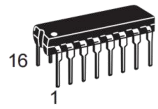
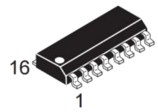
Micropower Phase-Locked Loop

Features

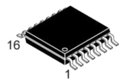
- Wide supply voltage range: 3.0V to 18V
- Low dynamic: 70μW (typ.) at
  power consumption: fo = 10 kHz, V_{DD} = 5V
- VCO frequency: 1.3 MHz (typ.) at V_{DD} = 10V
- Low frequency drift: 0.06%/°C at V_{DD} = 10V with temperature
- High VCO linearity: 1% (typ.)



DIP-16



SOP-16


TSSOP-16

Ordering Information

DEVICE	Package Type	MARKING	Packing	Packing Qty
CD4046BE	DIP-16	CD4046BE	TUBE	1000pcs/box
CD4046BM/TR	SOP-16	CD4046B	REEL	2500pcs/reel
CD4046BMT/TR	TSSOP-16	CD4046B	REEL	2500pcs/reel

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.

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

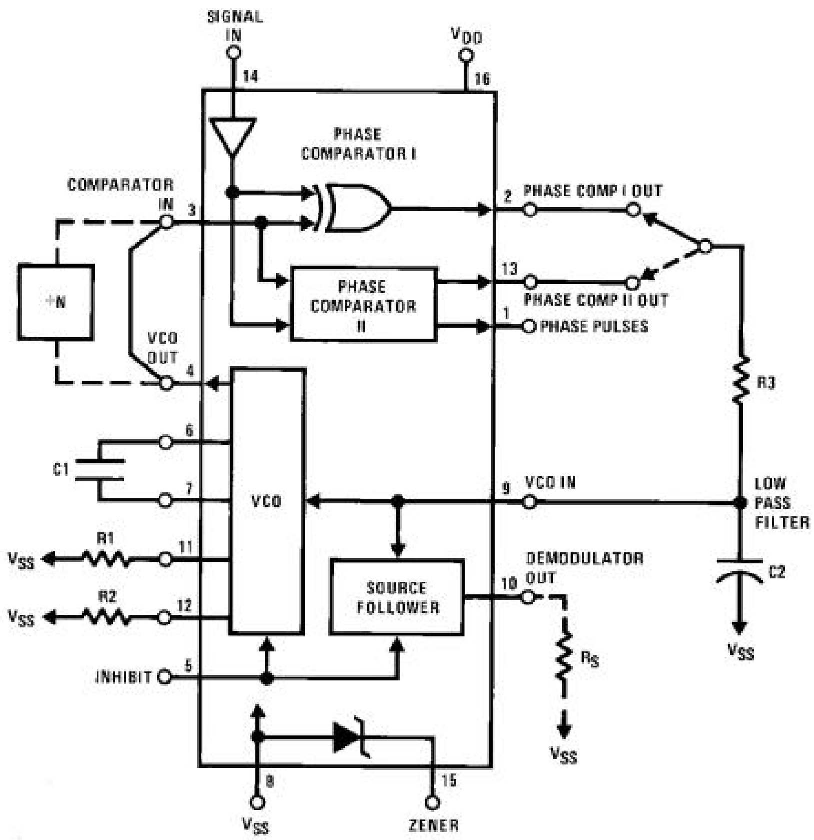
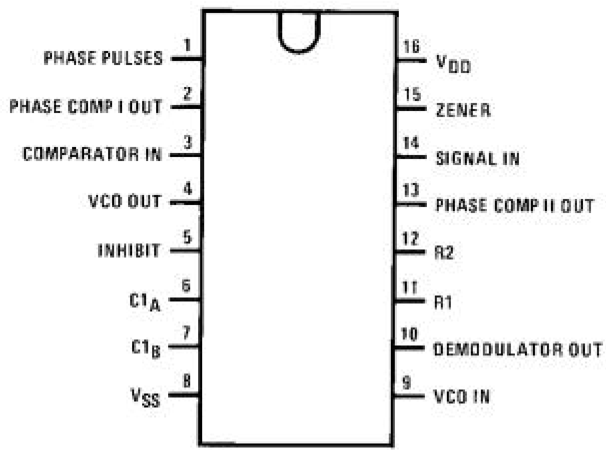


FIGURE 1

Dual-In-Line Package



Top View

Order Number CD4046B

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.

