

# Phase Locked Loop

## MC14046B

The MC14046B phase locked loop contains two phase comparators, a voltage-controlled oscillator (VCO), source follower, and zener diode. The comparators have two common signal inputs,  $PCA_{in}$  and  $PCB_{in}$ . Input  $PCA_{in}$  can be used directly coupled to large voltage signals, or indirectly coupled (with a series capacitor) to small voltage signals. The self-bias circuit adjusts small voltage signals in the linear region of the amplifier. Phase comparator 1 (an exclusive OR gate) provides a digital error signal  $PC1_{out}$ , and maintains  $90^\circ$  phase shift at the center frequency between  $PCA_{in}$  and  $PCB_{in}$  signals (both at 50% duty cycle). Phase comparator 2 (with leading edge sensing logic) provides digital error signals,  $PC2_{out}$  and LD, and maintains a  $0^\circ$  phase shift between  $PCA_{in}$  and  $PCB_{in}$  signals (duty cycle is immaterial). The linear VCO produces an output signal  $VCO_{out}$  whose frequency is determined by the voltage of input  $VCO_{in}$  and the capacitor and resistors connected to pins  $C1_A$ ,  $C1_B$ , R1, and R2. The source-follower output  $SF_{out}$  with an external resistor is used where the  $VCO_{in}$  signal is needed but no loading can be tolerated. The inhibit input  $Inh$ , when high, disables the VCO and source follower to minimize standby power consumption. The zener diode can be used to assist in power supply regulation.

Applications include FM and FSK modulation and demodulation, frequency synthesis and multiplication, frequency discrimination, tone decoding, data synchronization and conditioning, voltage-to-frequency conversion and motor speed control.

### Features

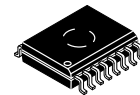
- Buffered Outputs Compatible with Low-Power TTL
- Diode Protection on All Inputs
- Supply Voltage Range = 3.0 to 18 V
- Pin-for-Pin Replacement for CD4046B
- Phase Comparator 1 is an Exclusive OR Gate and is Duty Cycle Limited
- Phase Comparator 2 Switches on Rising Edges and is not Duty Cycle Limited
- NLV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable
- These Devices are Pb-Free and are RoHS Compliant

### MAXIMUM RATINGS (Voltages Referenced to $V_{SS}$ )

| Symbol    | Parameter                               | Value                  | Unit             |
|-----------|---|------------------------|------------------|
| $V_{DD}$  | DC Supply Voltage Range                 | -0.5 to +18.0          | V                |
| $V_{in}$  | Input Voltage Range (All Inputs)        | -0.5 to $V_{DD} + 0.5$ | V                |
| $I_{in}$  | DC Input Current, per Pin               | $\pm 10$               | mA               |
| $P_D$     | Power Dissipation, per Package (Note 1) | 500                    | mW               |
| $T_A$     | Operating Temperature Range             | -55 to +125            | $^\circ\text{C}$ |
| $T_{stg}$ | Storage Temperature Range               | -65 to +150            | $^\circ\text{C}$ |

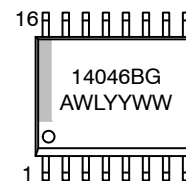
Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Temperature Derating: "D/DW" Packages: -7.0 mW/ $^\circ\text{C}$  From  $65^\circ\text{C}$  To  $125^\circ\text{C}$



SOIC-16 WB  
DW SUFFIX  
CASE 751G

### MARKING DIAGRAM



SOIC-16 WB

- A = Assembly Location
- WL, L = Wafer Lot
- YY, Y = Year
- WW, W = Work Week
- G = Pb-Free Indicator

### ORDERING INFORMATION

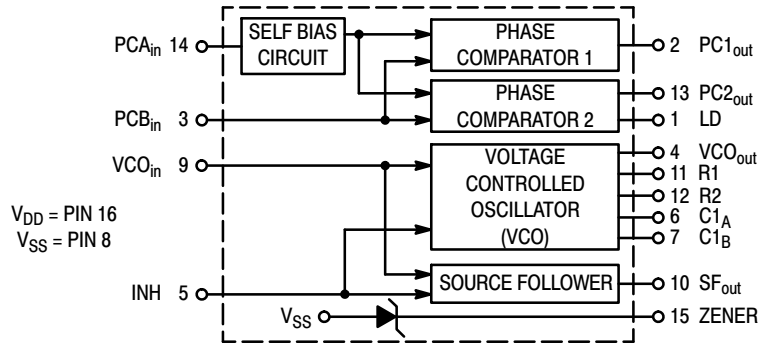
See detailed ordering and shipping information in the package dimensions section on page 6 of this data sheet.

