MC14046B

Phase Locked Loop

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° 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° 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 MHTL and 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
- Pb−Free Packages are Available*

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	±10	mA
P_D	Power Dissipation, per Package (Note 1)	500	mW
T_A	Operating Temperature Range	−55 to +125	°C
T_{stg}	Storage Temperature Range	−65 to +150	°C

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

1. Temperature Derating:
   Plastic “P and D/DW” Packages: – 7.0 mW/°C From 65°C To 125°C

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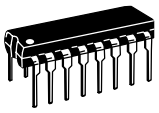
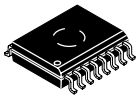
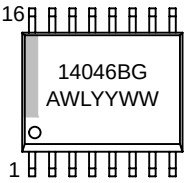
MARKING DIAGRAMS

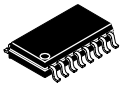


PDIP−16
P SUFFIX
CASE 648

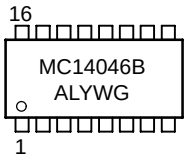


SOIC−16
DW SUFFIX
CASE 751G





SOEIAJ−16
F SUFFIX
CASE 966



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

ORDERING INFORMATION

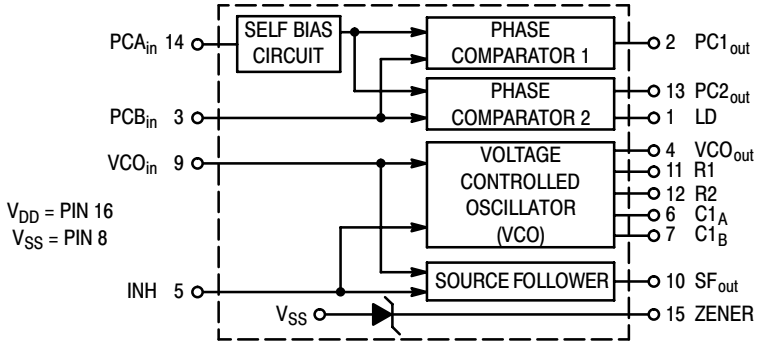
See detailed ordering and shipping information in the package dimensions section on page 4 of this data sheet.

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 $V_{SS} \le (V_{in}$ or $V_{out}) \le V_{DD}$.

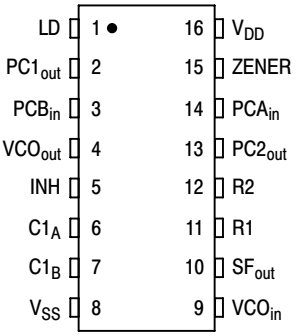
Unused inputs must always be tied to an appropriate logic voltage level (e.g., either V_{SS} or V_{DD}). Unused outputs must be left open.

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

BLOCK DIAGRAM



PIN ASSIGNMENT



ELECTRICAL CHARACTERISTICS (Voltages Referenced to V_{SS})

