

# 74HC4046A; 74HCT4046A

## Phase-locked loop with VCO

Rev. 3 — 8 June 2016

Product data sheet

### 1. General description

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The 74HC4046A; 74HCT4046A is a high-speed Si-gate CMOS device. It is specified in compliance with JEDEC standard no 7A.

### 2. Features and benefits

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- Low power consumption
- VCO-Inhibit control for ON/OFF keying and for low standby power consumption
- Center frequency up to 17 MHz (typical) at  $V_{CC} = 4.5\text{ V}$
- Choice of three phase comparators:
  - ◆ PC1: EXCLUSIVE-OR
  - ◆ PC2: Edge-triggered J-K flip-flop
  - ◆ PC3: Edge-triggered RS flip-flop
- Excellent Voltage Controlled Oscillator (VCO) linearity
- Low frequency drift with supply voltage and temperature variations
- Operating power supply voltage range:
  - ◆ VCO section 3.0 V to 6.0 V
  - ◆ Digital section 2.0 V to 6.0 V
- 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

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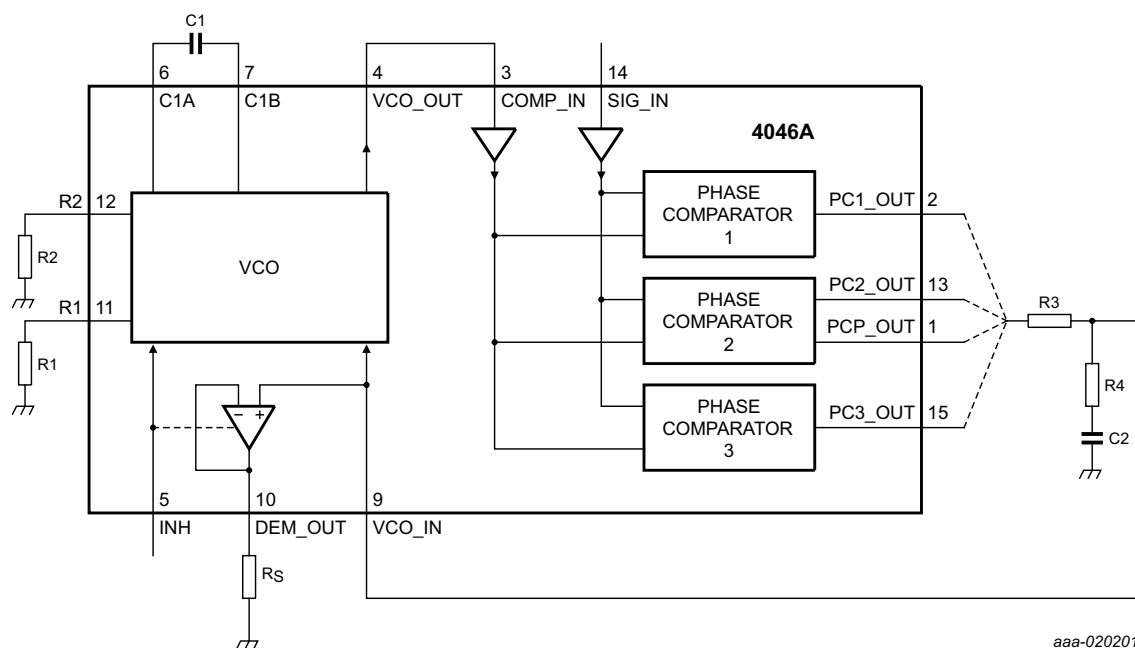
- FM modulation and demodulation
- Frequency synthesis and multiplication
- Frequency discrimination
- Tone decoding
- Data synchronization and conditioning
- Voltage-to-frequency conversion
- Motor-speed control

#### 4. Ordering information

### Table 1. Ordering information

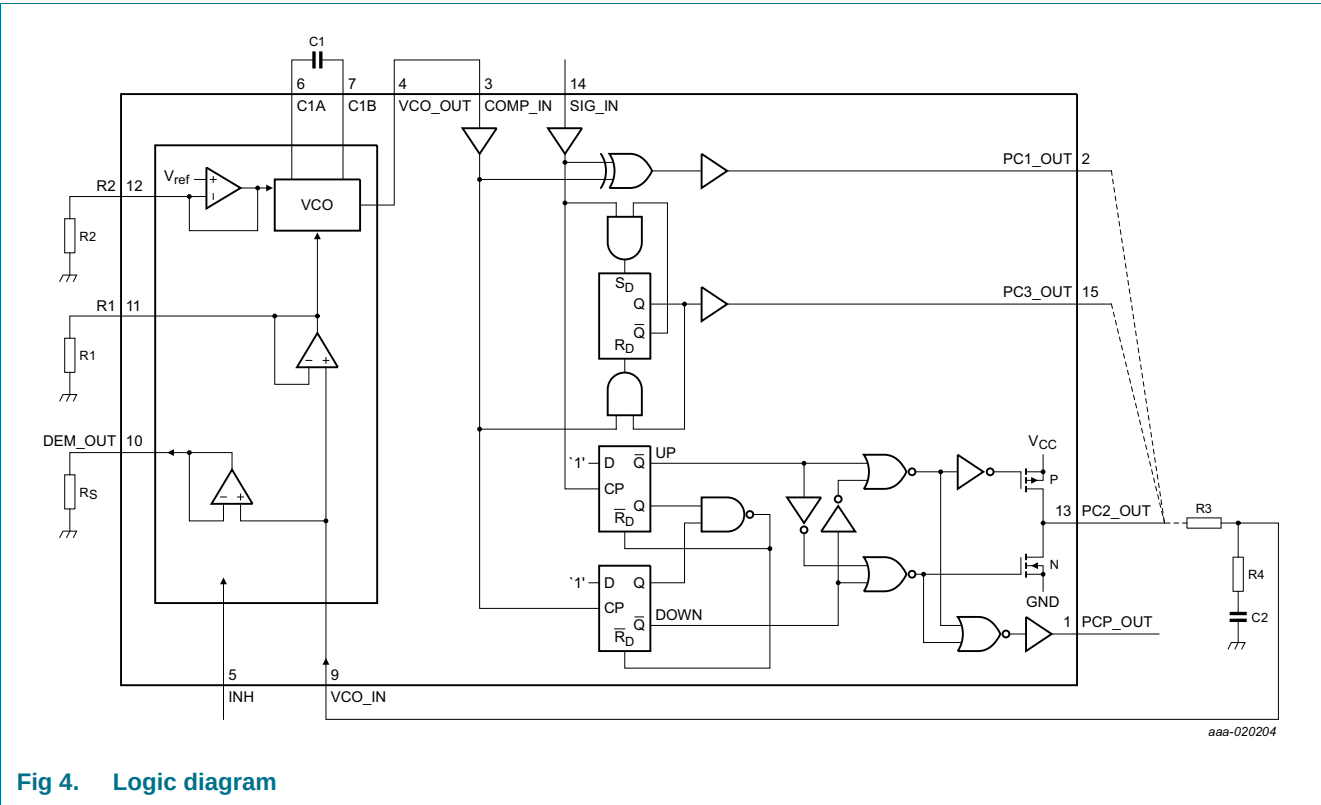
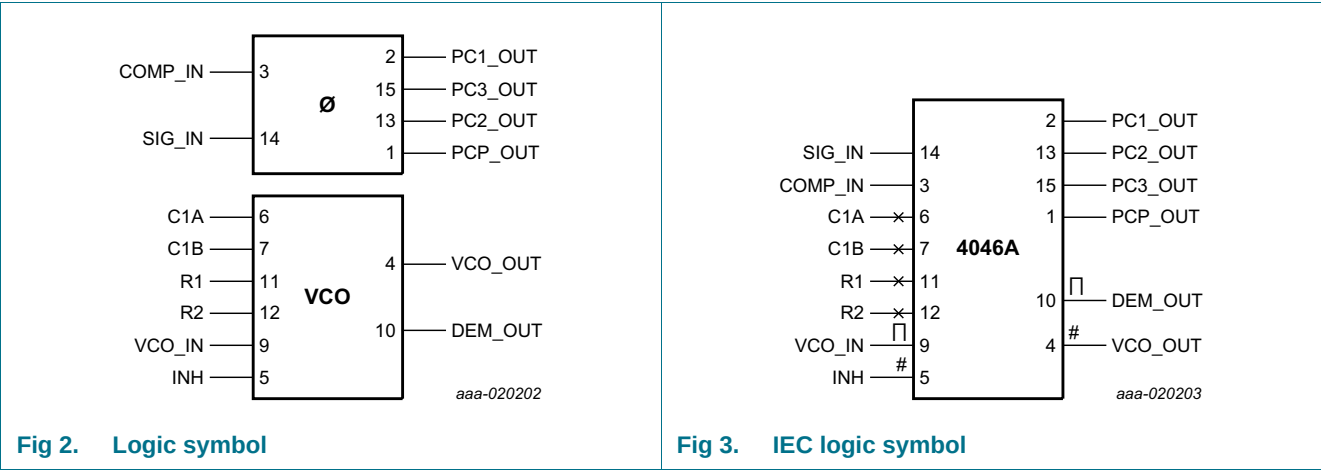
| Type number  | Package |                                                                        |          |
|--------------|---------|------------------------------------------------------------------------|----------|
|              | Name    | Description                                                            | Version  |
| 74HC4046AD   | SO16    | plastic small outline package; 16 leads; body width 3.9 mm             | SOT109-1 |
| 74HCT4046AD  |         |                                                                        |          |
| 74HC4046ADB  | SSOP16  | plastic shrink small outline package; 16 leads; body width 5.3 mm      | SOT338-1 |
| 74HCT4046ADB |         |                                                                        |          |
| 74HC4046APW  | TSSOP16 | plastic thin shrink small outline package; 16 leads; body width 4.4 mm | SOT403-1 |

## 5. Block diagram



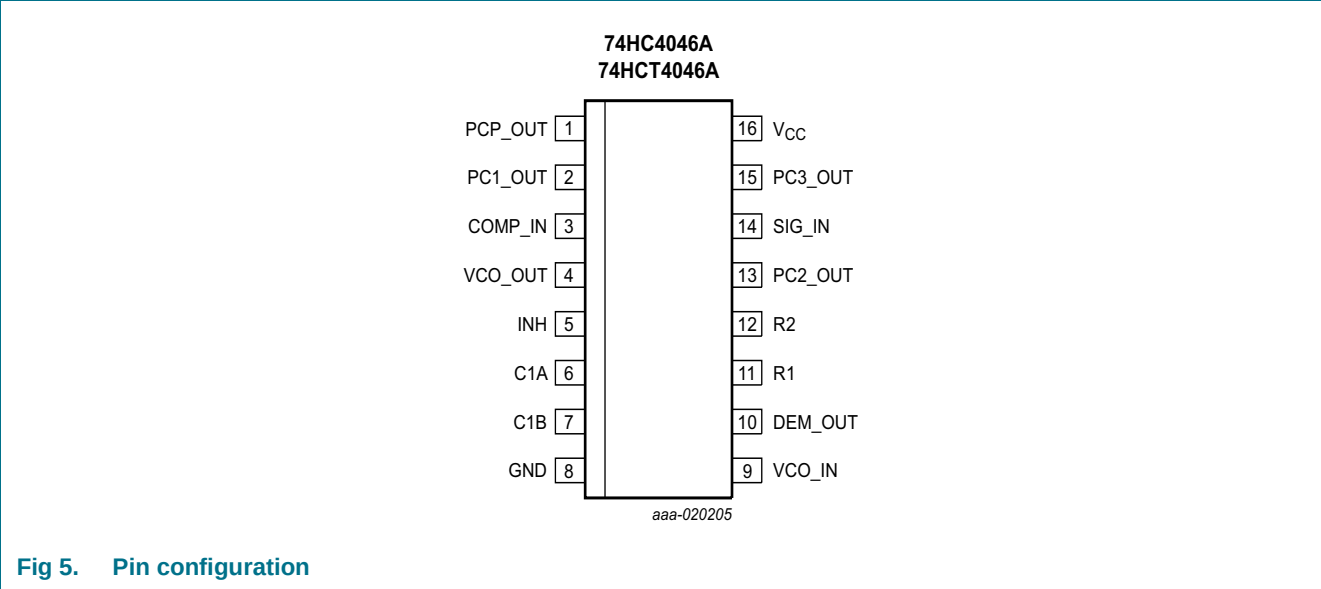
**Fig 1. Block diagram**

6. Functional diagram



7. Pinning information

7.1 Pinning



7.2 Pin description

Table 2. Pin description

| Symbol          | Pin | Description                   |
|-----------------|-----|-------------------------------|
| PCP_OUT         | 1   | phase comparator pulse output |
| PC1_OUT         | 2   | phase comparator 1 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_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     |
| SIG_IN          | 14  | signal input                  |
| PC3_OUT         | 15  | phase comparator 3 output     |
| V <sub>CC</sub> | 16  | supply voltage                |

## 8. Functional description

The 74HC4046A; 74HCT4046A is a phase-locked-loop circuit that comprises a linear voltage-controlled oscillator (VCO) and three different phase comparators (PC1, PC2 and PC3). It has a common signal input amplifier and a common comparator input (see [Figure 1](#)). The signal input can be directly coupled to a large voltage signal, or indirectly coupled (with a series capacitor) to a small voltage signal. A self-bias input circuit keeps small voltage signals within the linear region of the input amplifiers. With a passive low-pass filter, the 74HC4046A; 74HCT4046A forms a second-order loop PLL. The excellent VCO linearity is achieved by the use of linear op amp techniques.

### 8.1 VCO

The VCO requires one external capacitor C1 (between pins C1A and C1B) and one external resistor R1 (between pins R1 and GND). Alternatively, it requires 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 necessary (see [Figure 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. In contrast to conventional techniques, where the DEM\_OUT voltage is one threshold voltage lower than the VCO input voltage, the DEM\_OUT voltage equals 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. When the VCO input DC level is held constant, the VCO output signal has a duty cycle of 50 % (maximum expected deviation 1 %). 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.

The only difference between the 74HC4046A and 74HCT4046A is the input level specification of the INH input. This input disables the VCO section. The sections of the comparator are identical, so that there is no difference in the SIG\_IN or COMP\_IN inputs between the 74HC4046A and 74HCT4046A.

### 8.2 Phase comparators

The input signal can be coupled to the self-biasing amplifier at pin SIG\_IN, when the signal swing is between the standard HC family input logic levels. Capacitive coupling is required for signals with smaller swings.

### 8.2.1 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:

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

where:

$V_{DEM\_OUT}$  is the demodulator output at pin DEM\_OUT

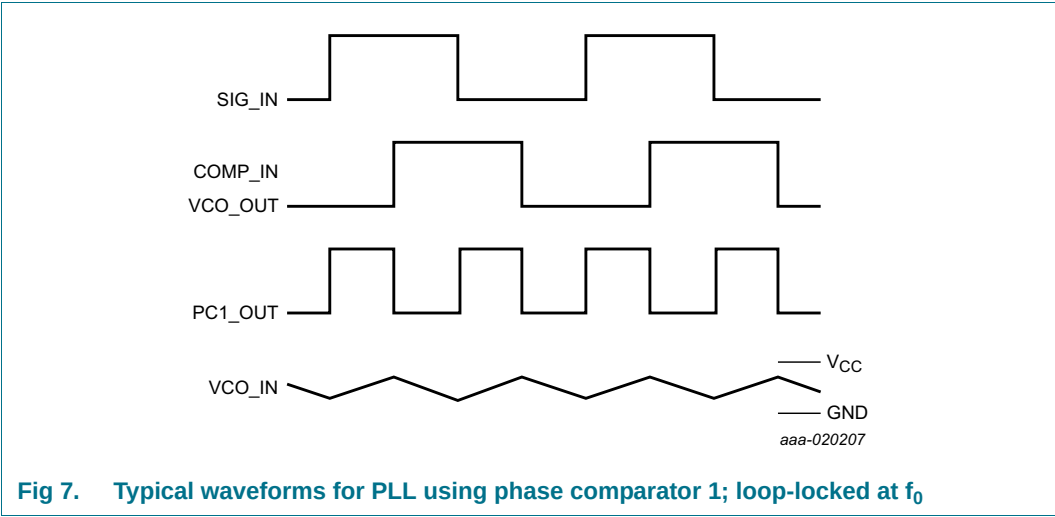
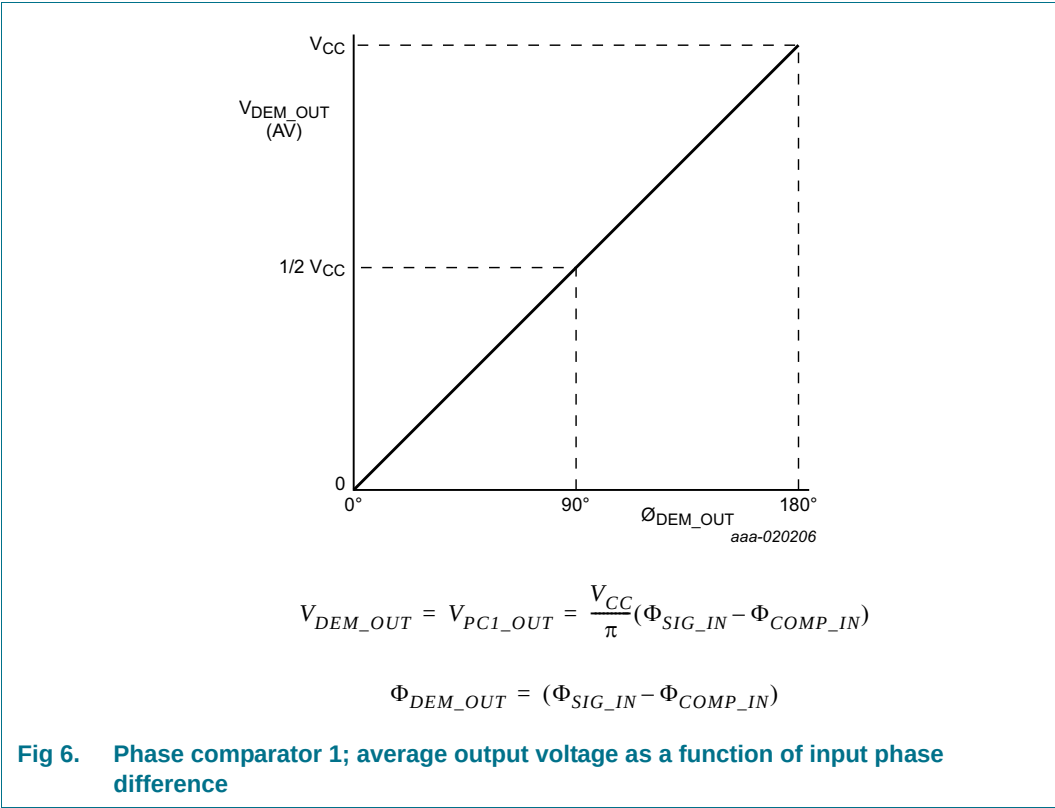
$V_{DEM\_OUT} = V_{PC1\_OUT}$  (via low-pass filter)

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

PC1 is fed to the VCO input via the low-pass filter and seen at the demodulator output at pin DEM\_OUT ( $V_{DEM\_OUT}$ ). The average output voltage from PC1 is the result of the phase differences of signals (SIG\_IN) and the comparator input (COMP\_IN). These phase differences are shown in [Figure 6](#). The average of  $V_{DEM\_OUT}$  is equal to  $0.5V_{CC}$  when there is no signal or noise at SIG\_IN. Using 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 7](#).

