

# Low Noise, High Frequency, 8th Order Butterworth Lowpass Filter

## FEATURES

- 8th Order Filter in a 14-Pin Package
- 140kHz Maximum Corner Frequency
- No External Components
- 50:1 and 100:1 Clock to Cutoff Frequency Ratio
- $80\mu\text{V}_{\text{RMS}}$  Total Wideband Noise
- 0.03% THD or Better
- Operates from  $\pm 2.37\text{V}$  to  $\pm 8\text{V}$  Power Supplies

## APPLICATIONS

- Antialiasing Filters
- Smoothing Filters
- Tracking High Frequency Lowpass Filters

## DESCRIPTION

The LTC<sup>®</sup>1064-2 is a monolithic 8th order lowpass Butterworth filter, which provides a maximally flat pass-band. The attenuation slope is  $-48\text{dB/octave}$  and the maximum attenuation is in excess of 80db. An external TTL or CMOS clock programs the filter's cutoff frequency. The clock to cutoff frequency ratio is 100:1 (Pin 10 at  $V^-$ ) or 50:1 (Pin 10 at  $V^+$ ). The maximum cutoff frequency is 140kHz. No external components are needed.

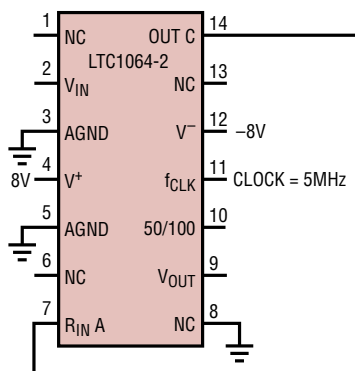
The LTC1064-2 features low wideband noise and low harmonic distortion even for input voltages up to  $3\text{V}_{\text{RMS}}$ . In fact the LTC1064-2 overall performance competes with equivalent multiple op amp RC active realizations. The LTC1064-2 is available in a 14-pin DIP or 16-pin surface mounted SW package. The LTC1064-2 is fabricated using LTC's enhanced analog CMOS Si-gate process.

The LTC1064-2 is pin compatible with the LTC1064-1.

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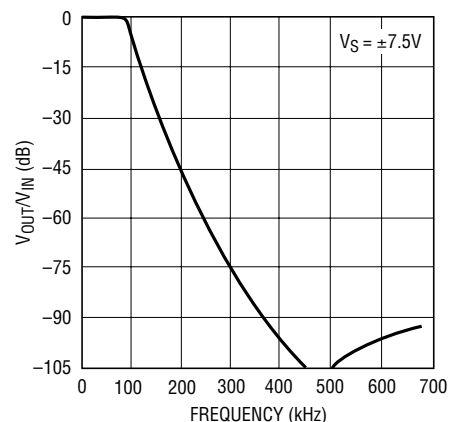
## TYPICAL APPLICATION

**8th Order Clock Sweeplable  
Lowpass Butterworth Filter**



NOTE: THE POWER SUPPLIES SHOULD BE BYPASSED BY A  $0.1\mu\text{F}$  CAPACITOR CLOSE TO THE PACKAGE. THE NC PINS 1, 6, 8, AND 13 SHOULD BE PREFERABLY GROUNDING.

**Measured Frequency Response**



1064-2 TA01b

# LTC1064-2

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|   |                |                             |                |
|---|----------------|-----------------------------|----------------|
| Total Supply Voltage ( $V^+$ to $V^-$ ) ..... | 16.5V          | Operating Temperature Range |                |
| Power Dissipation .....                       | 400mW          | LTC1064-2M (OBSOLETE) ..... | -55°C to 125°C |
| Storage Temperature Range .....               | -65°C to 150°C | LTC1064-2C .....            | -40°C to 85°C  |
| Lead Temperature (Soldering, 10 sec) .....    | 300°C          |                             |                |

## PACKAGE/ORDER INFORMATION

|   |   |  |  |
|---|---|--|--|
| <p>N PACKAGE<br/>14-LEAD PDIP<br/><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 110^{\circ}C/W</math></p> <p>J PACKAGE<br/>14-LEAD CERDIP</p> <p><b>OBSOLETE PACKAGE</b><br/>Consider the N14 Package for Alternate Source</p> | <p>ORDER PART NUMBER</p> <p>LTC1064-2CN</p> | <p>SW PACKAGE<br/>16-LEAD PLASTIC (WIDE) SO<br/><math>T_{JMAX} = 150^{\circ}C, \theta_{JA} = 130^{\circ}C/W</math></p> | <p>ORDER PART NUMBER</p> <p>LTC1064-2CSW</p> |
|---|---|--|--|

Consult LTC Marketing for parts specified with wider operating temperature ranges.

