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...±0.8% TLC14/MF4A-100...±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±} = ±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) CLKIN [1 8 FILTER IN CLKR [2 7 V_{CC+} LS [3 6 AGND V_{CC-} [4 5 FILTER OUT

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

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

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



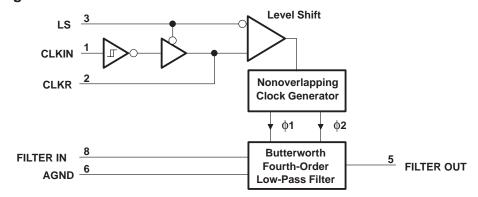
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TLC04/MF4A-50, TLC14/MF4A-100 **BUTTERWORTH FOURTH-ORDER LOW-PASS**

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functional block diagram



Terminal Functions

TERMINA	۸L	1/0	DESCRIPTION
NAME	NO.	1/0	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	0	Butterworth fourth-order low-pass filter output
LS	3	ı	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	ı	Negative supply voltage terminal



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

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

Supply voltage range, V _{CC+} (see Note 1)		±7\
	TLC04C/MF4A-50C, TLC14C/MF4A-100C 0°C	
	TLC04I/MF4A-50I, TLC14I/MF4A-100I40°C	to 85°C
	TLC04M/MF4A-50M, TLC14M/MF4A-100M55°C to	o 125°C
Storage temperature range, T _{sta}	65°C to	ວ 150°C
	case for 10 seconds	

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

recommended operating conditions

		TLC04/I	MF4A-50	TLC14/N	IF4A-100	UNIT
		MIN	MAX	MIN	MAX	UNII
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 fraguency f (and Note 3)	$V_{CC\pm} = \pm 2.5 \text{ V}$	5	1.5 x 10 ⁶	5	1.5 x 10 ⁶	Hz
Clock frequency, f _{clock} (see Note 2)	V _{CC±} = ±5 V	5	2x10 ⁶	5	2x10 ⁶	ПZ
Cutoff frequency, f _{CO} (see Note 3)		0.1	40 x 10 ³	0.05	20 x 10 ³	Hz
	TLC04C/MF4A-50C, TLC14C/MF4A-100C	0	70	0	70	
Operating free-air temperature, TA	TLC04I/MF4A-50I, TLC14I/MF4A-100I	-40	85	-40	85	°C
	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.

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

filter section

	PARAMETER		TEST SOMBITIONS	TLC04/MF4A-50			TLC14/MF4A-100			UNIT
			TEST CONDITIONS	MIN	TYP‡	MAX	MIN	TYP‡	MAX	UNII
Voo	Output offset voltage				25			50		mV
Von	Peak output voltage	V _{OM+}	R _I = 10 kΩ	1.8	2		1.8	2		V
VOM	reak output voltage	VOM-	K[= 10 K22	-1.25	-1.7		-1.25	-1.7		v
laa	Short-circuit output current	Source	$T_{\Delta} = 25^{\circ}C$, See Note 4		-0.5			-0.5		mA
los	Short-circuit output current	Sink	$T_A = 25$ °C, See Note 4		4			4		IIIA
ICC	Supply current		f _{Clock} = 250 kHz		1.2	2.25		1.2	2.25	mA

[‡] All typical values are at $T_A = 25$ °C.

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



[†] 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.

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

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

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

filter section

	PARAMETER		TEST	TLC	04/MF4 <i>A</i>	\-50	TLC1	4/MF4A	-100	UNIT
	LANAMETER		CONDITIONS	MIN	TYP [†]	MAX	MIN	TYP [†]	MAX	UNIT
Voo	Output offset voltage				150			200		mV
\/	Peak output voltage	V _{OM+}	P 10 kO	3.75	4.3		3.75	4.5		V
VOM	reak output voltage	V _{OM} -	$R_L = 10 \text{ k}\Omega$	-3.75	-4.1		-3.75	-4.1		V
la a	Chart aircuit autaut aurrant	Source	T _A = 25°C,		-2			-2		mA
los	Short-circuit output current	Sink	See Note 4		5			5		IIIA
Icc	Supply current	•	f _{clock} = 250 kHz		1.8	3		1.8	3	mA
ksvs	Supply voltage sensitivity (see	Figures 1 and 2)			-30			-30		dB

[†] All typical values are at $T_A = 25$ °C.

