

CD4046BM/CD4046BC Micropower Phase-Locked Loop

General Description

The CD4046B micropower phase-locked loop (PLL) consists of a low power, linear, voltage-controlled oscillator (VCO), a source follower, a zener diode, and two phase comparators. The two phase comparators have a common signal input and a common comparator input. The signal input can be directly coupled for a large voltage signal, or capacitively coupled to the self-biasing amplifier at the signal input for a small voltage signal.

Phase comparator I, an exclusive OR gate, provides a digital error signal (phase comp. I Out) and maintains 90° phase shifts at the VCO center frequency. Between signal input and comparator input (both at 50% duty cycle), it may lock onto the signal input frequencies that are close to harmonics of the VCO center frequency.

Phase comparator II is an edge-controlled digital memory network. It provides a digital error signal (phase comp. II Out) and lock-in signal (phase pulses) to indicate a locked condition and maintains a 0° phase shift between signal input and comparator input.

The linear voltage-controlled oscillator (VCO) produces an output signal (VCO Out) whose frequency is determined by the voltage at the VCO_{IN} input, and the capacitor and resistors connected to pin C1_A, C1_B, R1 and R2.

The source follower output of the VCO_{IN} (demodulator Out) is used with an external resistor of 10 kΩ or more.

The INHIBIT input, when high, disables the VCO and source follower to minimize standby power consumption. The zener diode is provided for power supply regulation, if necessary.

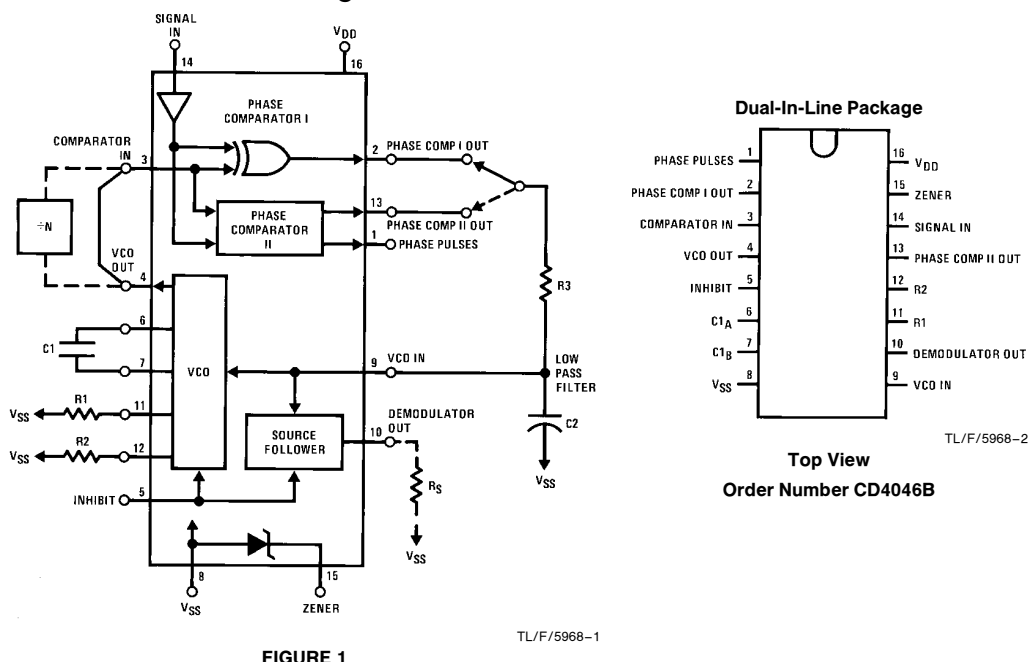
Features

- Wide supply voltage range 3.0V to 18V
- Low dynamic power consumption 70 μW (typ.) at $f_o = 10 \text{ kHz}$, $V_{DD} = 5V$
- VCO frequency 1.3 MHz (typ.) at $V_{DD} = 10V$
- Low frequency drift with temperature 0.06%/°C at $V_{DD} = 10V$
- High VCO linearity 1% (typ.)