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^{\circ}C$ .  $V_S = \pm 7.5V$ , 100:1,  $f_{CLK} = 2MHz$ ,  $R_1 = 10k$ , TTL clock input level unless otherwise specified.

| PARAMETER  | CONDITIONS                                    | MIN         | TYP    | MAX          | UNITS         |
|--|---|-------------|--------|--------------|---------------|
| Passband Gain (Note 2)                                 | Referenced to 0dB, 1Hz to 1kHz                | ● -0.5      |        | 0.15         | dB            |
| Gain TempCo  |   |             | 0.0002 |              | dB/°C         |
| -3dB Frequency   | 100:1   |             | 20     |              | kHz           |
|  | 50:1  |             | 40     |              | kHz           |
| Gain at -3dB Frequency                                 | Referenced to 0dB, $f_{IN} = 20kHz$           | ●           | -3     | -2.75        | dB            |
| Stopband Attenuation                                   | At $1.5f_{-3dB}$ , 50:1, $f_{IN} = 60kHz$     | ● -24       | -27    |              | dB            |
| Stopband Attenuation                                   | At $2f_{-3dB}$ , 100:1, $f_{IN} = 40kHz$      | ● -44       | -47    |              | dB            |
| Stopband Attenuation                                   | At $3f_{-3dB}$ , 100:1, $f_{IN} = 60kHz$      |             | -74    |              | dB            |
| Stopband Attenuation                                   | At $4f_{-3dB}$ , 100:1, $f_{IN} = 80kHz$      |             | -90    |              | dB            |
| Input Frequency Range                                  | 100:1   | 0           |        | $<f_{CLK}/2$ | kHz           |
|  | 50:1  | 0           |        | $<f_{CLK}$   | kHz           |
| Output Voltage Swing and Operating Input Voltage Range | $V_S = \pm 2.37V$                             | ● $\pm 1.1$ |        |              | V             |
|  | $V_S = \pm 5V$                                | ● $\pm 3.1$ |        |              | V             |
|  | $V_S = \pm 7.5V$                              | ● $\pm 5.0$ |        |              | V             |
| Total Harmonic Distortion                              | $V_S = \pm 5V$ , Input = $1V_{RMS}$ at 1kHz   |             | 0.015  |              | %             |
|  | $V_S = \pm 7.5V$ , Input = $3V_{RMS}$ at 1kHz |             | 0.03   |              | %             |
| Wideband Noise   | $V_S = \pm 5V$ , Input = GND 1Hz - 1.99MHz    |             | 80     |              | $\mu V_{RMS}$ |
|  | $V_S = \pm 7.5V$ , Input = GND 1Hz - 1.99MHz  |             | 90     |              | $\mu V_{RMS}$ |

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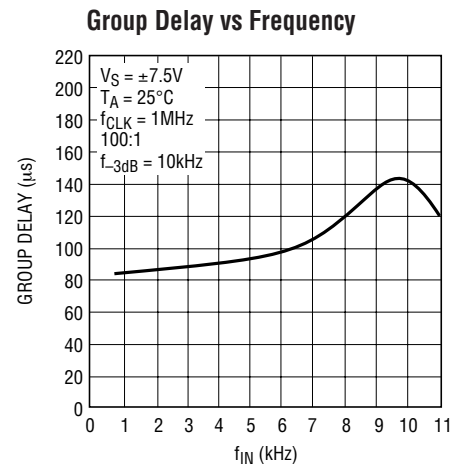
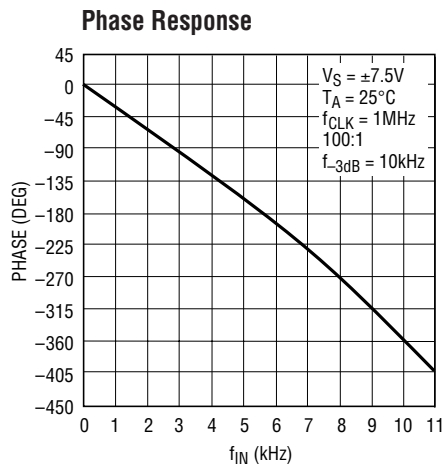
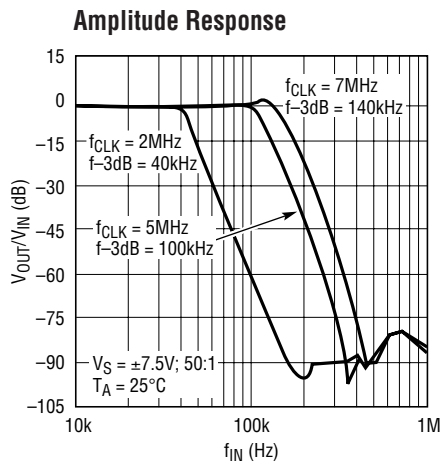
**ELECTRICAL CHARACTERISTICS** The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_S = \pm 7.5\text{V}$ , 100:1,  $f_{\text{CLK}} = 2\text{MHz}$ ,  $R_1 = 10\text{k}$ , TTL clock input level unless otherwise specified.

