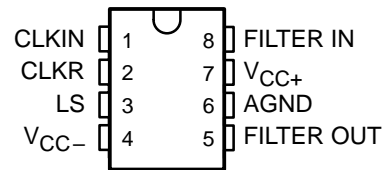


# TLC04/MF4A-50, TLC14/MF4A-100 BUTTERWORTH FOURTH-ORDER LOW-PASS SWITCHED-CAPACITOR FILTERS

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- **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 <sub>A</sub>	CLOCK-TO-CUTOFF FREQUENCY RATIO	PACKAGE	
		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).



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**

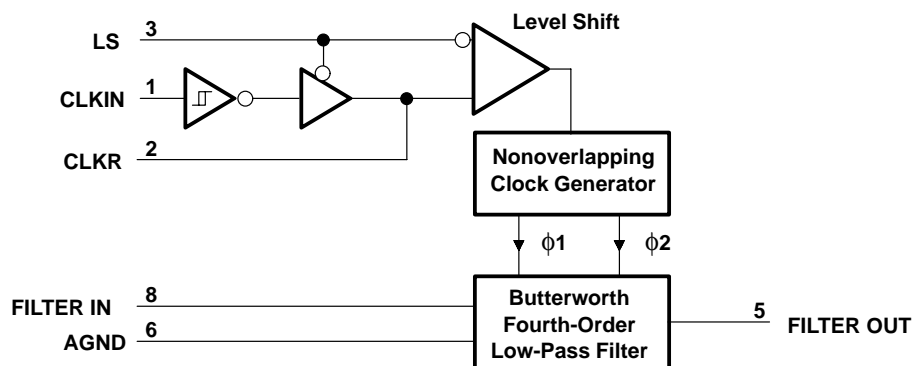
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## functional block diagram



## 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

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

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

† 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	$1.5 \times 10^6$	Hz
	$V_{CC\pm} = \pm 5$ V		5	$2 \times 10^6$	
Cutoff frequency, $f_{co}$ (see Note 3)	0.1	$40 \times 10^3$	0.05	$20 \times 10^3$	Hz
Operating free-air temperature, $T_A$	TLC04C/MF4A-50C, TLC14C/MF4A-100C		0	70	$^\circ\text{C}$
	TLC04I/MF4A-50I, TLC14I/MF4A-100I		-40	85	
	TLC04M/MF4A-50M, TLC14M/MF4A-100M		-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	$R_L = 10$ k $\Omega$	$V_{OM+}$	1.8	2	1.8	2	V	
		$V_{OM-}$	-1.25	-1.7	-1.25	-1.7		
$I_{OS}$ Short-circuit output current	$T_A = 25^\circ\text{C}$ , See Note 4	Source	-0.5			mA		
		Sink	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:  $I_{OS(source)}$  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.



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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	$V_{OM+}$	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	-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		CLKIN	$V_{CC+} = 10\text{ V}$ , $V_{CC-} = 0$	6.1		7	8.9
		$V_{CC+} = 5\text{ V}$ , $V_{CC-} = 0$		3.1	3.5	4.4		
$V_{IT-}$	Negative-going input threshold voltage	CLKIN	$V_{CC+} = 10\text{ V}$ , $V_{CC-} = 0$	1.3	3	3.8	V	
			$V_{CC+} = 5\text{ V}$ , $V_{CC-} = 0$	0.6	1.5	1.9		
$V_{\text{hys}}$	Hysteresis voltage ( $V_{IT+} - V_{IT-}$ )	CLKIN	$V_{CC+} = 10\text{ V}$ , $V_{CC-} = 0$	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	CLKR	$V_{CC} = 10\text{ V}$	$I_O = -10\text{ }\mu\text{A}$		9	V	
			$V_{CC} = 5\text{ V}$			4.5		
$V_{OL}$	Low-level output voltage	CLKR	$V_{CC} = 10\text{ V}$	$I_O = 10\text{ }\mu\text{A}$		1	V	
			$V_{CC} = 5\text{ V}$			0.5		
Input leakage current		CLKR	$V_{CC} = 10\text{ V}$	LS at midsupply, $T_A = 25^\circ\text{C}$		2	$\mu\text{A}$	
			$V_{CC} = 5\text{ V}$			2		
$I_O$	Output current	CLKR	$V_{CC} = 10\text{ V}$	CLKR and CLKIN shortened to $V_{CC-}$		-3	-7	mA
			$V_{CC} = 5\text{ V}$			-0.75	-2	
			$V_{CC} = 10\text{ V}$	CLKR and CLKIN shortened to $V_{CC+}$		3	7	mA
			$V_{CC} = 5\text{ V}$			0.75	2	

