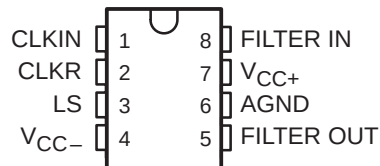


TLC04/MF4A-50, TLC14/MF4A-100 BUTTERWORTH FOURTH-ORDER LOW-PASS SWITCHED-CAPACITOR FILTERS

SLAS021A – NOVEMBER 1986 – REVISED MARCH 1995

- **Low Clock-to-Cutoff-Frequency Ratio Error**
TLC04/MF4A-50 . . . $\pm 0.8\%$
TLC14/MF4A-100 . . . $\pm 1\%$
- **Filter Cutoff Frequency Dependent Only on External-Clock Frequency Stability**
- **Minimum Filter Response Deviation Due to External Component Variations Over Time and Temperature**
- **Cutoff Frequency Range From 0.1 Hz to 30 kHz, $V_{CC\pm} = \pm 2.5$ V**
- **5-V to 12-V Operation**
- **Self Clocking or TTL-Compatible and CMOS-Compatible Clock Inputs**
- **Low Supply-Voltage Sensitivity**
- **Designed to be Interchangeable With National MF4-50 and MF4-100**

D OR P PACKAGE
(TOP VIEW)



description

The TLC04/MF4A-50 and TLC14/MF4A-100 are monolithic Butterworth low-pass switched-capacitor filters. Each is designed as a low-cost, easy-to-use device providing accurate fourth-order low-pass filter functions in circuit design configurations.

Each filter features cutoff frequency stability that is dependent only on the external-clock frequency stability. The cutoff frequency is clock tunable and has a clock-to-cutoff frequency ratio of 50:1 with less than $\pm 0.8\%$ error for the TLC04/MF4A-50 and a clock-to-cutoff frequency ratio of 100:1 with less than $\pm 1\%$ error for the TLC14/MF4A-100. The input clock features self-clocking or TTL- or CMOS-compatible options in conjunction with the level shift (LS) terminal.

The TLC04C/MF4A-50C and TLC14C/MF4A-100C are characterized for operation from 0°C to 70°C . The TLC04I/MF4A-50I and TLC14I/MF4A-100I are characterized for operation from -40°C to 85°C . The TLC04M/MF4A-50M and TLC14M/MF4A-100M are characterized over the full military temperature range of -55°C to 125°C .

AVAILABLE OPTIONS

T _A	CLOCK-TO-CUTOFF FREQUENCY RATIO	PACKAGE	
		SMALL OUTLINE (D)	PLASTIC DIP (P)
0°C to 70°C	50:1	TLC04CD/MF4A-50CD	TLC04CP/MF4A-50CP
	100:1	TLC14CD/MF4A-100CD	TLC14CP/MF4A-100CP
-40°C to 85°C	50:1	TLC04ID/MF4A-50ID	TLC04IP/MF4A-50IP
	100:1	TLC14ID/MF4A-100ID	TLC14IP/MF4A-100IP
-55°C to 125°C	50:1		TLC04MP/MF4A-50MP
	100:1		TLC14MP/MF4A-100MP

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC04CDR/MF4A-50CDR).



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

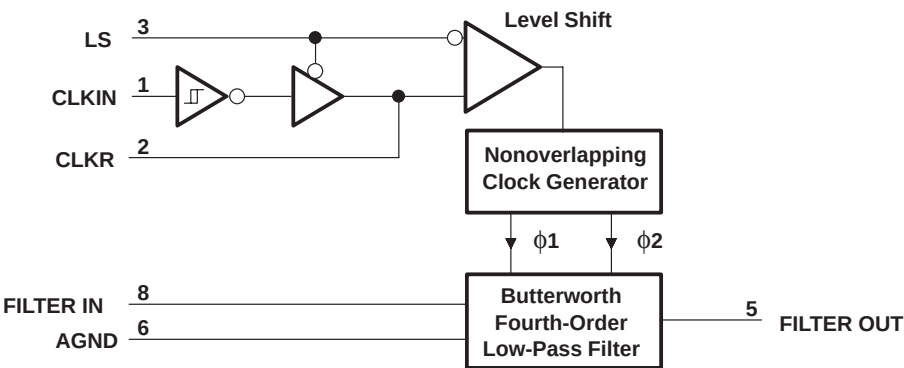
**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 1995, Texas Instruments Incorporated

TLC04/MF4A-50, TLC14/MF4A-100
BUTTERWORTH FOURTH-ORDER LOW-PASS
SWITCHED-CAPACITOR FILTERS
SLAS021A – NOVEMBER 1986 – REVISED MARCH 1995

functional block diagram



Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
AGND	6	I	Analog ground. The noninverting input to the operational amplifiers of the Butterworth fourth-order low-pass filter.
CLKIN	1	I	Clock in. CLKIN is the clock input terminal for CMOS-compatible clock or self-clocking options. For either option, LS is at V_{CC-} . For self-clocking, a resistor is connected between CLKIN and CLKR and a capacitor is connected from CLKIN to ground.
CLKR	2	I	Clock R. CLKR is the clock input for a TTL-compatible clock. For a TTL clock, LS is connected to midsupply and CLKIN can be left open, but it is recommended that it be connected to either V_{CC+} or V_{CC-} .
FILTER IN	8	I	Filter input
FILTER OUT	5	O	Butterworth fourth-order low-pass filter output
LS	3	I	Level shift. LS accommodates the various input clocking options. For CMOS-compatible clocks or self-clocking, LS is at V_{CC-} and for TTL-compatible clocks, LS is at midsupply.
V_{CC+}	7	I	Positive supply voltage terminal
V_{CC-}	4	I	Negative supply voltage terminal

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)[†]