This device contains protection circuitry to guard against damage due to high static voltages or electric fields. However, precautions must be taken to avoid applications of any voltage higher than maximum rated voltages to this high-impedance circuit. For proper operation,  $V_{in}$  and  $V_{out}$  should be constrained to the range  $V_{SS} \leq (V_{in} \text{ or } V_{out}) \leq V_{DD}$ .

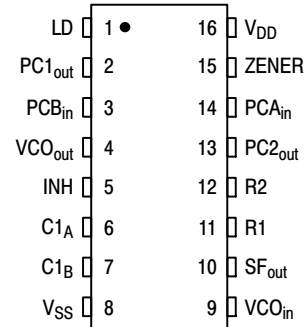
Unused inputs must always be tied to an appropriate logic voltage level (e.g., either  $V_{SS}$  or  $V_{DD}$ ). Unused outputs must be left open.

# MC14046B

## BLOCK DIAGRAM



## PIN ASSIGNMENT



## ELECTRICAL CHARACTERISTICS (Voltages Referenced to V<sub>SS</sub>)

| Characteristic  | Symbol   | V <sub>DD</sub><br>Vdc | - 55 °C  |       | 25 °C |          |       | 125 °C |       | Unit  |      |      |
|---|--|------------------------|--|-------|-------|----------|-------|--------|-------|-------|------|------|
|   |  |                        | Min  | Max   | Min   | Typ      | Max   | Min    | Max   |       |      |      |
| Output Voltage<br>V <sub>in</sub> = V <sub>DD</sub> or 0  | "0" Level  | V <sub>OL</sub>        | 5.0  | -     | 0.05  | -        | 0     | 0.05   | -     | 0.05  | Vdc  |      |
|   |  |                        | 10   | -     | 0.05  | -        | 0     | 0.05   | -     | 0.05  |      |      |
|   |  |                        | 15   | -     | 0.05  | -        | 0     | 0.05   | -     | 0.05  |      |      |
|   | V <sub>in</sub> = 0 or V <sub>DD</sub>   | "1" Level              | V <sub>OH</sub>                                    | 5.0   | 4.95  | -        | 4.95  | 5.0    | -     | 4.95  | -    | Vdc  |
|   |  |                        |  | 10    | 9.95  | -        | 9.95  | 10     | -     | 9.95  | -    |      |
|   |  |                        |  | 15    | 14.95 | -        | 14.95 | 15     | -     | 14.95 | -    |      |
| Input Voltage (Note 2)<br>(V <sub>O</sub> = 4.5 or 0.5 Vdc)<br>(V <sub>O</sub> = 9.0 or 1.0 Vdc)<br>(V <sub>O</sub> = 13.5 or 1.5 Vdc)  | "0" Level  | V <sub>IL</sub>        | 5.0  | -     | 1.5   | -        | 2.25  | 1.5    | -     | 1.5   | Vdc  |      |
|   |  |                        | 10   | -     | 3.0   | -        | 4.50  | 3.0    | -     | 3.0   |      |      |
|   |  |                        | 15   | -     | 4.0   | -        | 6.75  | 4.0    | -     | 4.0   |      |      |
|   | (V <sub>O</sub> = 0.5 or 4.5 Vdc)<br>(V <sub>O</sub> = 1.0 or 9.0 Vdc)<br>(V <sub>O</sub> = 1.5 or 13.5 Vdc) | "1" Level              | V <sub>IH</sub>                                    | 5.0   | 3.5   | -        | 3.5   | 2.75   | -     | 3.5   | -    | Vdc  |
|   |  |                        |  | 10    | 7.0   | -        | 7.0   | 5.50   | -     | 7.0   | -    |      |
|   |  |                        |  | 15    | 11    | -        | 11    | 8.25   | -     | 11    | -    |      |
| Output Drive Current<br>(V <sub>OH</sub> = 2.5 Vdc)<br>(V <sub>OH</sub> = 4.6 Vdc)<br>(V <sub>OH</sub> = 9.5 Vdc)<br>(V <sub>OH</sub> = 13.5 Vdc)   | Source   | I <sub>OH</sub>        | 5.0  | -1.2  | -     | -1.0     | -1.7  | -      | -0.7  | -     | mAdc |      |
