

74HCT9046A

PLL with band gap controlled VCO

Rev. 9 — 20 March 2020

Product data sheet

1. General description

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

2. Features and benefits

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

3. Applications

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

4. Ordering information

Table 1. Ordering information

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

5. Functional diagram

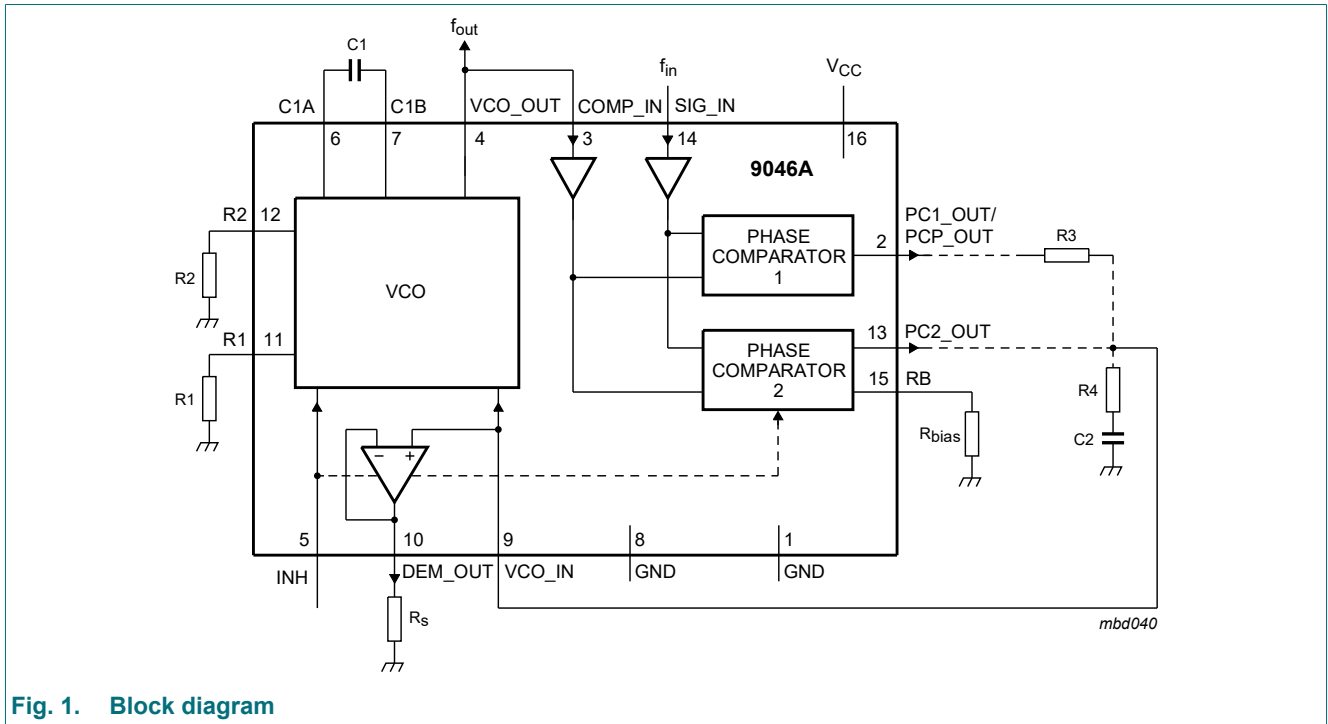


Fig. 1. Block diagram

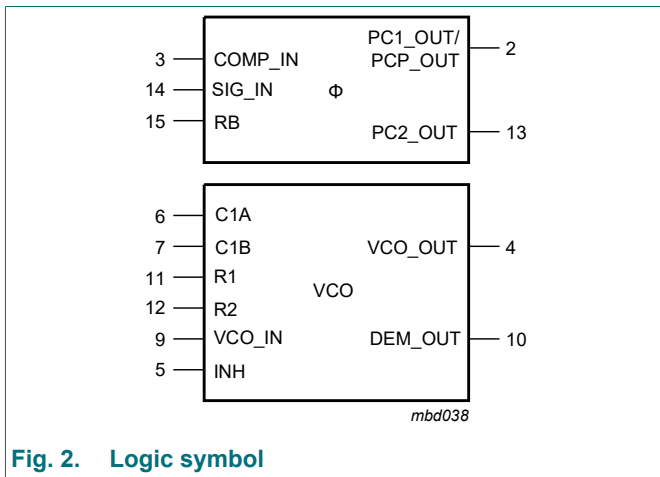


Fig. 2. Logic symbol

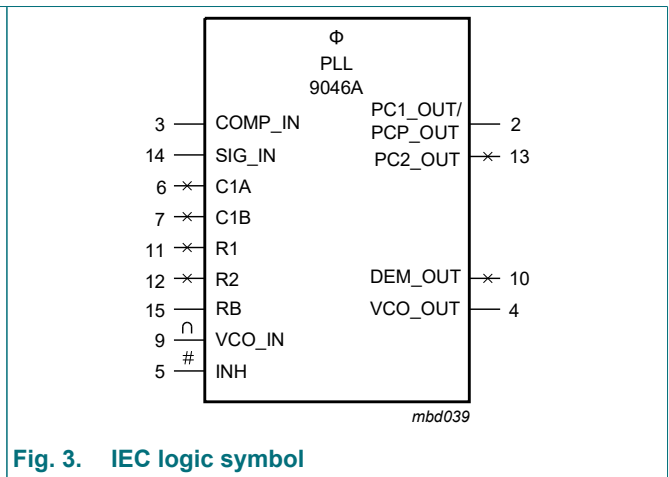


Fig. 3. IEC logic symbol

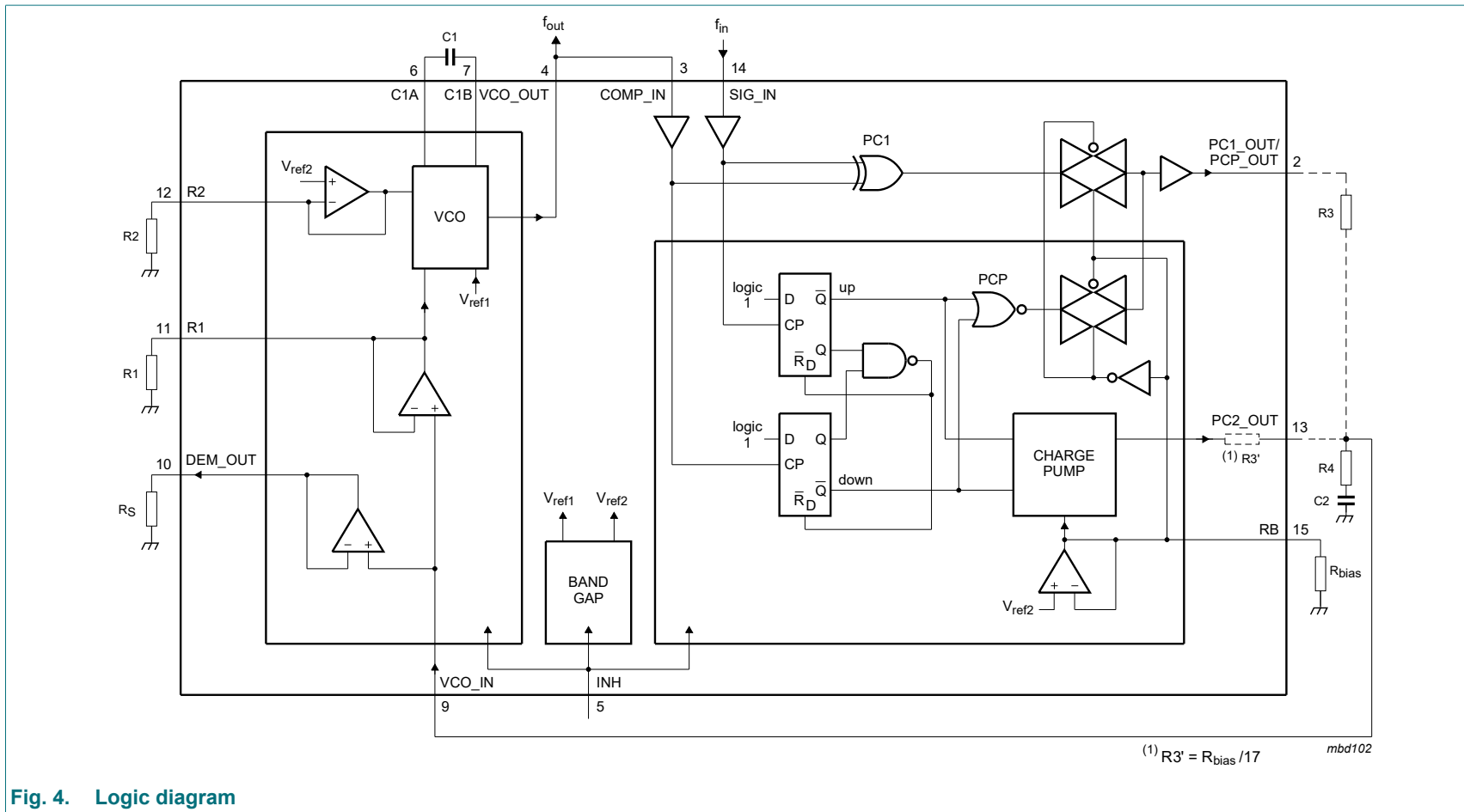
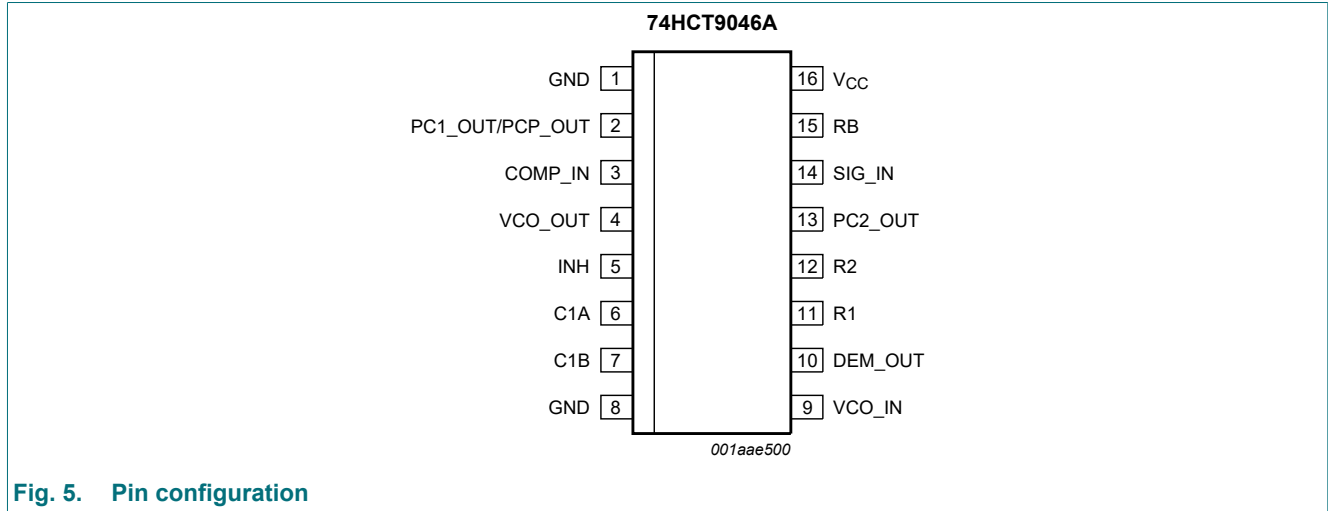


Fig. 4. Logic diagram

6. Pinning information

6.1. Pinning



6.2. Pin description

Table 2. Pin description

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

7. Functional description

The 74HCT9046A is a phase-locked-loop circuit that comprises a linear VCO and two different phase comparators (PC1 and PC2) with a common signal input amplifier and a common comparator input, see [Fig. 1](#). The signal input can be directly coupled to large voltage signals (CMOS level), or indirectly coupled (with a series capacitor) to small voltage signals. A self-bias input circuit keeps small voltage signals within the linear region of the input amplifiers. With a passive low-pass filter, the 74HCT9046A forms a second-order loop PLL.