Supply voltage range, $V_{CC\pm}$ (see Note 1)		± 7 V
Operating free-air temperature range, T_A :	TLC04C/MF4A-50C, TLC14C/MF4A-100C	0°C to 70°C
	TLC04I/MF4A-50I, TLC14I/MF4A-100I	–40°C to 85°C
	TLC04M/MF4A-50M, TLC14M/MF4A-100M ...	–55°C to 125°C
Storage temperature range, T_{stg}		–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260°C

[†] Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltage values are with respect to the AGND terminal.

recommended operating conditions

		TLC04/MF4A-50		TLC14/MF4A-100		UNIT
		MIN	MAX	MIN	MAX	
Positive supply voltage, V_{CC+}		2.25	6	2.25	6	V
Negative supply voltage, V_{CC-}		–2.25	–6	–2.25	–6	V
High-level input voltage, V_{IH}		2		2		V
Low-level input voltage, V_{IL}			0.8		0.8	V
Clock frequency, f_{clock} (see Note 2)	$V_{CC\pm} = \pm 2.5$ V	5	1.5×10^6	5	1.5×10^6	Hz
	$V_{CC\pm} = \pm 5$ V	5	2×10^6	5	2×10^6	
Cutoff frequency, f_{co} (see Note 3)		0.1	40×10^3	0.05	20×10^3	Hz
Operating free-air temperature, T_A	TLC04C/MF4A-50C, TLC14C/MF4A-100C	0	70	0	70	°C
	TLC04I/MF4A-50I, TLC14I/MF4A-100I	–40	85	–40	85	
	TLC04M/MF4A-50M, TLC14M/MF4A-100M	–55	125	–55	125	

NOTES: 2. Above 250 kHz, the input clock duty cycle should be 50% to allow the operational amplifiers the maximum time to settle while processing analog samples.

3. The cutoff frequency is defined as the frequency where the response is 3.01 dB less than the dc gain of the filter.

electrical characteristics over recommended operating free-air temperature range, $V_{CC+} = 2.5$ V, $V_{CC-} = -2.5$ V, $f_{clock} \leq 250$ kHz (unless otherwise noted)

filter section

PARAMETER			TEST CONDITIONS	TLC04/MF4A-50			TLC14/MF4A-100			UNIT
				MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V _{OO}	Output offset voltage			25			50			mV
V _{OM}	Peak output voltage	V _{OM+}	R _L = 10 kΩ	1.8	2		1.8	2		V
		V _{OM–}		–1.25	–1.7		–1.25	–1.7		
I _{OS}	Short-circuit output current	Source	T _A = 25°C, See Note 4	–0.5			–0.5			mA
		Sink		4			4			
I _{CC}	Supply current		f _{clock} = 250 kHz	1.2	2.25		1.2	2.25		mA

[‡] All typical values are at $T_A = 25^\circ\text{C}$.

NOTE 4: $I_{OS}(\text{source})$ is measured by forcing the output to its maximum positive voltage and then shorting the output to the V_{CC-} terminal. $I_{OS}(\text{sink})$ is measured by forcing the output to its maximum negative voltage and then shorting the output to the V_{CC+} terminal.

TLC04/MF4A-50, TLC14/MF4A-100

BUTTERWORTH FOURTH-ORDER LOW-PASS

SWITCHED-CAPACITOR FILTERS

SLAS021A – NOVEMBER 1986 – REVISED MARCH 1995

electrical characteristics over recommended operating free-air temperature range, $V_{CC+} = 5\text{ V}$, $V_{CC-} = -5\text{ V}$, $f_{\text{clock}} \leq 250\text{ kHz}$ (unless otherwise noted)

filter section

PARAMETER		TEST CONDITIONS	TLC04/MF4A-50			TLC14/MF4A-100			UNIT
			MIN	TYP [†]	MAX	MIN	TYP [†]	MAX	
V_{OO}	Output offset voltage		150			200			mV
V_{OM}	Peak output voltage	V_{OM+}	$R_L = 10\text{ k}\Omega$	3.75	4.3	3.75	4.5		V
		V_{OM-}		-3.75	-4.1	-3.75	-4.1		
I_{OS}	Short-circuit output current	Source	$T_A = 25^\circ\text{C}$, See Note 4	-2		-2			mA
		Sink		5		5			
I_{CC}	Supply current	$f_{\text{clock}} = 250\text{ kHz}$	1.8		3	1.8		3	mA
k_{SVS}	Supply voltage sensitivity (see Figures 1 and 2)		-30			-30			dB

[†] All typical values are at $T_A = 25^\circ\text{C}$.

NOTE 4: $I_{OS(\text{source})}$ is measured by forcing the output to its maximum positive voltage and then shorting the output to the V_{CC-} terminal. $I_{OS(\text{sink})}$ is measured by forcing the output to its maximum negative voltage and then shorting the output to the V_{CC+} terminal.

clocking section

PARAMETER		TEST CONDITIONS		MIN	TYP [†]	MAX	UNIT
V_{IT+}	Positive-going input threshold voltage		$V_{CC+} = 10\text{ V}$, $V_{CC-} = 0$	6.1	7	8.9	V
			$V_{CC+} = 5\text{ V}$, $V_{CC-} = 0$	3.1	3.5	4.4	
V_{IT-}	Negative-going input threshold voltage		$V_{CC+} = 10\text{ V}$, $V_{CC-} = 0$	1.3	3	3.8	V
			$V_{CC+} = 5\text{ V}$, $V_{CC-} = 0$	0.6	1.5	1.9	
V_{hys}	Hysteresis voltage ($V_{IT+} - V_{IT-}$)		$V_{CC+} = 10\text{ V}$, $V_{CC-} = 0$	2.3	4	7.6	V
			$V_{CC+} = 5\text{ V}$, $V_{CC-} = 0$	1.2	2	3.8	
V_{OH}	High-level output voltage		$V_{CC} = 10\text{ V}$	9			V
			$V_{CC} = 5\text{ V}$	4.5			
V_{OL}	Low-level output voltage		$V_{CC} = 10\text{ V}$	1			V
			$V_{CC} = 5\text{ V}$	0.5			
	Input leakage current		$V_{CC} = 10\text{ V}$	2			μA
			$V_{CC} = 5\text{ V}$	2			
I_O	Output current		$V_{CC} = 10\text{ V}$	-3	-7		mA
			$V_{CC} = 5\text{ V}$	-0.75	-2		
			$V_{CC} = 10\text{ V}$	3	7		mA
			$V_{CC} = 5\text{ V}$	0.75	2		