The frequency capture range ( $2f_c$ ) is defined as the frequency range of input signals on which the PLL locks when it was initially out-of-lock. The frequency lock range ( $2f_L$ ) is the frequency range of the input signals on which the loop stays locked when 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 can lock to input frequencies close to the harmonics of the VCO center frequency.



### 8.2.2 Phase Comparator 2 (PC2)

PC2 is a positive edge-triggered phase and frequency detector. When the PLL uses this comparator, positive signal transitions control the loop 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. The circuit functions as an up-down counter (see [Figure 4](#)) 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:

$$V_{DEM\_OUT} = \frac{V_{CC}}{4\pi}(\Phi_{SIG\_IN} - \Phi_{COMP\_IN})$$

where:

$V_{DEM\_OUT}$  is the demodulator output at pin DEM\_OUT

$V_{DEM\_OUT} = V_{PC2\_OUT}$  (via low-pass filter)

The phase comparator gain is:  $K_p = \frac{V_{CC}}{4\pi}(V/r)$

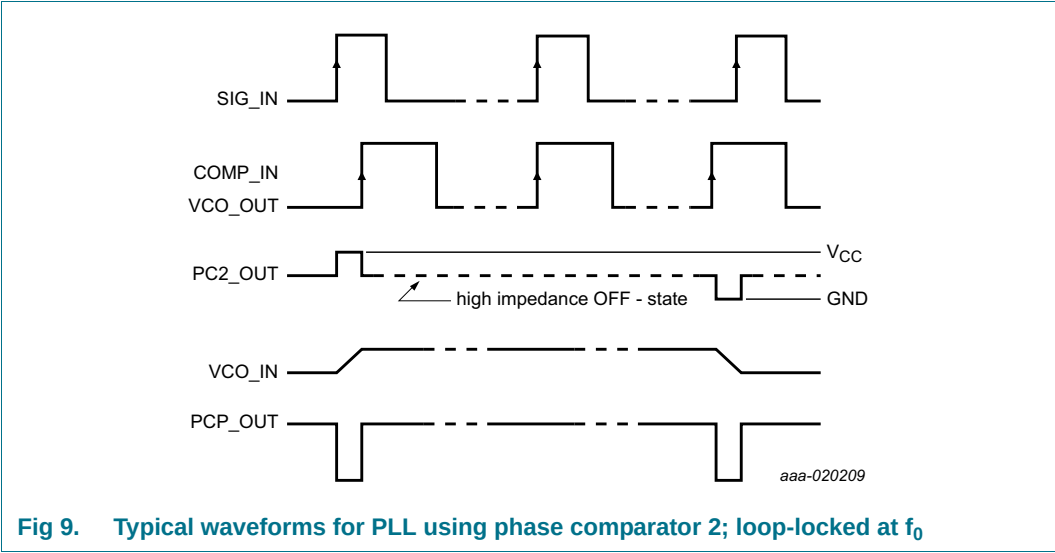
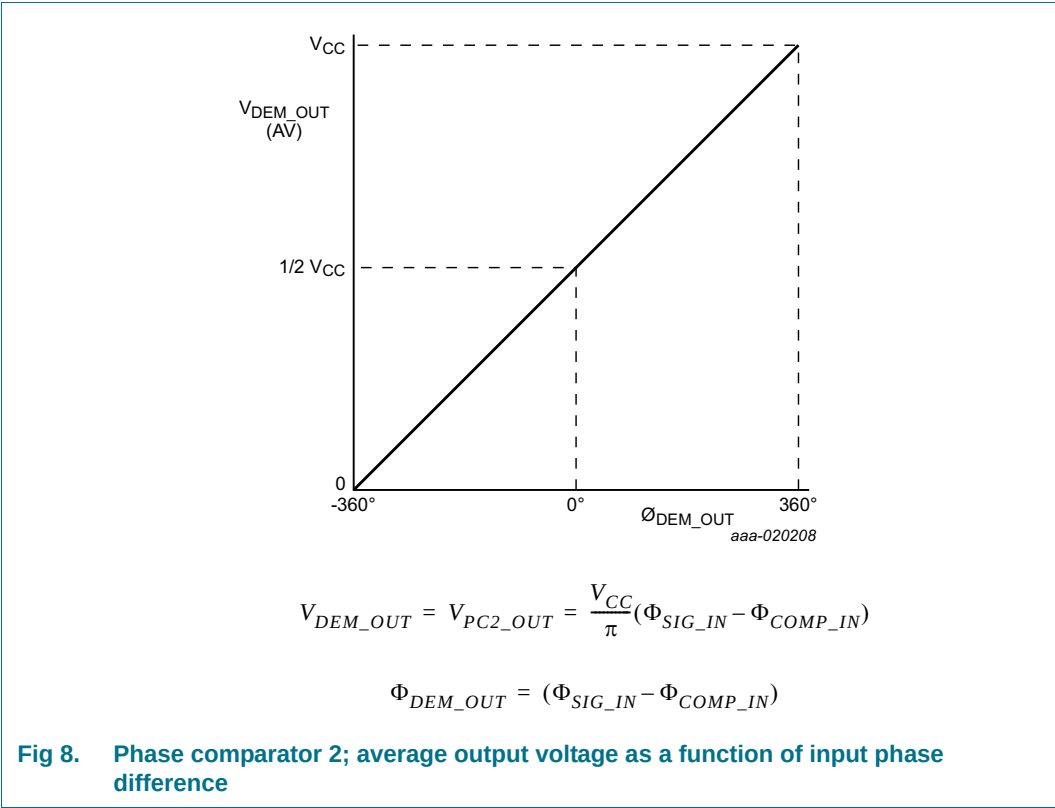
$V_{DEM\_OUT}$  is the resultant of the initial phase differences of SIG\_IN and COMP\_IN as shown in [Figure 8](#). Typical waveforms for the PC2 loop locked at  $f_0$  are shown in [Figure 9](#).

When the SIG\_IN and COMP\_IN frequencies are equal but the phase of SIG\_IN leads that of COMP\_IN, the p-type output driver at PC2\_OUT is held 'ON'. The time that it is held 'ON' corresponds to the phase difference ( $\Phi_{DEM\_OUT}$ ). When the phase of SIG\_IN lags that of COMP\_IN, the n-type driver is held 'ON'.

When the SIG\_IN frequency is higher than the COMP\_IN frequency, the p-type output driver is held 'ON' for most of the input signal cycle time. For the remainder of the cycle time, both n- and p-type drivers are 'OFF' (3-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. The voltage at capacitor (C2) of the low-pass filter, connected to PC2\_OUT, varies until the phase and frequency of the signal and comparator inputs are equal. At this stable point, the voltage on C2 remains constant as the PC2 output is in 3-state and the VCO\_IN input is in a high-impedance state. In this condition, the signal at the phase comparator pulse output (PCP\_OUT) is a HIGH level and 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. The power dissipation due to the low-pass filter is reduced because both n- and p-type output drivers are 'OFF' for most of the signal input cycle. 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.





### 8.2.3 Phase Comparator 3 (PC3)

PC3 is a positive edge-triggered sequential phase detector using an RS-type flip-flop. When the PLL is using this comparator, positive signal transitions control the loop 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:

$$V_{DEM\_OUT} = \frac{V_{CC}}{2\pi}(\Phi_{SIG\_IN} - \Phi_{COMP\_IN})$$

where:

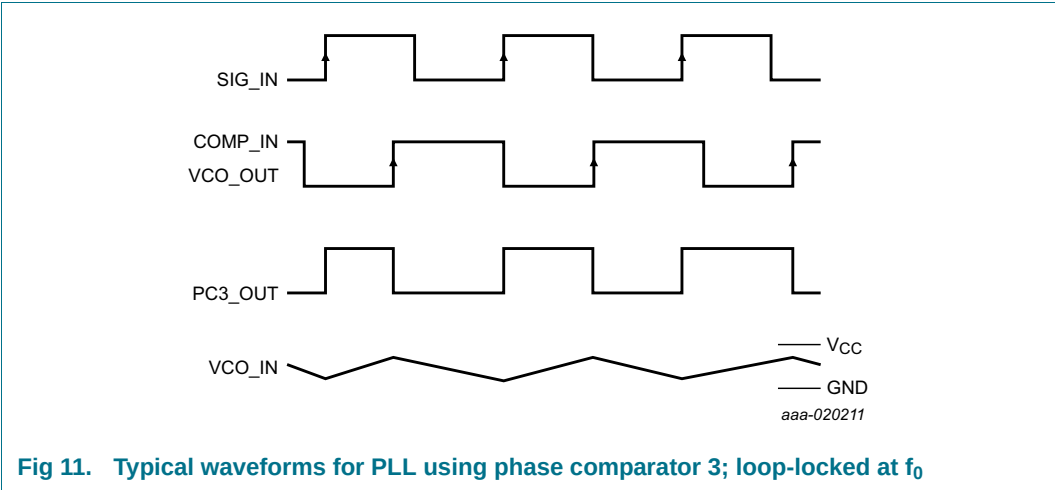
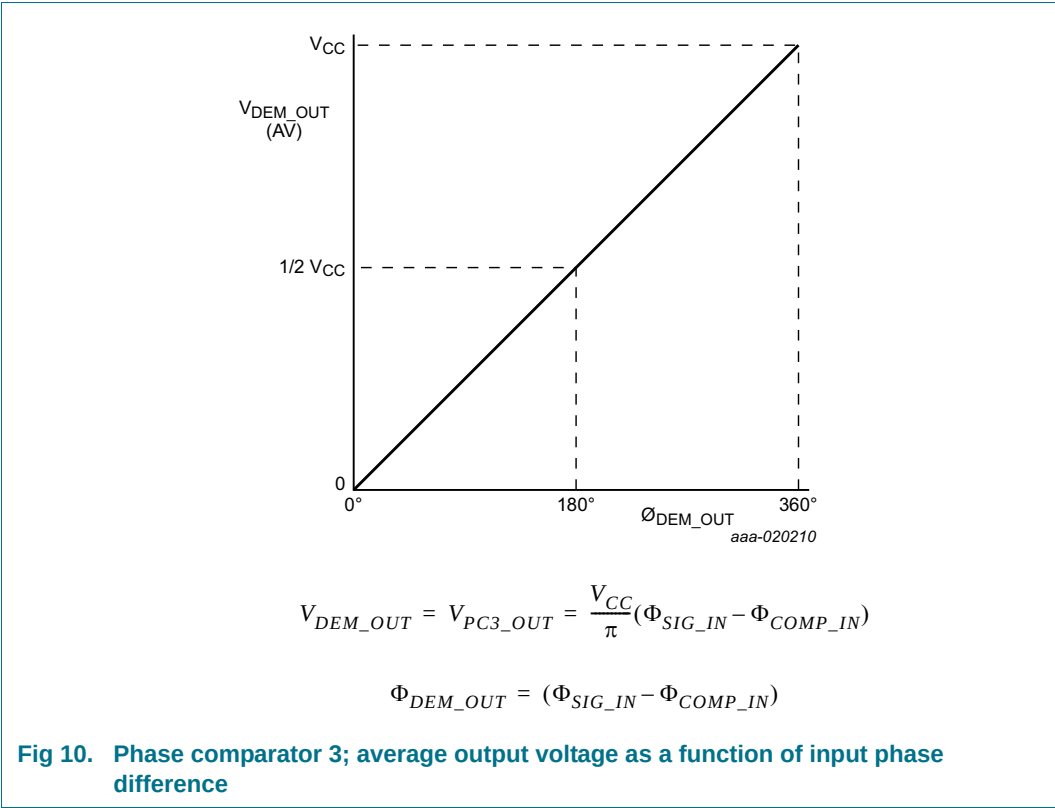
$V_{DEM\_OUT}$  is the demodulator output at pin DEM\_OUT

$V_{DEM\_OUT} = V_{PC3\_OUT}$  (via low-pass filter)

The phase comparator gain is:  $K_p = \frac{V_{CC}}{2\pi}(V/r)$

PC3 is fed to the VCO via the low-pass filter and seen at the demodulator output at pin DEM\_OUT. The average output from PC3 is the resultant of the phase differences of SIG\_IN and COMP\_IN, see [Figure 10](#). Typical waveforms for the PC3 loop locked at  $f_0$  are shown in [Figure 11](#).

The phase-to-output response characteristic of PC3 ([Figure 10](#)) differs from PC2 in that the phase angle between SIG\_IN and COMP\_IN varies between 0° and 360°. It is 180° at the center frequency. Also PC3 gives a greater voltage swing than PC2 for input phase differences. As a result, the ripple content of the VCO input signal is higher. The PLL lock range for this type of phase comparator and the capture range are dependent on the low-pass filter. With no signal present at SIG\_IN, the VCO adjusts to its lowest frequency via PC3.



## 9. 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  | $V_I < -0.5\text{ V}$ or $V_I > V_{CC} + 0.5\text{ V}$ | -    | $\pm 20$ | mA   |
| $I_{OK}$  | output clamping current | $V_O < -0.5\text{ V}$ or $V_O > V_{CC} + 0.5\text{ V}$ | -    | $\pm 20$ | mA   |
| $I_O$     | output current          | $-0.5\text{ V} < V_O < V_{CC} + 0.5\text{ V}$          | -    | $\pm 25$ | 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 | $T_{amb} = -40\text{ °C}$ to $+125\text{ °C}$          |      |          |      |
|           |                         | SO16 and (T)SSOP16 <a href="#">[1]</a>                 | -    | 500      | mW   |

[1] For SO16 package:  $P_{tot}$  derates linearly with 8 mW/K above 70 °C.

For SSOP16 and TSSOP16 packages:  $P_{tot}$  derates linearly with 5.5 mW/K above 60 °C.

## 10. Recommended operating conditions

**Table 4. Recommended operating conditions**

| Symbol              | Parameter                           | Conditions              | 74HC4046A |      |          | 74HCT4046A |      |          | Unit |
|---------------------|-------------------------------------|-------------------------|-----------|------|----------|------------|------|----------|------|
|                     |                                     |                         | Min       | Typ  | Max      | Min        | Typ  | Max      |      |
| $V_{CC}$            | supply voltage                      |                         | 3.0       | 5.0  | 6.0      | 4.5        | 5.0  | 5.5      | V    |
|                     |                                     | when VCO is not used    | 2.0       | 5.0  | 6.0      | 4.5        | 5.0  | 5.5      | V    |
| $V_I$               | input voltage                       |                         | 0         | -    | $V_{CC}$ | 0          | -    | $V_{CC}$ | V    |
| $V_O$               | output voltage                      |                         | 0         | -    | $V_{CC}$ | 0          | -    | $V_{CC}$ | V    |
| $\Delta t/\Delta V$ | input transition rise and fall rate | pin INH                 |           |      |          |            |      |          |      |
|                     |                                     | $V_{CC} = 2.0\text{ V}$ | -         | -    | 625      | -          | -    | -        | ns/V |
|                     |                                     | $V_{CC} = 4.5\text{ V}$ | -         | 1.67 | 139      | -          | 1.67 | 139      | ns/V |
|                     |                                     | $V_{CC} = 6.0\text{ V}$ | -         | -    | 83       | -          | -    | -        | ns/V |
| $T_{amb}$           | ambient temperature                 |                         | -40       | +25  | +125     | -40        | +25  | +125     | °C   |

## 11. Static characteristics

### 11.1 Static characteristics 74HC4046A

**Table 5.** Static characteristics 74HC4046A

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

| Symbol                                                               | Parameter                 | Conditions                                                                                                                                                        | Min  | Typ  | Max       | Unit             |
|----------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-----------|------------------|
| <b>Phase comparator section; <math>T_{amb} = 25\text{ °C}</math></b> |                           |                                                                                                                                                                   |      |      |           |                  |
| $V_{IH}$                                                             | HIGH-level input voltage  | pins SIG_IN, COMP_IN; DC coupled                                                                                                                                  |      |      |           |                  |
|                                                                      |                           | $V_{CC} = 2.0\text{ V}$                                                                                                                                           | 1.5  | 1.2  | -         | V                |
|                                                                      |                           | $V_{CC} = 4.5\text{ V}$                                                                                                                                           | 3.15 | 2.4  | -         | V                |
|                                                                      |                           | $V_{CC} = 6.0\text{ V}$                                                                                                                                           | 4.2  | 3.2  | -         | V                |
| $V_{IL}$                                                             | LOW-level input voltage   | pins SIG_IN, COMP_IN; DC coupled                                                                                                                                  |      |      |           |                  |
|                                                                      |                           | $V_{CC} = 2.0\text{ V}$                                                                                                                                           | -    | 0.8  | 0.5       | V                |
|                                                                      |                           | $V_{CC} = 4.5\text{ V}$                                                                                                                                           | -    | 2.1  | 1.35      | V                |
|                                                                      |                           | $V_{CC} = 6.0\text{ V}$                                                                                                                                           | -    | 2.8  | 1.8       | V                |
| $V_{OH}$                                                             | HIGH-level output voltage | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$                                                                                                                 |      |      |           |                  |
|                                                                      |                           | $I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 2.0\text{ V}$                                                                                                          | 1.9  | 2.0  | -         | V                |
|                                                                      |                           | $I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                          | 4.4  | 4.5  | -         | V                |
|                                                                      |                           | $I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 6.0\text{ V}$                                                                                                          | 5.9  | 6.0  | -         | V                |
|                                                                      |                           | $I_O = -4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                    | 3.98 | 4.32 | -         | V                |
|                                                                      |                           | $I_O = -5.2\text{ mA}$ ; $V_{CC} = 6.0\text{ V}$                                                                                                                  | 5.48 | 5.81 | -         | V                |
| $V_{OL}$                                                             | LOW-level output voltage  | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$                                                                                                                 |      |      |           |                  |
|                                                                      |                           | $I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 2.0\text{ V}$                                                                                                           | -    | 0    | 0.1       | V                |
|                                                                      |                           | $I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                           | -    | 0    | 0.1       | V                |
|                                                                      |                           | $I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 6.0\text{ V}$                                                                                                           | -    | 0    | 0.1       | V                |
|                                                                      |                           | $I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                     | -    | 0.15 | 0.26      | V                |
|                                                                      |                           | $I_O = 5.2\text{ mA}$ ; $V_{CC} = 6.0\text{ V}$                                                                                                                   | -    | 0.16 | 0.26      | V                |
| $I_I$                                                                | input leakage current     | pins SIG_IN, COMP_IN; $V_I = V_{CC}$ or GND                                                                                                                       |      |      |           |                  |
|                                                                      |                           | $V_{CC} = 2.0\text{ V}$                                                                                                                                           | -    | -    | $\pm 3$   | $\mu\text{A}$    |
|                                                                      |                           | $V_{CC} = 3.0\text{ V}$                                                                                                                                           | -    | -    | $\pm 7$   | $\mu\text{A}$    |
|                                                                      |                           | $V_{CC} = 4.5\text{ V}$                                                                                                                                           | -    | -    | $\pm 18$  | $\mu\text{A}$    |
|                                                                      |                           | $V_{CC} = 6.0\text{ V}$                                                                                                                                           | -    | -    | $\pm 30$  | $\mu\text{A}$    |
| $I_{OZ}$                                                             | OFF-state output current  | pin PC2_OUT; $V_I = V_{IH}$ or $V_{IL}$ ; $V_O = V_{CC}$ or GND                                                                                                   |      |      |           |                  |
|                                                                      |                           | $V_{CC} = 6.0\text{ V}$                                                                                                                                           | -    | -    | $\pm 0.5$ | $\mu\text{A}$    |
| $R_I$                                                                | input resistance          | pins SIG_IN, COMP_IN; $V_I$ at self-bias operating point; $\Delta V_I = 0.5\text{ V}$ ; see <a href="#">Figure 12</a> , <a href="#">13</a> and <a href="#">14</a> |      |      |           |                  |
|                                                                      |                           | $V_{CC} = 3.0\text{ V}$                                                                                                                                           | -    | 800  | -         | $\text{k}\Omega$ |
|                                                                      |                           | $V_{CC} = 4.5\text{ V}$                                                                                                                                           | -    | 250  | -         | $\text{k}\Omega$ |
|                                                                      |                           | $V_{CC} = 6.0\text{ V}$                                                                                                                                           | -    | 150  | -         | $\text{k}\Omega$ |