Characteristic	Symbol	V_{DD} Vdc	−55°C Min	−55°C Max	25°C Min	25°C Typ	25°C Max	125°C Min	125°C Max	Unit
Output Voltage "0" Level	V_{OL}	5.0	–	0.05	–	0	0.05	–	0.05	Vdc
V_{in} = V_{DD} or 0		10	–	0.05	–	0	0.05	–	0.05	
		15	–	0.05	–	0	0.05	–	0.05	
"1" Level	V_{OH}	5.0	4.95	–	4.95	5.0	–	4.95	–	Vdc
V_{in} = 0 or V_{DD}		10	9.95	–	9.95	10	–	9.95	–	
		15	14.95	–	14.95	15	–	14.95	–	
Input Voltage (Note 2) "0" Level	V_{IL}									Vdc
(V_O = 4.5 or 0.5 Vdc)		5.0	–	1.5	–	2.25	1.5	–	1.5	
(V_O = 9.0 or 1.0 Vdc)		10	–	3.0	–	4.50	3.0	–	3.0	
(V_O = 13.5 or 1.5 Vdc)		15	–	4.0	–	6.75	4.0	–	4.0	
(V_O = 0.5 or 4.5 Vdc) "1" Level	V_{IH}	5.0	3.5	–	3.5	2.75	–	3.5	–	Vdc
(V_O = 1.0 or 9.0 Vdc)		10	7.0	–	7.0	5.50	–	7.0	–	
(V_O = 1.5 or 13.5 Vdc)		15	11	–	11	8.25	–	11	–	
Output Drive Current	I_{OH}									mAdc
(V_{OH} = 2.5 Vdc) Source		5.0	– 1.2	–	– 1.0	– 1.7	–	– 0.7	–	
(V_{OH} = 4.6 Vdc)		5.0	– 0.25	–	– 0.2	– 0.36	–	– 0.14	–	
(V_{OH} = 9.5 Vdc)		10	– 0.62	–	– 0.5	– 0.9	–	– 0.35	–	
(V_{OH} = 13.5 Vdc)		15	– 1.8	–	– 1.5	– 3.5	–	– 1.1	–	
(V_{OL} = 0.4 Vdc) Sink	I_{OL}	5.0	0.64	–	0.51	0.88	–	0.36	–	mAdc
(V_{OL} = 0.5 Vdc)		10	1.6	–	1.3	2.25	–	0.9	–	
(V_{OL} = 1.5 Vdc)		15	4.2	–	3.4	8.8	–	2.4	–	
Input Current	I_{in}	15	–	± 0.1	–	±0.00001	± 0.1	–	± 1.0	μAdc
Input Capacitance	C_{in}	–	–	–	–	5.0	7.5	–	–	pF
Quiescent Current	I_{DD}	5.0	–	5.0	–	0.005	5.0	–	150	μAdc
(Per Package) Inh = PCA$_{in}$ = V_{DD},		10	–	10	–	0.010	10	–	300	
Zener = VCO$_{in}$ = 0 V, PCB$_{in}$ = V_{DD}		15	–	20	–	0.015	20	–	600	
or 0 V, I_{out} = 0 μA										
Total Supply Current (Note 3)	I_T	5.0	I_T = (1.46 μA/kHz) f + I_{DD}							mAdc
(Inh = "0", f_o = 10 kHz, C_L = 50 pF,		10	I_T = (2.91 μA/kHz) f + I_{DD}							
R1 = 1.0 MΩ, R2 = ∞ R_{SF} = ∞,		15	I_T = (4.37 μA/kHz) f + I_{DD}							
and 50% Duty Cycle)										

2. Noise immunity specified for worst−case input combination.
   Noise Margin for both "1" and "0" level = 1.0 Vdc min @ V_{DD} = 5.0 Vdc
   2.0 Vdc min @ V_{DD} = 10 Vdc
   2.5 Vdc min @ V_{DD} = 15 Vdc

3. To Calculate Total Current in General:

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

$$1 \times 10^{-1}\,V_{DD}^2\left(\frac{100\%\text{ Duty Cycle of PCA}_{in}}{100}\right) + I_Q$$

where: I_T in μA, C_L in pF, VCO$_{in}$, V_{DD} in Vdc, f in kHz, and R1, R2, R_{SF} in MΩ, C_L on VCO$_{out}$.

ELECTRICAL CHARACTERISTICS (Note 4) (C_L = 50 pF, T_A = 25°C)