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

7.1. Differences with respect to the familiar 74HCT4046A

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

7.2. VCO

The VCO requires one external capacitor C1 (between pins C1A and C1B) and one external resistor R1 (between pins R1 and GND) or two external resistors R1 and R2 (between pins R1 and GND, and R2 and GND). Resistor R1 and capacitor C1 determine the frequency range of the VCO. Resistor R2 enables the VCO to have a frequency offset if required (see [Fig. 4](#)).

The high input impedance of the VCO simplifies the design of the low-pass filters by giving the designer a wide choice of resistor/capacitor ranges. In order not to load the low-pass filter, a demodulator output of the VCO input voltage is provided at pin DEM_OUT. The DEM_OUT voltage equals that of the VCO input. If DEM_OUT is used, a series resistor (R_s) should be connected from pin DEM_OUT to GND; if unused, DEM_OUT should be left open. The VCO output (pin VCO_OUT) can be connected directly to the comparator input (pin COMP_IN), or connected via a

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

7.3. Phase comparators

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

7.3.1. Phase Comparator 1 (PC1)

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

$$V_{\text{DEM_OUT}} = \frac{V_{\text{CC}}}{\pi} (\Phi_{\text{SIG_IN}} - \Phi_{\text{COMP_IN}})$$

where:

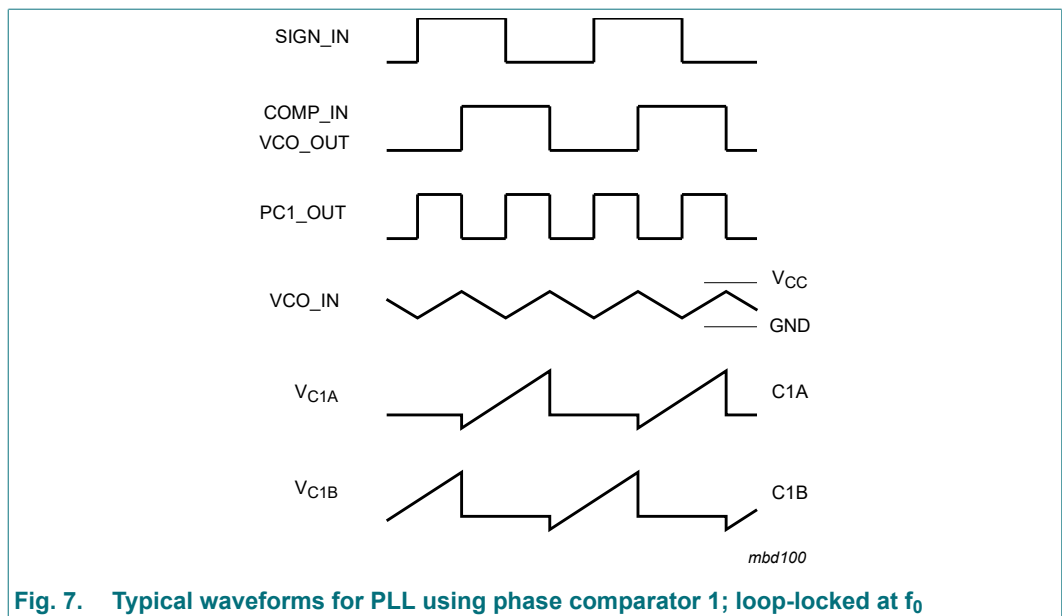
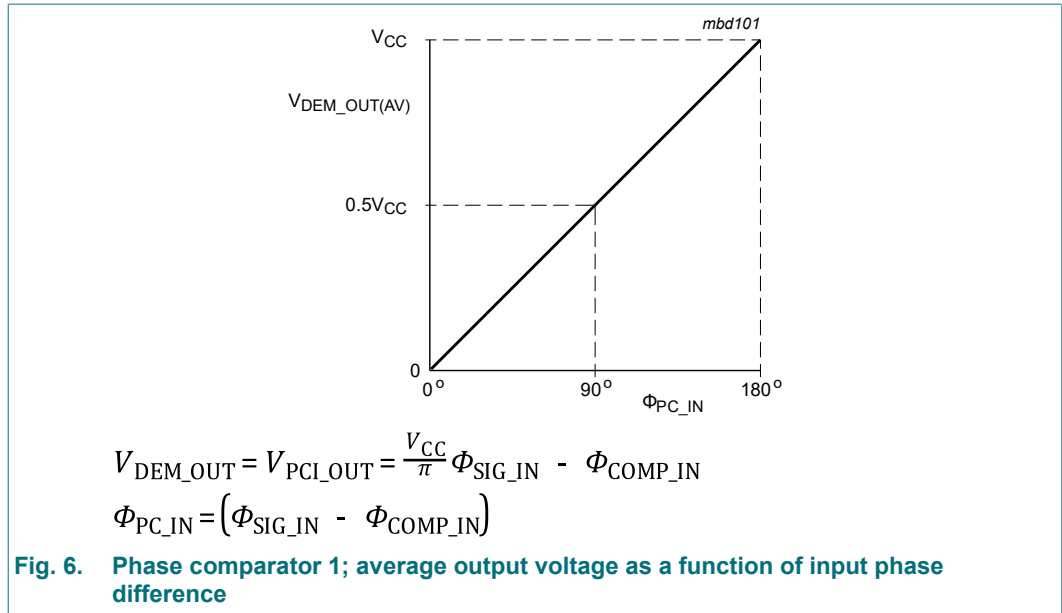
- $V_{\text{DEM_OUT}}$ is the demodulator output at pin DEM_OUT
- $V_{\text{DEM_OUT}} = V_{\text{PC1_OUT}}$ (via low-pass)

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

The average output voltage from PC1, fed to the VCO input via the low-pass filter and seen at the demodulator output at pin DEM_OUT ($V_{\text{DEM_OUT}}$), is the resultant of the phase differences of signals (SIG_IN) and the comparator input (COMP_IN) as shown in Fig. 6. The average of $V_{\text{DEM_OUT}}$ is equal to $0.5V_{\text{CC}}$ when there is no signal or noise at SIG_IN and with this input the VCO oscillates at the center frequency (f_0). Typical waveforms for the PC1 loop locked at f_0 are shown in Fig. 7. This figure also shows the actual waveforms across the VCO capacitor at pins C1A and C1B (V_{C1A} and V_{C1B}) to show the relation between these ramps and the VCO_OUT voltage.

The frequency capture range ($2f_0$) is defined as the frequency range of input signals on which the PLL will lock if it was initially out-of-lock. The frequency lock range ($2f_L$) is defined as the frequency range of the input signals on which the loop will stay locked if it was initially in lock. The capture range is smaller or equal to the lock range.

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



7.3.2. Phase Comparator 2 (PC2)

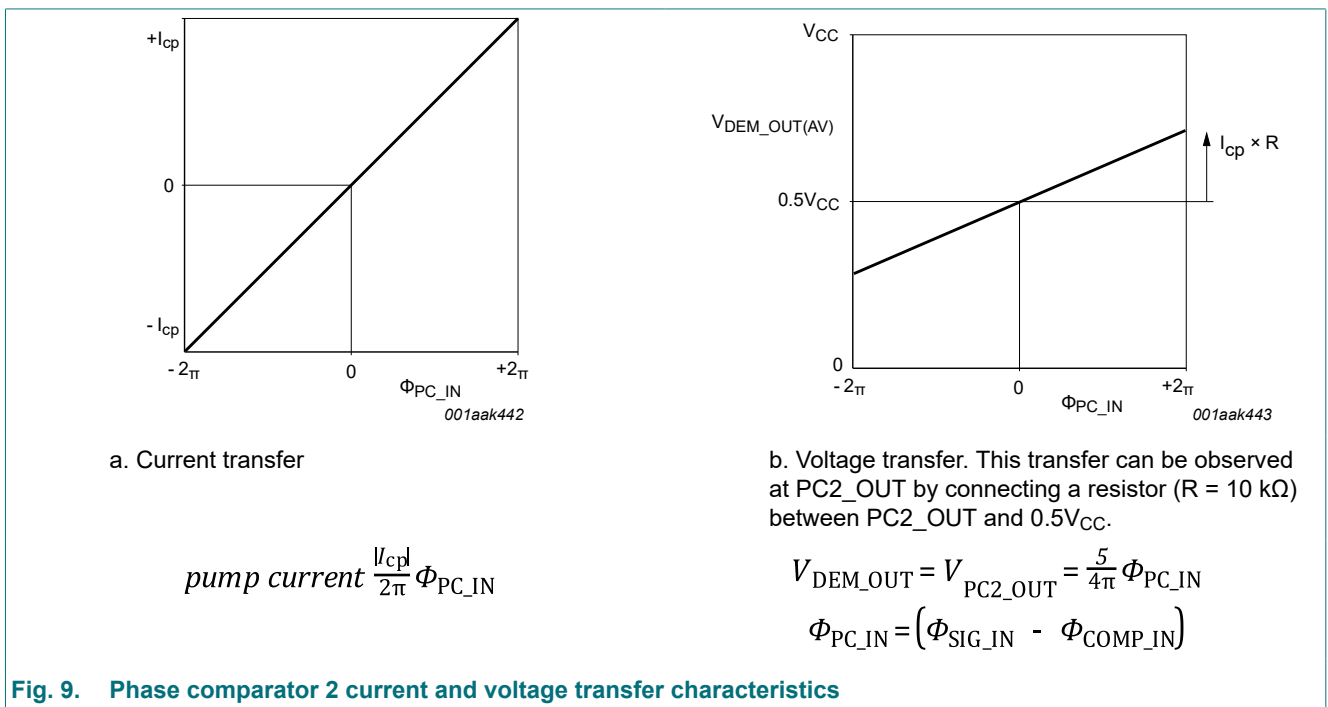
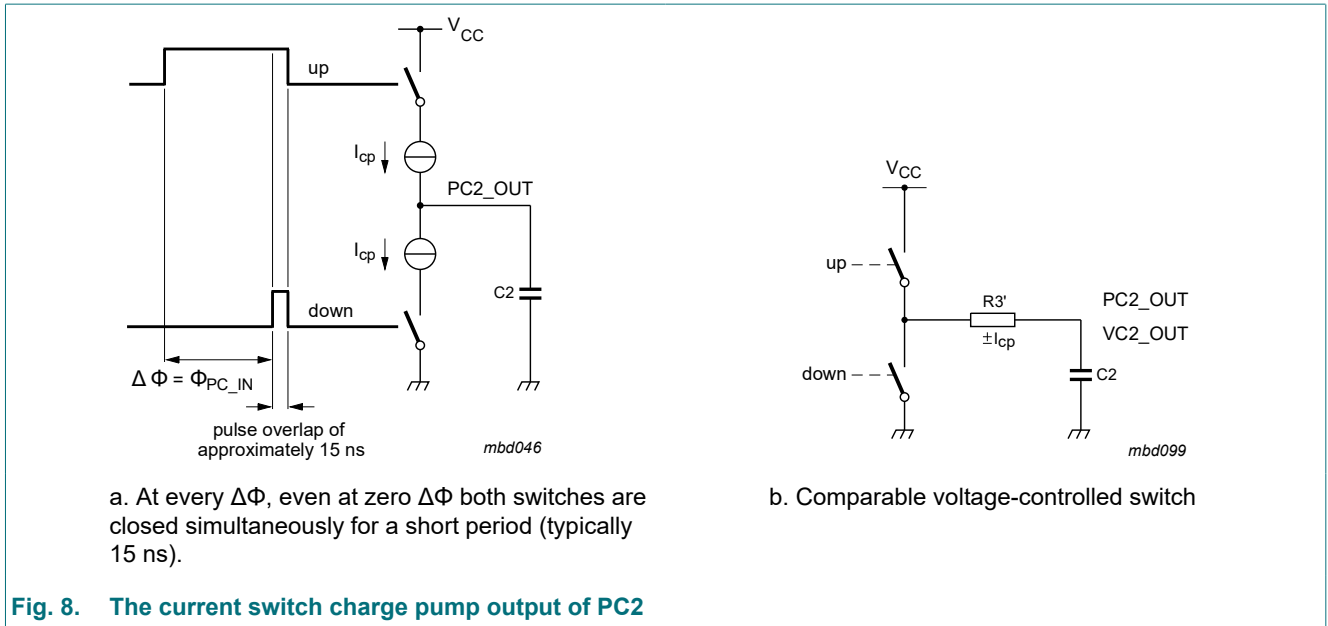
This is a positive edge-triggered phase and frequency detector. When the PLL is using this comparator, the loop is controlled by positive signal transitions and the duty cycles of SIG_IN and COMP_IN are not important. PC2 comprises two D-type flip-flops, control gating and a 3-state output stage with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

$$I_{\text{cp}} = 17 \times \frac{2.5}{R_{\text{bias}}} \text{ (A)}$$

Where R_{bias} is the external bias resistor between pin RB and ground.