Condition	Min	Max	UNITS
DC Supply Voltage (V_{DD})	-0.5	+18	V_{DC}
Input Voltage (V_{IN})	-0.5	+0.5	V_{DC}
Storage Temperature Range (T_S)	-65	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)

Condition	Min	Max	UNITS
DC Supply Voltage (V_{DD})	+3	+15	V_{DC}
Input Voltage (V_{IN})	0 to V_{DD} V_{DC}		-
Operating Temperature Range (T_A)	-40	+85	°C

DC Electrical Characteristics (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		-0.3		-10^{-5}	-0.3		-1.0	μA
		V_{DD} = 15V, V_{IN} = 15V		0.3		10-5	0.3		1.0	μA
C_{IN}	Input Capacitance	Any Input (Note 3)					7.5			pF
P_T	Total Power Dissipation	fo = 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} e 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* TA = 25°C, CL = 50 pF

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

*AC Parameters are guaranteed by DC correlated testing.

AC Electrical Characteristics* TA e 25°C, CL = 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
	Comparator Input	V_{DD} = 5V		106		MΩ
		V_{DD} = 10V		106		MΩ
		V_{DD} = 15V		106		MΩ
	AC-Coupled Signal Input Voltage Sensitivity	CSERIES = 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						
VCO_{IN}-VDEM	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				
		VCO_{IN} = 2.5V±0.3V, V_{DD} = 5V		0.1		%
		VCO_{IN} = 5V±2.5V, V_{DD} = 10V		0.6		%
		VCO_{IN} = 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