Applications

- FM demodulator and modulator
- Frequency synthesis and multiplication
- Frequency discrimination
- Data synchronization and conditioning
- Voltage-to-frequency conversion
- Tone decoding
- FSK modulation
- Motor speed control

Block & Connection Diagrams



Absolute Maximum Ratings (Notes 1 & 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

DC Supply Voltage (V_{DD})	−0.5 to +18 V_{DC}
Input Voltage (V_{IN})	−0.5 to V_{DD} + 0.5 V_{DC}
Storage Temperature Range (T_S)	−65°C to +150°C
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
Lead Temperature (T_L)	
(Soldering, 10 seconds)	260°C

Recommended Operating Conditions (Note 2)

DC Supply Voltage (V_{DD})	3 to 15 V_{DC}
Input Voltage (V_{IN})	0 to V_{DD} V_{DC}
Operating Temperature Range (T_A)	
CD4046BM	−55°C to +125°C
CD4046BC	−40°C to +85°C

DC Electrical Characteristics CD4046BM (Note 2)

Symbol	Parameter	Conditions	−55°C		+25°C			+125°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{DD}	Quiescent Device Current	Pin 5 = V_{DD} , Pin 14 = V_{DD} , Pin 3, 9 = V_{SS} V_{DD} = 5V		5		0.005	5		150	μA
		V_{DD} = 10V		10		0.01	10		300	μA
		V_{DD} = 15V		20		0.015	20		600	μA
		Pin 5 = V_{DD} , Pin 14 = Open, Pin 3, 2 = V_{SS} V_{DD} = 5V		45		5	35		185	μA
V_{OL}	Low Level Output Voltage	V_{DD} = 5V		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH}	High Level Output Voltage	V_{DD} = 5V	4.95		4.95	5		4.95		V
		V_{DD} = 10V	9.95		9.95	10		9.95		V
		V_{DD} = 15V	14.95		14.95	15		14.95		V
V_{IL}	Low Level Input Voltage Comparator and Signal In	V_{DD} = 5V, V_O = 0.5V or 4.5V		1.5		2.25	1.5		1.5	V
		V_{DD} = 10V, V_O = 1V or 9V		3.0		4.5	3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V or 13.5V		4.0		6.25	4.0		4.0	V
V_{IH}	High Level Input Voltage Comparator and Signal In	V_{DD} = 5V, V_O = 0.5V or 4.5V	3.5		3.5	2.75		3.5		V
		V_{DD} = 10V, V_O = 1V or 9V	7.0		7.0	5.5		7.0		V
		V_{DD} = 15V, V_O = 1.5V or 13.5V	11.0		11.0	8.25		11.0		V
I_{OL}	Low Level Output Current (Note 4)	V_{DD} = 5V, V_O = 0.4V	0.64		0.51	0.88		0.36		mA
		V_{DD} = 10V, V_O = 0.5V	1.6		1.3	2.25		0.9		mA
		V_{DD} = 15V, V_O = 1.5V	4.2		3.4	8.8		2.4		mA
I_{OH}	High Level Output Current (Note 4)	V_{DD} = 5V, V_O = 4.6V	−0.64		−0.51	−0.88		−0.36		mA
		V_{DD} = 10V, V_O = 9.5V	−1.6		−1.3	−2.25		−0.9		mA
		V_{DD} = 15V, V_O = 13.5V	−4.2		−3.4	−8.8		−2.4		mA
I_{IN}	Input Current	All Inputs Except Signal Input V_{DD} = 14V, V_{IN} = 0V		−0.1		−10 ^{−5}	−0.1		−1.0	μA
		V_{DD} = 15V, V_{IN} = 15V		0.1		10 ^{−5}	0.1		1.0	μA
C_{IN}	Input Capacitance	Any Input (Note 3)							7.5	pF
P_T	Total Power Dissipation	f_o = 10 kHz, R_1 = 1 M Ω R_2 = ∞ , $V_{CO_{IN}}$ = $V_{DD}/2$								
		V_{DD} = 5V				0.07				mW
		V_{DD} = 10V				0.6				mW
		V_{DD} = 15V				2.4				mW

DC Electrical Characteristics CD4046BC (Note 2)

