

Low Power 8th Order Pin Selectable Elliptic or Linear Phase Lowpass Filter

FEATURES

- 8th Order Pin Selectable Elliptic or Bessel Filter
- 4mA Supply Current with $\pm 5V$ Supplies
- 64dB Attenuation at $1.44 f_{CUTOFF}$ (Elliptic Response)
- f_{CUTOFF} Up to 30kHz (50:1 f_{CLK} to f_{CUTOFF} Ratio)
- $110\mu V_{RMS}$ Wideband Noise with $\pm 5V$ Supplies
- Operates at Single 5V Supply with $1V_{RMS}$ Input Range
- Operates Up to $\pm 8V$ Supplies
- TTL/CMOS Compatible Clock Input
- No External Components
- Available in 14-Pin Dip and 16-Pin SO Wide Packages

APPLICATIONS

- Antialiasing Filters
- Battery-Operated Instruments
- Telecommunication Filters

DESCRIPTION

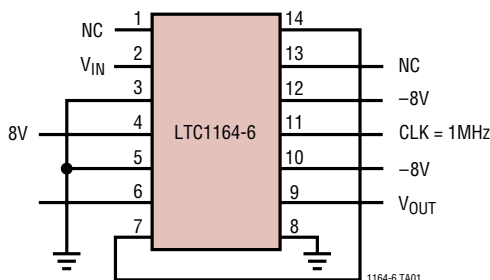
The LTC[®]1164-6 is a monolithic 8th order elliptic lowpass filter featuring clock-tunable cutoff frequency and low power supply current. Low power operation is achieved without compromising noise or distortion performance. At $\pm 5V$ supplies the LTC1164-6 uses only 4mA supply current while keeping wideband noise below $110\mu V_{RMS}$. With a single 5V supply, the LTC1164-6 can provide up to 10kHz cutoff frequency and 80dB signal-to-noise ratio while consuming only 2.5mA.

The LTC1164-6 provides an elliptic lowpass rolloff with stopband attenuation of 64dB at $1.44 f_{CUTOFF}$ and an f_{CLK} -to- f_{CUTOFF} ratio of 100:1 (Pin 10 to V^-). For a ratio of 100:1, f_{CUTOFF} can be clock-tuned up to 10kHz. For a f_{CLK} -to- f_{CUTOFF} ratio of 50:1 (Pin 10 to V^+), the LTC1164-6 provides an elliptic lowpass filter with f_{CUTOFF} frequencies up to 20kHz. When Pin 10 is connected to ground, the LTC1164-6 approximates an 8th order linear phase response with 65dB attenuation at $4.5 f_{-3dB}$ and f_{CLK}/f_{-3dB} ratio of 160:1. The LTC1164-6 is pin compatible with the LTC1064-1.

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TYPICAL APPLICATION

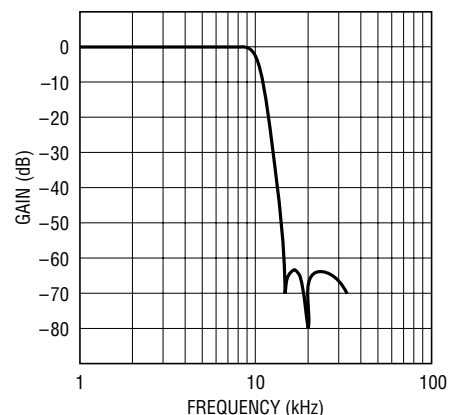
10kHz Anti-Aliasing Elliptic Filter



WIDEBAND NOISE = $115\mu V_{RMS}$

NOTE: THE CONNECTION FROM PIN 7 TO PIN 14 SHOULD BE MADE UNDER THE PACKAGE. THE POWER SUPPLIES SHOULD BE BYPASSED BY A $0.1\mu F$ CAPACITOR AS CLOSE TO THE PACKAGE AS POSSIBLE.

Frequency Response



1164-6 TA02

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ELECTRICAL CHARACTERISTICS The ● denotes specifications that apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ\text{C}$, $V_S = \pm 7.5\text{V}$, $R_L = 10\text{k}\Omega$, $T_A = 25^\circ\text{C}$, $f_{\text{CLK}} = 400\text{kHz}$, TTL or CMOS level (maximum clock rise or fall time $\leq 1\mu\text{s}$) and all gain measurements are referenced to passband gain, unless otherwise specified. $(f_{\text{CLK}}/f_{\text{CUTOFF}}) = 4\text{kHz}$ at 100:1 and 8kHz at 50:1.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Maximum f_{CLK} (Table 3)	$V_S \geq \pm 7.5\text{V}$		1.5		MHz
	$V_S \leq \pm 5\text{V}$		1.0		MHz
	$V_S = \text{Single } 5\text{V}, \text{AGND} = 2\text{V}$		1.0		MHz
Clock Feedthrough	Input at GND, $f = f_{\text{CLK}}$, Square Wave				
	$V_S = \pm 7.5\text{V}, (f_{\text{CLK}}/f_{\text{C}}) = 100:1$ $V_S = \pm 5\text{V}, (f_{\text{CLK}}/f_{\text{C}}) = 50:1$		500 200		μV_{RMS} μV_{RMS}
Wideband Noise	Input at GND, $1\text{Hz} \leq f < f_{\text{CLK}}$				
	$V_S = \pm 7.5\text{V}$ $V_S = \pm 2.5\text{V}$		$115 \pm 5\%$ $100 \pm 5\%$		μV_{RMS} μV_{RMS}
Input Impedance		45	75	110	$\text{k}\Omega$
Output DC Voltage Swing	$V_S = \pm 2.375\text{V}$	● ± 1.25	± 1.50		V
	$V_S = \pm 5\text{V}$	● ± 3.70	± 4.10		V
	$V_S = \pm 7.5\text{V}$	● ± 5.40	± 5.90		V
Output DC Offset	$V_S = \pm 5\text{V}, (f_{\text{CLK}}/f_{\text{C}}) = 100:1$		± 100	± 160	mV
Output DC Offset Tempco	$V_S = \pm 5\text{V}, (f_{\text{CLK}}/f_{\text{C}}) = 100:1$		± 100		$\mu\text{V}/^\circ\text{C}$
Power Supply Current	$V_S = \pm 2.375\text{V}, T_A > 25^\circ\text{C}$		2.5	4.0	mA
		●		4.5	mA
	$V_S = \pm 5\text{V}, T_A > 25^\circ\text{C}$		4.5	7.0	mA
		●		8.0	mA
	$V_S = \pm 7.5\text{V}, T_A > 25^\circ\text{C}$		7.0	11.0	mA
		●		12.5	mA
Power Supply Range			± 2.375	± 8	V