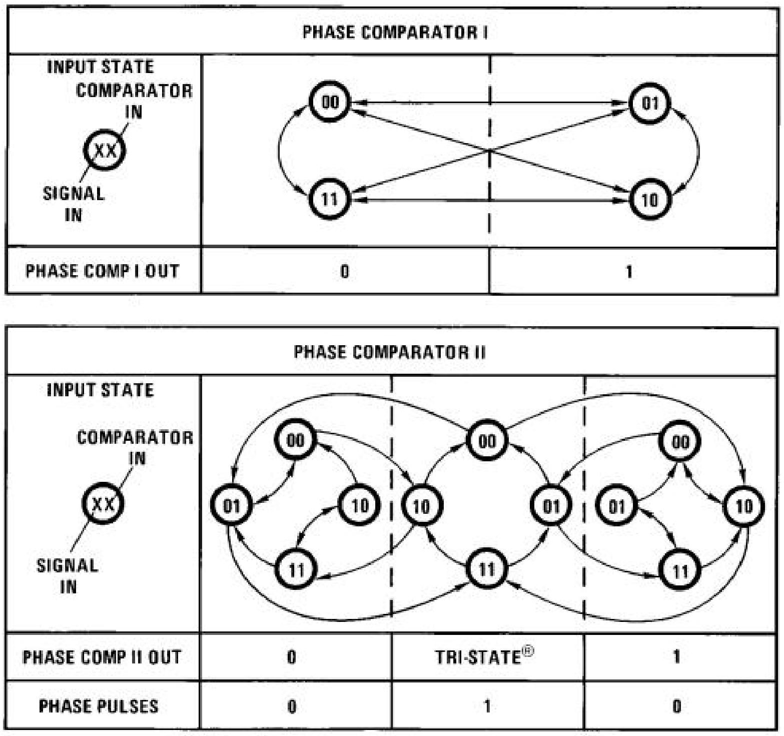


FIGURE 2

Typical Waveforms

PHASE COMPARATORI

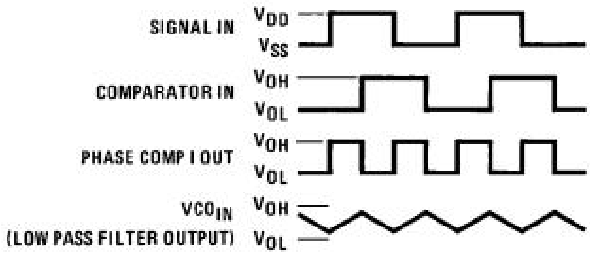


FIGURE 3. Typical Waveform Employing Phase Comparator I in Locked Condition

PHASE COMPARATORI

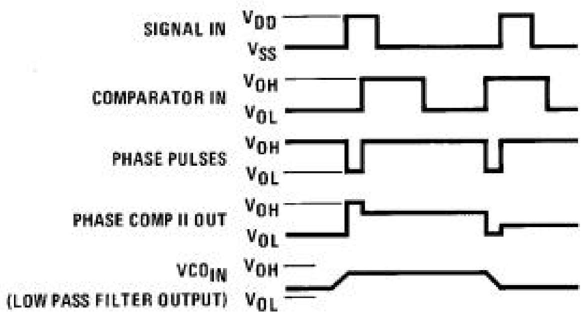


FIGURE 4. Typical Waveform Employing Phase Comparator II in Locked Condition

Typical Performance Characteristics

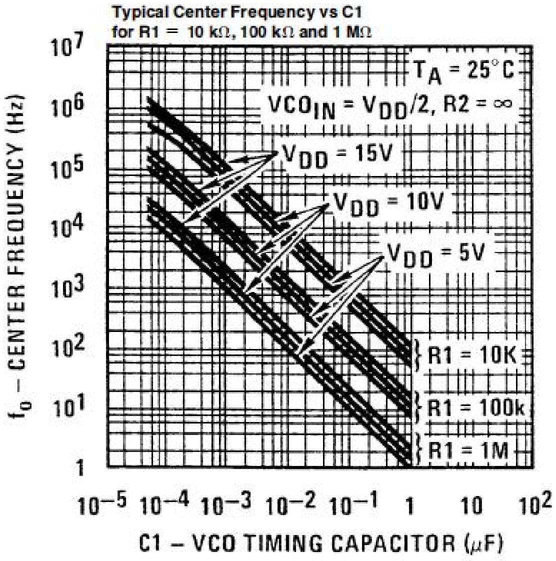


