

# CS1124

## Dual Variable-Reluctance Sensor Interface IC

The CS1124 is a monolithic integrated circuit designed primarily to condition signals used to monitor rotating parts.

The CS1124 is a dual channel device. Each channel interfaces to a Variable Reluctance Sensor, and monitors the signal produced when a metal object is moved past that sensor. An output is generated that is a comparison of the input voltage and the voltage produced at the  $IN_{Adj}$  lead. The resulting square-wave is available at the OUT pin.

When the DIAG pin is high, the reference voltage at  $IN_{Adj}$  is increased. This then requires a larger signal at the input to trip the comparator, and provides for a procedure to test for an open sensor.

### Features

- Dual Channel Capability
- Built-In Test Mode
- On-Chip Input Voltage Clamping
- Works from 5.0 V Supply
- Accurate Built-In Hysteresis
- Pb-Free Packages are Available

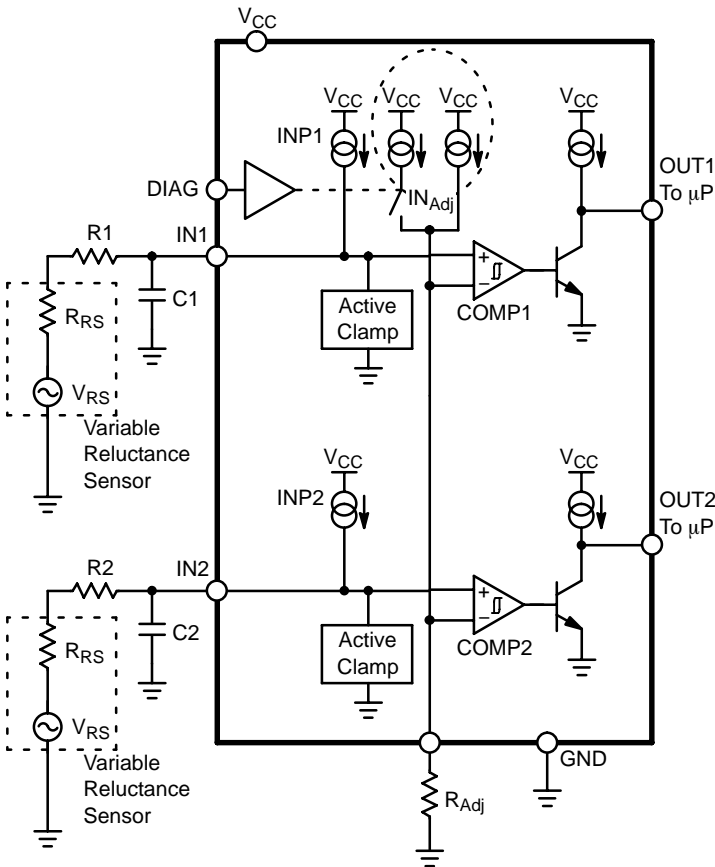


Figure 1. Block Diagram



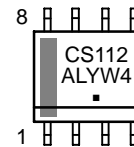
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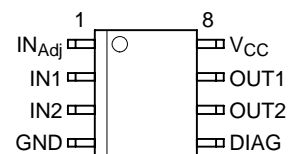
SOIC-8  
CASE 751

### MARKING DIAGRAM



CS1124 = Device Code  
A = Assembly Location  
L = Wafer Lot  
Y = Year  
W = Work Week  
▪ = Pb-Free Package

### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 3 of this data sheet.

## MAXIMUM RATINGS

Rating	Value	Unit
Storage Temperature Range	-65 to 150	°C
Ambient Operating Temperature	-40 to 125	°C
Supply Voltage Range (continuous)	-0.3 to 7.0	V
Input Voltage Range (at any input, R1 = R2 = 22 k)	-250 to 250	V
Maximum Junction Temperature	150	°C
ESD Susceptibility (Human Body Model)	2.0	kV
Lead Temperature Soldering:	Reflow: (SMD styles only) (Note 1)	230 peak
		°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. 60 second maximum above 183°C.