Symbol	Parameter	Conditions	−40°C		+25°C			+85°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I _{DD}	Quiescent Device Current	Pin 5 = V _{DD} , Pin 14 = V _{DD} , Pin 3, 9 = V _{SS} V _{DD} = 5V		20		0.005	20		150	μA
		V _{DD} = 10V		40		0.01	40		300	μA
		V _{DD} = 15V		80		0.015	80		600	μA
		Pin 5 = V _{DD} , Pin 14 = Open, Pin 3, 9 = V _{SS} V _{DD} = 5V		70		5	55		205	μA
		V _{DD} = 10V		530		20	410		710	μA
		V _{DD} = 15V		1500		50	1200		1800	μA
V _{OL}	Low Level Output Voltage	V _{DD} = 5V		0.05		0	0.05		0.05	V
		V _{DD} = 10V		0.05		0	0.05		0.05	V
		V _{DD} = 15V		0.05		0	0.05		0.05	V
V _{OH}	High Level Output Voltage	V _{DD} = 5V	4.95		4.95	5		4.95		V
		V _{DD} = 10V	9.95		9.95	10		9.95		V
		V _{DD} = 15V	14.95		14.95	15		14.95		V
V _{IL}	Low Level Input Voltage Comparator and Signal In	V _{DD} = 5V, V _O = 0.5V or 4.5V		1.5		2.25	1.5		1.5	V
		V _{DD} = 10V, V _O = 1V or 9V		3.0		4.5	3.0		3.0	V
		V _{DD} = 15V, V _O = 1.5V or 13.5V		4.0		6.25	4.0		4.0	V
V _{IH}	High Level Input Voltage Comparator and Signal In	V _{DD} = 5V, V _O = 0.5V or 4.5V	3.5		3.5	2.75		3.5		V
		V _{DD} = 10V, V _O = 1V or 9V	7.0		7.0	5.5		7.0		V
		V _{DD} = 15V, V _O = 1.5V or 13.5V	11.0		11.0	8.25		11.0		V
I _{OL}	Low Level Output Current (Note 4)	V _{DD} = 5V, V _O = 0.4V	0.52		0.44	0.88		0.36		mA
		V _{DD} = 10V, V _O = 0.5V	1.3		1.1	2.25		0.9		mA
		V _{DD} = 15V, V _O = 1.5V	3.6		3.0	8.8		2.4		mA
I _{OH}	High Level Output Current (Note 4)	V _{DD} = 5V, V _O = 4.6V	−0.52		−0.44	−0.88		−0.36		mA
		V _{DD} = 10V, V _O = 9.5V	−1.3		−1.1	−2.25		−0.9		mA
		V _{DD} = 15V, V _O = 13.5V	−3.6		−3.0	−8.8		−2.4		mA
I _{IN}	Input Current	All Inputs Except Signal Input V _{DD} = 15V, V _{IN} = 0V V _{DD} = 15V, V _{IN} = 15V		−0.3 0.3		−10 ^{−5} 10 ^{−5}	−0.3 0.3		−1.0 1.0	μA μA
C _{IN}	Input Capacitance	Any Input (Note 3)					7.5			pF
P _T	Total Power Dissipation	f _o = 10 kHz, R1 = 1 MΩ, R2 = ∞, VCO _{IN} = V _{DD} /2								
		V _{DD} = 5V				0.07				mW
		V _{DD} = 10V				0.6				mW
		V _{DD} = 15V				2.4				mW

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. They are not meant to imply that the devices should be operated at these limits. The table of "Recommended Operating Conditions" and "Electrical Characteristics" provides conditions for actual device operation.

Note 2: V_{SS} = 0V unless otherwise specified.

Note 3: Capacitance is guaranteed by periodic testing.

Note 4: I_{OH} and I_{OL} are tested one output at a time.

AC Electrical Characteristics* CD4046BM/CD4046BC T_A = 25°C, C_L = 50 pF

Symbol	Parameter	Conditions	Min	Typ	Max	Units	
VCO SECTION							
I _{DD}	Operating Current	f _o = 10 kHz, R1 = 1 MΩ, R2 = ∞, VCO _{IN} = V _{DD} /2 V _{DD} = 5V V _{DD} = 10V V _{DD} = 15V		20 90 200		μA μA μA	
f _{MAX}	Maximum Operating Frequency	C1 = 50 pF, R1 = 10 kΩ, R2 = ∞, VCO _{IN} = V _{DD} V _{DD} = 5V V _{DD} = 10V V _{DD} = 15V	0.4 0.6 1.0	0.8 1.2 1.6		MHz MHz MHz	
	Linearity	VCO _{IN} = 2.5V ±0.3V, R1 ≥ 10 kΩ, V _{DD} = 5V VCO _{IN} = 5V ±2.5V, R1 ≥ 400 kΩ, V _{DD} = 10V VCO _{IN} = 7.5V ±5V, R1 ≥ 1 MΩ, V _{DD} = 15V		1 1 1		% % %	
		Temperature-Frequency Stability No Frequency Offset, f _{MIN} = 0	%/°C ∝ 1/f, V _{DD} R2 = ∞ V _{DD} = 5V V _{DD} = 10V V _{DD} = 15V		0.12–0.24 0.04–0.08 0.015–0.03		%/°C %/°C %/°C
		Frequency Offset, f _{MIN} ≠ 0	V _{DD} = 5V V _{DD} = 10V V _{DD} = 15V		0.06–0.12 0.05–0.1 0.03–0.06		%/°C %/°C %/°C
	VCO _{IN}	Input Resistance	V _{DD} = 5V V _{DD} = 10V V _{DD} = 15V		10 ⁶ 10 ⁶ 10 ⁶		MΩ MΩ MΩ
	VCO	Output Duty Cycle	V _{DD} = 5V V _{DD} = 10V V _{DD} = 15V		50 50 50		% % %
t _{THL}	VCO Output Transition Time	V _{DD} = 5V		90	200	ns	
t _{THL}		V _{DD} = 10V V _{DD} = 15V		50 45	100 80	ns ns	