The current and voltage transfer function of PC2 are shown in Fig. 9.

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



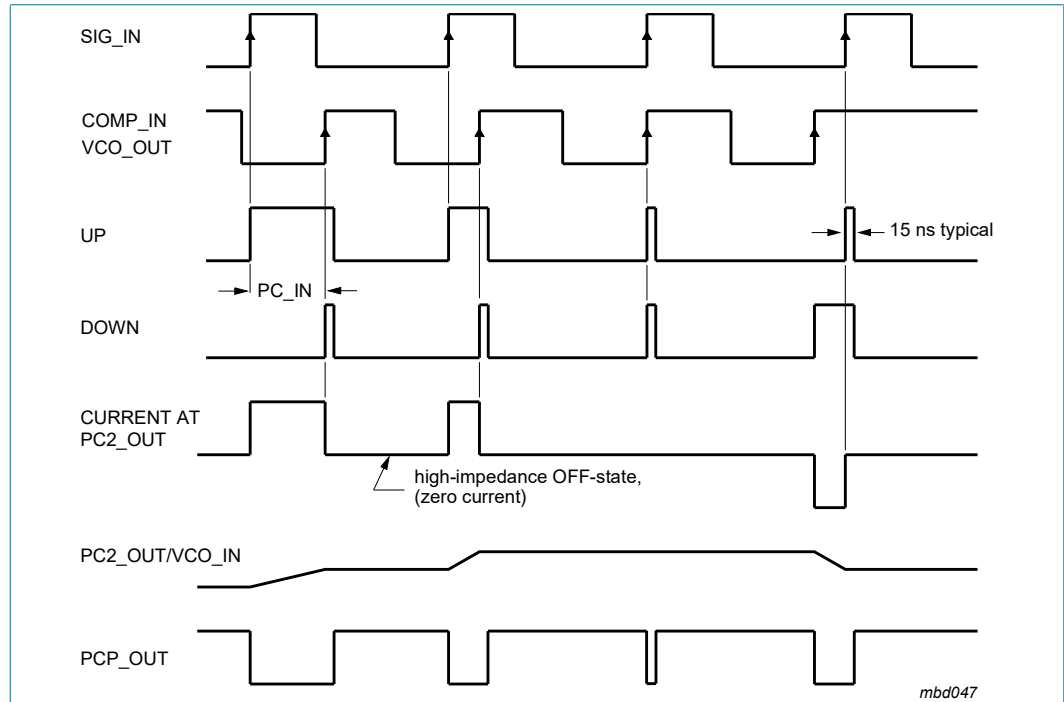
When the frequencies of SIG_IN and COMP_IN are equal but the phase of SIG_IN leads that of COMP_IN, the up output driver at PC2_OUT is held 'ON' for a time corresponding to the phase difference (Φ_{PC_IN}). When the phase of SIG_IN lags that of COMP_IN, the down or sink driver is held 'ON'.

When the frequency of SIG_IN is higher than that of COMP_IN, the source output driver is held 'ON' for most of the input signal cycle time and for the remainder of the cycle time both drivers are 'OFF' (3-state). If the SIG_IN frequency is lower than the COMP_IN frequency, then it is the sink driver that is held 'ON' for most of the cycle. Subsequently the voltage at the capacitor (C2) of the low-pass filter connected to PC2_OUT varies until the signal and comparator inputs are equal in both phase and frequency. At this stable point the voltage on C2 remains constant as the PC2 output is in 3-state and the VCO input at pin 9 is a high-impedance. Also in this condition the signal at the phase comparator pulse output (PCP_OUT) has a minimum output pulse width equal to the overlap time, so can be used for indicating a locked condition.

Thus for PC2 no phase difference exists between SIG_IN and COMP_IN over the full frequency range of the VCO. Moreover, the power dissipation due to the low-pass filter is reduced because both output drivers are OFF for most of the signal input cycle.

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

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



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

Fig. 10. Timing diagram for PC2

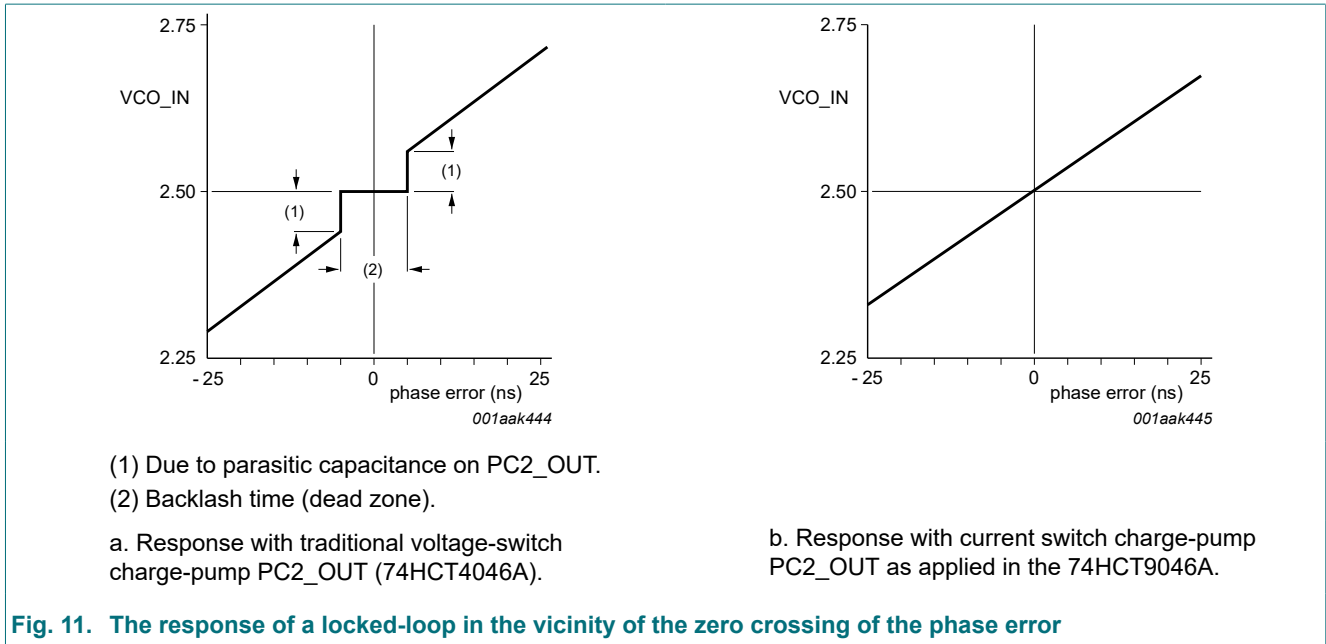


Fig. 11. The response of a locked-loop in the vicinity of the zero crossing of the phase error

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

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

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

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

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

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

Hence:

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

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

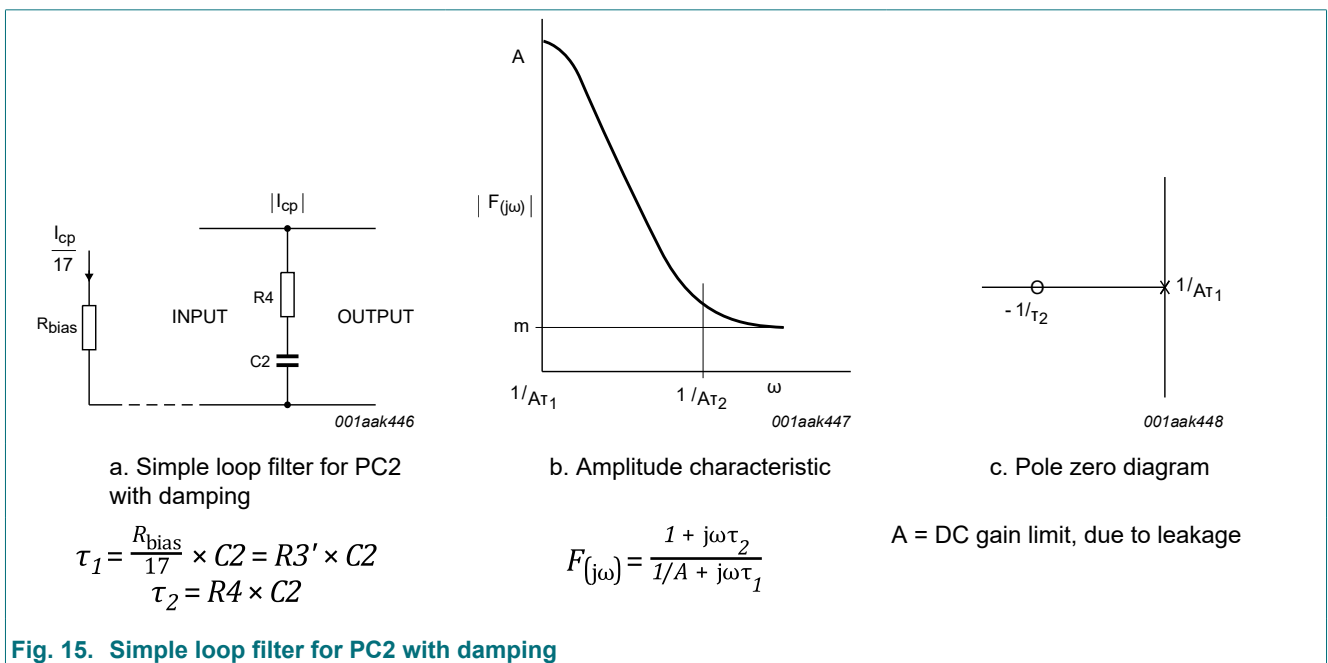
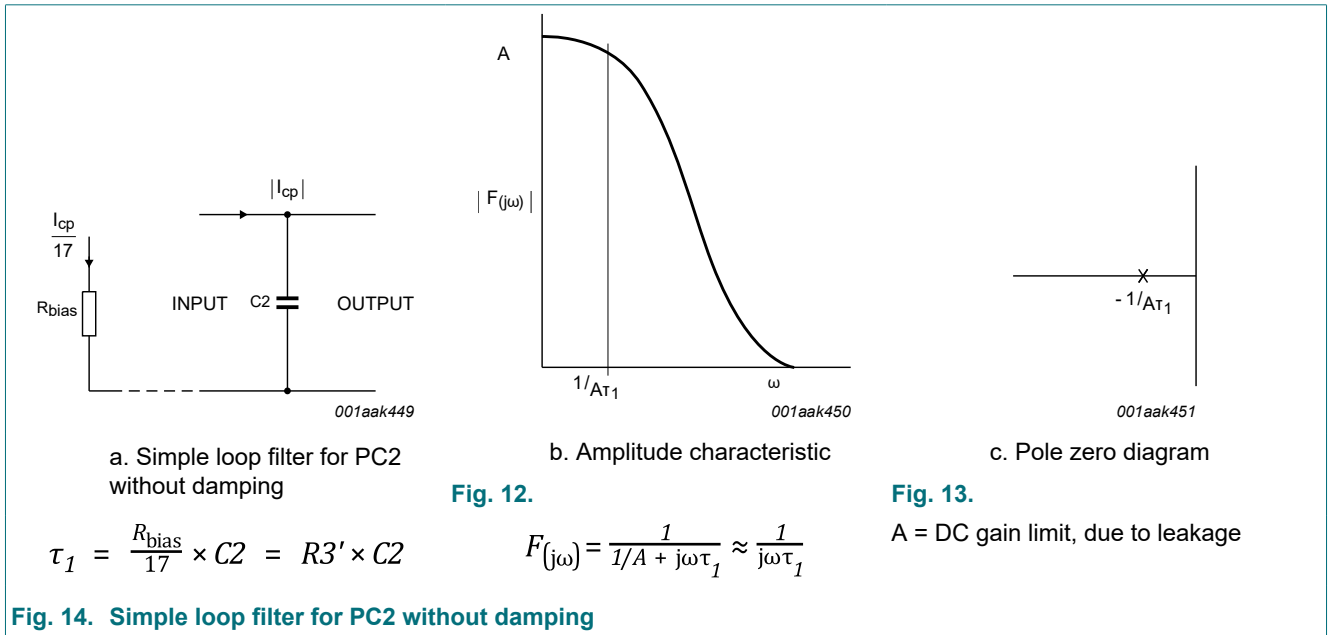
$$K_{PC2} = \frac{5}{4\pi} (V / r)$$

Again this illustrates the supply voltage independent behavior of PC2.