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

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**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 ( $f_{clock}/f_{CO}$ )	$f_{clock} \leq 250\text{ kHz}$ , $T_A = 25^\circ\text{C}$	49.27	50.07	50.87	99	100	101	Hz/Hz	
Temperature coefficient of clock-to-cutoff frequency ratio	$f_{clock} \leq 250\text{ kHz}$	$\pm 25$			$\pm 25$			ppm/°C	
Frequency response above and below cutoff frequency (see Note 5)	$f_{CO} = 5\text{ kHz}$ , $f_{clock} = 250\text{ kHz}$ , $T_A = 25^\circ\text{C}$	$f = 6\text{ kHz}$	-7.9	-7.57	-7.1				dB
		$f = 4.5\text{ kHz}$	-1.7	-1.46	-1.3				
	$f_{CO} = 5\text{ kHz}$ , $f_{clock} = 250\text{ kHz}$ , $T_A = 25^\circ\text{C}$	$f = 3\text{ kHz}$				-7.9	-7.42	-7.1	dB
		$f = 2.25\text{ kHz}$				-1.7	-1.51	-1.3	
Dynamic range (see Note 6)	$T_A = 25^\circ\text{C}$	80			78			dB	
Stop-band frequency attenuation at $2 f_{CO}$	$f_{clock} \leq 250\text{ kHz}$	24	25		24	25		dB	
Voltage amplification, dc	$f_{clock} \leq 250\text{ kHz}$ , $R_S \leq 2\text{ k}\Omega$	-0.15	0	0.15	-0.15	0	0.15	dB	
Peak-to-peak clock feedthrough voltage	$T_A = 25^\circ\text{C}$	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  $\mu\text{V}$  rms for the TLC04/MF4A-50 and 135  $\mu\text{V}$  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 ( $f_{clock}/f_{CO}$ )	$f_{clock} \leq 250\text{ kHz}$ , $T_A = 25^\circ\text{C}$	49.58	49.98	50.38	99	100	101	Hz/Hz	
Temperature coefficient of clock-to-cutoff frequency ratio	$f_{clock} \leq 250\text{ kHz}$	$\pm 15$			$\pm 15$			ppm/°C	
Frequency response above and below cutoff frequency (see Note 5)	$f_{CO} = 5\text{ kHz}$ , $f_{clock} = 250\text{ kHz}$ , $T_A = 25^\circ\text{C}$	$f = 6\text{ kHz}$	-7.9	-7.57	-7.1				dB
		$f = 4.5\text{ kHz}$	-1.7	-1.44	-1.3				
	$f_{CO} = 5\text{ kHz}$ , $f_{clock} = 250\text{ kHz}$ , $T_A = 25^\circ\text{C}$	$f = 3\text{ kHz}$				-7.9	-7.42	-7.1	dB
		$f = 2.25\text{ kHz}$				-1.7	-1.51	-1.3	
Dynamic range (see Note 6)	$T_A = 25^\circ\text{C}$	86			84			dB	
Stop-band frequency attenuation at $2 f_{CO}$	$f_{clock} \leq 250\text{ kHz}$	24	25		24	25		dB	
Voltage amplification, dc	$f_{clock} \leq 250\text{ kHz}$ , $R_S \leq 2\text{ k}\Omega$	-0.15	0	0.15	-0.15	0	0.15	dB	
Peak-to-peak clock feedthrough voltage	$T_A = 25^\circ\text{C}$	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  $\mu\text{V}$  rms for the TLC04/MF4A-50 and 178  $\mu\text{V}$  rms for the TLC14/MF4A-100.

