



**THE DATASHEET OF  
SG1731J**



## DC MOTOR PULSE WIDTH MODULATOR

### Description

The SG1731 is a pulse width modulator circuit designed specifically for DC motor control. It provides a bi-directional pulse train output in response to the magnitude and polarity of an analog error signal input. The device is useful as the control element in motor-driven servo systems for precision positioning and speed control, as well as in audio modulators and amplifiers using carrier frequencies to 350 kHz.

The circuit contains a triangle waveform oscillator, a wideband operational amplifier for error voltage generation, a summing/scaling network for level-shifting the triangle waveform, externally programmable PWM comparators and dual  $\pm 100$  mA,  $\pm 22$  V totem pole drivers with commutation diodes for full bridge output. A SHUTDOWN terminal forces the drivers into a floating high-impedance state when driven LOW. Supply voltage to the control circuitry and to the output drivers may be from either dual positive and negative supplies, or single-ended.

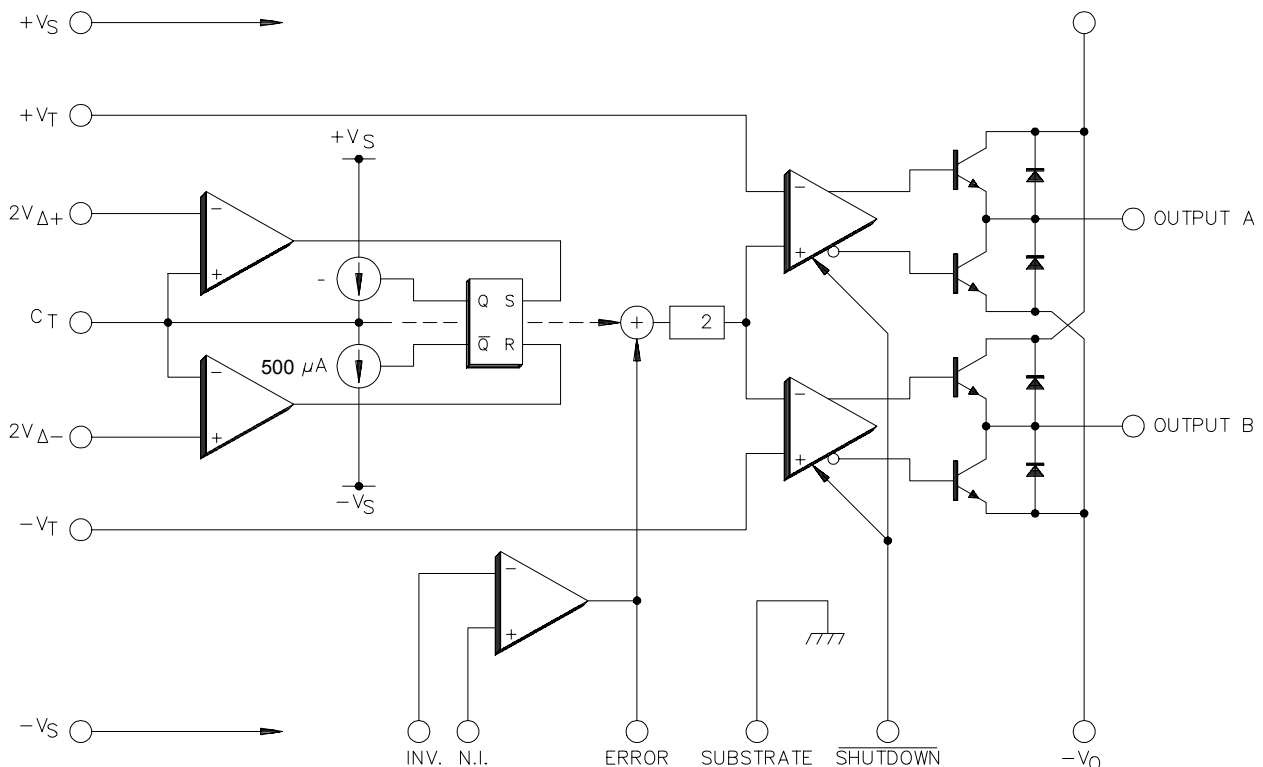
### Features

- $\pm 3.5$  V to  $\pm 15$  V Control Supply
- $\pm 2.5$  V to  $\pm 22$  V Driver Supply
- Dual 100 mA Source/Sink Output Drivers
- 5 kHz to 350 kHz Oscillator Range
- High Slew Rate Error Amplifier
- Adjustable Deadband Operation
- Digital  $\overline{\text{SHUTDOWN}}$  Input