7.4. Loop filter component selection

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

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



8. Limiting values

Table 3. Limiting values

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

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

[1] For SOT109-1 (SO16) package: P_{tot} derates linearly with 12.4 mW/K above 110 °C.

9. Recommended operating conditions

Table 4. Operating conditions

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

10. Static characteristics

Table 5. Static characteristics

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

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

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|----------------------------|---------------------------|---|------------|------------|------------|---------------|
| I_{OZ} | OFF-state output current | pin PC2_OUT; $V_{CC} = 5.5\text{ V}$; $V_I = V_{IH}$ or V_{IL} ; $V_O = V_{CC}$ or GND | - | - | ± 0.5 | μA |
| R_I | input resistance | SIG_IN and COMP_IN; $V_{CC} = 4.5\text{ V}$; V_I at self-bias operating point; $\Delta V_I = 0.5\text{ V}$; see Fig. 16 , Fig. 17 and Fig. 18 | - | 250 | - | k Ω |
| R_{bias} | bias resistance | $V_{CC} = 4.5\text{ V}$ | 25 | - | 250 | k Ω |
| I_{cp} | charge pump current | $V_{CC} = 4.5\text{ V}$; $R_{bias} = 40\text{ k}\Omega$ | ± 0.53 | ± 1.06 | ± 2.12 | mA |
| VCO section | | | | | | |
| V_{IH} | HIGH-level input voltage | pin INH; $V_{CC} = 4.5\text{ V}$ to 5.5 V ; DC coupled | 2.0 | 1.6 | - | V |
| V_{IL} | LOW-level input voltage | pin INH; $V_{CC} = 4.5\text{ V}$ to 5.5 V ; DC coupled | - | 1.2 | 0.8 | V |
| V_{OH} | HIGH-level output voltage | pin VCO_OUT; $V_{CC} = 4.5\text{ V}$; $V_I = V_{IH}$ or V_{IL} | | | | |
| | | $I_O = -20\ \mu\text{A}$ | 4.4 | 4.5 | - | V |
| | | $I_O = -4.0\text{ mA}$ | 3.98 | 4.32 | - | V |
| V_{OL} | LOW-level output voltage | pin VCO_OUT; $V_{CC} = 4.5\text{ V}$; $V_I = V_{IH}$ or V_{IL} | | | | |
| | | $I_O = 20\ \mu\text{A}$ | - | 0 | 0.1 | V |
| | | $I_O = 4.0\text{ mA}$ | - | 0.15 | 0.26 | V |
| | | pins C1A and C1B; $V_{CC} = 4.5\text{ V}$; $V_I = V_{IH}$ or V_{IL} ; $I_O = 4.0\text{ mA}$ | - | - | 0.40 | V |
| I_I | input leakage current | pins INH and VCO_IN; $V_{CC} = 5.5\text{ V}$; $V_I = V_{CC}$ or GND | - | - | ± 0.1 | μA |
| R1 | resistor 1 | $V_{CC} = 4.5\text{ V}$ | 3 | - | 300 | k Ω |
| R2 | resistor 2 | $V_{CC} = 4.5\text{ V}$ | 3 | - | 300 | k Ω |
| 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 | | | | |
| | | $V_{CC} = 4.5\text{ V}$ | 1.1 | - | 3.4 | V |
| | | $V_{CC} = 5.0\text{ V}$ | 1.1 | - | 3.9 | V |
| | | $V_{CC} = 5.5\text{ V}$ | 1.1 | - | 4.4 | V |
| Demodulator section | | | | | | |
| R_s | series resistance | $V_{CC} = 4.5\text{ V}$; at $R_s > 300\text{ k}\Omega$ the leakage current can influence V_{DEM_OUT} | 50 | - | 300 | k Ω |
| V_{offset} | offset voltage | VCO_IN to V_{DEM_OUT} ; $V_{CC} = 4.5\text{ V}$; $V_I = V_{VCO_IN} = 0.5V_{CC}$; values taken over R_s range; see Fig. 19 | - | ± 20 | - | mV |
| R_{dyn} | dynamic resistance | DEM_OUT; $V_{CC} = 4.5\text{ V}$; $V_{DEM_OUT} = 0.5 V_{CC}$ | - | 25 | - | Ω |
| General | | | | | | |
| I_{CC} | supply current | disabled; $V_{CC} = 5.5\text{ V}$; pin INH at V_{CC} | - | - | 8.0 | μA |
| ΔI_{CC} | additional supply current | pin INH; $V_I = V_{CC} - 2.1\text{ V}$; $V_{CC} = 4.5\text{ V}$; other inputs at V_{CC} or GND; | - | 100 | 360 | μA |
| C_I | input capacitance | | - | 3.5 | - | pF |

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

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

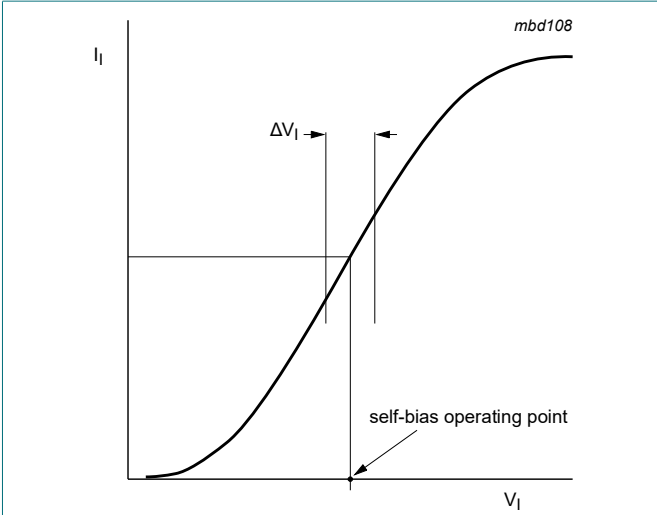


Fig. 16. Typical input resistance curve at SIG_IN and COMP_IN

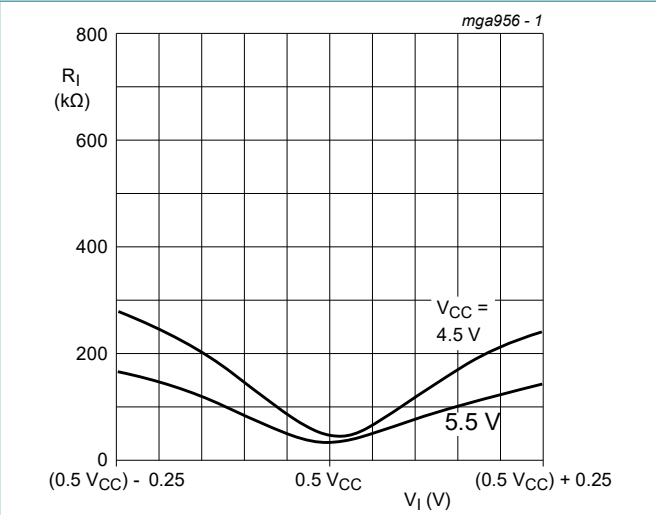


Fig. 17. Input resistance at SIG_IN; COMP_IN with $\Delta V_i = 0.5 \text{ V}$ at self-bias point

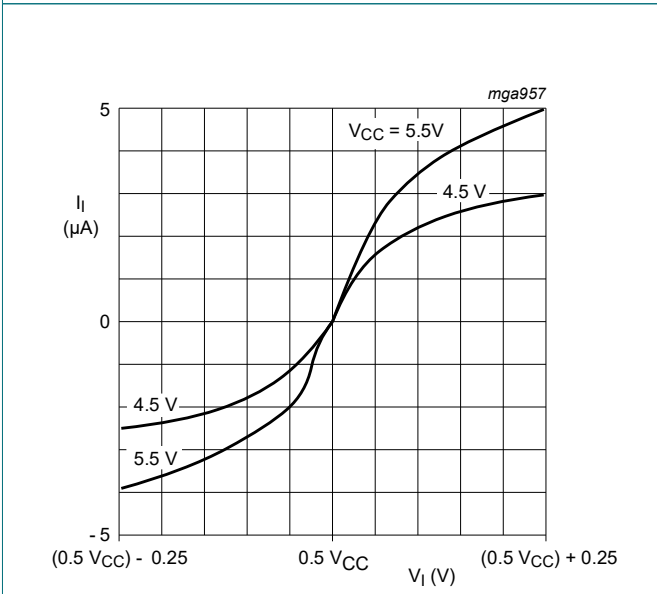


Fig. 18. Input current at SIG_IN; COMP_IN with $\Delta V_i = 0.5 \text{ V}$ at self-bias point