NOTE 4: $I_{OS(source)}$ is measured by forcing the output to its maximum positive voltage and then shorting the output to the V_{CC-} terminal. $I_{OS(sink)}$ 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
\/ı .	Positive-going input threshold voltage		$V_{CC+} = 10 V$	V _{CC} -=0	6.1	7	8.9	V
VIT+	rositive-going input tilleshold voltage		$V_{CC+} = 5 V$,	VCC-=0	3.1	3.5	4.4	·
\/: -	Negative-going input threshold voltage	CLKIN	$V_{CC+} = 10 V$	VCC-=0	1.3	3	3.8	V
VIT-	Negative-going input threshold voltage	CLKIN	$V_{CC+} = 5 V$,	VCC-=0	0.6	1.5	1.9	V
٧,	Hysteresis voltage (V _{IT+} – V _{IT} _)]	$V_{CC+} = 10 V$	VCC-=0	2.3	4	7.6	V
V _{hys}	Trysteresis voltage (v + - v _)		$V_{CC+} = 5 V$,	VCC-=0	1.2	2	3.8	v
Va	High-level output voltage		V _{CC} = 10 V	I _O = -10 μA	9			V
VOH	Tilgit-level output voltage		V _{CC} = 5 V	10 = - 10 μΑ	4.5			
\/a.	Low-level output voltage]	V _{CC} = 10 V	Io - 10 !! A			1	V
VOL	Low-level output voltage		V _{CC} = 5 V	ΙΟ = 10 μΑ			0.5	V
	Input lookogo gurrent	CLKR	V _{CC} = 10 V	LS at midsupply,			2	
	Input leakage current	CLKK	V _{CC} = 5 V	T _A = 25°C			2	μΑ
]	V _{CC} = 10 V	CLKR and CLKIN	-3	-7		A
	Output ourrent		V _{CC} = 5 V	shortened to V _{CC} -	-0.75	-2		mA mA
10	Output current		V _{CC} = 10 V	CLKR and CLKIN	3	7		
			V _{CC} = 5 V	shortened to V _{CC+}	0.75	2		IIIA

 $[\]uparrow$ All typical values are at T_A = 25°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)

DARAMETER	TEOT COM	NITIONIO.	TLC	04/MF4 <i>A</i>	\-50	TLC	UNIT		
PARAMETER	TEST COND	DITIONS	MIN	TYP†	MAX	MIN	TYP†	MAX	UNII
Maximum clock frequency, f _{max}	See Note 2		1.5	3		1.5	3		MHz
Clock-to-cutoff-frequency ratio (f _{clock} /f _{co})	$f_{Clock} \le 250 \text{ kHz},$	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
	$f_{CO} = 5 \text{ kHz},$	f = 6 kHz	-7.9	-7.57	-7.1				-ID
Frequency response above and below	$f_{clock} = 250 \text{ kHz},$ $T_A = 25^{\circ}\text{C}$	f = 4.5 kHz	-1.7	-1.46	-1.3				dB
cutoff frequency (see Note 5)	f _{CO} = 5 kHz,	f = 3 kHz				-7.9	-7.42	-7.1	dB
	$f_{Clock} = 250 \text{ kHz},$ $T_A = 25^{\circ}\text{C}$	f = 2.25 kHz				-1.7	-1.51	-1.3	uв
Dynamic range (see Note 6)	T _A = 25°C			80			78		dB
Stop-band frequency attentuation at 2 f _{CO}	f _{Clock} ≤ 250 kHz		24	25		24	25		dB
Voltage amplification, dc	$f_{Clock} \le 250 \text{ kHz},$	$RS \leq 2 \; k\Omega$	-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 $T_A = 25$ °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 $106 \,\mu\text{V}$ 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)

DARAMETER	TEAT 00115	NITIONO	TLC	04/MF4 <i>A</i>	\-50	TLC	14/MF4A	-100		
PARAMETER	TEST CONE	ITIONS	MIN	TYP†	MAX	MIN	TYP†	MAX	UNIT	
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,	$T_A = 25^{\circ}C$	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	
	$f_{CO} = 5 \text{ kHz},$	f = 6 kHz	-7.9	-7.57	-7.1				.ID	
Frequency response above and below	$f_{Clock} = 250 \text{ kHz},$ $T_A = 25^{\circ}\text{C}$	f = 4.5 kHz	-1.7	-1.44	-1.3				dB	
cutoff frequency (see Note 5)	f _{CO} = 5 kHz,	f = 3 kHz				-7.9	-7.42	-7.1	dB	
	$f_{clock} = 250 \text{ kHz},$ $T_A = 25^{\circ}\text{C}$	f = 2.25 kHz				-1.7	-1.51	-1.3	UD	
Dynamic range (see Note 6)	T _A = 25°C			86			84		dB	
Stop-band frequency attentuation at 2 f _{CO}	f _{clock} ≤ 250 kHz		24	25		24	25		dB	
Voltage amplification, dc	f _{Clock} ≤ 250 kHz,	$RS \le 2 k\Omega$	-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 $T_A = 25$ °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 μ V rms for the TLC04/MF4A-50 and 178 μ V rms for the TLC14/MF4A-100.