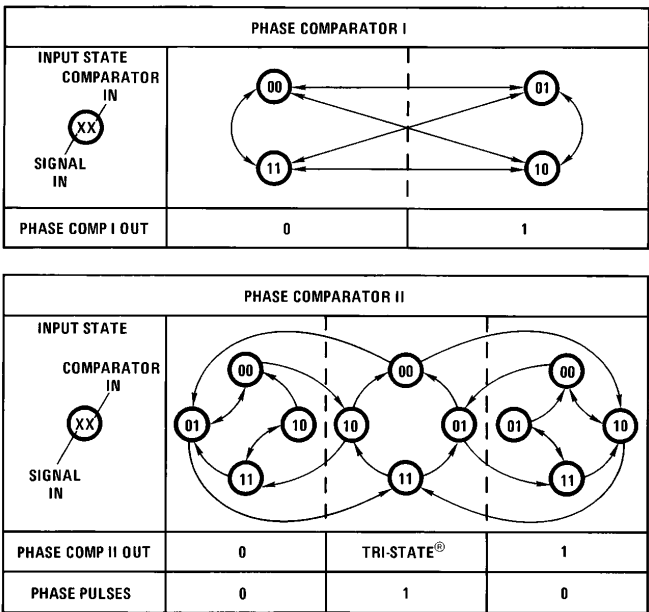
*AC Parameters are guaranteed by DC correlated testing.

AC Electrical Characteristics* CD4046BM/CD4046BC T_A = 25°C, C_L = 50 pF (Continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
PHASE COMPARATORS SECTION						
R _{IN}	Input Resistance Signal Input	V _{DD} = 5V	1	3		MΩ
		V _{DD} = 10V	0.2	0.7		MΩ
		V _{DD} = 15V	0.1	0.3		MΩ
		V _{DD} = 5V		10 ⁶		MΩ
		V _{DD} = 10V		10 ⁶		MΩ
		V _{DD} = 15V		10 ⁶		MΩ
	AC-Coupled Signal Input Voltage Sensitivity	C _{SERIES} = 1000 pF f = 50 kHz				
		V _{DD} = 5V		200	400	mV
		V _{DD} = 10V		400	800	mV
		V _{DD} = 15V		700	1400	mV
DEMODULATOR OUTPUT						
V _{COIN} – V _{DEM}	Offset Voltage	RS ≥ 10 kΩ, V _{DD} = 5V		1.50	2.2	V
		RS ≥ 10 kΩ, V _{DD} = 10V		1.50	2.2	V
		RS ≥ 50 kΩ, V _{DD} = 15V		1.50	2.2	V
	Linearity	RS ≥ 50 kΩ				
		V _{COIN} = 2.5V ± 0.3V, V _{DD} = 5V		0.1		%
V _{COIN} = 5V ± 2.5V, V _{DD} = 10V			0.6		%	
	V _{COIN} = 7.5V ± 5V, V _{DD} = 15V		0.8		%	
ZENER DIODE						
V _Z	Zener Diode Voltage	I _Z = 50 μA	6.3	7.0	7.7	V
R _Z	Zener Dynamic Resistance	I _Z = 1 mA		100		Ω

*AC Parameters are guaranteed by DC correlated testing.

