

February 1998 - Revised May 2000

High-Speed CMOS Logic Phase-Locked-Loop with VCO

Features

- **Operating Frequency Range**
 - Up to 18MHz (Typ) at $V_{CC} = 5V$
 - Minimum Center Frequency of 12MHz at $V_{CC} = 4.5V$
- **Choice of Three Phase Comparators**
 - EXCLUSIVE-OR
 - Edge-Triggered JK Flip-Flop
 - Edge-Triggered RS Flip-Flop
- **Excellent VCO Frequency Linearity**
- **VCO-Inhibit Control for ON/OFF Keying and for Low Standby Power Consumption**
- **Minimal Frequency Drift**
- **Operating Power Supply Voltage Range**
 - VCO Section 3V to 6V
 - Digital Section 2V to 6V
- **Fanout (Over Temperature Range)**
 - Standard Outputs 10 LSTTL Loads
 - Bus Driver Outputs 15 LSTTL Loads
- **Wide Operating Temperature Range ... -55°C to 125°C**
- **Balanced Propagation Delay and Transition Times**
- **Significant Power Reduction Compared to LSTTL Logic ICs**
- **HC Types**
 - 2V to 6V Operation
 - High Noise Immunity: $N_{IL} = 30\%$, $N_{IH} = 30\%$ of V_{CC} at $V_{CC} = 5V$
- **HCT Types**
 - 4.5V to 5.5V Operation
 - Direct LSTTL Input Logic Compatibility, $V_{IL} = 0.8V$ (Max), $V_{IH} = 2V$ (Min)
 - CMOS Input Compatibility, $I_I \leq 1\mu A$ at V_{OL} , V_{OH}

Description

The 'HC4046A and 'HCT4046A are high-speed silicon-gate CMOS devices that are pin compatible with the CD4046B of the "4000B" series. They are specified in compliance with JEDEC standard number 7.

The 'HC4046A and 'HCT4046A are phase-locked-loop circuits that contain a linear voltage-controlled oscillator (VCO) and three different phase comparators (PC1, PC2 and PC3). A signal input and a comparator input are common to each comparator.

The signal input can be directly coupled to large voltage signals, or indirectly coupled (with a series capacitor) to small voltage signals. A self-bias input circuit keeps small voltage signals within the linear region of the input amplifiers. With a passive low-pass filter, the 4046A forms a second-order loop PLL. The excellent VCO linearity is achieved by the use of linear op-amp techniques.

Ordering Information

PART NUMBER	TEMP. RANGE (°C)	PACKAGE
CD54HC4046AF	-55 to 125	16 Ld Cerdip
CD54HC4046AF3A	-55 to 125	16 Ld Cerdip
CD74HC4046AE	-55 to 125	16 Ld PDIP
CD74HC4046AM	-55 to 125	16 Ld SOIC
CD54HCT4046AF3A	-55 to 125	16 Ld Cerdip
CD74HCT4046AE	-55 to 125	16 Ld PDIP
CD74HCT4046AM	-55 to 125	16 Ld SOIC

NOTES:

1. When ordering, use the entire part number. Add the suffix 96 to obtain the variant in the tape and reel.
2. Wafer and die for this part number is available which meets all electrical specifications. Please contact your local TI sales office or customer service for ordering information.

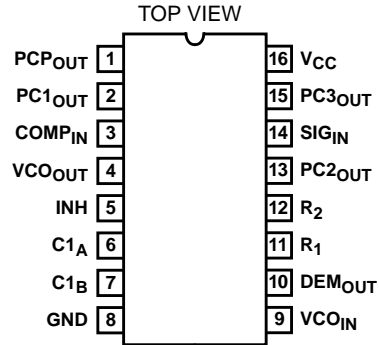
Applications

- FM Modulation and Demodulation
- Frequency Synthesis and Multiplication
- Frequency Discrimination
- Tone Decoding
- Data Synchronization and Conditioning
- Voltage-to-Frequency Conversion
- Motor-Speed Control

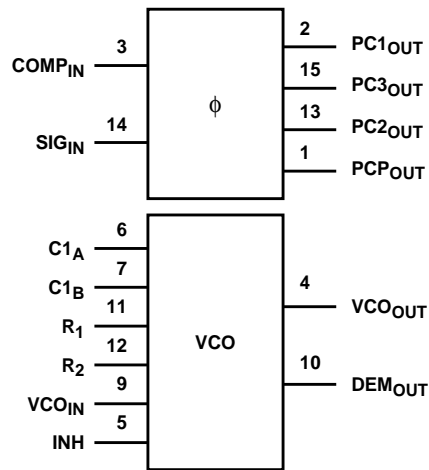
CD54/74HC4046A, CD54/74HCT4046A

Pinout

CD54HC4046A, CD54HCT4046A (CERDIP)
CD74HC4046A, CD74HCT4046A (PDIP, SOIC)



Functional Diagram



Pin Descriptions

PIN NUMBER	SYMBOL	NAME AND FUNCTION
1	PCP _{OUT}	Phase Comparator Pulse Output
2	PC1 _{OUT}	Phase Comparator 1 Output
3	COMP _{IN}	Comparator Input
4	VCO _{OUT}	VCO Output
5	INH	Inhibit Input
6	C1 _A	Capacitor C1 Connection A
7	C1 _B	Capacitor C1 Connection B
8	GND	Ground (0V)
9	VCO _{IN}	VCO Input
10	DEM _{OUT}	Demodulator Output
11	R ₁	Resistor R1 Connection
12	R ₂	Resistor R2 Connection
13	PC2 _{OUT}	Phase Comparator 2 Output
14	SIG _{IN}	Signal Input
15	PC3 _{OUT}	Phase Comparator 3 Output
16	V _{CC}	Positive Supply Voltage

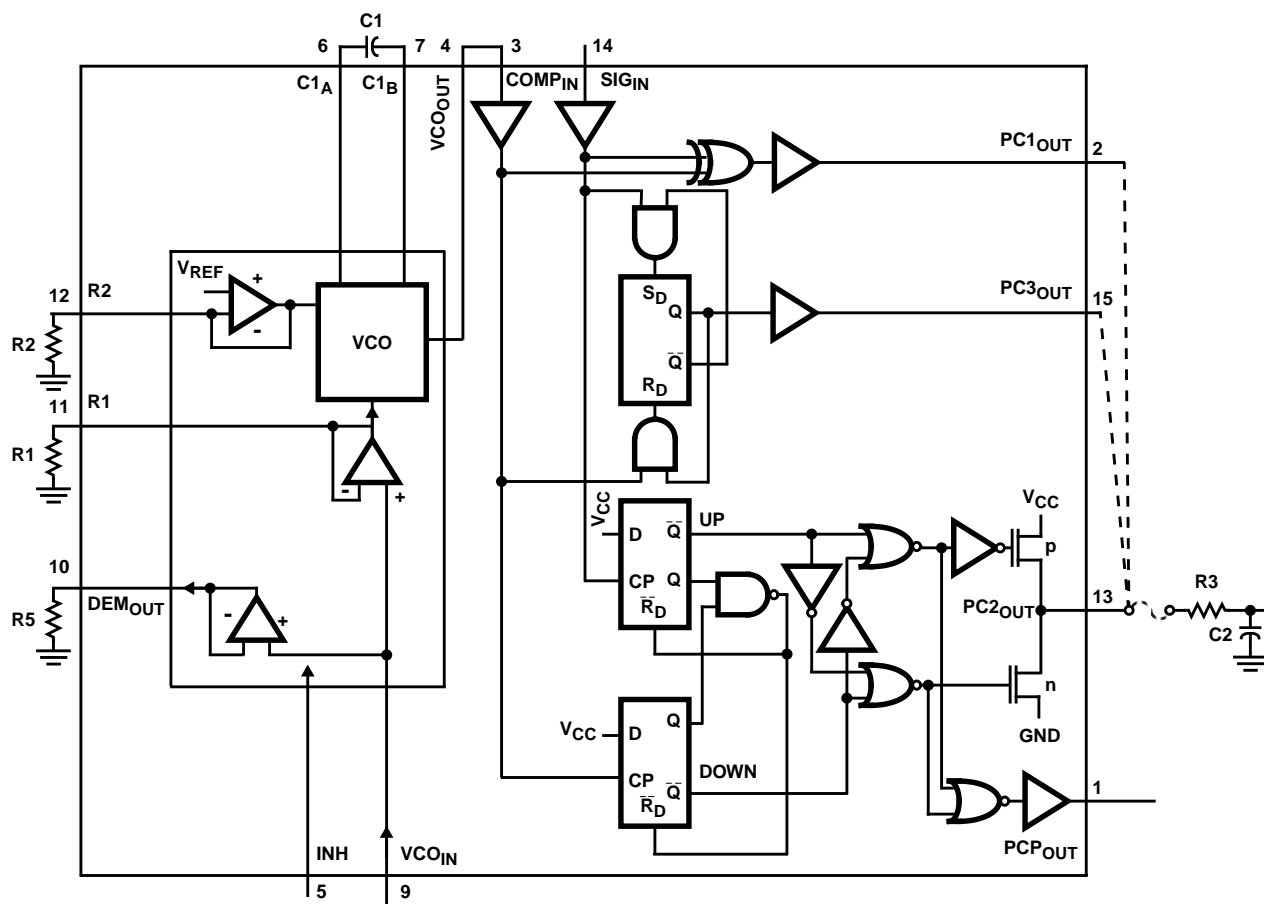


FIGURE 1. LOGIC DIAGRAM

General Description

VCO

The VCO requires one external capacitor C1 (between C1_A and C1_B) and one external resistor R1 (between R₁ and GND) or two external resistors R1 and R2 (between R₁ and GND, and R₂ and GND). Resistor R1 and capacitor C1 determine the frequency range of the VCO. Resistor R2 enables the VCO to have a frequency offset if required. See logic diagram, Figure 1.

The high input impedance of the VCO simplifies the design of low-pass filters by giving the designer a wide choice of resistor/capacitor ranges. In order not to load the low-pass filter, a demodulator output of the VCO input voltage is provided at pin 10 (DEM_{OUT}). In contrast to conventional techniques where the DEM_{OUT} voltage is one threshold voltage lower than the VCO input voltage, here the DEM_{OUT} voltage equals that of the VCO input. If DEM_{OUT} is used, a load resistor (R_S) should be connected from DEM_{OUT} to GND; if unused, DEM_{OUT} should be left open. The VCO output (VCO_{OUT}) can be connected directly to the comparator input (COMP_{IN}), or connected via a frequency-divider. The VCO output signal has a guaranteed duty factor of 50%. A LOW level at the inhibit input (INH) enables the VCO and demodulator, while a HIGH level turns both off to minimize standby power consumption.

Phase Comparators

The signal input (SIG_{IN}) can be directly coupled to the self-biasing amplifier at pin 14, provided that the signal swing is between the standard HC family input logic levels. Capacitive coupling is required for signals with smaller swings.

Phase Comparator 1 (PC1)

This is an Exclusive-OR network. The signal and comparator input frequencies (f_i) must have a 50% duty factor to obtain the maximum locking range. The transfer characteristic of PC1, assuming ripple ($f_r = 2f_i$) is suppressed, is:

$V_{\text{DEMOUT}} = (V_{\text{CC}}/\pi) (\phi_{\text{SIGIN}} - \phi_{\text{COMPIN}})$ where V_{DEMOUT} is the demodulator output at pin 10; $V_{\text{DEMOUT}} = V_{\text{PC1OUT}}$ (via low-pass filter).