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## TYPICAL CHARACTERISTICS

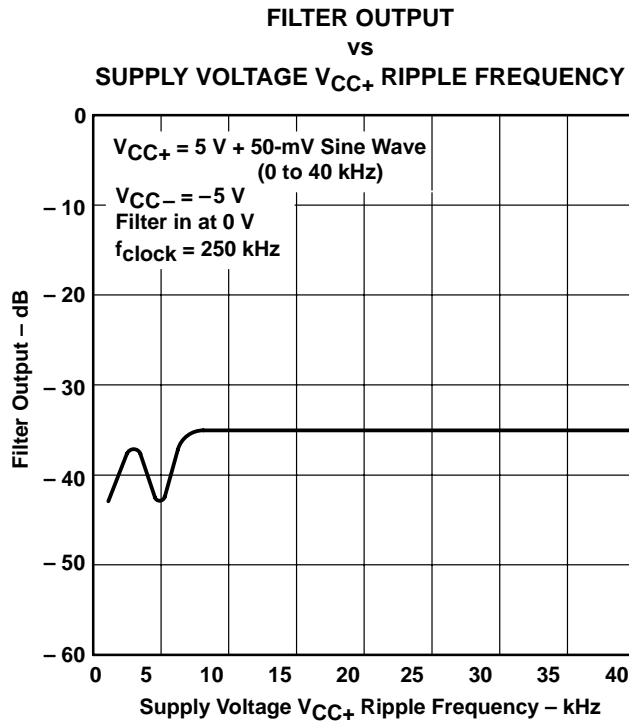


Figure 1

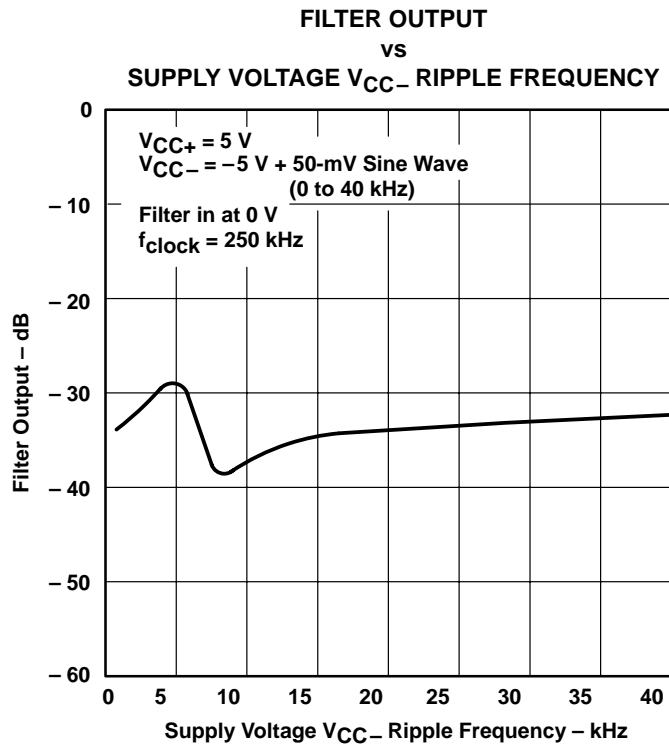


Figure 2