TYPICAL CHARACTERISTICS

FILTER OUTPUT vs $\label{eq:vcc} \text{SUPPLY VOLTAGE V}_{\text{CC+}} \text{ RIPPLE FREQUENCY}$

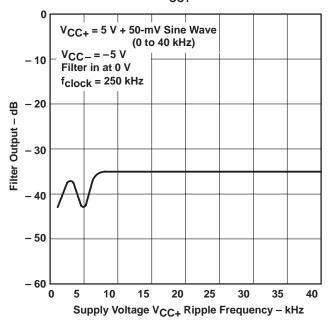
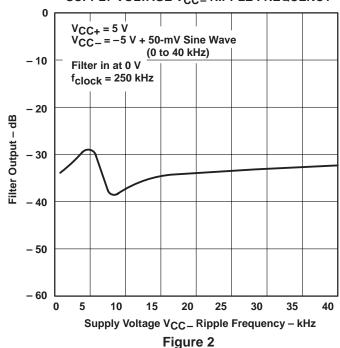


Figure 1

FILTER OUTPUT

vs SUPPLY VOLTAGE V_{CC}_ RIPPLE FREQUENCY





APPLICATION INFORMATION

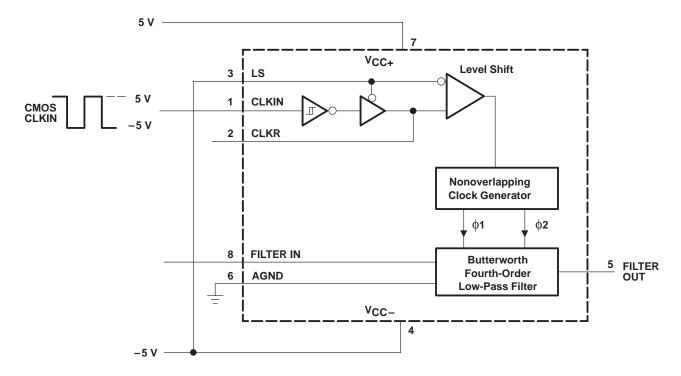


Figure 3. CMOS-Clock-Driven Dual-Supply Operation

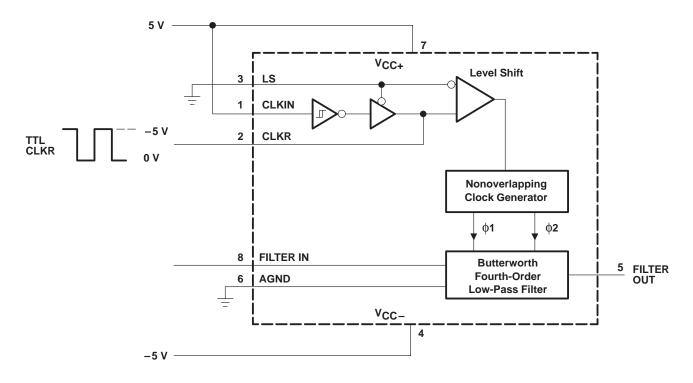


Figure 4. TTL-Clock-Driven Dual-Supply Operation



APPLICATION INFORMATION

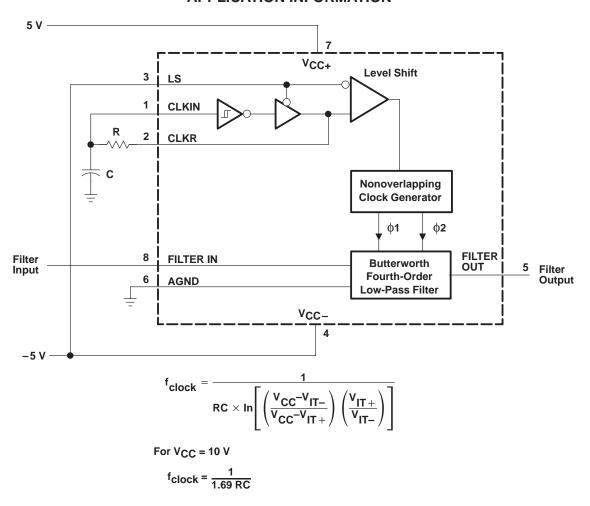
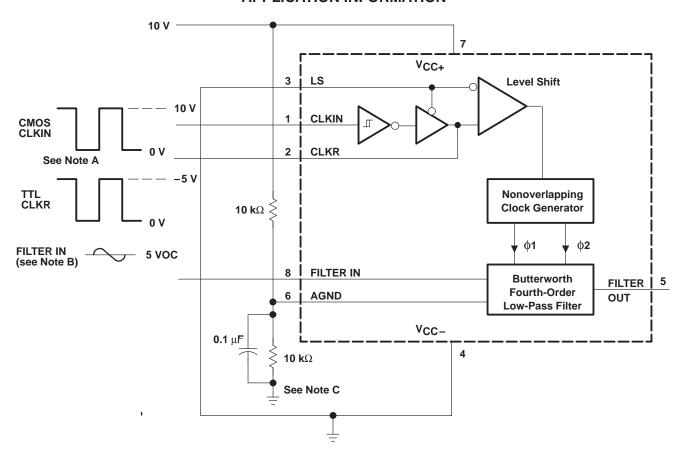


Figure 5. Self-Clocking Through Schmitt-Trigger Oscillator Dual-Supply Operation

APPLICATION INFORMATION

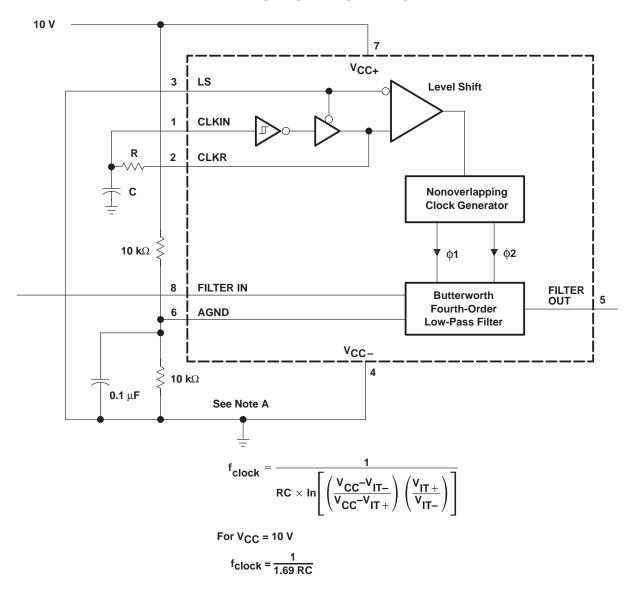