### High Reliability Features

- Available to MIL-STD-883
- Available to DSCC
  - Standard Microcircuit Drawing (SMD)
- MSC-AMS level "S" Processing Available

### Block Diagram



**Figure 1** · Block Diagram

## Absolute Maximum Ratings (Note 1)

Supply Voltage ( $\pm V_S$ ) .....	$\pm 18$ V	Output Driver Diode Current (continuous) .....	200 mA
Analog Inputs .....	$\pm V_S$	Output Driver Diode Current (peak, 500 ns) .....	400 mA
Digital Inputs (SHUTDOWN) .....	$-V_S - 0.3$ V to $-V_S + 18$ V	Operating Junction Temperature	
Output Driver Supply Voltage ( $\pm V_O$ ) .....	$\pm 25$ V	Hermetic (J - Package) .....	150°C
Source/Sink Output Current (continuous) .....	200 mA	Plastic (N - Package) .....	150°C
Source/Sink Output Current (peak, 500 ns) .....	400 mA	Storage Temperature Range .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C
		RoHS Peak Package Solder Reflow Temp.(40 sec. max. exp.).....	260°C (+0, -5)

Note 1. Values beyond which damage may occur. Extended operation at the maximum levels may degrade performance and affect reliability.

## Thermal Data

J Package:		
Thermal Resistance-Junction to Case, $\theta_{JC}$ .....	30°C/W	Note A. Junction Temperature Calculation: $T_J = T_A + (P_D \times \theta_{JA})$ .
Thermal Resistance-Junction to Ambient, $\theta_{JA}$ .....	80°C/W	Note B. The above numbers for $\theta_{JC}$ are maximums for the limiting thermal resistance of the package in a standard mounting configuration. The $\theta_{JA}$ numbers are meant to be guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.
N Package:		
Thermal Resistance-Junction to Case, $\theta_{JC}$ .....	40°C/W	
Thermal Resistance-Junction to Ambient, $\theta_{JA}$ .....	65°C/W	
L Package:		
Thermal Resistance-Junction to Case, $\theta_{JC}$ .....	35°C/W	
Thermal Resistance-Junction to Ambient, $\theta_{JA}$ .....	120°C/W	

## Recommended Operating Conditions (Note 2)

Supply Voltage Range ( $\pm V_S$ ) .....	$\pm 3.5$ V to $\pm 15$ V	Oscillator Frequency Range .....	10 Hz to 350 kHz
Error Amp Common-Mode Range .....	$-V_S + 3$ V to $V_S - 3$ V	Oscillator Voltage (Peak-to-Peak) .....	1 V to 10 V
Output Driver Supply Voltage Range .....	$\pm 2.5$ V to $\pm 22$ V	Oscillator Timing Capacitor ( $C_T$ ) .....	200 pF to 2.5 $\mu$ F
Source/Sink Output Current (continuous) .....	100 mA	Operating Ambient Temperature Range	
Source/Sink Output Current (peak, 500 ns) .....	200 mA	SG1731 .....	-55°C to 125°C
Output Driver Diode Current (continuous) .....	100 mA	SG2731 .....	-25°C to 85°C
Output Driver Diode Current (peak, 500 ns) .....	200 mA	SG3731 .....	0°C to 70°C

Note 2. Range over which the device is functional and parameter limits are guaranteed.

## Electrical Characteristics

(Unless otherwise specified, these specifications apply over the operating ambient temperatures for SG1731 with  $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ , SG2731 with  $-25^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ , SG3731 with  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ ,  $V_S = \pm 15$  V, and  $V_O = \pm 22$  V. Low duty cycle pulse testing techniques are used which maintains junction and case temperatures equal to the ambient temperature.)