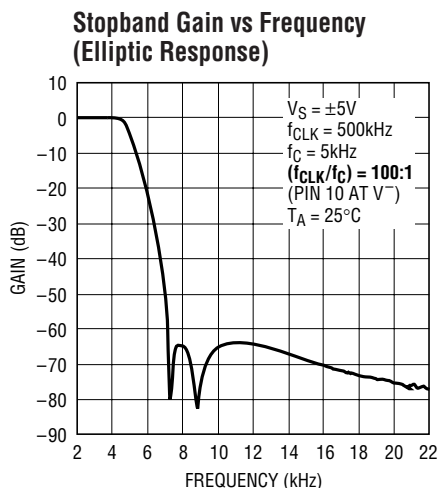
Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: Connecting any pin to voltages greater than V^+ or less than V^- may cause latch-up. It is recommended that no sources operating from external supplies be applied prior to power-up of the LTC1164-6.

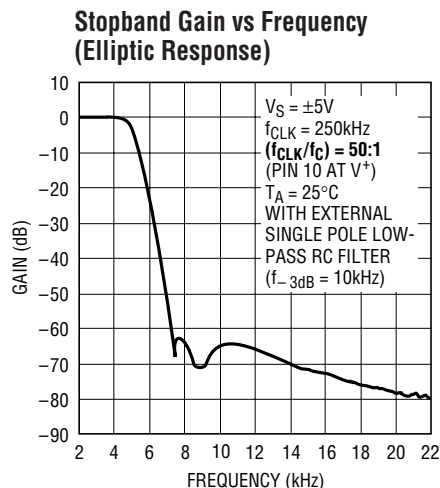
Note 3: All gains are measured relative to passband gain.

Note 4: The cutoff frequency of the filter is abbreviated as f_{CUTOFF} or f_{C} .

TYPICAL PERFORMANCE CHARACTERISTICS



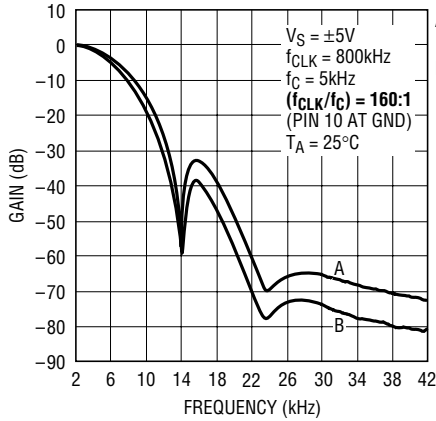
1164-6 G01



1164-6 G02

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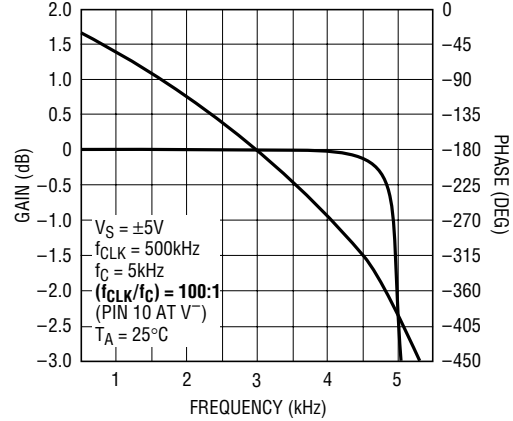
TYPICAL PERFORMANCE CHARACTERISTICS

Stopband Gain vs Frequency
(Linear Phase Response)

- A. RESPONSE WITHOUT EXTERNAL RC FILTER
- B. RESPONSE WITH AN EXTERNAL SINGLE POLE LOWPASS RC FILTER (f_{-3dB} AT 10kHz)

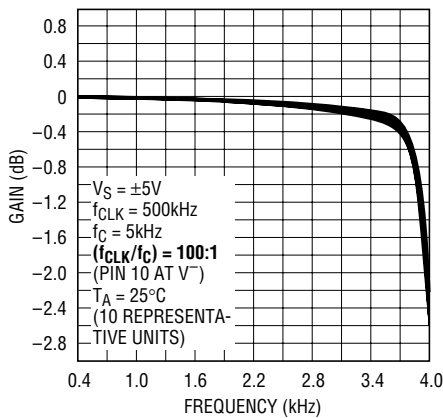
1164-6 G03

Passband Gain and Phase vs Frequency



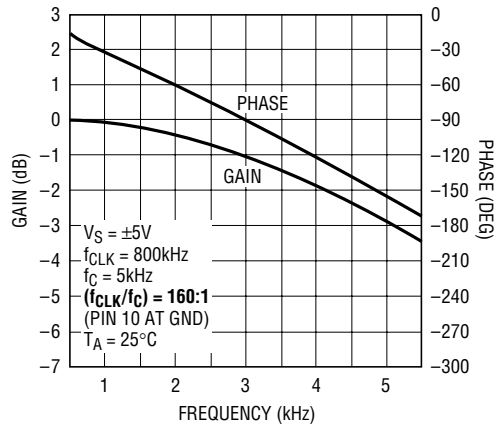
1164-6 G04

Passband Gain vs Frequency



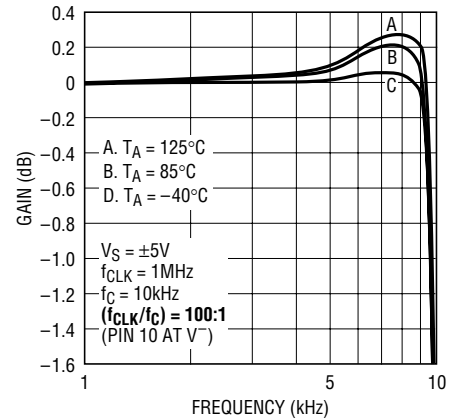
1164-6 G05

Passband Gain and Phase vs Frequency (Linear Phase Response)