[†] All typical values are at $T_A = 25^\circ\text{C}$.

operating characteristics over recommended operating free-air temperature range, $V_{CC+} = 2.5\text{ V}$, $V_{CC-} = -2.5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		TLC04/MF4A-50			TLC14/MF4A-100			UNIT
			MIN	TYP†	MAX	MIN	TYP†	MAX	
Maximum clock frequency, f _{max}	See Note 2		1.5	3		1.5	3		MHz
Clock-to-cutoff-frequency ratio (f _{clock} /f _{co})	f _{clock} ≤ 250 kHz, T _A = 25°C		49.27	50.07	50.87	99	100	101	Hz/Hz
Temperature coefficient of clock-to-cutoff frequency ratio	f _{clock} ≤ 250 kHz		±25			±25			ppm/°C
Frequency response above and below cutoff frequency (see Note 5)	f _{co} = 5 kHz, f _{clock} = 250 kHz, T _A = 25°C	f = 6 kHz	−7.9	−7.57	−7.1				dB
		f = 4.5 kHz	−1.7	−1.46	−1.3				
	f _{co} = 5 kHz, f _{clock} = 250 kHz, T _A = 25°C	f = 3 kHz				−7.9	−7.42	−7.1	dB
		f = 2.25 kHz				−1.7	−1.51	−1.3	
Dynamic range (see Note 6)	T _A = 25°C		80			78			dB
Stop-band frequency attenuation at 2 f _{co}	f _{clock} ≤ 250 kHz		24	25		24	25		dB
Voltage amplification, dc	f _{clock} ≤ 250 kHz, R _S ≤ 2 kΩ		−0.15	0	0.15	−0.15	0	0.15	dB
Peak-to-peak clock feedthrough voltage	T _A = 25°C		5			5			mV

† All typical values are at $T_A = 25^\circ\text{C}$.

- NOTES: 2. Above 250 kHz, the input clock duty cycle should be 50% to allow the operational amplifiers the maximum time to settle while processing analog samples.
5. The frequency responses at f are referenced to a dc gain of 0 dB.
6. The dynamic range is referenced to 1.06 V rms (1.5 V peak) where the wideband noise over a 30-kHz bandwidth is typically 106 μV rms for the TLC04/MF4A-50 and 135 μV rms for the TLC14/MF4A-100.

operating characteristics over recommended operating free-air temperature range, $V_{CC+} = 5\text{ V}$, $V_{CC-} = -5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		TLC04/MF4A-50			TLC14/MF4A-100			UNIT
			MIN	TYP†	MAX	MIN	TYP†	MAX	
Maximum clock frequency, f _{max}	See Note 2		2	4		2	4		MHz
Clock-to-cutoff-frequency ratio (f _{clock} /f _{co})	f _{clock} ≤ 250 kHz, T _A = 25°C		49.58	49.98	50.38	99	100	101	Hz/Hz
Temperature coefficient of clock-to-cutoff frequency ratio	f _{clock} ≤ 250 kHz		±15			±15			ppm/°C
Frequency response above and below cutoff frequency (see Note 5)	f _{co} = 5 kHz, f _{clock} = 250 kHz, T _A = 25°C	f = 6 kHz	−7.9	−7.57	−7.1				dB
		f = 4.5 kHz	−1.7	−1.44	−1.3				
	f _{co} = 5 kHz, f _{clock} = 250 kHz, T _A = 25°C	f = 3 kHz				−7.9	−7.42	−7.1	dB
		f = 2.25 kHz				−1.7	−1.51	−1.3	
Dynamic range (see Note 6)	T _A = 25°C		86			84			dB
Stop-band frequency attenuation at 2 f _{co}	f _{clock} ≤ 250 kHz		24	25		24	25		dB
Voltage amplification, dc	f _{clock} ≤ 250 kHz, R _S ≤ 2 kΩ		−0.15	0	0.15	−0.15	0	0.15	dB
Peak-to-peak clock feedthrough voltage	T _A = 25°C		7			7			mV

† All typical values are at $T_A = 25^\circ\text{C}$.

- NOTES: 2. Above 250 kHz, the input clock duty cycle should be 50% to allow the operational amplifiers the maximum time to settle while processing analog samples.
5. The frequency responses at f are referenced to a dc gain of 0 dB.
6. The dynamic range is referenced to 2.82 V rms (4 V peak) where the wideband noise over a 30-kHz bandwidth is typically 142 μV rms for the TLC04/MF4A-50 and 178 μV rms for the TLC14/MF4A-100.