Phase Comparator State Diagrams



TL/F/5968-3

FIGURE 2

Typical Waveforms

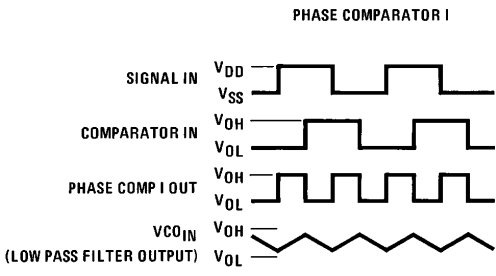


FIGURE 3. Typical Waveform Employing Phase Comparator I in Locked Condition

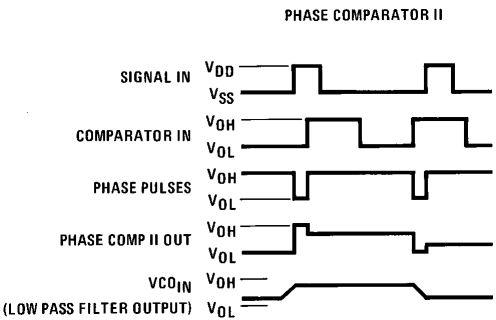
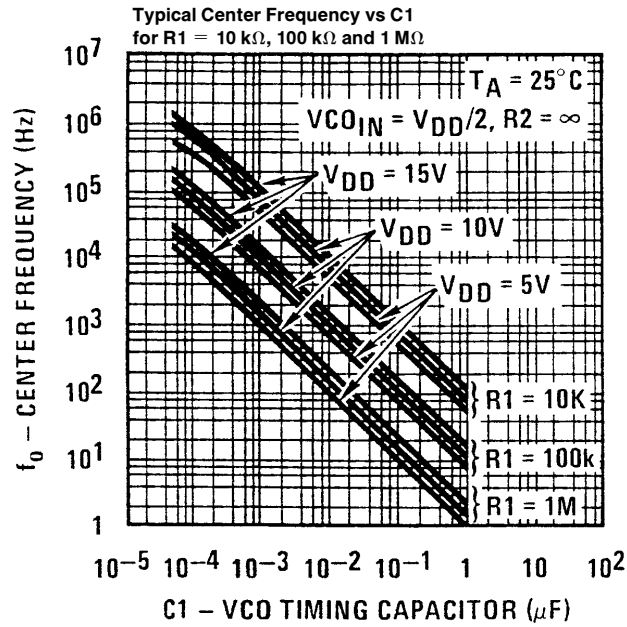


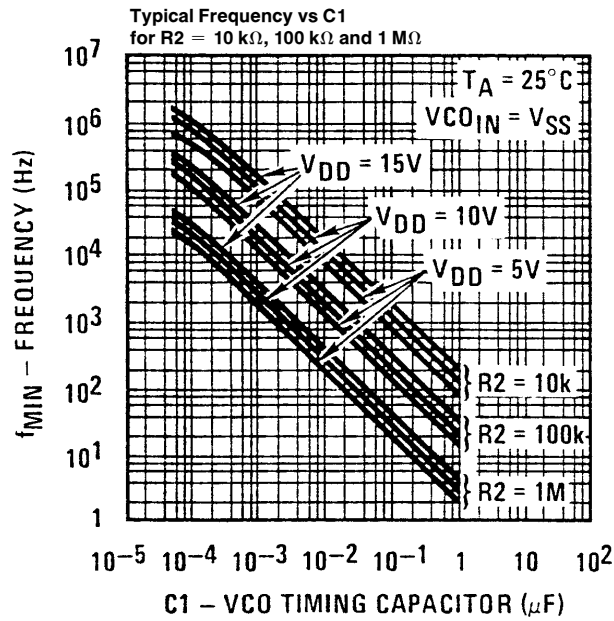
FIGURE 4. Typical Waveform Employing Phase Comparator II in Locked Condition

Typical Performance Characteristics



TL/F/5968-6

FIGURE 5a



TL/F/5968-13

FIGURE 5b

Note: To obtain approximate total power dissipation of PLL system for no-signal input: Phase Comparator I, $P_D(\text{Total}) = P_D(f_0) + P_D(f_{MIN}) + P_D(R_S)$; Phase Comparator II, $P_D(\text{Total}) = P_D(f_{MIN})$.

Typical Performance Characteristics (Continued)