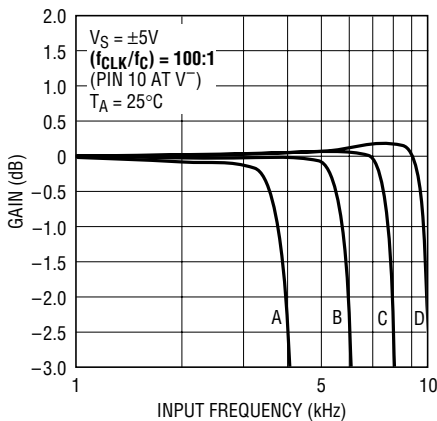


1164-6 G11

Maximum Passband over Temperature

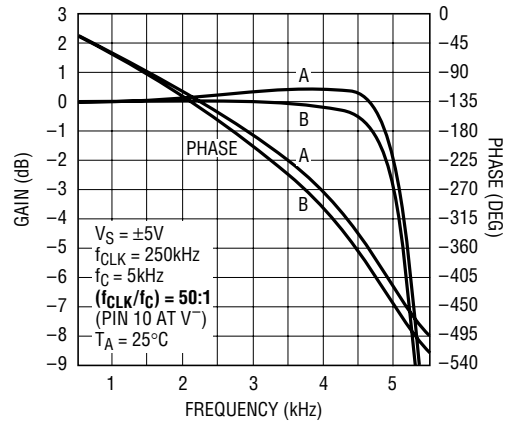


1164-6 G07

Passband vs Frequency and f_{CLK} 

1164-6 G06

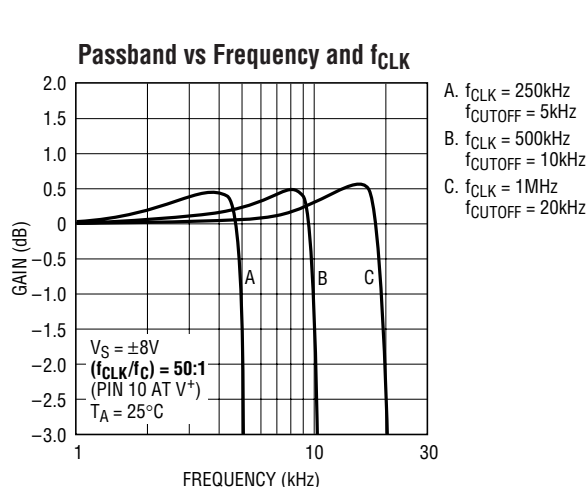
- A. $f_{CLK} = 400kHz$
 $f_{CUTOFF} = 4kHz$
- B. $f_{CLK} = 600kHz$
 $f_{CUTOFF} = 6kHz$
- C. $f_{CLK} = 800kHz$
 $f_{CUTOFF} = 8kHz$
- D. $f_{CLK} = 1MHz$
 $f_{CUTOFF} = 10kHz$

Passband Gain and Phase vs Frequency and f_{CLK} 

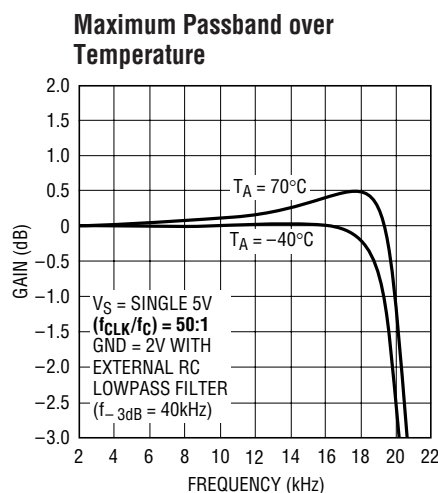
1164-6 G08

- A. RESPONSE WITHOUT EXTERNAL SINGLE POLE RC FILTER
- B. RESPONSE WITH AN EXTERNAL SINGLE POLE LOWPASS RC FILTER (f_{-3dB} AT 10kHz)