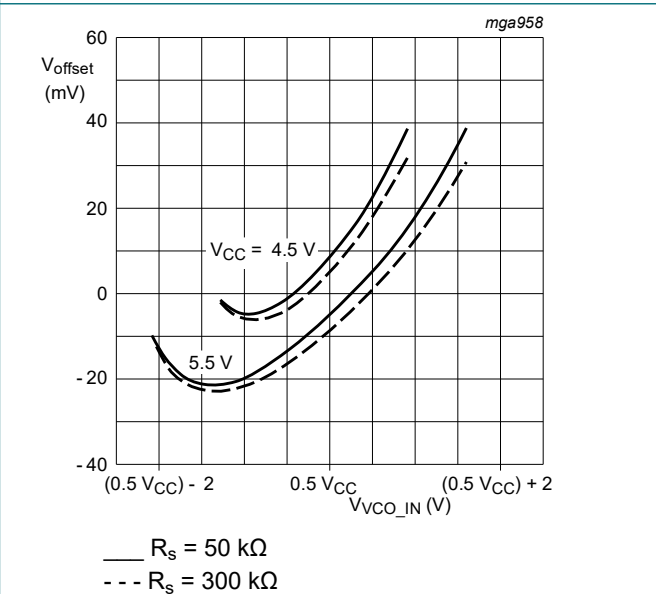


Fig. 19. Offset voltage at demodulator output as a function of VCO_IN and R_s

11. Dynamic characteristics

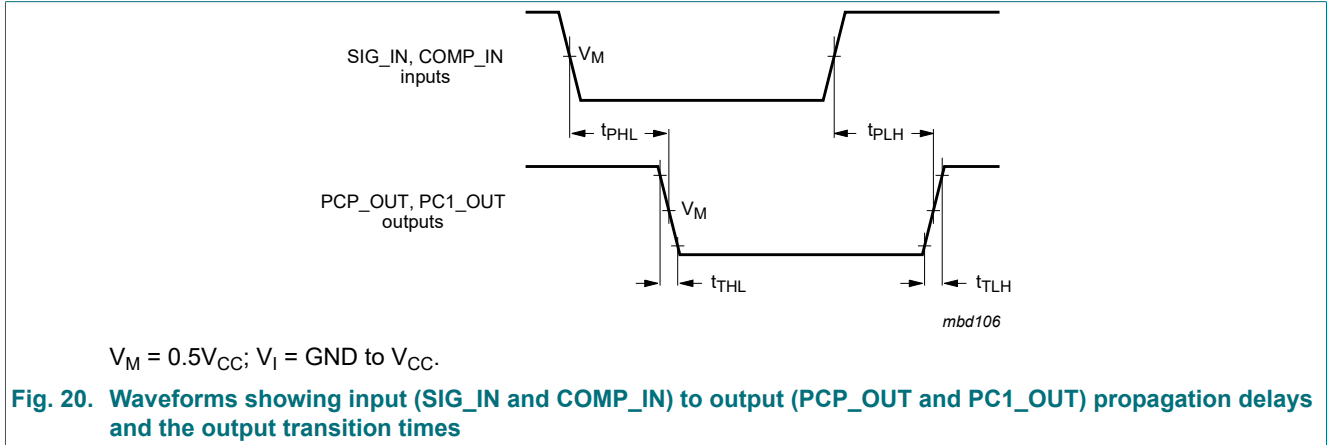
Table 6. Dynamic characteristics

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

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit | |
|---|--------------------------------------|---|--------|------|------|------|-----|
| T_{amb} = 25 °C | | | | | | | |
| Phase comparator section | | | | | | | |
| t _{pd} | propagation delay | SIG_IN, COMP_IN to PC1_OUT; V _{CC} = 4.5 V; see Fig. 20 | - | 23 | 40 | ns | |
| | | SIG_IN, COMP_IN to PCP_OUT; V _{CC} = 4.5 V; see Fig. 20 | - | 35 | 68 | ns | |
| t _{en} | enable time | SIG_IN, COMP_IN to PC2_OUT; V _{CC} = 4.5 V; see Fig. 21 | - | 30 | 56 | ns | |
| t _{dis} | disable time | SIG_IN, COMP_IN to PC2_OUT; V _{CC} = 4.5 V; see Fig. 21 | - | 36 | 65 | ns | |
| t _t | transition time | V _{CC} = 4.5 V; see Fig. 20 | - | 7 | 15 | ns | |
| V _{i(p-p)} | peak-to-peak input voltage | pin SIGN_IN or COMP_IN; V _{CC} = 4.5 V; AC coupled; f _i = 1 MHz | [2] | 50 | - | mV | |
| VCO section | | | | | | | |
| Δf | frequency deviation | V _{CC} = 5.0 V; V _{VCO_IN} = 3.9 V; R1 = 10 kΩ; R2 = 10 kΩ; C1 = 1 nF | [3] | -10 | - | +10 | % |
| f ₀ | center frequency | V _{CC} = 4.5 V; duty cycle = 50 %; V _{VCO_IN} = 0.5V _{CC} ; R1 = 4.3 kΩ; R2 = ∞ Ω; C1 = 40 pF; see Fig. 25 and Fig. 33 | | 11.0 | 15.0 | - | MHz |
| | | V _{CC} = 5 V; duty cycle = 50 %; V _{VCO_IN} = 0.5V _{CC} ; R1 = 3 kΩ; R2 = ∞ Ω; C1 = 40 pF; see Fig. 25 and Fig. 33 | | - | 16.0 | - | MHz |
| Δf/f | relative frequency variation | V _{CC} = 4.5 V; R1 = 100 kΩ; R2 = ∞ Ω; C1 = 100 pF; see Fig. 26 and Fig. 27 | [4] | - | 0.4 | - | % |
| δ | duty cycle | VCO_OUT; V _{CC} = 4.5 V | - | 50 | - | % | |
| General | | | | | | | |
| C _{PD} | power dissipation capacitance | | [5][6] | - | 20 | - | pF |
| T_{amb} = -40 °C to +85 °C | | | | | | | |
| Phase comparator section | | | | | | | |
| t _{pd} | propagation delay | SIG_IN, COMP_IN to PC1_OUT; V _{CC} = 4.5 V; see Fig. 20 | - | - | 50 | ns | |
| | | SIG_IN, COMP_IN to PCP_OUT; V _{CC} = 4.5 V; see Fig. 20 | - | - | 85 | ns | |
| t _{en} | enable time | SIG_IN, COMP_IN to PC2_OUT; V _{CC} = 4.5 V; see Fig. 21 | - | - | 70 | ns | |
| t _{dis} | disable time | SIG_IN, COMP_IN to PC2_OUT; V _{CC} = 4.5 V; see Fig. 21 | - | - | 81 | ns | |
| t _t | transition time | V _{CC} = 4.5 V; see Fig. 20 | - | - | 19 | ns | |
| VCO section | | | | | | | |
| Δf/ΔT | frequency variation with temperature | V _{CC} = 4.5 V; V _{VCO_IN} = 0.5V _{CC} ; recommended range: R1 = 10 kΩ; R2 = 10 kΩ; C1 = 1 nF; see Fig. 22, Fig. 23 and Fig. 24 | [7] | - | 0.06 | - | %/K |

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

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



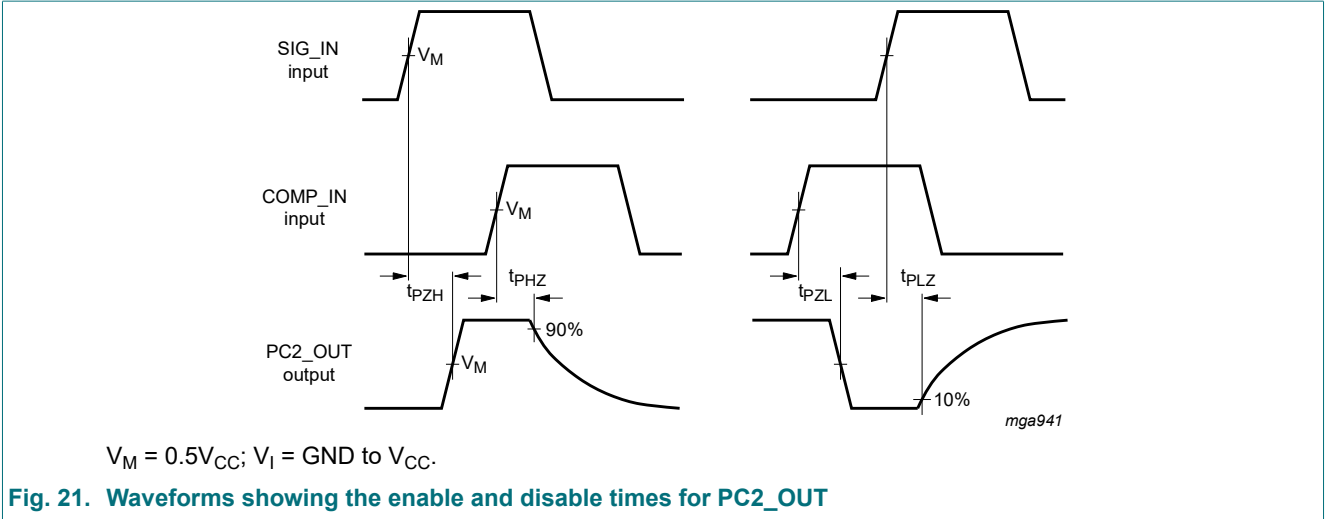


Fig. 21. Waveforms showing the enable and disable times for PC2_OUT

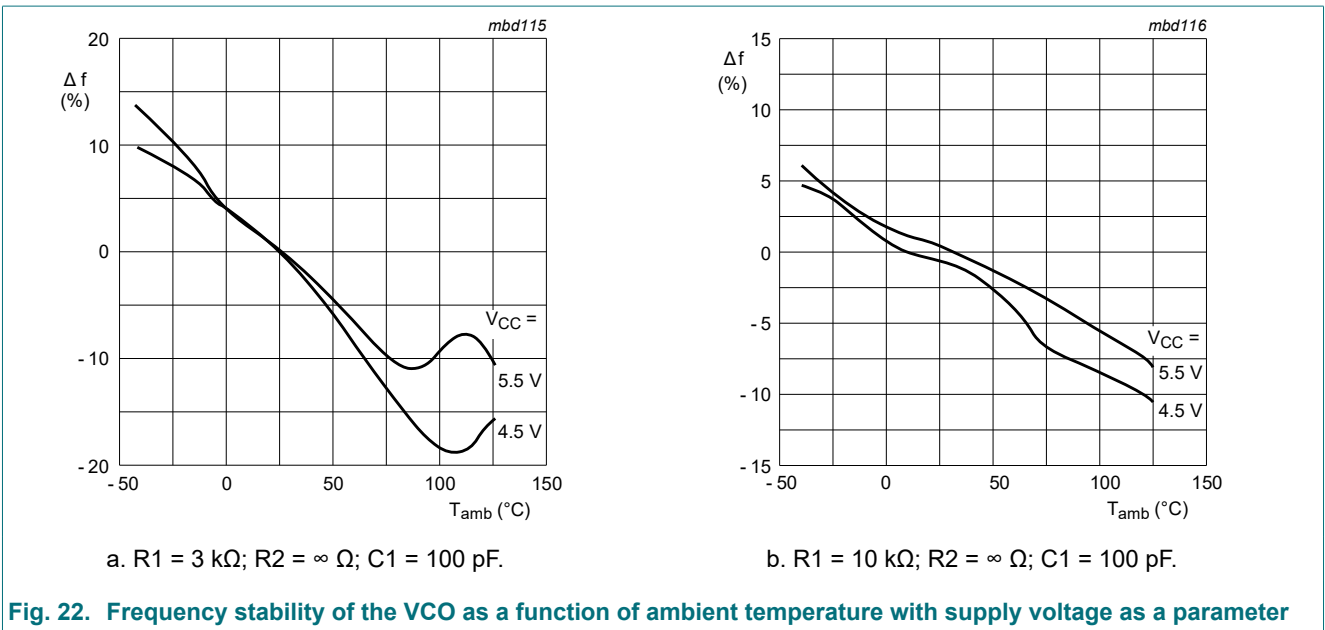
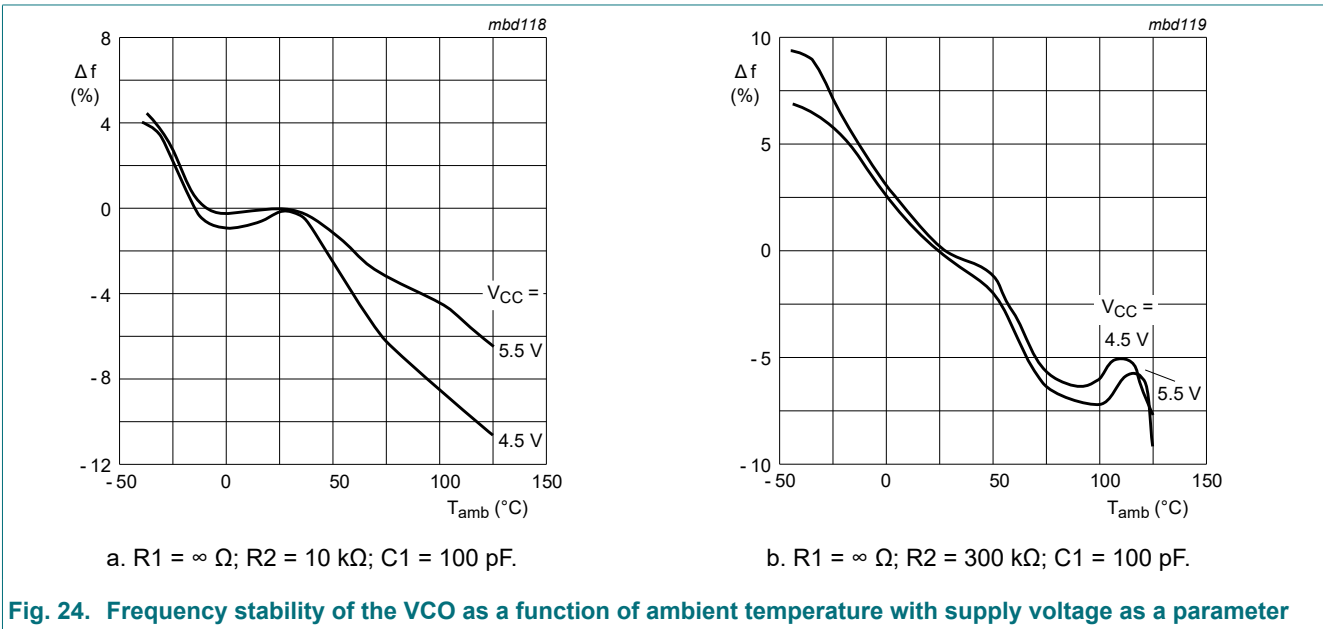
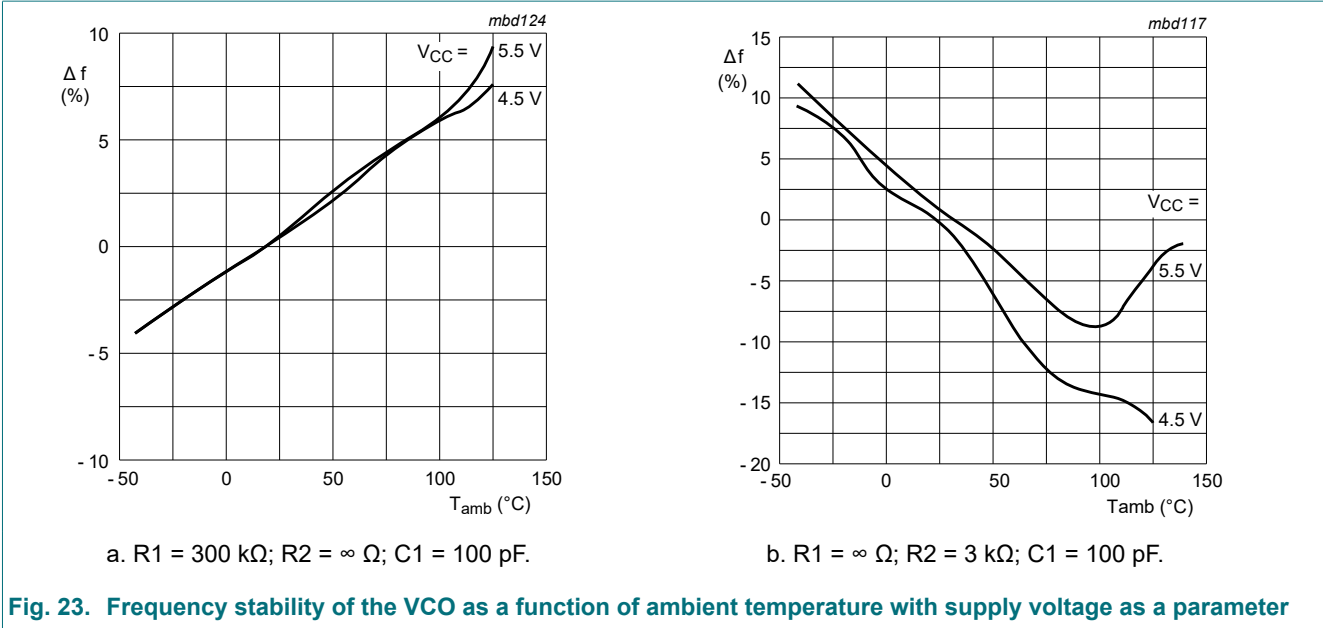