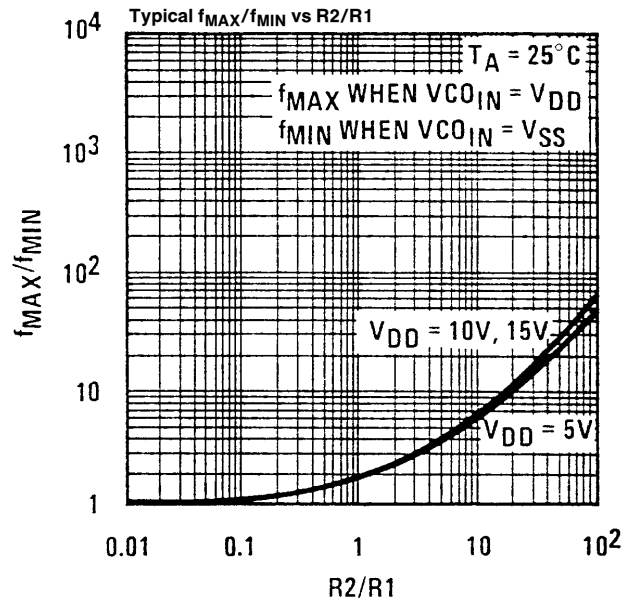


FIGURE 5C

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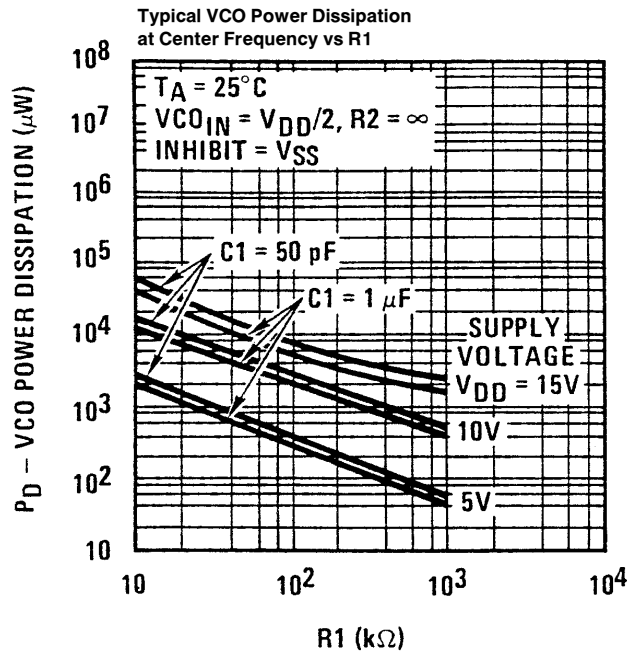


FIGURE 6a

TL/F/5968-15

Note: To obtain approximate total power dissipation of PLL system for no-signal input: Phase Comparator I, $P_D(\text{Total}) = P_D(f_o) + P_D(f_{MIN}) + P_D(R_S)$; Phase Comparator II, $P_D(\text{Total}) = P_D(f_{MIN})$.

Typical Performance Characteristics (Continued)

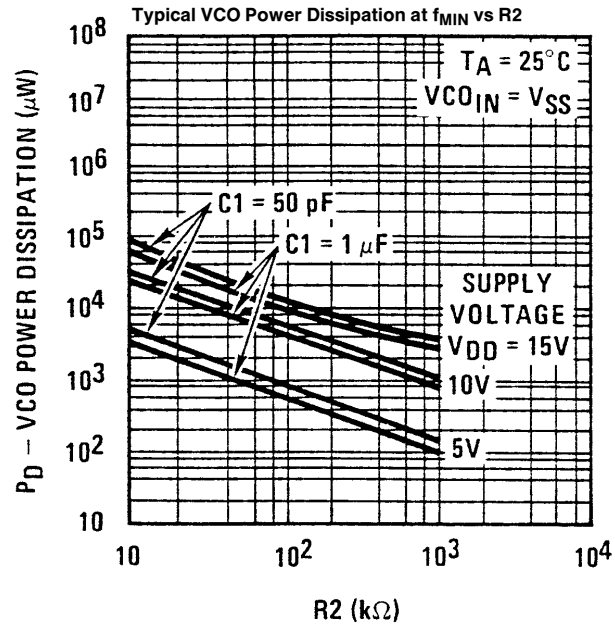


FIGURE 6b

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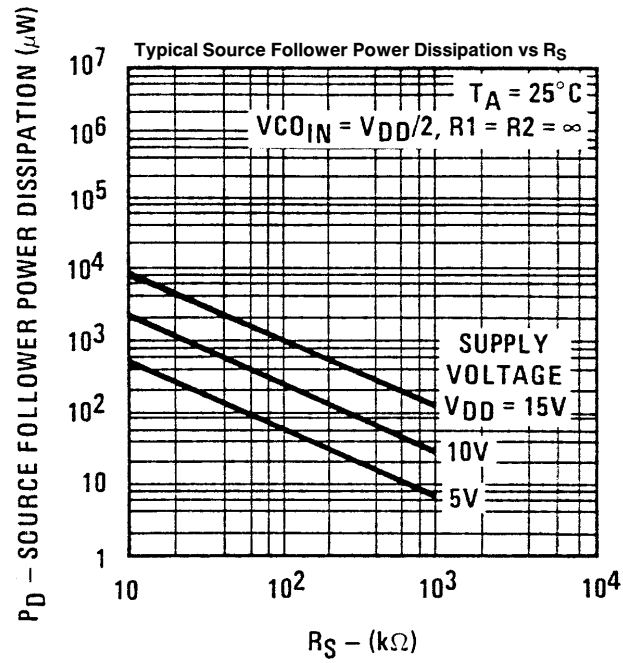
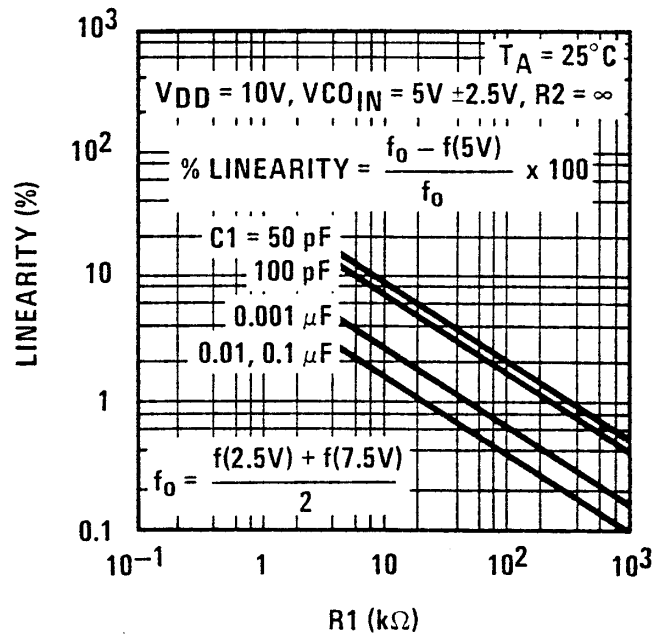