TLC04/MF4A-50, TLC14/MF4A-100 BUTTERWORTH FOURTH-ORDER LOW-PASS SWITCHED-CAPACITOR FILTERS

SLAS021A – NOVEMBER 1986 – REVISED MARCH 1995

TYPICAL CHARACTERISTICS

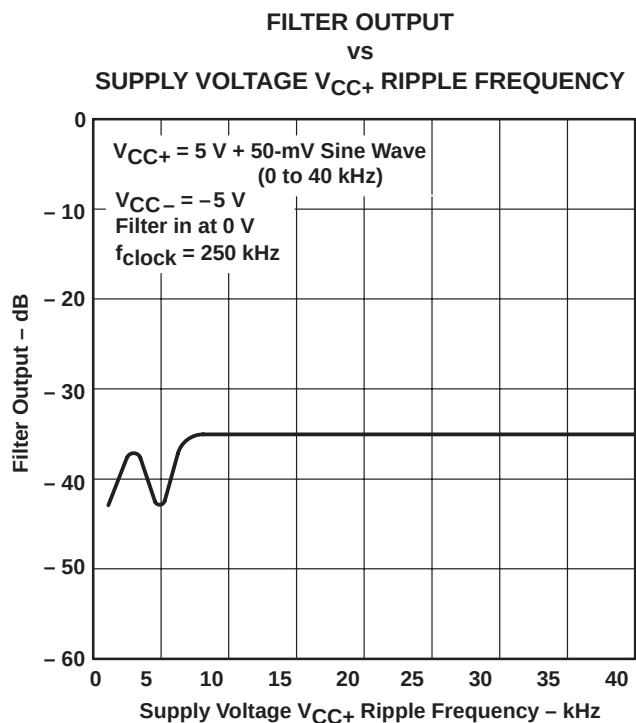


Figure 1