Fig. 22. Frequency stability of the VCO as a function of ambient temperature with supply voltage as a parameter



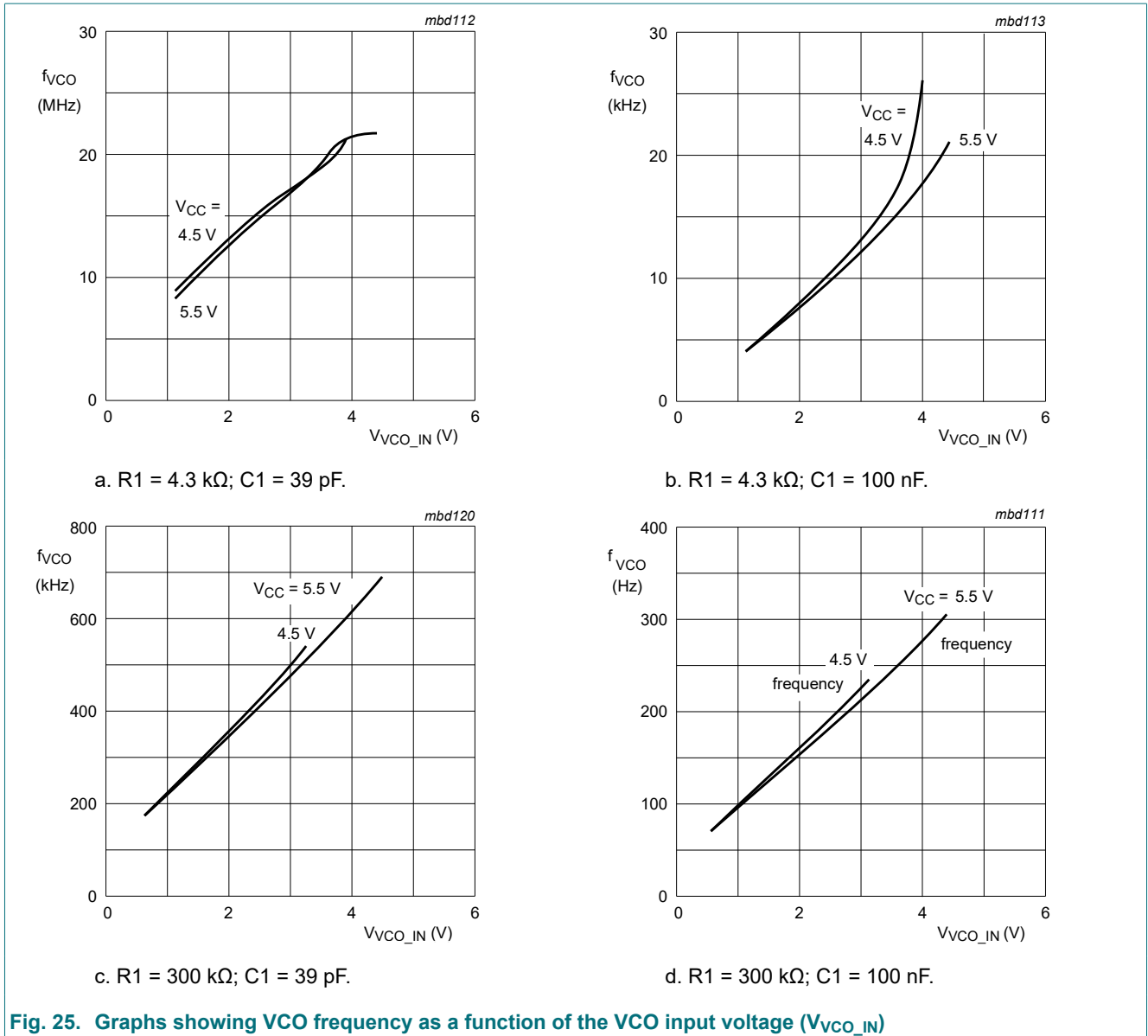
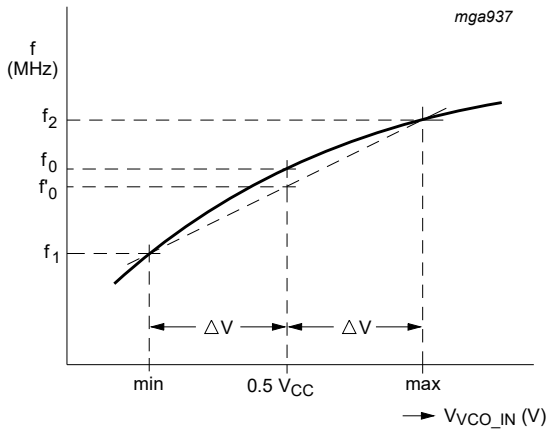


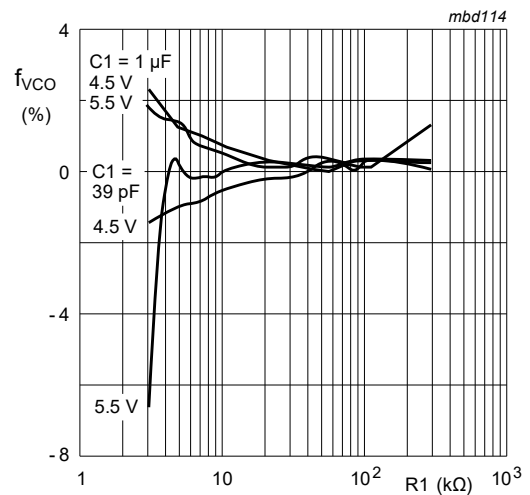
Fig. 25. Graphs showing VCO frequency as a function of the VCO input voltage (V_{VCO_IN})



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

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

Fig. 26. Definition of VCO frequency linearity: $\Delta V = 0.5 V$



$R_2 = \infty \Omega$ and $\Delta V = 0.5 V$

Fig. 27. Frequency linearity as a function of R_1 , C_1 and V_{CC}

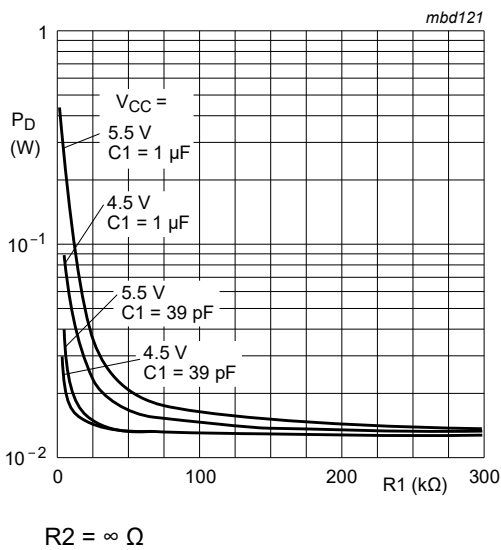


Fig. 28. Power dissipation as a function of R_1

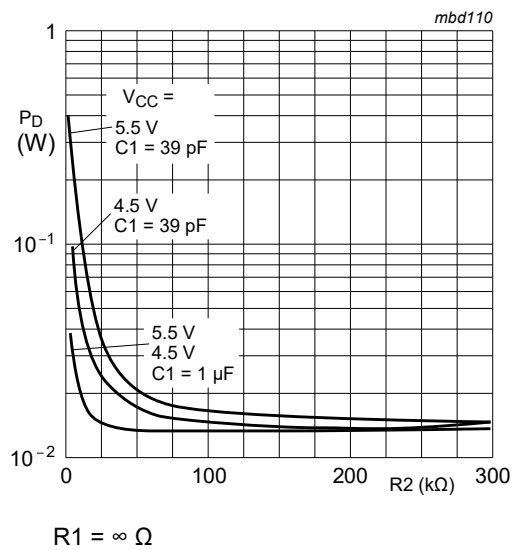


Fig. 29. Power dissipation as a function of R_2

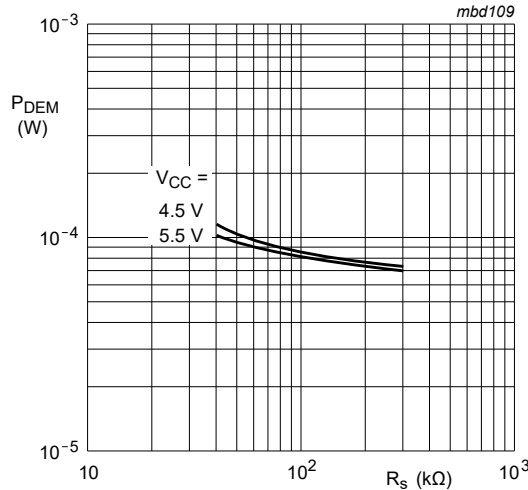


Fig. 30. Typical power dissipation as a function of R_s

12. Application information

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

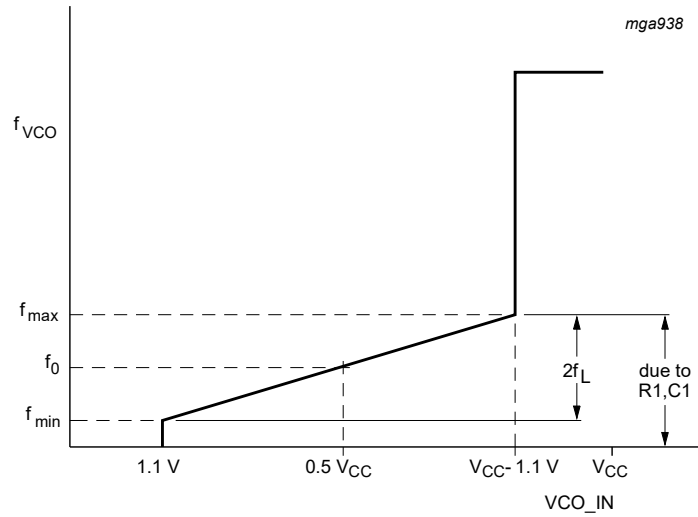
Values of the selected components should be within the ranges shown in [Table 7](#).