**Table 5. Static characteristics 74HC4046A**

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

| Symbol                                      | Parameter                 | Conditions                                                                                          | Min  | Typ  | Max      | Unit |
|---------------------------------------------|---------------------------|-----------------------------------------------------------------------------------------------------|------|------|----------|------|
| <b>VCO section; T<sub>amb</sub> = 25 °C</b> |                           |                                                                                                     |      |      |          |      |
| V <sub>IH</sub>                             | HIGH-level input voltage  | pin INH                                                                                             |      |      |          |      |
|                                             |                           | V <sub>CC</sub> = 3.0 V                                                                             | 2.1  | 1.7  | -        | V    |
|                                             |                           | V <sub>CC</sub> = 4.5 V                                                                             | 3.15 | 2.4  | -        | V    |
|                                             |                           | V <sub>CC</sub> = 6.0 V                                                                             | 4.2  | 3.2  | -        | V    |
| V <sub>IL</sub>                             | LOW-level input voltage   | pin INH                                                                                             |      |      |          |      |
|                                             |                           | V <sub>CC</sub> = 3.0 V                                                                             | -    | 1.3  | 0.9      | V    |
|                                             |                           | V <sub>CC</sub> = 4.5 V                                                                             | -    | 2.1  | 1.35     | V    |
|                                             |                           | V <sub>CC</sub> = 6.0 V                                                                             | -    | 2.8  | 1.8      | V    |
| V <sub>OH</sub>                             | HIGH-level output voltage | pin VCO_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                    |      |      |          |      |
|                                             |                           | I <sub>O</sub> = -20 µA; V <sub>CC</sub> = 3.0 V                                                    | 2.9  | 3.0  | -        | V    |
|                                             |                           | I <sub>O</sub> = -20 µA; V <sub>CC</sub> = 4.5 V                                                    | 4.4  | 4.5  | -        | V    |
|                                             |                           | I <sub>O</sub> = -20 µA; V <sub>CC</sub> = 6.0 V                                                    | 5.9  | 6.0  | -        | V    |
|                                             |                           | I <sub>O</sub> = -4 mA; V <sub>CC</sub> = 4.5 V                                                     | 3.98 | 4.32 | -        | V    |
|                                             |                           | I <sub>O</sub> = -5.2 mA; V <sub>CC</sub> = 6.0 V                                                   | 5.48 | 5.81 | -        | V    |
| V <sub>OL</sub>                             | LOW-level output voltage  | pin VCO_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                    |      |      |          |      |
|                                             |                           | I <sub>O</sub> = 20 µA; V <sub>CC</sub> = 3.0 V                                                     | -    | 0    | 0.1      | V    |
|                                             |                           | I <sub>O</sub> = 20 µA; V <sub>CC</sub> = 4.5 V                                                     | -    | 0    | 0.1      | V    |
|                                             |                           | I <sub>O</sub> = 20 µA; V <sub>CC</sub> = 6.0 V                                                     | -    | 0    | 0.1      | V    |
|                                             |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                      | -    | 0.15 | 0.26     | V    |
|                                             |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                    | -    | 0.16 | 0.26     | V    |
|                                             |                           | pins C1A, C1B; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                  |      |      |          |      |
|                                             |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                      | -    | -    | 0.40     | V    |
|                                             |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                    | -    | -    | 0.40     | V    |
| I <sub>I</sub>                              | input leakage current     | pins INH, VCO_IN; V <sub>I</sub> = V <sub>CC</sub> or GND                                           |      |      |          |      |
|                                             |                           | V <sub>CC</sub> = 6.0 V                                                                             | -    | -    | ±0.1     | µA   |
| R1                                          | resistor 1                | V <sub>CC</sub> = 3.0 V to 6.0 V <a href="#">[1]</a>                                                | 3    | -    | 300      | kΩ   |
| R2                                          | resistor 2                | V <sub>CC</sub> = 3.0 V to 6.0 V <a href="#">[1]</a>                                                | 3    | -    | 300      | kΩ   |
| C1                                          | capacitor 1               | V <sub>CC</sub> = 3.0 V to 6.0 V                                                                    | 40   | -    | no limit | pF   |
| V <sub>VCO_IN</sub>                         | voltage on pin VCO_IN     | over the range specified for R1; for linearity see <a href="#">Figure 22</a> and <a href="#">23</a> |      |      |          |      |
|                                             |                           | V <sub>CC</sub> = 3.0 V                                                                             | 1.1  | -    | 1.9      | V    |
|                                             |                           | V <sub>CC</sub> = 4.5 V                                                                             | 1.1  | -    | 3.4      | V    |
|                                             |                           | V <sub>CC</sub> = 6.0 V                                                                             | 1.1  | -    | 4.9      | V    |

**Table 5. Static characteristics 74HC4046A**

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

| Symbol                                                                                              | Parameter                 | Conditions                                                                                                                                                                                                                                                                                                                                  | Min                               | Typ                              | Max                               | Unit             |
|-----------------------------------------------------------------------------------------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------|-----------------------------------|------------------|
| <b>Demodulator section; <math>T_{amb} = 25\text{ °C}</math></b>                                     |                           |                                                                                                                                                                                                                                                                                                                                             |                                   |                                  |                                   |                  |
| $R_s$                                                                                               | series resistance         | at $R_s > 300\text{ k}\Omega$ , the leakage current can influence $V_{DEM\_OUT}$<br>$V_{CC} = 3.0\text{ V}$ to $6.0\text{ V}$                                                                                                                                                                                                               | 50                                | -                                | 300                               | $\text{k}\Omega$ |
| $V_{offset}$                                                                                        | offset voltage            | VCO_IN to $V_{DEM\_OUT}$ ; $V_I = V_{VCO\_IN} = 0.5V_{CC}$ ; values taken over $R_s$ range; see <a href="#">Figure 15</a><br>$V_{CC} = 3.0\text{ V}$<br>$V_{CC} = 4.5\text{ V}$<br>$V_{CC} = 6.0\text{ V}$                                                                                                                                  | -                                 | $\pm 30$<br>$\pm 20$<br>$\pm 10$ | -                                 | mV               |
| $R_{dyn}$                                                                                           | dynamic resistance        | DEM_OUT; $V_{DEM\_OUT} = 0.5V_{CC}$<br>$V_{CC} = 3.0\text{ V}$ to $6.0\text{ V}$                                                                                                                                                                                                                                                            | -                                 | 25                               | -                                 | $\Omega$         |
| <b>General; <math>T_{amb} = 25\text{ °C}</math></b>                                                 |                           |                                                                                                                                                                                                                                                                                                                                             |                                   |                                  |                                   |                  |
| $I_{CC}$                                                                                            | supply current            | VCO disabled; pins COMP_IN, INH and SIG_IN at $V_{CC}$ ; pin VCO_IN at GND; $I_I$ at pins COMP_IN and SIGN_IN to be excluded<br>$V_{CC} = 6.0\text{ V}$                                                                                                                                                                                     | -                                 | -                                | 8.0                               | $\mu\text{A}$    |
| $C_I$                                                                                               | input capacitance         | pin INH                                                                                                                                                                                                                                                                                                                                     | -                                 | 3.5                              | -                                 | pF               |
| <b>Phase comparator section; <math>T_{amb} = -40\text{ °C}</math> to <math>+85\text{ °C}</math></b> |                           |                                                                                                                                                                                                                                                                                                                                             |                                   |                                  |                                   |                  |
| $V_{IH}$                                                                                            | HIGH-level input voltage  | pins SIG_IN, COMP_IN; DC coupled<br>$V_{CC} = 2.0\text{ V}$<br>$V_{CC} = 4.5\text{ V}$<br>$V_{CC} = 6.0\text{ V}$                                                                                                                                                                                                                           | 1.5<br>3.15<br>4.2                | -                                | -                                 | V                |
| $V_{IL}$                                                                                            | LOW-level input voltage   | pins SIG_IN, COMP_IN; DC coupled<br>$V_{CC} = 2.0\text{ V}$<br>$V_{CC} = 4.5\text{ V}$<br>$V_{CC} = 6.0\text{ V}$                                                                                                                                                                                                                           | -                                 | -                                | 0.5<br>1.35<br>1.8                | V                |
| $V_{OH}$                                                                                            | HIGH-level output voltage | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 2.0\text{ V}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 6.0\text{ V}$<br>$I_O = -4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$<br>$I_O = -5.2\text{ mA}$ ; $V_{CC} = 6.0\text{ V}$ | 1.9<br>4.4<br>5.9<br>3.84<br>5.34 | -                                | -                                 | V                |
| $V_{OL}$                                                                                            | LOW-level output voltage  | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 2.0\text{ V}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 6.0\text{ V}$<br>$I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$<br>$I_O = 5.2\text{ mA}$ ; $V_{CC} = 6.0\text{ V}$      | -                                 | -                                | 0.1<br>0.1<br>0.1<br>0.33<br>0.33 | V                |

**Table 5. Static characteristics 74HC4046A**

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

| Symbol                                           | Parameter                 | Conditions                                                                                                                                   | Min  | Typ | Max  | Unit |
|--------------------------------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|------|-----|------|------|
| I <sub>I</sub>                                   | input leakage current     | pins SIG_IN, COMP_IN; V <sub>I</sub> = V <sub>CC</sub> or GND                                                                                |      |     |      |      |
|                                                  |                           | V <sub>CC</sub> = 2.0 V                                                                                                                      | -    | -   | ±4   | μA   |
|                                                  |                           | V <sub>CC</sub> = 3.0 V                                                                                                                      | -    | -   | ±9   | μA   |
|                                                  |                           | V <sub>CC</sub> = 4.5 V                                                                                                                      | -    | -   | ±23  | μA   |
|                                                  |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -    | -   | ±38  | μA   |
| I <sub>OZ</sub>                                  | OFF-state output current  | pin PC2_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub> ; V <sub>O</sub> = V <sub>CC</sub> or GND                                   |      |     |      |      |
|                                                  |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -    | -   | ±5   | μA   |
| VCO section; T <sub>amb</sub> = −40 °C to +85 °C |                           |                                                                                                                                              |      |     |      |      |
| V <sub>IH</sub>                                  | HIGH-level input voltage  | pin INH                                                                                                                                      |      |     |      |      |
|                                                  |                           | V <sub>CC</sub> = 3.0 V                                                                                                                      | 2.1  | -   | -    | V    |
|                                                  |                           | V <sub>CC</sub> = 4.5 V                                                                                                                      | 3.15 | -   | -    | V    |
|                                                  |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | 4.2  | -   | -    | V    |
| V <sub>IL</sub>                                  | LOW-level input voltage   | pin INH                                                                                                                                      |      |     |      |      |
|                                                  |                           | V <sub>CC</sub> = 3.0 V                                                                                                                      | -    | -   | 0.9  | V    |
|                                                  |                           | V <sub>CC</sub> = 4.5 V                                                                                                                      | -    | -   | 1.35 | V    |
|                                                  |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -    | -   | 1.8  | V    |
| V <sub>OH</sub>                                  | HIGH-level output voltage | pin VCO_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                             |      |     |      |      |
|                                                  |                           | I <sub>O</sub> = −20 μA; V <sub>CC</sub> = 3.0 V                                                                                             | 2.9  | -   | -    | V    |
|                                                  |                           | I <sub>O</sub> = −20 μA; V <sub>CC</sub> = 4.5 V                                                                                             | 4.4  | -   | -    | V    |
|                                                  |                           | I <sub>O</sub> = −20 μA; V <sub>CC</sub> = 6.0 V                                                                                             | 5.9  | -   | -    | V    |
|                                                  |                           | I <sub>O</sub> = −4 mA; V <sub>CC</sub> = 4.5 V                                                                                              | 3.84 | -   | -    | V    |
|                                                  |                           | I <sub>O</sub> = −5.2 mA; V <sub>CC</sub> = 6.0 V                                                                                            | 5.34 | -   | -    | V    |
| V <sub>OL</sub>                                  | LOW-level output voltage  | pin VCO_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                             |      |     |      |      |
|                                                  |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 3.0 V                                                                                              | -    | -   | 0.1  | V    |
|                                                  |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 4.5 V                                                                                              | -    | -   | 0.1  | V    |
|                                                  |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 6.0 V                                                                                              | -    | -   | 0.1  | V    |
|                                                  |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                                                               | -    | -   | 0.33 | V    |
|                                                  |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                                                             | -    | -   | 0.33 | V    |
|                                                  |                           | pins C1A, C1B; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                           |      |     |      |      |
|                                                  |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                                                               | -    | -   | 0.47 | V    |
|                                                  |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                                                             | -    | -   | 0.47 | V    |
| I <sub>I</sub>                                   | input leakage current     | pins INH, VCO_IN; V <sub>I</sub> = V <sub>CC</sub> or GND                                                                                    |      |     |      |      |
|                                                  |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -    | -   | ±1   | μA   |
| General; T <sub>amb</sub> = −40 °C to +85 °C     |                           |                                                                                                                                              |      |     |      |      |
| I <sub>CC</sub>                                  | supply current            | VCO disabled; pins COMP_IN, INH and SIG_IN at V <sub>CC</sub> ; pin VCO_IN at GND; I <sub>I</sub> at pins COMP_IN and SIGN_IN to be excluded |      |     |      |      |
|                                                  |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -    | -   | 80.0 | μA   |



**Table 5. Static characteristics 74HC4046A**

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

| Symbol                                                         | Parameter                 | Conditions                                                                                                 | Min  | Typ | Max  | Unit |
|----------------------------------------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------|------|-----|------|------|
| Phase comparator section; T <sub>amb</sub> = −40 °C to +125 °C |                           |                                                                                                            |      |     |      |      |
| V <sub>IH</sub>                                                | HIGH-level input voltage  | pins SIG_IN, COMP_IN; DC coupled                                                                           |      |     |      |      |
|                                                                |                           | V <sub>CC</sub> = 2.0 V                                                                                    | 1.5  | -   | -    | V    |
|                                                                |                           | V <sub>CC</sub> = 4.5 V                                                                                    | 3.15 | -   | -    | V    |
|                                                                |                           | V <sub>CC</sub> = 6.0 V                                                                                    | 4.2  | -   | -    | V    |
| V <sub>IL</sub>                                                | LOW-level input voltage   | pins SIG_IN, COMP_IN; DC coupled                                                                           |      |     |      |      |
|                                                                |                           | V <sub>CC</sub> = 2.0 V                                                                                    | -    | -   | 0.5  | V    |
|                                                                |                           | V <sub>CC</sub> = 4.5 V                                                                                    | -    | -   | 1.35 | V    |
|                                                                |                           | V <sub>CC</sub> = 6.0 V                                                                                    | -    | -   | 1.8  | V    |
| V <sub>OH</sub>                                                | HIGH-level output voltage | pins PCP_OUT, PCn_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                 |      |     |      |      |
|                                                                |                           | I <sub>O</sub> = −20 μA; V <sub>CC</sub> = 2.0 V                                                           | 1.9  | -   | -    | V    |
|                                                                |                           | I <sub>O</sub> = −20 μA; V <sub>CC</sub> = 4.5 V                                                           | 4.4  | -   | -    | V    |
|                                                                |                           | I <sub>O</sub> = −20 μA; V <sub>CC</sub> = 6.0 V                                                           | 5.9  | -   | -    | V    |
|                                                                |                           | I <sub>O</sub> = −4 mA; V <sub>CC</sub> = 4.5 V                                                            | 3.7  | -   | -    | V    |
|                                                                |                           | I <sub>O</sub> = −5.2 mA; V <sub>CC</sub> = 6.0 V                                                          | 5.2  | -   | -    | V    |
| V <sub>OL</sub>                                                | LOW-level output voltage  | pins PCP_OUT, PCn_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                 |      |     |      |      |
|                                                                |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 2.0 V                                                            | -    | -   | 0.1  | V    |
|                                                                |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 4.5 V                                                            | -    | -   | 0.1  | V    |
|                                                                |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 6.0 V                                                            | -    | -   | 0.1  | V    |
|                                                                |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                             | -    | -   | 0.4  | V    |
|                                                                |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                           | -    | -   | 0.4  | V    |
| I <sub>I</sub>                                                 | input leakage current     | pins SIG_IN, COMP_IN; V <sub>I</sub> = V <sub>CC</sub> or GND                                              |      |     |      |      |
|                                                                |                           | V <sub>CC</sub> = 2.0 V                                                                                    | -    | -   | ±5   | μA   |
|                                                                |                           | V <sub>CC</sub> = 3.0 V                                                                                    | -    | -   | ±11  | μA   |
|                                                                |                           | V <sub>CC</sub> = 4.5 V                                                                                    | -    | -   | ±27  | μA   |
|                                                                |                           | V <sub>CC</sub> = 6.0 V                                                                                    | -    | -   | ±45  | μA   |
| I <sub>OZ</sub>                                                | OFF-state output current  | pin PC2_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub> ; V <sub>O</sub> = V <sub>CC</sub> or GND |      |     |      |      |
|                                                                |                           | V <sub>CC</sub> = 6.0 V                                                                                    | -    | -   | ±10  | μA   |
| VCO section; T <sub>amb</sub> = −40 °C to +125 °C              |                           |                                                                                                            |      |     |      |      |
| V <sub>IH</sub>                                                | HIGH-level input voltage  | pin INH                                                                                                    |      |     |      |      |
|                                                                |                           | V <sub>CC</sub> = 3.0 V                                                                                    | 2.1  | -   | -    | V    |
|                                                                |                           | V <sub>CC</sub> = 4.5 V                                                                                    | 3.15 | -   | -    | V    |
|                                                                |                           | V <sub>CC</sub> = 6.0 V                                                                                    | 4.2  | -   | -    | V    |
| V <sub>IL</sub>                                                | LOW-level input voltage   | pin INH                                                                                                    |      |     |      |      |
|                                                                |                           | V <sub>CC</sub> = 3.0 V                                                                                    | -    | -   | 0.9  | V    |
|                                                                |                           | V <sub>CC</sub> = 4.5 V                                                                                    | -    | -   | 1.35 | V    |
|                                                                |                           | V <sub>CC</sub> = 6.0 V                                                                                    | -    | -   | 1.8  | V    |