|   |  |                        | 5.0  | -0.25 | -     | -0.2     | -0.36 | -      | -0.14 | -     |      |      |
|   |  |                        | 10   | -0.62 | -     | -0.5     | -0.9  | -      | -0.35 | -     |      |      |
|   | (V <sub>OL</sub> = 0.4 Vdc)<br>(V <sub>OL</sub> = 0.5 Vdc)<br>(V <sub>OL</sub> = 1.5 Vdc)                    | Sink                   | I <sub>OL</sub>                                    | 5.0   | 0.64  | -        | 0.51  | 0.88   | -     | 0.36  | -    | mAdc |
|   |  |                        |  | 10    | 1.6   | -        | 1.3   | 2.25   | -     | 0.9   | -    |      |
|   |  |                        |  | 15    | 4.2   | -        | 3.4   | 8.8    | -     | 2.4   | -    |      |
| Input Current   | I <sub>in</sub>  | 15                     | -  | ±0.1  | -     | ±0.00001 | ±0.1  | -      | ±1.0  | μAdc  |      |      |
| Input Capacitance   | C <sub>in</sub>  | -                      | -  | -     | -     | 5.0      | 7.5   | -      | -     | pF    |      |      |
| Quiescent Current<br>(Per Package) Inh = PCA <sub>in</sub> = V <sub>DD</sub> ,<br>Zener = VCO <sub>in</sub> = 0 V, PCB <sub>in</sub> = V <sub>DD</sub><br>or 0 V, I <sub>out</sub> = 0 μA | I <sub>DD</sub>  | 5.0                    | -  | 5.0   | -     | 0.005    | 5.0   | -      | 150   | μAdc  |      |      |
|   |  | 10                     | -  | 10    | -     | 0.010    | 10    | -      | 300   |       |      |      |
|   |  | 15                     | -  | 20    | -     | 0.015    | 20    | -      | 600   |       |      |      |
| Total Supply Current (Note 3)<br>(Inh = "0", f <sub>o</sub> = 10 kHz, C <sub>L</sub> = 50 pF,<br>R1 = 1.0 MΩ, R2 = ∞, R <sub>SF</sub> = ∞,<br>and 50% Duty Cycle)                         | I <sub>T</sub>   | 5.0                    | I <sub>T</sub> = (1.46 μA/kHz) f + I <sub>DD</sub> |       |       |          |       |        |       | mAdc  |      |      |
|   |  | 10                     | I <sub>T</sub> = (2.91 μA/kHz) f + I <sub>DD</sub> |       |       |          |       |        |       |       |      |      |
|   |  | 15                     | I <sub>T</sub> = (4.37 μA/kHz) f + I <sub>DD</sub> |       |       |          |       |        |       |       |      |      |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

2. Noise immunity specified for worst-case input combination.

Noise Margin for both "1" and "0" level =  
 1.0 Vdc min @ V<sub>DD</sub> = 5.0 Vdc  
 2.0 Vdc min @ V<sub>DD</sub> = 10 Vdc  
 2.5 Vdc min @ V<sub>DD</sub> = 15 Vdc

3. To Calculate Total Current in General:

$$I_T \approx 2.2 \times V_{DD} \left( \frac{V_{CO_{in}} - 1.65}{R1} + \frac{V_{DD} - 1.35}{R2} \right)^{3/4} + 1.6 \times \left( \frac{V_{CO_{in}} - 1.65}{R_{SF}} \right)^{3/4} + 1 \times 10^{-3} (C_L + 9) V_{DD} f +$$

$$1 \times 10^{-1} V_{DD}^2 \left( \frac{100\% \text{ Duty Cycle of PCA}_{in}}{100} \right) + I_Q \quad \text{where: } I_T \text{ in } \mu\text{A}, C_L \text{ in pF, } V_{CO_{in}}, V_{DD} \text{ in Vdc, } f \text{ in kHz, and } R1, R2, R_{SF} \text{ in M}\Omega, C_L \text{ on VCO}_{out}$$