The average output voltage from PC1, fed to the VCO input via the low-pass filter and seen at the demodulator output at pin 10 (V_{DEMOUT}), is the resultant of the phase differences of signals (SIG_{IN}) and the comparator input (COMP_{IN}) as shown in Figure 2. The average of V_{DEM} is equal to $1/2 V_{\text{CC}}$ when there is no signal or noise at SIG_{IN} , and with this input the VCO oscillates at the center frequency (f_0). Typical waveforms for the PC1 loop locked at f_0 are shown in Figure 3.

The frequency capture range ($2f_C$) is defined as the frequency range of input signals on which the PLL will lock if it was initially out-of-lock. The frequency lock range ($2f_L$) is defined as the frequency range of input signals on which the loop will stay locked if it was initially in lock. The capture range is smaller or equal to the lock range.

With PC1, the capture range depends on the low-pass filter characteristics and can be made as large as the lock range. This configuration retains lock behavior even with very noisy input signals. Typical of this type of phase comparator is that it can lock to input frequencies close to the harmonics of the VCO center frequency.

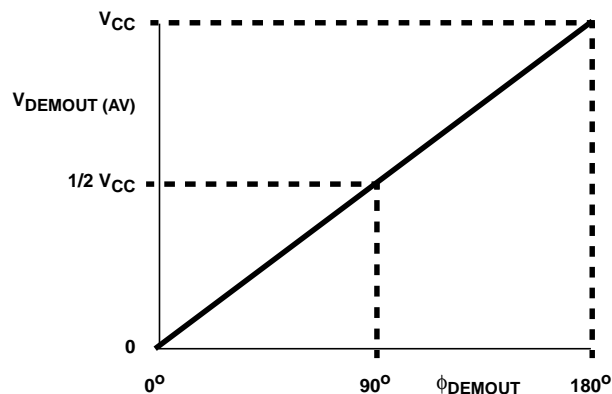


FIGURE 2. PHASE COMPARATOR 1: AVERAGE OUTPUT VOLTAGE vs INPUT PHASE DIFFERENCE:
 $V_{DEMOUT} = V_{PC1OUT} = (V_{CC}/\pi) (\phi_{SIGIN} - \phi_{COM-PIIN})$; $\phi_{DEMOUT} = (\phi_{SIGIN} - \phi_{COMPIIN})$

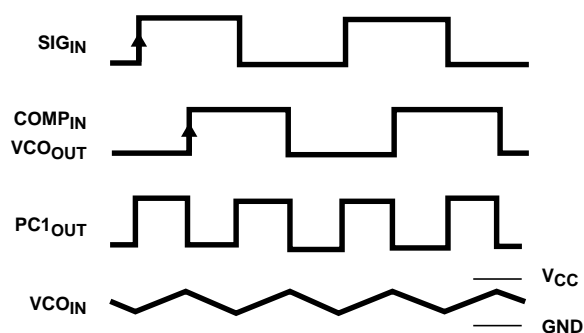


FIGURE 3. TYPICAL WAVEFORMS FOR PLL USING PHASE COMPARATOR 1, LOOP LOCKED AT f_0

Phase Comparator 2 (PC2)

This is a positive edge-triggered phase and frequency detector. When the PLL is using this comparator, the loop is controlled by positive signal transitions and the duty factors of SIG_{IN} and $COMP_{IN}$ are not important. PC2 comprises two D-type flip-flops, control-gating and a three-state output stage. The circuit functions as an up-down counter (Figure 1) where SIG_{IN} causes an up-count and $COMP_{IN}$ a down-count. The transfer function of PC2, assuming ripple ($f_r = f_i$) is suppressed, is:

$V_{DEMOUT} = (V_{CC}/4\pi) (\phi_{SIGIN} - \phi_{COMPIIN})$ where V_{DEMOUT} is the demodulator output at pin 10; $V_{DEMOUT} = V_{PC2OUT}$ (via low-pass filter).

The average output voltage from PC2, fed to the VCO via the low-pass filter and seen at the demodulator output at pin 10 (V_{DEMOUT}), is the resultant of the phase differences of SIG_{IN} and $COMP_{IN}$ as shown in Figure 4. Typical waveforms for the PC2 loop locked at f_0 are shown in Figure 5.

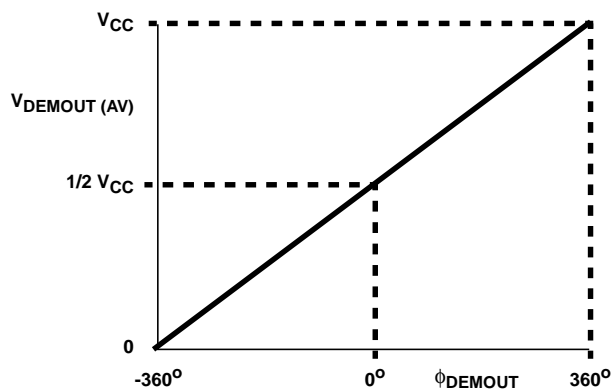


FIGURE 4. PHASE COMPARATOR 2: AVERAGE OUTPUT VOLTAGE vs INPUT PHASE DIFFERENCE:
 $V_{DEMOUT} = V_{PC2OUT} = (V_{CC}/4\pi) (\phi_{SIGIN} - \phi_{COM-PIIN})$; $\phi_{DEMOUT} = (\phi_{SIGIN} - \phi_{COMPIIN})$

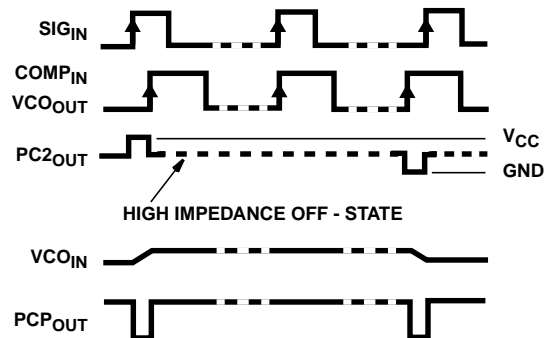


FIGURE 5. TYPICAL WAVEFORMS FOR PLL USING PHASE COMPARATOR 2, LOOP LOCKED AT f_0

When the frequencies of SIG_{IN} and $COMP_{IN}$ are equal but the phase of SIG_{IN} leads that of $COMP_{IN}$, the p-type output driver at $PC2_{OUT}$ is held "ON" for a time corresponding to the phase difference (ϕ_{DEMOUT}). When the phase of SIG_{IN} lags that of $COMP_{IN}$, the n-type driver is held "ON".

When the frequency of SIG_{IN} is higher than that of $COMP_{IN}$, the p-type output driver is held "ON" for most of the input signal cycle time, and for the remainder of the cycle both n- and p-type drivers are "OFF" (three-state). If the SIG_{IN} frequency is lower than the $COMP_{IN}$ frequency, then it is the n-type driver that is held "ON" for most of the cycle. Subsequently, the voltage at the capacitor (C2) of the low-pass filter connected to $PC2_{OUT}$ varies until the signal and comparator inputs are equal in both phase and frequency. At this stable

point the voltage on C2 remains constant as the PC2 output is in three-state and the VCO input at pin 9 is a high impedance. Also in this condition, the signal at the phase comparator pulse output (PCP_{OUT}) is a HIGH level and so can be used for indicating a locked condition.

Thus, for PC2, no phase difference exists between SIG_{IN} and COMP_{IN} over the full frequency range of the VCO. Moreover, the power dissipation due to the low-pass filter is reduced because both p- and n-type drivers are "OFF" for most of the signal input cycle. It should be noted that the PLL lock range for this type of phase comparator is equal to the capture range and is independent of the low-pass filter. With no signal present at SIG_{IN}, the VCO adjusts, via PC2, to its lowest frequency.

Phase Comparator 3 (PC3)

This is a positive edge-triggered sequential phase detector using an RS-type flip-flop. When the PLL is using this comparator, the loop is controlled by positive signal transitions and the duty factors of SIG_{IN} and COMP_{IN} are not important. The transfer characteristic of PC3, assuming ripple ($f_r = f_i$) is suppressed, is:

$V_{DEMOUT} = (V_{CC}/2\pi) (f_{SIGIN} - f_{COMPIN})$ where V_{DEMOUT} is the demodulator output at pin 10; $V_{DEMOUT} = V_{PC3OUT}$ (via low-pass filter).

The average output from PC3, fed to the VCO via the low-pass filter and seen at the demodulator at pin 10 (V_{DEMOUT}), is the resultant of the phase differences of SIG_{IN} and COMP_{IN} as shown in Figure 6. Typical waveforms for the PC3 loop locked at f_o are shown in Figure 7.

The phase-to-output response characteristic of PC3 (Figure 6) differs from that of PC2 in that the phase angle between SIG_{IN} and COMP_{IN} varies between 0° and 360° and is 180° at the center frequency. Also PC3 gives a greater voltage swing than PC2 for input phase differences but as a consequence the ripple content of the VCO input signal is higher. With no signal present at SIG_{IN}, the VCO adjusts, via PC3, to its highest frequency.

The only difference between the HC and HCT versions is the input level specification of the INH input. This input disables the VCO section. The comparator's sections are identical, so that there is no difference in the SIG_{IN} (pin 14) or COMP_{IN} (pin 3) inputs between the HC and the HCT versions.

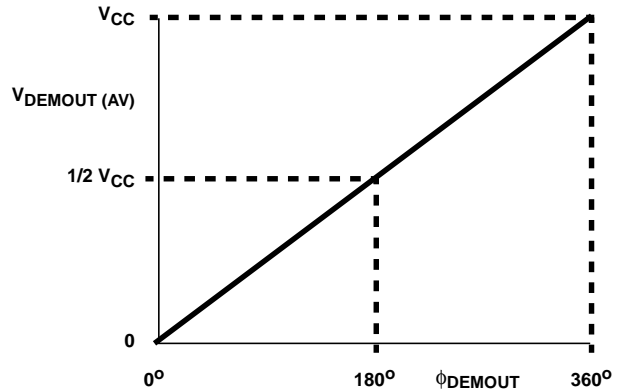


FIGURE 6. PHASE COMPARATOR 3: AVERAGE OUTPUT VOLTAGE vs INPUT PHASE DIFFERENCE:
 $V_{DEMOUT} = V_{PC3OUT} = (V_{CC}/2\pi) (\phi_{SIGIN} - \phi_{COMPIN})$; $\phi_{DEMOUT} = (\phi_{SIGIN} - \phi_{COMPIN})$

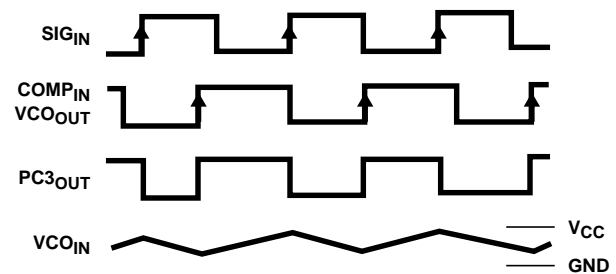


FIGURE 7. TYPICAL WAVEFORMS FOR PLL USING PHASE COMPARATOR 3, LOOP LOCKED AT f_o

CD54/74HC4046A, CD54/74HCT4046A

Absolute Maximum Ratings

DC Supply Voltage, V_{CC}	-0.5V to 7V
DC Input Diode Current, I_{IK}	
For $V_I < -0.5V$ or $V_I > V_{CC} + 0.5V$	$\pm 20mA$
DC Output Diode Current, I_{OK}	
For $V_O < -0.5V$ or $V_O > V_{CC} + 0.5V$	$\pm 20mA$
DC Drain Current, per Output, I_O	
For $-0.5V < V_O < V_{CC} + 0.5V$	$\pm 25mA$
DC Output Source or Sink Current per Output Pin, I_O	
For $V_O > -0.5V$ or $V_O < V_{CC} + 0.5V$	$\pm 25mA$
DC V_{CC} or Ground Current, I_{CC}	$\pm 50mA$

Thermal Information

Thermal Resistance (Typical, Note 3)	θ_{JA} ($^{\circ}C/W$)
PDIP Package	90
SOIC Package	115
Maximum Junction Temperature	150 $^{\circ}C$
Maximum Storage Temperature Range	-65 $^{\circ}C$ to 150 $^{\circ}C$
Maximum Lead Temperature (Soldering 10s)	300 $^{\circ}C$
(SOIC - Lead Tips Only)	

Operating Conditions

Temperature Range, T_A	-55 $^{\circ}C$ to 125 $^{\circ}C$
Supply Voltage Range, V_{CC}	
HC Types	.2V to 6V
HCT Types	.4.5V to 5.5V
DC Input or Output Voltage, V_I, V_O	0V to V_{CC}
Input Rise and Fall Time	
2V	1000ns (Max)
4.5V	500ns (Max)
6V	400ns (Max)

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

- θ_{JA} is measured with the component mounted on an evaluation PC board in free air.