NOTES: A. The external clock used must be of CMOS level because the clock is input to a CMOS Schmitt trigger.

- 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

APPLICATION INFORMATION



NOTE A: AGND must be biased to midsupply.

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



APPLICATION INFORMATION

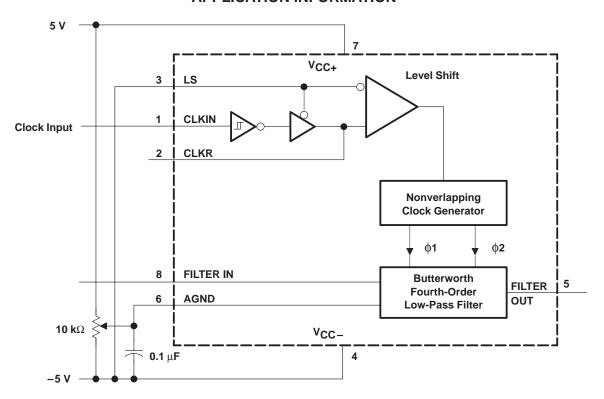
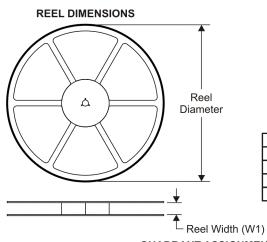
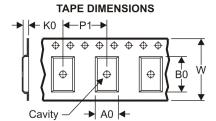


Figure 8. DC Offset Adjustment



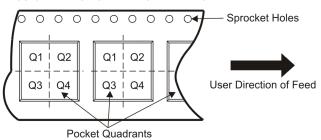
TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device		Package Drawing			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





*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

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