# MC14046B

## ELECTRICAL CHARACTERISTICS (Note 4) ( $C_L = 50$ pF, $T_A = 25^\circ\text{C}$ )

| Characteristic   | Symbol    | $V_{DD}$<br>Vdc | Minimum     | Typical         | Maximum           | Units |
|--|-----------|-----------------|-------------|-----------------|-------------------|-------|
|  |           |                 | Device      |                 | Device            |       |
| Output Rise Time<br>$t_{TLH} = (3.0 \text{ ns/pF}) C_L + 30 \text{ ns}$<br>$t_{TLH} = (1.5 \text{ ns/pF}) C_L + 15 \text{ ns}$<br>$t_{TLH} = (1.1 \text{ ns/pF}) C_L + 10 \text{ ns}$      | $t_{TLH}$ | 5.0<br>10<br>15 | –<br>–<br>– | 180<br>90<br>65 | 350<br>150<br>110 | ns    |
| Output Fall Time<br>$t_{THL} = (1.5 \text{ ns/pF}) C_L + 25 \text{ ns}$<br>$t_{THL} = (0.75 \text{ ns/pF}) C_L + 12.5 \text{ ns}$<br>$t_{THL} = (0.55 \text{ ns/pF}) C_L + 9.5 \text{ ns}$ | $t_{THL}$ | 5.0<br>10<br>15 | –<br>–<br>– | 100<br>50<br>37 | 175<br>75<br>55   | ns    |

## PHASE COMPARATORS 1 and 2

|  |          |         |                    |      |      |           |
|--|----------|---------|--------------------|------|------|-----------|
| Input Resistance – $PCA_{in}$  | $R_{in}$ | 5.0     | 1.0                | 2.0  | –    | $M\Omega$ |
|  |          | 10      | 0.2                | 0.4  | –    |           |
|  |          | 15      | 0.1                | 0.2  | –    |           |
| – $PCB_{in}$   | $R_{in}$ | 15      | 150                | 1500 | –    | $M\Omega$ |
| Minimum Input Se–sitivity<br>AC Coupled — $PCA_{in}$<br>C series = 1000 pF, $f = 50$ kHz | $V_{in}$ | 5.0     | –                  | 200  | 300  | mV p–p    |
|  |          | 10      | –                  | 400  | 600  |           |
|  |          | 15      | –                  | 700  | 1050 |           |
| DC Coupled – $PCA_{in}$ , $PCB_{in}$   | –        | 5 to 15 | See Noise Immunity |      |      |           |

## VOLTAGE CONTROLLED OSCILLATOR (VCO)

|   |           |         |     |       |   |           |
|---|-----------|---------|-----|-------|---|-----------|
| Maximum Frequency<br>( $VCO_{in} = V_{DD}$ , $C1 = 50$ pF<br>$R1 = 5.0$ k $\Omega$ , and $R2 = \infty$ )  | $f_{max}$ | 5.0     | 0.5 | 0.7   | – | MHz       |
|   |           | 10      | 1.0 | 1.4   | – |           |
|   |           | 15      | 1.4 | 1.9   | – |           |
| Temperature – Frequency Stability<br>( $R2 = \infty$ )  | –         | 5.0     | –   | 0.12  | – | %/°C      |
|   |           | 10      | –   | 0.04  | – |           |
|   |           | 15      | –   | 0.015 | – |           |
| Linearity ( $R2 = \infty$ )<br>( $VCO_{in} = 2.5$ V $\pm$ 0.3 V, $R1 > 10$ k $\Omega$ )<br>( $VCO_{in} = 5.0$ V $\pm$ 2.5 V, $R1 > 400$ k $\Omega$ )<br>( $VCO_{in} = 7.5$ V $\pm$ 5.0 V, $R1 \geq 1000$ k $\Omega$ ) | –         | 5.0     | –   | 1.0   | – | %         |
|   |           | 10      | –   | 1.0   | – |           |
|   |           | 15      | –   | 1.0   | – |           |
| Output Duty Cycle   | –         | 5 to 15 | –   | 50    | – | %         |
| Input Resistance – $VCO_{in}$   | $R_{in}$  | 15      | 150 | 1500  | – | $M\Omega$ |