DC Electrical Specifications

PARAMETER	SYMBOL	TEST CONDITIONS		V _{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS
		V _I (V)	I _O (mA)		MIN	TYP	MAX	MIN	MAX	MIN	MAX	
HC TYPES												
VCO SECTION												
INH High Level Input Voltage	V _{IH}	-	-	3	2.1	-	-	2.1	-	2.1	-	V
				4.5	3.15	-	-	3.15	-	3.15	-	V
				6	4.2	-	-	4.2	-	4.2	-	V
INH Low Level Input Voltage	V _{IL}	-	-	3	-	-	0.9	-	0.9	-	0.9	V
				4.5	-	-	1.35	-	1.35	-	1.35	V
				6	-	-	1.8	-	1.8	-	1.8	V
VCO _{OUT} High Level Output Voltage CMOS Loads	V _{OH}	V _{IH} or V _{IL}	-0.02	3	2.9	-	-	2.9	-	2.9	-	V
			-0.02	4.5	4.4	-	-	4.4	-	4.4	-	V
			-0.02	6	5.9	-	-	5.9	-	5.9	-	V
VCO _{OUT} High Level Output Voltage TTL Loads	V _{OH}	V _{IH} or V _{IL}	-	-	-	-	-	-	-	-	-	V
			-4	4.5	3.98	-	-	3.84	-	3.7	-	V
			-5.2	6	5.48	-	-	5.34	-	5.2	-	V
VCO _{OUT} Low Level Output Voltage CMOS Loads	V _{OL}	V _{IH} or V _{IL}	0.02	2	-	-	0.1	-	0.1	-	0.1	V
			0.02	4.5	-	-	0.1	-	0.1	-	0.1	V
			0.02	6	-	-	0.1	-	0.1	-	0.1	V
VCO _{OUT} Low Level Output Voltage TTL Loads	V _{OL}	V _{IH} or V _{IL}	-	-	-	-	-	-	-	-	-	V
			4	4.5	-	-	0.26	-	0.33	-	0.4	V
			5.2	6	-	-	0.26	-	0.33	-	0.4	V
C1A, C1B Low Level Output Voltage (Test Purposes Only)	V _{OL}	V _{IL} or V _{IH}	4	4.5	-	-	0.40	-	0.47	-	0.54	V
			5.2	6	-	-	0.40	-	0.47	-	0.54	V

CD54/74HC4046A, CD54/74HCT4046A

DC Electrical Specifications (Continued)

PARAMETER	SYMBOL	TEST CONDITIONS		V _{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS
		V _I (V)	I _O (mA)		MIN	TYP	MAX	MIN	MAX	MIN	MAX	
INH VCO _{IN} Input Leakage Current	I _I	V _{CC} or GND	-	6	-	-	±0.1	-	±1	-	±1	μA
R1 Range (Note 4)	-	-	-	4.5	3	-	300	-	-	-	-	kΩ
R2 Range (Note 4)	-	-	-	4.5	3	-	300	-	-	-	-	kΩ
C1 Capacitance Range	-	-	-	3	-	-	No Limit	-	-	-	-	pF
				4.5	-	-		-	-	-	-	pF
				6	-	-		-	-	-	-	pF
VCO _{IN} Operating Voltage Range	-	Over the range specified for R1 for Linearity See Figure 10, and 35 - 38 (Note 5)	3	1.1	-	1.9	-	-	-	-	V	
			4.5	1.1	-	3.2	-	-	-	-	V	
			6	1.1	-	4.6	-	-	-	-	V	
PHASE COMPARATOR SECTION												
SIG _{IN} , COMP _{IN} DC Coupled High-Level Input Voltage	V _{IH}	-	-	2	1.5	-	-	1.5	-	1.5	-	V
				4.5	3.15	-	-	3.15	-	3.15	-	V
				6	4.2	-	-	4.2	-	4.2	-	V
SIG _{IN} , COMP _{IN} DC Coupled Low-Level Input Voltage	V _{IL}	-	-	2	-	-	0.5	-	0.5	-	0.5	V
				4.5	-	-	1.35	-	1.35	-	1.35	V
				6	-	-	1.8	-	1.8	-	1.8	V
PCP _{OUT} , PCn OUT High-Level Output Voltage CMOS Loads	V _{OH}	V _{IL} or V _{IH}	-0.02	2	1.9	-	-	1.9	-	1.9	-	V
				4.5	4.4	-	-	4.4	-	4.4	-	V
				6	5.9	-	-	5.9	-	5.9	-	V
PCP _{OUT} , PCn OUT High-Level Output Voltage TTL Loads	V _{OH}	V _{IL} or V _{IH}	-4	4.5	3.98	-	-	3.84	-	3.7	-	V
			-5.2	6	5.48	-	-	5.34	-	5.2	-	V
PCP _{OUT} , PCn OUT Low-Level Output Voltage CMOS Loads	V _{OL}	V _{IL} or V _{IH}	0.02	2	-	-	0.1	-	0.1	-	0.1	V
				4.5	-	-	0.1	-	0.1	-	0.1	V
				6	-	-	0.1	-	0.1	-	0.1	V
PCP _{OUT} , PCn OUT Low-Level Output Voltage TTL Loads	V _{OL}	V _{IL} or V _{IH}	4	4.5	-	-	0.26	-	0.33	-	0.4	V
			5.2	6	-	-	0.26	-	0.33	-	0.4	V
SIG _{IN} , COMP _{IN} Input Leakage Current	I _I	V _{CC} or GND	-	2	-	-	±3	-	±4	-	±5	μA
				3	-	-	±7	-	±9	-	±11	μA
				4.5	-	-	±18	-	±23	-	±29	μA
				6	-	-	±30	-	±38	-	±45	μA
PC2 _{OUT} Three-State Off-State Current	I _{OZ}	V _{IL} or V _{IH}	-	6	-	-	±0.5	-	±5	-	±10	μA
SIG _{IN} , COMP _{IN} Input Resistance	R _I	V _I at Self-Bias Operation Point: ΔV _I , 0.5V, See Figure 10		3	-	800	-	-	-	-	-	kΩ
				4.5	-	250	-	-	-	-	-	kΩ
				6	-	150	-	-	-	-	-	kΩ
DEMODULATOR SECTION												
Resistor Range	R _S	at R _S > 300kΩ Leakage Current Can Influence V _{DEMOUT}		3	50	-	300	-	-	-	-	kΩ
				4.5	50	-	300	-	-	-	-	kΩ
				6	50	-	300	-	-	-	-	kΩ

CD54/74HC4046A, CD54/74HCT4046A

DC Electrical Specifications (Continued)

PARAMETER	SYMBOL	TEST CONDITIONS		V _{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS
		V _I (V)	I _O (mA)		MIN	TYP	MAX	MIN	MAX	MIN	MAX	
Offset Voltage V _{COIN} to V _{DEM}	V _{OFF}	V _I = V _{VCO IN} = $\frac{V_{CC}}{2}$ Values Taken Over R _S Range See Figure 24		3	-	±30	-	-	-	-	-	mV
				4.5	-	±20	-	-	-	-	-	mV
				6	-	±10	-	-	-	-	-	mV
Dynamic Output Resistance at DEM _{OUT}	R _D	V _{DEMOUT} = $\frac{V_{CC}}{2}$		3	-	25	-	-	-	-	-	Ω
				4.5	-	25	-	-	-	-	-	Ω
				6	-	25	-	-	-	-	-	Ω
Quiescent Device Current	I _{CC}	Pins 3, 5 and 14 at V _{CC} Pin 9 at GND, I ₁ at Pins 3 and 14 to be excluded		6	-	-	8	-	80	-	160	μA
HCT TYPES												
VCO SECTION												
INH High Level Input Voltage	V _{IH}	-	-	4.5 to 5.5	2	-	-	2	-	2	-	V
INH Low Level Input Voltage	V _{IL}	-	-	4.5 to 5.5	-	-	0.8	-	0.8	-	0.8	V
VCO _{OUT} High Level Output Voltage CMOS Loads	V _{OH}	V _{IH} or V _{IL}	-0.02	4.5	4.4	-	-	4.4	-	4.4	-	V
VCO _{OUT} High Level Output Voltage TTL Loads			-4	4.5	3.98	-	-	3.84	-	3.7	-	V
VCO _{OUT} Low Level Output Voltage CMOS Loads	V _{OL}	V _{IH} or V _{IL}	0.02	4.5	-	-	0.1	-	0.1	-	0.1	V
VCO _{OUT} Low Level Output Voltage TTL Loads			4	4.5	-	-	0.26	-	0.33	-	0.4	V
C1A, C1B Low Level Output Voltage (Test Purposes Only)	V _{OL}	V _{IH} or V _{IL}	4	4.5	-	-	0.40	-	0.47	-	0.54	V
INH VCO _{IN} Input Leakage Current	I _I	Any Voltage Between V _{CC} and GND		5.5	-		±0.1	-	±1	-	±1	μA
R1 Range (Note 4)	-	-	-	4.5	3	-	300	-	-	-	-	kΩ
R2 Range (Note 4)	-	-	-	4.5	3	-	300	-	-	-	-	kΩ
C1 Capacitance Range	-	-	-	4.5	0	-	No Limit	-	-	-	-	pF
VCO _{IN} Operating Voltage Range	-	Over the range specified for R1 for Linearity See Figure 10, and 35 - 38 (Note 5)		4.5	1.1	-	3.2	-	-	-	-	V
PHASE COMPARATOR SECTION												
SIG _{IN} , COMP _{IN} DC Coupled High-Level Input Voltage	V _{IH}	-	-	4.5 to 5.5	2	-	-	2	-	2	-	V

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DC Electrical Specifications (Continued)

PARAMETER	SYMBOL	TEST CONDITIONS		V _{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS
		V _I (V)	I _O (mA)		MIN	TYP	MAX	MIN	MAX	MIN	MAX	
SIG _{IN} , COMP _{IN} DC Coupled Low-Level Input Voltage	V _{IL}	-	-	4.5 to 5.5	-	-	0.8	-	0.8	-	0.8	V
PCP _{OUT} , PCn OUT High-Level Output Voltage CMOS Loads	V _{OH}	V _{IL} or V _{IH}	-	4.5	4.4	-	-	4.4	-	4.4	-	V
PCP _{OUT} , PCn OUT High-Level Output Voltage TTL Loads	V _{OH}	V _{IL} or V _{IH}	-	4.5	3.98	-	-	3.84	-	3.7	-	V
PCP _{OUT} , PCn OUT Low-Level Output Voltage CMOS Loads	V _{OL}	V _{IL} or V _{IH}	-	4.5	-	-	0.1	-	0.1	-	0.1	V
PCP _{OUT} , PCn OUT Low-Level Output Voltage TTL Loads	V _{OL}	V _{IL} or V _{IH}	-	4.5	-	-	0.26	-	0.33	-	0.4	V
SIG _{IN} , COMP _{IN} Input Leakage Current	I _I	Any Voltage Between V _{CC} and GND	-	5.5	-	-	±30		±38		±45	μA
PC2 _{OUT} Three-State Off-State Current	I _{OZ}	V _{IL} or V _{IH}	-	5.5	-	-	±0.5	±5	-	-	±10	μA
SIG _{IN} , COMP _{IN} Input Resistance	R _I	V _I at Self-Bias Operation Point: ΔV _I , 0.5V, See Figure 10		4.5	-	250	-	-	-	-	-	kΩ
DEMODULATOR SECTION												
Resistor Range	R _S	at R _S > 300kΩ Leakage Current Can Influence V _{DEM OUT}		4.5	5	-	300	-	-	-	-	kΩ
Offset Voltage VCO _{IN} to V _{DEM}	V _{OFF}	V _I = V _{VCO IN} = $\frac{V_{CC}}{2}$ Values taken over R _S Range See Figure 24		4.5	-	±20	-	-	-	-	-	mV
Dynamic Output Resistance at DEM _{OUT}	R _D	V _{DEM OUT} = $\frac{V_{CC}}{2}$		4.5	-	25	-	-	-	-	-	Ω
Quiescent Device Current	I _{CC}	V _{CC} or GND	-	5.5	-	-	8	-	80	-	160	μA
Additional Quiescent Device Current Per Input Pin: 1 Unit Load	ΔI _{CC} Note 6	V _{CC} -2.1 Excluding Pin 5	-	4.5 to 5.5	-	100	360	-	450	-	490	μA

NOTES:

- The value for R1 and R2 in parallel should exceed 2.7kΩ.
- The maximum operating voltage can be as high as V_{CC} -0.9V, however, this may result in an increased offset voltage.
- For dual-supply systems theoretical worst case (V_I = 2.4V, V_{CC} = 5.5V) specification is 1.8mA.

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HCT Input Loading Table

INPUT	UNIT LOADS
INH	1

NOTE: Unit load is ΔI_{CC} limit specific in DC Electrical Specifications Table, e.g., 360 μ A max. at 25°C.

Switching Specifications $C_L = 50$ pF, Input $t_r, t_f = 6$ ns

PARAMETER	SYMBOL	TEST CONDITIONS	V _{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS	
				MIN	TYP	MAX	MIN	MAX	MIN	MAX		
HC TYPES												
PHASE COMPARATOR SECTION												
Propagation Delay SIG _{IN} , COMP _{IN} to PC _I OUT	t _{PLH} , t _{PHL}		2	-	-	200	-	250	-	300	ns	
			4.5	-	-	40	-	50	-	60	ns	
			6	-	-	34	-	43	-	51	ns	
SIG _{IN} , COMP _{IN} to PCP _{OUT}			2	-	-	300	-	375	-	450	ns	
			4.5	-	-	60	-	75	-	90	ns	
			6	-	-	51	-	64	-	77	ns	
SIG _{IN} , COMP _{IN} to PC3 _{OUT}			2	-	-	245	-	305	-	307	ns	
			4.5	-	-	49	-	61	-	74	ns	
			6	-	-	42	-	52	-	63	ns	
Output Transition Time	t _{THL} , t _{TLH}		2	-	-	75	-	95	-	110	ns	
			4.5	-	-	15	-	19	-	22	ns	
			6	-	-	13	-	16	-	19	ns	
Output Enable Time, SIG _{IN} , COMP _{IN} to PC2 _{OUT}	t _{PZH} , t _{PZL}		2	-	-	265	-	330	-	400	ns	
			4.5	-	-	53	-	66	-	80	ns	
			6	-	-	45	-	56	-	68	ns	
Output Disable Time, SIG _{IN} , COMP _{IN} to PC2 _{OUT}	t _{PHZ} , t _{PLZ}		2	-	-	315	-	395	-	475	ns	
			4.5	-	-	63	-	79	-	95	ns	
			6	-	-	54	-	67	-	81	ns	
AC Coupled Input Sensitivity (p-p) at SIG _{IN} or COMP _{IN}		V _{I(P-P)}	3	-	11	-	-	-	-	-	mV	
			4.5	-	15	-	-	-	-	-	-	mV
			6	-	33	-	-	-	-	-	-	mV
VCO SECTION												
Frequency Stability with Temperature Change	$\frac{\Delta f}{\Delta T}$	R ₁ = 100kΩ, R ₂ = ∞	3	-		-	TYP 0.11		-	-	%/°C	
			4.5	-		-			-	-	%/°C	
			6	-		-			-	-	%/°C	
Maximum Frequency	f _{MAX}	C ₁ = 50pF R ₁ = 3.5kΩ R ₂ = ∞	3	-	24	-	-	-	-	-	MHz	
			4.5	-	24	-	-	-	-	-	MHz	
			6	-	24	-	-	-	-	-	MHz	
		C ₁ = 0pF R ₁ = 9.1kΩ R ₂ = ∞	3	-	38	-	-	-	-	-	MHz	
			4.5	-	38	-	-	-	-	-	MHz	
			6	-	38	-	-	-	-	-	MHz	

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Switching Specifications $C_L = 50\text{pF}$, Input $t_r, t_f = 6\text{ns}$ (Continued)

PARAMETER	SYMBOL	TEST CONDITIONS	V _{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS	
				MIN	TYP	MAX	MIN	MAX	MIN	MAX		
Center Frequency		C ₁ = 40pF R ₁ = 3kΩ R ₂ = ∞ VCO _{IN} = VCC/2	3	7	10	-	-	-	-	-	MHz	
			4.5	12	17	-	-	-	-	-	MHz	
			6	14	21	-	-	-	-	-	MHz	
Frequency Linearity	Δf _{VCO}	R ₁ = 100kΩ R ₂ = ∞ C ₁ = 100pF	3	-	0.4	-	-	-	-	-	%	
			4.5	-	0.4	-	-	-	-	-	%	
			6	-	0.4	-	-	-	-	-	%	
Offset Frequency		R ₂ = 220kΩ C ₁ = 1nF	3	-	400	-	-	-	-	-	kHz	
			4.5	-	400	-	-	-	-	-	kHz	
			6	-	400	-	-	-	-	-	kHz	
DEMODULATOR SECTION												
V _{OUT} V _S f _{IN}		R ₁ = 100kΩ R ₂ = ∞ C ₁ = 100pF R _S = 10kΩ R ₃ = 100kΩ C ₂ = 100pF	3	-	-	-	-	-	-	-	mV/kHz	
			4.5	-	330	-	-	-	-	-	mV/kHz	
			6	-	-	-	-	-	-	-	mV/kHz	
HCT TYPES												
PHASE COMPARATOR SECTION												
Propagation Delay SIG _{IN} , COMP _{IN} to PC _{1OUT}	t _{PHL} , t _{PLH}	C _L = 50pF	4.5	-	-	45	-	56	-	68	ns	
	SIG _{IN} , COMP _{IN} to PC _{2OUT}	t _{PHL} , t _{PLH}	C _L = 50pF	4.5	-	-	68	-	85	-	102	ns
	SIG _{IN} , COMP _{IN} to PC _{3OUT}	t _{PHL} , t _{PLH}	C _L = 50pF	4.5	-	-	58	-	73	-	87	ns
Output Transition Time	t _{TLH} , t _{THL}	C _L = 50pF	4.5	-	-	15	-	19	-	22	ns	
Output Enable Time, SIG _{IN} , COMP _{IN} to PC _{2OUT}	t _{PZH} , t _{PZL}	C _L = 50pF	4.5	-	-	60	-	75	-	90	pF	
Output Disable Time, SIG _{IN} , COMP _{IN} to PC _{2OUT}	t _{PHZ} , t _{PLZ}	C _L = 50pF	4.5	-	-	68	-	85	-	102	pF	
AC Coupled Input Sensitivity (P-P) at SIG _{IN} or COMP _{IN}		V _{I(P-P)}	3	-	11	-	-	-	-	-	mV	
			4.5	-	15	-	-	-	-	-	mV	
			6	-	33	-	-	-	-	-	mV	
VCO SECTION												
Frequency Stability with Temperature Change	Δf ΔT	R ₁ = 100kΩ, R ₂ = ∞	4.5	-	0.11	-	-	-	-	-	%/°C	
Maximum Frequency	f _{MAX}	C ₁ = 50pF R ₁ = 3.5kΩ R ₂ = ∞	4.5	-	24	-	-	-	-	-	MHz	
		C ₁ = 0pF R ₁ = 9.1kΩ R ₂ = ∞	4.5	-	38	-	-	-	-	-	MHz	
Center Frequency		C ₁ = 40pF R ₁ = 3kΩ R ₂ = ∞ VCO _{IN} = VCC/2	3	7	10	-	-	-	-	-	MHz	
			4.5	12	17	-	-	-	-	-	MHz	
			6	14	21	-	-	-	-	-	MHz	

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Switching Specifications $C_L = 50\text{pF}$, Input $t_r, t_f = 6\text{ns}$ (Continued)

PARAMETER	SYMBOL	TEST CONDITIONS	V_{CC} (V)	25°C			-40°C TO 85°C		-55°C TO 125°C		UNITS
				MIN	TYP	MAX	MIN	MAX	MIN	MAX	
Frequency Linearity	Δf_{VCO}	$R_1 = 100\text{k}\Omega$ $R_2 = \infty$ $C_1 = 100\text{pF}$	4.5	-	0.4	-	-	-	-	-	%
Offset Frequency		$R_2 = 220\text{k}\Omega$ $C_1 = 1\text{nF}$	4.5	-	400	-	-	-	-	-	kHz
DEMODULATOR SECTION											
$V_{OUT} V_S f_{IN}$		$R_1 = 100\text{k}\Omega$ $R_2 = \infty$ $C_1 = 100\text{pF}$ $R_S = 10\text{k}\Omega$ $R_3 = 100\text{k}\Omega$ $C_2 = 100\text{pF}$	4.5	-	330	-	-	-	-	-	mV/kHz

Test Circuits and Waveforms

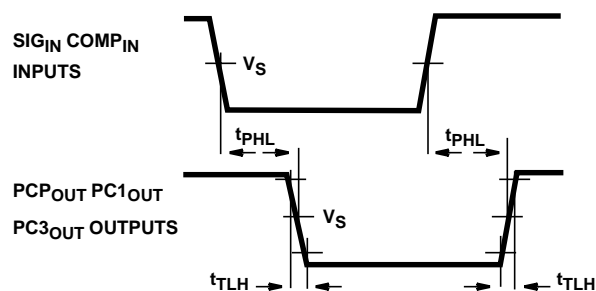


FIGURE 8. INPUT TO OUTPUT PROPAGATION DELAYS AND OUTPUT TRANSITION TIMES

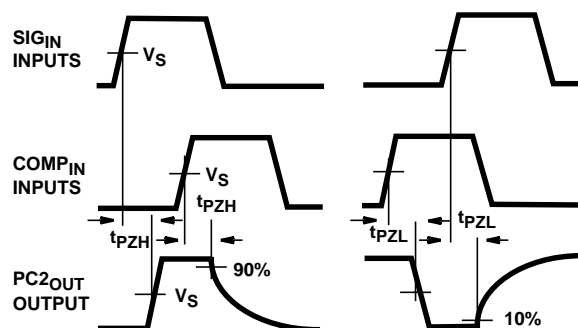


FIGURE 9. THREE STATE ENABLE AND DISABLE TIMES FOR PC2_OUT

Typical Performance Curves

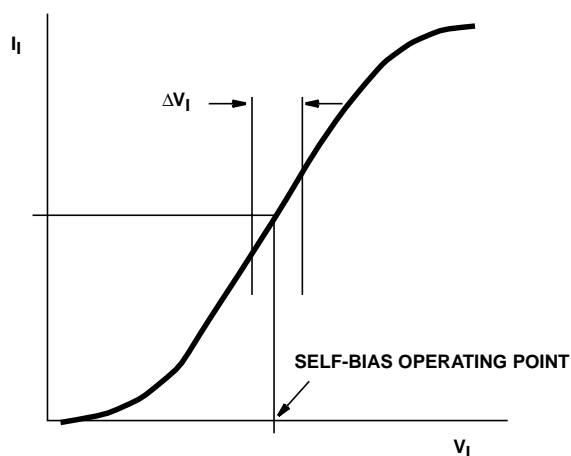


FIGURE 10. TYPICAL INPUT RESISTANCE CURVE AT SIG_IN, COMP_IN

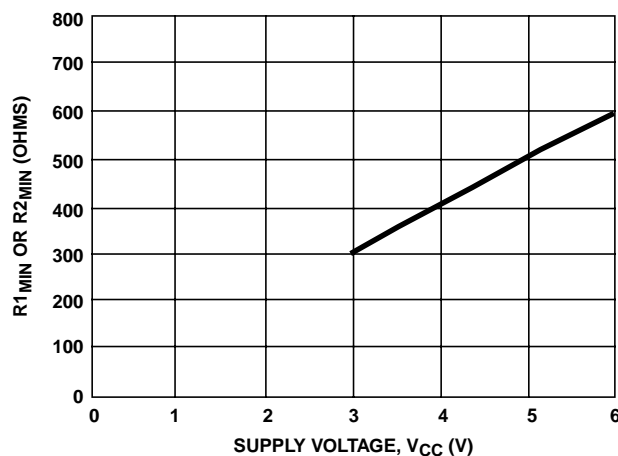


FIGURE 11. HC/HCT4046A R1 (MIN) OR R2 (MIN) vs SUPPLY VOLTAGE (V_{CC})

Typical Performance Curves (Continued)

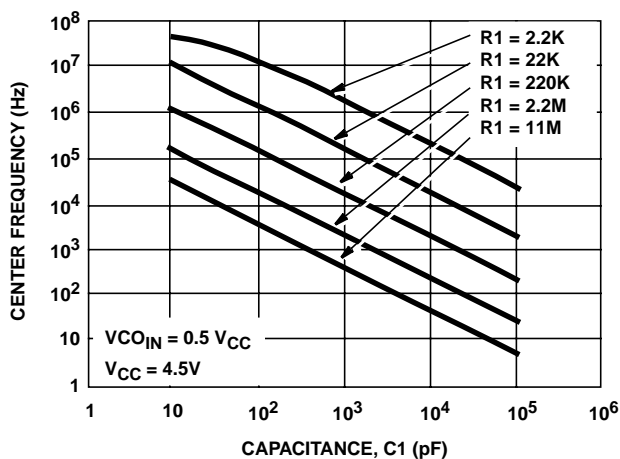


FIGURE 12. HC4046A TYPICAL CENTER FREQUENCY vs R1, C1 ($V_{CC} = 4.5V$)

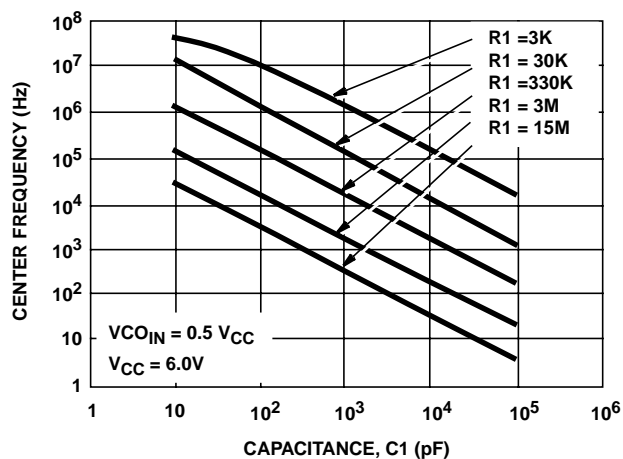


FIGURE 13. HC4046A TYPICAL CENTER FREQUENCY vs R1, C1 ($V_{CC} = 6V$)

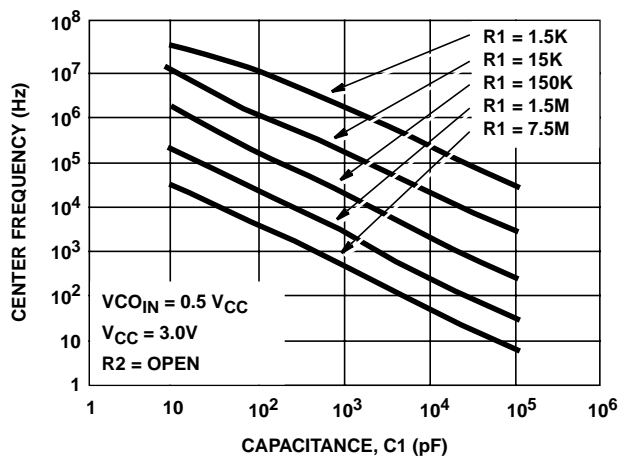


FIGURE 14. HC4046A TYPICAL CENTER FREQUENCY vs R1, C1 ($V_{CC} = 3V$, $R_2 = OPEN$)

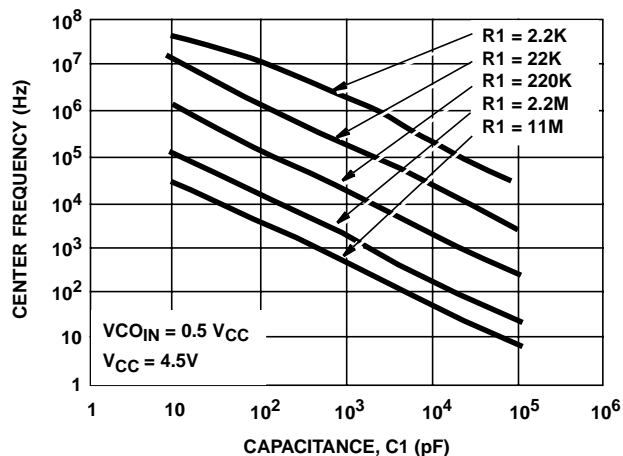


FIGURE 15. HCT4046A TYPICAL CENTER FREQUENCY vs R1, C1 ($V_{CC} = 4.5V$)

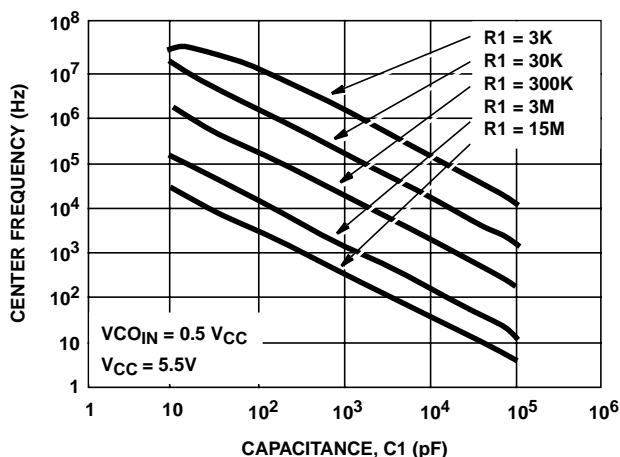


FIGURE 16. HCT4046A TYPICAL CENTER FREQUENCY vs R1, C1 ($V_{CC} = 5.5V$)

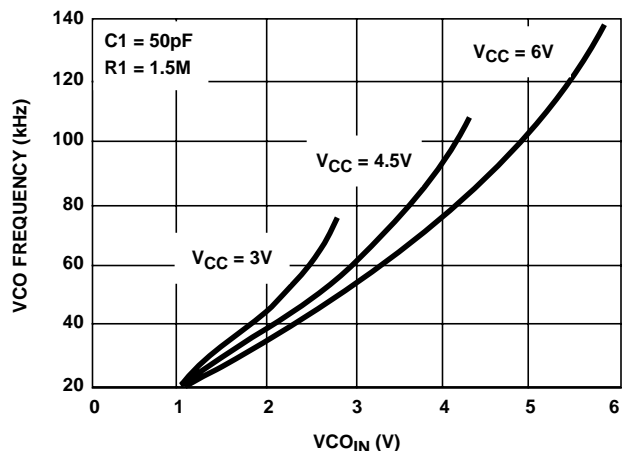


FIGURE 17. HC4046A TYPICAL VCO FREQUENCY vs V_{COIN} ($R_1 = 1.5M\Omega$, $C_1 = 50pF$)

Typical Performance Curves (Continued)

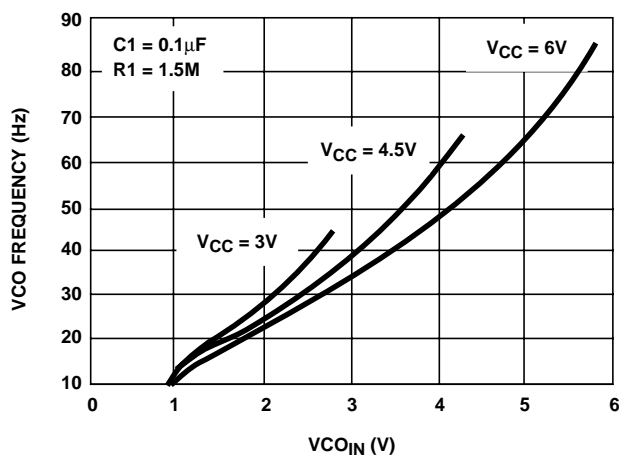


FIGURE 18. HC4046A TYPICAL VCO FREQUENCY vs VCO_{IN} (R1 = 1.5MΩ, C1 = 0.1μF)

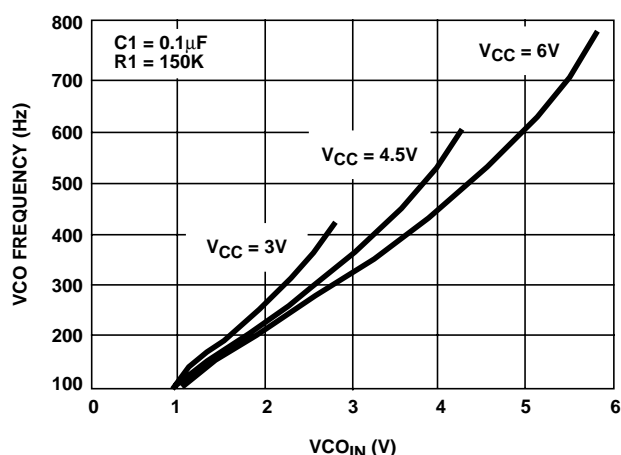


FIGURE 19. HC4046A TYPICAL VCO FREQUENCY vs VCO_{IN} (R1 = 150kΩ, C1 = 0.1μF)

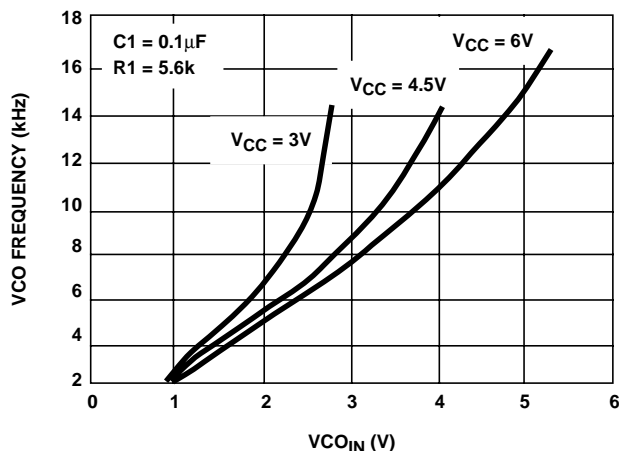


FIGURE 20. HC4046A TYPICAL VCO FREQUENCY vs VCO_{IN} (R1 = 5.6kΩ, C1 = 0.1μF)

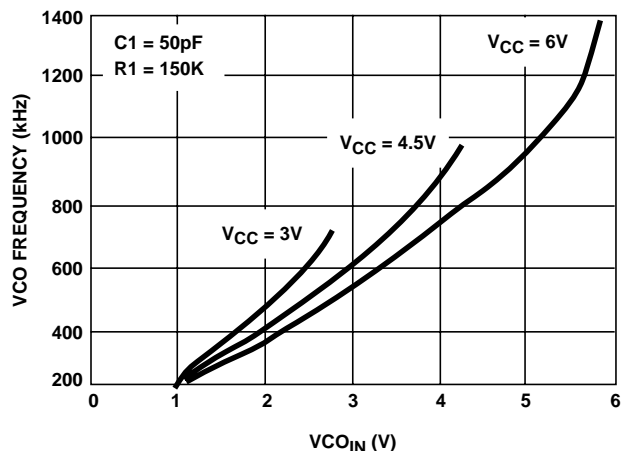


FIGURE 21. HC4046A TYPICAL VCO FREQUENCY vs VCO_{IN} (R1 = 150kΩ, C1 = 0.1μF)

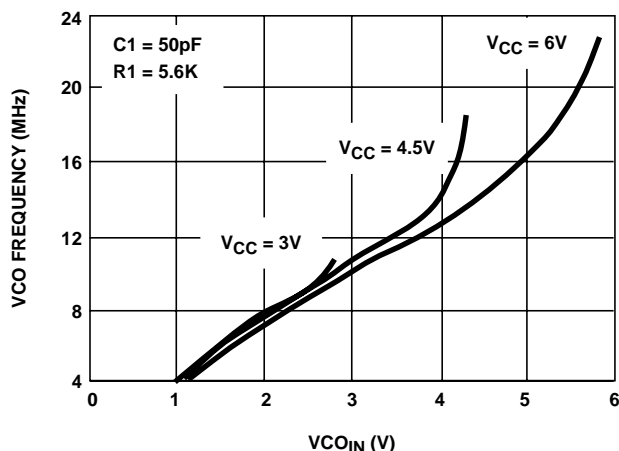


FIGURE 22. HC4046A TYPICAL VCO FREQUENCY vs VCO_{IN} (R1 = 5.6kΩ, C1 = 50pF)

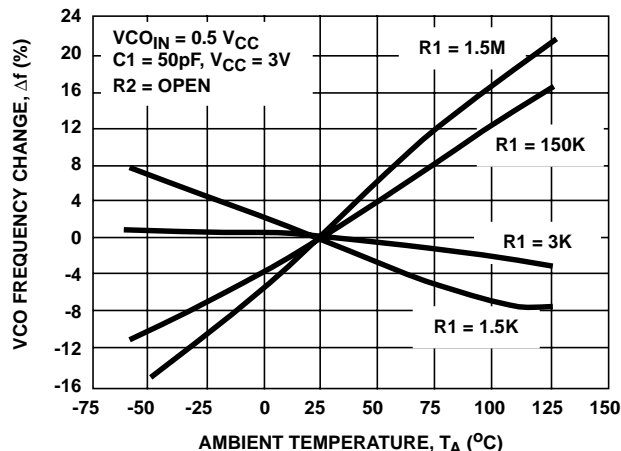


FIGURE 23. HC4046A TYPICAL CHANGE IN VCO FREQUENCY vs AMBIENT TEMPERATURE AS A FUNCTION OF R1 (VCC = 3V)

Typical Performance Curves (Continued)

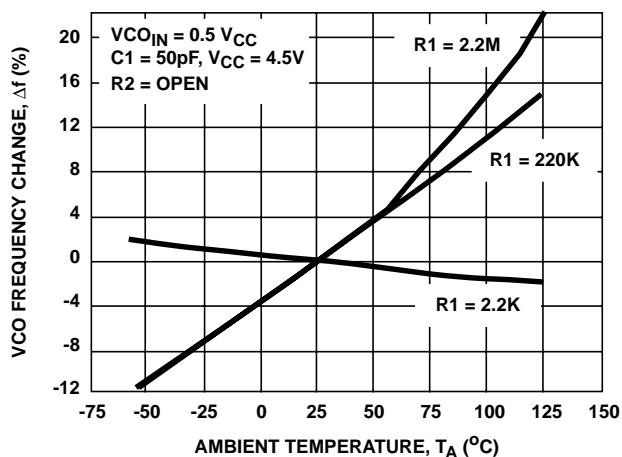


FIGURE 24. HC4046A TYPICAL CHANGE IN VCO FREQUENCY vs AMBIENT TEMPERATURE AS A FUNCTION OF $R1$ ($V_{CC} = 4.5\text{V}$)

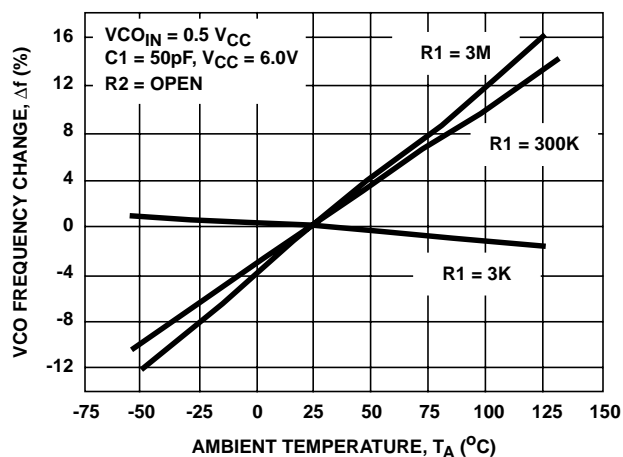


FIGURE 25. HC4046A TYPICAL CHANGE IN VCO FREQUENCY vs AMBIENT TEMPERATURE AS A FUNCTION OF $R1$ ($V_{CC} = 6\text{V}$)

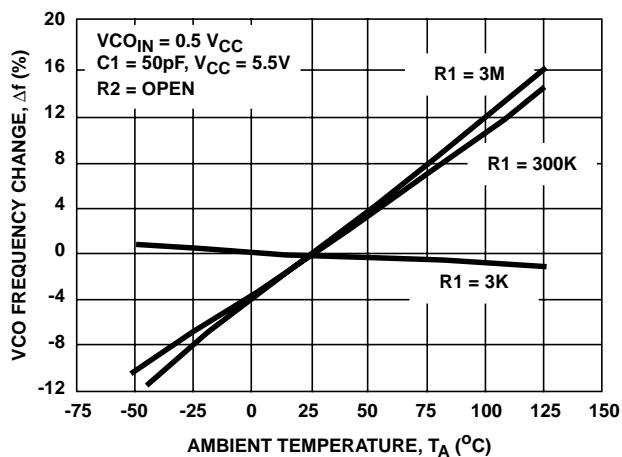


FIGURE 26. HCT4046A TYPICAL CHANGE IN VCO FREQUENCY vs AMBIENT TEMPERATURE AS A FUNCTION OF $R1$

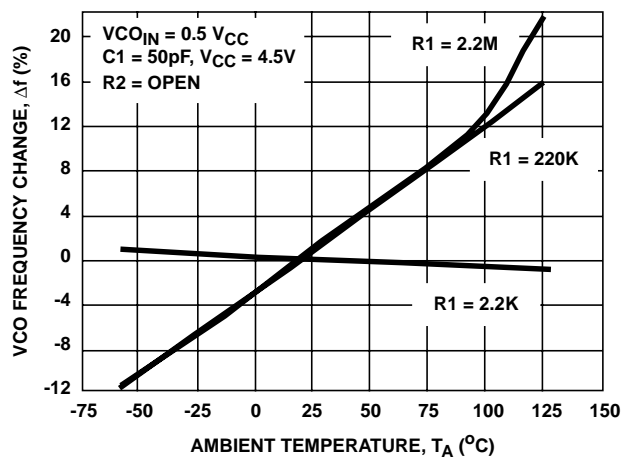


FIGURE 27. HC4046A TYPICAL CHANGE IN VCO FREQUENCY vs AMBIENT TEMPERATURE AS A FUNCTION OF $R1$ ($V_{CC} = 4.5\text{V}$)

Typical Performance Curves (Continued)

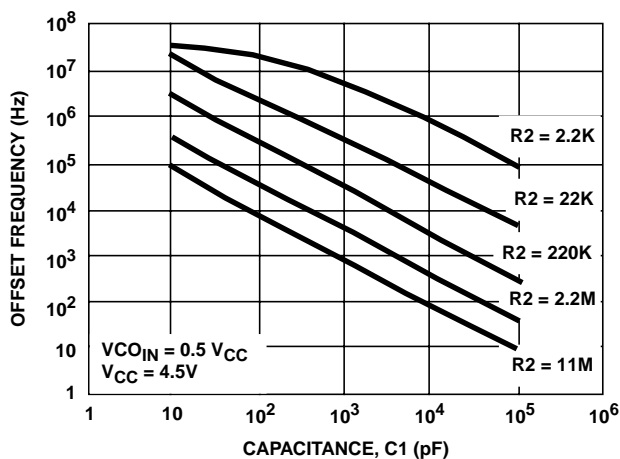


FIGURE 28. HC4046A OFFSET FREQUENCY vs R2, C1 ($V_{CC} = 4.5V$)

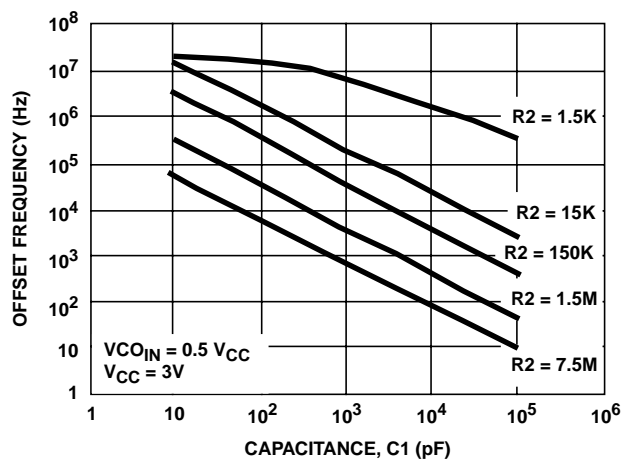


FIGURE 29. HC4046A OFFSET FREQUENCY vs R2, C1 ($V_{CC} = 3V$)

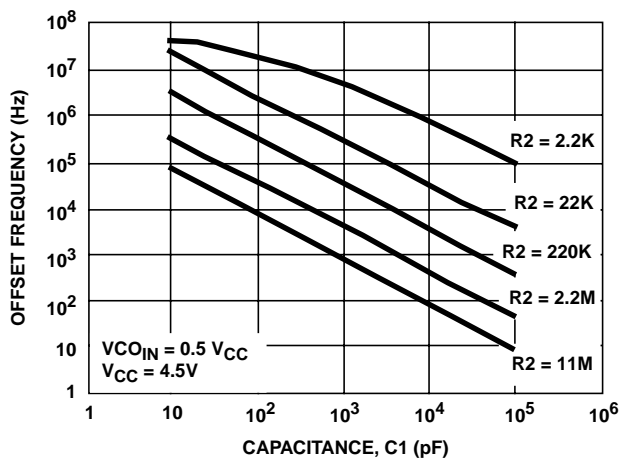


FIGURE 30. HCT4046A OFFSET FREQUENCY vs R2, C1 ($V_{CC} = 4.5V$)

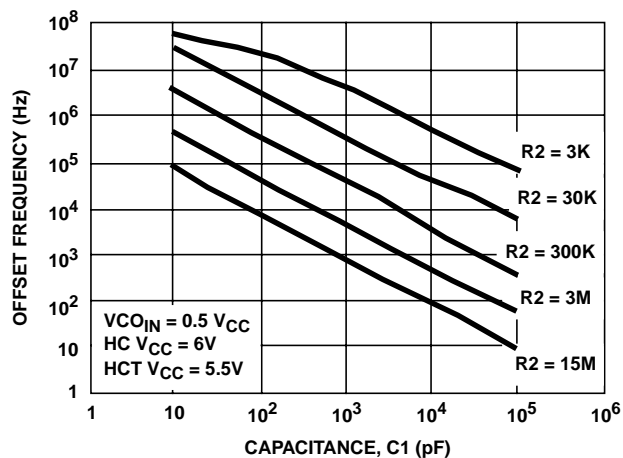


FIGURE 31. HC4046A AND HCT4046A OFFSET FREQUENCY vs R2, C1 ($V_{CC} = 6V$, $V_{CC} = 5.5V$)

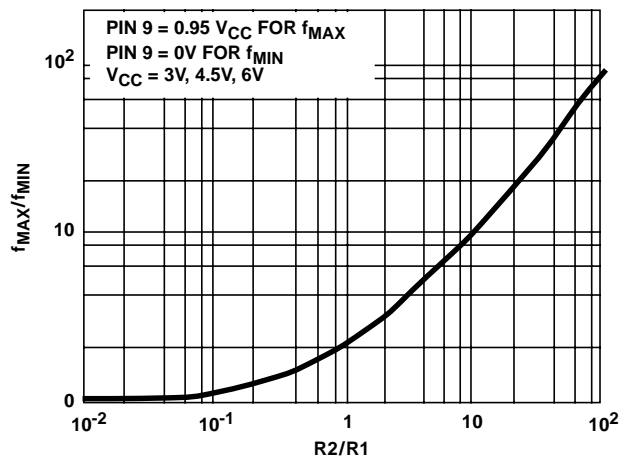


FIGURE 32. HC4046A f_{MIN}/f_{MAX} vs R2/R1 ($V_{CC} = 3V, 4.5V, 6V$)

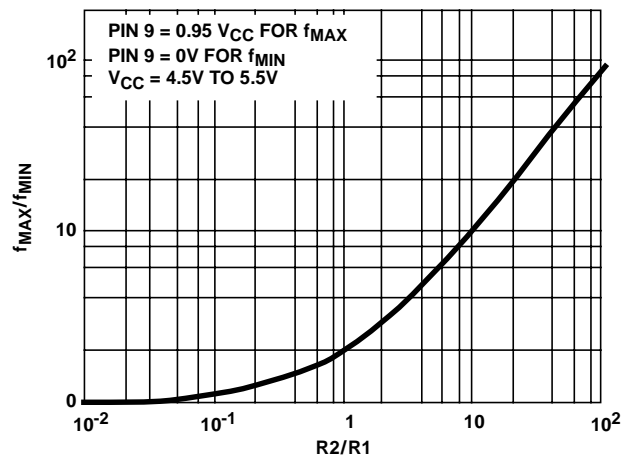


FIGURE 33. HCT4046A f_{MAX}/f_{MIN} vs R2/R1 ($V_{CC} = 4.5V$ TO $5.5V$)

Typical Performance Curves (Continued)

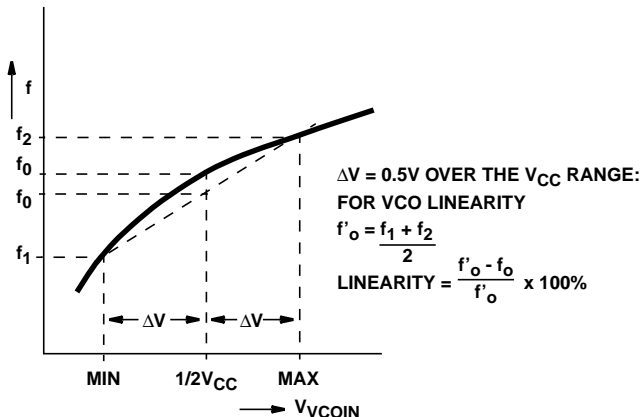


FIGURE 34. DEFINITION OF VCO FREQUENCY LINEARITY

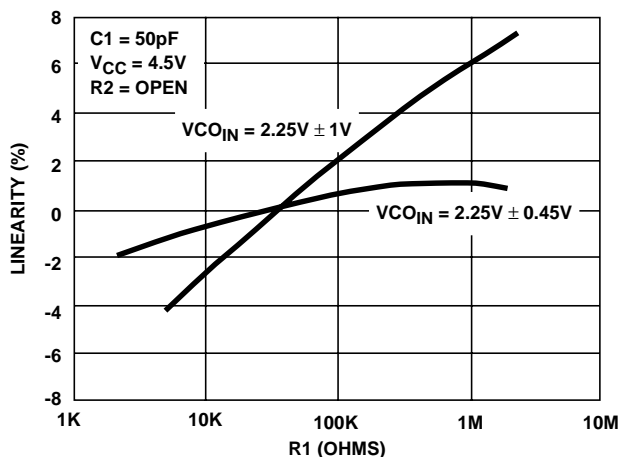


FIGURE 35. HC4046A VCO LINEARITY vs $R1$ ($V_{CC} = 4.5V$)

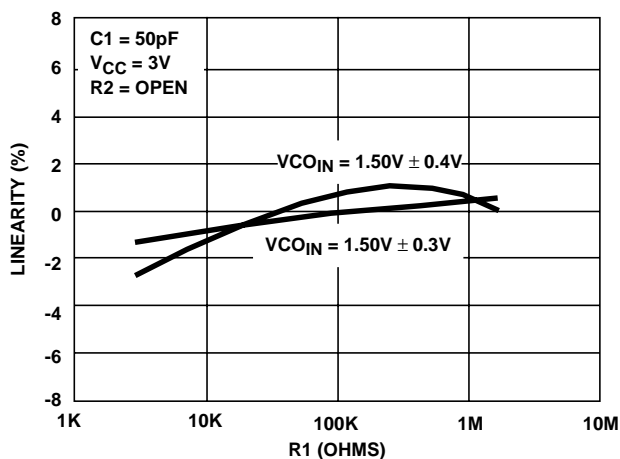


FIGURE 36. HC4046A VCO LINEARITY vs $R1$ ($V_{CC} = 3V$)

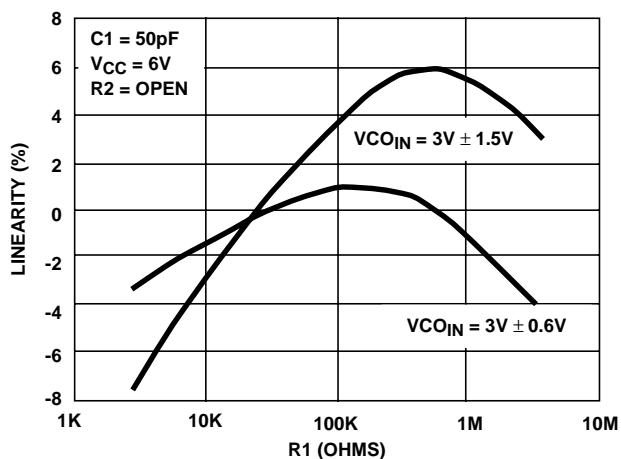


FIGURE 37. HC4046A VCO LINEARITY vs $R1$ ($V_{CC} = 6V$)

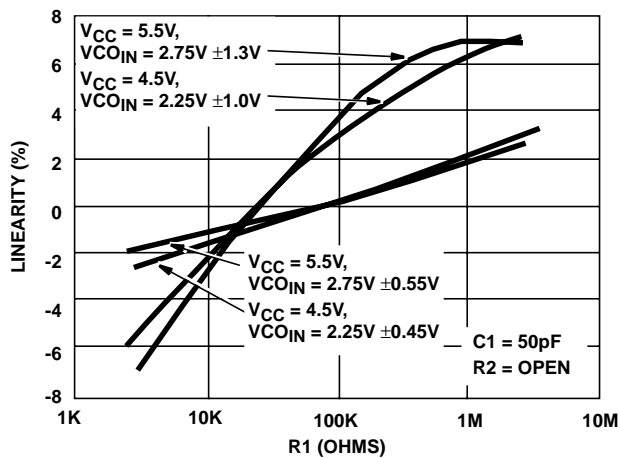


FIGURE 38. HCT4046A VCO LINEARITY vs $R1$ ($V_{CC} = 4.5V$, $V_{CC} = 5.5V$)

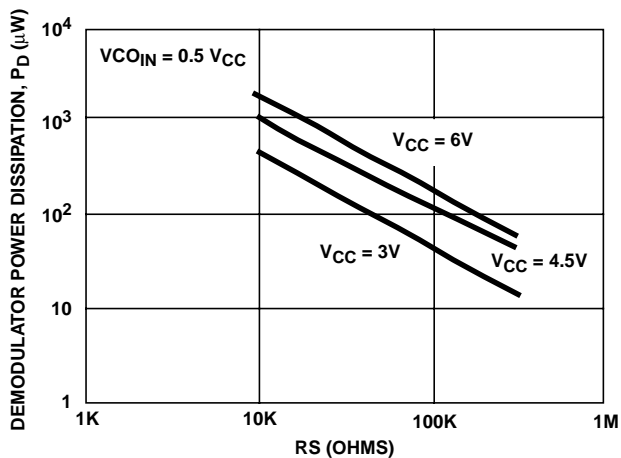


FIGURE 39. HC4046A DEMODULATOR POWER DISSIPATION vs R_S (TYP) ($V_{CC} = 3V, 4.5V, 6V$)

Typical Performance Curves (Continued)

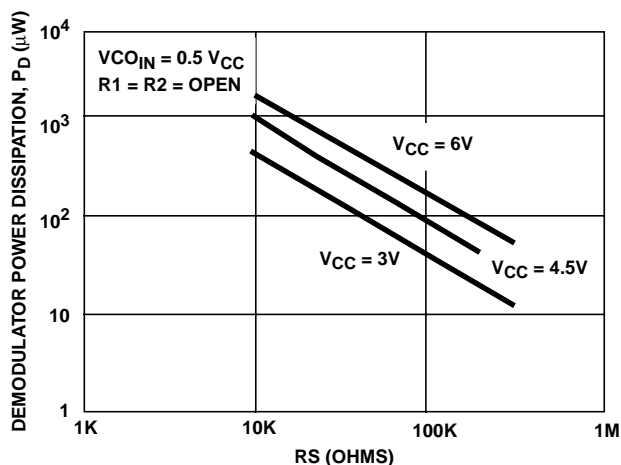


FIGURE 40. HCT4046A DEMODULATOR POWER DISSIPATION vs R_S (TYP) ($V_{CC} = 3V, 4.5V, 6V$)

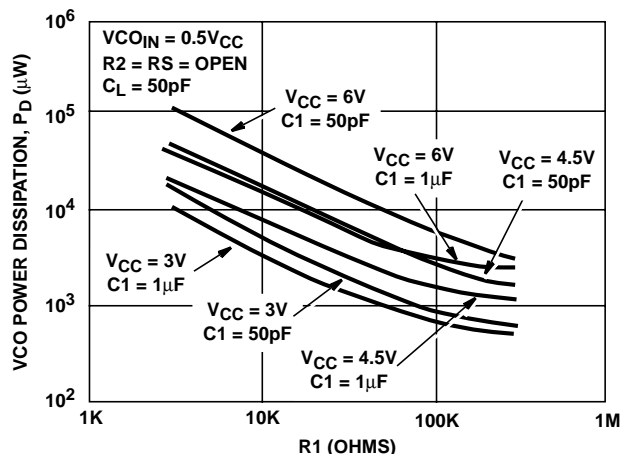


FIGURE 41. HC4046A VCO POWER DISSIPATION vs R_1 ($C_1 = 50pF, 1\mu F$)

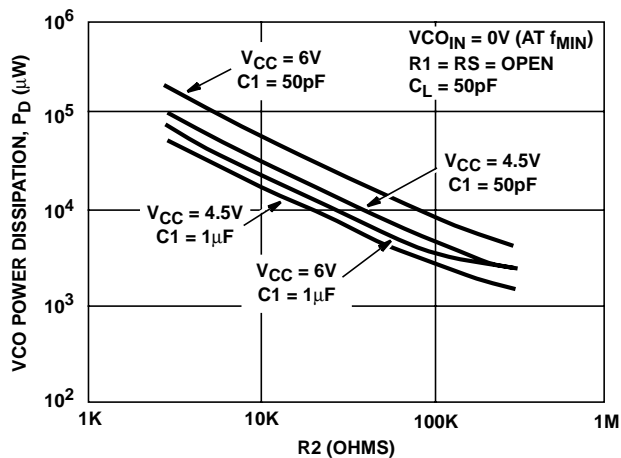


FIGURE 42. HCT4046A VCO POWER DISSIPATION vs R_2 ($C_1 = 50pF, 1\mu F$)

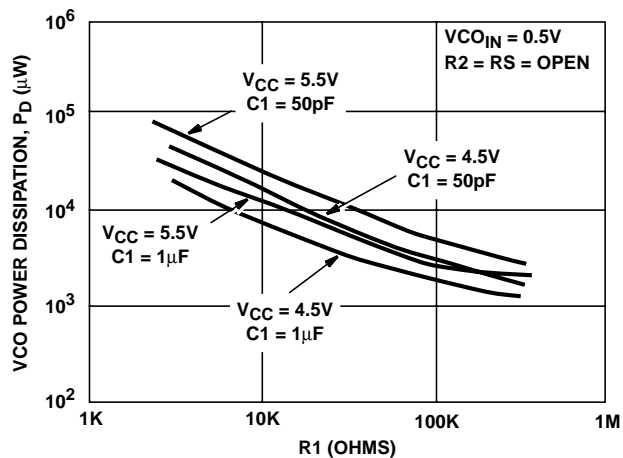


FIGURE 43. HCT4046A VCO POWER DISSIPATION vs R_1 ($C_1 = 50pF, 1\mu F$)

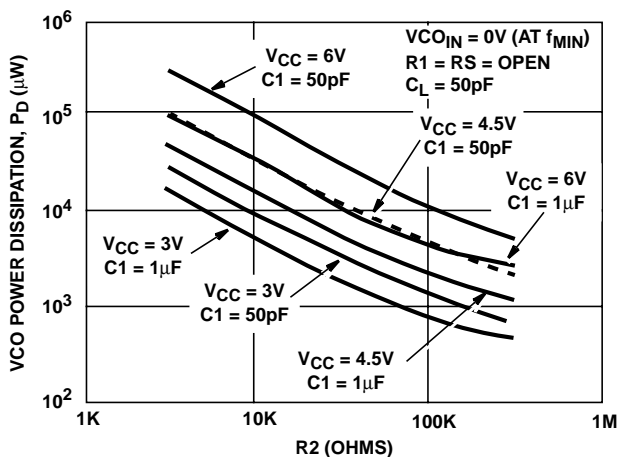


FIGURE 44. HC4046A VCO POWER DISSIPATION vs R_2 ($C_1 = 50pF, 1\mu F$)

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HC/HCT4046A C_{PD}

CHIP SECTION	HC	HCT	UNIT
Comparator 1	48	50	pF
Comparators 2 and 3	39	48	pF
VCO	61	53	pF

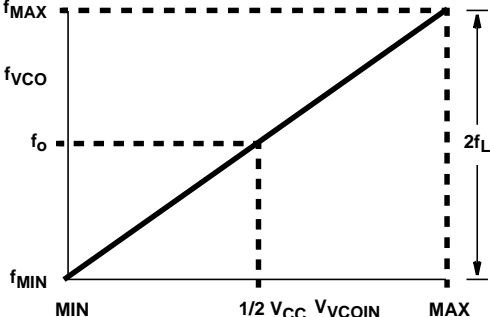
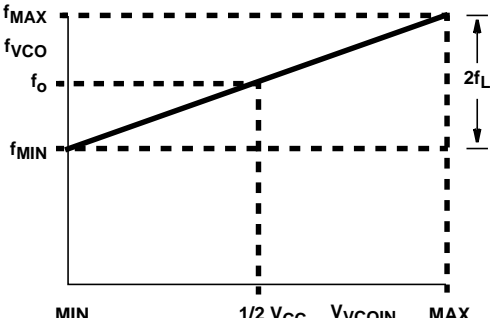
Application Information

This information is a guide for the approximation of values of external components to be used with the 'HC4046A and 'HCT4046A in a phase-lock-loop system.

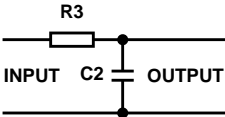
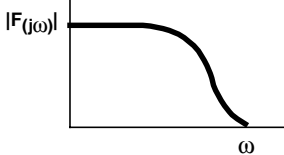
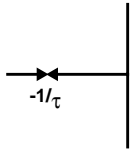
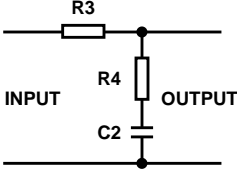
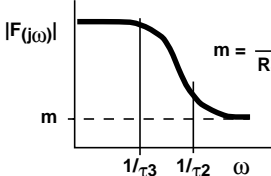
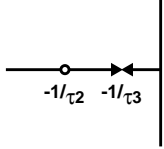
References should be made to Figures 12 through 16 and Figures 28 through 33 as indicated in the table.

Values of the selected components should be within the following ranges:

R1	Between 3kΩ and 300kΩ
R2	Between 3kΩ and 300kΩ
R1 + R2	Parallel Value > 2.7kΩ
C1	Greater Than 40pF

SUBJECT	PHASE COMPARATOR	DESIGN CONSIDERATIONS
VCO Frequency Without Extra Offset	PC1, PC2 or PC3	<p>VCO Frequency Characteristic</p> <p>With $R2 = \infty$ and $R1$ within the range $3k\Omega < R1 < 300k\Omega$, the characteristics of the VCO operation will be as shown in Figures 12 - 16. (Due to $R1$, $C1$ time constant a small offset remains when $R2 = \infty$.)</p>  <p>FIGURE 45. FREQUENCY CHARACTERISTIC OF VCO OPERATING WITHOUT OFFSET: f_o = CENTER FREQUENCY: $2f_L$ = FREQUENCY LOCK RANGE</p>
	PC1	<p>Selection of $R1$ and $C1$</p> <p>Given f_o, determine the values of $R1$ and $C1$ using Figures 12 - 16.</p>
	PC2 or PC3	<p>Given f_{MAX} calculate f_o as $f_{MAX}/2$ and determine the values of $R1$ and $C1$ using Figures 12 - 16. To obtain $2f_L$: $2f_L \approx 1.2 (V_{CC} - 1.8V)/(R1C1)$ where valid range of V_{COIN} is $1.1V < V_{COIN} < V_{CC} - 0.9V$</p>
VCO Frequency with Extra Offset	PC1, PC2 or PC3	<p>VCO Frequency Characteristic</p> <p>With $R1$ and $R2$ within the ranges $3k\Omega < R1 < 300k\Omega$, $3k\Omega < R2 < 300k\Omega$, the characteristics of the VCO operation will be as shown in Figures 28 - 33.</p>  <p>FIGURE 46. FREQUENCY CHARACTERISTIC OF VCO OPERATING WITH OFFSET: f_o = CENTER FREQUENCY: $2f_L$ = FREQUENCY LOCK RANGE</p>
	PC1, PC2 or PC3	<p>Selection of $R1$, $R2$ and $C1$</p> <p>Given f_o and f_L, offset frequency, f_{MIN}, may be calculated from $f_{MIN} \approx f_o - 1.6 f_L$. Obtain the values of $C1$ and $R2$ by using Figures 28 - 31. Calculate the values of $R1$ from Figures 32 - 33.</p>

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SUBJECT	PHASE COMPARATOR	DESIGN CONSIDERATIONS
PLL Conditions with No Signal at the SIG _{IN} Input	PC1	VCO adjusts to f_0 with $\phi_{\text{DEMOUT}} = 90^\circ$ and $V_{\text{VCOIN}} = 1/2 V_{\text{CC}}$ (see Figure 2)
	PC2	VCO adjusts to f_{MIN} with $\phi_{\text{DEMOUT}} = -360^\circ$ and $V_{\text{VCOIN}} = 0V$ (see Figure 4)
	PC3	VCO adjusts to f_{MAX} with $\phi_{\text{DEMOUT}} = 360^\circ$ and $V_{\text{VCOIN}} = V_{\text{CC}}$ (see Figure 6)
PLL Frequency Capture Range	PC1, PC2 or PC3	<p>Loop Filter Component Selection</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p>(A) $\tau = R3 \times C2$</p> </div> <div style="text-align: center;">  <p>(B) AMPLITUDE CHARACTERISTIC</p> </div> <div style="text-align: center;">  <p>(C) POLE-ZERO DIAGRAM</p> </div> </div> <p>A small capture range ($2f_c$) is obtained if $\tau > 2f_c \approx 1/\pi (2\pi f_L/\tau.)^{1/2}$</p> <p align="center">FIGURE 47. SIMPLE LOOP FILTER FOR PLL WITHOUT OFFSET</p>
		<div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p>(A) $\tau_1 = R3 \times C2$; $\tau_2 = R4 \times C2$; $\tau_3 = (R3 + R4) \times C2$</p> </div> <div style="text-align: center;">  <p>(B) AMPLITUDE CHARACTERISTIC</p> </div> <div style="text-align: center;">  <p>(C) POLE-ZERO DIAGRAM</p> </div> </div> <p align="center">FIGURE 48. SIMPLE LOOP FILTER FOR PLL WITH OFFSET</p>
PLL Locks on Harmonics at Center Frequency	PC1 or PC3	Yes
	PC2	No
Noise Rejection at Signal Input	PC1	High
	PC2 or PC3	Low
AC Ripple Content when PLL is Locked	PC1	$f_r = 2f_i$, large ripple content at $\phi_{\text{DEMOUT}} = 90^\circ$
	PC2	$f_r = f_i$, small ripple content at $\phi_{\text{DEMOUT}} = 0^\circ$
	PC3	$f_r = f_{\text{SIGIN}}$, large ripple content at $\phi_{\text{DEMOUT}} = 180^\circ$

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