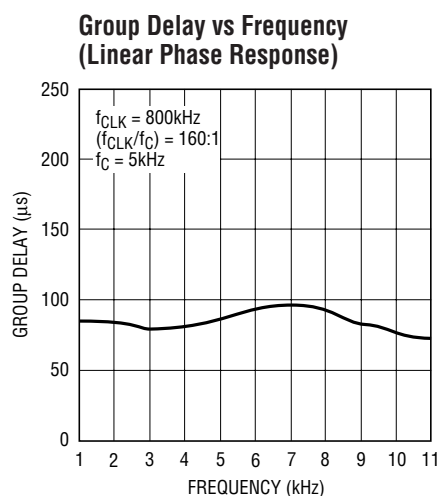
TYPICAL PERFORMANCE CHARACTERISTICS



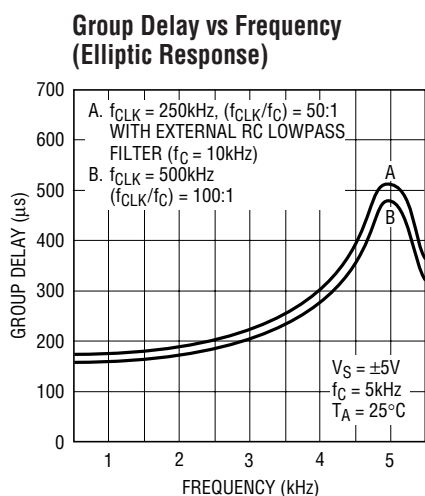
1164-6 G09



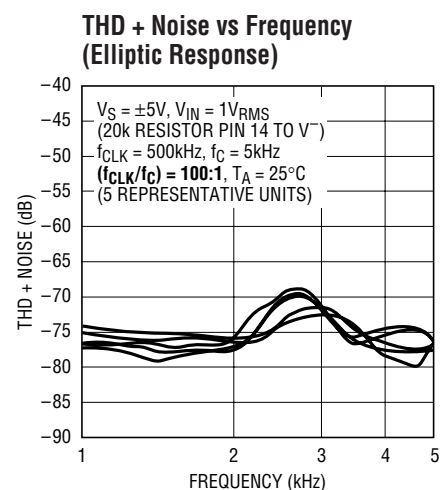
1164-6 G10



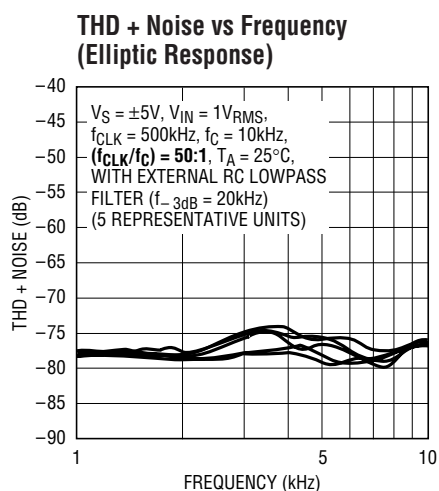
1164-6 G22



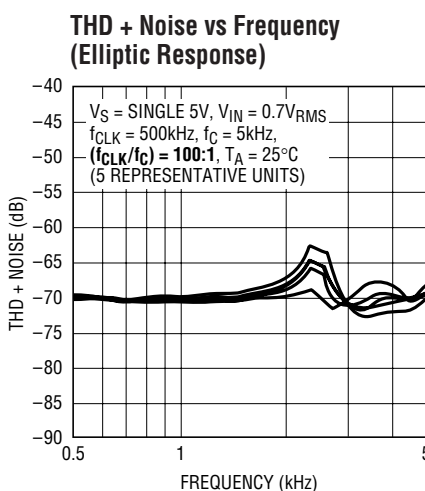
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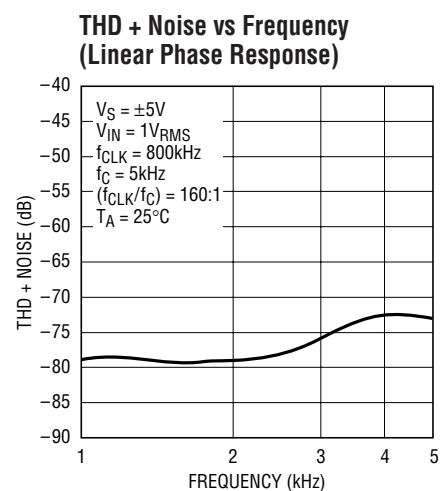
1164-6 G13



1164-6 G14



1164-6 G16

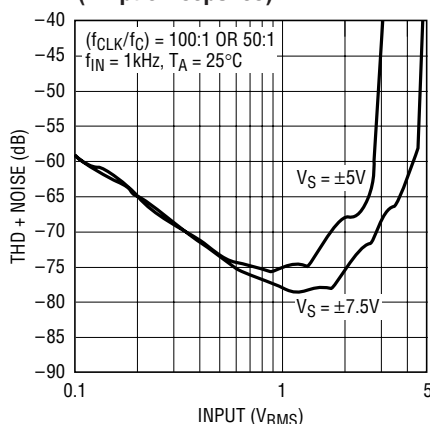


1164-6 G23

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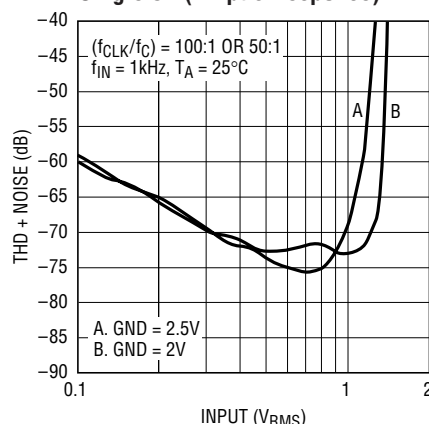
TYPICAL PERFORMANCE CHARACTERISTICS

THD + Noise vs RMS Input
(Elliptic Response)



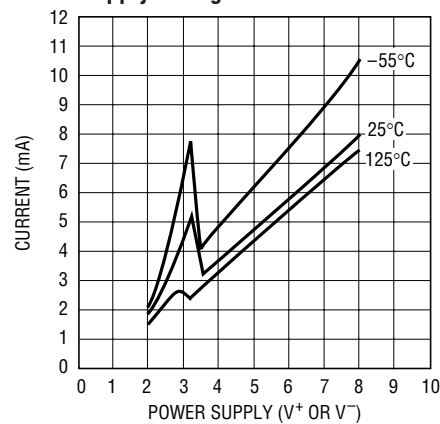
1164-6 G17

THD + Noise vs RMS Input for
Single 5V (Elliptic Response)



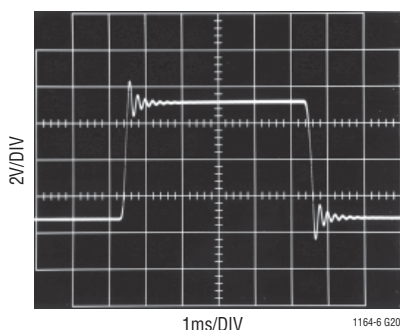
1164-6 G18

Power Supply Current vs Power
Supply Voltage



1164-6 G19

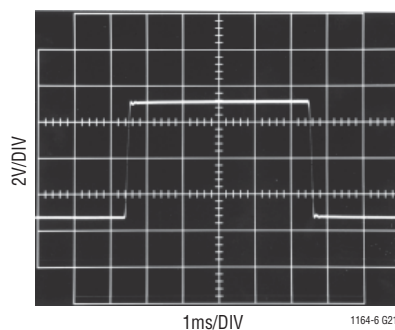
Transient Response



1164-6 G20

$V_S = \pm 7.5V$, $V_{IN} = \pm 3V$ 100Hz SQUARE WAVE
 $f_{CLK} = 500kHz$, $(f_{CLK}/f_C) = 100:1$, $f_{CUTOFF} = 5kHz$
ELLIPTIC RESPONSE

Transient Response



1164-6 G21

$V_S = \pm 7.5V$, $V_{IN} = \pm 3V$ 100Hz SQUARE WAVE
 $f_{CLK} = 800kHz$, $(f_{CLK}/f_C) = 160:1$, $f_{CUTOFF} = 5kHz$
LINEAR PHASE RESPONSE

PIN FUNCTIONS (14-Lead Dual-In-Line Package)

NC (Pins 1, 8, 13): Pins 1, 8, and 13 are not connected to any internal circuit point on the device and should preferably be tied to analog ground.

V_{IN} (Pin 2): The input pin is connected internally through a 50k resistor tied to the inverting input of an op amp.