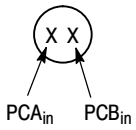
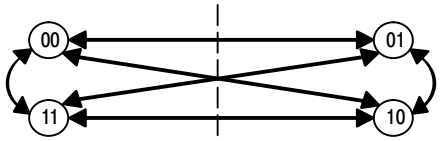
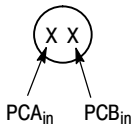
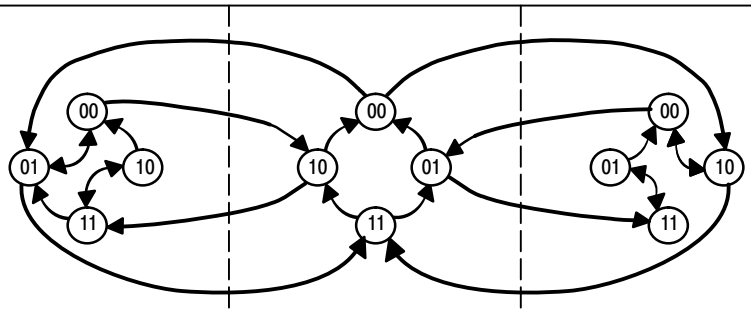
Characteristic	Symbol	V_{DD} Vdc	Minimum Device	Typical	Maximum Device	Units
Output Rise Time	t_{TLH}					ns
t_{TLH} = (3.0 ns/pF) C_L + 30 ns		5.0	−	180	350	
t_{TLH} = (1.5 ns/pF) C_L + 15 ns		10	−	90	150	
t_{TLH} = (1.1 ns/pF) C_L + 10 ns		15	−	65	110	
Output Fall Time	t_{THL}					ns
t_{THL} = (1.5 ns/pF) C_L + 25 ns		5.0	−	100	175	
t_{THL} = (0.75 ns/pF) C_L + 12.5 ns		10	−	50	75	
t_{THL} = (0.55 ns/pF) C_L + 9.5 ns		15	−	37	55	
PHASE COMPARATORS 1 and 2						
Input Resistance − PCA_{in}	R_{in}	5.0	1.0	2.0	−	MΩ
		10	0.2	0.4	−	
		15	0.1	0.2	−	
− PCB_{in}	R_{in}	15	150	1500	−	MΩ
Minimum Input Se−sitivity	V_{in}	5.0	−	200	300	mV p–p
AC Coupled — PCA_{in}		10	−	400	600	
C series = 1000 pF, f = 50 kHz		15	−	700	1050	
DC Coupled − PCA_{in}, PCB_{in}	−	5 to 15	See Noise Immunity			
VOLTAGE CONTROLLED OSCILLATOR (VCO)						
Maximum Frequency	f_{max}	5.0	0.5	0.7	−	MHz
(VCO_{in} = V_{DD}, C1 = 50 pF		10	1.0	1.4	−	
R1 = 5.0 kΩ, and R2 = ∞)		15	1.4	1.9	−	
Temperature − Frequency Stability	−	5.0	−	0.12	−	%/°C
(R2 = ∞)		10	−	0.04	−	
		15	−	0.015	−	
Linearity (R2 = ∞)	−					%
(VCO_{in} = 2.5 V ± 0.3 V, R1 > 10 kΩ)		5.0	−	1.0	−	
(VCO_{in} = 5.0 V ± 2.5 V, R1 > 400 kΩ)		10	−	1.0	−	
(VCO_{in} = 7.5 V ± 5.0 V, R1 ≥ 1000 kΩ)		15	−	1.0	−	
Output Duty Cycle	−	5 to 15	−	50	−	%
Input Resistance − VCO_{in}	R_{in}	15	150	1500	−	MΩ
SOURCE−FOLLOWER						
Offset Voltage	−	5.0	−	1.65	2.2	V
(VCO_{in} minus SF_{out}, RSF > 500 kΩ)		10	−	1.65	2.2	
		15	−	1.65	2.2	
Linearity	−					%
(VCO_{in} = 2.5 V ± 0.3 V, R_{SF} > 50 kΩ)		5.0	−	0.1	−	
(VCO_{in} = 5.0 V ± 2.5 V, R_{SF} > 50 kΩ)		10	−	0.6	−	
(VCO_{in} = 7.5 V ± 5.0 V, R_{SF} > 50 kΩ)		15	−	0.8	−	
ZENER DIODE						
Zener Voltage (I_z = 50 μA)	V_Z	−	6.7	7.0	7.3	V
Dynamic Resistance (I_z = 1.0 mA)	R_Z	−	−	100	−	Ω

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

ORDERING INFORMATION

Device	Package	Shipping†
MC14046BCP	PDIP−16	500 Units / Rail
MC14046BCPG	PDIP−16 (Pb−Free)	500 Units / Rail
MC14046BDW	SOIC−16 WB	47 Units / Rail
MC14046BDWG	SOIC−16 WB (Pb−Free)	47 Units / Rail
MC14046BDWR2	SOIC−16 WB	1000 Units / Tape & Reel
MC14046BDWR2G	SOIC−16 WB (Pb−Free)	1000 Units / Tape & Reel
MC14046BF	SOEIAJ−16	50 Units / Rail
MC14046BFEL	SOEIAJ−16	2000 Units / Tape & Reel
MC14046BFELG	SOEIAJ−16 (Pb−Free)	2000 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.