## SOURCE–FOLLOWER

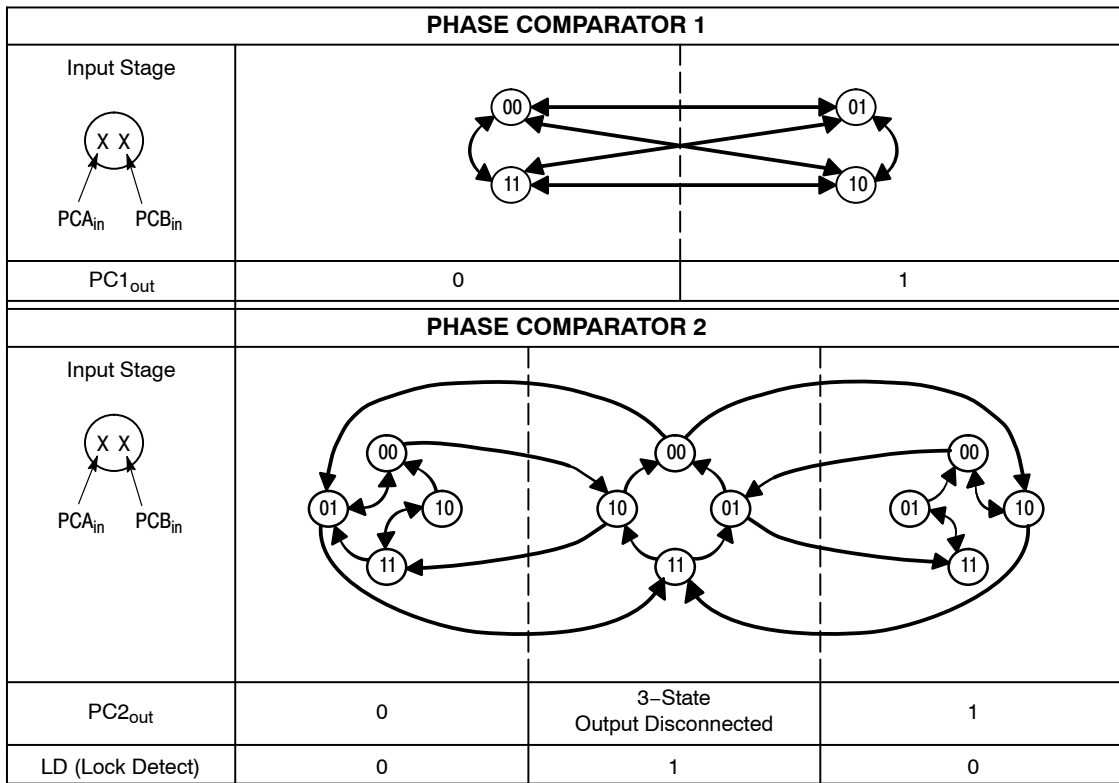
|  |   |     |   |      |     |   |
|--|---|-----|---|------|-----|---|
| Offset Voltage<br>( $VCO_{in}$ minus $SF_{out}$ , $RSF > 500$ k $\Omega$ )   | – | 5.0 | – | 1.65 | 2.2 | V |
|  |   | 10  | – | 1.65 | 2.2 |   |
|  |   | 15  | – | 1.65 | 2.2 |   |
| Linearity<br>( $VCO_{in} = 2.5$ V $\pm$ 0.3 V, $RSF > 50$ k $\Omega$ )<br>( $VCO_{in} = 5.0$ V $\pm$ 2.5 V, $RSF > 50$ k $\Omega$ )<br>( $VCO_{in} = 7.5$ V $\pm$ 5.0 V, $RSF > 50$ k $\Omega$ ) | – | 5.0 | – | 0.1  | –   | % |
|  |   | 10  | – | 0.6  | –   |   |
|  |   | 15  | – | 0.8  | –   |   |