GND (Pins 3, 5): The filter performance depends on the quality of the analog signal ground. For either dual or single supply operation, an analog ground plane surrounding the package is recommended. The analog ground plane should be connected to any digital ground at a single point. For dual supply operation, Pins 3 and 5 should be connected to the analog ground plane. For single supply operation Pins 3 and 5 should be biased at 1/2 supply and they should be bypassed to the analog ground plane with

at least a 1 μ F capacitor (Figure 2). For single 5V operation at the highest f_{CLK} of 1MHz, Pins 3 and 5 should be biased at 2V. This minimizes passband gain and phase variations (see Typical Performance Characteristics curves: Maximum Passband for Single 5V, 50:1; and THD + Noise vs RMS Input for Single 5V, 50:1).

V^+ (Pins 4, 12): The V^+ (Pin 4) and the V^- (Pin 12) should be bypassed with a 0.1 μ F capacitor to an adequate analog ground. The filter's power supplies should be isolated from other digital or high voltage analog supplies. A low noise linear supply is recommended. Using a switching power supply will lower the signal-to-noise ratio of the filter. The supply during power-up should have a slew rate less than 1V/ μ s. When V^+ is applied before V^- and V^-

* OPTIONAL

1164-6.501

POWER SUPPLY	HIGH LEVEL	LOW LEVEL
Dual Supply = $\pm 7.5V$	$\geq 2.18V$	$\leq 0.5V$
Dual Supply = $\pm 5V$	$\geq 1.45V$	$\leq 0.5V$
Dual Supply = $\pm 2.5V$	$\geq 0.73V$	$\leq -2.0V$
Single Supply = $12V$	$\geq 7.80V$	$\leq 6.5V$
Single Supply = $5V$	$\geq 1.45V$	$\leq 0.5V$

LT1006, $f_C < 5\text{kHz}$
 LT1200, $f_C > 5\text{kHz}$

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APPLICATIONS INFORMATION

Passband Response

The passband response of the LTC1164-6 is optimized for a f_{CLK}/f_{CUTOFF} ratio of 100:1. Minimum passband ripple occurs from 1Hz to 80% of f_{CUTOFF} . Although the passband of the LTC1164-6 is optimized for ratio f_{CLK}/f_{CUTOFF} of 100:1, if a ratio of 50:1 is desired, connect a single pole lowpass RC ($f_{-3dB} = 2 f_{CUTOFF}$) at the output of the filter. The RC will make the passband gain response as flat as the 100:1 case. If the RC is omitted, and clock frequencies are below 500kHz the passband gain will peak by 0.4dB at 90% f_{CUTOFF} .

Table 2. Typical Passband Ripple with Single 5V Supply ($f_{CLK}/f_C = 100:1$, GND = 2V, 30kHz, Fixed Single Pole, Lowpass RC Filter at Pin 9 (See Typical Applications))

PASSBAND FREQUENCY	PASSBAND GAIN (REFERENCED TO 0dB)			
	$f_{CUTOFF} = 1kHz$		$f_{CUTOFF} = 10kHz$	
	$T_A = 25^{\circ}C$ (dB)	$T_A = 0^{\circ}C$ (dB)	$T_A = 25^{\circ}C$ (dB)	$T_A = 70^{\circ}C$ (dB)
% of f_{CUTOFF}				
10	0.00	0.00	0.00	0.00
20	-0.02	0.00	0.01	0.01
30	-0.05	-0.01	-0.01	0.01
40	-0.10	-0.02	-0.02	0.02
50	-0.13	-0.03	-0.01	0.03
60	-0.15	-0.01	0.01	0.05
70	-0.18	-0.01	0.01	0.07
80	-0.25	-0.08	-0.05	0.02
90	-0.39	-0.23	-0.18	-0.05
f_{CUTOFF}	-2.68	-2.79	-2.74	-2.68

The gain peaking can approximate a $\sin \chi/\chi$ correction for some applications. (See Typical Performance Characteristics curve, Passband vs Frequency and f_{CLK} at $f_{CLK}/f_C = 50:1$.)

When the LTC1164-6 operates with a single 5V supply and its cutoff frequency is clock-tuned to 10kHz, an output single pole RC filter can also help maintain outstanding passband flatness from 0°C to 70°C. Table 2 shows details.

Clock Feedthrough

Clock feedthrough is defined as, the RMS value of the clock frequency and its harmonics that are present at the filter's output (Pin 9). The clock feedthrough is tested with the input (Pin 2) grounded and, it depends on PC board layout and on the value of the power supplies. With proper layout techniques the values of the clock feedthrough are shown in Table 3.

Table 3. Clock Feedthrough

V_S	50:1	100:1
$\pm 2.5V$	60 μV_{RMS}	60 μV_{RMS}
$\pm 5V$	100 μV_{RMS}	200 μV_{RMS}
$\pm 7.5V$	150 μV_{RMS}	500 μV_{RMS}

Note: The clock feedthrough at $\pm 2.5V$ supplies is imbedded in the wideband noise of the filter. (The clock signal is a square wave.)

Any parasitic switching transients during the rise and fall edges of the incoming clock are not part of the clock feedthrough specifications. Switching transients have frequency contents much higher than the applied clock; their amplitude strongly depends on scope probing techniques as well as grounding and power supply bypassing. The clock feedthrough, if bothersome, can be greatly reduced by adding a simple R/C lowpass network at the output of the filter (Pin 9). This R/C will completely eliminate any switching transient.

Wideband Noise

The wideband noise of the filter is the total RMS value of the device's noise spectral density and it is used to determine the operating signal-to-noise ratio. Most of its frequency contents lie within the filter passband and it cannot be reduced with post filtering. For instance, the LTC1164-6 wideband noise at $\pm 2.5V$ supply is 100 μV_{RMS} , 90 μV_{RMS} of which have frequency contents from DC up to the filter's cutoff frequency. The total wideband noise (μV_{RMS}) is nearly independent of the value of the clock. The clock feedthrough specifications are not part of the wideband noise.

Speed Limitations

The LTC1164-6 optimizes AC performance versus power consumption. To avoid op amp slew rate limiting at maximum clock frequencies, the signal amplitude should be kept below a specified level as shown on Table 4.

Aliasing

Aliasing is an inherent phenomenon of sampled data systems and it occurs when input frequencies close to the sampling frequency are applied. For the LTC1164-6 case, an input signal whose frequency is in the range of $f_{CLK} \pm 4\%$, will be aliased back into the filter's passband. If, for instance, an LTC1164-6 operating with a 100kHz clock

APPLICATIONS INFORMATION

and 1kHz cutoff frequency receives a 98.5kHz, 10mV_{RMS} input signal, a 1.5kHz, 10μV_{RMS} alias signal will appear at its output. When the LTC1164-6 operates with a clock-to-cutoff frequency of 50:1, aliasing occurs at twice the clock frequency. Table 5 shows details.