Table 7. Survey of components

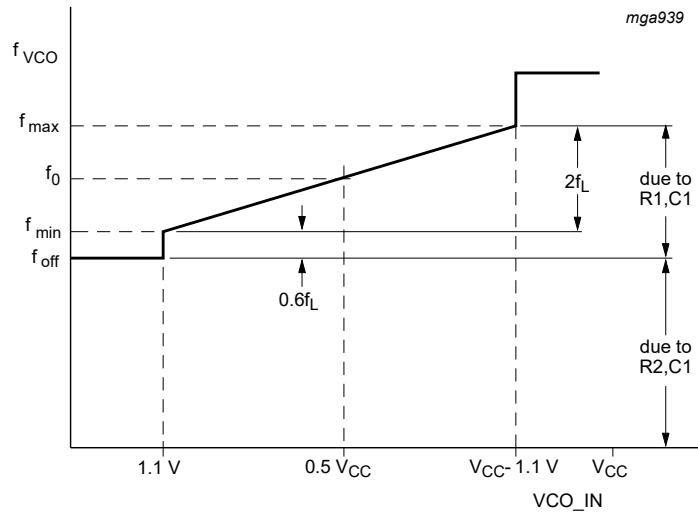
| Component | Value |
|-----------|-------------------------|
| R1 | between 3 kΩ and 300 kΩ |
| R2 | between 3 kΩ and 300 kΩ |
| R1 + R2 | parallel value > 2.7 kΩ |
| C1 | > 40 pF |

Table 8. Design considerations for VCO section

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



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



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

Fig. 31. Frequency characteristic of VCO

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

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

Table 9. Transfer functions of phase comparators and filters

| Phase comparator | Explanation | Figure | Filter type | Transfer function |
|------------------|---|----------|--------------------------------|---|
| PC1 | $K_{PC1} = \frac{V_{CC}}{\pi} V/r$ | Fig. 32a | passive filter without damping | $F(j\omega) = \frac{1}{1 + j\omega\tau_1}$ |
| | $\tau_1 = R3 \times C2;$ $\tau_2 = R4 \times C2;$ $\tau_3 = R4 \times C3;$ $A = 10^5 = \text{DC gain amplitude}$ | Fig. 32b | passive filter with damping | $F(j\omega) = \frac{1 + j\omega\tau_2}{1 + j\omega(\tau_1 + \tau_2)}$ |
| | | Fig. 32c | active filter with damping | $F(j\omega) = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1} \approx \frac{1 + j\omega\tau_2}{j\omega\tau_1}$ |
| PC2 | $K_{PC} + \frac{5}{4\pi} V/r$ $\tau_1 = R3' \times C2;$ $\tau_2 = R4 \times C2;$ $\tau_3 = R4 \times C3;$ $R3' = R_{bias}/17;$ $R_{bias} = 25 \text{ k}\Omega \text{ to } 250 \text{ k}\Omega$ | Fig. 32d | passive filter with damping | $F(j\omega) = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1} \approx \frac{1 + j\omega\tau_2}{j\omega\tau_1}$ $A = 10^5 = \text{DC gain amplitude}$ |
| | | Fig. 32e | active filter with damping | $F(j\omega) = \frac{1 + j\omega\tau_2}{1/A + j\omega\tau_1} \approx \frac{1 + j\omega\tau_2}{j\omega\tau_1}$ $A = 10^5 = \text{DC gain amplitude}$ |

Table 10. General design considerations

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

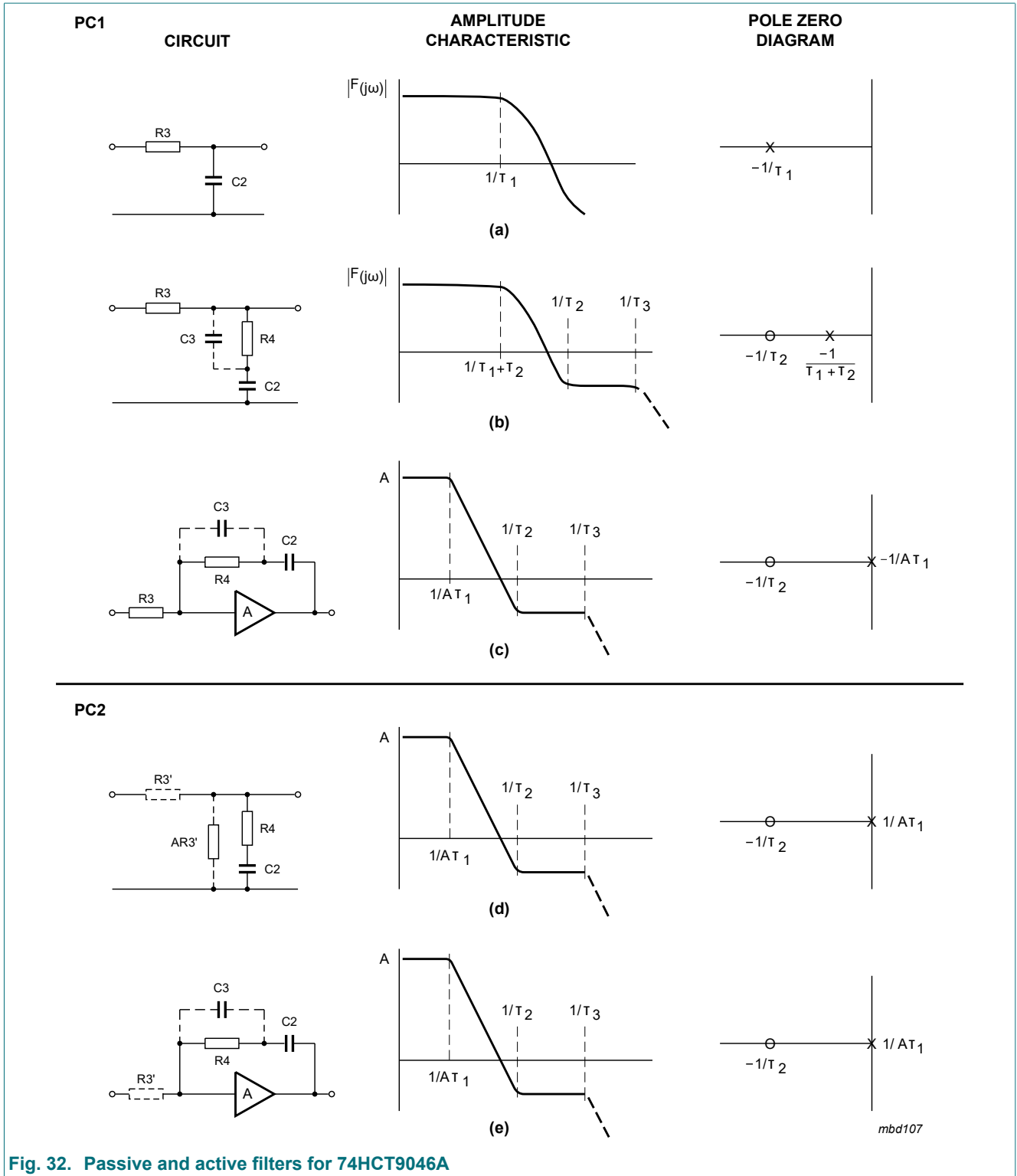
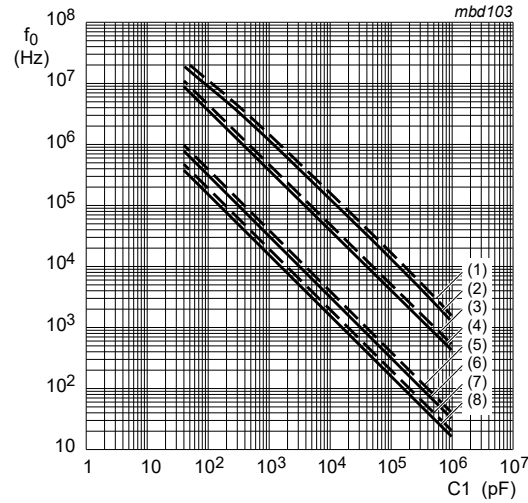
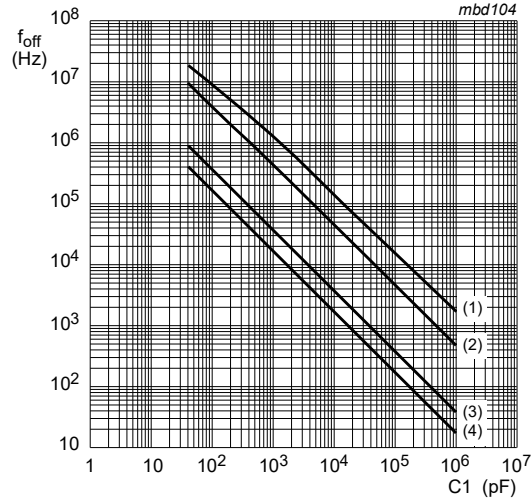


Fig. 32. Passive and active filters for 74HCT9046A



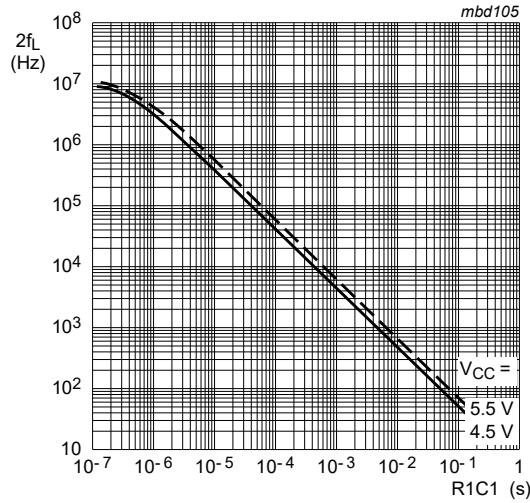
- (1) $V_{CC} = 5.5 \text{ V}$; $R_1 = 3 \text{ k}\Omega$.
 - (2) $V_{CC} = 4.5 \text{ V}$; $R_1 = 3 \text{ k}\Omega$.
 - (3) $V_{CC} = 5.5 \text{ V}$; $R_1 = 10 \text{ k}\Omega$.
 - (4) $V_{CC} = 4.5 \text{ V}$; $R_1 = 10 \text{ k}\Omega$.
 - (5) $V_{CC} = 5.5 \text{ V}$; $R_1 = 150 \text{ k}\Omega$.
 - (6) $V_{CC} = 4.5 \text{ V}$; $R_1 = 150 \text{ k}\Omega$.
 - (7) $V_{CC} = 5.5 \text{ V}$; $R_1 = 300 \text{ k}\Omega$.
 - (8) $V_{CC} = 4.5 \text{ V}$; $R_1 = 300 \text{ k}\Omega$.
- $R_2 = \infty \Omega$; $V_{VCO_IN} = 0.5V_{CC}$; $INH = GND$; $T_{amb} = 25 \text{ }^\circ\text{C}$.

Fig. 33. Typical value of VCO center frequency (f_0) as a function of C_1



- (1) $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$; $R_2 = 3 \text{ k}\Omega$.
 - (2) $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$; $R_2 = 10 \text{ k}\Omega$.
 - (3) $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$; $R_2 = 150 \text{ k}\Omega$.
 - (4) $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$; $R_2 = 300 \text{ k}\Omega$.
- $R_1 = \infty \Omega$; $V_{VCO_IN} = 0.5V_{CC}$; $INH = GND$; $T_{amb} = 25 \text{ }^\circ\text{C}$.

Fig. 34. Typical value of frequency offset as a function of C_1



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

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

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

12.2. PLL design example

The frequency synthesizer used in the design example shown in [Fig. 36](#) has the following parameters:

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

The open loop gain is:

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

and the closed loop:

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

where:

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

The programmable counter ratio K_n can be found as follows:

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

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

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

The values can be determined using the information in [Table 8](#).

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

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

The VCO gain is:

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

The gain of the phase comparator PC2 is:

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

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

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

The transfer functions of the filter is given by:

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

Where:

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

$$\tau_2 = R4 \times C2$$

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

This results in:

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

or:

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

This can be written as:

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

with the natural frequency ω_n defined as:

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

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

In [Fig. 37](#) the output frequency response to a step of input frequency is shown.

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

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

Rewriting the equation for natural frequency results in:

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

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

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

When $C2 = 470$ nF, it follows:

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

Hence the current source bias resistance

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

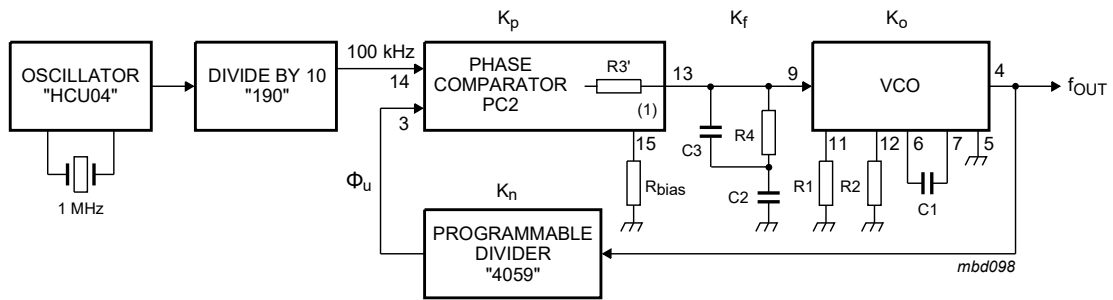
With $\zeta = 0.707$ ($0.5 \times \tau_2 \times \omega_n$) it follows:

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

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

For extra ripple suppression a capacitor $C3$ can be connected in parallel with $R4$, with an extra $\tau_3 = R4 \times C3$.