APPLICATION INFORMATION

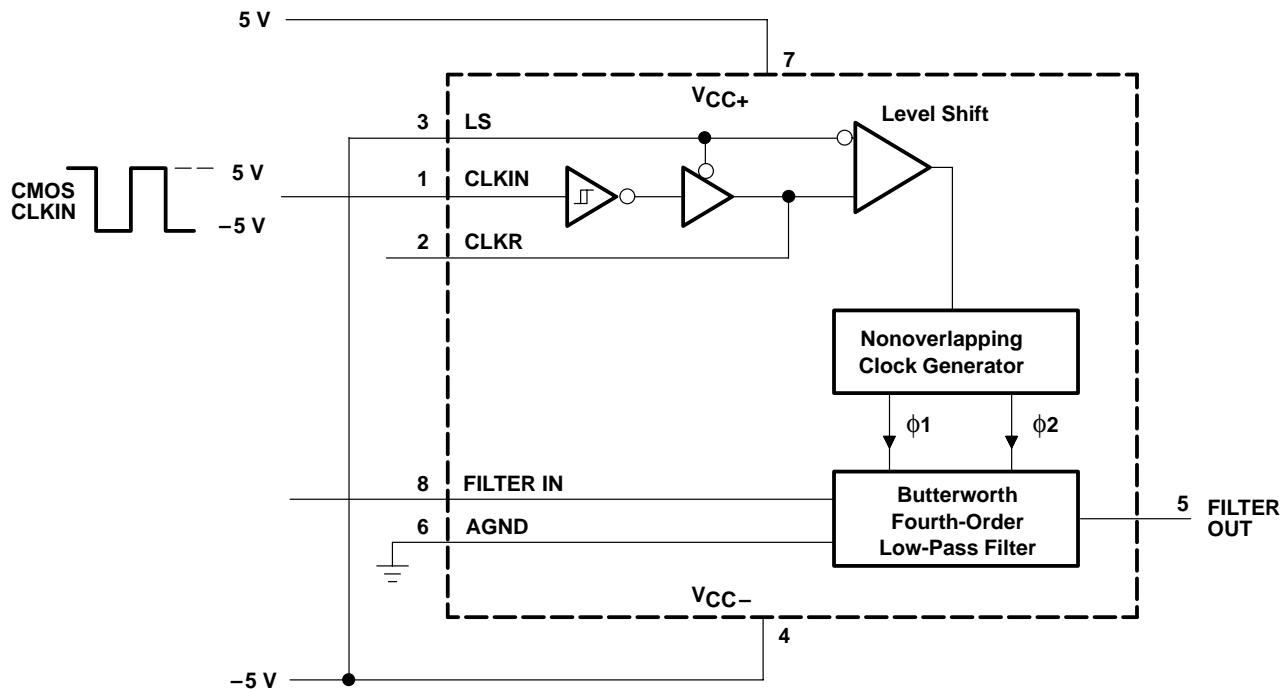


Figure 3. CMOS-Clock-Driven Dual-Supply Operation

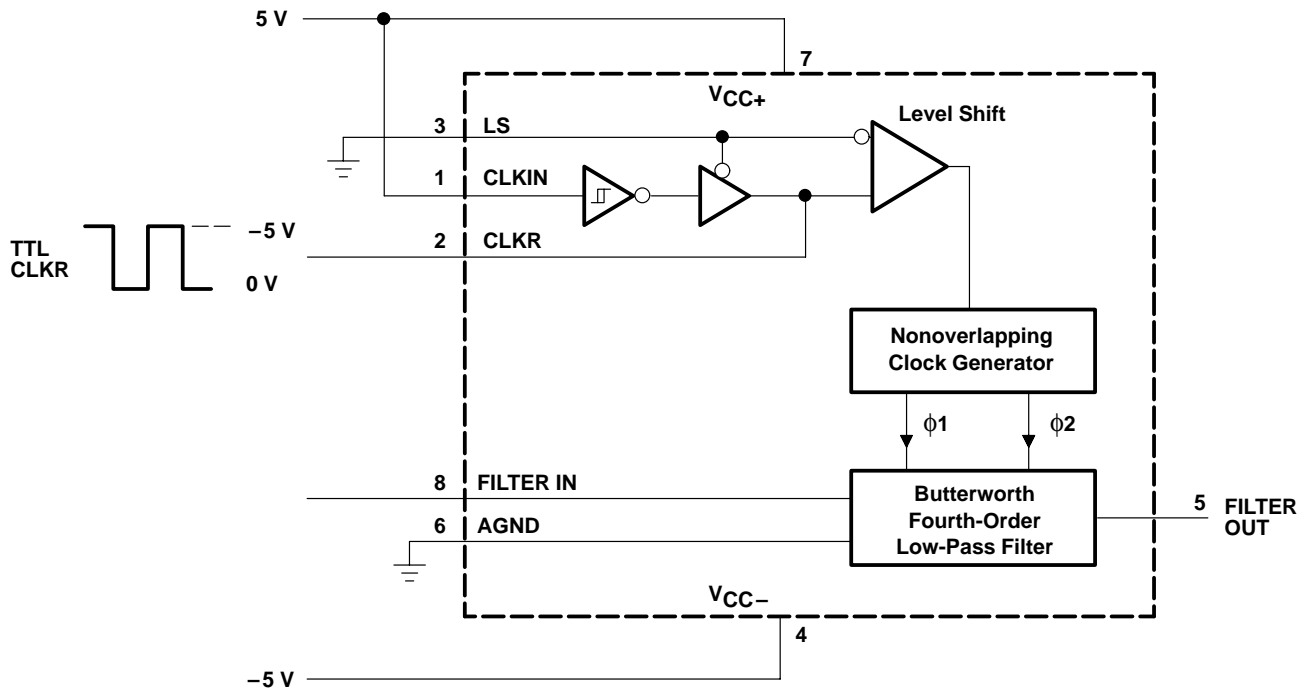
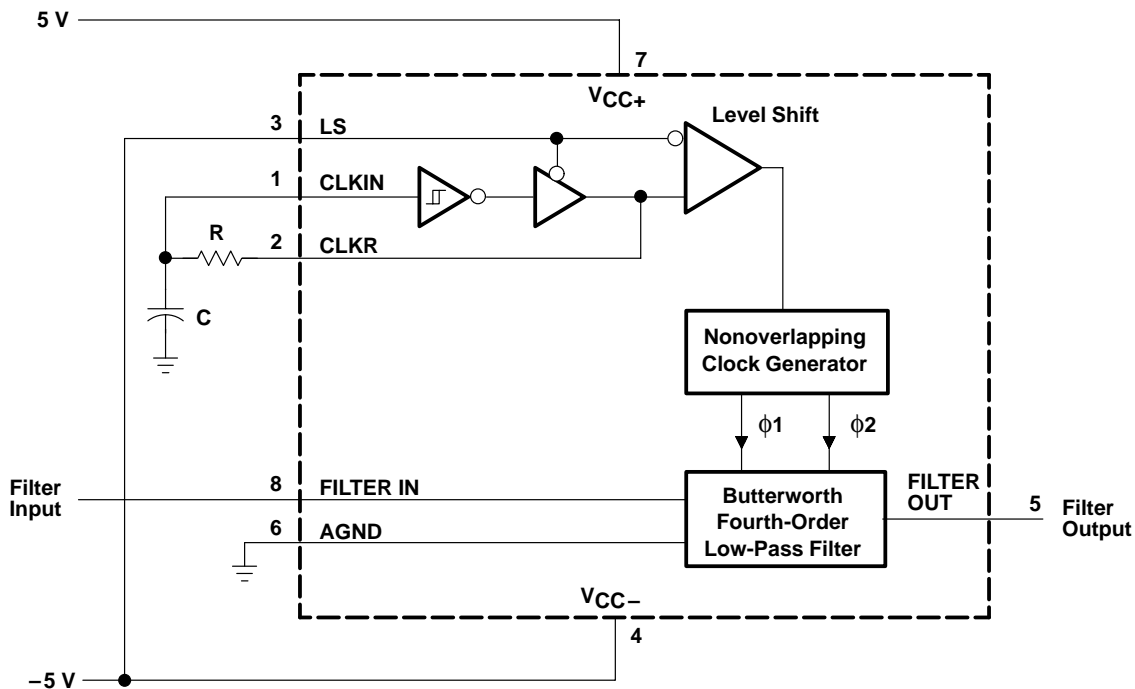