**Table 5. Static characteristics 74HC4046A**

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

| Symbol                                        | Parameter                 | Conditions                                                                                                                                   | Min | Typ | Max   | Unit |
|-----------------------------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-------|------|
| V <sub>OH</sub>                               | HIGH-level output voltage | pin VCO_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                             |     |     |       |      |
|                                               |                           | I <sub>O</sub> = -20 μA; V <sub>CC</sub> = 3.0 V                                                                                             | 2.9 | -   | -     | V    |
|                                               |                           | I <sub>O</sub> = -20 μA; V <sub>CC</sub> = 4.5 V                                                                                             | 4.4 | -   | -     | V    |
|                                               |                           | I <sub>O</sub> = -20 μA; V <sub>CC</sub> = 6.0 V                                                                                             | 5.9 | -   | -     | V    |
|                                               |                           | I <sub>O</sub> = -4 mA; V <sub>CC</sub> = 4.5 V                                                                                              | 3.7 | -   | -     | V    |
|                                               |                           | I <sub>O</sub> = -5.2 mA; V <sub>CC</sub> = 6.0 V                                                                                            | 5.2 | -   | -     | V    |
| V <sub>OL</sub>                               | LOW-level output voltage  | pin VCO_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                             |     |     |       |      |
|                                               |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 3.0 V                                                                                              | -   | -   | 0.1   | V    |
|                                               |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 4.5 V                                                                                              | -   | -   | 0.1   | V    |
|                                               |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 6.0 V                                                                                              | -   | -   | 0.1   | V    |
|                                               |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                                                               | -   | -   | 0.4   | V    |
|                                               |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                                                             | -   | -   | 0.4   | V    |
|                                               |                           | pins C1A, C1B; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                           |     |     |       |      |
|                                               |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                                                               | -   | -   | 0.54  | V    |
|                                               |                           | I <sub>O</sub> = 5.2 mA; V <sub>CC</sub> = 6.0 V                                                                                             | -   | -   | 0.54  | V    |
| I <sub>I</sub>                                | input leakage current     | pins INH, VCO_IN; V <sub>I</sub> = V <sub>CC</sub> or GND                                                                                    |     |     |       |      |
|                                               |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -   | -   | ±1    | μA   |
| General; T <sub>amb</sub> = -40 °C to +125 °C |                           |                                                                                                                                              |     |     |       |      |
| I <sub>CC</sub>                               | supply current            | VCO disabled; pins COMP_IN, INH and SIG_IN at V <sub>CC</sub> ; pin VCO_IN at GND; I <sub>I</sub> at pins COMP_IN and SIGN_IN to be excluded |     |     |       |      |
|                                               |                           | V <sub>CC</sub> = 6.0 V                                                                                                                      | -   | -   | 160.0 | μA   |

[1] The parallel value of R1 and R2 should be more than 2.7 kΩ. Optimum performance is achieved when R1 and/ or R2 are/is &gt; 10 kΩ.

## 11.2 Static characteristics 74HCT4046A

**Table 6. Static characteristics 74HCT4046A**

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

| Symbol                                                               | Parameter                 | Conditions                                                                                                                                                                                      | Min  | Typ  | Max       | Unit             |
|----------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-----------|------------------|
| <b>Phase comparator section; <math>T_{amb} = 25\text{ °C}</math></b> |                           |                                                                                                                                                                                                 |      |      |           |                  |
| $V_{IH}$                                                             | HIGH-level input voltage  | pins SIG_IN, COMP_IN; DC coupled<br>$V_{CC} = 4.5\text{ V}$                                                                                                                                     | 3.15 | 2.4  | -         | V                |
| $V_{IL}$                                                             | LOW-level input voltage   | pins SIG_IN, COMP_IN; DC coupled<br>$V_{CC} = 4.5\text{ V}$                                                                                                                                     | -    | 2.1  | 1.35      | V                |
| $V_{OH}$                                                             | HIGH-level output voltage | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                   | 4.4  | 4.5  | -         | V                |
|                                                                      |                           | $I_O = -4\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                         | 3.98 | 4.32 | -         | V                |
| $V_{OL}$                                                             | LOW-level output voltage  | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                    | -    | 0    | 0.1       | V                |
|                                                                      |                           | $I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                   | -    | 0.15 | 0.26      | V                |
| $I_I$                                                                | input leakage current     | pins SIG_IN, COMP_IN; $V_I = V_{CC}$ or GND<br>$V_{CC} = 5.5\text{ V}$                                                                                                                          | -    | -    | $\pm 30$  | $\mu\text{A}$    |
| $I_{OZ}$                                                             | OFF-state output current  | pin PC2_OUT; $V_I = V_{IH}$ or $V_{IL}$ ; $V_O = V_{CC}$ or GND<br>$V_{CC} = 5.5\text{ V}$                                                                                                      | -    | -    | $\pm 0.5$ | $\mu\text{A}$    |
| $R_I$                                                                | input resistance          | pins SIG_IN, COMP_IN; $V_I$ at self-bias operating point;<br>$\Delta V_I = 0.5\text{ V}$ ; see <a href="#">Figure 12</a> , <a href="#">13</a> and <a href="#">14</a><br>$V_{CC} = 4.5\text{ V}$ | -    | 250  | -         | $\text{k}\Omega$ |
| <b>VCO section; <math>T_{amb} = 25\text{ °C}</math></b>              |                           |                                                                                                                                                                                                 |      |      |           |                  |
| $V_{IH}$                                                             | HIGH-level input voltage  | pin INH<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$                                                                                                                                            | 2.0  | 1.6  | -         | V                |
| $V_{IL}$                                                             | LOW-level input voltage   | pin INH<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$                                                                                                                                            | -    | 1.2  | 0.8       | V                |
| $V_{OH}$                                                             | HIGH-level output voltage | pin VCO_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                             | 4.4  | 4.5  | -         | V                |
|                                                                      |                           | $I_O = -4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                  | 3.98 | 4.32 | -         | V                |
| $V_{OL}$                                                             | LOW-level output voltage  | pin VCO_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                              | -    | 0    | 0.1       | V                |
|                                                                      |                           | $I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                   | -    | 0.15 | 0.26      | V                |
|                                                                      |                           | pins C1A, C1B; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                      | -    | -    | 0.40      | V                |
| $I_I$                                                                | input leakage current     | pins INH, VCO_IN; $V_{CC} = 5.5\text{ V}$ ; $V_I = V_{CC}$ or GND                                                                                                                               | -    | -    | $\pm 0.1$ | $\mu\text{A}$    |
| R1                                                                   | resistor 1                | $V_{CC} = 4.5\text{ V}$ <a href="#">[1]</a>                                                                                                                                                     | 3    | -    | 300       | $\text{k}\Omega$ |
| R2                                                                   | resistor 2                | $V_{CC} = 4.5\text{ V}$ <a href="#">[1]</a>                                                                                                                                                     | 3    | -    | 300       | $\text{k}\Omega$ |
| C1                                                                   | capacitor 1               | $V_{CC} = 4.5\text{ V}$                                                                                                                                                                         | 40   | -    | no limit  | pF               |
| $V_{VCO\_IN}$                                                        | voltage on pin VCO_IN     | over the range specified for R1;<br>for linearity see <a href="#">Figure 22</a> and <a href="#">23</a><br>$V_{CC} = 4.5\text{ V}$                                                               | 1.1  | -    | 3.4       | V                |

**Table 6. Static characteristics 74HCT4046A**

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

| Symbol                                                        | Parameter                 | Conditions                                                                                                                                                                   | Min  | Typ | Max  | Unit |
|---------------------------------------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|------|------|
| Demodulator section; T <sub>amb</sub> = 25 °C                 |                           |                                                                                                                                                                              |      |     |      |      |
| R <sub>s</sub>                                                | series resistance         | at R <sub>s</sub> > 300 kΩ, the leakage current can influence V <sub>DEM_OUT</sub>                                                                                           |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 4.5 V                                                                                                                                                      | 50   | -   | 300  | kΩ   |
| V <sub>offset</sub>                                           | offset voltage            | VCO_IN to V <sub>DEM_OUT</sub> ; V <sub>I</sub> = V <sub>VCO_IN</sub> = 0.5V <sub>CC</sub> ; values taken over R <sub>s</sub> range; see <a href="#">Figure 15</a>           |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 4.5 V                                                                                                                                                      | -    | ±20 | -    | mV   |
| R <sub>dyn</sub>                                              | dynamic resistance        | DEM_OUT; V <sub>DEM_OUT</sub> = 0.5V <sub>CC</sub>                                                                                                                           |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 4.5 V                                                                                                                                                      | -    | 25  | -    | Ω    |
| General; T <sub>amb</sub> = 25 °C                             |                           |                                                                                                                                                                              |      |     |      |      |
| I <sub>CC</sub>                                               | supply current            | VCO disabled; pins COMP_IN, INH and SIG_IN at V <sub>CC</sub> ; pin VCO_IN at GND; I <sub>I</sub> at pins COMP_IN and SIGN_IN to be excluded                                 |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 6 V                                                                                                                                                        | -    | -   | 8.0  | μA   |
| ΔI <sub>CC</sub>                                              | additional supply current | pin INH; V <sub>I</sub> = V <sub>CC</sub> – 2.1 V; pins COMP_IN and SIG_IN at V <sub>CC</sub> ; pin VCO_IN at GND; I <sub>I</sub> at pins COMP_IN and SIGN_IN to be excluded |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 4.5 V to 5.5 V                                                                                                                                             | -    | 100 | 360  | μA   |
| C <sub>I</sub>                                                | input capacitance         | pin INH                                                                                                                                                                      | -    | 3.5 | -    | pF   |
| Phase comparator section; T <sub>amb</sub> = –40 °C to +85 °C |                           |                                                                                                                                                                              |      |     |      |      |
| V <sub>IH</sub>                                               | HIGH-level input voltage  | pins SIG_IN, COMP_IN; DC coupled                                                                                                                                             |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 4.5 V                                                                                                                                                      | 3.15 | -   | -    | V    |
| V <sub>IL</sub>                                               | LOW-level input voltage   | pins SIG_IN, COMP_IN; DC coupled                                                                                                                                             |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 4.5 V                                                                                                                                                      | -    | -   | 1.35 | V    |
| V <sub>OH</sub>                                               | HIGH-level output voltage | pins PCP_OUT, PCn_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                                                   |      |     |      |      |
|                                                               |                           | I <sub>O</sub> = –20 μA; V <sub>CC</sub> = 4.5 V                                                                                                                             | 4.4  | -   | -    | V    |
|                                                               |                           | I <sub>O</sub> = –4 mA; V <sub>CC</sub> = 4.5 V                                                                                                                              | 3.84 | -   | -    | V    |
| V <sub>OL</sub>                                               | LOW-level output voltage  | pins PCP_OUT, PCn_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub>                                                                                                   |      |     |      |      |
|                                                               |                           | I <sub>O</sub> = 20 μA; V <sub>CC</sub> = 4.5 V                                                                                                                              | -    | -   | 0.1  | V    |
|                                                               |                           | I <sub>O</sub> = 4 mA; V <sub>CC</sub> = 4.5 V                                                                                                                               | -    | -   | 0.33 | V    |
| I <sub>I</sub>                                                | input leakage current     | pins SIG_IN, COMP_IN; V <sub>I</sub> = V <sub>CC</sub> or GND                                                                                                                |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 5.5 V                                                                                                                                                      | -    | -   | ±38  | μA   |
| I <sub>OZ</sub>                                               | OFF-state output current  | pin PC2_OUT; V <sub>I</sub> = V <sub>IH</sub> or V <sub>IL</sub> ; V <sub>O</sub> = V <sub>CC</sub> or GND                                                                   |      |     |      |      |
|                                                               |                           | V <sub>CC</sub> = 5.5 V                                                                                                                                                      | -    | -   | ±5   | μA   |

**Table 6. Static characteristics 74HCT4046A**

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

| Symbol                                                                                                                           | Parameter                 | Conditions                                                                                                                                                                                         | Min  | Typ | Max      | Unit          |
|----------------------------------------------------------------------------------------------------------------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|----------|---------------|
| <b>VCO section; <math>T_{amb} = -40\text{ }^{\circ}\text{C}</math> to <math>+85\text{ }^{\circ}\text{C}</math></b>               |                           |                                                                                                                                                                                                    |      |     |          |               |
| $V_{IH}$                                                                                                                         | HIGH-level input voltage  | pin INH<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$                                                                                                                                               | 2.0  | -   | -        | V             |
| $V_{IL}$                                                                                                                         | LOW-level input voltage   | pin INH<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$                                                                                                                                               | -    | -   | 0.8      | V             |
| $V_{OH}$                                                                                                                         | HIGH-level output voltage | pin VCO_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                | 4.4  | -   | -        | V             |
|                                                                                                                                  |                           | $I_O = -4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                     | 3.84 | -   | -        | V             |
| $V_{OL}$                                                                                                                         | LOW-level output voltage  | pin VCO_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                 | -    | -   | 0.1      | V             |
|                                                                                                                                  |                           | $I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                      | -    | -   | 0.33     | V             |
|                                                                                                                                  |                           | pins C1A, C1B; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                         | -    | -   | 0.47     | V             |
| $I_I$                                                                                                                            | input leakage current     | pins INH, VCO_IN; $V_I = V_{CC}$ or GND<br>$V_{CC} = 5.5\text{ V}$                                                                                                                                 | -    | -   | $\pm 1$  | $\mu\text{A}$ |
| <b>General; <math>T_{amb} = -40\text{ }^{\circ}\text{C}</math> to <math>+85\text{ }^{\circ}\text{C}</math></b>                   |                           |                                                                                                                                                                                                    |      |     |          |               |
| $I_{CC}$                                                                                                                         | supply current            | VCO disabled; pins COMP_IN, INH and SIG_IN at $V_{CC}$ ;<br>pin VCO_IN at GND; $I_I$ at pins COMP_IN and SIGN_IN to be excluded<br>$V_{CC} = 6\text{ V}$                                           | -    | -   | 80.0     | $\mu\text{A}$ |
| $\Delta I_{CC}$                                                                                                                  | additional supply current | pin INH; $V_I = V_{CC} - 2.1\text{ V}$ ; pins COMP_IN and SIG_IN at $V_{CC}$ ;<br>pin VCO_IN at GND; $I_I$ at pins COMP_IN and SIGN_IN to be excluded<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$ | -    | -   | 450      | $\mu\text{A}$ |
| <b>Phase comparator section; <math>T_{amb} = -40\text{ }^{\circ}\text{C}</math> to <math>+125\text{ }^{\circ}\text{C}</math></b> |                           |                                                                                                                                                                                                    |      |     |          |               |
| $V_{IH}$                                                                                                                         | HIGH-level input voltage  | pins SIG_IN, COMP_IN; DC coupled<br>$V_{CC} = 4.5\text{ V}$                                                                                                                                        | 3.15 | -   | -        | V             |
| $V_{IL}$                                                                                                                         | LOW-level input voltage   | pins SIG_IN, COMP_IN; DC coupled<br>$V_{CC} = 4.5\text{ V}$                                                                                                                                        | -    | -   | 1.35     | V             |
| $V_{OH}$                                                                                                                         | HIGH-level output voltage | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                      | 4.4  | -   | -        | V             |
|                                                                                                                                  |                           | $I_O = -4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                     | 3.7  | -   | -        | V             |
| $V_{OL}$                                                                                                                         | LOW-level output voltage  | pins PCP_OUT, PCn_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                       | -    | -   | 0.1      | V             |
|                                                                                                                                  |                           | $I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                      | -    | -   | 0.4      | V             |
| $I_I$                                                                                                                            | input leakage current     | pins SIG_IN, COMP_IN; $V_I = V_{CC}$ or GND<br>$V_{CC} = 5.5\text{ V}$                                                                                                                             | -    | -   | $\pm 45$ | $\mu\text{A}$ |
| $I_{OZ}$                                                                                                                         | OFF-state output current  | pin PC2_OUT; $V_I = V_{IH}$ or $V_{IL}$ ; $V_O = V_{CC}$ or GND<br>$V_{CC} = 5.5\text{ V}$                                                                                                         | -    | -   | $\pm 10$ | $\mu\text{A}$ |

**Table 6. Static characteristics 74HCT4046A**

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

| Symbol                                                                                  | Parameter                 | Conditions                                                                                                                                                                                         | Min | Typ | Max     | Unit          |
|-----------------------------------------------------------------------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|---------|---------------|
| <b>VCO section; <math>T_{amb} = -40\text{ °C}</math> to <math>+125\text{ °C}</math></b> |                           |                                                                                                                                                                                                    |     |     |         |               |
| $V_{IH}$                                                                                | HIGH-level input voltage  | pin INH<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$                                                                                                                                               | 2.0 | -   | -       | V             |
| $V_{IL}$                                                                                | LOW-level input voltage   | pin INH<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$                                                                                                                                               | -   | -   | 0.8     | V             |
| $V_{OH}$                                                                                | HIGH-level output voltage | pin VCO_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = -20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                | 4.4 | -   | -       | V             |
|                                                                                         |                           | $I_O = -4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                     | 3.7 | -   | -       | V             |
| $V_{OL}$                                                                                | LOW-level output voltage  | pin VCO_OUT; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 20\text{ }\mu\text{A}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                 | -   | -   | 0.1     | V             |
|                                                                                         |                           | $I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                                                                      | -   | -   | 0.4     | V             |
|                                                                                         |                           | pins C1A, C1B; $V_I = V_{IH}$ or $V_{IL}$<br>$I_O = 4\text{ mA}$ ; $V_{CC} = 4.5\text{ V}$                                                                                                         | -   | -   | 0.54    | V             |
| $I_I$                                                                                   | input leakage current     | pins INH, VCO_IN; $V_I = V_{CC}$ or GND<br>$V_{CC} = 5.5\text{ V}$                                                                                                                                 | -   | -   | $\pm 1$ | $\mu\text{A}$ |
| <b>General; <math>T_{amb} = -40\text{ °C}</math> to <math>+125\text{ °C}</math></b>     |                           |                                                                                                                                                                                                    |     |     |         |               |
| $I_{CC}$                                                                                | supply current            | VCO disabled; pins COMP_IN, INH and SIG_IN at $V_{CC}$ ;<br>pin VCO_IN at GND; $I_I$ at pins COMP_IN and SIGN_IN to be excluded<br>$V_{CC} = 6\text{ V}$                                           | -   | -   | 160.0   | $\mu\text{A}$ |
| $\Delta I_{CC}$                                                                         | additional supply current | pin INH; $V_I = V_{CC} - 2.1\text{ V}$ ; pins COMP_IN and SIG_IN at $V_{CC}$ ;<br>pin VCO_IN at GND; $I_I$ at pins COMP_IN and SIGN_IN to be excluded<br>$V_{CC} = 4.5\text{ V}$ to $5.5\text{ V}$ | -   | -   | 490     | $\mu\text{A}$ |

[1] The parallel value of R1 and R2 should be more than 2.7 k $\Omega$ . Optimum performance is achieved when R1 and/ or R2 are/is > 10 k $\Omega$ .