## ZENER DIODE

|                                      |       |   |     |     |     |          |
|--------------------------------------|-------|---|-----|-----|-----|----------|
| Zener Voltage ( $I_z = 50$ $\mu$ A)  | $V_Z$ | – | 6.7 | 7.0 | 7.3 | V        |
| Dynamic Resistance ( $I_z = 1.0$ mA) | $R_Z$ | – | –   | 100 | –   | $\Omega$ |

4. The formula given is for the typical characteristics only.

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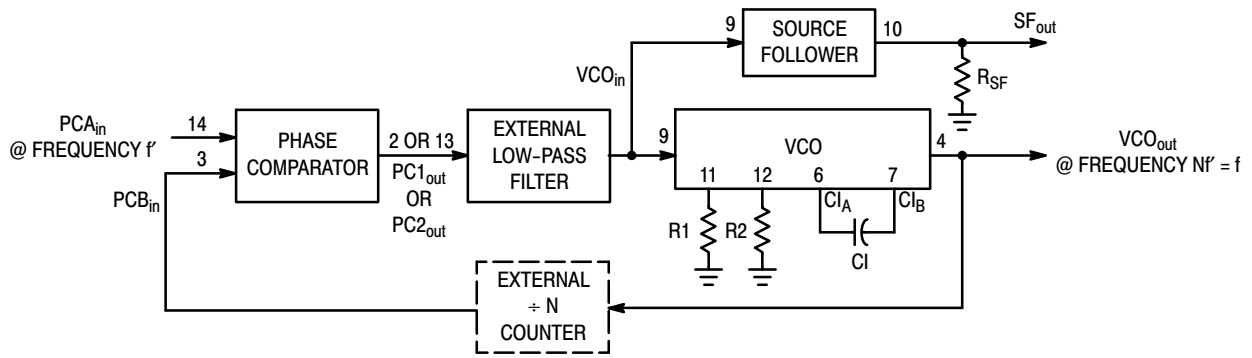
Refer to Waveforms in Figure 3.

**Figure 1. Phase Comparators State Diagrams**

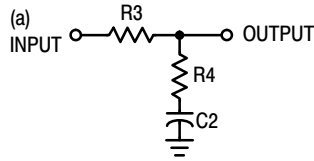
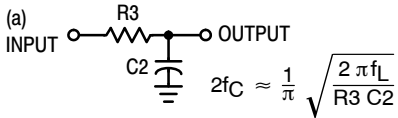
| Characteristic   | Using Phase Comparator 1   | Using Phase Comparator 2  |
|--|--|---|
| No signal on input PCA <sub>in</sub> .   | VCO in PLL system adjusts to center frequency (f <sub>0</sub> ).   | VCO in PLL system adjusts to minimum frequency (f <sub>min</sub> ). |
| Phase angle between PCA <sub>in</sub> and PCB <sub>in</sub> .  | 90° at center frequency (f <sub>0</sub> ), approaching 0° and 180° at ends of lock range (2f <sub>L</sub> )  | Always 0° in lock (positive rising edges).                          |
| Locks on harmonics of center frequency.  | Yes  | No  |
| Signal input noise rejection.  | High   | Low   |
| Lock frequency range (2f <sub>L</sub> ).   | The frequency range of the input signal on which the loop will stay locked if it was initially in lock; 2f <sub>L</sub> = full VCO frequency range = f <sub>max</sub> - f <sub>min</sub> .   |   |
| Capture frequency range (2f <sub>C</sub> ).  | The frequency range of the input signal on which the loop will lock if it was initially out of lock.   |   |
|  | Depends on low-pass filter characteristics (see Figure 3). f <sub>C</sub> ≤ f <sub>L</sub>   | f <sub>C</sub> = f <sub>L</sub>                                     |
| Center frequency (f <sub>0</sub> ).  | The frequency of VCO <sub>out</sub> , when VCO <sub>in</sub> = 1/2 V <sub>DD</sub>   |   |
| VCO output frequency (f).  | $f_{min} = \frac{1}{R_2(C_1 + 32 \text{ pF})} \quad (V_{CO} \text{ input} = V_{SS})$ $f_{max} = \frac{1}{R_1(C_1 + 32 \text{ pF})} + f_{min} \quad (V_{CO} \text{ input} = V_{DD})$ <p>Where: 10K ≤ R<sub>1</sub> ≤ 1 M<br/>                     10K ≤ R<sub>2</sub> ≤ 1 M<br/>                     100pF ≤ C<sub>1</sub> ≤ .01 μF</p> |   |
| Note: These equations are intended to be a design guide. Since calculated component values may be in error by as much as a factor of 4, laboratory experimentation may be required for fixed designs. Part to part frequency variation with identical passive components is typically less than ± 20%. |  |   |