Table 4. Maximum V_{IN} vs V_S and f_{CLK}

POWER SUPPLY	MAXIMUM f _{CLK}	MAXIMUM V _{IN}
±7.5V	1.5MHz	1V _{RMS} (f _{IN} > 35kHz)
	1MHz	3V _{RMS} (f _{IN} > 25kHz)
	≥1MHz	0.7V _{RMS} (f _{IN} > 250kHz)
±5V	1MHz	2.5V _{RMS} (f _{IN} > 25kHz)
	1MHz	0.5V _{RMS} (f _{IN} > 100kHz)
Single 5V	1MHz	0.7V _{RMS} (f _{IN} > 25kHz)
	1MHz	0.5V _{RMS} (f _{IN} > 100kHz)

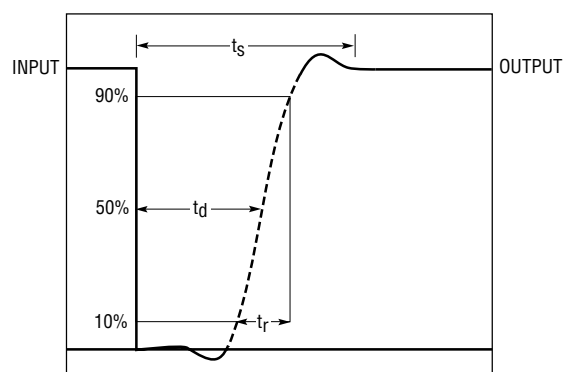
Table 5. Aliasing (f_{CLK} = 100kHz)

INPUT FREQUENCY (V _{IN} = 1V _{RMS}) (kHz)	OUTPUT LEVEL (Relative to Input) (dB)	OUTPUT FREQUENCY (Aliased Frequency) (kHz)
f _{CLK} /f _C = 100:1, f _{CUTOFF} = 1kHz		
96 (or 104)	-75.0	4.0
97 (or 103)	-68.0	3.0
98 (or 102)	-65.0	2.0
98.5 (or 101.5)	-60.0	1.5
99 (or 101)	-3.2	1.0
99.5 (or 100.5)	-0.5	0.5
f _{CLK} /f _C = 50:1, f _{CUTOFF} = 2kHz		
192 (or 208)	-76.0	8.0
194 (or 206)	-68.0	6.0
196 (or 204)	-63.0	4.0
198 (or 202)	-3.4	2.0
199 (or 201)	-1.3	1.0
199.5 (or 200.5)	-0.9	0.5

Table 6. Transient Response of LTC Lowpass Filters

LOWPASS FILTER	DELAY TIME* (SEC)	RISE TIME** (SEC)	SETTLING TIME*** (SEC)	OVER-SHOOT (%)
LTC1064-3 Bessel	0.50/f _C	0.34/f _C	0.80/f _C	0.5
LTC1164-5 Linear Phase	0.43/f _C	0.34/f _C	0.85/f _C	0
LTC1164-6 Linear Phase	0.43/f _C	0.34/f _C	1.15/f _C	1
LTC1264-7 Linear Phase	1.15/f _C	0.36/f _C	2.05/f _C	5
LTC1164-7 Linear Phase	1.20/f _C	0.39/f _C	2.20/f _C	5
LTC1064-7 Linear Phase	1.20/f _C	0.39/f _C	2.20/f _C	5
LTC1164-5 Butterworth	0.80/f _C	0.48/f _C	2.40/f _C	11
LTC1164-6 Elliptic	0.85/f _C	0.54/f _C	4.30/f _C	18
LTC1064-4 Elliptic	0.90/f _C	0.54/f _C	4.50/f _C	20
LTC1064-1 Elliptic	0.85/f _C	0.54/f _C	6.50/f _C	20

* To 50% ±5%, ** 10% to 90% ±5%, *** To 1% ±0.5%



$$\text{RISE TIME (} t_r \text{)} = \frac{0.54}{f_{\text{CUTOFF}}} \pm 5\%$$

$$\text{SETTLING TIME (} t_s \text{)} = \frac{4.3}{f_{\text{CUTOFF}}} \pm 5\%$$

(TO 1% OF OUTPUT)

$$\text{TIME DELAY (} t_d \text{)} = \text{GROUP DELAY} \approx \frac{0.85}{f_{\text{CUTOFF}}}$$

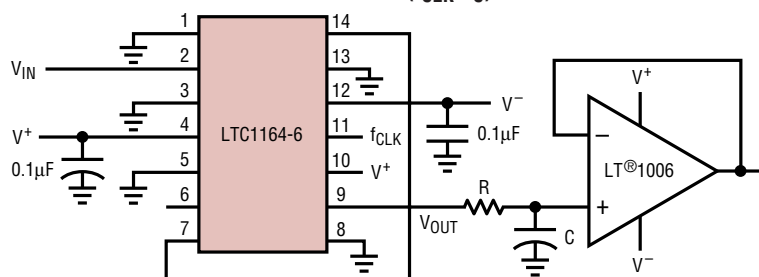
(TO 50% OF OUTPUT)

1164-6 F04

Figure 4

TYPICAL APPLICATIONS

8th Order Elliptic Lowpass Filter
(f_{CLK}/f_C = 50:1)

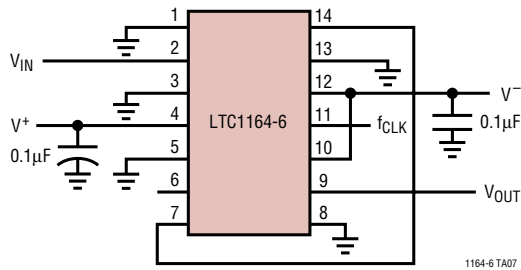


- NOTES:
1. OPTIONAL OUTPUT BUFFER
1/2πRC = (2)(f_{CUTOFF})
 2. PINS 1, 8, 13 CAN BE GROUNDED OR LEFT FLOATING

1164-6 TA06

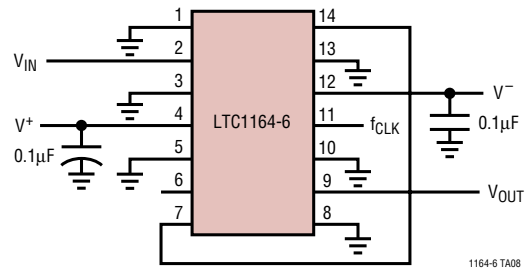
TYPICAL APPLICATIONS

8th Order Elliptic Lowpass Filter ($f_{CLK}/f_C = 100:1$)