11.3 Graphs

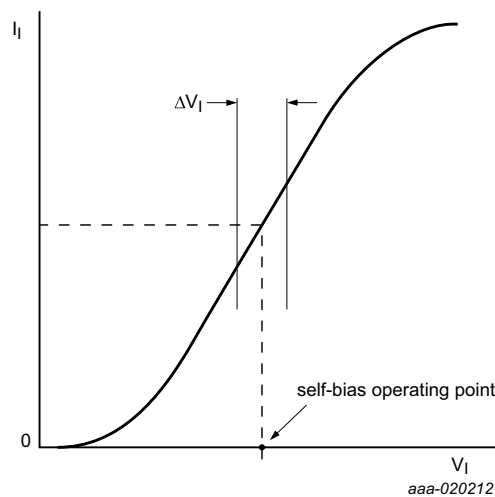


Fig 12. Typical input resistance curve at SIG\_IN and COMP\_IN

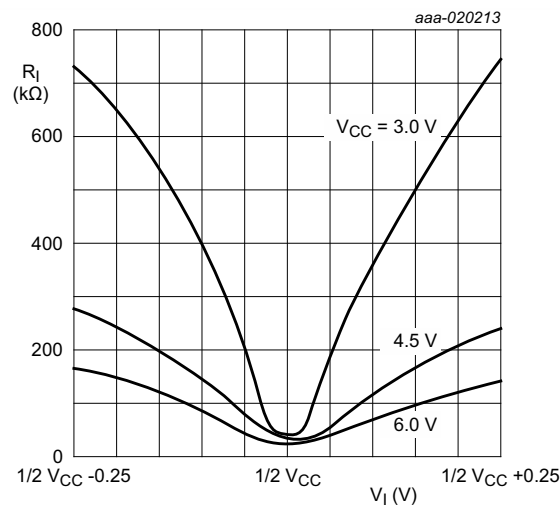


Fig 13. Input resistance at SIG\_IN, COMP\_IN with  $\Delta V_I = 0.5$  V at self-bias point

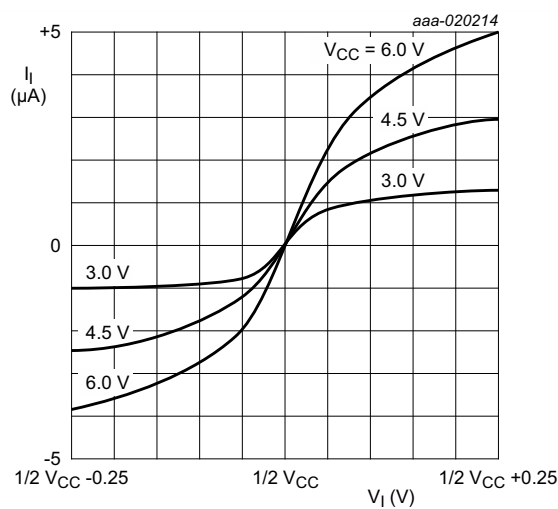


Fig 14. Input current at SIG\_IN, COMP\_IN with  $\Delta V_I = 0.5$  V at self-bias point

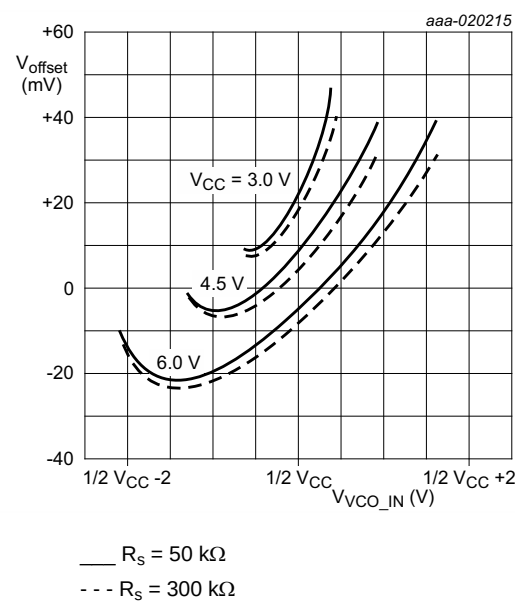


Fig 15. Offset voltage at demodulator output as a function of VCO\_IN and  $R_S$

## 12. Dynamic characteristics

### 12.1 Dynamic characteristics 74HC4046A

**Table 7. Dynamic characteristics 74HC4046A<sup>[1]</sup>**

$GND = 0\text{ V}$ ;  $t_r = t_f = 6\text{ ns}$ ;  $C_L = 50\text{ pF}$

| Symbol                                                               | Parameter                  | Conditions                                                                    | Min | Typ | Max | Unit |
|----------------------------------------------------------------------|----------------------------|-------------------------------------------------------------------------------|-----|-----|-----|------|
| <b>Phase comparator section; <math>T_{amb} = 25\text{ °C}</math></b> |                            |                                                                               |     |     |     |      |
| $t_{pd}$                                                             | propagation delay          | pins SIG_IN, COMP_IN to PC1_OUT; see <a href="#">Figure 16</a> <sup>[1]</sup> |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 63  | 200 | ns   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 23  | 40  | ns   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 18  | 34  | ns   |
|                                                                      |                            | pins SIG_IN, COMP_IN to PCP_OUT; see <a href="#">Figure 16</a> <sup>[1]</sup> |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 96  | 340 | ns   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 35  | 68  | ns   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 28  | 58  | ns   |
|                                                                      |                            | pins SIG_IN, COMP_IN to PC3_OUT; see <a href="#">Figure 16</a> <sup>[1]</sup> |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 77  | 270 | ns   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 28  | 54  | ns   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 22  | 46  | ns   |
| $t_{en}$                                                             | enable time                | pins SIG_IN, COMP_IN to PC2_OUT; see <a href="#">Figure 17</a> <sup>[1]</sup> |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 83  | 280 | ns   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 30  | 56  | ns   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 24  | 48  | ns   |
| $t_{dis}$                                                            | disable time               | pins SIG_IN, COMP_IN to PC2_OUT; see <a href="#">Figure 17</a> <sup>[1]</sup> |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 99  | 325 | ns   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 36  | 65  | ns   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 29  | 55  | ns   |
| $t_t$                                                                | transition time            | see <a href="#">Figure 16</a> <sup>[1]</sup>                                  |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 19  | 75  | ns   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 7   | 15  | ns   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 6   | 13  | ns   |
| $V_{i(p-p)}$                                                         | peak-to-peak input voltage | pins SIGN_IN, COMP_IN; AC coupled; $f_i = 1\text{ MHz}$                       |     |     |     |      |
|                                                                      |                            | $V_{CC} = 2.0\text{ V}$                                                       | -   | 9   | -   | mV   |
|                                                                      |                            | $V_{CC} = 3.0\text{ V}$                                                       | -   | 11  | -   | mV   |
|                                                                      |                            | $V_{CC} = 4.5\text{ V}$                                                       | -   | 15  | -   | mV   |
|                                                                      |                            | $V_{CC} = 6.0\text{ V}$                                                       | -   | 33  | -   | mV   |



**Table 7. Dynamic characteristics 74HC4046A<sup>[1]</sup> ...continued**GND = 0 V;  $t_r = t_f = 6$  ns;  $C_L = 50$  pF.

| Symbol                                                                   | Parameter                     | Conditions                                                                                                                                                              | Min  | Typ  | Max | Unit |
|--------------------------------------------------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-----|------|
| <b>VCO section; <math>T_{amb} = 25</math> °C</b>                         |                               |                                                                                                                                                                         |      |      |     |      |
| $f_0$                                                                    | center frequency              | $V_{VCO\_IN} = 0.5V_{CC}$ ; duty cycle = 50 %; $R1 = 3$ k $\Omega$ ; $R2 = \infty$ $\Omega$ ; $C1 = 40$ pF; see <a href="#">Figure 20</a> and <a href="#">Figure 21</a> |      |      |     |      |
|                                                                          |                               | $V_{CC} = 3.0$ V                                                                                                                                                        | 7.0  | 10.0 | -   | MHz  |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | 11.0 | 17.0 | -   | MHz  |
|                                                                          |                               | $V_{CC} = 5.0$ V                                                                                                                                                        | -    | 19.0 | -   | MHz  |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | 13.0 | 21.0 | -   | MHz  |
| $\Delta f/f$                                                             | relative frequency variation  | $R1 = 100$ k $\Omega$ ; $R2 = \infty$ $\Omega$ ; $C1 = 100$ pF; see <a href="#">Figure 22</a> and <a href="#">Figure 23</a>                                             |      |      |     |      |
|                                                                          |                               | $V_{CC} = 3.0$ V                                                                                                                                                        | -    | 1.0  | -   | %    |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | -    | 0.4  | -   | %    |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | -    | 0.3  | -   | %    |
| $\delta$                                                                 | duty cycle                    | pin VCO_OUT; $V_{CC} = 3.0$ V to 6.0 V                                                                                                                                  | -    | 50   | -   | %    |
| <b>General; <math>T_{amb} = 25</math> °C</b>                             |                               |                                                                                                                                                                         |      |      |     |      |
| $C_{PD}$                                                                 | power dissipation capacitance | <a href="#">[3]</a>                                                                                                                                                     | -    | 24   | -   | pF   |
| <b>Phase comparator section; <math>T_{amb} = -40</math> °C to +85 °C</b> |                               |                                                                                                                                                                         |      |      |     |      |
| $t_{pd}$                                                                 | propagation delay             | pins SIG_IN, COMP_IN to PC1_OUT; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                                                                      |      |      |     |      |
|                                                                          |                               | $V_{CC} = 2.0$ V                                                                                                                                                        | -    | -    | 250 | ns   |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | -    | -    | 50  | ns   |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | -    | -    | 43  | ns   |
|                                                                          |                               | pins SIG_IN, COMP_IN to PCP_OUT; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                                                                      |      |      |     |      |
|                                                                          |                               | $V_{CC} = 2.0$ V                                                                                                                                                        | -    | -    | 425 | ns   |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | -    | -    | 85  | ns   |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | -    | -    | 72  | ns   |
|                                                                          |                               | pins SIG_IN, COMP_IN to PC3_OUT; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                                                                      |      |      |     |      |
|                                                                          |                               | $V_{CC} = 2.0$ V                                                                                                                                                        | -    | -    | 340 | ns   |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | -    | -    | 68  | ns   |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | -    | -    | 58  | ns   |
| $t_{en}$                                                                 | enable time                   | pins SIG_IN, COMP_IN to PC2_OUT; see <a href="#">Figure 17</a> <a href="#">[1]</a>                                                                                      |      |      |     |      |
|                                                                          |                               | $V_{CC} = 2.0$ V                                                                                                                                                        | -    | -    | 350 | ns   |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | -    | -    | 70  | ns   |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | -    | -    | 60  | ns   |
| $t_{dis}$                                                                | disable time                  | pins SIG_IN, COMP_IN to PC2_OUT; see <a href="#">Figure 17</a> <a href="#">[1]</a>                                                                                      |      |      |     |      |
|                                                                          |                               | $V_{CC} = 2.0$ V                                                                                                                                                        | -    | -    | 405 | ns   |
|                                                                          |                               | $V_{CC} = 4.5$ V                                                                                                                                                        | -    | -    | 81  | ns   |
|                                                                          |                               | $V_{CC} = 6.0$ V                                                                                                                                                        | -    | -    | 69  | ns   |

**Table 7.** Dynamic characteristics 74HC4046A<sup>[1]</sup> ...continuedGND = 0 V;  $t_r = t_f = 6$  ns;  $C_L = 50$  pF.

| Symbol                                                         | Parameter                            | Conditions                                                                                                                                  | Min | Typ  | Max | Unit |
|----------------------------------------------------------------|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----|------|-----|------|
| t <sub>t</sub>                                                 | transition time                      | see <a href="#">Figure 16</a> <sup>[1]</sup>                                                                                                |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 2.0 V                                                                                                                     | -   | -    | 95  | ns   |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | -    | 19  | ns   |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | -    | 16  | ns   |
| VCO section; T <sub>amb</sub> = −40 °C to +85 °C               |                                      |                                                                                                                                             |     |      |     |      |
| Δf/ΔT                                                          | frequency variation with temperature | V <sub>VCO_IN</sub> = 0.5V <sub>CC</sub> ; R1 = 100 kΩ; R2 = ∞ kΩ; C1 = 100 pF; see <a href="#">Figure 18</a> and <a href="#">Figure 19</a> |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 3.0 V                                                                                                                     | -   | 0.20 | -   | %/K  |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | 0.15 | -   | %/K  |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | 0.14 | -   | %/K  |
| Phase comparator section; T <sub>amb</sub> = −40 °C to +125 °C |                                      |                                                                                                                                             |     |      |     |      |
| t <sub>pd</sub>                                                | propagation delay                    | pins SIG_IN, COMP_IN to PC1_OUT; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                               |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 2.0 V                                                                                                                     | -   | -    | 300 | ns   |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | -    | 60  | ns   |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | -    | 51  | ns   |
|                                                                |                                      | pins SIG_IN, COMP_IN to PCP_OUT; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                               |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 2.0 V                                                                                                                     | -   | -    | 510 | ns   |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | -    | 102 | ns   |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | -    | 87  | ns   |
|                                                                |                                      | pins SIG_IN, COMP_IN to PC3_OUT; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                               |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 2.0 V                                                                                                                     | -   | -    | 405 | ns   |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | -    | 81  | ns   |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | -    | 69  | ns   |
| t <sub>en</sub>                                                | enable time                          | pins SIG_IN, COMP_IN to PC2_OUT; see <a href="#">Figure 17</a> <sup>[1]</sup>                                                               |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 2.0 V                                                                                                                     | -   | -    | 420 | ns   |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | -    | 84  | ns   |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | -    | 71  | ns   |
| t <sub>dis</sub>                                               | disable time                         | pins SIG_IN, COMP_IN to PC2_OUT; see <a href="#">Figure 17</a> <sup>[1]</sup>                                                               |     |      |     |      |
|                                                                |                                      | V <sub>CC</sub> = 2.0 V                                                                                                                     | -   | -    | 490 | ns   |
|                                                                |                                      | V <sub>CC</sub> = 4.5 V                                                                                                                     | -   | -    | 98  | ns   |
|                                                                |                                      | V <sub>CC</sub> = 6.0 V                                                                                                                     | -   | -    | 83  | ns   |

**Table 7.** Dynamic characteristics 74HC4046A<sup>[1]</sup> ...continuedGND = 0 V;  $t_r = t_f = 6 \text{ ns}$ ;  $C_L = 50 \text{ pF}$ .

| Symbol | Parameter       | Conditions                                   | Min | Typ | Max | Unit |
|--------|-----------------|----------------------------------------------|-----|-----|-----|------|
| $t_t$  | transition time | see <a href="#">Figure 16</a> <sup>[1]</sup> |     |     |     |      |
|        |                 | $V_{CC} = 2.0 \text{ V}$                     | -   | -   | 110 | ns   |
|        |                 | $V_{CC} = 4.5 \text{ V}$                     | -   | -   | 22  | ns   |
|        |                 | $V_{CC} = 6.0 \text{ V}$                     | -   | -   | 19  | 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] Applies to the phase comparator section only (VCO disabled). For power dissipation of the VCO and demodulator sections, see [Figure 24](#), [Figure 25](#) and [Figure 26](#)

[3]  $C_{PD}$  is used to determine the dynamic power dissipation ( $P_D$  in  $\mu\text{W}$ ).

$P_D = C_{PD} \times V_{CC}^2 \times f_i \times N + \Sigma(C_L \times V_{CC}^2 \times f_o)$  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;

$\Sigma(C_L \times V_{CC}^2 \times f_o)$  = sum of outputs.

