK}}$   | $0.01f_{\text{CLK}}$   | -3 dB                                             |
| $0.9875f_{\text{CLK}}$ | $0.0125f_{\text{CLK}}$ | -10.2 dB                                          |
| $0.985f_{\text{CLK}}$  | $0.015f_{\text{CLK}}$  | -17.7 dB                                          |
| $0.9825f_{\text{CLK}}$ | $0.0175f_{\text{CLK}}$ | -24.3 dB                                          |
| $0.98f_{\text{CLK}}$   | $0.02f_{\text{CLK}}$   | -30 dB                                            |
| $0.975f_{\text{CLK}}$  | $0.025f_{\text{CLK}}$  | -40 dB                                            |
| $0.97f_{\text{CLK}}$   | $0.03f_{\text{CLK}}$   | -48 dB                                            |
| $0.965f_{\text{CLK}}$  | $0.035f_{\text{CLK}}$  | -54.5 dB                                          |
| $0.96f_{\text{CLK}}$   | $0.04f_{\text{CLK}}$   | -60.4 dB                                          |
| $0.955f_{\text{CLK}}$  | $0.045f_{\text{CLK}}$  | -65.5 dB                                          |
| $0.95f_{\text{CLK}}$   | $0.05f_{\text{CLK}}$   | -70.16 dB                                         |
| $0.94f_{\text{CLK}}$   | $0.06f_{\text{CLK}}$   | -78.25 dB                                         |
| $0.93f_{\text{CLK}}$   | $0.07f_{\text{CLK}}$   | -85.3 dB                                          |
| $0.9f_{\text{CLK}}$    | $0.1f_{\text{CLK}}$    | -100.3 dB                                         |



$$\frac{f_{\text{CLK}}}{20} \leq \frac{1}{2\pi RC} \leq \frac{f_{\text{CLK}}}{10}$$

1063 F10

Figure 10. Adding an Input Anti-Aliasing RC

## APPLICATIONS INFORMATION

### Group Delay

The group delay of the LTC1063 closely approximates the delay of an ideal 5-pole Butterworth lowpass filter (Figure 11, Curve A). To linearize the group delay of the LTC1063 (Figure 11, Curve B), use an input resistor about six times higher than the maximum value of  $R_{IN}$ , shown in Table 1. The passband response of the group delay corrected filter approximates a 5-pole Bessel response while its transition band rolls off like a Butterworth.

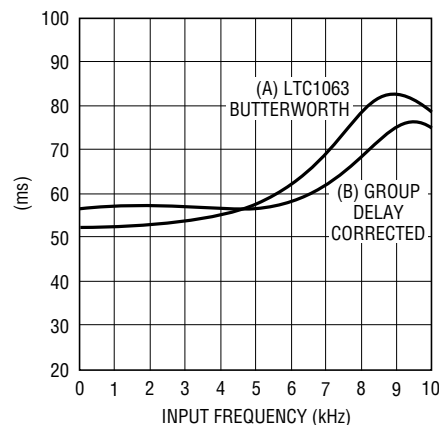
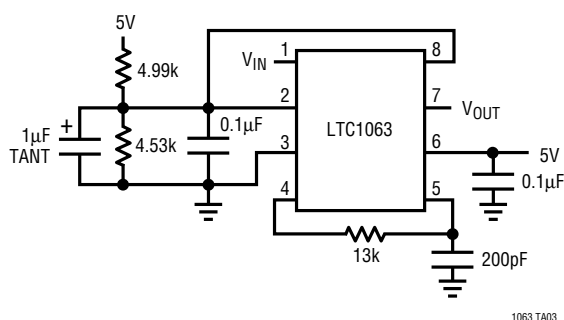