FIGURE 5a

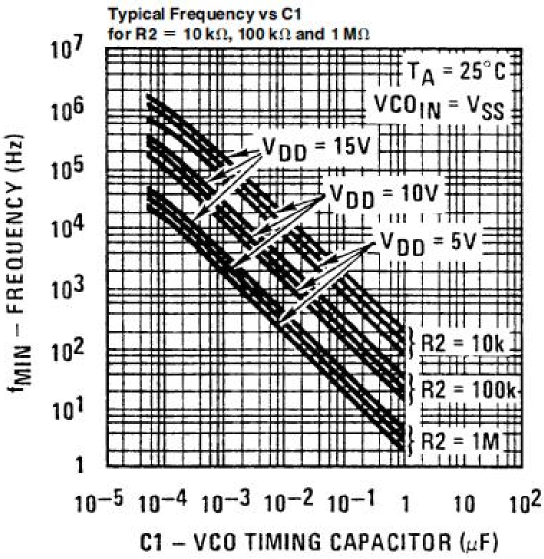


FIGURE 5b

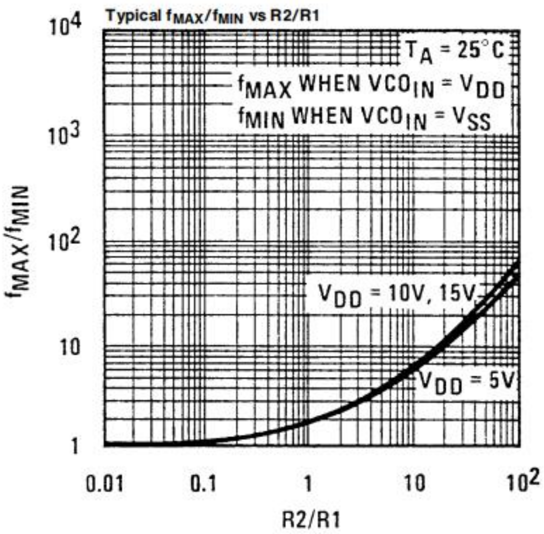


FIGURE 5C

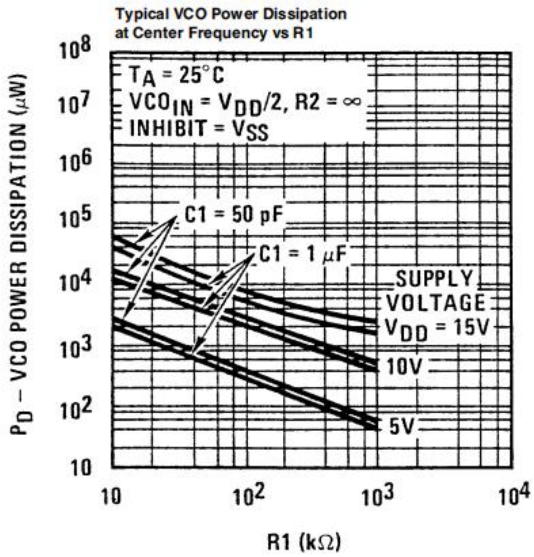


FIGURE 6a

Note: To obtain approximate total power dissipation of PLL system for no-signal input: Phase Comparator I, PD (Total) - PD (fo) + PD (fMIN) + PD (RS); Phas - Comparator II, PD (Total) - PD (fMIN).

Typical Performance Characteristics (Continued)