| PARAMETER                    | CONDITIONS  | MIN         | TYP            | MAX                        | UNITS                        |
|------------------------------|---|-------------|----------------|----------------------------|------------------------------|
| Output DC Offset (Note 2)    | $V_S = \pm 7.5\text{V}$   |             | $\pm 30$       | $\pm 125$                  | mV                           |
| Output DC Offset TempCo      | $V_S = \pm 5\text{V}$   |             | $\pm 90$       |                            | $\mu\text{V}/^\circ\text{C}$ |
| Input Impedance              |   | 10          | 20             |                            | $\text{k}\Omega$             |
| Output Impedance             | $f_{\text{OUT}} = 10\text{kHz}$   |             | 2              |                            | $\Omega$                     |
| Output Short-Circuit Current | Source/Sink   |             | 3/1            |                            | mA                           |
| Clock Feedthrough            |   |             | 200            |                            | $\mu\text{V}_{\text{RMS}}$   |
| Maximum Clock Frequency      | 50% Duty Cycle, $V_S = \pm 5\text{V}$<br>50% Duty Cycle, $T_A = 25^\circ\text{C}$ , $V_S = \pm 7.5\text{V}$   |             |                | 5<br>7                     | MHz<br>MHz                   |
| Power Supply Current         | $V_S = \pm 2.37\text{V}$ , $f_{\text{CLK}} = 1\text{MHz}$<br>$V_S = \pm 5\text{V}$ , $f_{\text{CLK}} = 1\text{MHz}$<br>$V_S = \pm 7.5\text{V}$ , $f_{\text{CLK}} = 1\text{MHz}$ | ●<br>●<br>● | 11<br>14<br>17 | 22<br>23<br>26<br>28<br>32 | mA<br>mA<br>mA<br>mA<br>mA   |
| Power Supply Voltage Range   |   | ●           | $\pm 2.37$     | $\pm 8$                    | V                            |

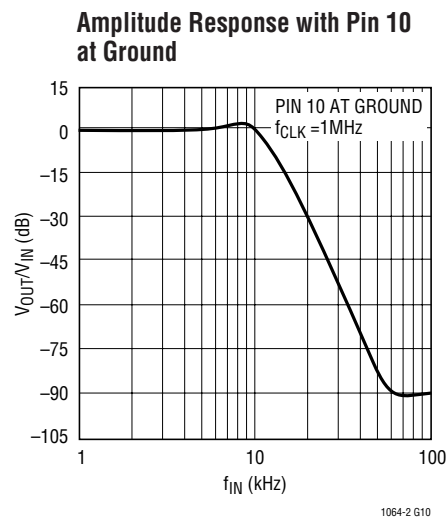
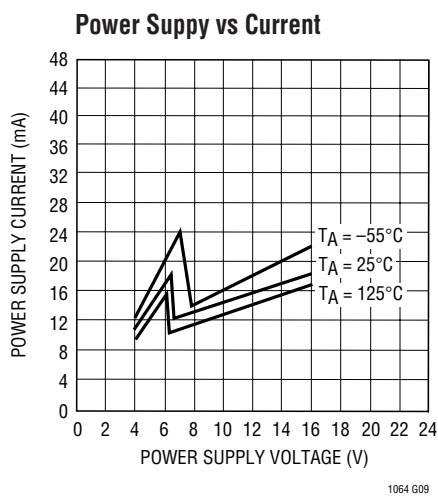
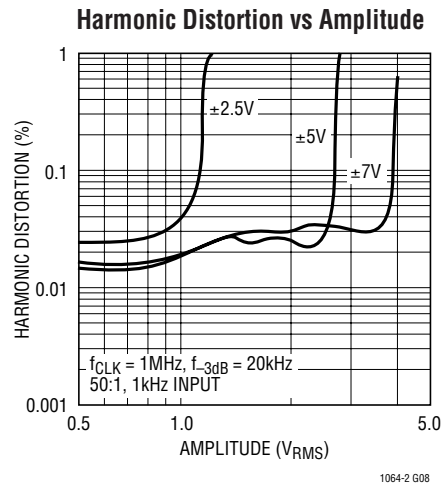
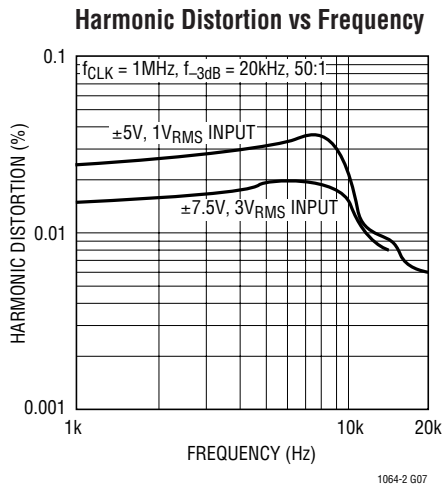
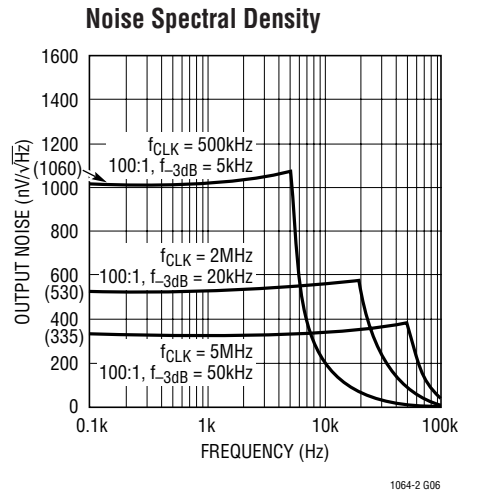
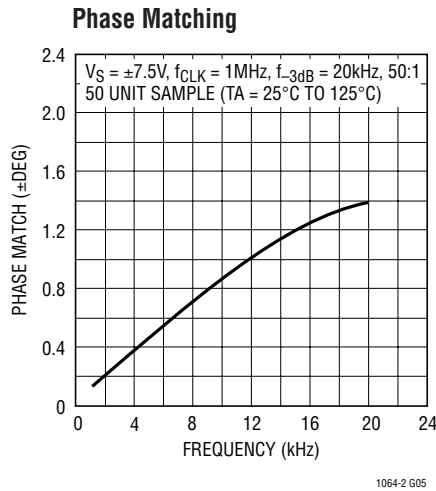
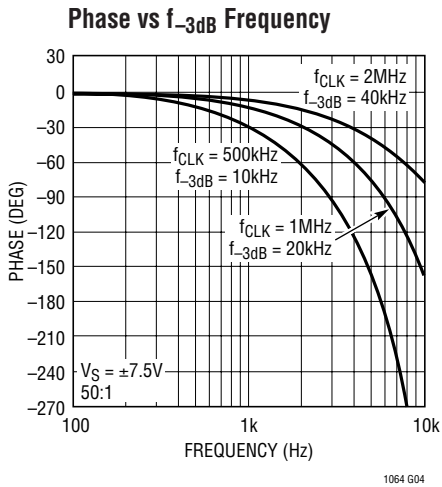
**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** For tighter specifications please contact LTC Marketing.