## 12.2 Dynamic characteristics 74HCT4046A

**Table 8.** Dynamic characteristics 74HCT4046A<sup>[1]</sup>GND = 0 V;  $t_r = t_f = 6 \text{ ns}$ ;  $C_L = 50 \text{ pF}$ .

| Symbol                                                                            | Parameter                    | Conditions                                                                                                                                                                                  | Min  | Typ  | Max | Unit |
|-----------------------------------------------------------------------------------|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-----|------|
| <b>Phase comparator section; <math>T_{amb} = 25 \text{ }^\circ\text{C}</math></b> |                              |                                                                                                                                                                                             |      |      |     |      |
| $t_{pd}$                                                                          | propagation delay            | pins SIG_IN, COMP_IN to PC1_OUT; $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                                                    | -    | 23   | 40  | ns   |
|                                                                                   |                              | pins SIG_IN, COMP_IN to PCP_OUT; $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                                                    | -    | 35   | 68  | ns   |
|                                                                                   |                              | pins SIG_IN, COMP_IN to PC3_OUT; $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                                                    | -    | 28   | 54  | ns   |
| $t_{en}$                                                                          | enable time                  | pins SIG_IN, COMP_IN to PC2_OUT; $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 17</a> <sup>[1]</sup>                                                                                    | -    | 30   | 56  | ns   |
| $t_{dis}$                                                                         | disable time                 | pins SIG_IN, COMP_IN to PC2_OUT; $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 17</a> <sup>[1]</sup>                                                                                    | -    | 36   | 65  | ns   |
| $t_t$                                                                             | transition time              | $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 16</a> <sup>[1]</sup>                                                                                                                     | -    | 7    | 15  | ns   |
| $V_{i(p-p)}$                                                                      | peak-to-peak input voltage   | pins SIGN_IN, COMP_IN; AC coupled; $V_{CC} = 4.5 \text{ V}$ ; $f_i = 1 \text{ MHz}$                                                                                                         | -    | 15   | -   | mV   |
| <b>VCO section; <math>T_{amb} = 25 \text{ }^\circ\text{C}</math></b>              |                              |                                                                                                                                                                                             |      |      |     |      |
| $f_0$                                                                             | center frequency             | $V_{VCO\_IN} = 0.5V_{CC}$ ; duty cycle = 50 %; $R1 = 3 \text{ k}\Omega$ ; $R2 = \infty \text{ }\Omega$ ; $C1 = 40 \text{ pF}$ ; see <a href="#">Figure 20</a> and <a href="#">Figure 21</a> |      |      |     |      |
|                                                                                   |                              | $V_{CC} = 4.5 \text{ V}$                                                                                                                                                                    | 11.0 | 17.0 | -   | MHz  |
|                                                                                   |                              | $V_{CC} = 5.0 \text{ V}$                                                                                                                                                                    | -    | 19.0 | -   | MHz  |
| $\Delta f/f$                                                                      | relative frequency variation | $R1 = 100 \text{ k}\Omega$ ; $R2 = \infty \text{ }\Omega$ ; $C1 = 100 \text{ pF}$ ; $V_{CC} = 4.5 \text{ V}$ ; see <a href="#">Figure 22</a> and <a href="#">Figure 23</a>                  | -    | 0.4  | -   | %    |
| $\delta$                                                                          | duty cycle                   | pin VCO_OUT; $V_{CC} = 4.5 \text{ V}$                                                                                                                                                       | -    | 50   | -   | %    |

**Table 8. Dynamic characteristics 74HCT4046A** [\[1\]](#) ...continuedGND = 0 V;  $t_r = t_f = 6$  ns;  $C_L = 50$  pF.

| Symbol                                                                                 | Parameter                            | Conditions                                                                                                                                     | Min  | Typ | Max | Unit |
|----------------------------------------------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|-----|------|
| <b>General; <math>T_{amb} = 25</math> °C</b>                                           |                                      |                                                                                                                                                |      |     |     |      |
| $C_{PD}$                                                                               | power dissipation capacitance        | <a href="#">[2]</a> <a href="#">[3]</a>                                                                                                        | -    | 24  | -   | pF   |
| <b>Phase comparator section; <math>T_{amb} = -40</math> °C to <math>+85</math> °C</b>  |                                      |                                                                                                                                                |      |     |     |      |
| $t_{pd}$                                                                               | propagation delay                    | pins SIG_IN, COMP_IN to PC1_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                           | -    | -   | 50  | ns   |
|                                                                                        |                                      | pins SIG_IN, COMP_IN to PCP_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                           | -    | -   | 85  | ns   |
|                                                                                        |                                      | pins SIG_IN, COMP_IN to PC3_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                           | -    | -   | 68  | ns   |
| $t_{en}$                                                                               | enable time                          | pins SIG_IN, COMP_IN to PC2_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 17</a> <a href="#">[1]</a>                                           | -    | -   | 70  | ns   |
| $t_{dis}$                                                                              | disable time                         | pins SIG_IN, COMP_IN to PC2_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 17</a> <a href="#">[1]</a>                                           | -    | -   | 81  | ns   |
| $t_t$                                                                                  | transition time                      | $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                                                            | -    | -   | 19  | ns   |
| <b>VCO section; <math>T_{amb} = -40</math> °C to <math>+85</math> °C</b>               |                                      |                                                                                                                                                |      |     |     |      |
| $\Delta f/\Delta T$                                                                    | frequency variation with temperature | $V_{VCO\_IN} = 0.5V_{CC}$ ; $R1 = 100$ k $\Omega$ ; $R2 = \infty$ k $\Omega$ ; $C1 = 100$ pF; $V_{CC} = 4.5$ V; see <a href="#">Figure 18b</a> | 0.15 | -   | -   | %/K  |
| <b>Phase comparator section; <math>T_{amb} = -40</math> °C to <math>+125</math> °C</b> |                                      |                                                                                                                                                |      |     |     |      |
| $t_{pd}$                                                                               | propagation delay                    | pins SIG_IN, COMP_IN to PC1_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                           | -    | -   | 60  | ns   |
|                                                                                        |                                      | pins SIG_IN, COMP_IN to PCP_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                           | -    | -   | 102 | ns   |
|                                                                                        |                                      | pins SIG_IN, COMP_IN to PC3_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                           | -    | -   | 81  | ns   |
| $t_{en}$                                                                               | enable time                          | pins SIG_IN, COMP_IN to PC2_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 17</a> <a href="#">[1]</a>                                           | -    | -   | 84  | ns   |
| $t_{dis}$                                                                              | disable time                         | pins SIG_IN, COMP_IN to PC2_OUT; $V_{CC} = 4.5$ V; see <a href="#">Figure 17</a> <a href="#">[1]</a>                                           | -    | -   | 98  | ns   |
| $t_t$                                                                                  | transition time                      | $V_{CC} = 4.5$ V; see <a href="#">Figure 16</a> <a href="#">[1]</a>                                                                            | -    | -   | 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] Applies to the phase comparator section only (VCO disabled). For power dissipation of the VCO and demodulator sections, see [Figure 24](#), [Figure 25](#) and [Figure 26](#)

[3]  $C_{PD}$  is used to determine the dynamic power dissipation ( $P_D$  in  $\mu$ W).

$P_D = C_{PD} \times V_{CC}^2 \times f_i \times N + \Sigma(C_L \times V_{CC}^2 \times f_o)$  where:

$f_i$  = input frequency in MHz;

$f_o$  = output frequency in MHz;

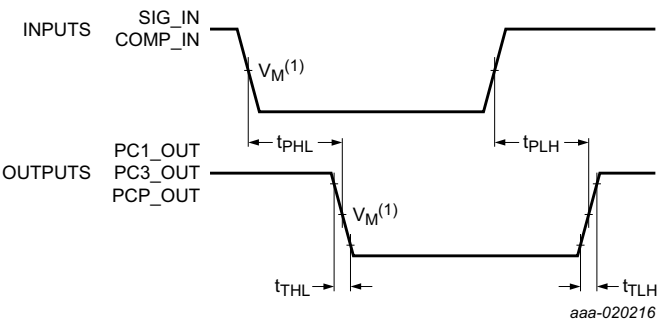
$C_L$  = output load capacitance in pF;

$V_{CC}$  = supply voltage in V;

$N$  = total load switching outputs;

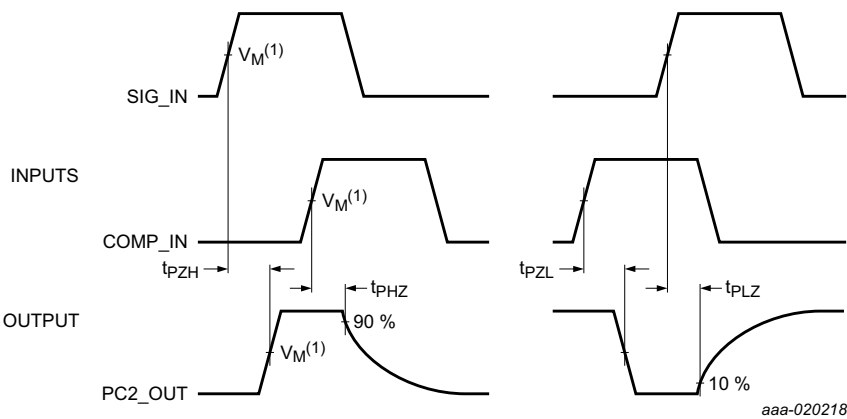
$\Sigma(C_L \times V_{CC}^2 \times f_o)$  = sum of outputs.

12.3 Waveforms and graphs



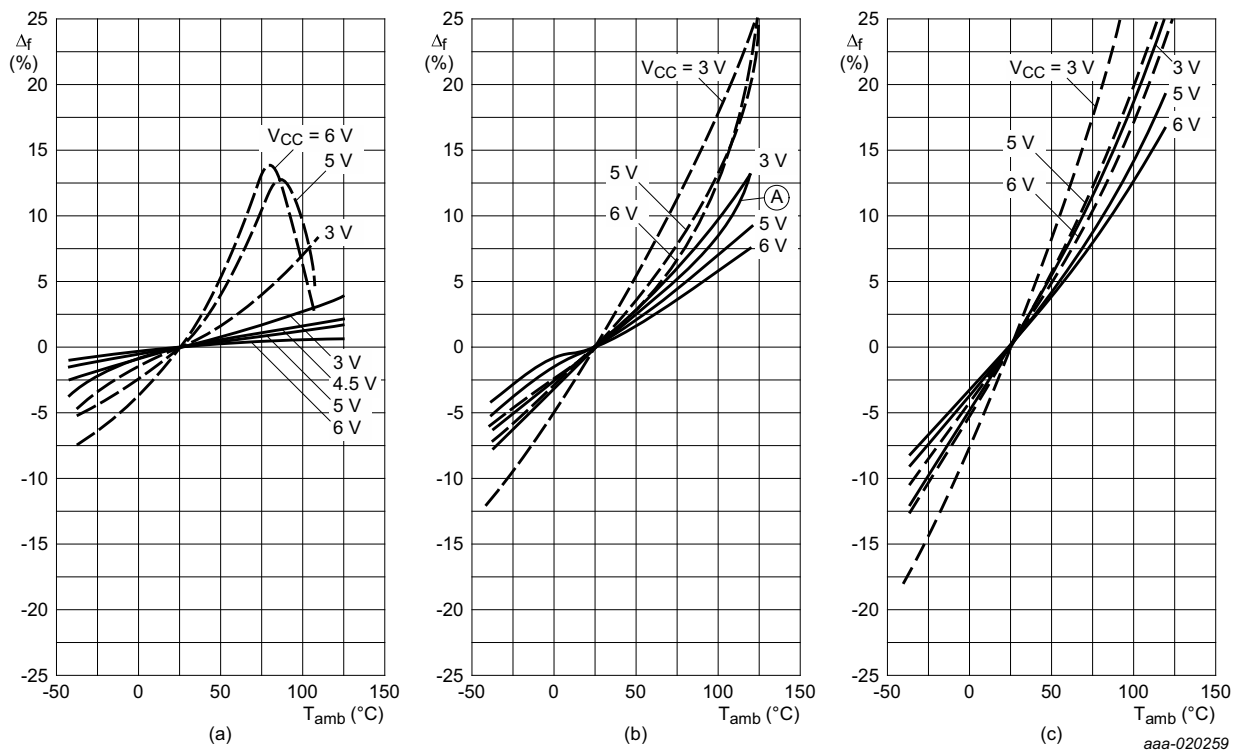
$V_M = 0.5V_{CC}$ ;  $V_I = \text{GND to } V_{CC}$ .

Fig 16. Waveforms showing input (SIG\_IN, COMP\_IN) to output (PC1\_OUT, PC3\_OUT, PCP\_OUT) propagation delays and the output transition times



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

Fig 17. Waveforms showing the enable and disable times for PC2\_OUT



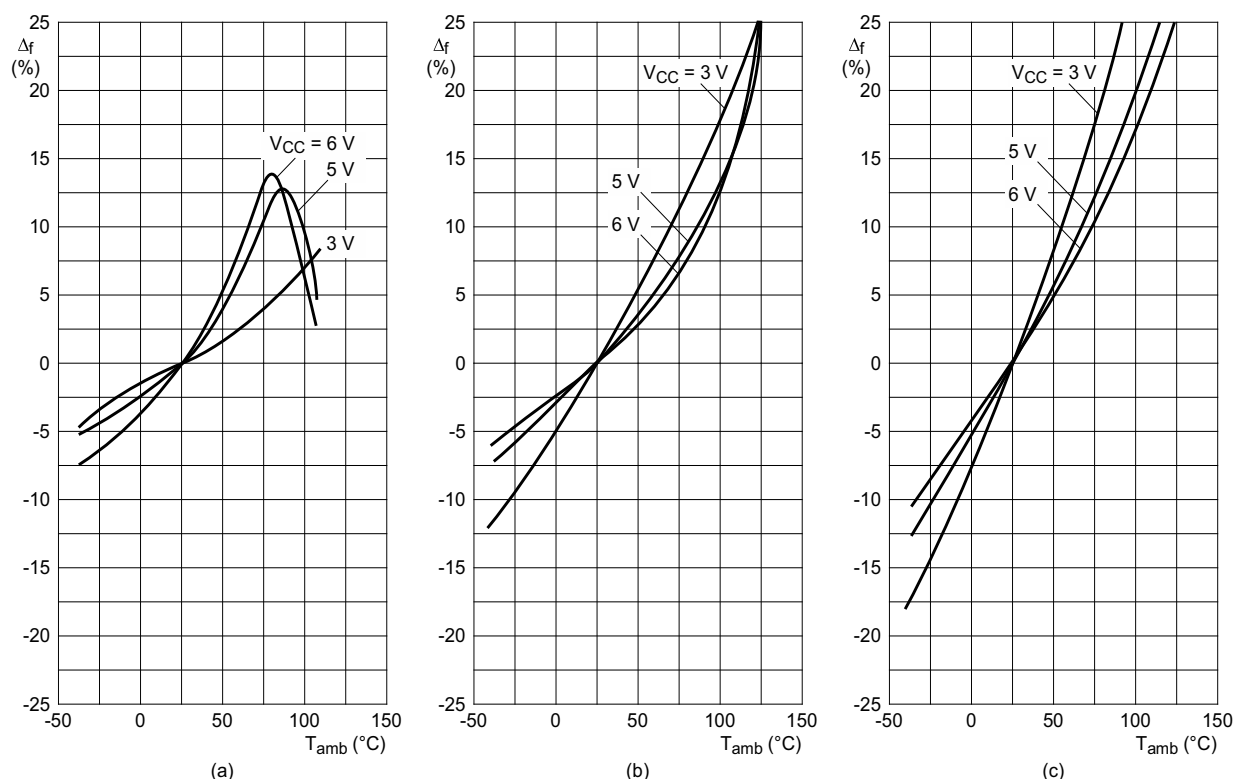
To obtain optimum temperature stability,  $C1$  must be as small as possible but larger than  $100\text{ pF}$ .

In (b), the frequency stability for  $R1 = R2 = 10\text{ k}\Omega$  at  $5\text{ V}$  is also given (curve A). The total VCO bias current sets this curve, and is not simply the addition of the two  $10\text{ k}\Omega$  stability curves.  $C1 = 100\text{ pF}$ ;  $V_{VCO\_IN} = 0.5V_{CC}$ ; This curve is set as follows:

— Without offset  $R2 = \infty\text{ k}\Omega$ : (a)  $R1 = 3\text{ k}\Omega$ ; (b)  $R1 = 10\text{ k}\Omega$ ; (c)  $R1 = 300\text{ k}\Omega$ .

- - - With offset  $R1 = \infty\text{ k}\Omega$ : (a)  $R2 = 3\text{ k}\Omega$ ; (b)  $R2 = 10\text{ k}\Omega$ ; (c)  $R2 = 300\text{ k}\Omega$ .

**Fig 18. Frequency stability of the VCO as a function of ambient temperature**

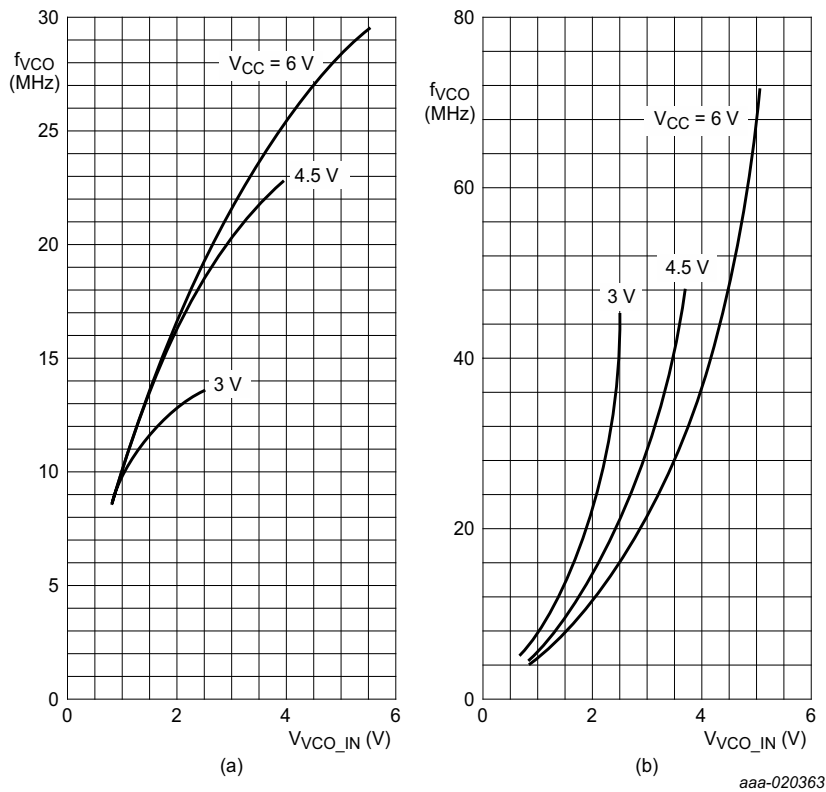


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To obtain optimum temperature stability, C1 must be as small as possible but larger than 100 pF.

\_\_\_ With offset;  $R_1 = \infty \text{ k}\Omega$ : (a)  $R_2 = 3 \text{ k}\Omega$ ; (b)  $R_2 = 10 \text{ k}\Omega$ ; (c)  $R_2 = 300 \text{ k}\Omega$ .