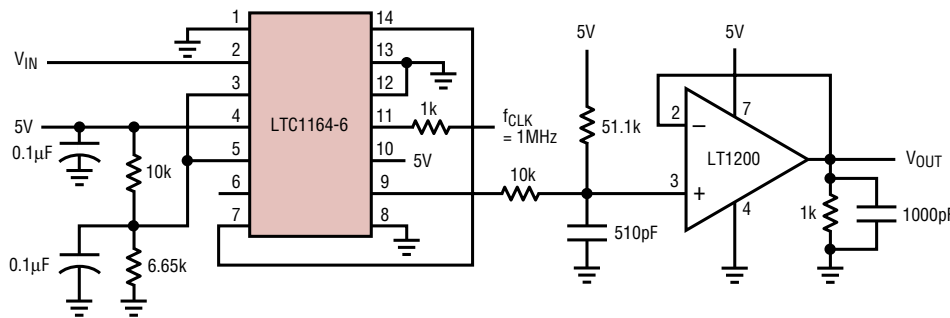
1164-6 TA07

8th Order Linear Phase Lowpass Filter ($f_{CLK}/f_C = 160:1$)



1164-6 TA08

8th Order 20kHz Cutoff, Elliptic Filter Operating with a Single 5V Supply and Driving 1k, 1000pF Load

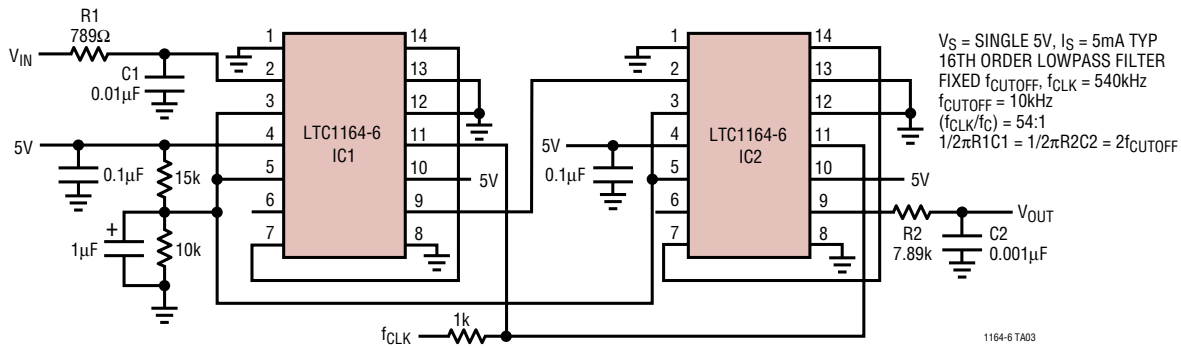


NOTES:

1. TOTAL SUPPLY CURRENT $I_S = 4\text{mA}$ (EXCLUDING OUTPUT LOAD CURRENT)
2. FLAT PASSBAND UP TO 18kHz, $f_{-3dB} = 20\text{kHz}$
3. THD + NOISE $\leq -70\text{dB}$, $1V_{P-P} \leq V_{IN} \leq 3V_{P-P}$, $f_{IN} = 1\text{kHz}$