Figure 4. TTL-Clock-Driven Dual-Supply Operation

**APPLICATION INFORMATION**



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

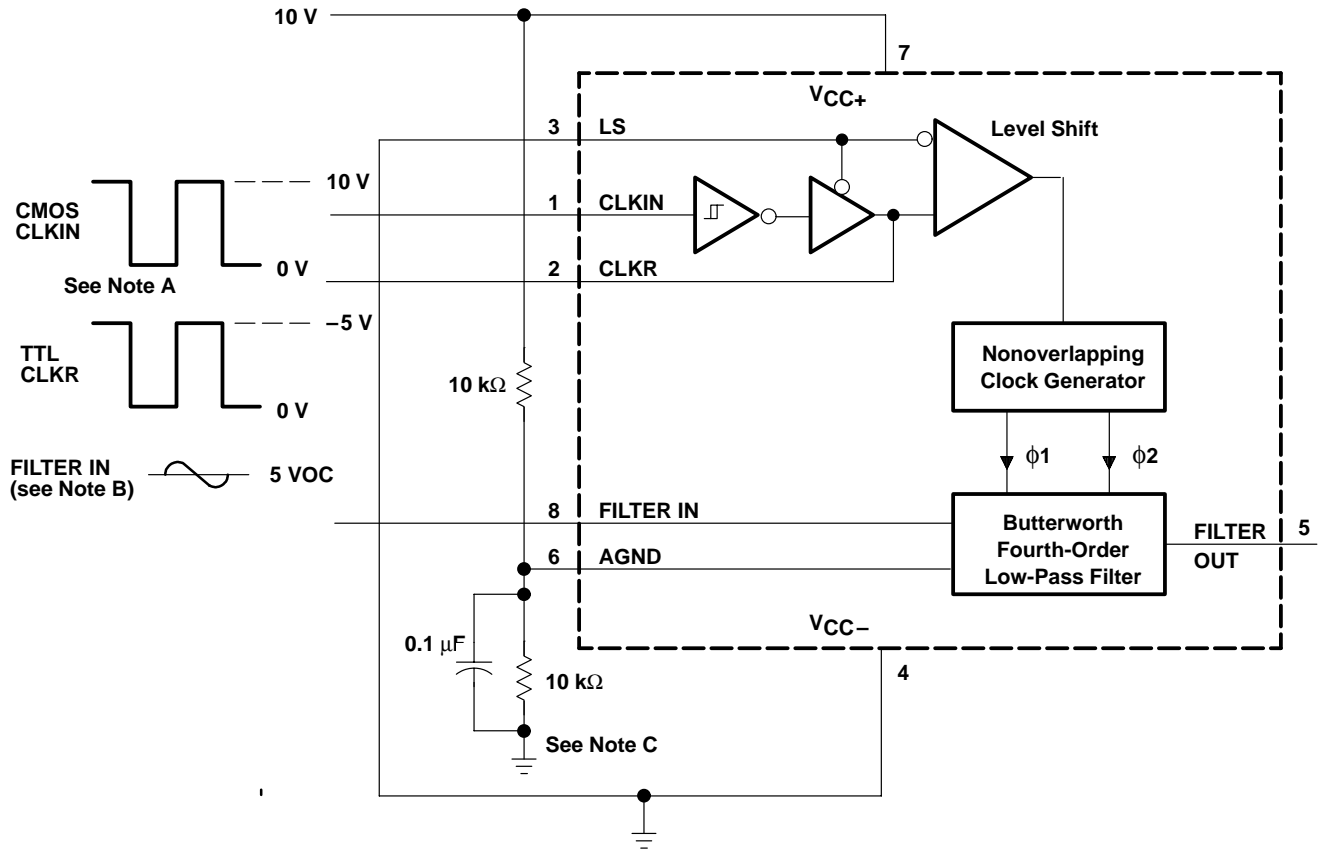
For  $V_{CC} = 10 \text{ V}$

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

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