**TYPICAL PERFORMANCE CHARACTERISTICS**



TYPICAL PERFORMANCE CHARACTERISTICS



## TYPICAL PERFORMANCE CHARACTERISTICS

**Table 1. Gain/Delay,  $f_{-3dB} = 1\text{kHz}$ ,  
LTC1064-2 Typical Response  $V_S = \pm 5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 50\text{kHz}$ , Ratio = Pin 10 at  $V^+$  (fltr 50:1)**

| FREQUENCY (kHz) | GAIN (dB) | DELAY (ms) |
|-----------------|-----------|------------|
| 0.200           | -0.247    | 0.857      |
| 0.300           | -0.270    | 0.872      |
| 0.400           | -0.290    | 0.893      |
| 0.500           | -0.300    | 0.929      |
| 0.600           | -0.320    | 0.983      |
| 0.700           | -0.370    | 1.071      |
| 0.800           | -0.520    | 1.210      |
| 0.900           | -1.200    | 1.364      |
| 1.000           | -3.380    | 1.381      |
| 1.100           | -7.530    | 1.192      |
| 1.200           | -12.670   | 0.935      |

**Table 2. Gain,  $f_{-3dB} = 1\text{kHz}$ ,  
LTC1064-2 Typical Response  $V_S = \pm 5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 50\text{kHz}$ , Ratio = Pin 10 at  $V^+$  (fltr 50:1)**

| FREQUENCY (kHz) | GAIN (dB) |
|-----------------|-----------|
| 0.500           | -0.298    |
| 1.000           | -3.380    |
| 1.500           | -27.500   |
| 2.000           | -47.200   |
| 2.500           | -63.300   |
| 3.000           | -75.190   |
| 3.500           | -86.100   |
| 4.000           | -95.310   |
| 4.500           | -104.240  |
| 5.000           | -109.650  |
| 5.500           | -121.930  |
| 6.000           | -123.920  |
| 6.500           | -114.150  |
| 7.000           | -116.990  |
| 7.500           | -120.070  |
| 8.000           | -113.470  |
| 8.500           | -130.090  |
| 9.000           | -114.770  |
| 9.500           | -117.760  |

**Table 3. Gain/Delay,  $f_{-3dB} = 1\text{kHz}$ ,  
LTC1064-2 Typical Response  $V_S = \pm 5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 100\text{kHz}$ , Ratio = Pin 10 at  $V^-$  (fltr 100:1)**

| FREQUENCY (kHz) | GAIN (dB) | DELAY (ms) |
|-----------------|-----------|------------|
| 0.200           | -0.213    | 0.821      |
| 0.300           | -0.240    | 0.837      |
| 0.400           | -0.260    | 0.858      |
| 0.500           | -0.280    | 0.893      |
| 0.600           | -0.310    | 0.947      |
| 0.700           | -0.370    | 1.034      |
| 0.800           | -0.530    | 1.172      |
| 0.900           | -1.200    | 1.325      |
| 1.000           | -3.370    | 1.346      |
| 1.100           | -7.500    | 1.158      |
| 1.200           | -12.640   | 0.899      |

**Table 4. Gain,  $f_{-3dB} = 1\text{kHz}$ ,  
LTC1064-2 Typical Response  $V_S = \pm 5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 100\text{kHz}$ , Ratio = Pin 10 at  $V^-$  (fltr 100:1)**

| FREQUENCY (kHz) | GAIN (dB) |
|-----------------|-----------|
| 0.500           | -0.279    |
| 1.000           | -3.370    |
| 1.500           | -27.500   |
| 2.000           | -47.200   |
| 2.500           | -62.300   |
| 3.000           | -75.130   |
| 3.500           | -86.090   |
| 4.000           | -95.210   |
| 4.500           | -103.030  |
| 5.000           | -108.690  |
| 5.500           | -114.830  |
| 6.000           | -120.540  |
| 6.500           | -114.750  |
| 7.000           | -116.430  |
| 7.500           | -120.790  |
| 8.000           | -121.290  |
| 8.500           | -119.970  |
| 9.000           | -120.020  |
| 9.500           | -125.170  |