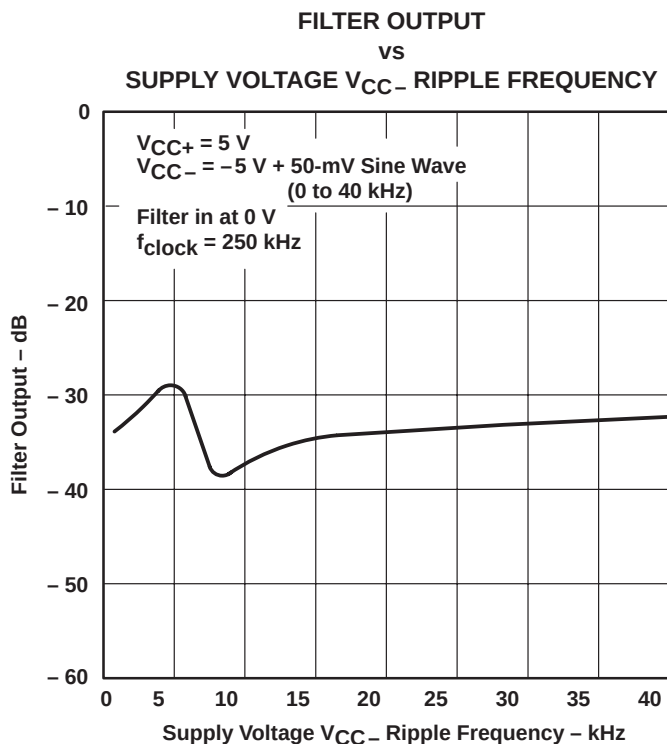


Figure 2

APPLICATION INFORMATION

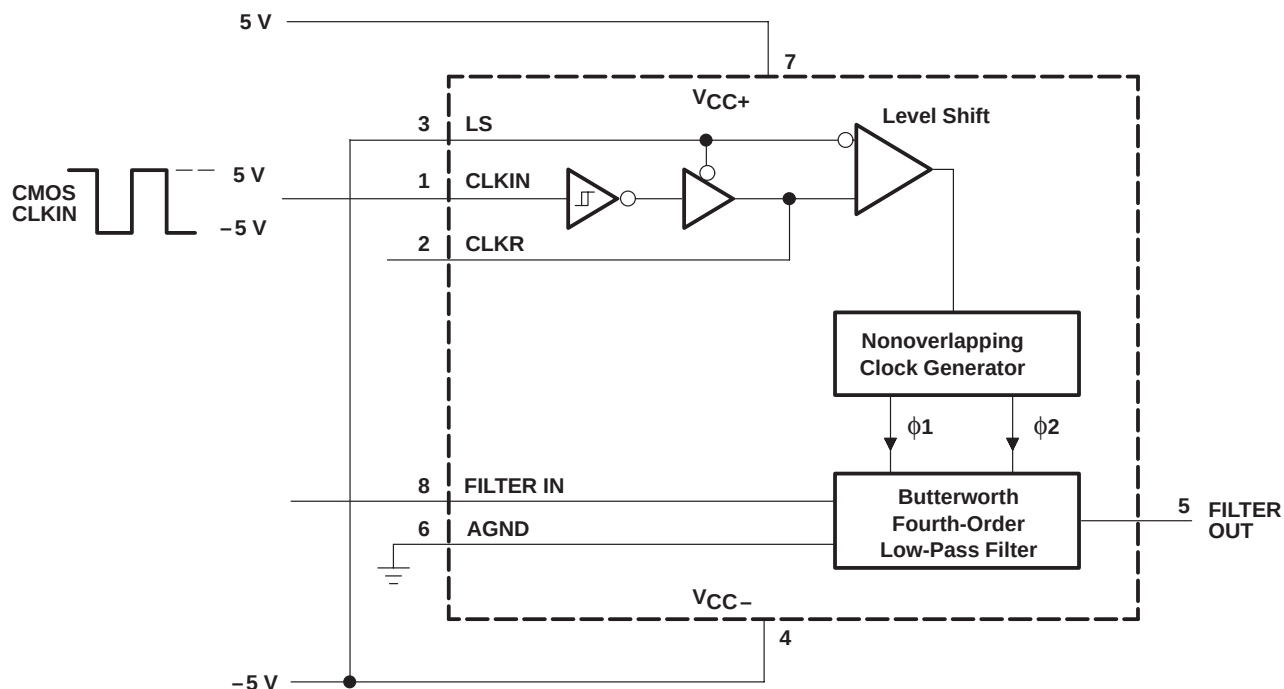


Figure 3. CMOS-Clock-Driven Dual-Supply Operation

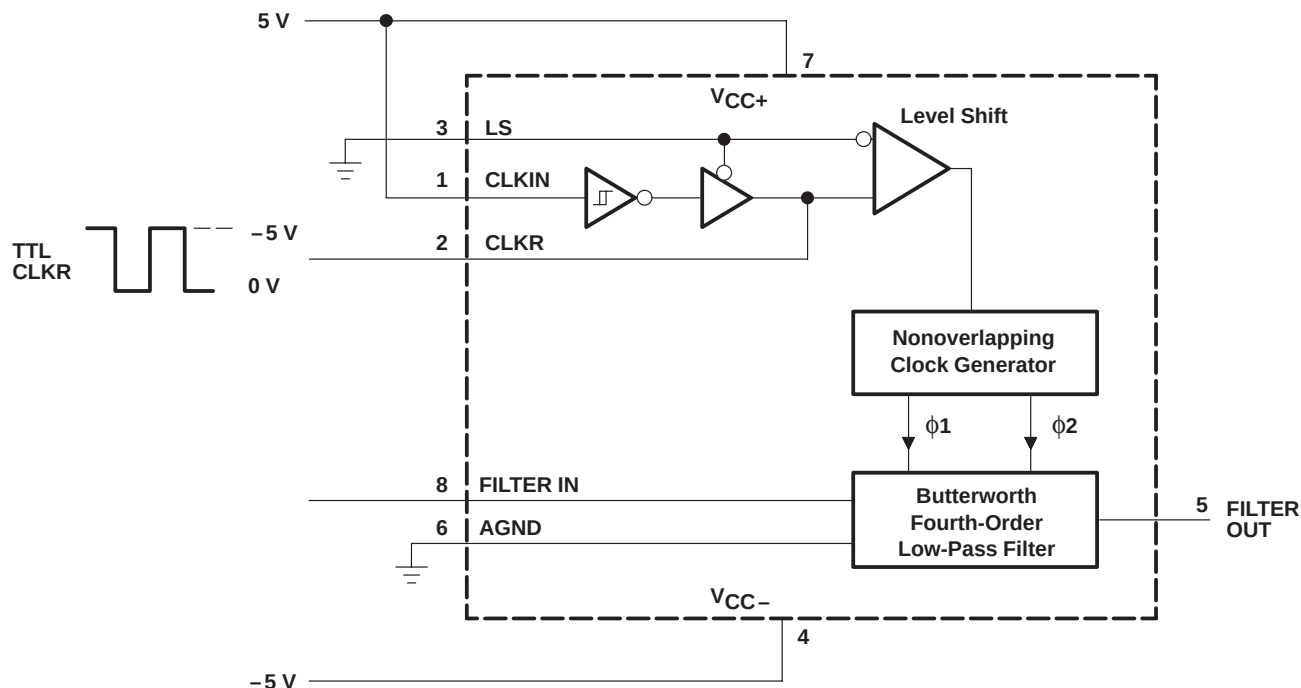
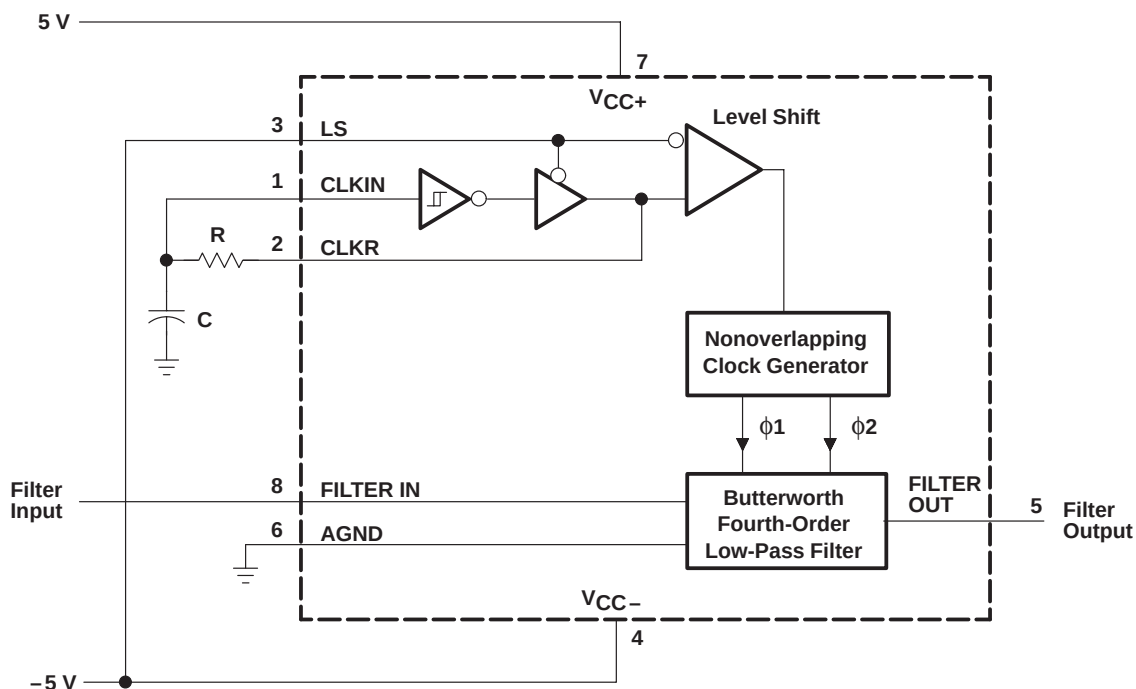