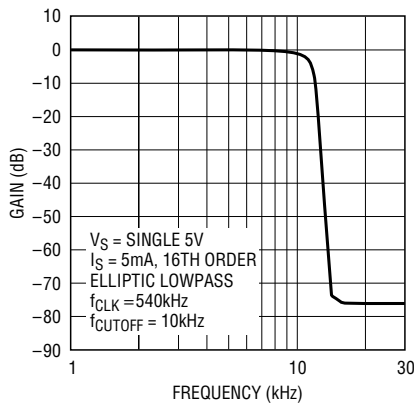
1164-6 TA09

Single 5V, 16th Order Lowpass Filter $f_{CUTOFF} = 10\text{kHz}$



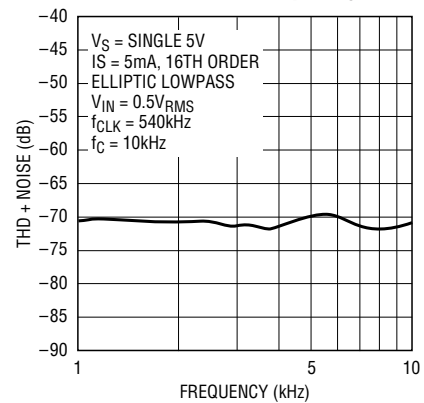
1164-6 TA03

Gain vs Frequency



1164-6 TA04

THD + Noise vs Frequency

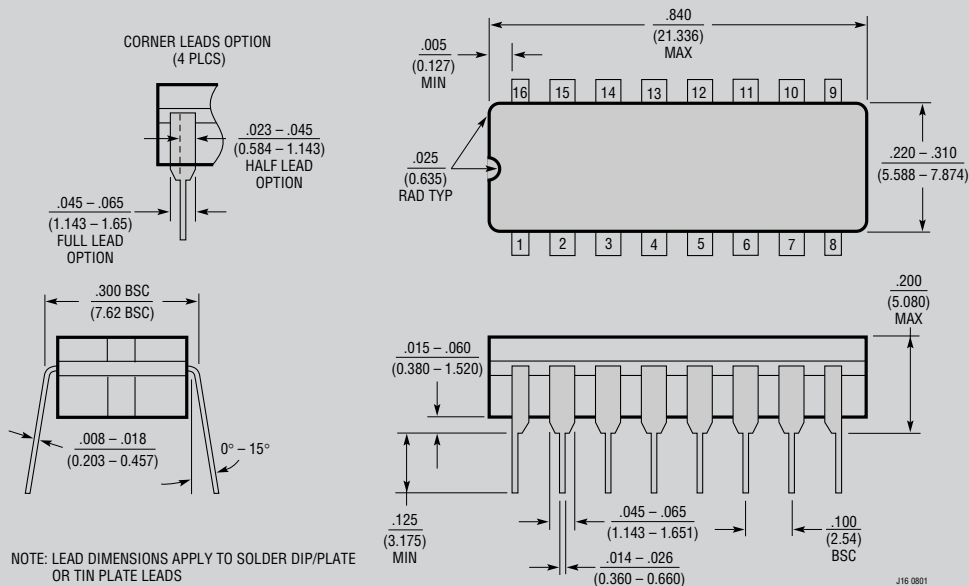


1164-6 TA05

11646fa

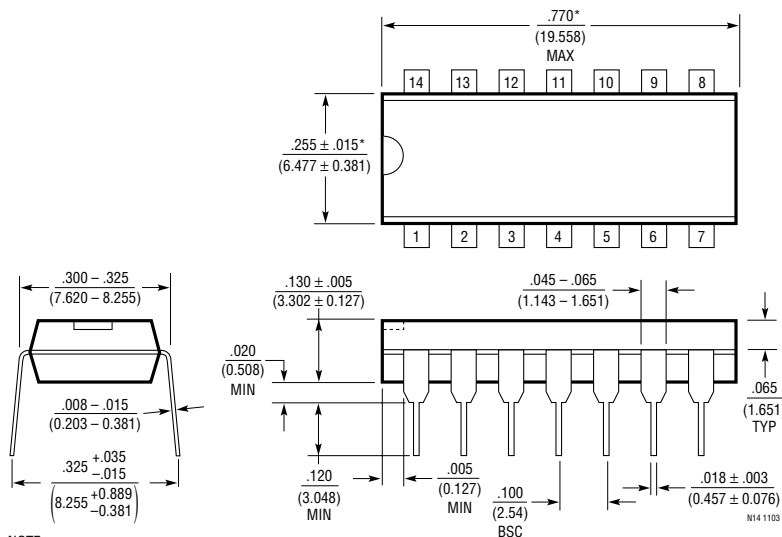
PACKAGE DESCRIPTION

J Package 14-Lead Cerdip (Narrow .300 Inch, Hermetic) (Reference LTC DWG # 05-08-1110)



OBSOLETE PACKAGE

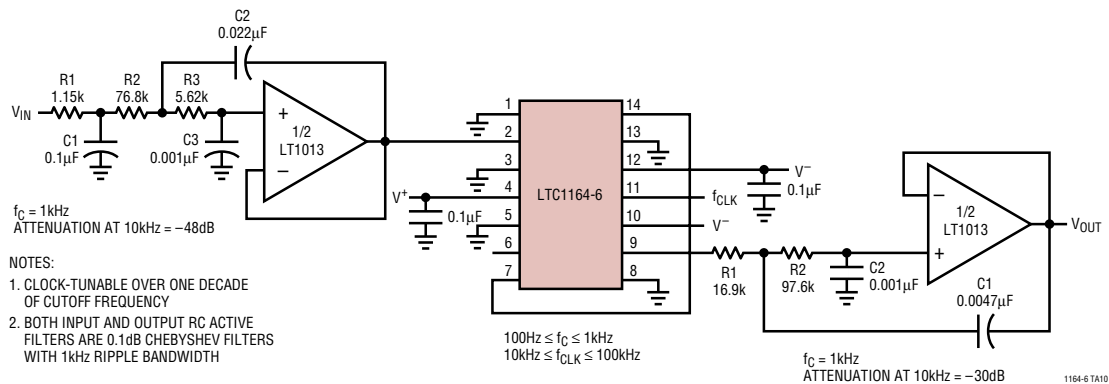
N Package 14-Lead PDIP (Narrow .300 Inch) (Reference LTC DWG # 05-08-1510)



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

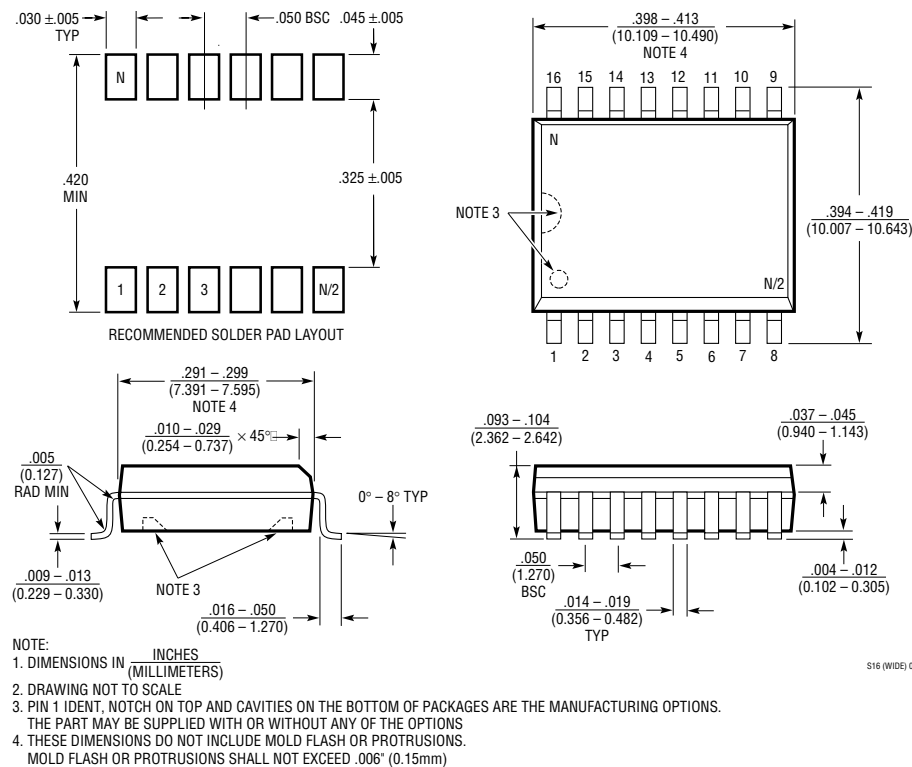
TYPICAL APPLICATION

8th Order Low Power, Clock-Tunable Elliptic Filter with Active RC Input Antialiasing Filter and Output Smoothing Filter



PACKAGE DESCRIPTION

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



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1069-1	Low Power, 8th Order Elliptic Lowpass	Operates from a Single 3.3V to ±5V Supply
LTC1069-6	Very Low Power 8th Order Elliptic Lowpass	Optimized for 3V/5V Single Supply Operation, Consumes 1mA at 3V

11646fa



**Стандарт
Электрон
Связь**

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С нами вы становитесь еще успешнее!

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