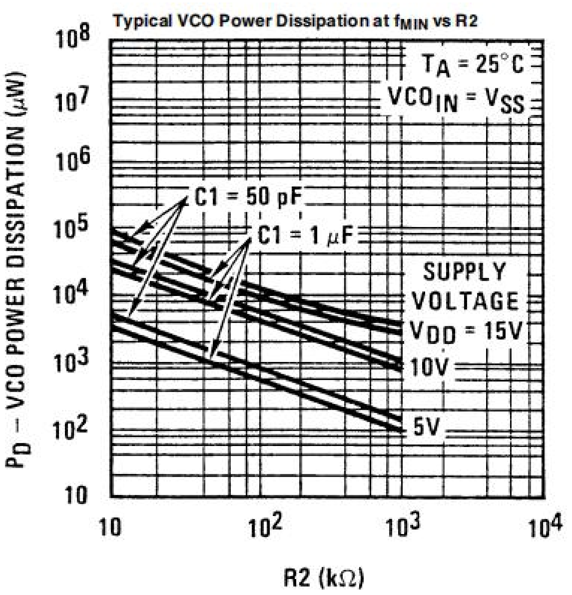


FIGURE 6b

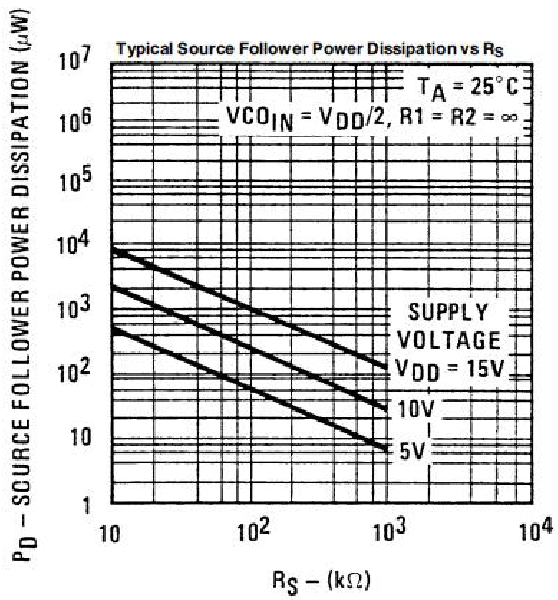


FIGURE 6c

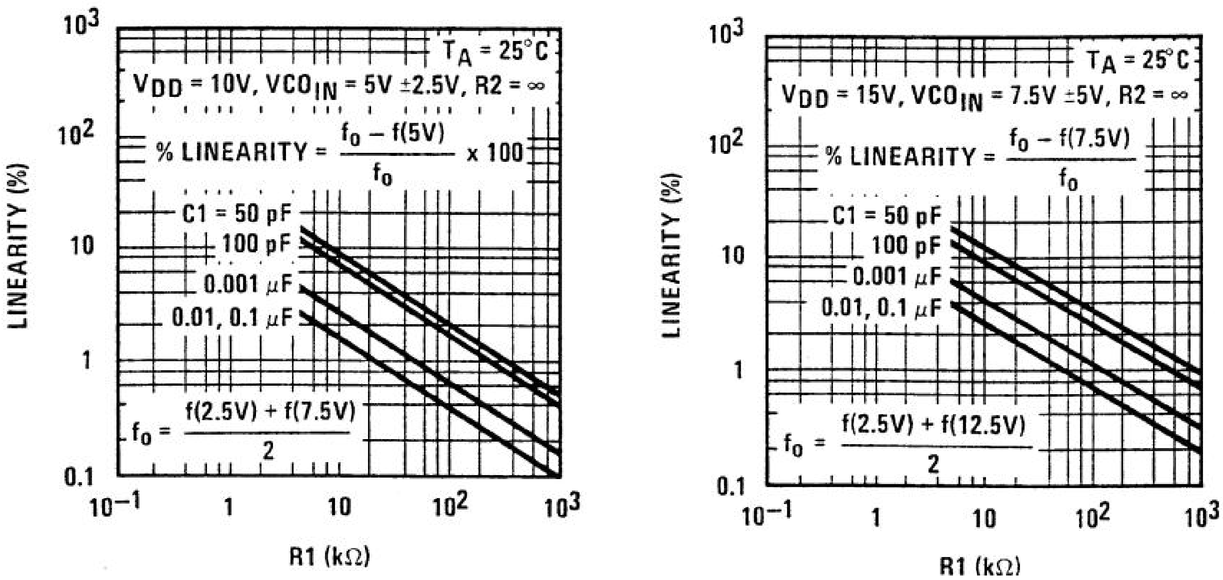
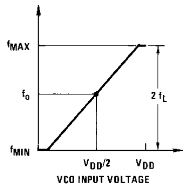
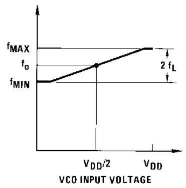
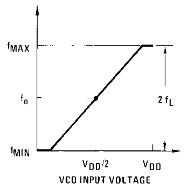
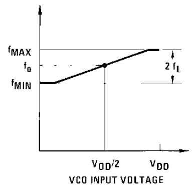
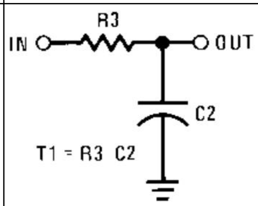
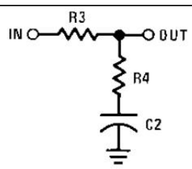


FIGURE 7. Typical VCO Linearity vs R1 and C1

Note: To obtain approximate total power dissipation of PLL system for no-signal input: Phase Comparator I, PD (Total) - PD (fo) + PD (fMIN) + PD (RS); Phase Comparator II, P_D (Total) - PD (fMIN).