Figure 4. TTL-Clock-Driven Dual-Supply Operation

TLC04/MF4A-50, TLC14/MF4A-100 BUTTERWORTH FOURTH-ORDER LOW-PASS SWITCHED-CAPACITOR FILTERS

SLAS021A – NOVEMBER 1986 – REVISED MARCH 1995

APPLICATION INFORMATION



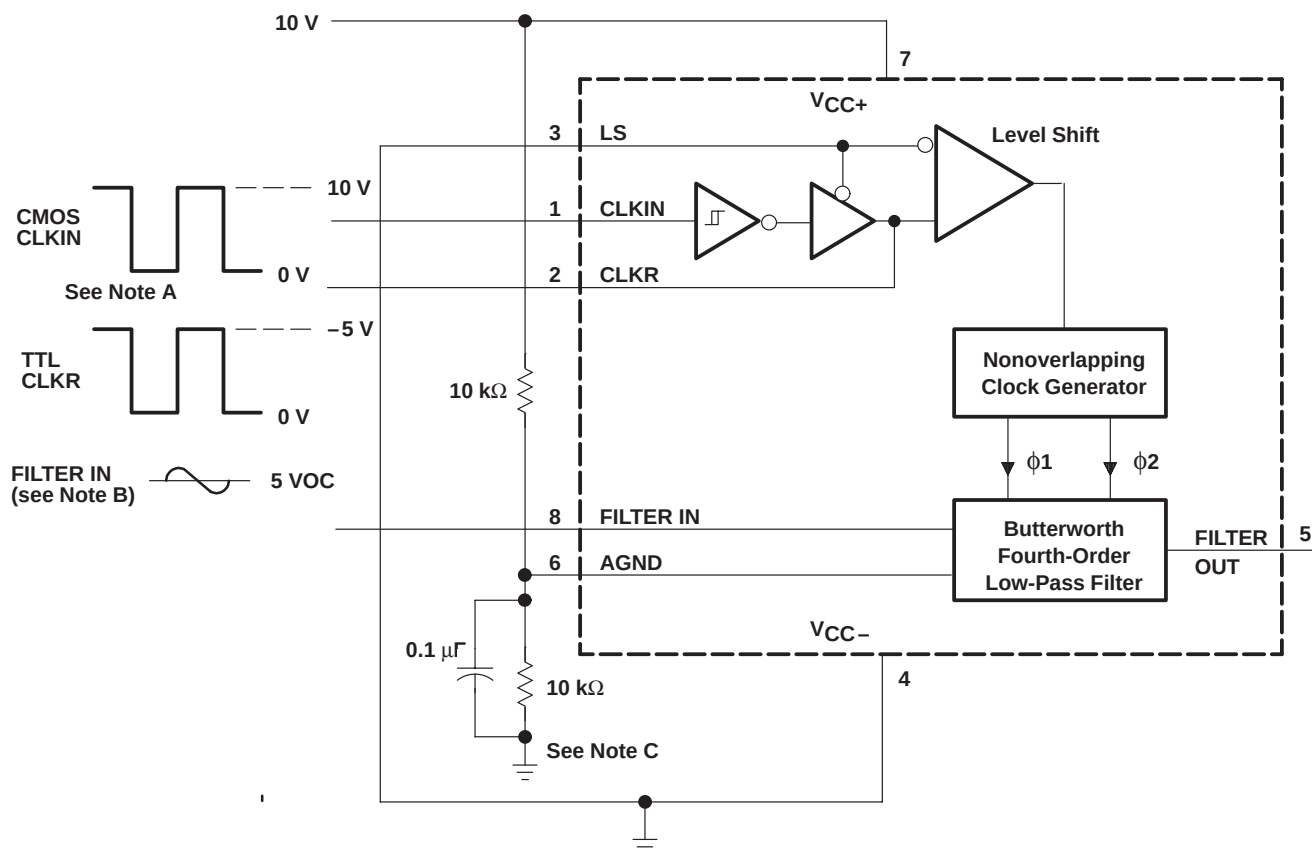
$$f_{\text{clock}} = \frac{1}{RC \times \ln \left[\left(\frac{V_{CC} - V_{IT-}}{V_{CC} - V_{IT+}} \right) \left(\frac{V_{IT+}}{V_{IT-}} \right) \right]}$$