APPLICATION INFORMATION



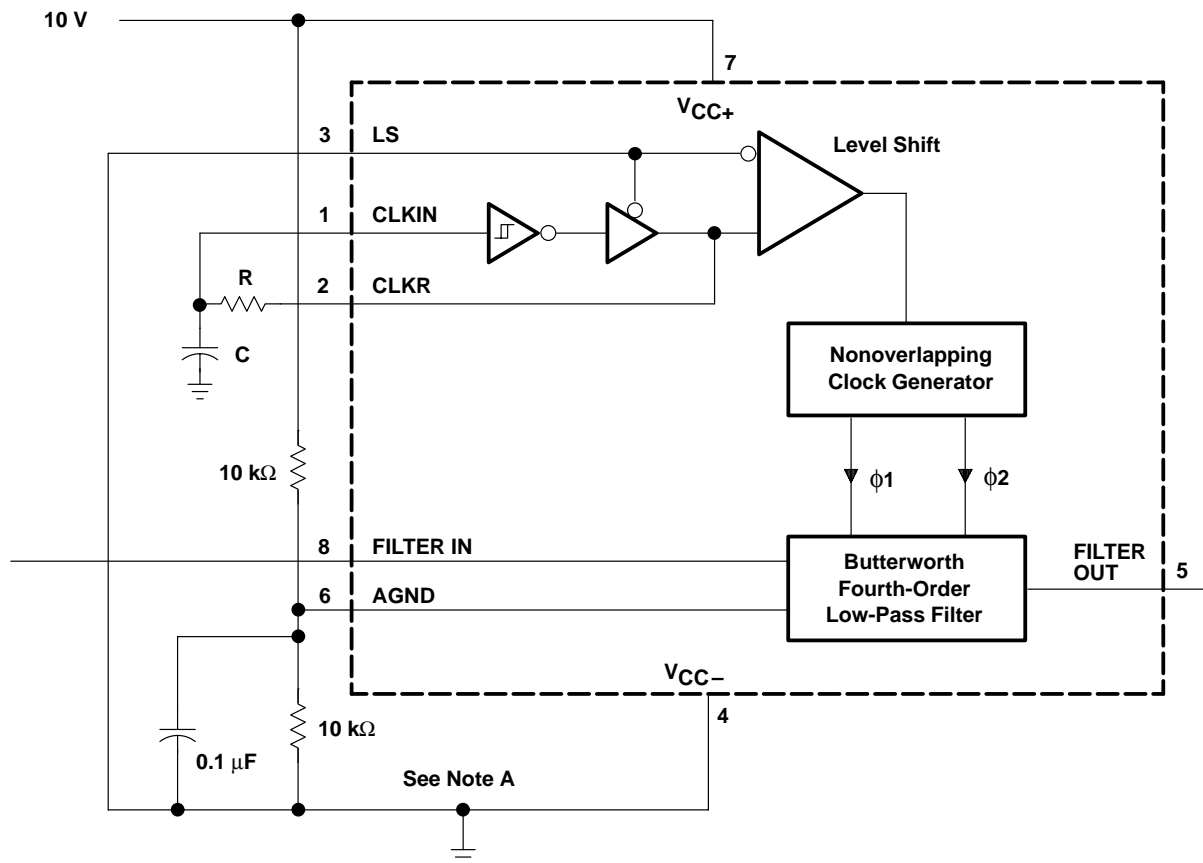
- NOTES: A. The external clock used must be of CMOS level because the clock is input to a CMOS Schmitt trigger.  
 B. The filter input signal should be dc-biased to midsupply or ac-coupled to the terminal.  
 C. AGND must be biased to midsupply.