Parameter	Test Conditions	SG1731/2731/3731			Units
		Min.	Typ.	Max.	
<b>Oscillator Section</b>					
$C_T$ Charging Current	$T_A = 25^\circ\text{C}$	450	500	550	$\mu\text{A}$
	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$	400		600	$\mu\text{A}$
$2V_{\Delta\pm}$ Input Bias Current	$V_{\text{CM}} = \pm 5$ V			-20	$\mu\text{A}$
Initial Oscillator Frequency	$C_T = 1000$ pF, $2V_{\Delta\pm} = \pm 5$ V, $T_A = 25^\circ\text{C}$	22.5	25.0	27.5	kHz
Temperature Stability (Note 3)	$C_T = 1000$ pF, $2V_{\Delta\pm} = \pm 5$ V			10	%
<b>Error Amplifier Section (Note 5)</b>					
Input Offset Voltage				10	mV
Input Bias Current				3	$\mu\text{A}$
Input Offset Current				600	nA
Open Loop Voltage Gain	$R_L = 2$ k $\Omega$	70			dB
Output Voltage Swing	$R_L = 2$ k $\Omega$	$\pm 10$			V
Common-Mode Rejection Ratio		70			dB
Slew Rate (Notes 3 and 4)	$T_A = 25^\circ\text{C}$	5	10		V/ $\mu\text{s}$
Unity Gain Bandwidth (Notes 3 and 4)	$T_A = 25^\circ\text{C}$	0.7	1		MHz
<b>PWM Comparators</b>					
Input Bias Current	$\pm V_T = \pm 3$ V			6	$\mu\text{A}$

## Electrical Characteristics (Continued)

Parameter	Test Conditions	SG1731/2731/3731			Units
		Min.	Typ.	Max.	
<b>SHUTDOWN Section</b>					
Logic Threshold	$-V_S = -3.5 \text{ V to } -15 \text{ V}$	$V_S + 0.8$		$V_S + 2.0$	V
SHUTDOWN HIGH Current	$V_{\text{SHUTDOWN}} = -V_S + 2.4 \text{ V}$			400	$\mu\text{A}$
SHUTDOWN LOW Current	$V_{\text{SHUTDOWN}} = -V_S$			-1.0	mA
<b>Output Drivers (Each Output)</b>					
HIGH Output Voltage	$I_{\text{SOURCE}} = 20 \text{ mA}$	19.2			V
	$I_{\text{SOURCE}} = 100 \text{ mA}$	19.0			V
LOW Output Voltage	$I_{\text{SINK}} = 20 \text{ mA}$			-19.2	V
	$I_{\text{SINK}} = 100 \text{ mA}$			-19.0	V
Driver Risettime	$C_L = 1000 \text{ pF}$			300	ns
Driver Falltime	$C_L = 1000 \text{ pF}$			300	ns
<b>Total Supply Current</b>					
$V_S$ Supply Current	$V_{\text{SHUTDOWN}} = -V_S + 0.8 \text{ V}$			14	mA
$V_O$ Supply Current	$V_{\text{SHUTDOWN}} = -V_S + 0.8 \text{ V}$			6	mA

Note 3. These parameters, although guaranteed, are not tested in production.  
 Note 4. Unity Gain Inverting 10 k $\Omega$  Feedback Resistance.

Note 5.  $V_{\text{CM}} = \pm 12 \text{ V}$ .

## Application Information

### SUPPLY VOLTAGE

The SG1731 requires a supply voltage for the control circuitry ( $V_S$ ) and for the power output drivers ( $V_O$ ). Each supply may be either balanced positive and negative with respect to ground, or single-ended. The only restrictions are:

1. The voltage between  $+V_S$  and  $-V_S$  must be at least 7.0 V; but no more than 44 V.
2. The voltage between  $+V_O$  and  $-V_O$  must be at least 5.0 V; but no more than 44 V.
3.  $+V_O$  must be at least 5 V more positive than  $-V_S$ . This eliminates the combination of a single-ended positive control supply with a single-ended negative driver supply.

### SUBSTRATE CONNECTION

The substrate connection (Pin 10) must always be connected to either  $-V_S$  or  $-V_O$ , whichever is more negative. The substrate must also be well bypassed to ground with a high quality capacitor.

### OSCILLATOR

The triangle oscillator consists of two voltage comparators, a set/reset flip-flop, a bi-directional 500  $\mu\text{A}$  current source, and an external timing capacitor  $C_T$ . A positive reference voltage ( $2V_{\Delta+}$ ) applied to Pin 2 determines the positive peak value of the triangle, and a negative reference voltage ( $2V_{\Delta-}$ ) at Pin 7 sets the negative peak value of the triangle waveform. Since the value of the internal current source is fixed at a nominal  $\pm 500 \mu\text{A}$ , the oscillator period is a function of the selected peak-to-peak voltage excursion and the value of  $C_T$ . The theoretical expression for the oscillator period is:

$$T_{\text{OSC}} = \frac{2C_T \text{ dV}}{5 \times 10^{-4}} \quad (\text{Eq.1})$$

where  $C_T$  is the timing capacitor in Farads and dV is  $V_{\text{OSC}}$  in Volts peak-to-peak.