## TYPICAL PERFORMANCE CHARACTERISTICS

**Table 5. Gain,  $f_{-3dB} = 20\text{kHz}$ ,  
LTC1064-2 Typical Response  $V_S = \pm 7.5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 1\text{MHz}$ , Ratio = Pin 10 at  $V^+$  (fltr 50:1)**

| FREQUENCY (kHz) | GAIN (dB) |
|-----------------|-----------|
| 10.000          | -0.308    |
| 20.000          | -3.350    |
| 30.000          | -27.400   |
| 40.000          | -47.100   |
| 50.000          | -62.300   |
| 60.000          | -74.890   |
| 70.000          | -85.430   |
| 80.000          | -95.070   |
| 90.000          | -103.150  |
| 100.000         | -108.700  |
| 110.000         | -107.520  |
| 120.000         | -108.030  |
| 130.000         | -104.990  |
| 140.000         | -106.090  |
| 150.000         | -105.320  |

**Table 7. Gain Non-Butterworth Response (Pin 10 to GND),  
LTC1064-2 Typical Response  $V_S = \pm 5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 100\text{kHz}$**

| FREQUENCY (kHz) | GAIN (dB) |
|-----------------|-----------|
| 0.500           | -0.012    |
| 1.000           | 1.240     |
| 1.500           | -14.690   |
| 2.000           | -28.600   |
| 2.500           | -41.100   |
| 3.000           | -52.500   |
| 3.500           | -62.800   |
| 4.000           | -71.500   |
| 4.500           | -79.370   |
| 5.000           | -86.730   |
| 5.500           | -93.340   |
| 6.000           | -99.350   |
| 6.500           | -105.270  |
| 7.000           | -113.270  |
| 7.500           | -114.600  |
| 8.000           | -114.010  |
| 8.500           | -122.810  |
| 9.000           | -122.980  |
| 9.500           | -119.450  |

**Table 6. Gain,  $f_{-3dB} = 140\text{kHz}$ ,  
LTC1064-2 Typical Response  $V_S = \pm 7.5\text{V}$ ,  $T_A = 25^\circ\text{C}$ ,  
 $f_{CLK} = 7\text{MHz}$ , Ratio = Pin 10 at  $V^+$  (fltr 50:1)**

| FREQUENCY (kHz) | GAIN (dB) |
|-----------------|-----------|
| 50.00           | -0.238    |
| 60.00           | -0.140    |
| 70.00           | 0.050     |
| 80.00           | 0.350     |
| 90.00           | 0.810     |
| 100.00          | 1.450     |
| 110.00          | 2.110     |
| 120.00          | 1.830     |
| 130.00          | -0.700    |
| 140.00          | -4.840    |
| 150.00          | -9.350    |
| 160.00          | -13.690   |
| 170.00          | -17.760   |
| 180.00          | -21.600   |
| 190.00          | -25.200   |
| 200.00          | -28.500   |
| 210.00          | -31.800   |
| 220.00          | -34.800   |
| 230.00          | -37.700   |
| 240.00          | -40.500   |
| 250.00          | -43.200   |
| 260.00          | -45.700   |
| 270.00          | -48.200   |
| 280.00          | -50.500   |
| 290.00          | -52.700   |
| 300.00          | -54.900   |

## PIN FUNCTIONS (Pin Numbers Refer to the 14-Pin Package)

**NC (Pins 1, 6, 8 and 13):** The “no connection” pins should be preferably grounded. These pins are not internally connected.

**$V_{IN}$ ,  $V_{OUT}$  (Pins 2, 9):** The input Pin 2 is connected to an 18k resistor tied to the inverting input of an op amp. Pin 2 is protected against static discharge. The device’s output, Pin 9, is the output of an op amp which can typically source/sink 3mA/1mA. Although the internal op amps are unity gain stable, driving long coax cables is not recommended.

When testing the device for noise and distortion, the output, Pin 9, should be buffered. (Figure 1) *The op amp power supply wire (or trace) should be connected directly to the power source. To eliminate switching transients from filter output, buffer filter output with a third order lowpass (Figure 5).*

**AGND (Pins 3, 5):** For dual supply operation these pins should be connected to a ground plane. For single supply operation both pins should be tied to one half supply, (Figure 3).

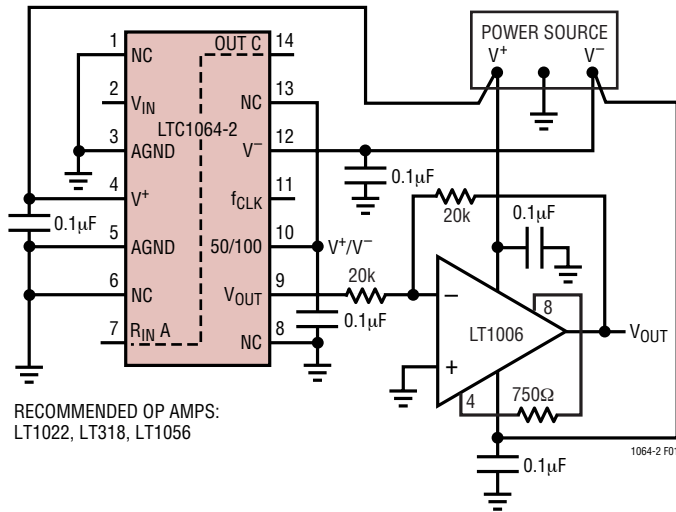
**$V^+$ ,  $V^-$  (Pins 4, 12):** Should be bypassed with a 0.1 $\mu$ F capacitor to an adequate AGND. Low noise, nonswitching power supplies are recommended. *To avoid latchup when the power supplies exhibit high turn-on transients, a 1N5817 Schottky diode should be added from the  $V^+$  and  $V^-$  pins to ground (Figures 1, 2 and 3).*

**$R_{IN A}$ , OUT C (Pins 7, 14):** A very short connection between Pin 7 and Pin 14 is recommended. This connection should be preferably done under the IC package. In a breadboard use a one inch, or less, shielded coaxial cable: the shield should be grounded. In a PC board, use a one inch trace or less; surround the trace by a ground plane.