<table>
<tr><th colspan="4">PHASE COMPARATOR 1</th></tr>
<tr><td>Input Stage
 
</td><td colspan="3"> 
</td></tr>
<tr><td>PC1$_{out}$</td><td>0</td><td colspan="2">1</td></tr>
<tr><td></td><td colspan="3">PHASE COMPARATOR 2</td></tr>
<tr><td>Input Stage
 
</td><td colspan="3"> 
</td></tr>
<tr><td>PC2$_{out}$</td><td>0</td><td>3−State
Output Disconnected</td><td>1</td></tr>
<tr><td>LD (Lock Detect)</td><td>0</td><td>1</td><td>0</td></tr>
</table>

Refer to Waveforms in Figure 3.

Figure 1. Phase Comparators State Diagrams

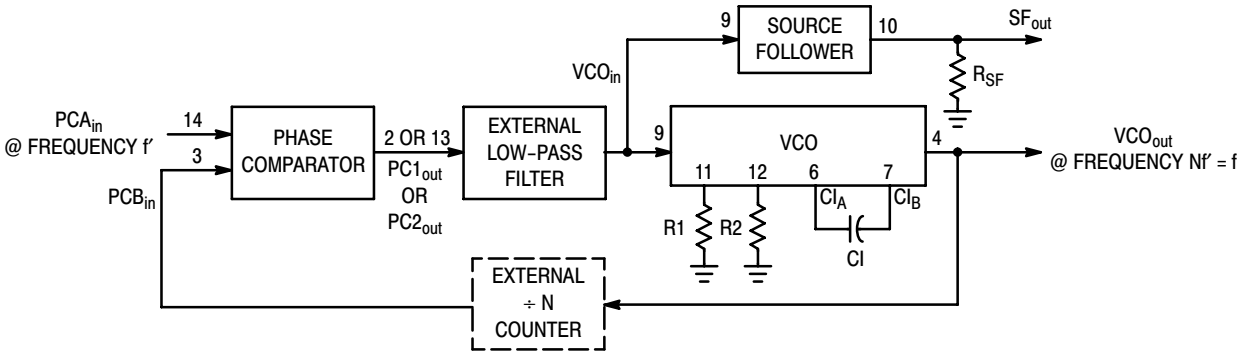
<table>
<tr><th>Characteristic</th><th>Using Phase Comparator 1</th><th>Using Phase Comparator 2</th></tr>
<tr><td>No signal on input PCA$_{in}$.</td><td>VCO in PLL system adjusts to center frequency (f_0).</td><td>VCO in PLL system adjusts to minimum frequency (f_{min}).</td></tr>
<tr><td>Phase angle between PCA$_{in}$ and PCB$_{in}$.</td><td>90° at center frequency (f_0), approaching 0° and 180° at ends of lock range ($2f_L$)</td><td>Always 0° in lock (positive rising edges).</td></tr>
<tr><td>Locks on harmonics of center frequency.</td><td>Yes</td><td>No</td></tr>
<tr><td>Signal input noise rejection.</td><td>High</td><td>Low</td></tr>
<tr><td>Lock frequency range ($2f_L$).</td><td colspan="2">The frequency range of the input signal on which the loop will stay locked if it was initially in lock; $2f_L$ = full VCO frequency range = $f_{max} - f_{min}$.</td></tr>
<tr><td rowspan="2">Capture frequency range ($2f_C$).</td><td colspan="2">The frequency range of the input signal on which the loop will lock if it was initially out of lock.</td></tr>
<tr><td>Depends on low−pass filter characteristics (see Figure 3). $f_C \le f_L$</td><td>$f_C = f_L$</td></tr>
<tr><td>Center frequency (f_0).</td><td colspan="2">The frequency of VCO$_{out}$, when VCO$_{in}$ = 1/2 V_{DD}</td></tr>
<tr><td>VCO output frequency (f).

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%.</td><td colspan="2">$f_{min} = \frac{1}{R_2(C_1 + 32\ pF)}$ (V_{CO} input = V_{SS})

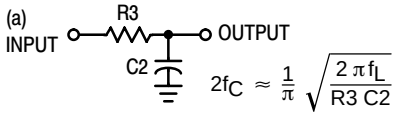
$f_{max} = \frac{1}{R_1(C_1 + 32\ pF)} + f_{min}$ (V_{CO} input = V_{DD})

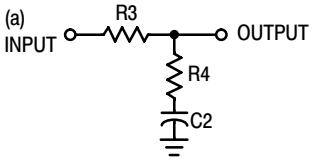
Where: $10K \le R_1 \le 1\ M$
$10K \le R_2 \le 1\ M$
$100pF \le C_1 \le .01\ \mu F$</td></tr>
</table>

Figure 2. Design Information



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_C is then placed from the midpoint to ground. The value for C_C should be such that the corner frequency of this network does not significantly affect Ω_n. In Figure B, the ratio of R3 to R4 sets the damping, R4 ≅ (0.1)(R3) for optimum results.