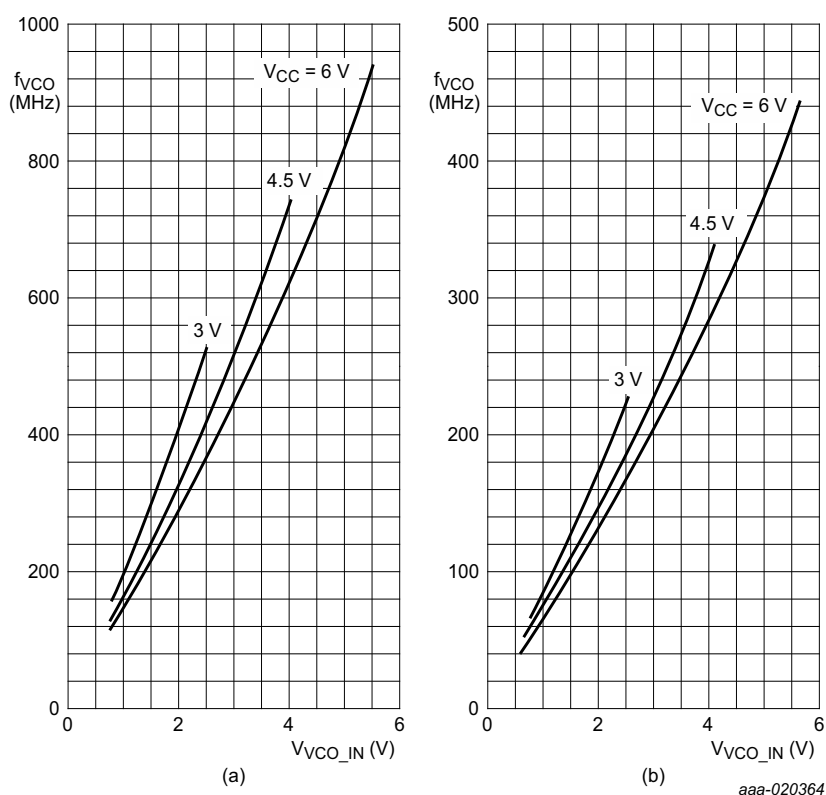
**Fig 19. Frequency stability of the VCO as a function of ambient temperature**



To obtain optimum temperature stability, C1 must be as small as possible but larger than 100 pF.  
(a)  $R1 = 3\text{ k}\Omega$ ;  $C1 = 40\text{ pF}$  (b)  $R1 = 3\text{ k}\Omega$ ;  $C1 = 100\text{ nF}$

Fig 20. Graphs showing VCO frequency as a function of the VCO input voltage

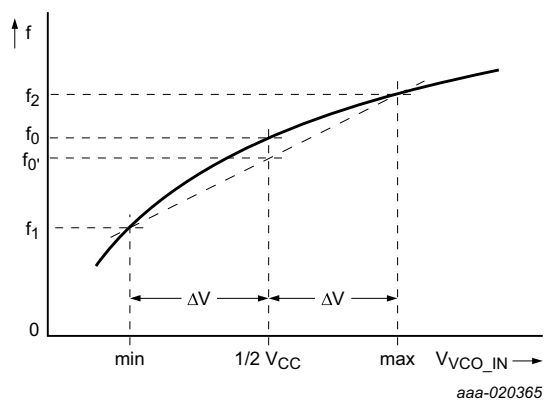




To obtain optimum temperature stability, C1 must be as small as possible but larger than 100 pF.

(a) R1 = 300 k $\Omega$ ; C1 = 40 pF (b) R1 = 300 k $\Omega$ ; C1 = 100 nF

**Fig 21. Graphs showing VCO frequency as a function of the VCO input voltage**

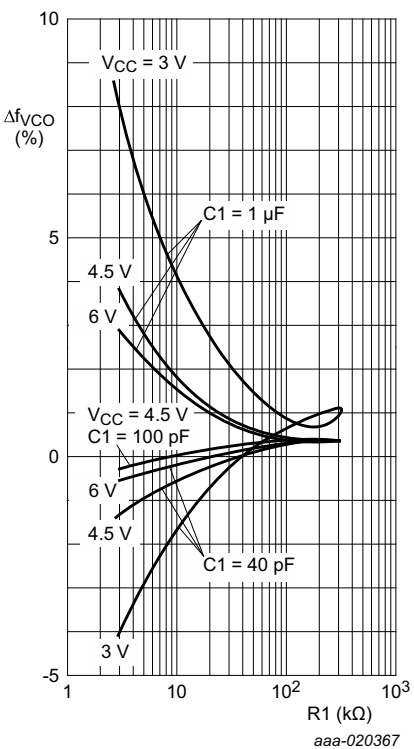


$\Delta V = 0.5\text{ V}$  over the  $V_{CC}$  range.

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

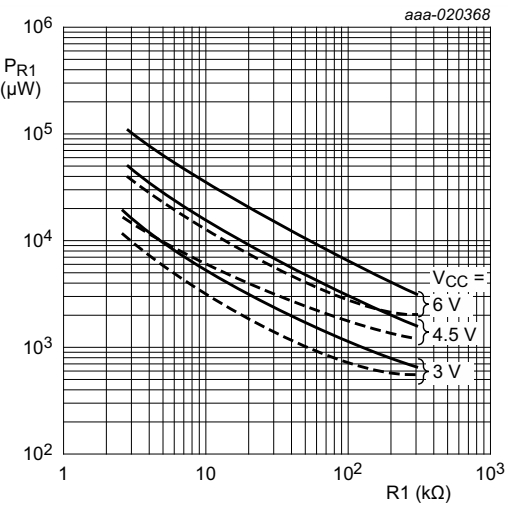
$$\text{linearity} = \frac{f'_0 - f_0}{f'_0} \times 100\%$$

Fig 22. Definition of VCO frequency linearity



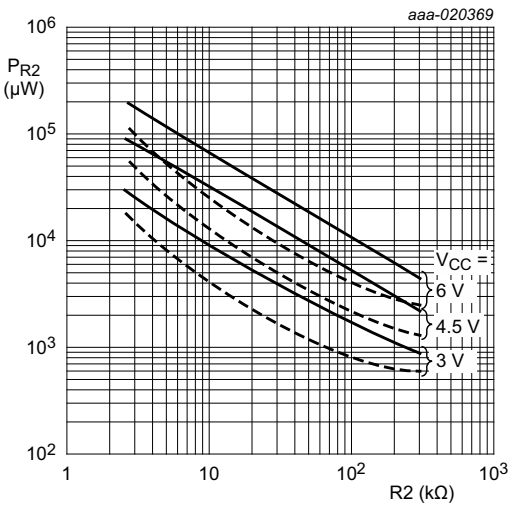
$R_2 = \infty\ \Omega$ ;  $\Delta V = 0.5\text{ V}$

Fig 23. Frequency linearity as a function of  $R_1$ ,  $C_1$



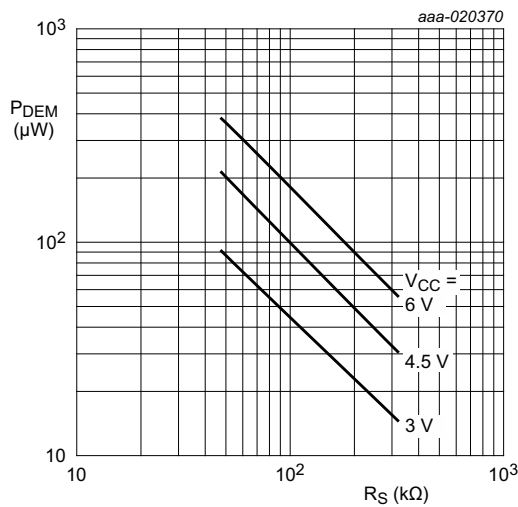
$R_2 = \infty\ \Omega$ ;  $C_L = 50\text{ pF}$ ;  $V_{VCO\_IN} = 0.5V_{CC}$ ;  $T_{amb} = 25\text{ }^\circ\text{C}$   
—  $C_1 = 40\text{ pF}$ ; - - -  $C_1 = 1\text{ }\mu\text{F}$

Fig 24. Power dissipation as a function of  $R_1$



$R_1 = \infty\ \Omega$ ;  $C_L = 50\text{ pF}$ ;  $V_{VCO\_IN} = \text{GND}$ ;  $T_{amb} = 25\text{ }^\circ\text{C}$   
—  $C_1 = 40\text{ pF}$ ; - - -  $C_1 = 1\text{ }\mu\text{F}$

Fig 25. Power dissipation as a function of  $R_2$



$R1 = R2 = \infty \Omega$ ;  $V_{VCO\_IN} = 0.5V_{CC}$ ;  $T_{amb} = 25\text{ }^{\circ}\text{C}$

Fig 26. Typical power dissipation of demodulator sections as a function of  $R_S$

## 13. Application information

This information is a guide for the approximation of values of external components to be used with the 74HC4046A; 74HCT4046A in a phase-locked-loop system.

References should be made to [Figure 30](#), [Figure 31](#) and [Figure 32](#) as indicated in [Table 10](#).

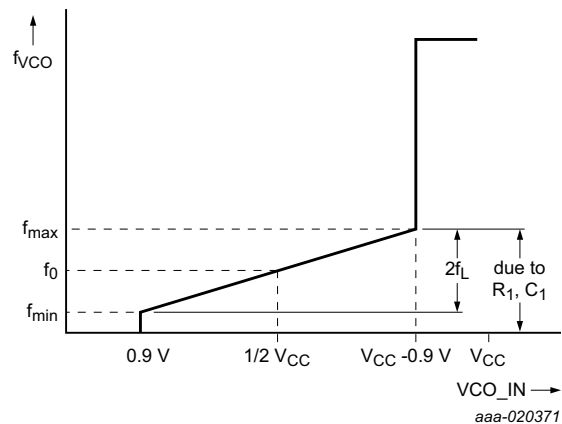
Values of the selected components should be within the ranges shown in [Table 9](#).

**Table 9. Survey of components**

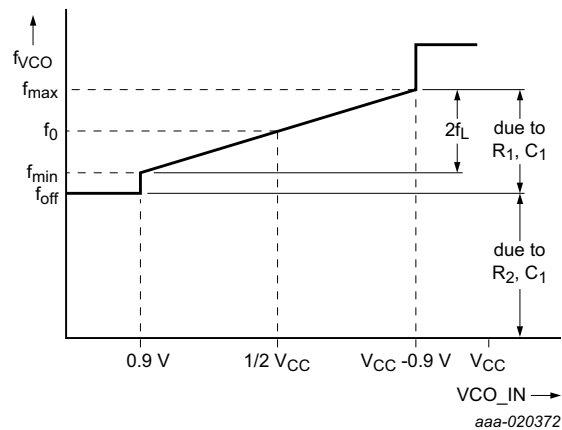
| Component | Value                                   |
|-----------|-----------------------------------------|
| R1        | between 3 k $\Omega$ and 300 k $\Omega$ |
| R2        | between 3 k $\Omega$ and 300 k $\Omega$ |
| R1 + R2   | parallel value > 2.7 k $\Omega$         |
| C1        | > 40 pF                                 |

**Table 10. Design considerations for VCO section**

| Subject                                | Phase comparator | Design consideration                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| VCO frequency without extra offset     | PC1, PC2 or PC3  | VCO frequency characteristic. With $R2 = \infty$ and $R1$ within the range $3 \text{ k}\Omega < R1 < 300 \text{ k}\Omega$ , the characteristics of the VCO operation is as shown in <a href="#">Figure 27a</a> . (Due to $R1$ , $C1$ time constant a small offset remains when $R2 = \infty \Omega$ ).                                                                  |
|                                        | PC1              | Selection of $R1$ and $C1$ . Given $f_0$ , determine the values of $R1$ and $C1$ using <a href="#">Figure 30</a> .                                                                                                                                                                                                                                                      |
|                                        | PC2 or PC3       | Given $f_{\max}$ and $f_0$ , determine the values of $R1$ and $C1$ using <a href="#">Figure 30</a> ; use <a href="#">Figure 32</a> to obtain $2f_L$ and then use it to calculate $f_{\min}$ .                                                                                                                                                                           |
| VCO frequency with extra offset        | PC1, PC2 or PC3  | VCO frequency characteristic with $R1$ and $R2$ within the ranges $3 \text{ k}\Omega < R1 < 300 \text{ k}\Omega$ , $3 \text{ k}\Omega < R2 < 300 \text{ k}\Omega$ . The characteristics of the VCO operation are as shown in <a href="#">Figure 27b</a> .                                                                                                               |
|                                        | PC1, PC2 or PC3  | Selection of $R1$ , $R2$ and $C1$ . Given $f_0$ and $f_L$ determine the value of product $R1C1$ by using <a href="#">Figure 32</a> . Calculate $f_{\text{off}}$ from the equation $f_{\text{off}} = f_0 - 1.6f_L$ . Obtain the values of $C1$ and $R2$ by using <a href="#">Figure 31</a> . Calculate the value of $R1$ from the value of $C1$ and the product $R1C1$ . |
| PLL conditions no signal at pin SIG_IN | PC1              | VCO adjusts to $f_0$ with $\Phi_{\text{DEM\_OUT}} = 90^\circ$ and $V_{\text{VCO\_IN}} = 0.5V_{\text{CC}}$ , see <a href="#">Figure 6</a>                                                                                                                                                                                                                                |
|                                        | PC2              | VCO adjusts to $f_0$ with $\Phi_{\text{DEM\_OUT}} = -360^\circ$ and $V_{\text{VCO\_IN}} = \text{minimum}$ , see <a href="#">Figure 8</a>                                                                                                                                                                                                                                |
|                                        | PC3              | VCO adjusts to $f_0$ with $\Phi_{\text{DEM\_OUT}} = -360^\circ$ and $V_{\text{VCO\_IN}} = \text{minimum}$ , see <a href="#">Figure 10</a>                                                                                                                                                                                                                               |



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

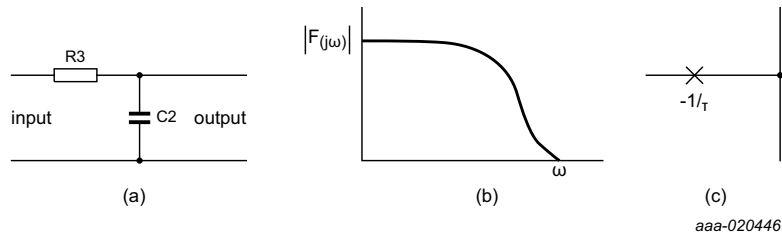


b. Operating with offset;  $f_0$  = center frequency;  $2f_L$  = frequency lock range.

Fig 27. Frequency characteristic of VCO

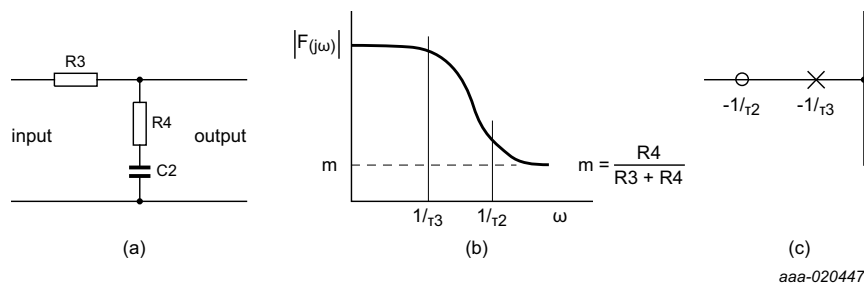
Table 11. General design considerations

| Subject                                    | Phase comparator | Design consideration                                                                  |
|--------------------------------------------|------------------|---------------------------------------------------------------------------------------|
| PLL frequency capture range                | PC1, PC2 or PC3  | Loop filter component selection, see <a href="#">Figure 28</a> and <a href="#">29</a> |
| 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 $\Phi_{\text{DEM\_OUT}} = 90^\circ$            |
|                                            | PC2              | $f_r = f_i$ ; small ripple content at $\Phi_{\text{DEM\_OUT}} = 0^\circ$              |
|                                            | PC3              | $f_r = f_i$ ; large ripple content at $\Phi_{\text{DEM\_OUT}} = 180^\circ$            |



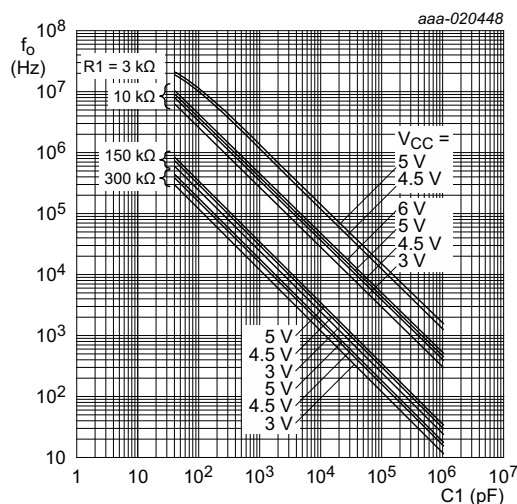
$R3 \geq 500 \Omega$ .  
A small capture range ( $2f_c$ ) is obtained if  $2f_c = \frac{1}{\pi} \sqrt{2\pi f_L / \tau}$   
(a)  $\tau = R3 \times C2$   
(b) amplitude characteristics  
(c) pole-zero diagram

Fig 28. Simple loop filter for PLL without offset



$R3 + R4 \geq 500 \Omega$ .  
(a)  $\tau1 = R3 \times C2$ ;  $\tau2 = R4 \times C2$ ;  $\tau3 = (R3 + R4) \times C2$   
(b) amplitude characteristics  
(c) pole-zero diagram

Fig 29. Simple loop filter for PLL with offset

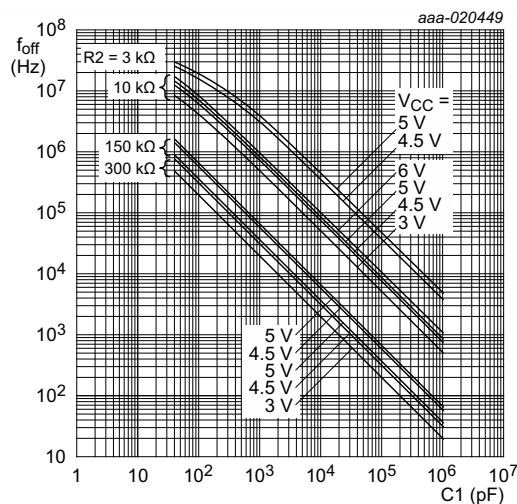


To obtain optimum VCO performance,  $C_1$  must be as small as possible but larger than 100 pF.

Interpolation for various values of  $R_1$  can be easily calculated because a constant  $R_1C_1$  product produces almost the same VCO output frequency.

$R_2 = \infty \Omega$ ;  $V_{VCO\_IN} = 0.5V_{CC}$ ;  $INH = GND$ ;  $T_{amb} = 25^\circ C$ .

**Fig 30. Typical value of VCO center frequency ( $f_0$ ) as a function of  $C_1$**

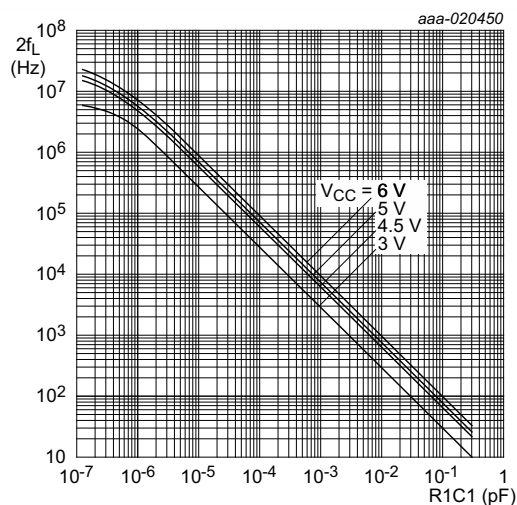


To obtain optimum VCO performance,  $C_1$  must be as small as possible but larger than 100 pF.

Interpolation for various values of  $R_2$  can be easily calculated because a constant  $R_2C_1$  product produces almost the same VCO output frequency.

$R_1 = \infty \Omega$ ;  $V_{VCO\_IN} = 0.5V_{CC}$ ;  $INH = GND$ ;  $T_{amb} = 25^\circ C$ .

**Fig 31. Typical value of frequency offset as a function of  $C_1$**



$V_{VCO\_IN} = 0.9\text{ V}$  to  $(V_{CC} - 0.9)\text{ V}$ ;  $R2 = \infty\ \Omega$ .