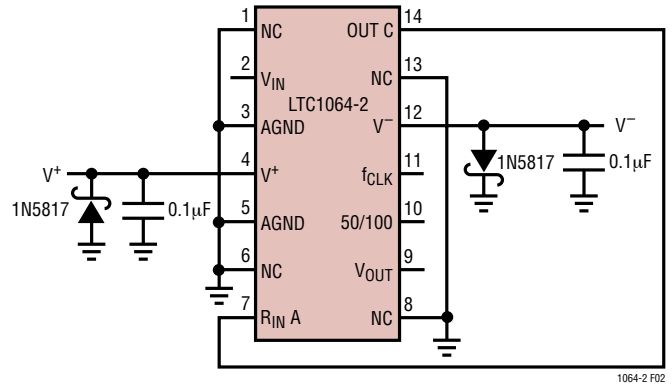
**50/100 (Pin 10):** The DC level at this pin determines the ratio of clock frequency to the  $-3$ dB frequency of the filter. The ratio is 50:1 when Pin 10 is at  $V^+$  and 100:1 when Pin 10 is at  $V^-$ . This pin should be bypassed with a 0.1 $\mu$ F capacitor to analog ground when it’s connected to  $V^-$  or  $V^+$  (Figure 1). See Tables 1 through 7 for typical gain and delay responses for the two ratios.

**$f_{CLK}$  (Pin 11):** For  $\pm 5$ V supplies the logic threshold level is 1.4V. For  $\pm 8$ V and 0V to 5V supplies the logic threshold levels are 2.2V and 3V respectively. The logic threshold levels vary  $\pm 100$ mV over the full military temperature range. The recommended duty cycle of the input clock is 50% although for clock frequencies below 500kHz the clock “on” time can be as low as 200ns. The maximum clock frequency for  $\pm 5$ V supplies is 4MHz. For  $\pm 7$ V supplies and above, the maximum clock frequency is 7MHz. Do not allow the clock levels to exceed the power supplies. For single supply operation  $\geq 6$ V use level shifting at Pin 11 with T<sup>2</sup>L levels (Figure 4).

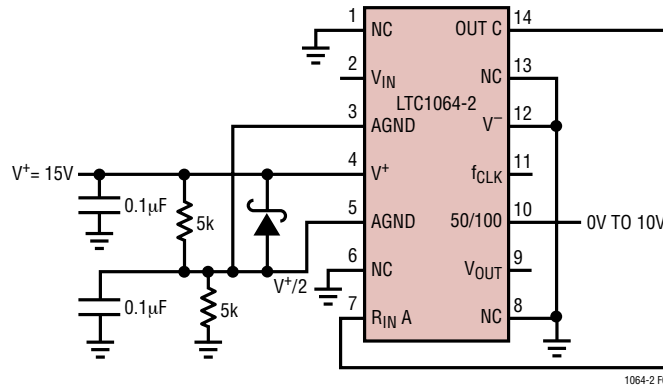
## TYPICAL APPLICATIONS



**Figure 1. Buffering the Filter Output. The Buffer Op Amp Should Not Share the LTC1064-2 Power Lines.**



**Figure 2. Using Schottky Diodes to Protect the IC from Transient Supply Reversal.**



**Figure 3. Single Supply Operation. If Fast Power Up or Down Transients are Expected, Use a 1N5817 Schottky Diode Between Pin 4 and Pin 5. For  $V^+ = 5V$ , Derive the Mid-Supply Voltage with a 7.5k Resistor and an LT1004 2.5V Reference.**



TYPICAL APPLICATIONS

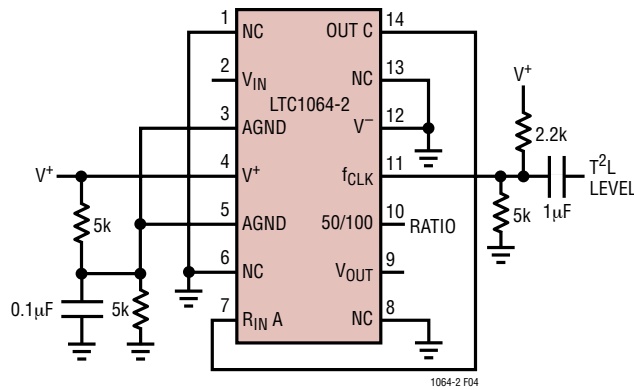


Figure 4. Level Shifting the Input T<sup>2</sup>L Clock for Single Supply Operation ≥ 6V.