Figure 11. Group Delay

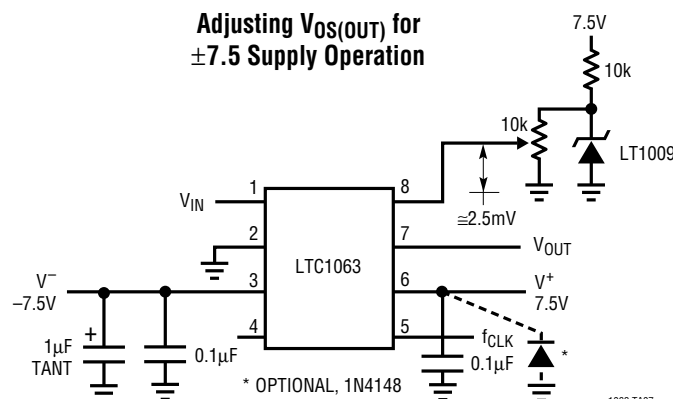
## TYPICAL APPLICATIONS

### Single 5V Supply Operation ( $f_C = 3.4\text{kHz}$ )



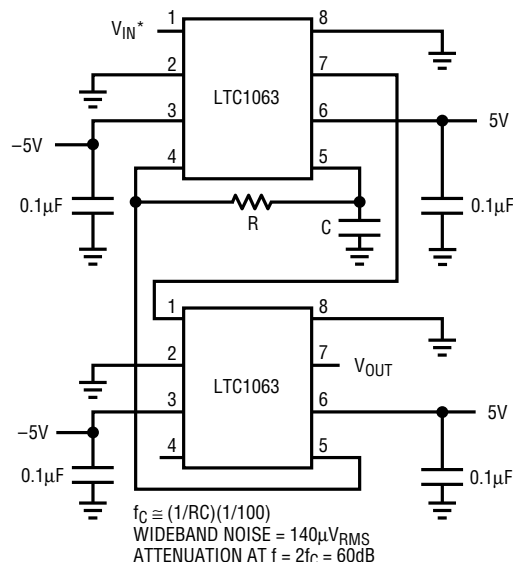
1063 TA03

### Adjusting $V_{OS(OUT)}$ for $\pm 7.5\text{V}$ Supply Operation



1063 TA07

### Cascading Two LTC1063s for Steeper Roll-Off

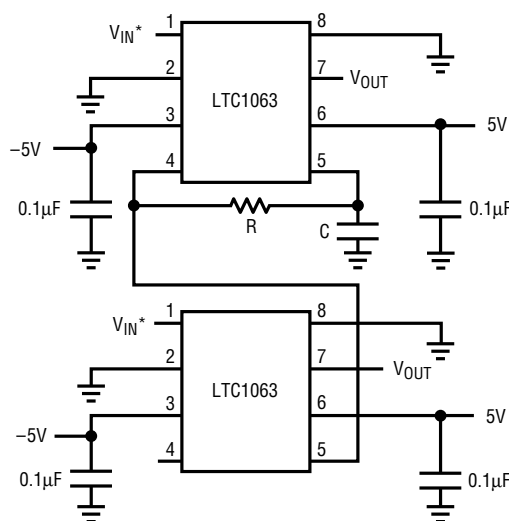


$f_C \approx (1/RC)(1/100)$   
WIDEBAND NOISE =  $140\mu\text{V}_{\text{RMS}}$   
ATTENUATION AT  $f = 2f_C = 60\text{dB}$

\* IF THE INPUT VOLTAGE CAN EXCEED  $V^+$ ,  
CONNECT A SIGNAL DIODE BETWEEN PIN 1 AND  $V^+$ .