**Figure 2. Design Information**

# MC14046B



## Typical Low-Pass Filters



Typically:

$$R_4 C_2 = \frac{6N}{f_{\max}} - \frac{N}{2\pi \Delta f}$$

$$(R_3 + 3,000\Omega) C_2 = \frac{100N\Delta f}{f_{\max}^2} - R_4 C_2$$

$$\Delta f = f_{\max} - f_{\min}$$

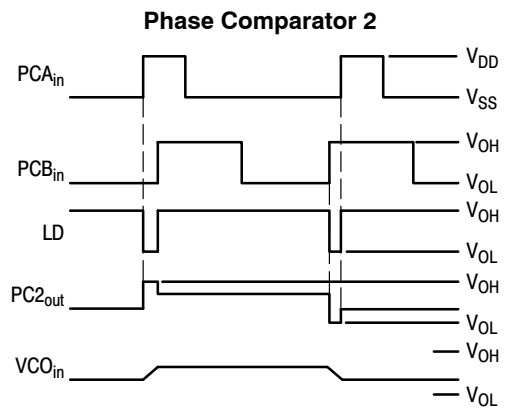
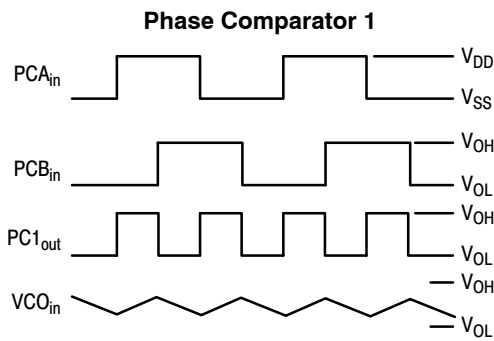
NOTE: Sometimes R3 is split into two series resistors each R3 ÷ 2. A capacitor C<sub>C</sub> is then placed from the midpoint to ground. The value for C<sub>C</sub> should be such that the corner frequency of this network does not significantly affect Ω<sub>n</sub>. In Figure B, the ratio of R3 to R4 sets the damping, R4 ≅ (0.1)(R3) for optimum results.

## LOW-PASS FILTER

Definitions: N = Total division ratio in feedback loop  
 $K\phi = V_{DD}/\pi$  for Phase Comparator 1  
 $K\phi = V_{DD}/4\pi$  for Phase Comparator 2  
 $KVCO = \frac{2\pi \Delta f_{VCO}}{V_{DD} - 2V}$   
 for a typical design  $\Omega_n \cong \frac{2\pi f_r}{10}$  (at phase detector input)  
 $\zeta \cong 0.707$

| Filter A  | Filter B  |
|---|---|
| $\omega_n = \sqrt{\frac{K\phi KVCO}{NR_3 C_2}}$ | $\omega_n = \sqrt{\frac{K\phi KVCO}{NC_2(R_3 + R_4)}}$  |
| $\zeta = \frac{N\omega_n}{2K\phi KVCO}$         | $\zeta = 0.5 \omega_n (R_3 C_2 + \frac{N}{K\phi KVCO})$ |
| $F(s) = \frac{1}{R_3 C_2 S + 1}$                | $F(s) = \frac{R_3 C_2 S + 1}{S(R_3 C_2 + R_4 C_2) + 1}$ |

## Waveforms



Note: for further information, see:

- (1) F. Gardner, "Phase-Lock Techniques", John Wiley and Son, New York, 1966.
- (2) G. S. Moschytz, "Miniature RC Filters Using Phase-Locked Loop", BSTJ, May, 1965.
- (3) Garth Nash, "Phase-Lock Loop Design Fundamentals", AN-535, Motorola Inc.
- (4) A. B. Przedpelski, "Phase-Locked Loop Design Articles", AR254, reprinted by Motorola Inc.