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

**Fig 32. Typical frequency lock range ( $2f_L$ ) as a function of the product  $R1C1$**



### 13.1 PLL design example

The frequency synthesizer used in the design example shown in [Figure 33](#) 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:

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

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:

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

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

The values of R1, R2 and C1; R2 = 10 k $\Omega$  (adjustable) set the VCO.

The values can be determined using the information in [Table 10](#) and [Table 11](#).

With  $f_0 = 2.5 \text{ MHz}$  and  $f_L = 500 \text{ kHz}$ , the following values ( $V_{CC} = 5.0 \text{ V}$ ) are given:

R1 = 10 k $\Omega$

R2 = 10 k $\Omega$

C1 = 500 pF

The VCO gain is:

$$K_v = \frac{2f_L \times 2\pi}{(V_{CC} - 0.9) - 0.9} = \frac{1 \text{ MHz}}{3.2} \times 2\pi \approx 2 \times 10^6 \text{ r/s/V}$$

The gain of the phase comparator is:

$$K_p = \frac{V_{CC}}{4 \times \pi} = 0.4 \text{ V/r}$$

The transfer gain of the filter is calculated as follows:

$$K_f = \frac{1 + \tau_2 s}{1 + (\tau_1 + \tau_2) s}$$

Where:

$$\tau_1 = R3 \times C2$$

$$\tau_2 = R4 \times C2$$

The characteristic equation is:  $1 + H(s) \times G(s) = 0$

It results in:

$$s^2 + \frac{1 + K_p \times K_v \times K_n \times \tau_2}{(\tau_1 + \tau_2)} \times s + \frac{K_p \times K_v \times K_n}{(\tau_1 + \tau_2)} = 0$$

The natural frequency  $\omega_n$  defined as:

$$\omega_n = \sqrt{\frac{K_p \times K_v \times K_n}{(\tau_1 + \tau_2)}}$$

and the damping value ( $\zeta$ ) given as:  $\zeta = \frac{1}{2\omega_n} \times \frac{1 + K_p \times K_v \times K_n \times \tau_2}{(\tau_1 + \tau_2)}$

In [Figure 34](#), the output frequency response to a step of input frequency is shown.

The overshoot and settling time percentages are now used to determine  $\omega_n$ .

[Figure 34](#) shows that the damping ratio  $\zeta = 0.45$  produces an overshoot of less than 20 % and settle to within 5 % at  $\omega_n t = 5$ . The required settling time is 1 ms. It results in:

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

Rewriting the equation for natural frequency results in:

$$(\tau_1 + \tau_2) = \frac{K_p \times K_v \times K_n}{(\omega_n)^2}$$

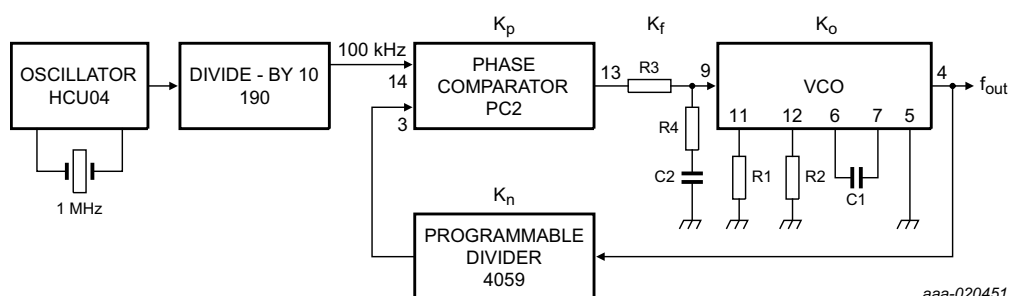
The maximum overshoot occurs at  $N_{\max}$ :

$$(\tau_1 + \tau_2) = \frac{0.4 \times 2 \times 10^6}{5000^2 \times 30} = 0.0011 \text{ s}$$

When  $C2 = 470 \text{ nF}$ , then:

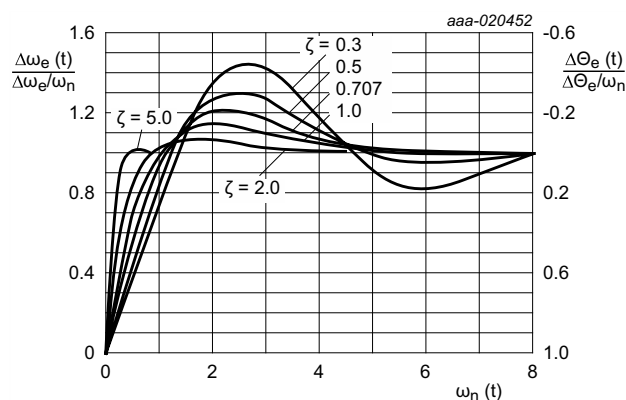
$$R4 = \frac{(\tau_1 + \tau_2) \times 2 \times \omega_n \times \zeta - 1}{K_p \times K_v \times K_n \times C2} = 315 \text{ } \Omega$$

R3 can be calculated:  $R3 = \frac{\tau_1}{C2} - R4 = 2 \text{ k}\Omega$

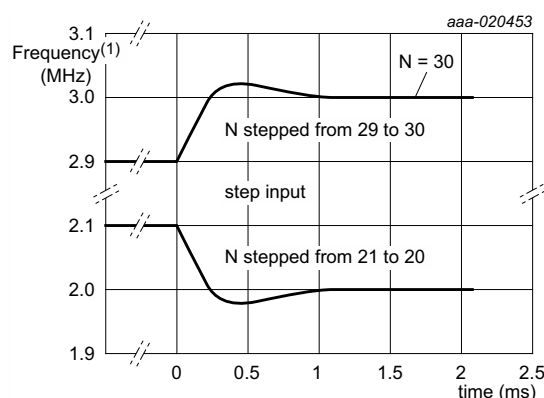


For an extensive description and application example, refer to “*Application note*” ordering number 9398 649 90011.

**Fig 33. Frequency synthesizer**



**Fig 34. Type 2, second order frequency step response**



The output frequency is proportional to the VCO control voltage. As a result, 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 using a simple RC filter. The filter has a long time constant when compared with the phase detector sampling rate but short when compared with the PLL response time.

**Fig 35. Frequency compared to the time response**

14. Package outline

SO16: plastic small outline package; 16 leads; body width 3.9 mm

SOT109-1

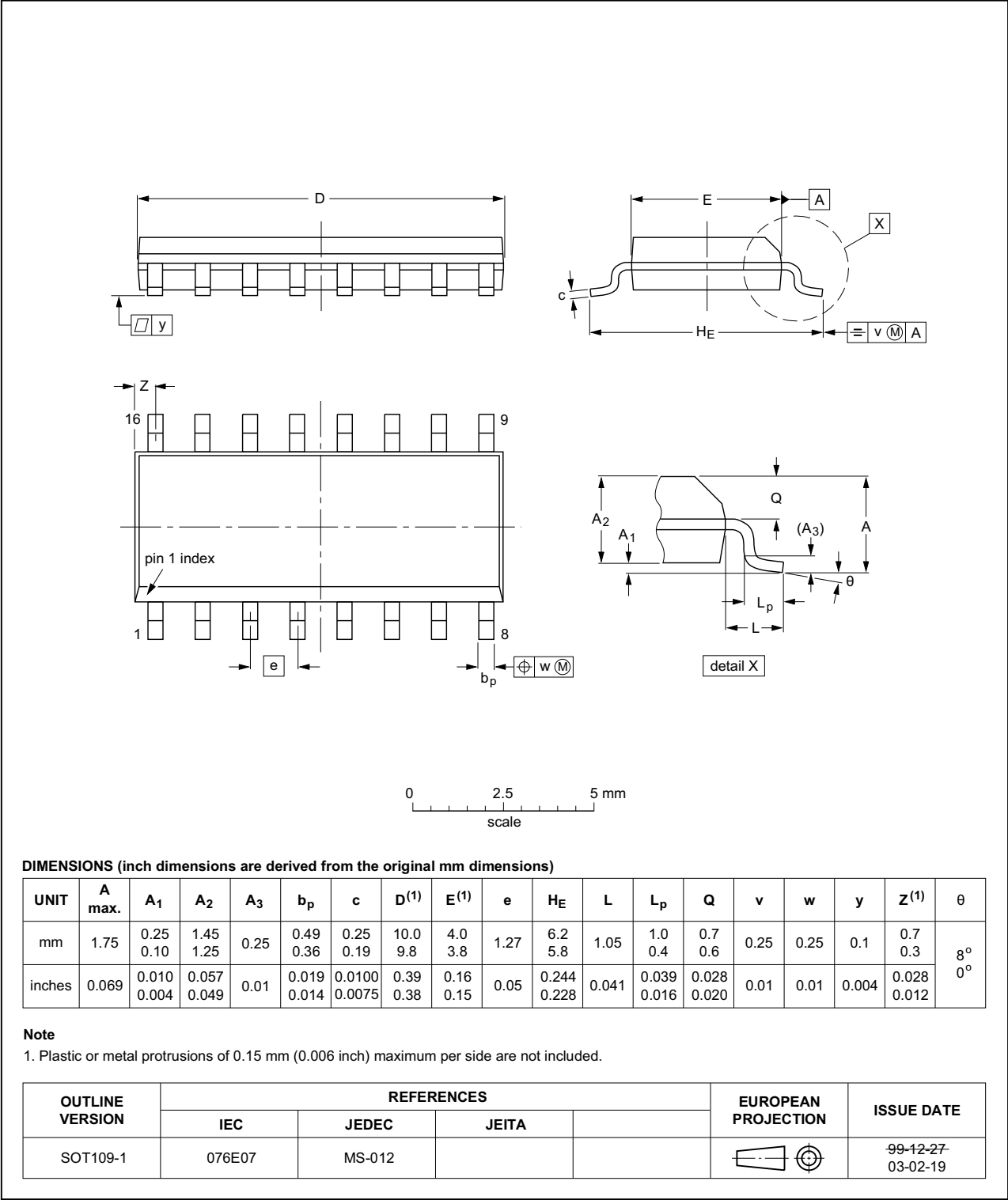


Fig 36. Package outline SOT109-1 (SO16)

SSOP16: plastic shrink small outline package; 16 leads; body width 5.3 mm

SOT338-1

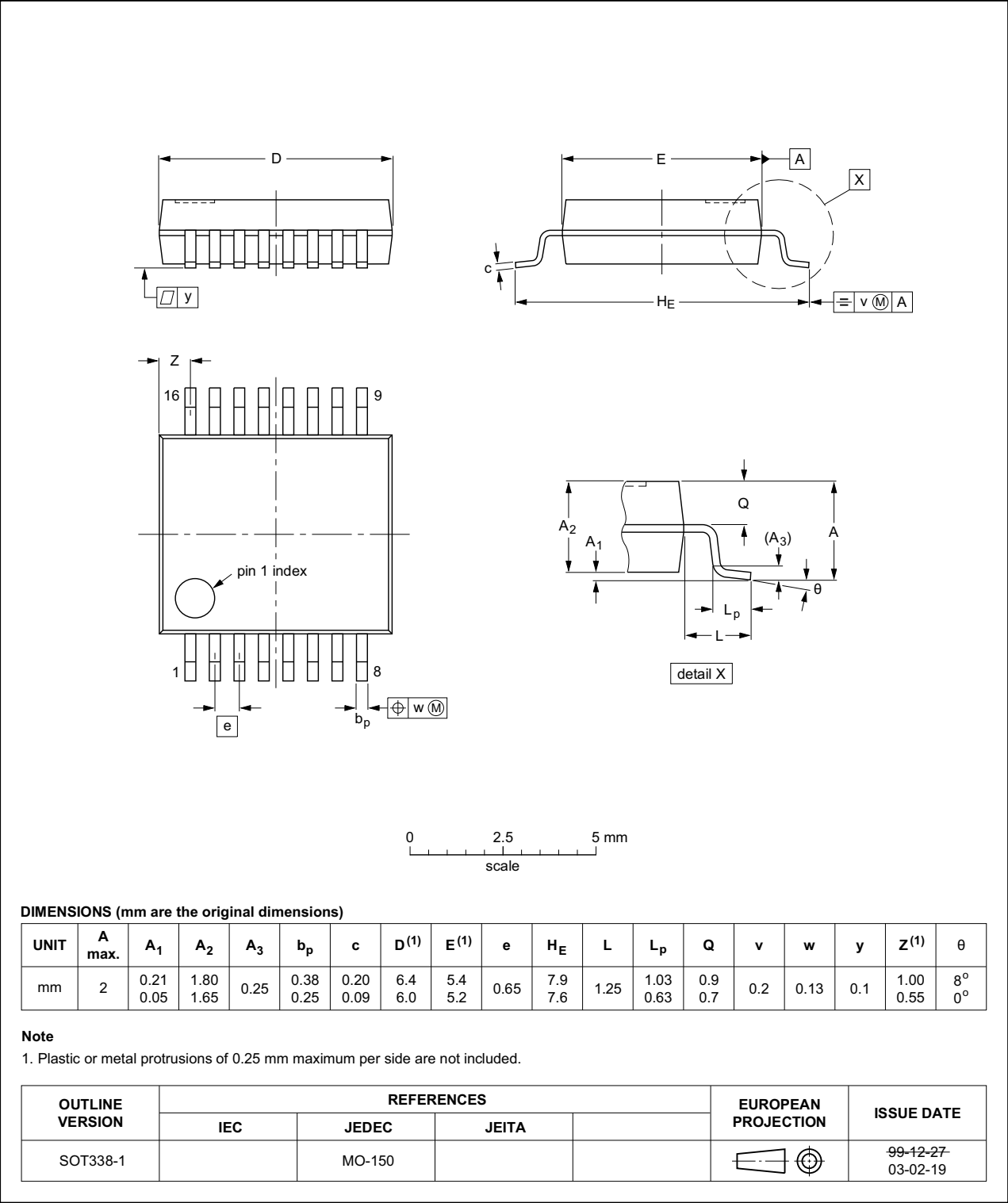


Fig 37. Package outline SOT338-1 (SSOP16)

TSSOP16: plastic thin shrink small outline package; 16 leads; body width 4.4 mm

SOT403-1

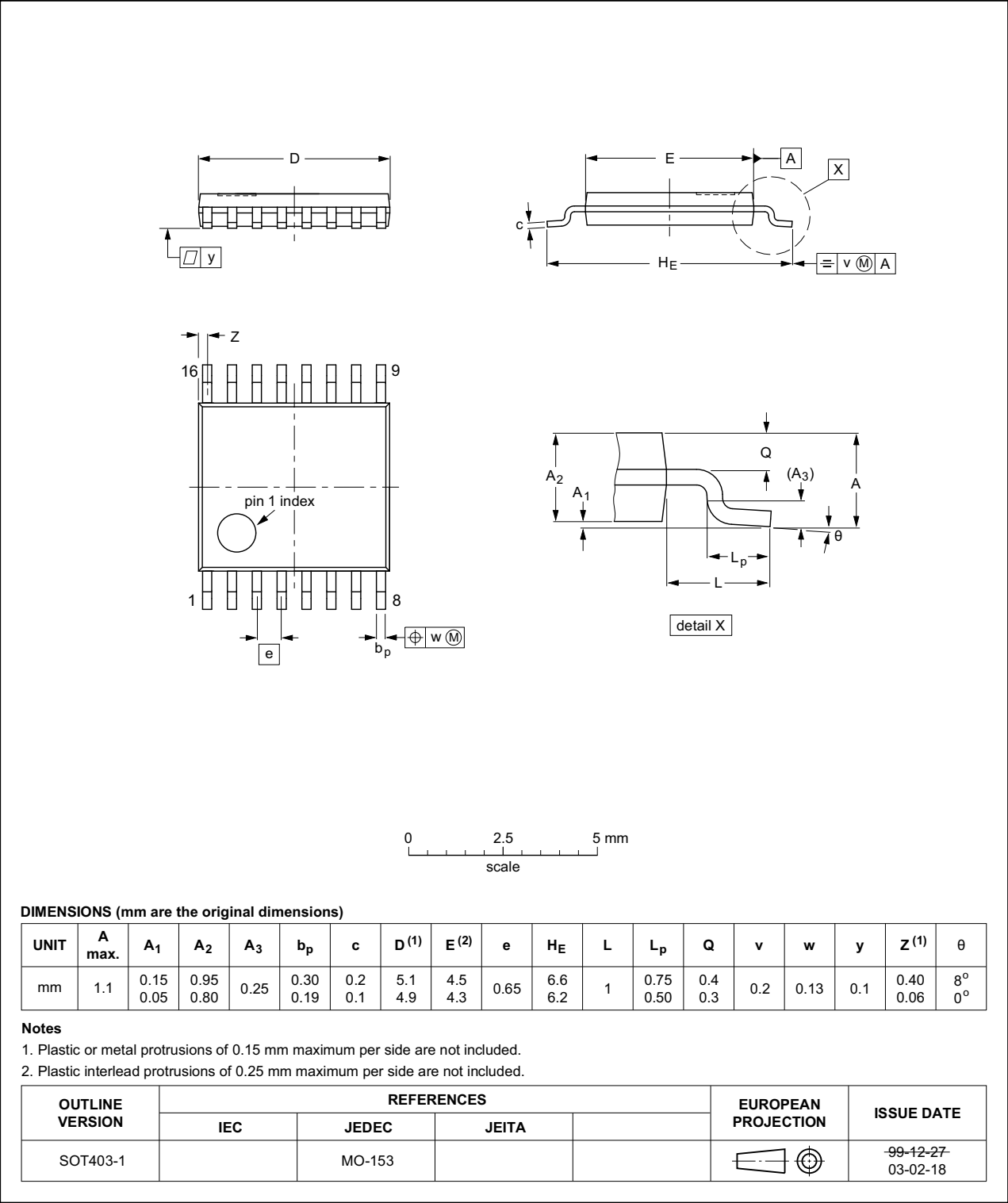


Fig 38. Package outline SOT403-1 (TSSOP16)

## 15. Abbreviations

Table 12. Abbreviations

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

## 16. Revision history

Table 13. Revision history

| Document ID           | Release date                                                                                                                                                                                                                                         | Data sheet status       | Change notice | Supersedes            |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------|-----------------------|
| 74HC_HCT4046A v.3     | 20160608                                                                                                                                                                                                                                             | Product data sheet      | -             | 74HC_HCT4046A_CNV v.2 |
| Modifications:        | <ul style="list-style-type: none"><li>The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors.</li><li>Legal texts have been adapted to the new company name where appropriate.</li></ul> |                         |               |                       |
| 74HC_HCT4046A_CNV v.2 | 19971125                                                                                                                                                                                                                                             | Product specification   | -             | 74HC_HCT4046A v.1     |
| 74HC_HCT4046A v.1     | 19930901                                                                                                                                                                                                                                             | Objective specification | -             | -                     |

## 17. Legal information

### 17.1 Data sheet status

| Document status <sup>[1][2]</sup> | Product status <sup>[3]</sup> | 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".

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