For $V_{CC} = 10 \text{ V}$

$$f_{\text{clock}} = \frac{1}{1.69 RC}$$

Figure 5. Self-Clocking Through Schmitt-Trigger Oscillator Dual-Supply Operation

APPLICATION INFORMATION



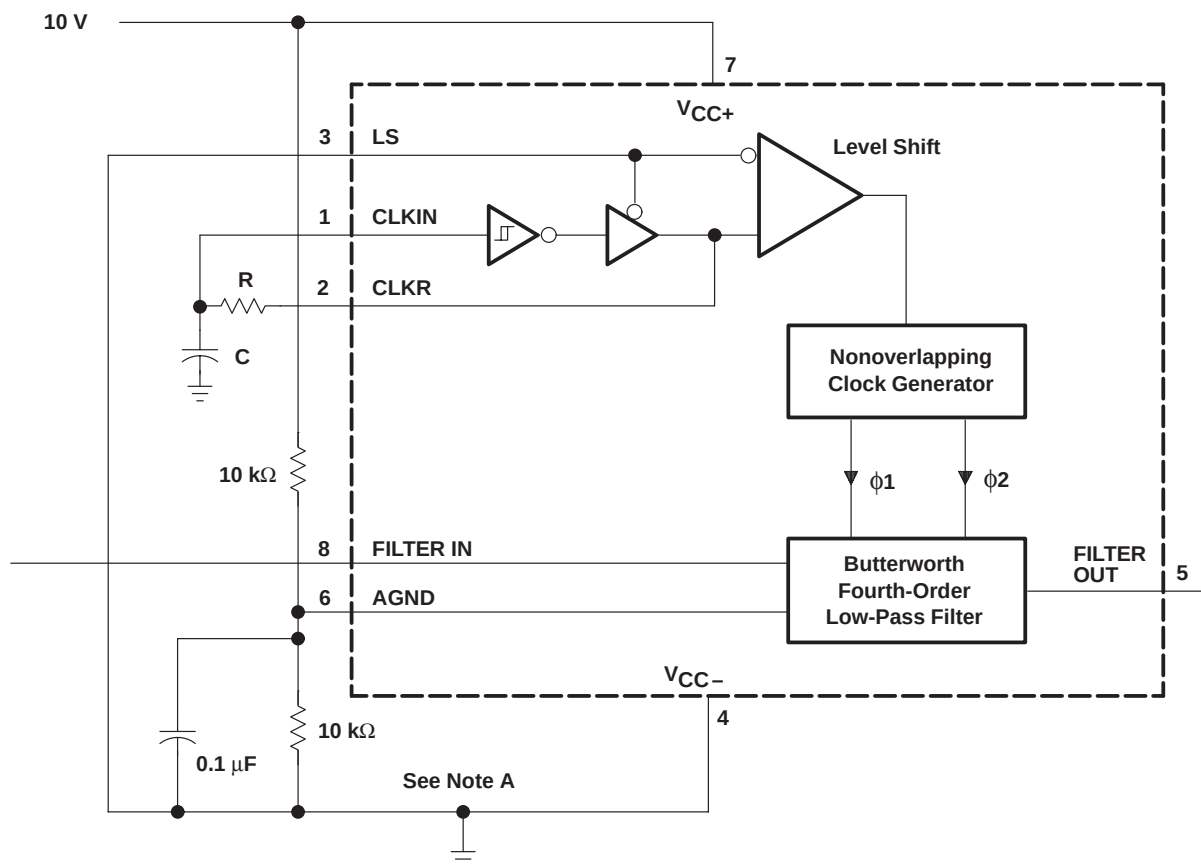
- NOTES: A. The external clock used must be of CMOS level because the clock is input to a CMOS Schmitt trigger.
 B. The filter input signal should be dc-biased to midsupply or ac-coupled to the terminal.
 C. AGND must be biased to midsupply.

Figure 6. External-Clock-Driven Single-Supply Operation

TLC04/MF4A-50, TLC14/MF4A-100 BUTTERWORTH FOURTH-ORDER LOW-PASS SWITCHED-CAPACITOR FILTERS

SLAS021A – NOVEMBER 1986 – REVISED MARCH 1995

APPLICATION INFORMATION



$$f_{\text{clock}} = \frac{1}{RC \times \ln \left[\left(\frac{V_{CC} - V_{IT-}}{V_{CC} - V_{IT+}} \right) \left(\frac{V_{IT+}}{V_{IT-}} \right) \right]}$$

For $V_{CC} = 10 \text{ V}$

$$f_{\text{clock}} = \frac{1}{1.69 RC}$$

NOTE A: AGND must be biased to midsupply.

Figure 7. Self Clocking Through Schmitt-Trigger Oscillator Single-Supply Operation