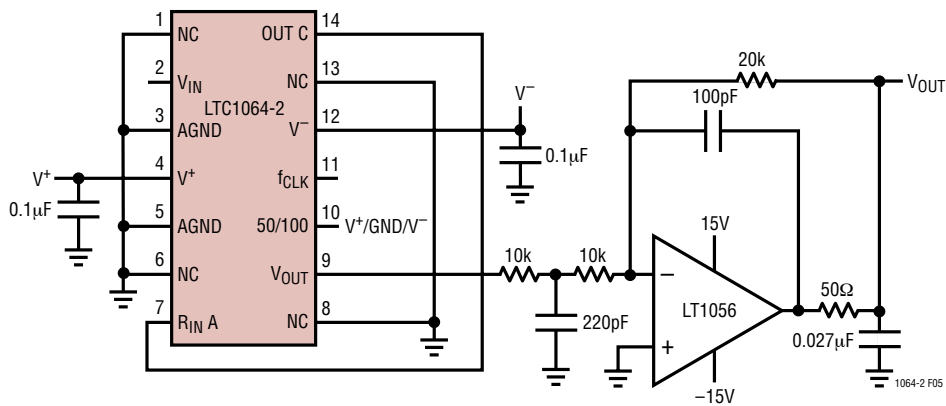
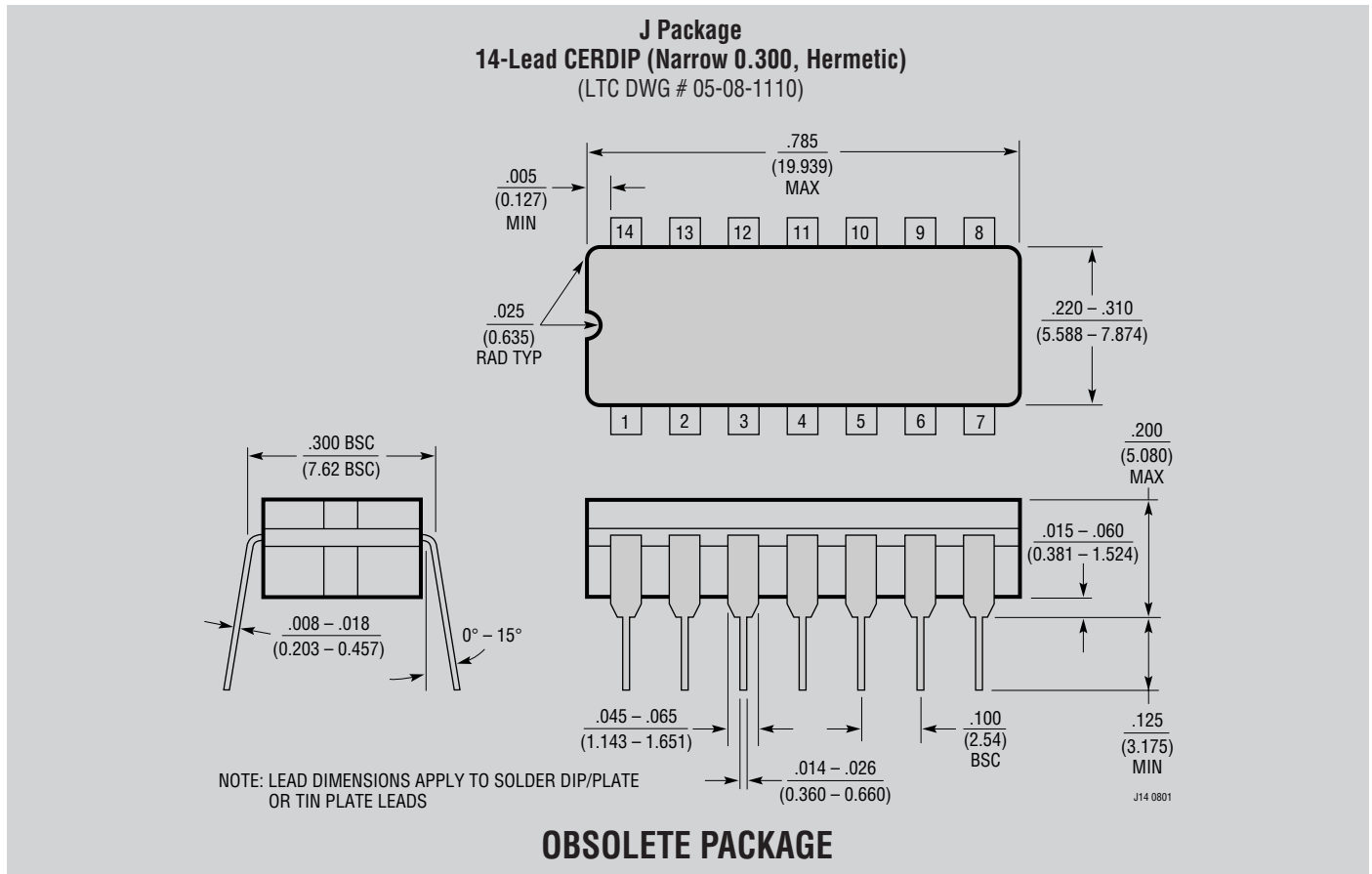