As a design aid, the solutions to Equation 1 over the recommended range of  $T_{\text{OSC}}$  and  $V_{\text{OSC}}$  are given in graphic form in Figure 1. The lower limit on  $T_{\text{OSC}}$  is 1.85  $\mu\text{s}$ , corresponding to a maximum frequency of 350 kHz. The maximum value of  $V_{\text{OSC}}$ , ( $2V_{\Delta+}$ ) - ( $2V_{\Delta-}$ ), is 10 V peak-to-peak for linear waveforms.

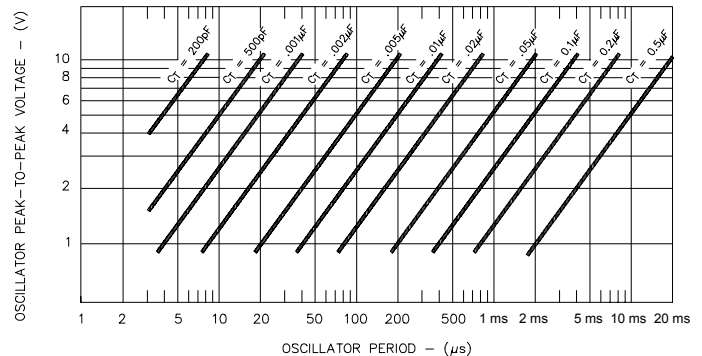


Figure 2 · SG1731 Oscillator Period VS.  $V_{\text{OSC}}$  and  $C_T$

### ERROR AMPLIFIER

The error amplifier of the SG1731 is a conventional internally-compensated operational amplifier with low output impedance. All of the usual feedback and frequency compensation techniques may be used to control the closed-loop gain characteristics. The control supply voltage  $\pm V_S$  will determine the input common mode range and output voltage swing; both will extend to within 3 V of the  $V_S$  supply.

### PULSE WIDTH MODULATION

Pulse width modulation occurs by comparing the triangle waveform to a fixed upper ( $+V_T$ ) and lower ( $-V_T$ ) threshold voltage. A crossing above the upper threshold causes Output A to switch to the HIGH state, and a crossing below

## Application Information (Continued)

the lower threshold causes Output B to switch to the HIGH state. If  $\pm V_s$  is less than  $\pm 8$  V then  $\pm V_T$  can be obtained with resistors from  $\pm V_s$ . If  $\pm V_s$  is greater than  $\pm 8$  V use zeners.

Threshold crossings are generated by shifting the triangle waveform up and down with the error voltage (Pin 5). A positive error voltage will result in a pulse width modulated output at Driver A (Pin 13). Similarly, a negative error voltage produces a pulse train at Driver B (Pin 12). Figure 2 illustrates this process for the case where  $V_{\Delta+}$  is greater than  $V_T$ .

It is important to note that the triangle shifting circuit also attenuates the waveform seen at  $C_T$  by a factor of 2. This results in a waveform at the PWM comparators with a positive peak of  $V_{\Delta+}$  and a negative peak of  $V_{\Delta-}$ , and must be taken into account when selecting the values for  $+V_T$  and  $-V_T$ .