FIGURE 6c

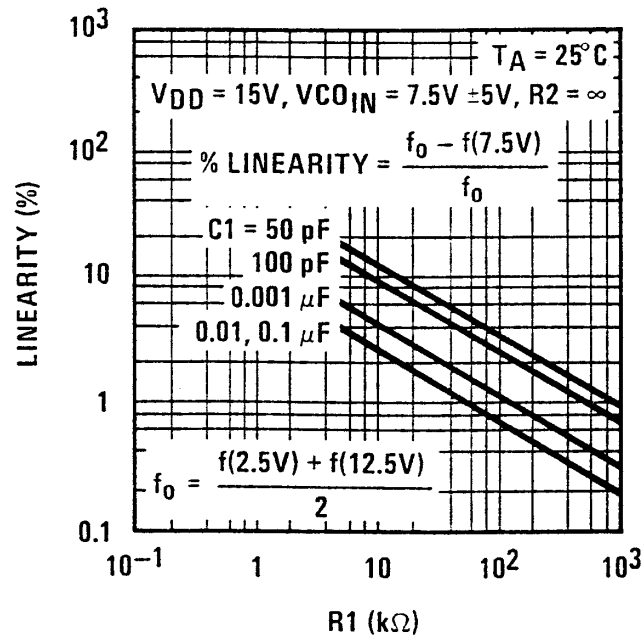
TL/F/5968-17

Note: To obtain approximate total power dissipation of PLL system for no-signal input: Phase Comparator I, $P_D(\text{Total}) = P_D(f_o) + P_D(f_{\text{MIN}}) + P_D(R_S)$; Phase Comparator II, $P_D(\text{Total}) = P_D(f_{\text{MIN}})$.

Typical Performance Characteristics (Continued)



TL/F/5968-18



TL/F/5968-19

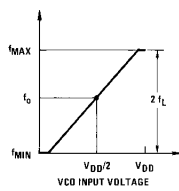
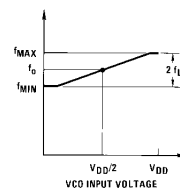
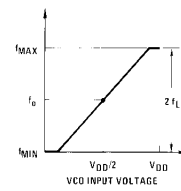
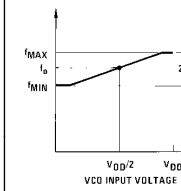
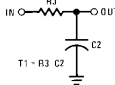
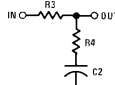
FIGURE 7. Typical VCO Linearity vs R1 and C1

Note: To obtain approximate total power dissipation of PLL system for no-signal input: Phase Comparator I, $P_D(\text{Total}) = P_D(f_0) + P_D(f_{\text{MIN}}) + P_D(R_S)$; Phase Comparator II, $P_D(\text{Total}) = P_D(f_{\text{MIN}})$.

Design Information

This information is a guide for approximating the value of external components for the CD4046B in a phase-locked-loop system. The selected external components must be within the following ranges: $R_1, R_2 \geq 10 \text{ k}\Omega$, $R_S \geq 10 \text{ k}\Omega$, $C_1 \geq 50 \text{ pF}$.

In addition to the given design information, refer to *Figure 5* for R_1 , R_2 and C_1 component selections.