Figure 3. General Phase-Locked Loop Connections and Waveforms

# MC14046B

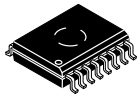
## ORDERING INFORMATION

| Device        | Package                 | Shipping†                |
|---------------|-------------------------|--------------------------|
| MC14046BDWG   | SOIC-16 WB<br>(Pb-Free) | 47 Units / Tube          |
| MC14046BDWR2G | SOIC-16 WB<br>(Pb-Free) | 1000 Units / Tape & Reel |

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

\*NLV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable.

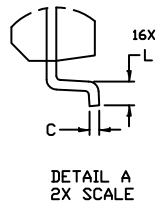
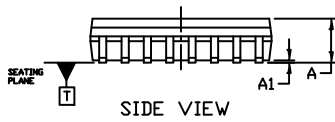
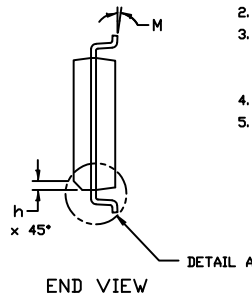
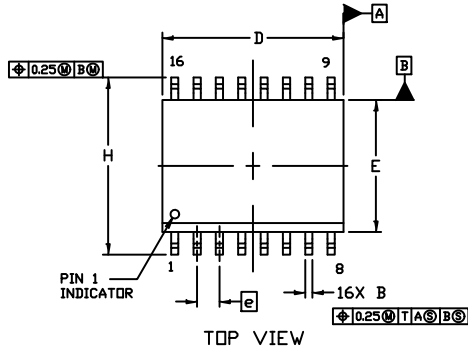
# MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS



1  
SCALE 1:1

SOIC-16 WB  
CASE 751G  
ISSUE E

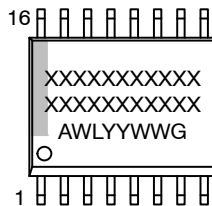
DATE 08 OCT 2021



- NOTES:
- DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
  - CONTROLLING DIMENSION: MILLIMETERS
  - DIMENSION *b* DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF *B* DIMENSION AT MAXIMUM MATERIAL CONDITION.
  - DIMENSIONS *D* AND *E* DO NOT INCLUDE MOLD PROTRUSIONS.
  - MAXIMUM MOLD PROTRUSION OR FLASH TO BE 0.15 PER SIDE.

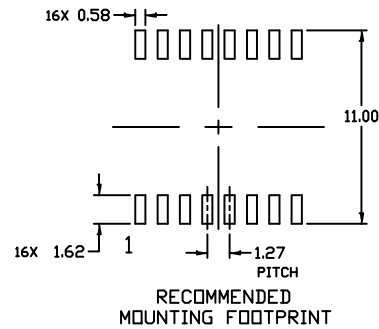
| DIM | MILLIMETERS |       |
|-----|-------------|-------|
|     | MIN.        | MAX.  |
| A   | 2.35        | 2.65  |
| A1  | 0.10        | 0.25  |
| B   | 0.35        | 0.49  |
| C   | 0.23        | 0.32  |
| D   | 10.15       | 10.45 |
| E   | 7.40        | 7.60  |
| e   | 1.27 BSC    |       |
| H   | 10.05       | 10.55 |
| h   | 0.53 REF    |       |
| L   | 0.50        | 0.90  |
| M   | 0°          | 7°    |

### GENERIC MARKING DIAGRAM\*



- XXXXX = Specific Device Code
- A = Assembly Location
- WL = Wafer Lot
- YY = Year
- WW = Work Week
- G = Pb-Free Package

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present. Some products may not follow the Generic Marking.



|                  |             |  |
|------------------|-------------|--|
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