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

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**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

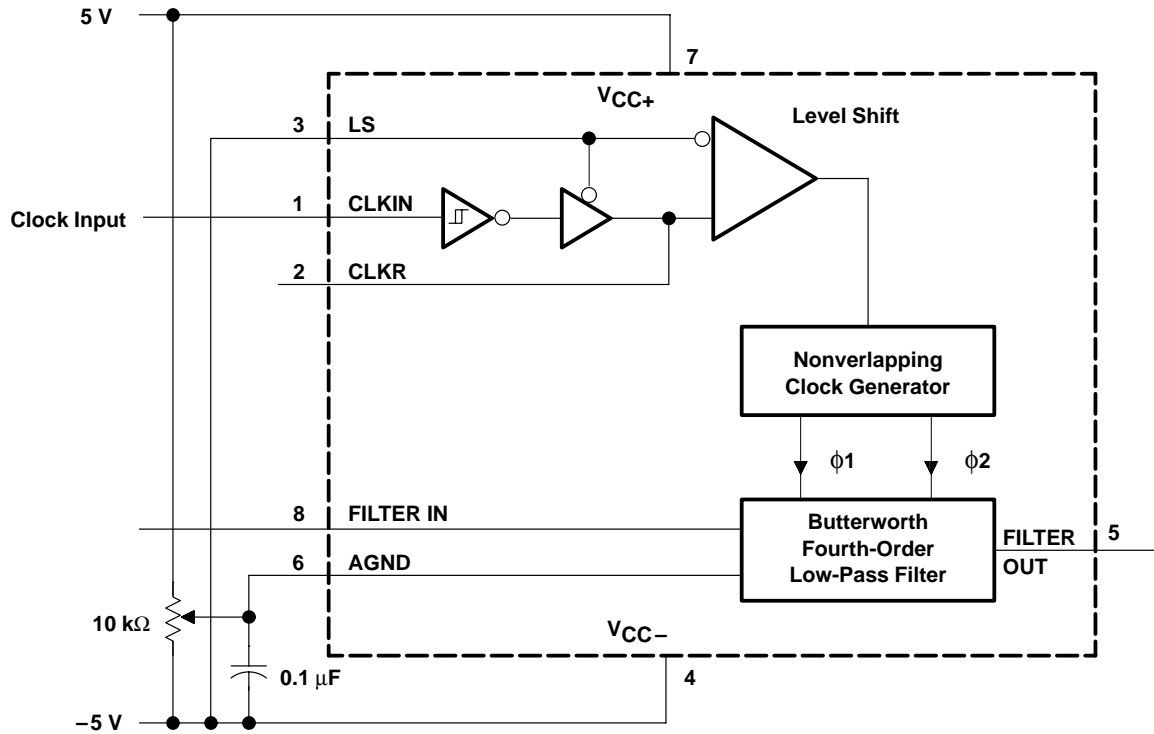


Figure 8. DC Offset Adjustment

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