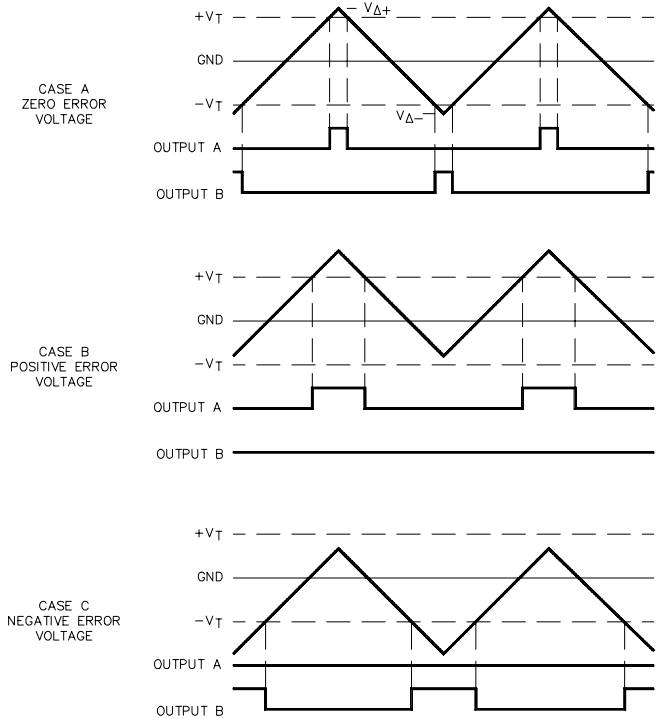


Figure 3 - Pulse Width Modulation with No Deadband

## Application Circuits

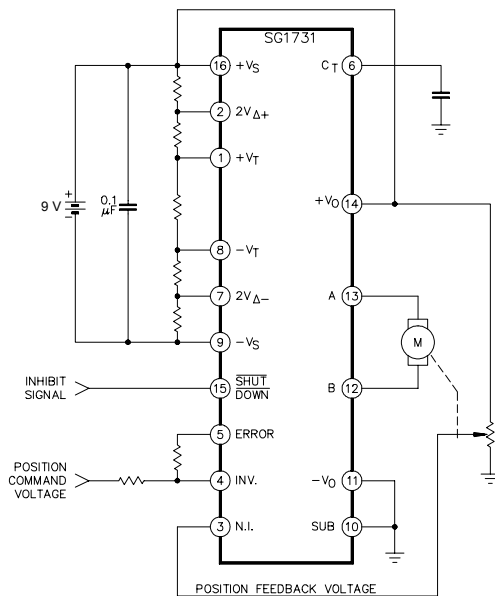


Figure 4

In this simple battery-powered position servo, the control supply and driver supply are both single-ended positive with respect to ground.

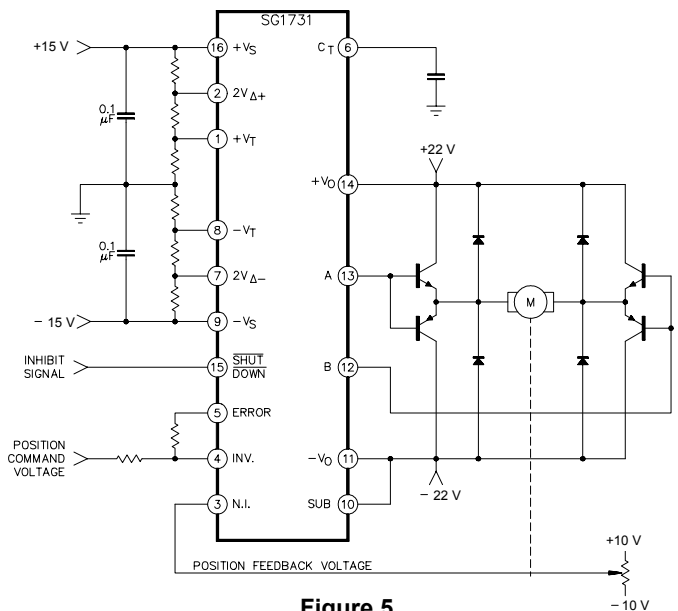
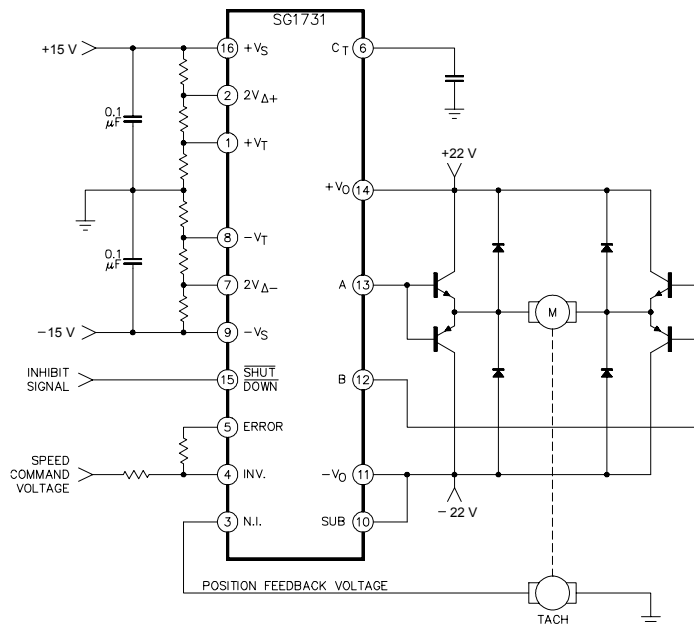