APPLICATION INFORMATION

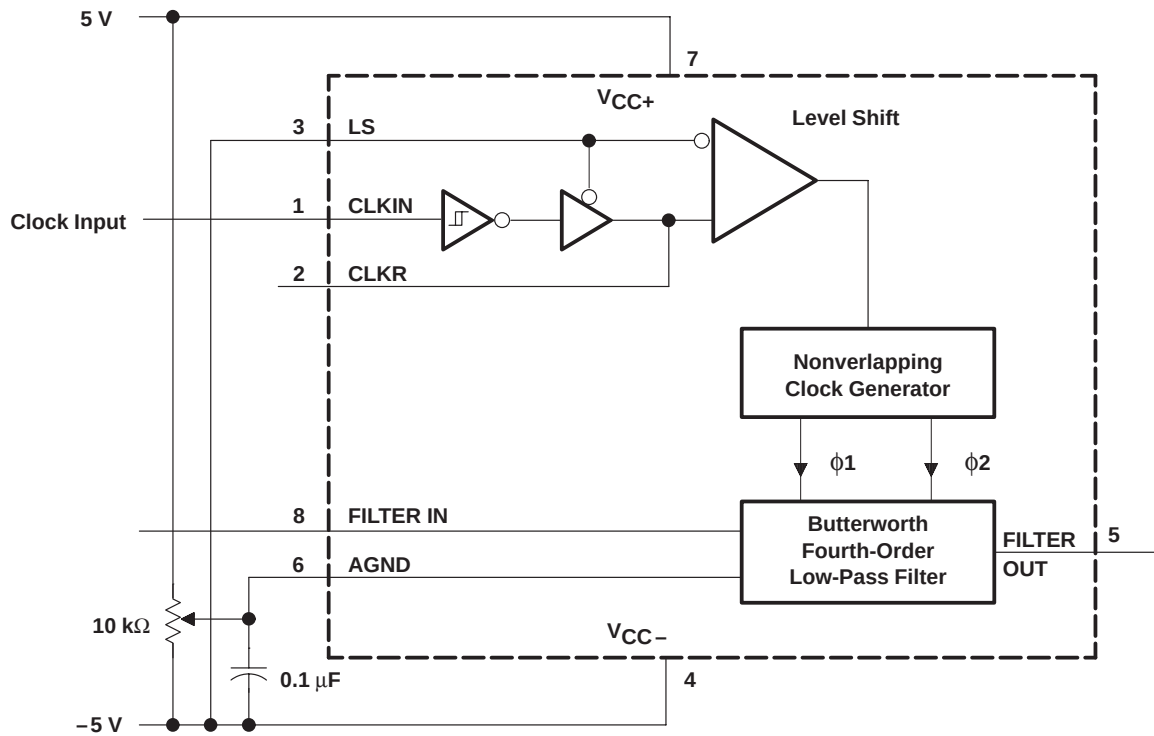
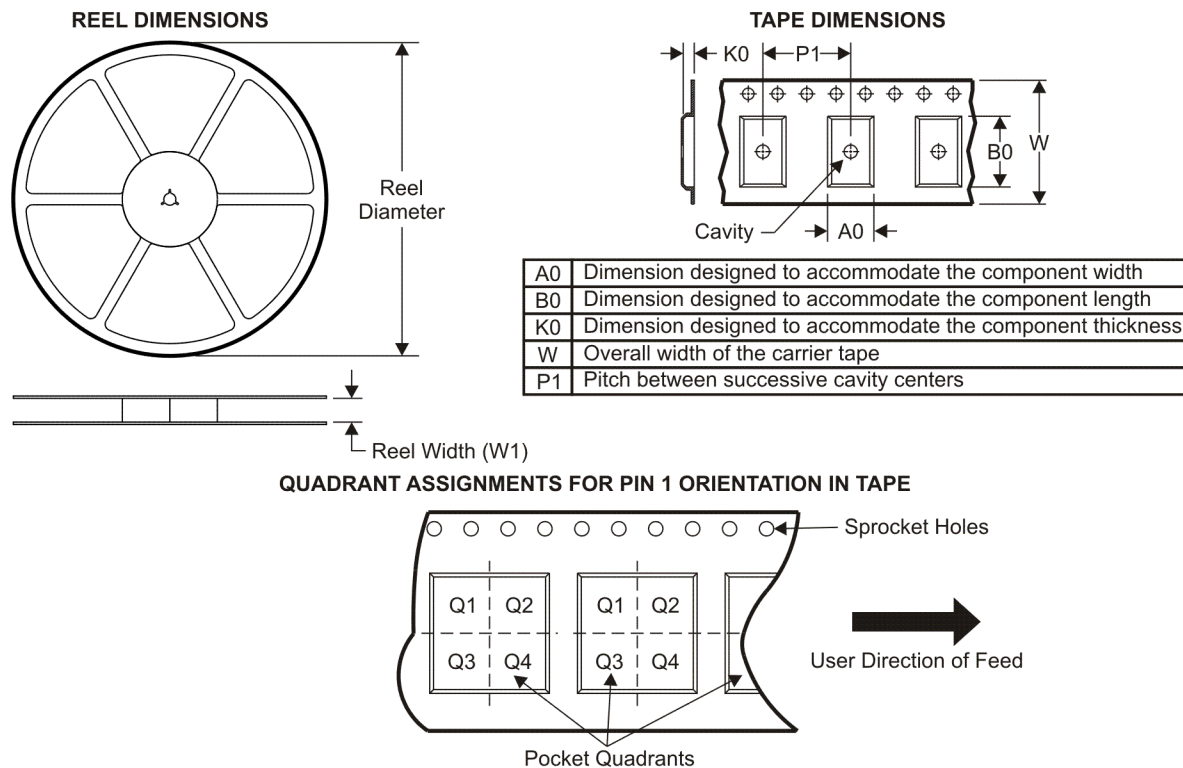


Figure 8. DC Offset Adjustment

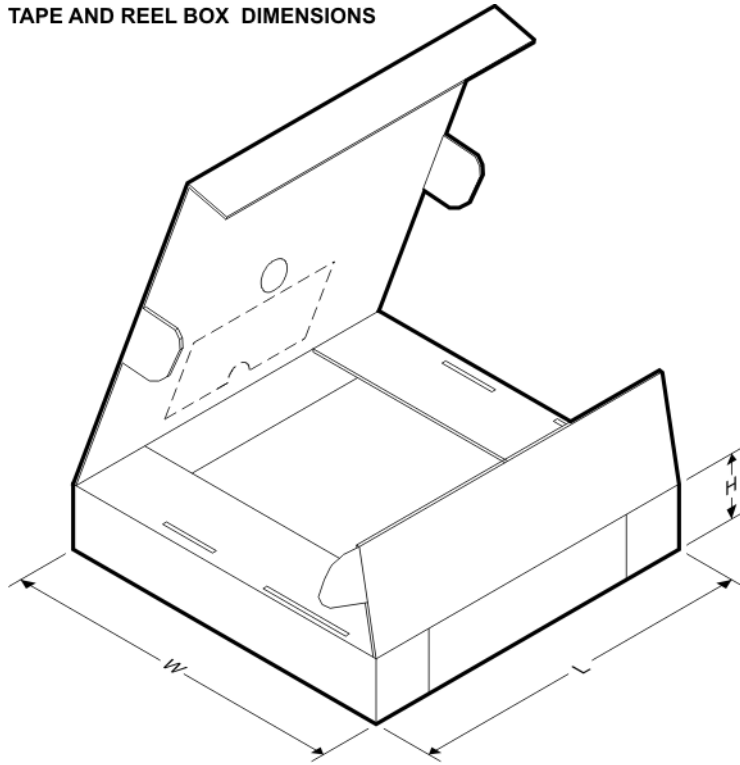
TAPE AND REEL INFORMATION



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC04IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC14CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC04IDR	SOIC	D	8	2500	346.0	346.0	29.0
TLC14CDR	SOIC	D	8	2500	346.0	346.0	29.0

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
RF/IF and ZigBee® Solutions	www.ti.com/lprf

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Medical	www.ti.com/medical
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated