74HCT9046A

PLL with band gap controlled VCO

Rev. 8 — 31 January 2019 Product data sheet

1. General description

The 74HCT9046A. This device features reduced input threshold levels to allow interfacing to TTL logic levels. Inputs also include clamp diodes, this enables the use of current limiting resistors to interface inputs to voltages in excess of V_{CC}.

2. Features and benefits

- Operation power supply voltage range from 4.5 V to 5.5 V
- Low power consumption
- Complies with JEDEC standard no. 7A
- Inhibit control for ON/OFF keying and for low standby power consumption
- Center frequency up to 17 MHz (typical) at V_{CC} = 5.5 V
- Choice of two phase comparators:
  - PC1: EXCLUSIVE-OR
  - PC2: Edge-triggered JK flip-flop
- No dead zone of PC2
- Charge pump output on PC2, whose current is set by an external resistor R_{bias}
- Center frequency tolerance ±10 %
- Excellent Voltage Controlled Oscillator (VCO) linearity
- Low frequency drift with supply voltage and temperature variations
- On-chip band gap reference
- Glitch free operation of VCO, even at very low frequencies
- Zero voltage offset due to operational amplifier buffering
- ESD protection:
  - HBM JESD22-A114F exceeds 2000 V
  - MM JESD22-A115-A exceeds 200 V

3. Applications

- FM modulation and demodulation where a small center frequency tolerance is essential
- Frequency synthesis and multiplication where a low jitter is required (e.g. video picture-in-picture)
- Frequency discrimination
- Tone decoding
- Data synchronization and conditioning
- Voltage-to-frequency conversion
- Motor-speed control

4. Ordering information

Table 1. Ordering information

Type number	Package			
	Temperature range	Name	Description	Version
74HCT9046AD	-40 °C to +125 °C	SO16	plastic small outline package; 16 leads; body width 3.9 mm	SOT109-1

nexperia

5. Functional diagram

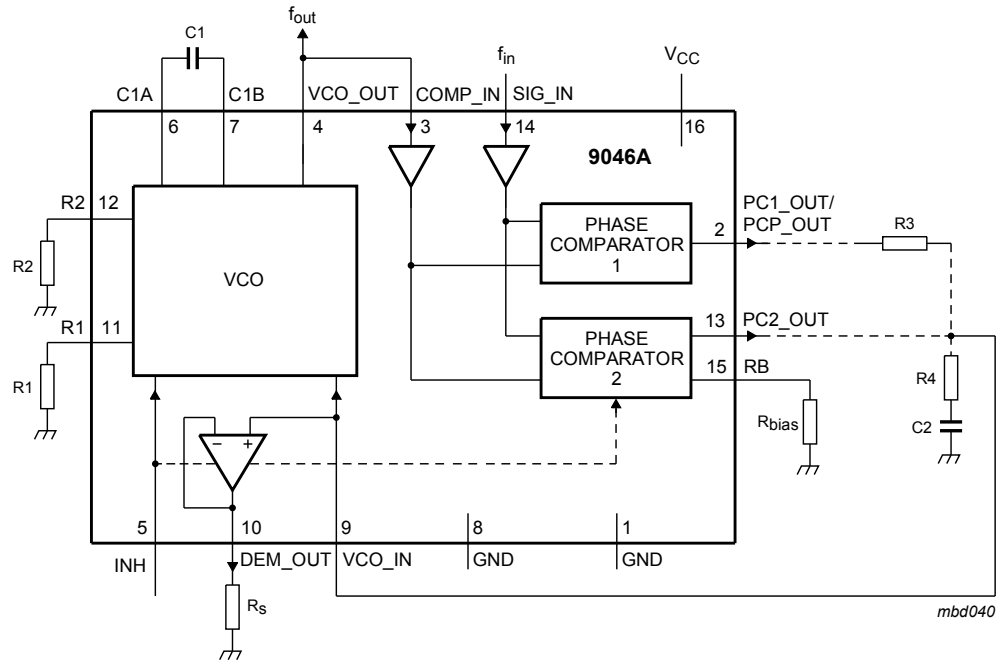


Fig. 1. Block diagram

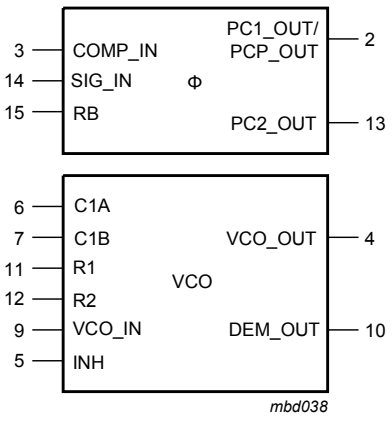


Fig. 2. Logic symbol

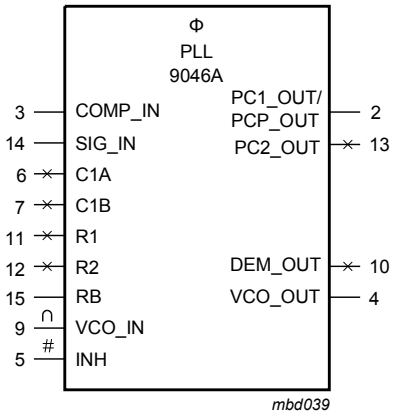


Fig. 3. IEC logic symbol

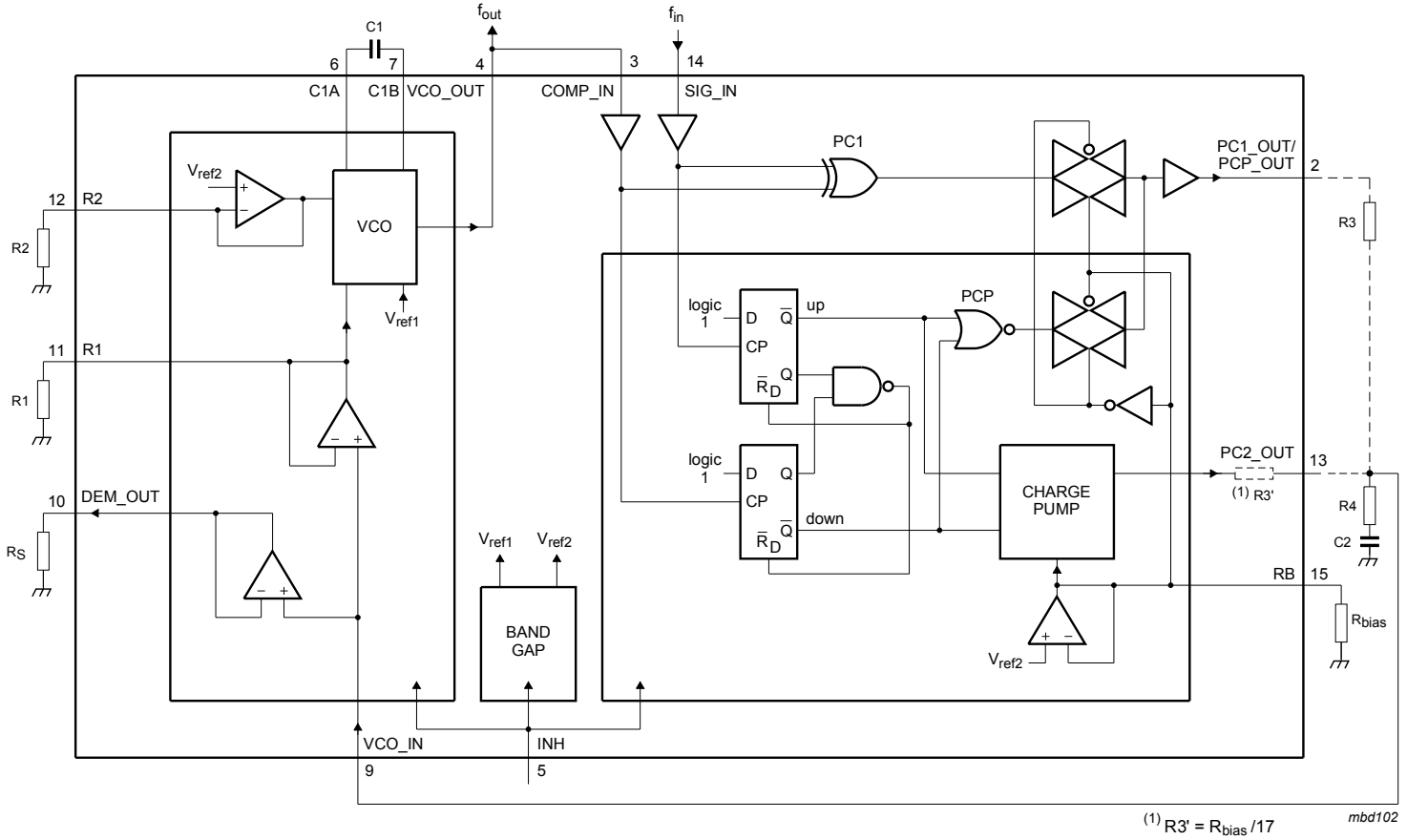


Fig. 4. Logic diagram

6. Pinning information

6.1. Pinning

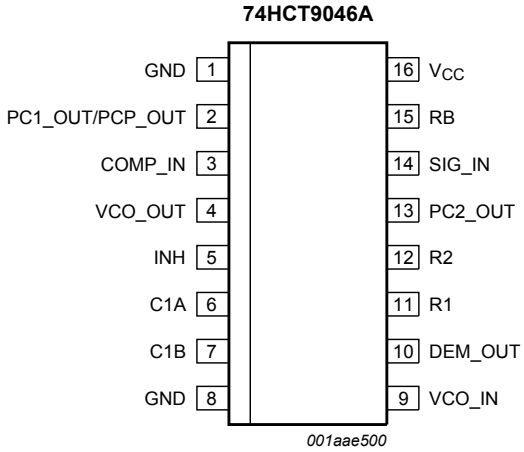


Fig. 5. Pin configuration

6.2. Pin description

Table 2. Pin description

Symbol	Pin	Description
GND	1	ground (0 V) of phase comparators
PC1_OUT/PCP_OUT	2	phase comparator 1 output or phase comparator pulse output
COMP_IN	3	comparator input
VCO_OUT	4	VCO output
INH	5	inhibit input
C1A	6	capacitor C1 connection A
C1B	7	capacitor C1 connection B
GND	8	ground (0 V) VCO
VCO_IN	9	VCO input
DEM_OUT	10	demodulator output
R1	11	resistor R1 connection
R2	12	resistor R2 connection
PC2_OUT	13	phase comparator 2 output; current source adjustable with R_{bias}
SIG_IN	14	signal input
RB	15	bias resistor (R_{bias}) connection
V_{CC}	16	supply voltage

7. Functional description

The 74HCT9046A is a phase-locked-loop circuit that comprises a linear VCO and two different phase comparators (PC1 and PC2) with a common signal input amplifier and a common comparator input, see Figure 1. The signal input can be directly coupled to large voltage signals (CMOS level), 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 74HCT9046A forms a second-order loop PLL.

The principle of this phase-locked-loop is based on the familiar 74HCT4046A. However extra features are built-in, allowing very high-performance phase-locked-loop applications. This is done, at the expense of PC3, which is skipped in this 74HCT9046A. The PC2 is equipped with a current source output stage here. Further a band gap is applied for all internal references, allowing a small center frequency tolerance. The details are summed up in Section 7.1. If one is familiar with the 74HCT4046A already, it will do to read this section only.

7.1. Differences with respect to the familiar 74HCT4046A

- A center frequency tolerance of maximum ±10 %.
- The on board band gap sets the internal references resulting in a minimal frequency shift at supply voltage variations and temperature variations.
- The value of the frequency offset is determined by an internal reference voltage of 2.5 V instead of V_{CC} - 0.7 V; In this way the offset frequency will not shift over the supply voltage range.
- A current switch charge pump output on pin PC2_OUT allows a virtually ideal performance of PC2; The gain of PC2 is independent of the voltage across the low-pass filter; Further a passive low-pass filter in the loop achieves an active performance. The influence of the parasitic capacitance of the PC2 output plays no role here, resulting in a true correspondence of the output correction pulse and the phase difference even up to phase differences as small as a few nanoseconds.
- Because of its linear performance without dead zone, higher impedance values for the filter, hence lower C-values, can be chosen; correct operation will not be influenced by parasitic capacitances as in case of the voltage source output using the 74HCT4046A.
- No PC3 on pin RB but instead a resistor connected to GND, which sets the load/unload currents of the charge pump (PC2).
- Extra GND pin 1 to allow an excellent FM demodulator performance even at 10 MHz and higher.
- Combined function of pin PC1_OUT/PCP_OUT. If pin RB is connected to V_{CC} (no bias resistor R_{bias}) pin PC1_OUT/PCP_OUT has its familiar function viz. output of PC1. If at pin RB a resistor (R_{bias}) is connected to GND it is assumed that PC2 has been chosen as phase comparator. Connection of R_{bias} is sensed by internal circuitry and this changes the function of pin PC1_OUT/PCP_OUT into a lock detect output (PCP_OUT) with the same characteristics as PCP_OUT of pin 1 of the 74HCT4046A.
- The inhibit function differs. For the 74HCT4046A a HIGH-level at the inhibit input (pin INH) disables the VCO and demodulator, while a LOW-level turns both on. For the 74HCT9046A a HIGH-level on the inhibit input disables the whole circuit to minimize standby power consumption.

7.2. VCO

The VCO requires one external capacitor C1 (between pins C1A and C1B) and one external resistor R1 (between pins R1 and GND) or two external resistors R1 and R2 (between pins 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 Fig. 4).

The high input impedance of the VCO simplifies the design of the 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 DEM_OUT. The DEM_OUT voltage equals that of the VCO input. If DEM_OUT is used, a series resistor (R_s) should be connected from pin DEM_OUT to GND; if unused, DEM_OUT should be left open. The VCO output (pin VCO_OUT) can be connected directly to the comparator input (pin COMP_IN), or connected via a

frequency divider. The output signal has a duty cycle of 50 % (maximum expected deviation 1 %), if the VCO input is held at a constant DC level. A LOW-level at the inhibit input (pin INH) enables the VCO and demodulator, while a HIGH-level turns both off to minimize standby power consumption.

7.3. Phase comparators

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

7.3.1. Phase Comparator 1 (PC1)

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

$$V_{DEM\_OUT} = \frac{V_{CC}}{\pi}\left(\Phi_{SIG\_IN} - \Phi_{COMP\_IN}\right)$$

where:

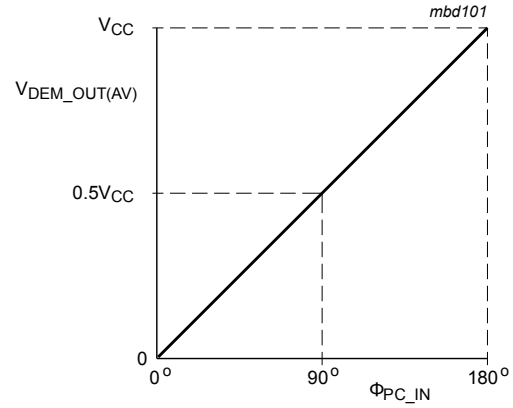
- V_{DEM_OUT} is the demodulator output at pin DEM_OUT
- $V_{DEM\_OUT} = V_{PC1\_OUT}$ (via low-pass)

The phase comparator gain is: $K_p = \frac{V_{CC}}{\pi}\left(V / r\right)$

The average output voltage from PC1, fed to the VCO input via the low-pass filter and seen at the demodulator output at pin DEM_OUT (V_{DEM_OUT}), is the resultant of the phase differences of signals (SIG_IN) and the comparator input (COMP_IN) as shown in Fig. 6. The average of V_{DEM_OUT} is equal to $0.5V_{CC}$ 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 Fig. 7. This figure also shows the actual waveforms across the VCO capacitor at pins C1A and C1B (V_{C1A} and V_{C1B}) to show the relation between these ramps and the VCO_OUT voltage.

The frequency capture range ($2f_0$) 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 the 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 remains locked even with very noisy input signals. Typical behavior of this type of phase comparator is that it may lock to input frequencies close to the harmonics of the VCO center frequency.



$$V_{DEM\_OUT} = V_{PCI\_OUT} = \frac{V_{CC}}{\pi}\Phi_{SIG\_IN} - \Phi_{COMP\_IN}$$

$$\Phi_{PC\_IN} = \left(\Phi_{SIG\_IN} - \Phi_{COMP\_IN}\right)$$

Fig. 6. Phase comparator 1; average output voltage as a function of input phase difference

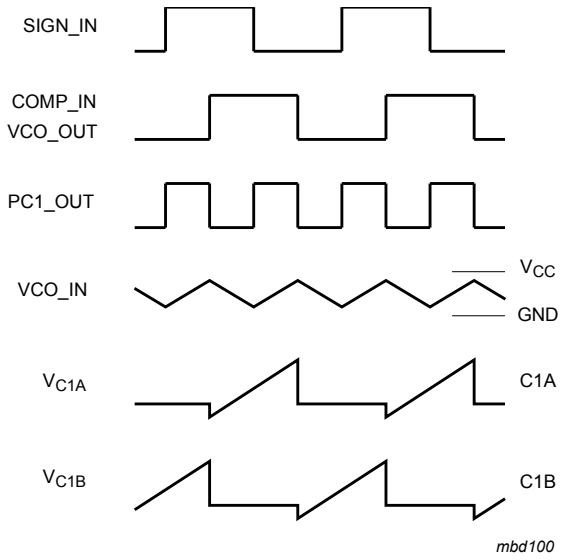


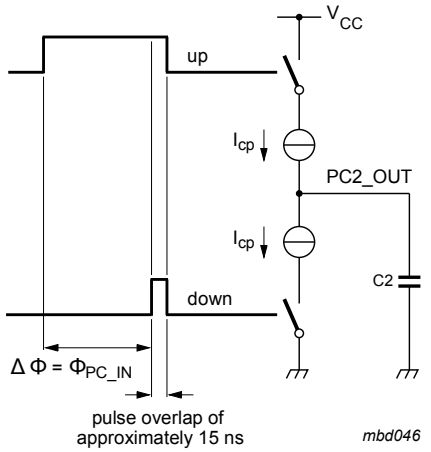
Fig. 7. Typical waveforms for PLL using phase comparator 1; loop-locked at f_0

7.3.2. Phase Comparator 2 (PC2)

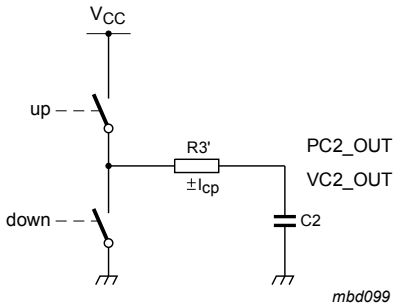
This is a positive edge-triggered phase and frequency detector. When the PLL is using this comparator, the loop is controlled by positive signal transitions and the duty cycles of SIG_IN and COMP_IN are not important. PC2 comprises two D-type flip-flops, control gating and a 3-state output stage with sink and source transistors acting as current sources, henceforth called charge pump output of PC2. The circuit functions as an up-down counter (see Fig. 4) where SIG_IN causes an up-count and COMP_IN a down count. The current switch charge pump output allows a virtually ideal performance of PC2, due to appliance of some pulse overlap of the up and down signals, see Fig. 8a. The pump current I_{cp} is independent from the supply voltage and is set by the internal band gap reference of 2.5 V.

$I_{cp} = 17 \times \frac{2.5}{R_{bias}}(A)$ Where R_{bias} is the external bias resistor between pin RB and ground.
The current and voltage transfer function of PC2 are shown in Fig. 9.

The phase comparator gain is: $K_P = \frac{|I_{cp}|}{2\pi}(A / r)$

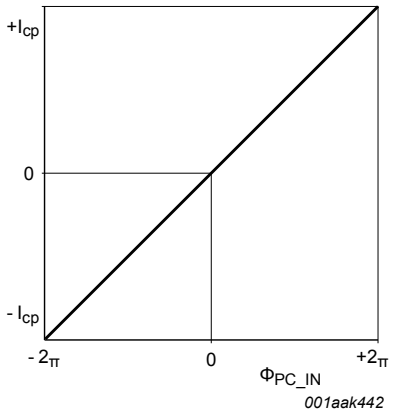


a. At every ΔΦ, even at zero ΔΦ both switches are closed simultaneously for a short period (typically 15 ns).

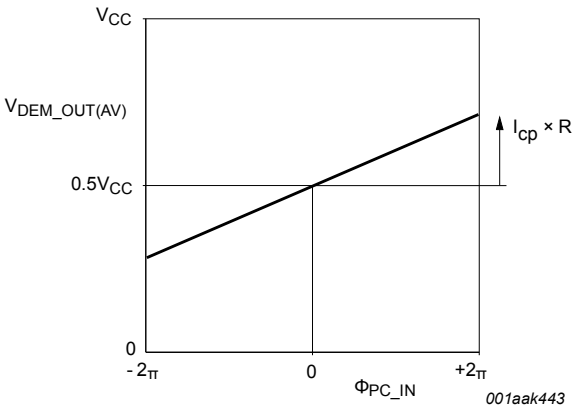


b. Comparable voltage-controlled switch

Fig. 8. The current switch charge pump output of PC2



a. Current transfer



b. Voltage transfer. This transfer can be observed at PC2_OUT by connecting a resistor (R = 10 kΩ) between PC2_OUT and $0.5V_{CC}$.

$$pump\ current\ \frac{|I_{cp}|}{2\pi}\Phi_{PC\_IN}$$

$$V_{DEM\_OUT} = V_{PC2\_OUT} = \frac{5}{4\pi}\Phi_{PC\_IN}$$

$$\Phi_{PC\_IN} = \left(\Phi_{SIG\_IN} - \Phi_{COMP\_IN}\right)$$

Fig. 9. Phase comparator 2 current and voltage transfer characteristics

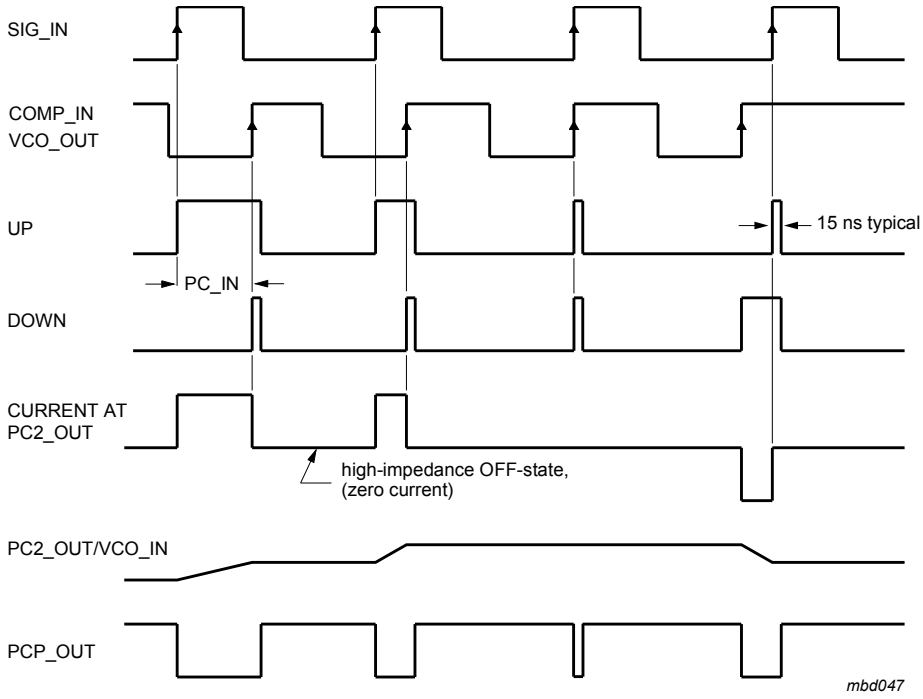
When the frequencies of SIG_IN and COMP_IN are equal but the phase of SIG_IN leads that of COMP_IN, the up output driver at PC2_OUT is held ‘ON’ for a time corresponding to the phase difference (Φ_{PC_IN}). When the phase of SIG_IN lags that of COMP_IN, the down or sink driver is held ‘ON’.

When the frequency of SIG_IN is higher than that of COMP_IN, the source output driver is held ‘ON’ for most of the input signal cycle time and for the remainder of the cycle time both drivers are ‘OFF’ (3-state). If the SIG_IN frequency is lower than the COMP_IN frequency, then it is the sink 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 3-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) has a minimum output pulse width equal to the overlap time, 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 output drivers are OFF for most of the signal input cycle.

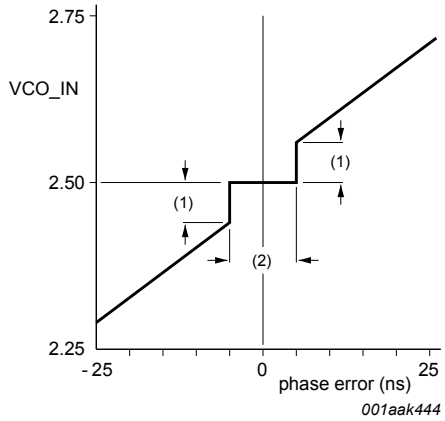
It should be noted that the PLL lock range for this type of phase comparator is equal to the capture range and is independent of the low-pass filter. With no signal present at SIG_IN the VCO adjust, via PC2, to its lowest frequency.

By using current sources as charge pump output on PC2, the dead zone or backlash time could be reduced to zero. Also, the pulse widening due to the parasitic output capacitance plays no role here. This enables a linear transfer function, even in the vicinity of the zero crossing. The differences between a voltage switch charge pump and a current switch charge pump are shown in Fig. 11.



The pulse overlap of the up and down signals (typically 15 ns).

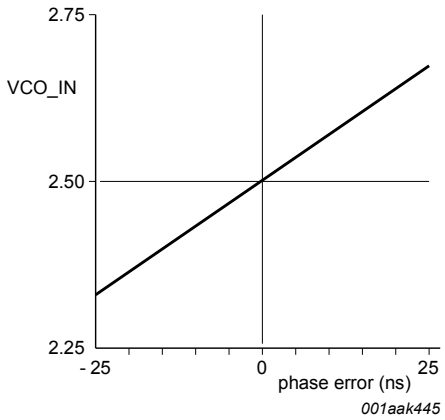
Fig. 10. Timing diagram for PC2



(1) Due to parasitic capacitance on PC2_OUT.

(2) Backlash time (dead zone).

a. Response with traditional voltage-switch charge-pump PC2_OUT (74HCT4046A).



b. Response with current switch charge-pump PC2_OUT as applied in the 74HCT9046A.

Fig. 11. The response of a locked-loop in the vicinity of the zero crossing of the phase error

The design of the low-pass filter is somewhat different when using current sources. The external resistor R3 is no longer present when using PC2 as phase comparator. The current source is set by R_{bias}. A simple capacitor behaves as an ideal integrator now, because the capacitor is charged by a constant current. The transfer function of the voltage switch charge pump may be used. In fact it is even more valid, because the transfer function is no longer restricted for small changes only. Further the current is independent from both the supply voltage and the voltage across the filter. For one that is familiar with the low-pass filter design of the 74HCT4046A a relation may show how R_{bias} relates with a fictive series resistance, called R3'.

This relation can be derived by assuming first that a voltage controlled switch PC2 of the 74HCT4046A is connected to the filter capacitance C2 via this fictive R3' (see Fig. 8b). Then during the PC2 output pulse the charge current equals:

$$|I_{cp}| = \frac{V_{CC} - V_{C2(0)}}{R3'}$$

With the initial voltage $V_{C2(0)}$ at: $0.5V_{CC}$ = 2.5 V, $|I_{cp}| = \frac{2.5}{R3'}$

As shown before the charge current of the current switch of the 74HCT9046A is:

$$|I_{cp}| = 17 \times \frac{2.5}{R_{bias}}$$

Hence:

$$R3' = \frac{R_{bias}}{17}(\Omega)$$

Using this equivalent resistance R3' for the filter design the voltage can now be expressed as a transfer function of PC2; assuming ripple ($f_r = f_i$) is suppressed, as:

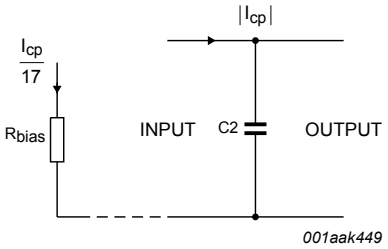
$$K_{PC2} = \frac{5}{4\pi}(V / r)$$

Again this illustrates the supply voltage independent behavior of PC2.

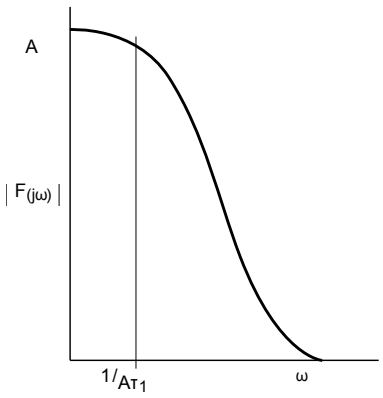
7.4. Loop filter component selection

Examples of PC2 combined with a passive filter are shown in Fig. 14 and Fig. 15.
Fig. 14 shows that PC2 with only a C2 filter behaves as a high-gain filter. For stability the damped version of Fig. 15 with series resistance R4 is preferred.

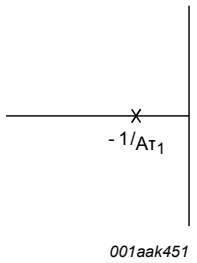
Practical design values for R_{bias} are between 25 kΩ and 250 kΩ with R3' = 1.5 kΩ to 15 kΩ for the filter design. Higher values for R3' require lower values for the filter capacitance which is very advantageous at low values of the loop natural frequency ω_n.



a. Simple loop filter for PC2 without damping



b. Amplitude characteristic



c. Pole zero diagram

Fig. 12.

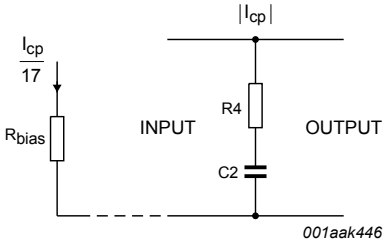
$$\tau_1 = \frac{R_{bias}}{17} \times C2 = R3' \times C2$$

Fig. 13.

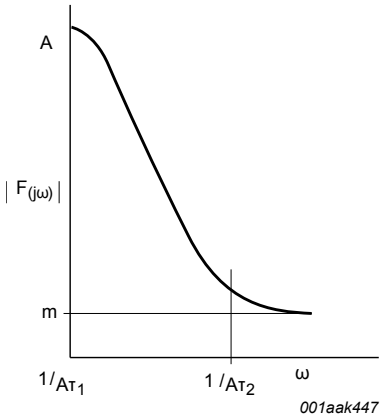
$$F_{(j\omega)} = \frac{1}{1/A + j\omega\tau_1} \approx \frac{1}{j\omega\tau_1}$$

A = DC gain limit, due to leakage

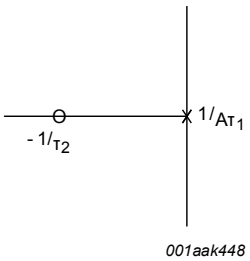
Fig. 14. Simple loop filter for PC2 without damping



a. Simple loop filter for PC2 with damping



b. Amplitude characteristic



c. Pole zero diagram

$$\tau_1 = \frac{R_{bias}}{17} \times C2 = R3' \times C2$$
$$\tau_2 = R4 \times C2$$

$$F_{(j\omega)} = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1}$$

A = DC gain limit, due to leakage

Fig. 15. Simple loop filter for PC2 with damping

8. Limiting values

Table 3. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134). Voltages are referenced to GND (ground = 0 V).

Symbol	Parameter	Conditions	Min	Max	Unit
V_{CC}	supply voltage		-0.5	+7	V
I_{IK}	input clamping current	$V_I < -0.5$ V or $V_I > V_{CC} + 0.5$ V	-	±20	mA
I_{OK}	output clamping current	$V_O < -0.5$ V or $V_O > V_{CC} + 0.5$ V	-	±20	mA
I_O	output current	-0.5 V $< V_O < V_{CC} + 0.5$ V	-	±25	mA
I_{CC}	supply current		-	+50	mA
I_{GND}	ground current		-50	-	mA
T_{stg}	storage temperature		-65	+150	°C
P_{tot}	total power dissipation	T_{amb} = -40 °C to +125 °C [1]	-	500	mW

[1] P_{tot} derates linearly with 8 mW/K above 70 °C.

9. Recommended operating conditions

Table 4. Operating conditions

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{CC}	supply voltage		4.5	5.0	5.5	V
V_I	input voltage		0	-	V_{CC}	V
V_O	output voltage		0	-	V_{CC}	V
T_{amb}	ambient temperature		-40		+125	°C
$\Delta t/\Delta V$	input transition rise and fall rate	pin INH; V_{CC} = 4.5 V	-	1.67	139	ns/V

10. Static characteristics

Table 5. Static characteristics

At recommended operating conditions; voltages are referenced to GND (ground = 0 V).

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{amb} = 25 °C						
Phase comparator section						
V_{IH}	HIGH-level input voltage	pins SIG_IN and COMP_IN; V_{CC} = 4.5 V; DC coupled	3.15	2.4	-	V
V_{IL}	LOW-level input voltage	pins SIG_IN and COMP_IN; V_{CC} = 4.5 V; DC coupled	-	2.1	1.35	V
V_{OH}	HIGH-level output voltage	pins PCP_OUT and PCn_OUT; V_{CC} = 4.5 V; $V_I = V_{IH}$ or V_{IL}				
		I_O = -20 µA	4.4	4.5	-	V
		I_O = -4.0 mA	3.98	4.32	-	V
V_{OL}	LOW-level output voltage	pins PCP_OUT and PCn_OUT; V_{CC} = 4.5 V; $V_I = V_{IH}$ or V_{IL}				
		I_O = 20 µA	-	0	0.1	V
		I_O = 4.0 mA	-	0.15	0.26	V
I_I	input leakage current	pins SIG_IN and COMP_IN; V_{CC} = 5.5 V; $V_I = V_{CC}$ or GND	-	-	±30	µA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{OZ}	OFF-state output current	pin PC2_OUT; V_{CC} = 5.5 V; V_I = V_{IH} or V_{IL}; V_O = V_{CC} or GND	-	-	±0.5	µA
R_I	input resistance	SIG_IN and COMP_IN; V_{CC} = 4.5 V; V_I at self-bias operating point; ΔV_I = 0.5 V; see Fig. 16, Fig. 17 and Fig. 18	-	250	-	kΩ
R_{bias}	bias resistance	V_{CC} = 4.5 V	25	-	250	kΩ
I_{cp}	charge pump current	V_{CC} = 4.5 V; R_{bias} = 40 kΩ	±0.53	±1.06	±2.12	mA
VCO section						
V_{IH}	HIGH-level input voltage	pin INH; V_{CC} = 4.5 V to 5.5 V; DC coupled	2.0	1.6	-	V
V_{IL}	LOW-level input voltage	pin INH; V_{CC} = 4.5 V to 5.5 V; DC coupled	-	1.2	0.8	V
V_{OH}	HIGH-level output voltage	pin VCO_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = -20 µA	4.4	4.5	-	V
		I_O = -4.0 mA	3.98	4.32	-	V
V_{OL}	LOW-level output voltage	pin VCO_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = 20 µA	-	0	0.1	V
		I_O = 4.0 mA	-	0.15	0.26	V
		pins C1A and C1B; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}; I_O = 4.0 mA	-	-	0.40	V
I_I	input leakage current	pins INH and VCO_IN; V_{CC} = 5.5 V; V_I = V_{CC} or GND	-	-	±0.1	µA
R1	resistor 1	V_{CC} = 4.5 V	3	-	300	kΩ
R2	resistor 2	V_{CC} = 4.5 V	3	-	300	kΩ
C1	capacitor 1	V_{CC} = 4.5 V	40	-	no limit	pF
V_{VCO_IN}	voltage on pin VCO_IN	over the range specified for R1				
		V_{CC} = 4.5 V	1.1	-	3.4	V
		V_{CC} = 5.0 V	1.1	-	3.9	V
		V_{CC} = 5.5 V	1.1	-	4.4	V
Demodulator section						
R_s	series resistance	V_{CC} = 4.5 V; at R_s > 300 kΩ the leakage current can influence V_{DEM_OUT}	50	-	300	kΩ
V_{offset}	offset voltage	VCO_IN to V_{DEM_OUT}; V_{CC} = 4.5 V; V_I = V_{VCO_IN} = 0.5V_{CC}; values taken over R_s range; see Fig. 19	-	±20	-	mV
R_{dyn}	dynamic resistance	DEM_OUT; V_{CC} = 4.5 V; V_{DEM_OUT} = 0.5 V_{CC}	-	25	-	Ω
General						
I_{CC}	supply current	disabled; V_{CC} = 5.5 V; pin INH at V_{CC}	-	-	8.0	µA
ΔI_{CC}	additional supply current	pin INH; V_I = V_{CC} - 2.1 V; V_{CC} = 4.5 V; other inputs at V_{CC} or GND;	-	100	360	µA
C_I	input capacitance		-	3.5	-	pF

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{amb} = -40 °C to +85 °C						
Phase comparator section						
V_{IH}	HIGH-level input voltage	pins SIG_IN and COMP_IN; V_{CC} = 4.5 V; DC coupled	3.15	-	-	V
V_{IL}	LOW-level input voltage	pins SIG_IN and COMP_IN; V_{CC} = 4.5 V; DC coupled	-	-	1.35	V
V_{OH}	HIGH-level output voltage	pins PCP_OUT and PCn_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = -20 µA	4.4	-	-	V
		I_O = -4.0 mA	3.84	-	-	V
V_{OL}	LOW-level output voltage	pins PCP_OUT and PCn_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = 20 µA	-	-	0.1	V
		I_O = 4.0 mA	-	-	0.33	V
I_I	input leakage current	SIG_IN and COMP_IN; V_{CC} = 5.5 V; V_I = V_{CC} or GND	-	-	±38	µA
I_{OZ}	OFF-state output current	PC2_OUT; V_{CC} = 5.5 V; V_I = V_{IH} or V_{IL}; V_O = V_{CC} or GND	-	-	±5.0	µA
VCO section						
V_{IH}	HIGH-level input voltage	pin INH; V_{CC} = 4.5 V to 5.5 V; DC coupled	2.0	-	-	V
V_{IL}	LOW-level input voltage	pin INH; V_{CC} = 4.5 V to 5.5 V; DC coupled	-	-	0.8	V
V_{OH}	HIGH-level output voltage	pin VCO_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = -20 µA	4.4	-	-	V
		I_O = -4.0 mA	3.84	-	-	V
V_{OL}	LOW-level output voltage	pin VCO_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = 20 µA	-	-	0.1	V
		I_O = 4.0 mA	-	-	0.33	V
		pins C1A and C1B; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}; I_O = 4.0 mA	-	-	0.47	V
I_I	input leakage current	pins INH and VCO_IN; V_{CC} = 5.5 V; V_I = V_{CC} or GND	-	-	±1.0	µA
General						
I_{CC}	supply current	disabled; V_{CC} = 5.5 V; pin INH at V_{CC}	-	-	80.0	µA
ΔI_{CC}	additional supply current	per input pin; V_I = V_{CC} - 2.1 V; V_{CC} = 4.5 V; other inputs at V_{CC} or GND;	-	-	450	µA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{amb} = -40 °C to +125 °C						
Phase comparator section						
V_{IH}	HIGH-level input voltage	pins SIG_IN and COMP_IN; V_{CC} = 4.5 V; DC coupled	3.15	-	-	V
V_{IL}	LOW-level input voltage	pins SIG_IN and COMP_IN; V_{CC} = 4.5 V; DC coupled	-	-	1.35	V
V_{OH}	HIGH-level output voltage	pins PCP_OUT and PCn_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = -20 µA	4.4	-	-	V
		I_O = -4.0 mA	3.7	-	-	V
V_{OL}	LOW-level output voltage	pins PCP_OUT and PCn_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = 20 µA	-	-	0.1	V
		I_O = 4.0 mA	-	-	0.4	V
I_I	input leakage current	pins SIG_IN and COMP_IN; V_{CC} = 5.5 V; V_I = V_{CC} or GND	-	-	±45	µA
I_{OZ}	OFF-state output current	pin PC2_OUT; V_{CC} = 5.5 V; V_I = V_{IH} or V_{IL}; V_O = V_{CC} or GND	-	-	±10.0	µA
VCO section						
V_{IH}	HIGH-level input voltage	pin INH; V_{CC} = 4.5 V to 5.5 V; DC coupled	2.0	-	-	V
V_{IL}	LOW-level input voltage	pin INH; V_{CC} = 4.5 V to 5.5 V; DC coupled	-	-	0.8	V
V_{OH}	HIGH-level output voltage	pin VCO_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = -20 µA	4.4	-	-	V
		I_O = -4.0 mA	3.7	-	-	V
V_{OL}	LOW-level output voltage	pin VCO_OUT; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}				
		I_O = 20 µA	-	-	0.1	V
		I_O = 4.0 mA	-	-	0.4	V
		pins C1A and C1B; V_{CC} = 4.5 V; V_I = V_{IH} or V_{IL}; I_O = 4.0 mA	-	-	0.54	V
I_I	input leakage current	pins INH and VCO_IN; V_{CC} = 5.5 V; V_{CC} or GND	-	-	±1.0	µA
General						
I_{CC}	supply current	disabled; V_{CC} = 5.5 V; pin INH at V_{CC}	-	-	160.0	µA
ΔI_{CC}	additional supply current	per input pin; V_I = V_{CC} - 2.1 V; V_{CC} = 4.5 V; other inputs at V_{CC} or GND	-	-	490	µA

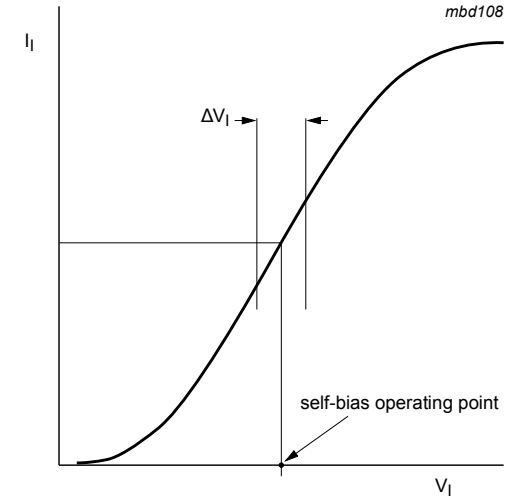


Fig. 16. Typical input resistance curve at SIG_IN and COMP_IN

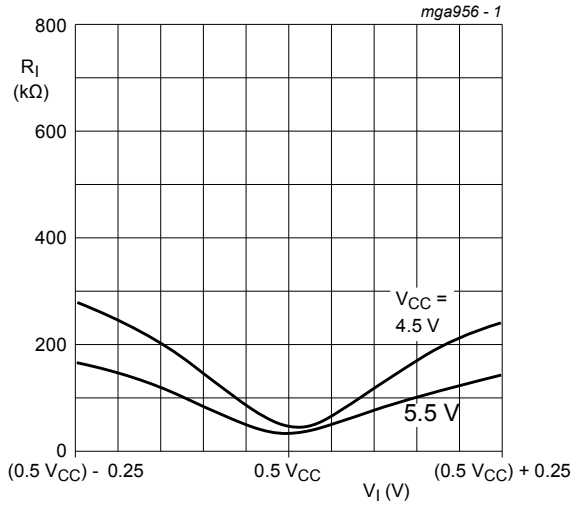


Fig. 17. Input resistance at SIG_IN; COMP_IN with ΔV_I = 0.5 V at self-bias point

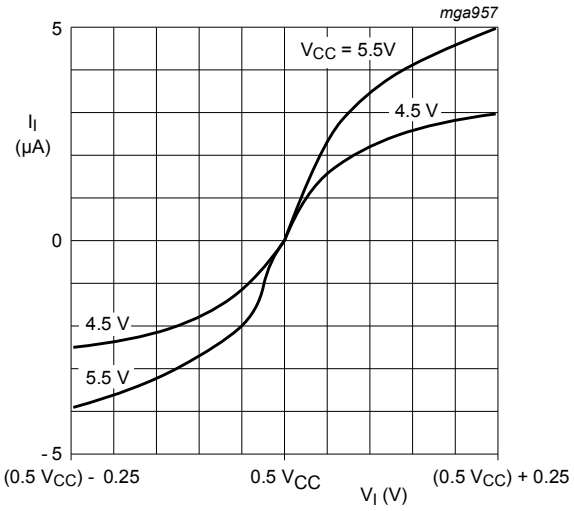


Fig. 18. Input current at SIG_IN; COMP_IN with ΔV_I = 0.5 V at self-bias point

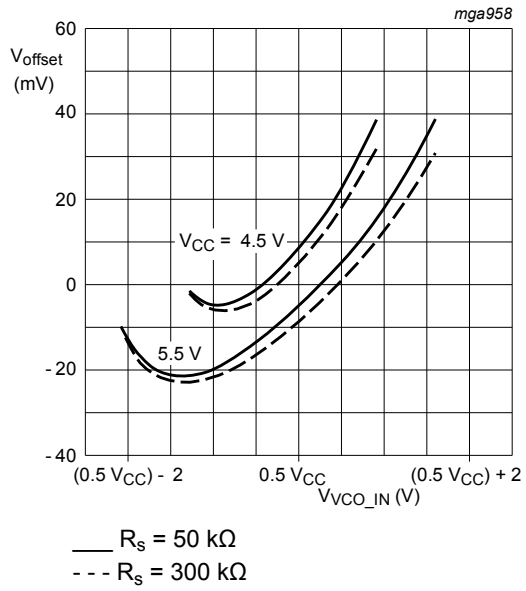


Fig. 19. Offset voltage at demodulator output as a function of VCO_IN and R_s

11. Dynamic characteristics

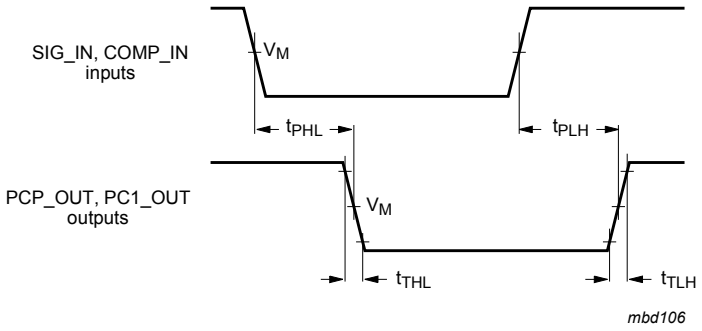
Table 6. Dynamic characteristics

GND = 0 V; $t_r = t_f$ = 6 ns; C_L = 50 pF. [1]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{amb} = 25 °C						
Phase comparator section						
t_{pd}	propagation delay	SIG_IN, COMP_IN to PC1_OUT; V_{CC} = 4.5 V; see Fig. 20	-	23	40	ns
		SIG_IN, COMP_IN to PCP_OUT; V_{CC} = 4.5 V; see Fig. 20	-	35	68	ns
t_{en}	enable time	SIG_IN, COMP_IN to PC2_OUT; V_{CC} = 4.5 V; see Fig. 21	-	30	56	ns
t_{dis}	disable time	SIG_IN, COMP_IN to PC2_OUT; V_{CC} = 4.5 V; see Fig. 21	-	36	65	ns
t_t	transition time	V_{CC} = 4.5 V; see Fig. 20	-	7	15	ns
$V_{i(p-p)}$	peak-to-peak input voltage	pin SIGN_IN or COMP_IN; V_{CC} = 4.5 V; AC coupled; f_i = 1 MHz [2]	-	50	-	mV
VCO section						
Δf	frequency deviation	V_{CC} = 5.0 V; V_{VCO_IN} = 3.9 V; R1 = 10 kΩ; R2 = 10 kΩ; C1 = 1 nF [3]	-10	-	+10	%
f_0	center frequency	V_{CC} = 4.5 V; duty cycle = 50 %; $V_{VCO\_IN} = 0.5V_{CC}$; R1 = 4.3 kΩ; R2 = ∞ Ω; C1 = 40 pF; see Fig. 25 and Fig. 33	11.0	15.0	-	MHz
		V_{CC} = 5 V; duty cycle = 50 %; $V_{VCO\_IN} = 0.5V_{CC}$; R1 = 3 kΩ; R2 = ∞ Ω; C1 = 40 pF; see Fig. 25 and Fig. 33	-	16.0	-	MHz
Δf/f	relative frequency variation	V_{CC} = 4.5 V; R1 = 100 kΩ; R2 = ∞ Ω; C1 = 100 pF; see Fig. 26 and Fig. 27 [4]	-	0.4	-	%
δ	duty cycle	VCO_OUT; V_{CC} = 4.5 V	-	50	-	%
General						
C_{PD}	power dissipation capacitance	[5][6]	-	20	-	pF
T_{amb} = -40 °C to +85 °C						
Phase comparator section						
t_{pd}	propagation delay	SIG_IN, COMP_IN to PC1_OUT; V_{CC} = 4.5 V; see Fig. 20	-	-	50	ns
		SIG_IN, COMP_IN to PCP_OUT; V_{CC} = 4.5 V; see Fig. 20	-	-	85	ns
t_{en}	enable time	SIG_IN, COMP_IN to PC2_OUT; V_{CC} = 4.5 V; see Fig. 21	-	-	70	ns
t_{dis}	disable time	SIG_IN, COMP_IN to PC2_OUT; V_{CC} = 4.5 V; see Fig. 21	-	-	81	ns
t_t	transition time	V_{CC} = 4.5 V; see Fig. 20	-	-	19	ns
VCO section						
Δf/ΔT	frequency variation with temperature	V_{CC} = 4.5 V; $V_{VCO\_IN} = 0.5V_{CC}$; recommended range: R1 = 10 kΩ; R2 = 10 kΩ; C1 = 1 nF; see Fig. 22, Fig. 23 and Fig. 24 [7]	-	0.06	-	%/K

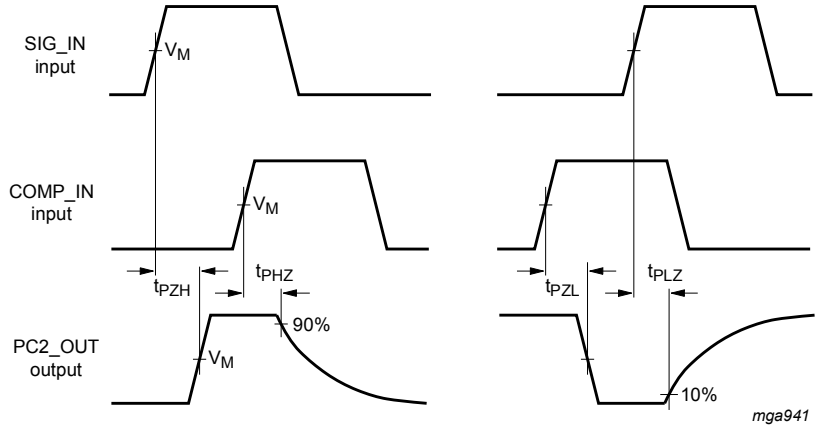
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{amb} = -40 °C to +125 °C						
Phase comparator section						
t_{pd}	propagation delay	SIG_IN, COMP_IN to PC1_OUT; V_{CC} = 4.5 V; see Fig. 20	-	-	60	ns
		SIG_IN, COMP_IN to PCP_OUT; V_{CC} = 4.5 V; see Fig. 20	-	-	102	ns
t_{en}	enable time	SIG_IN, COMP_IN to PC2_OUT; V_{CC} = 4.5 V; see Fig. 21	-	-	84	ns
t_{dis}	disable time	SIG_IN, COMP_IN to PC2_OUT; V_{CC} = 4.5 V; see Fig. 21	-	-	98	ns
t_t	transition time	V_{CC} = 4.5 V; see Fig. 20	-	-	22	ns

[1] t_{pd} is the same as t_{PLH} and t_{PHL}; t_{dis} is the same as t_{PLZ} and t_{PHZ}; t_{en} is the same as t_{PZL} and t_{PZH}; t_t is the same as t_{TLH} and t_{THL}.
[2] This is the (peak to peak) input sensitivity.
[3] This is the center frequency tolerance.
[4] This is the frequency linearity.
[5] C_{PD} is used to determine the dynamic power dissipation (P_D in µW).
$P_D = C_{PD} \times V_{CC}^2 \times f_i \times N + \sum(C_L \times V_{CC}^2 \times f_o)$ where:
f_i = input frequency in MHz;
f_o = output frequency in MHz;
C_L = output load capacitance in pF;
V_{CC} = supply voltage in V;
N = total load switching outputs;
$\sum(C_L \times V_{CC}^2 \times f_o)$ = sum of outputs.
[6] Applies to the phase comparator section only (pin INH = HIGH). For power dissipation of the VCO and demodulator sections, see Fig. 28, Fig. 29 and Fig. 30.
[7] This is the frequency stability with temperature change.



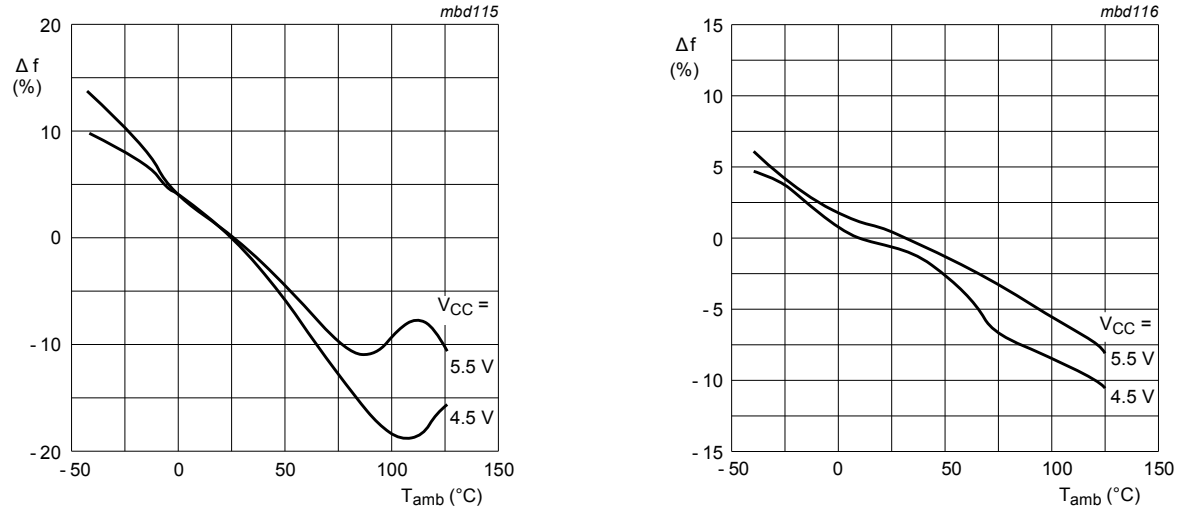
$V_M = 0.5V_{CC}$; V_I = GND to V_{CC}.

Fig. 20. Waveforms showing input (SIG_IN and COMP_IN) to output (PCP_OUT and PC1_OUT) propagation delays and the output transition times



$V_M = 0.5V_{CC}$; V_I = GND to V_{CC}.

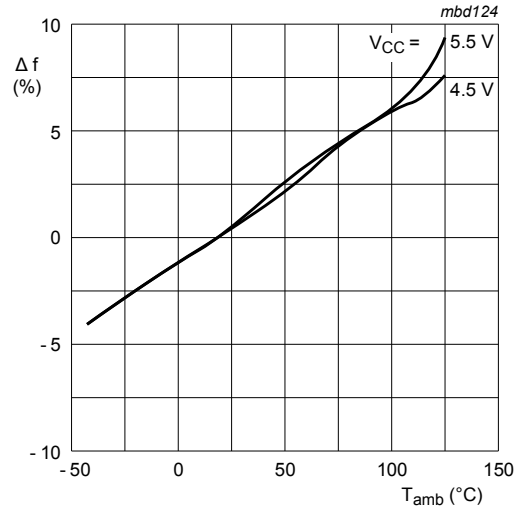
Fig. 21. Waveforms showing the enable and disable times for PC2_OUT



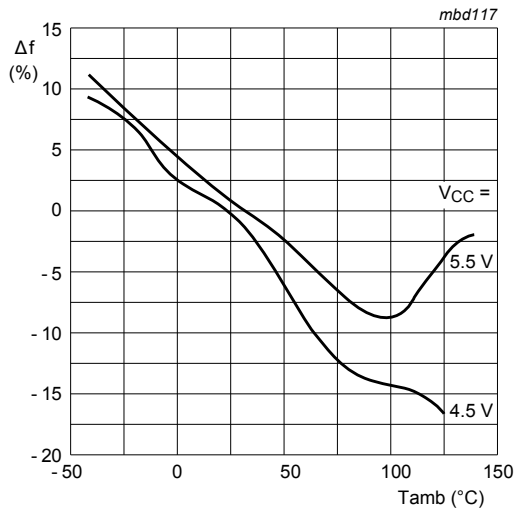
a. R1 = 3 kΩ; R2 = ∞ Ω; C1 = 100 pF.

b. R1 = 10 kΩ; R2 = ∞ Ω; C1 = 100 pF.

Fig. 22. Frequency stability of the VCO as a function of ambient temperature with supply voltage as a parameter

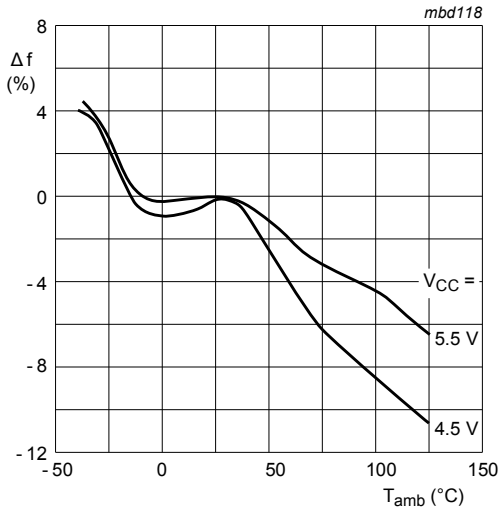


a. R1 = 300 kΩ; R2 = ∞ Ω; C1 = 100 pF.

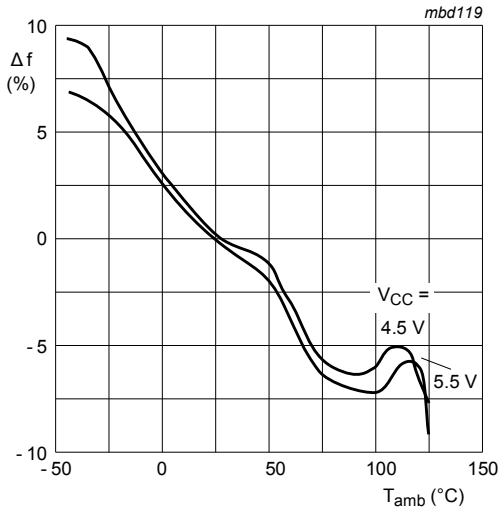


b. R1 = ∞ Ω; R2 = 3 kΩ; C1 = 100 pF.

Fig. 23. Frequency stability of the VCO as a function of ambient temperature with supply voltage as a parameter

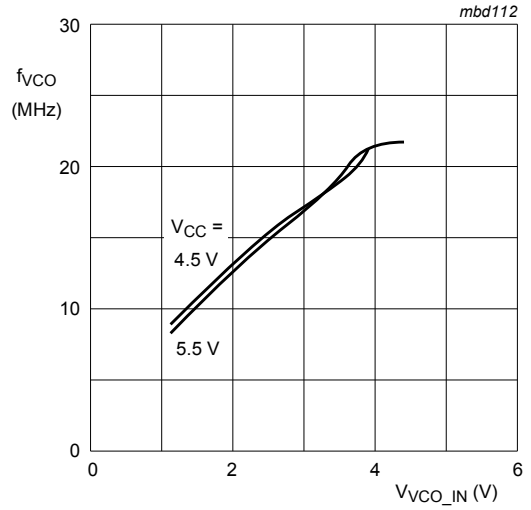


a. R1 = ∞ Ω; R2 = 10 kΩ; C1 = 100 pF.

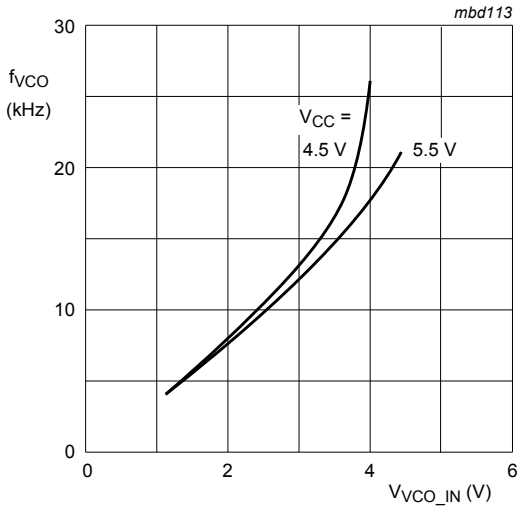


b. R1 = ∞ Ω; R2 = 300 kΩ; C1 = 100 pF.

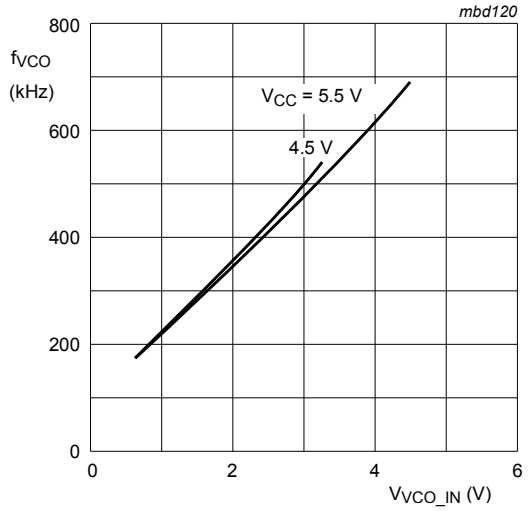
Fig. 24. Frequency stability of the VCO as a function of ambient temperature with supply voltage as a parameter



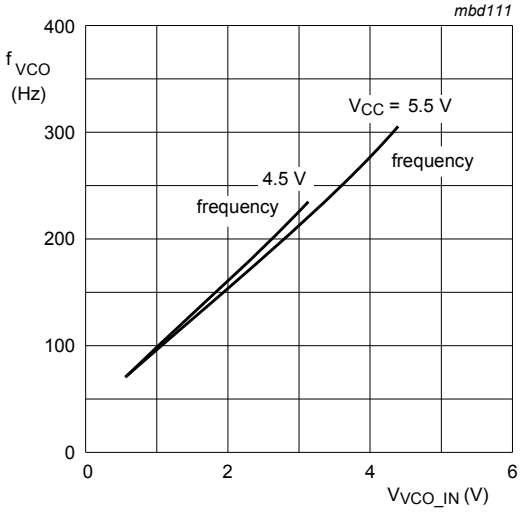
a. R1 = 4.3 kΩ; C1 = 39 pF.



b. R1 = 4.3 kΩ; C1 = 100 nF.

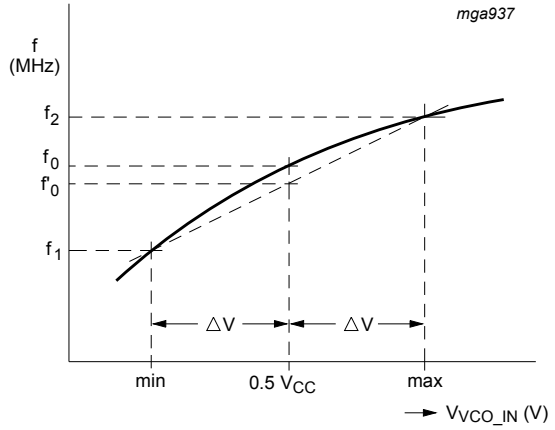


c. R1 = 300 kΩ; C1 = 39 pF.



d. R1 = 300 kΩ; C1 = 100 nF.

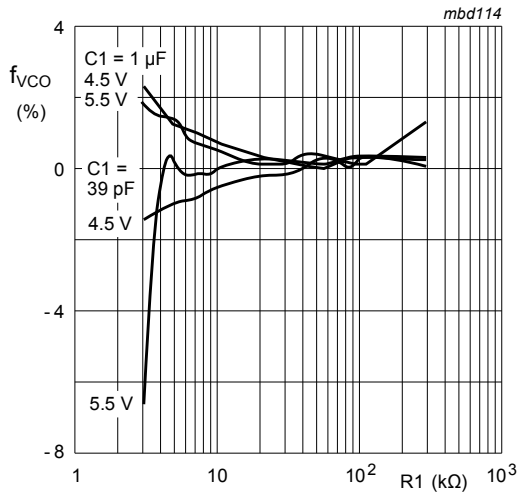
Fig. 25. Graphs showing VCO frequency as a function of the VCO input voltage (V_{VCO_IN})



$$f'_0 = \frac{f_1 + f_2}{2}$$

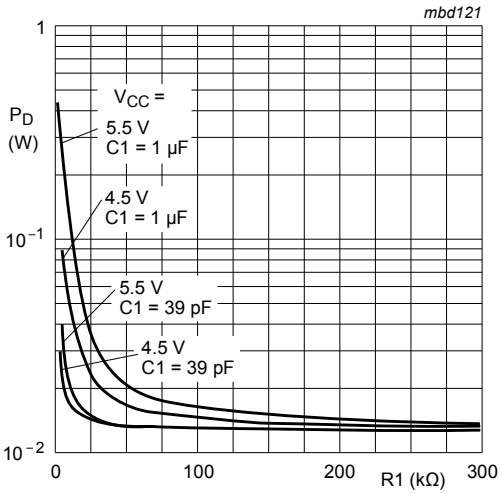
$$\text{linearity} = \frac{f'_0 - f_0}{f_0} \times 100\ \%$$

Fig. 26. Definition of VCO frequency linearity: ΔV = 0.5 V over the V_{CC} range



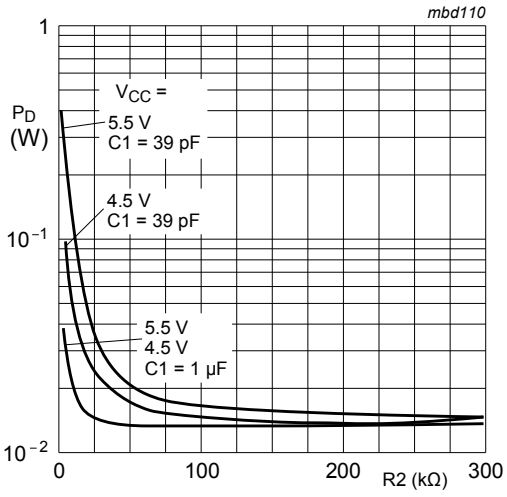
R2 = ∞ Ω and ΔV = 0.5 V

Fig. 27. Frequency linearity as a function of R1, C1 and V_{CC}



R2 = ∞ Ω

Fig. 28. Power dissipation as a function of R1



R1 = ∞ Ω

Fig. 29. Power dissipation as a function of R2

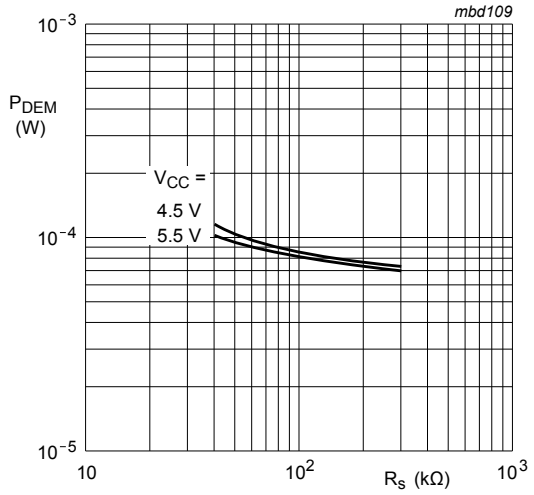


Fig. 30. Typical power dissipation as a function of R_S

12. Application information

This information is a guide for the approximation of values of external components to be used with the 74HCT9046A in a phase-locked-loop system.

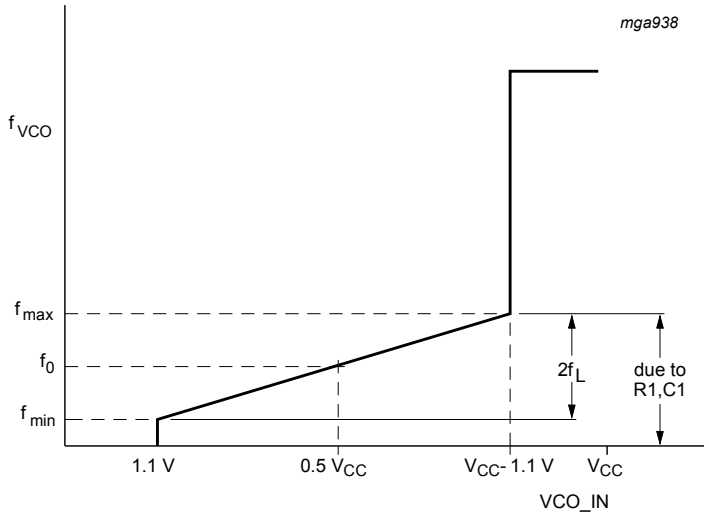
Values of the selected components should be within the ranges shown in Table 7.

Table 7. Survey of components

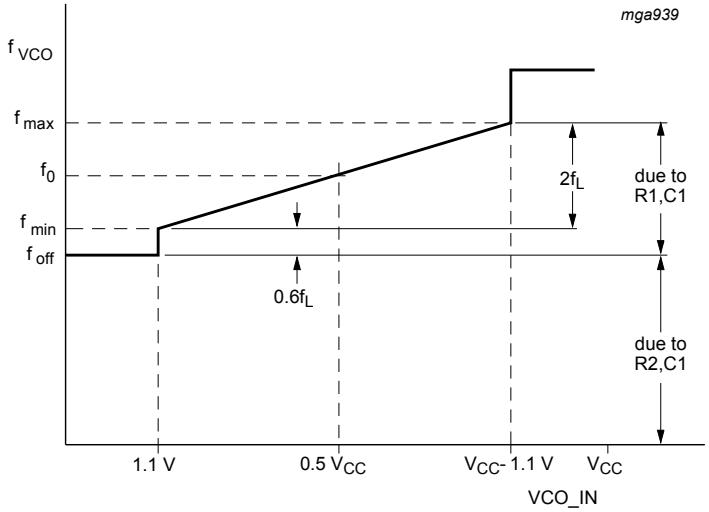
Component	Value
R1	between 3 kΩ and 300 kΩ
R2	between 3 kΩ and 300 kΩ
R1 + R2	parallel value > 2.7 kΩ
C1	> 40 pF

Table 8. Design considerations for VCO section

Subject	Phase comparator	Design consideration
VCO frequency **without extra offset**	PC1, PC2	VCO frequency characteristic. With R2 = ∞ and R1 within the range 3 kΩ < R1 < 300 kΩ, the characteristics of the VCO operation will be as shown in Fig. 31a. (Due to R1, C1 time constant a small offset remains when R2 = ∞ Ω).
	PC1	Selection of R1 and C1. Given f_0, determine the values of R1 and C1 using Fig. 33.
	PC2	Given f_{max} and f_0 determine the values of R1 and C1 using Fig. 33; use Fig. 35 to obtain $2f_L$ and then use this to calculate f_{min}.
VCO frequency **with extra offset**	PC1, PC2	VCO frequency characteristic. With R1 and R2 within the ranges 3 kΩ < R1 < 300 kΩ; 3 kΩ < R2 < 300 kΩ, the characteristics of the VCO operation is as shown in Fig. 31b.
	PC1, PC2	Selection of R1, R2 and C1. Given f_0 and f_L determine the value of product R1C1 by using Fig. 35. Calculate f_{off} from the equation $f_{off} = f_0 - 1.6f_L$. Obtain the values of C1 and R2 by using Fig. 34. Calculate the value of R1 from the value of C1 and the product R1C1.
PLL conditions with no signal at pin SIG_IN	PC1	VCO adjusts to f_0 with Φ_{PC_IN} = 90° and $V_{VCO\_IN} = 0.5V_{CC}$
	PC2	VCO adjusts to f_{offset} with Φ_{PC_IN} = -360° and V_{VCO_IN} = minimum



a. Operating without offset; f_0 = center frequency; $2f_L$ = frequency lock range.



b. Operating with offset; f_0 = center frequency; $2f_L$ = frequency lock range.

Fig. 31. Frequency characteristic of VCO

12.1. Filter design considerations for PC1 and PC2 of the 74HCT9046A

Fig. 32 shows some examples of passive and active filters to be used with the phase comparators of the 74HCT9046A. Transfer functions of phase comparators and filters are given in Table 9.

Table 9. Transfer functions of phase comparators and filters

Phase comparator	Explanation	Figure	Filter type	Transfer function
PC1	$K_{PC1} = \frac{V_{CC}}{\pi} V/r$	Fig. 32a	passive filter without damping	$F_{(j\omega)} = \frac{1}{1 + j\omega\tau_1}$
	τ_1 = R3 x C2; τ_2 = R4 x C2; τ_3 = R4 x C3; A = 10^5 = DC gain amplitude	Fig. 32b	passive filter with damping	$F_{(j\omega)} = \frac{1 + j\omega\tau_2}{1 + j\omega(\tau_1 + \tau_2)}$
		Fig. 32c	active filter with damping	$F_{(j\omega)} = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1} \approx \frac{1 + j\omega\tau_2}{j\omega\tau_1}$
PC2	$K_{PC} + \frac{5}{4\pi} V/r$ τ_1 = R3' x C2; τ_2 = R4 x C2; τ_3 = R4 x C3; R3' = R_{bias}/17; R_{bias} = 25 kΩ to 250 kΩ	Fig. 32d	passive filter with damping	$F_{(j\omega)} = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1} \approx \frac{1 + j\omega\tau_2}{j\omega\tau_1}$ A = 10^5 = DC gain amplitude
		Fig. 32e	active filter with damping	$F_{(j\omega)} = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1} \approx \frac{1 + j\omega\tau_2}{j\omega\tau_1}$ A = 10^5 = DC gain amplitude

Table 10. General design considerations

Subject	Phase comparator	Design consideration
PLL locks on harmonics at center frequency	PC1	yes
	PC2	no
Noise rejection at signal input	PC1	high
	PC2	low
AC ripple content when PLL is locked	PC1	$f_r = 2f_i$; large ripple content at $\Phi_{PC\_IN} = 90°$
	PC2	$f_r = f_i$; small ripple content at $\Phi_{PC\_IN} = 0°$

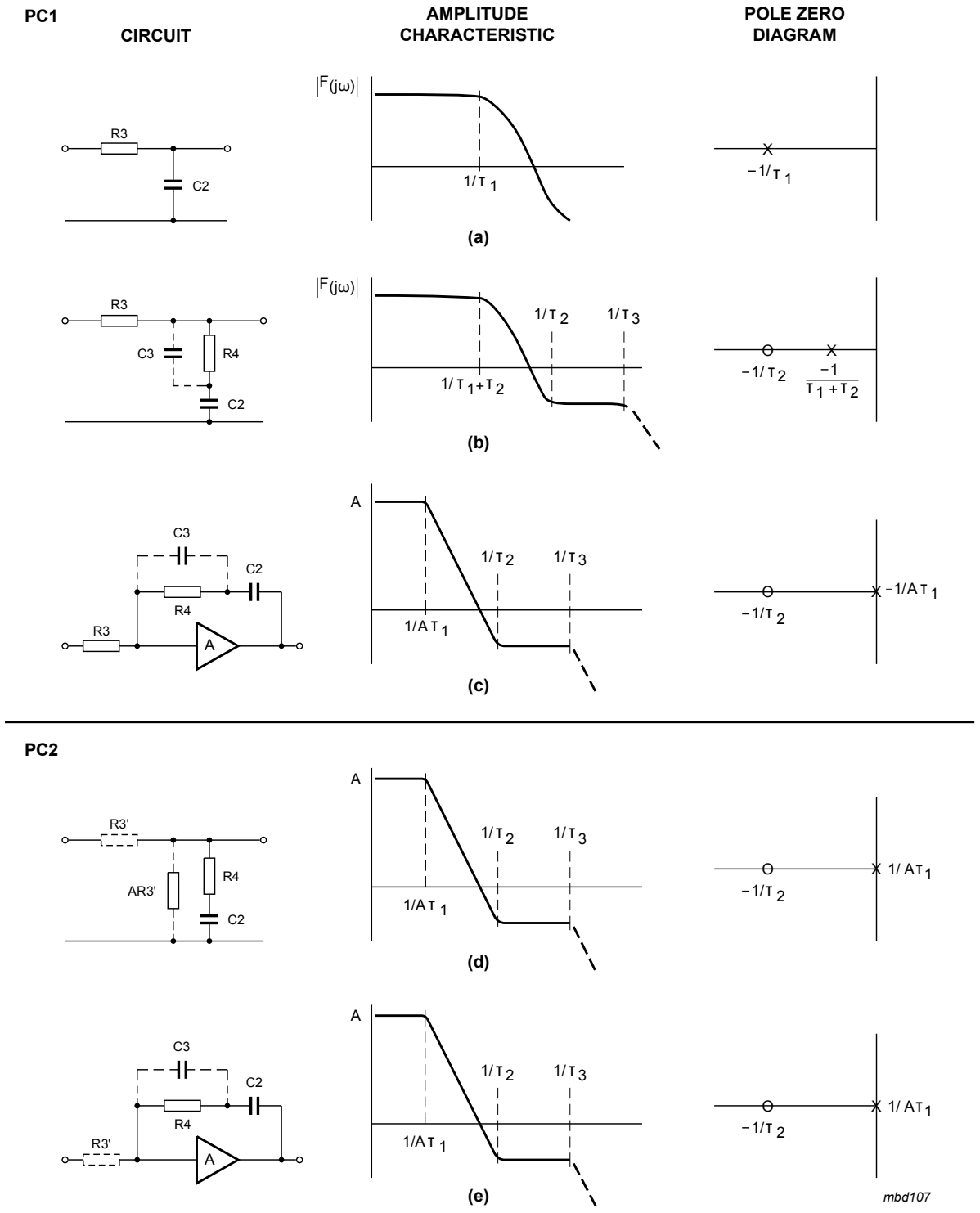
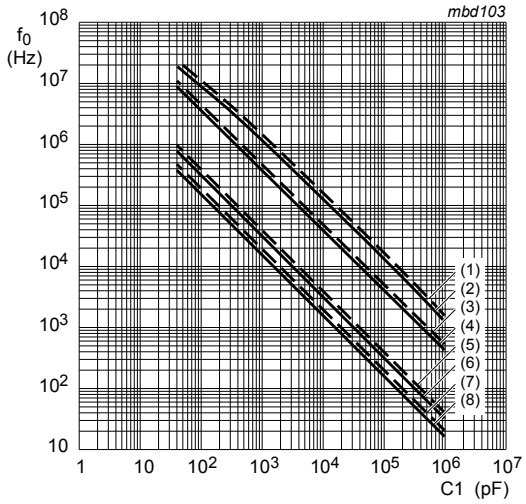
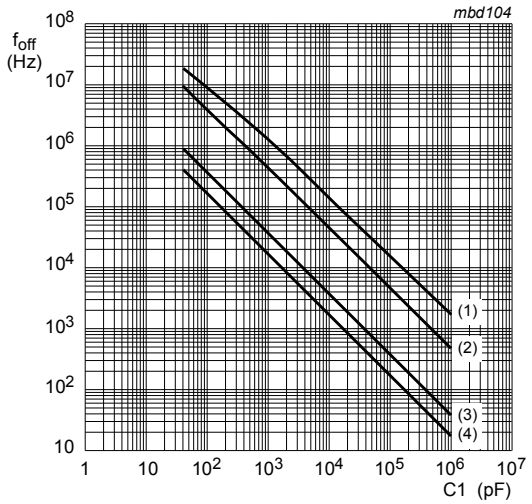


Fig. 32. Passive and active filters for 74HCT9046A



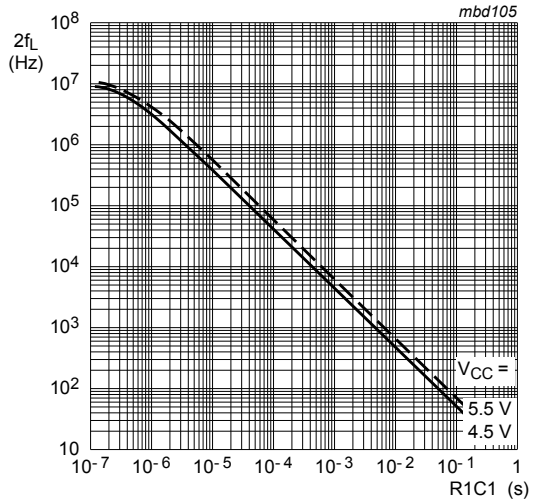
(1) V_{CC} = 5.5 V; R1 = 3 kΩ.
(2) V_{CC} = 4.5 V; R1 = 3 kΩ.
(3) V_{CC} = 5.5 V; R1 = 10 kΩ.
(4) V_{CC} = 4.5 V; R1 = 10 kΩ.
(5) V_{CC} = 5.5 V; R1 = 150 kΩ.
(6) V_{CC} = 4.5 V; R1 = 150 kΩ.
(7) V_{CC} = 5.5 V; R1 = 300 kΩ.
(8) V_{CC} = 4.5 V; R1 = 300 kΩ.
R2 = ∞ Ω; V_{VCO_IN} = 0.5V_{CC}; INH = GND; T_{amb} = 25 °C.

Fig. 33. Typical value of VCO center frequency (f_0) as a function of C1



(1) V_{CC} = 4.5 V to 5.5 V; R1 = 3 kΩ.
(2) V_{CC} = 4.5 V to 5.5 V; R1 = 10 kΩ.
(3) V_{CC} = 4.5 V to 5.5 V; R1 = 150 kΩ.
(4) V_{CC} = 4.5 V to 5.5 V; R1 = 300 kΩ.
R1 = ∞ Ω; V_{VCO_IN} = 0.5V_{CC}; INH = GND; T_{amb} = 25 °C.

Fig. 34. Typical value of frequency offset as a function of C1



$$K_v = \frac{2f_L}{V_{VCO\_IN}\ \text{range}} 2\pi(r / s / V)$$

V_{VCO_IN} = 1.1 V to (V_{CC} - 1.1) V

Fig. 35. Typical frequency lock range $2f_L$ as a function of the product R1 and C1

12.2. PLL design example

The frequency synthesizer used in the design example shown in Fig. 36 has the following parameters:

- Output frequency: 2 MHz to 3 MHz
- Frequency steps: 100 kHz
- Settling time: 1 ms
- Overshoot: < 20 %

The open loop gain is:

$$H(s) \times G(s) = K_p \times K_f \times K_o \times K_n$$

and the closed loop:

$$\frac{\Phi_u}{\Phi_i} = \frac{K_p \times K_f \times K_o \times K_n}{1 + K_p \times K_f \times K_o \times K_n}$$

where:

- K_p = phase comparator gain
- K_f = low-pass filter transfer gain
- K_o = K_v/s VCO gain
- K_n = $^1/_n$ divider ratio

The programmable counter ratio K_n can be found as follows:

$$N_{\min} = \frac{f_{\text{OUT}}}{f_{\text{step}}} = \frac{2\ MHz}{100\ kHz} = 20$$

$$N_{\max} = \frac{f_{\text{OUT}}}{f_{\text{step}}} = \frac{3\ MHz}{100\ kHz} = 30$$

The VCO is set by the values of R1, R2 and C1; R2 = 10 kΩ (adjustable).

The values can be determined using the information in Table 8.

With f_0 = 2.5 MHz and f_L = 500 kHz this gives the following values (V_{CC} = 5.0 V):

- R1 = 30 kΩ
- R2 = 30 kΩ
- C1 = 100 pF

The VCO gain is:

$$K_v = \frac{2f_L \times 2\pi}{(V_{CC} - 1.1) - 1.1} = \frac{1\ \text{MHz}}{2.8} \times 2\pi \approx 2.24 \times 10^6 r / s / V$$

The gain of the phase comparator PC2 is:

$$K_p = \frac{5}{4 \times \pi} = 0.4\ V / r$$

Using PC2 with the passive filter as shown in Fig. 36 results in a high gain loop with the same performance as a loop with an active filter. Hence loop filter equations as for a high gain loop should be used. The current source output of PC2 can be simulated then with a fictive filter resistance:

$$R3' = \frac{R_{bias}}{17}$$

The transfer functions of the filter is given by:

$$K_f = \frac{1 + s\tau_2}{s\tau_2}$$

Where:

$$\tau_1 = R3' \times C2$$

$$\tau_2 = R4 \times C2$$

The characteristic equation is: $1 + K_p \times K_f \times K_o \times K_n$

This results in:

$$1 + K_p\left(\frac{1 + s\tau_2}{s\tau_1}\right)\frac{K_v}{s}K_n = 0$$

or:

$$s^2 + sK_pK_vK_n\frac{\tau_2}{\tau_1} + K_pK_vK_n / \tau_1 = 0$$

This can be written as:

$$s^2 + 2\xi\omega_n s + (\omega_n)^2 = 0$$

with the natural frequency ω_n defined as:

$$\omega_n = \sqrt{\frac{K_p \times K_v \times K_n}{\tau_1}}$$

and the damping value given as: $\zeta = 0.5 \times \tau_2 \times \omega_n$

In Fig. 37 the output frequency response to a step of input frequency is shown.

The overshoot and settling time percentages are now used to determine ω_n. From Fig. 37 it can be seen that the damping ratio $\zeta = 0.707$ will produce an overshoot of less than 20 % and settle to within 5 % at $\omega_n t = 5$. The required settling time is 1 ms. This results in:

$$\omega_n = \frac{5}{t} = \frac{5}{0.001} = 5 \times 10^3 r / s$$

Rewriting the equation for natural frequency results in:

$$\tau_1 = \frac{K_p \times K_v \times K_n}{(\omega_n)^2}$$

The maximum overshoot occurs at $N_{max} = 30$; hence $K_n = {}^1\!/_{30}$:

$$\tau_1 = \frac{0.4 \times 2.24 \times 10^6}{5000^2 \times 30} = 0.0012$$

When C2 = 470 nF, it follows:

$$R3' = \frac{\tau_1}{C2} = \frac{0.0012}{470 \times 10^{-9}} = 2550\ \Omega$$

Hence the current source bias resistance

$$R_{bias} = 17 \times 2550 = 43\ k\Omega$$

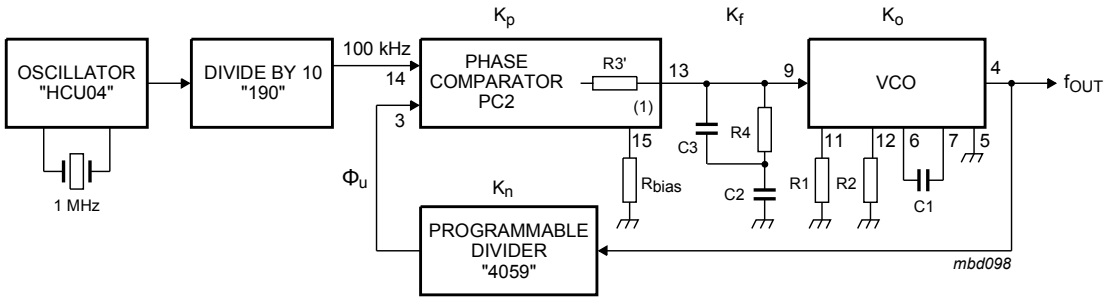
With $\zeta = 0.707$ ($0.5 \times \tau_2 \times \omega_n$) it follows:

$$\tau_2 = \frac{0.707}{0.5 \times 5000} = 0.00028$$

$$R4 = \frac{\tau_2}{C2} = \frac{0.00028}{470 \times 10^{-9}} = 600\ \Omega$$

For extra ripple suppression a capacitor C3 can be connected in parallel with R4, with an extra τ_3 = R4 x C3.

For stability reasons τ_3 should be < $0.1\tau_2$, hence C3 < 0.1C2 or C3 = 39 nF.



(1) R3'= fictive resistance

R3' = $\frac{R_{bias}}{17}$

C1 = 100 pF

C2 = 470 nF

C3 = 39 nF

R1 = 30 kΩ

R2 = 30 kΩ

R3' = 2 550 Ω

R_{bias} = 43 kΩ

R4 = 600 Ω

Fig. 36. Frequency synthesizer

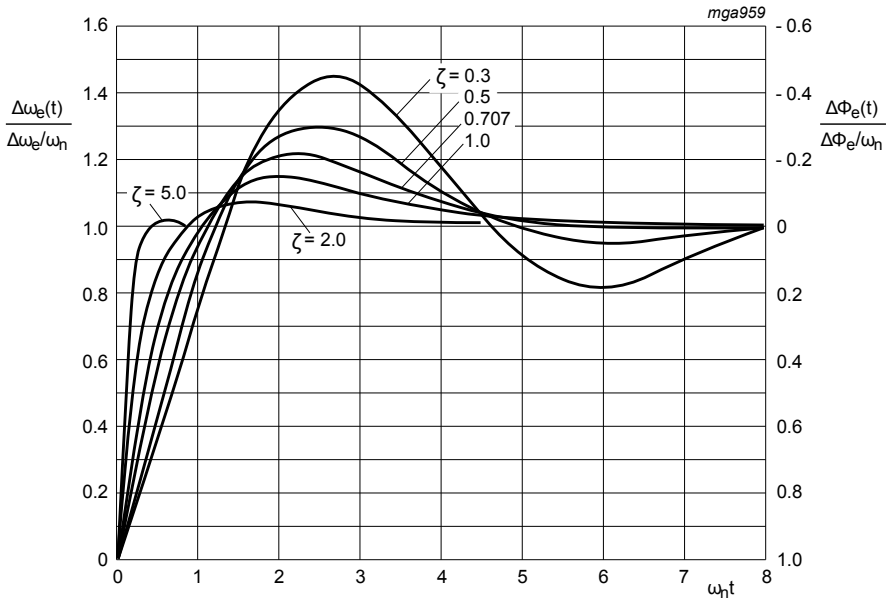


Fig. 37. Type 2, second order frequency step response

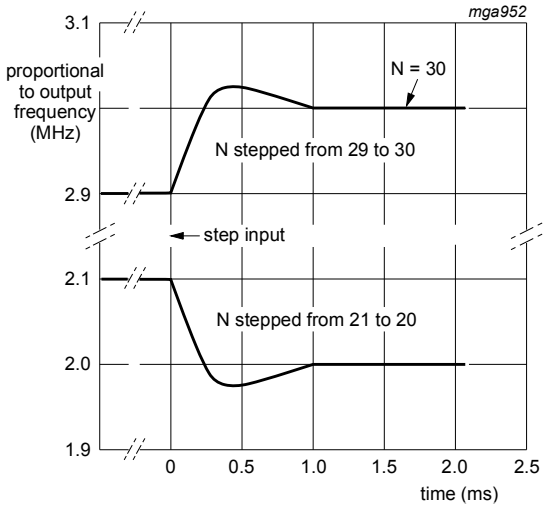
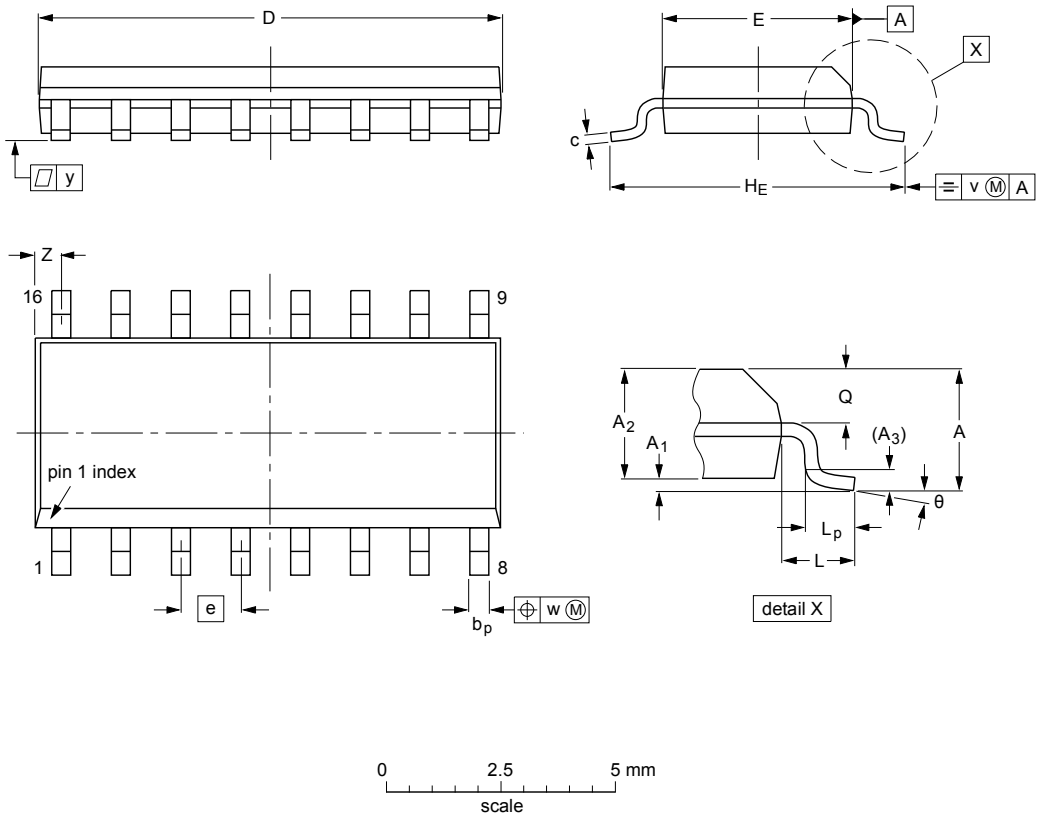


Fig. 38. Frequency compared to the time response

Since the output frequency is proportional to the VCO control voltage, the PLL frequency response can be observed with an oscilloscope by monitoring pin VCO_IN of the VCO. The average frequency response, as calculated by the Laplace method, is found experimentally by smoothing this voltage at pin VCO_IN with a simple RC filter, whose time constant is long compared with the phase detector sampling rate but short compared with the PLL response time.

13. Package outline

SO16: plastic small outline package; 16 leads; body width 3.9 mm **SOT109-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(1)}$	e	H_E	L	L_p	Q	v	w	y	$Z^{(1)}$	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	10.0 9.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8^o 0^o
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.39 0.38	0.16 0.15	0.05	0.244 0.228	0.041	0.039 0.016	0.028 0.020	0.01	0.01	0.004	0.028 0.012	

Note

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT109-1	076E07	MS-012				~~99-12-27~~ 03-02-19

Fig. 39. Package outline SOT109-1 (SO16)

14. Abbreviations

Table 11. Abbreviations

Acronym	Description
CMOS	Complementary Metal Oxide Semiconductor
DUT	Device Under Test
ESD	ElectroStatic Discharge
HBM	Human Body Model
MM	Machine Model
PLL	Phase Locked Loop
TTL	Transistor-Transistor Logic
VCO	Voltage Controlled Oscillator

15. Revision history

Table 12. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
74HCT9046A v.8	20190131	Product data sheet	-	74HCT9046A v.7
Modifications:	• The format of this data sheet has been redesigned to comply with the identity guidelines of Nexperia. • Legal texts have been adapted to the new company name where appropriate. • Type number 74HCT9046APW (SOT403-1/TSSOP16) removed.			
74HCT9046A v.7	20160229	Product data sheet	-	74HCT9046A v.6
Modifications:	• Type number 74HCT9046AN (SOT38-4) removed.			
74HCT9046A v.6	20090915	Product data sheet	-	74HCT9046A v.5
Modifications:	• The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors. • Legal texts have been adapted to the new company name where appropriate. • $V_{i(p-p)}$ value changed from 15 mV to 50 mV in Section 11. • $\Delta f/\Delta T$ value moved from minimum to typical column Section 11. • Package version SOT38-1 changed to SOT38-4.			
74HCT9046A v.5	20031030	Product specification	-	74HCT9046A v.4
74HCT9046A v.4	20030515	Product specification	-	74HCT9046A v.3
74HCT9046A v.3	19990111	Product specification	-	-

16. Legal information

Data sheet status

Document status [1][2]	Product status [3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the internet at https://www.nexperia.com.

Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. Nexperia does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

Short data sheet — A short data sheet is an extract from a full data sheet with the same product type number(s) and title. A short data sheet is intended for quick reference only and should not be relied upon to contain detailed and full information. For detailed and full information see the relevant full data sheet, which is available on request via the local Nexperia sales office. In case of any inconsistency or conflict with the short data sheet, the full data sheet shall prevail.

Product specification — The information and data provided in a Product data sheet shall define the specification of the product as agreed between Nexperia and its customer, unless Nexperia and customer have explicitly agreed otherwise in writing. In no event however, shall an agreement be valid in which the Nexperia product is deemed to offer functions and qualities beyond those described in the Product data sheet.

Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, Nexperia does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. Nexperia takes no responsibility for the content in this document if provided by an information source outside of Nexperia.

In no event shall Nexperia be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, Nexperia's aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of Nexperia.

Right to make changes — Nexperia reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — Nexperia products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an Nexperia product can reasonably be expected to result in personal injury, death or severe property or environmental damage. Nexperia and its suppliers accept no liability for inclusion and/or use of Nexperia products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Quick reference data — The Quick reference data is an extract of the product data given in the Limiting values and Characteristics sections of this document, and as such is not complete, exhaustive or legally binding.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. Nexperia makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using Nexperia products, and Nexperia accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the Nexperia product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

Nexperia does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using Nexperia products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). Nexperia does not accept any liability in this respect.

Limiting values — Stress above one or more limiting values (as defined in the Absolute Maximum Ratings System of IEC 60134) will cause permanent damage to the device. Limiting values are stress ratings only and (proper) operation of the device at these or any other conditions above those given in the Recommended operating conditions section (if present) or the Characteristics sections of this document is not warranted. Constant or repeated exposure to limiting values will permanently and irreversibly affect the quality and reliability of the device.

Terms and conditions of commercial sale — Nexperia products are sold subject to the general terms and conditions of commercial sale, as published at http://www.nexperia.com/profile/terms, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. Nexperia hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of Nexperia products by customer.

No offer to sell or license — Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Non-automotive qualified products — Unless this data sheet expressly states that this specific Nexperia product is automotive qualified, the product is not suitable for automotive use. It is neither qualified nor tested in accordance with automotive testing or application requirements. Nexperia accepts no liability for inclusion and/or use of non-automotive qualified products in automotive equipment or applications.

In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without Nexperia's warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond Nexperia's specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies Nexperia for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond Nexperia's standard warranty and Nexperia's product specifications.

Translations — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

Contents

For more information, please visit: http://www.nexperia.com
For sales office addresses, please send an email to: salesaddresses@nexperia.com
Date of release: 31 January 2019