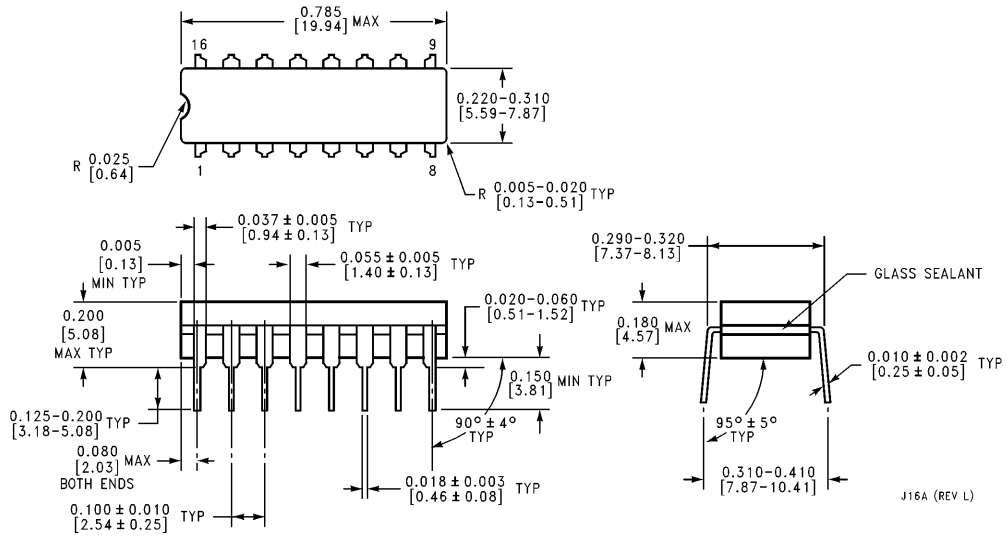
Characteristics	Using Phase Comparator I		Using Phase Comparator II	
	VCO Without Offset R2 = ∞	VCO With Offset	VCO Without Offset R2 = ∞	VCO With Offset
VCO Frequency	 TL/F/5968-7	 TL/F/5968-8	 TL/F/5968-9	 TL/F/5968-10
For No Signal Input	VCO in PLL system will adjust to center frequency, f_o		VCO in PLL system will adjust to lowest operating frequency, f_min	
Frequency Lock Range, 2 f_L	2 f_L = full VCO frequency range 2 f_L = f_max - f_min			
Frequency Capture Range, 2 f_C	 TL/F/5968-11		$2 f_C \approx \frac{1}{\pi} \sqrt{\frac{2 \pi f_L}{\tau 1}}$ $f_C = f_L$	
Loop Filter Component Selection	 TL/F/5968-12			
Phase Angle Between Single and Comparator	90° at center frequency (f_o), approximating 0° and 180° at ends of lock range (2 f_L)		Always 0° in lock	
Locks on Harmonics of Center Frequency	Yes		No	
Signal Input Noise Rejection	High		Low	
VCO Component Selection	Given: f_o. Use f_o with Figure 5a to determine R1 and C1.	Given: f_o and f_L. Calculate f_min from the equation f_min = f_o - f_L. Use f_min with Figure 5b to determine R2 and C1. Calculate f_max / f_min from the equation f_max / f_min = (f_o + f_L) / (f_o - f_L). Use f_max / f_min with Figure 5c to determine ratio R2/ R1 to obtain R1.	Given: f_max. Calculate f_o from the equation f_o = f_max / 2. Use f_o with Figure 5a to determine R1 and C1.	Given: f_min and f_max. Use f_min with Figure 5b to determine R2 and C1. Calculate f_max / f_min. Use f_max / f_min with Figure 5c to determine ratio R2/ R1 to obtain R1.

References

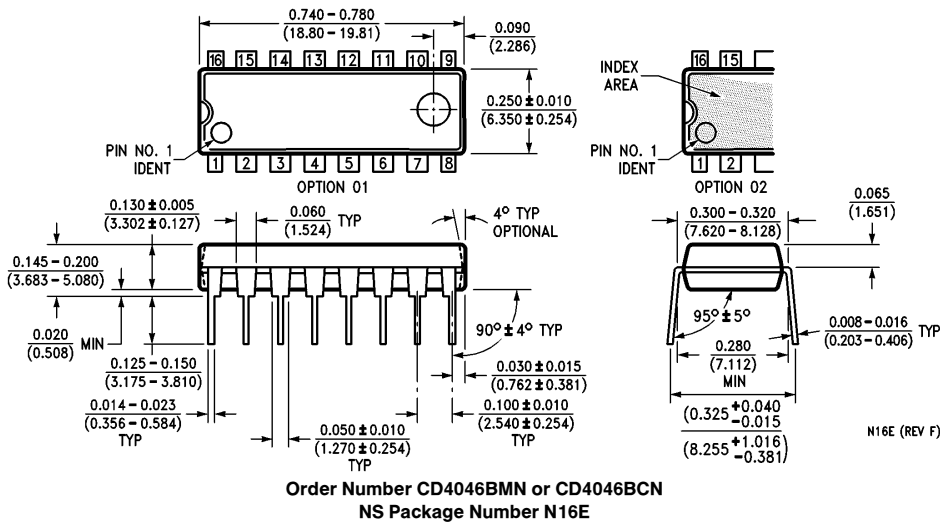
G.S. Moschytz, "Miniaturized RC Filters Using Phase-Locked Loop", BSTJ, May, 1965.
 Floyd Gardner, "Phaselock Techniques", John Wiley & Sons, 1966.



Physical Dimensions inches (millimeters)



Physical Dimensions inches (millimeters) (Continued)



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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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