Figure 5

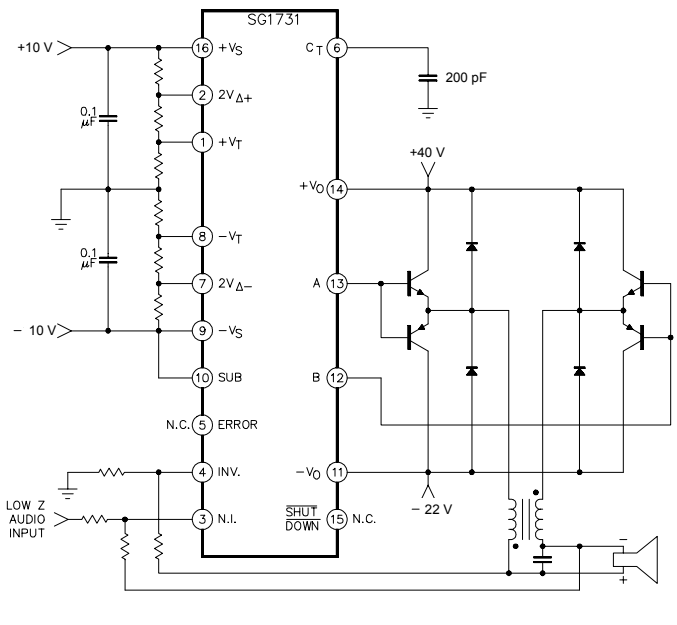
A high torque position servo is obtained by buffering the output drivers to obtain higher output current.

## Application Circuits (Continued)



**Figure 6**

Bi-directional speed control results when the feedback voltage transducer is a tachometer.



**Figure 7**

The two-quadrant transfer function of the SG1731 is ideal for pulse width modulated audio power amplifiers.

## Connection Diagrams & Ordering Information (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1731J- 883B SG1731J-DESC SG1731J	-55°C to 125°C -55°C to 125°C -55°C to 125°C	<p>N Package: RoHS Compliant / Pb-free Transition DC: 0503 N Package: RoHS / Pb-free 100% Matte Tin Lead Finish</p>
16-PIN PLASTIC DIP N - PACKAGE	SG2731N SG3731N	-25°C to 85°C 0°C to 70°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L- PACKAGE	SG1731L SG1731L- 883B	-55°C to 125°C -55°C to 125°C	

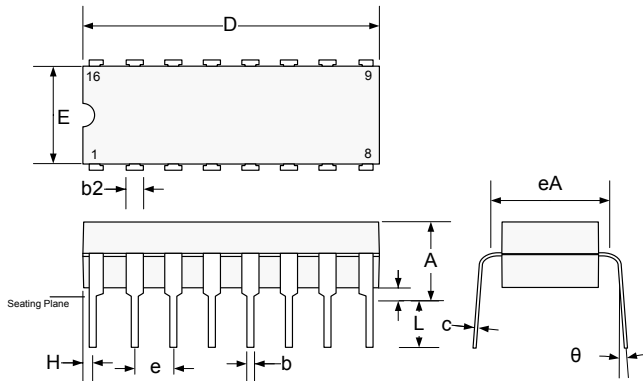
Note 1. All packages are viewed from the top.

Note 2. Contact factory for leadless chip carrier availability.

Note 3. Hermetic Packages J, L use Sn63/Pb37 hot solder lead finish, Contact factory for availability of RoHS versions.

## Package Outline Dimensions

Controlling dimensions are in inches, metric equivalents are shown for general information.