1063 TA04

### Sharing Clock for Multichannel Applications

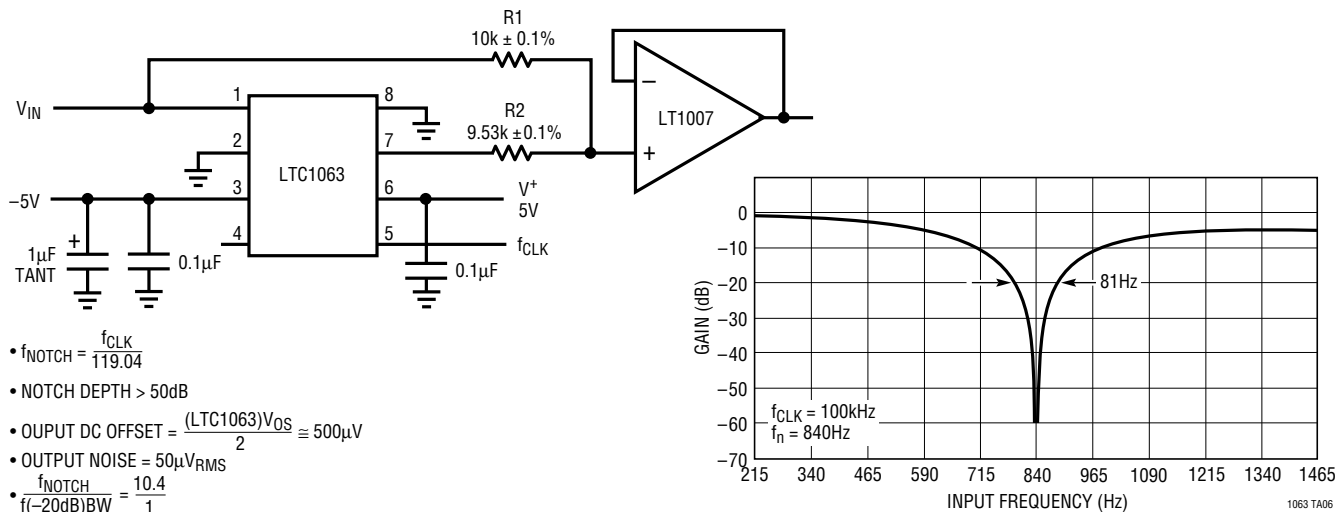


\* IF THE INPUT VOLTAGE CAN EXCEED  $V^+$ ,  
CONNECT A SIGNAL DIODE BETWEEN PIN 1 AND  $V^+$ .

1063 TA05

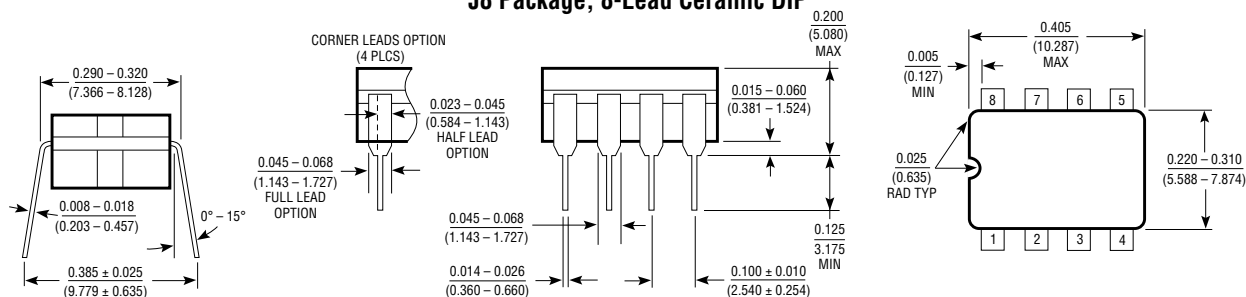
## TYPICAL APPLICATIONS

### Low Noise DC Accurate Clock-Tunable Notch



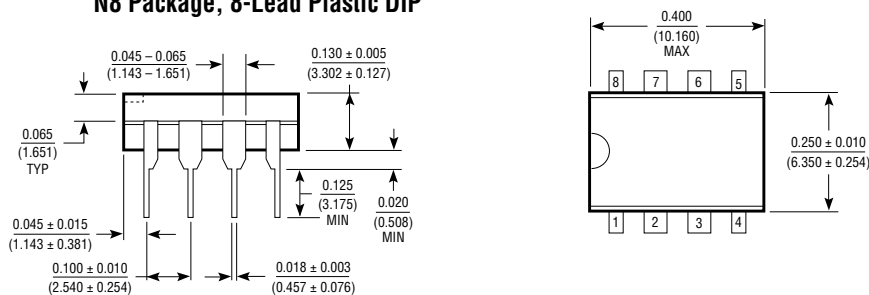
## PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise noted.

### J8 Package, 8-Lead Ceramic DIP

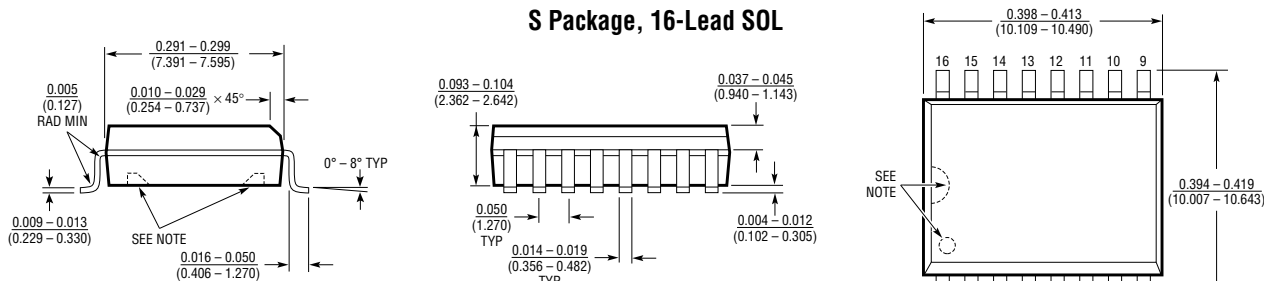


NOTE: LEAD DIMENSIONS APPLY TO SOLDER DIP OR TIN PLATE LEADS.

### N8 Package, 8-Lead Plastic DIP



### S Package, 16-Lead SOL



NOTE:  
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.