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



(1) R3' = fictive resistance

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

$$C1 = 100 \text{ pF}$$

$$C2 = 470 \text{ nF}$$

$$C3 = 39 \text{ nF}$$

$$R1 = 30 \text{ k}\Omega$$

$$R2 = 30 \text{ k}\Omega$$

$$R3' = 2\,550 \text{ }\Omega$$

$$R_{bias} = 43 \text{ k}\Omega$$

$$R4 = 600 \text{ }\Omega$$

Fig. 36. Frequency synthesizer

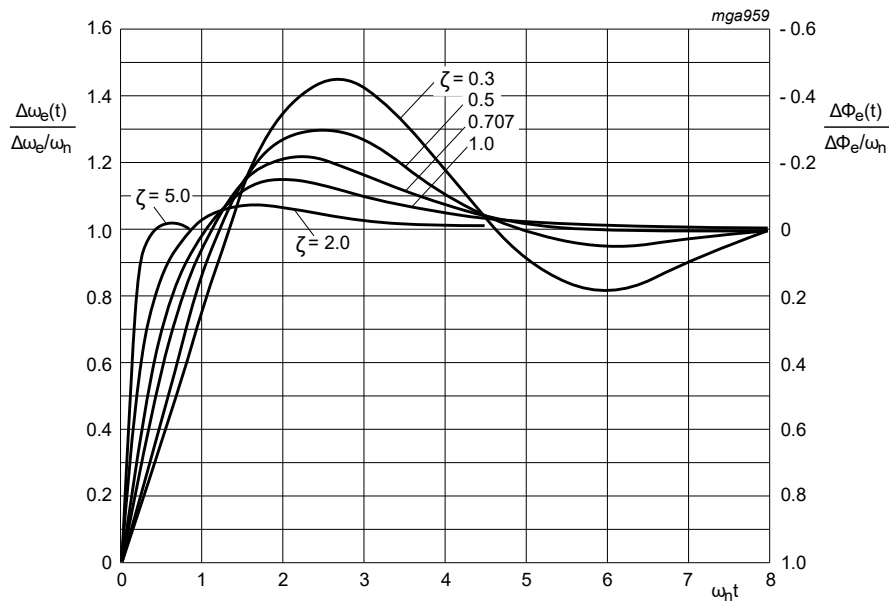


Fig. 37. Type 2, second order frequency step response

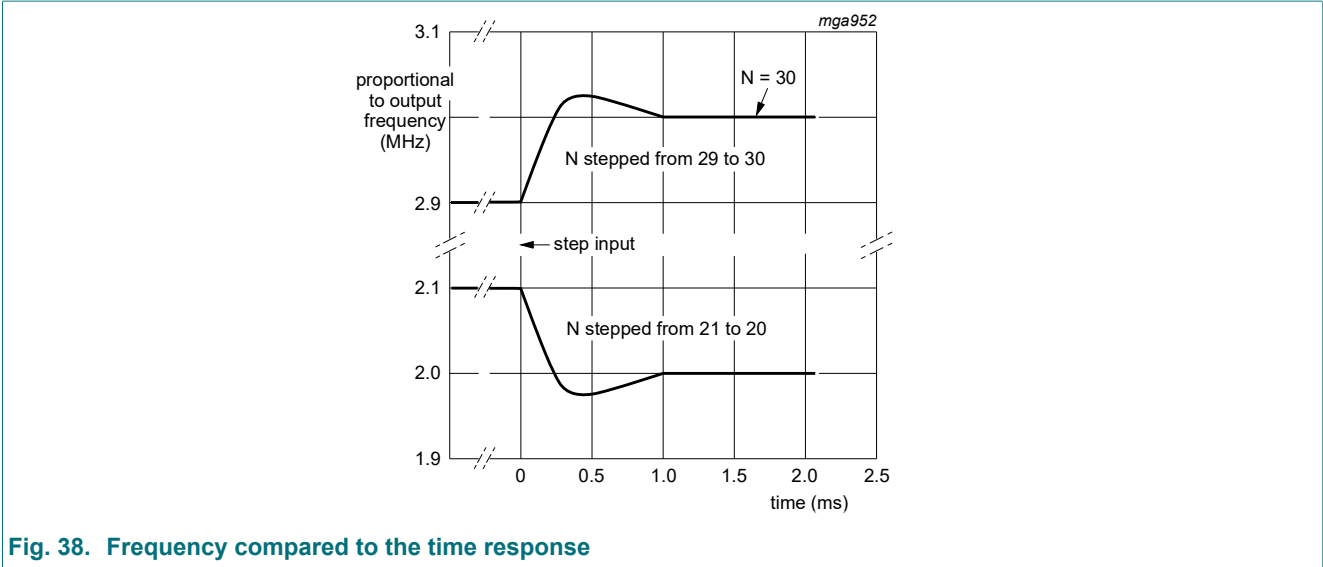


Fig. 38. Frequency compared to the time response

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

13. Package outline

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

SOT109-1

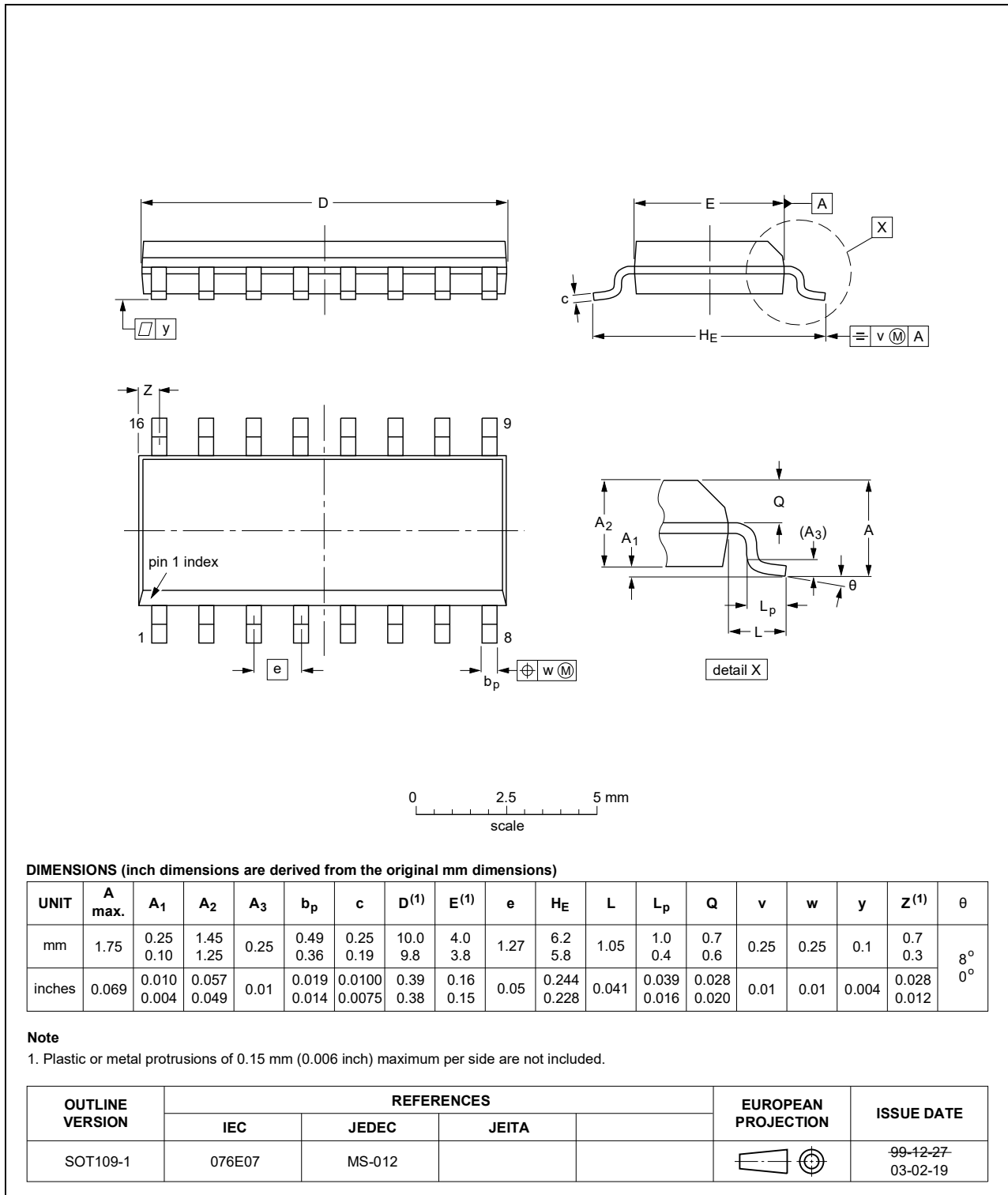


Fig. 39. Package outline SOT109-1 (SO16)

14. Abbreviations

Table 11. Abbreviations

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

15. Revision history

Table 12. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|----------------|---|-----------------------|---------------|----------------|
| 74HCT9046A v.9 | 20190320 | Product data sheet | - | 74HCT9046A v.8 |
| Modifications: | <ul style="list-style-type: none"> • Fig. 34: typo corrected in the conditions | | | |
| 74HCT9046A v.8 | 20190131 | Product data sheet | - | 74HCT9046A v.7 |
| Modifications: | <ul style="list-style-type: none"> • The format of this data sheet has been redesigned to comply with the identity guidelines of Nexperia. • Legal texts have been adapted to the new company name where appropriate. • Type number 74HCT9046APW (SOT403-1/TSSOP16) removed. | | | |
| 74HCT9046A v.7 | 20160229 | Product data sheet | - | 74HCT9046A v.6 |
| Modifications: | <ul style="list-style-type: none"> • Type number 74HCT9046AN (SOT38-4) removed. | | | |
| 74HCT9046A v.6 | 20090915 | Product data sheet | - | 74HCT9046A v.5 |
| Modifications: | <ul style="list-style-type: none"> • The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors. • Legal texts have been adapted to the new company name where appropriate. • $V_{i(p-p)}$ value changed from 15 mV to 50 mV in Section 11. • $\Delta f/\Delta T$ value moved from minimum to typical column Section 11. • Package version SOT38-1 changed to SOT38-4. | | | |
| 74HCT9046A v.5 | 20031030 | Product specification | - | 74HCT9046A v.4 |
| 74HCT9046A v.4 | 20030515 | Product specification | - | 74HCT9046A v.3 |
| 74HCT9046A v.3 | 19990111 | Product specification | - | - |

16. Legal information

Data sheet status

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

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

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Contents

| | |
|--|-----------|
| 1. General description | 1 |
| 2. Features and benefits | 1 |
| 3. Applications | 1 |
| 4. Ordering information | 1 |
| 5. Functional diagram | 2 |
| 6. Pinning information | 4 |
| 6.1. Pinning..... | 4 |
| 6.2. Pin description..... | 4 |
| 7. Functional description | 5 |
| 7.1. Differences with respect to the familiar 74HCT4046A.. | 5 |
| 7.2. VCO..... | 5 |
| 7.3. Phase comparators..... | 6 |
| 7.3.1. Phase Comparator 1 (PC1)..... | 6 |
| 7.3.2. Phase Comparator 2 (PC2)..... | 7 |
| 7.4. Loop filter component selection..... | 11 |
| 8. Limiting values | 12 |
| 9. Recommended operating conditions | 12 |
| 10. Static characteristics | 12 |
| 11. Dynamic characteristics | 17 |
| 12. Application information | 23 |
| 12.1. Filter design considerations for PC1 and PC2 of the 74HCT9046A..... | 25 |
| 12.2. PLL design example..... | 29 |
| 13. Package outline | 33 |
| 14. Abbreviations | 34 |
| 15. Revision history | 34 |
| 16. Legal information | 35 |

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