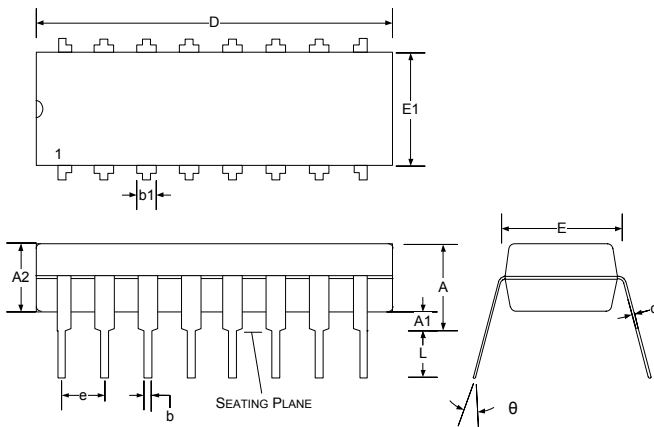


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	5.08	-	0.200
b	0.38	0.51	0.015	0.020
b2	1.04	1.65	0.045	0.065
c	0.20	0.38	0.008	0.015
D	19.30	19.94	0.760	0.785
E	5.59	7.11	0.220	0.280
e	2.54 BSC		0.100 BSC	
eA	7.37	7.87	0.290	0.310
H	0.63	1.78	0.025	0.070
L	3.18	5.08	0.125	0.200
$\alpha$	-	15°	-	15°
Q	0.51	1.02	0.020	0.040

**Note:**

Dimensions do not include protrusions; these shall not exceed 0.155mm (.006") on any side. Lead dimension shall not include solder coverage.

**Figure 8 - J 16-Pin Ceramic Dual In-line Package Dimensions**



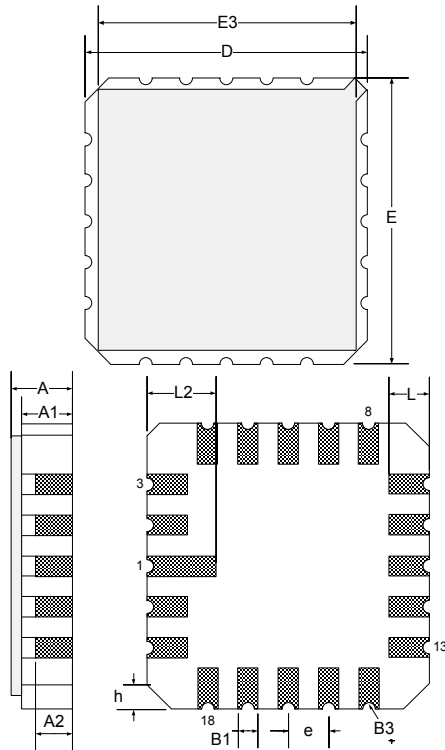
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	5.33	-	0.210
A1	0.38	-	0.015	-
A2	3.30 Typ.		0.130 Typ.	
b	0.36	0.56	0.014	0.022
b1	1.14	1.78	0.045	0.070
c	0.20	0.36	0.008	0.014
D	18.67	19.69	0.735	0.775
e	2.54 BSC		0.100 BSC	
E	7.62	8.26	0.300	0.325
E1	6.10	7.11	0.240	0.280
L	2.92	0.381	0.115	0.150
$\theta$	-	15°	-	15°

**Note:**

Dimensions do not include protrusions; these shall not exceed 0.155mm (.006") on any side. Lead dimension shall not include solder coverage.

**Figure 9 - N 16-Pin Plastic Dual In-line Package Dimensions**

## Package Outline Dimensions (Continued)



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
D/E	8.64	9.14	0.340	0.360
E3	-	8.128	-	0.320
e	1.270 BSC		0.050 BSC	
B1	0.635 TYP		0.025 TYP	
L	1.02	1.52	0.040	0.060
A	1.626	2.286	0.064	0.090
h	1.016 TYP		0.040 TYP	
A1	1.372	1.68	0.054	0.066
A2	-	1.168	-	0.046
L2	1.91	2.41	0.075	0.95
B3	0.203R		0.008R	

**Note:**

All exposed metalized area shall be gold plated 60 micro-inch minimum thickness over nickel plated unless otherwise specified in purchase order.

**Figure 10 - L 20-Pin Ceramic LCC Package Outline Dimensions**



**Microsemi Corporate Headquarters**  
One Enterprise, Aliso Viejo,  
CA 92656 USA

**Within the USA:** +1 (800) 713-4113  
**Outside the USA:** +1 (949) 380-6100  
**Sales:** +1 (949) 380-6136  
**Fax:** +1 (949) 215-4996

**E-mail:** [sales.support@microsemi.com](mailto:sales.support@microsemi.com)

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