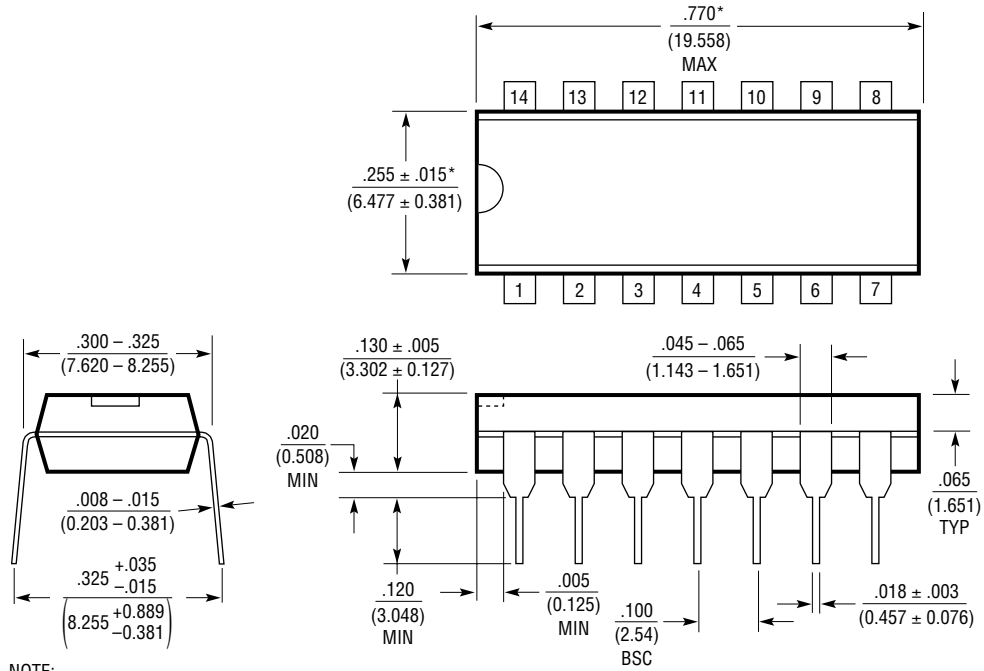
Figure 5. Adding an Output Buffer-Filter to Eliminate Any Clock Feedthrough. Passband ±0.1dB to 50kHz, -3dB at 94kHz.

# PACKAGE DESCRIPTION



# PACKAGE DESCRIPTION

**N Package**  
**14-Lead PDIP (Narrow 0.300)**  
 (LTC DWG # 05-08-1510)

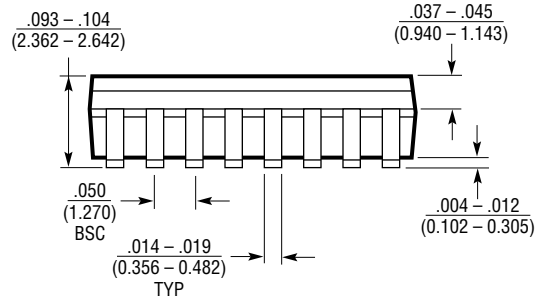
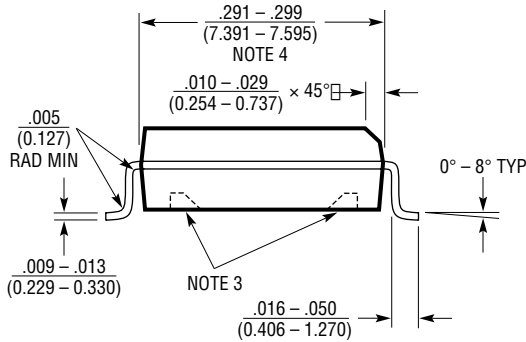
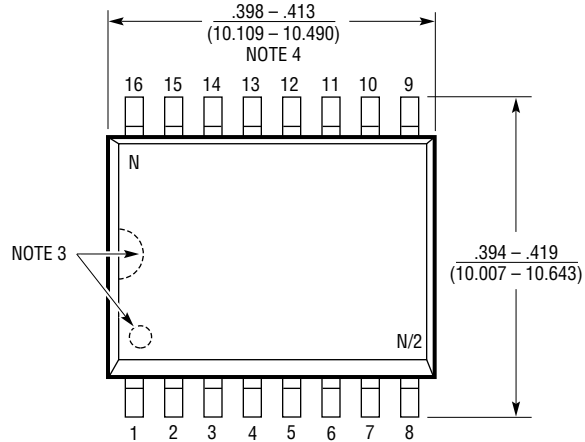
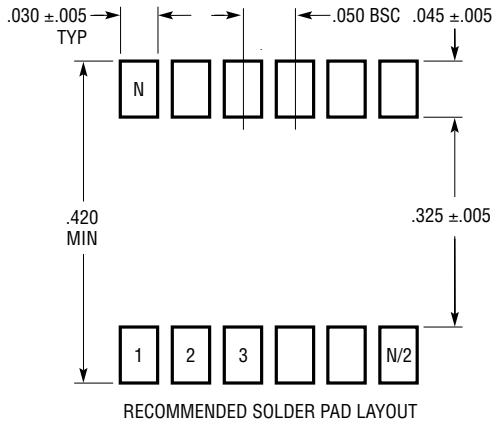


NOTE:  
 1. DIMENSIONS ARE  $\frac{\text{INCHES}}{\text{MILLIMETERS}}$   
 \*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

N14 1002

# 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