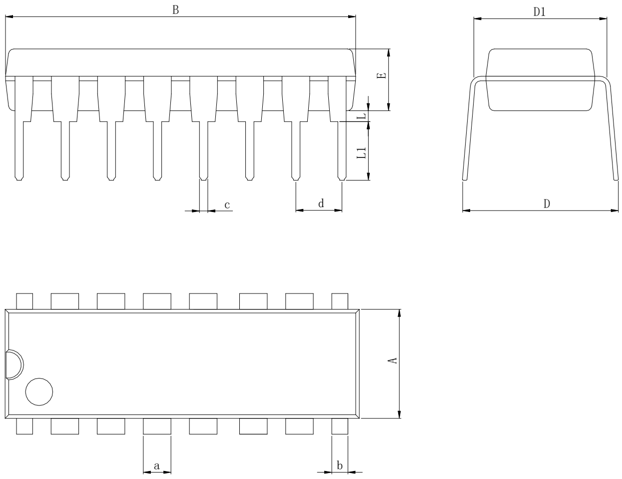
Design Information

This information is a guide for approximating the value of external components for the CD4046B in a phase-lockedloop system. The selected external components must be within the following ranges: R1, R2 ≥ 10 kΩ, RS ≥ 10 kΩ, C1 ≥ 50 pF. In addition to the given design information, refer to Figure 5 for R1, R2 and C1 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				
For No Signal Input	VCO in PLL system will adjust to center frequency, fo		VCO in PLL system will adjust to lowest operating frequency, fmin	
Frequency Lock Range, 2 fL	2 fL = full VCO frequency range 2 fL = fmax - fmin			
Frequency Capture Range, 2 fC		$2fc \approx \frac{1}{\pi}\sqrt{\frac{2\pi fL}{\pi 1}}$	fC = fL	
Loop Filter Component Selection		For 2 fC, see Ref.		
Phase Angle Between Single and Comparator	90° at center frequency (fo), approximating 0° and 180° at ends of lock range (2 fL)		Always 0° in lock	
Locks on Harmonics of Center Frequency	Yes		No	
Signal Input Noise Rejection	High		Low	
VCO Component Selection	Given: fo. Use fo with Figure 5a to determine R1 and C1.	Given: fo and fL. Calculate fmin from the equation fmin = fo - fL. Use fmin with Figure 5b to determine R2 and C1. Calculate $\frac{fmax}{fmin}$ from the equation $\frac{fmax}{fmin} = \frac{fo + fL}{fo - fL}$ Use $\frac{fmax}{fmin}$ with Figure 5c to determine ratio R2/ R1 to obtain R1.	Given: fmax. Calculate fo from the equation $Fo = \frac{fmax}{2}$ Use fo with Figure 5a to determine R1 and C1.	Given： fmin and fmax Use fmin with Figure 5b to Determine $\frac{fmax}{fmin}$ Use $\frac{fmax}{fmin}$ with Figure 5c to determine ration R2/R1 to obtain R1.

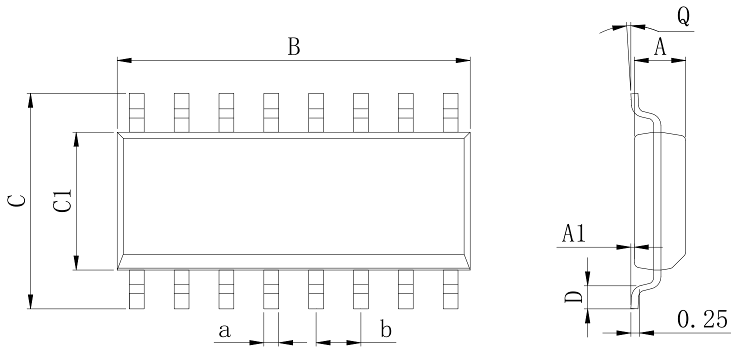
Physical Dimensions

DIP16



Dimensions In Millimeters(DIP16)											
Symbol:	A	B	D	D1	E	L	L1	a	b	c	d
Min:	6.10	18.94	8.40	7.42	3.10	0.50	300	1.50	0.85	0.40	2.54 BSC
Max:	6.68	19.56	9.00	7.82	3.55	0.70	3.60	1.55	0.90	0.50	

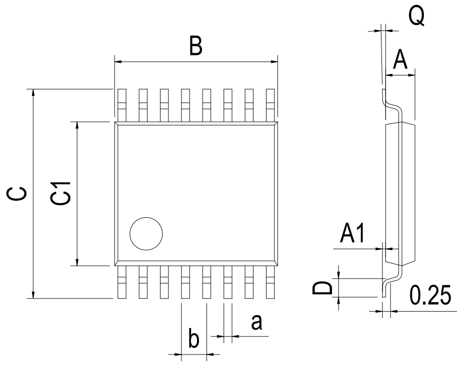
SOP16



Dimensions In Millimeters(SOP16)									
Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	1.35	0.05	9.80	5.80	3.80	0.40	0°	0.35	1.27 BSC
Max:	1.55	0.20	10.0	6.20	4.00	0.80	8°	0.45	

Physical Dimensions

TSSOP16



Dimensions In Millimeters(TSSOP16)									
Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	0.85	0.05	4.90	6.20	4.30	0.40	0°	0.20	0.65 BSC
Max:	0.95	0.20	5.10	6.60	4.50	0.80	8°	0.25	

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