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

$$K_{VCO} = \frac{2\pi\Delta f_{VCO}}{V_{DD} - 2\,V}$$

for a typical design $\Omega_n \cong \frac{2\pi f_r}{10}$ (at phase detector input)

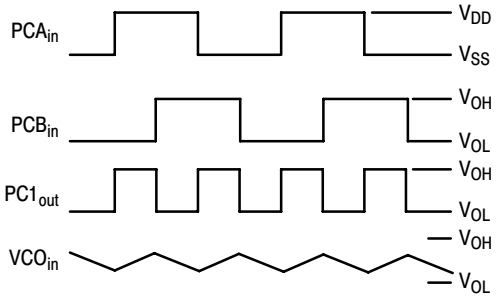
$\zeta \cong 0.707$

LOW−PASS FILTER

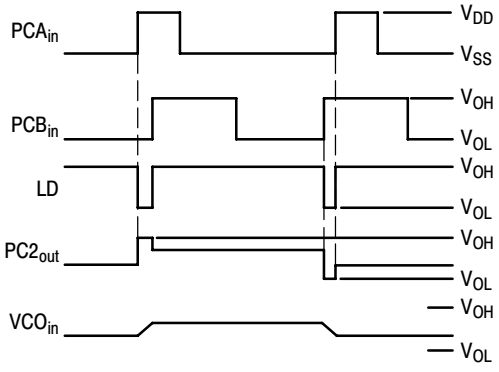
Filter A	Filter B
$\omega_n = \sqrt{\frac{K\phi K_{VCO}}{NR_3C_2}}$	$\omega_n = \sqrt{\frac{K\phi K_{VCO}}{NC_2(R_3 + R_4)}}$
$\zeta = \frac{N\omega_n}{2K\phi K_{VCO}}$	$\zeta = 0.5\,\omega_n\,(R_3C_2 + \frac{N}{K\phi K_{VCO}})$
$F(s) = \frac{1}{R_3C_2S + 1}$	$F(s) = \frac{R_3C_2S + 1}{S(R_3C_2 + R_4C_2) + 1}$

Waveforms

Phase Comparator 1



Phase Comparator 2



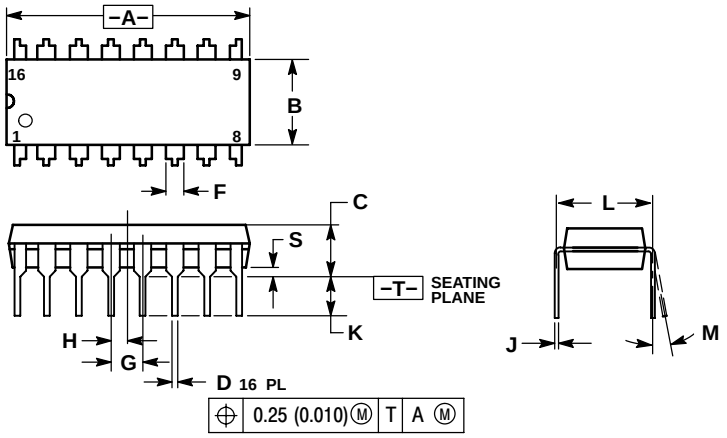
Note: for further information, see:

(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

PACKAGE DIMENSIONS

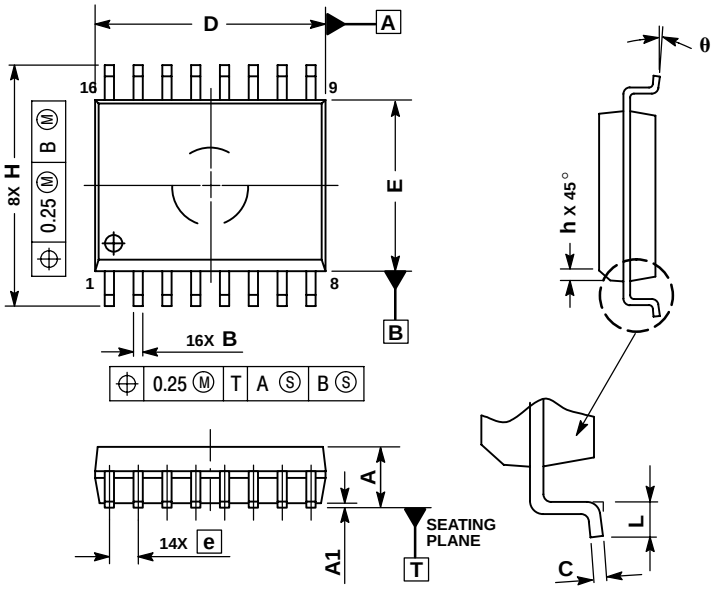
PDIP−16
P SUFFIX
PLASTIC DIP PACKAGE
CASE 648−08
ISSUE T



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.740	0.770	18.80	19.55
B	0.250	0.270	6.35	6.85
C	0.145	0.175	3.69	4.44
D	0.015	0.021	0.39	0.53
F	0.040	0.70	1.02	1.77
G	0.100 BSC		2.54 BSC	
H	0.050 BSC		1.27 BSC	
J	0.008	0.015	0.21	0.38
K	0.110	0.130	2.80	3.30
L	0.295	0.305	7.50	7.74
M	0 °	10 °	0 °	10 °
S	0.020	0.040	0.51	1.01

SOIC−16 WB
DW SUFFIX
PLASTIC SOIC PACKAGE
CASE 751G−03
ISSUE C

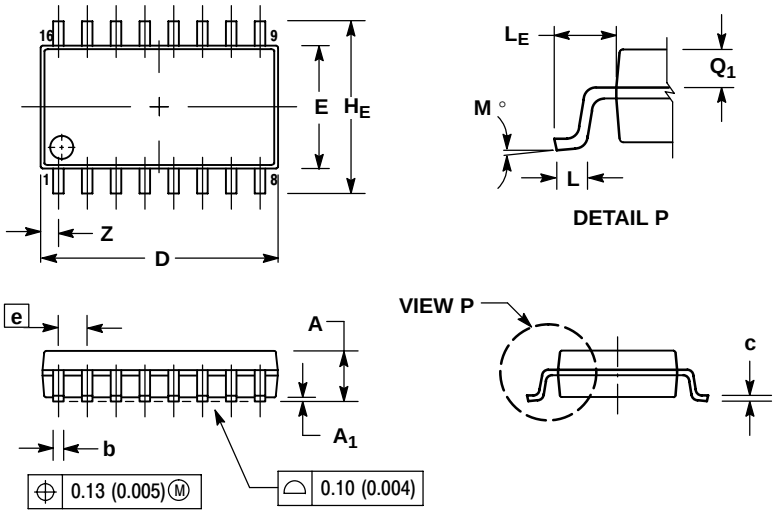


NOTES:
1. DIMENSIONS ARE IN MILLIMETERS.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DIMENSIONS D AND E DO NOT INLCUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS	
DIM	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	0.25	0.75
L	0.50	0.90
q	0 °	7 °

PACKAGE DIMENSIONS

SOEIAJ−16
F SUFFIX
PLASTIC EIAJ SOIC PACKAGE
CASE 966−01
ISSUE O



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS D AND E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS AND ARE MEASURED AT THE PARTING LINE. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
5. THE LEAD WIDTH DIMENSION (b) DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 (0.003) TOTAL IN EXCESS OF THE LEAD WIDTH DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT. MINIMUM SPACE BETWEEN PROTRUSIONS AND ADJACENT LEAD TO BE 0.46 (0.018).

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	---	2.05	---	0.081
A_1	0.05	0.20	0.002	0.008
b	0.35	0.50	0.014	0.020
c	0.18	0.27	0.007	0.011
D	9.90	10.50	0.390	0.413
E	5.10	5.45	0.201	0.215
e	1.27 BSC		0.050 BSC	
H_E	7.40	8.20	0.291	0.323
L	0.50	0.85	0.020	0.033
L_E	1.10	1.50	0.043	0.059
M	0 °	10 °	0 °	10 °
Q_1	0.70	0.90	0.028	0.035
Z	---	0.78	---	0.031

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