ELECTRICAL CHARACTERISTICS (4.5 V < V<sub>CC</sub> < 5.5 V, -40°C < T<sub>A</sub> < 125°C, V<sub>DIAG</sub> = 0; unless otherwise specified.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
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V<sub>CC</sub> SUPPLY

Operating Current Supply	V <sub>CC</sub> = 5.0 V	-	-	5.0	mA
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## Sensor Inputs

Input Threshold – Positive	V <sub>DIAG</sub> = Low	135	160	185	mV
	V <sub>DIAG</sub> = High	135	160	185	mV
Input Threshold – Negative	V <sub>DIAG</sub> = Low	-185	-160	-135	mV
	V <sub>DIAG</sub> = High	135	160	185	mV
Input Bias Current (INP1, INP2)	V <sub>IN</sub> = 0.336 V	-16	-11	-6.0	μA
Input Bias Current (DIAG)	V <sub>DIAG</sub> = 0 V	-	-	1.0	μA
Input Bias Current Factor (K <sub>i</sub> ) (I <sub>NAdj</sub> = INP × K <sub>i</sub> )	V <sub>IN</sub> = 0.336 V, V <sub>DIAG</sub> = Low	-	100	-	%INP
	V <sub>IN</sub> = 0.336 V, V <sub>DIAG</sub> = High	152	155	157	%INP
Bias Current Matching	INP1 or INP2 to I <sub>NAdj</sub> , V <sub>IN</sub> = 0.336 V	-1.0	0	1.0	μA
Input Clamp – Negative	I <sub>IN</sub> = -50 μA	-0.5	-0.25	0	V
	I <sub>IN</sub> = -12 mA	-0.5	-0.30	0	V
Input Clamp – Positive	I <sub>IN</sub> = +12 mA	5.0	7.0	9.0	V
Output Low Voltage	I <sub>OUT</sub> = 1.6 mA	-	0.2	0.4	V
Output High Voltage	I <sub>OUT</sub> = -1.6 mA	V <sub>CC</sub> - 0.5	V <sub>CC</sub> - 0.2	-	V
Mode Change Time Delay	-	0	-	20	μs
Input to Output Delay	I <sub>OUT</sub> = 1.0 mA	-	1.0	20	μs
Output Rise Time	C <sub>LOAD</sub> = 30 pF	-	0.5	2.0	μs
Output Fall Time	C <sub>LOAD</sub> = 30 pF	-	0.05	2.0	μs
Open-Sensor Positive Threshold	V <sub>DIAG</sub> = High, R <sub>IN(Adj)</sub> = 40 k. Note 2	29.4	54	86.9	kΩ

## Logic Inputs

DIAG Input Low Threshold	-	-	-	0.2 × V <sub>CC</sub>	V
DIAG Input High Threshold	-	0.7 × V <sub>CC</sub>	-	-	V
DIAG Input Resistance	V <sub>IN</sub> = 0.3 × V <sub>CC</sub> , V <sub>CC</sub> = 5.0 V	8.0	22	70	kΩ
	V <sub>IN</sub> = V <sub>CC</sub> , V <sub>CC</sub> = 5.0 V	8.0	22	70	kΩ

2. This parameter is guaranteed by design, but not parametrically tested in production.

# CS1124

## PACKAGE PIN DESCRIPTION

PIN # SOIC-8	PIN SYMBOL	FUNCTION
1	IN <sub>Adj</sub>	External resistor to ground that sets the trip levels of both channels. Functions for both diagnostic and normal mode
2	IN1	Input to channel 1
3	IN2	Input to channel 2
4	GND	Ground
5	DIAG	Diagnostic mode switch. Normal mode is low
6	OUT2	Output of channel 2
7	OUT1	Output of channel 1
8	V <sub>CC</sub>	Positive 5.0 volt supply input

## ORDERING INFORMATION

Device	Package	Shipping†
CS1124YD8	SOIC-8 NB	96 Units / Rail
CS1124YD8G	SOIC-8 NB (Pb-Free)	96 Units / Rail
CS1124YDR8	SOIC-8 NB	96 Units / Rail
CS1124YDR8G	SOIC-8 NB (Pb-Free)	96 Units / Rail

†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.

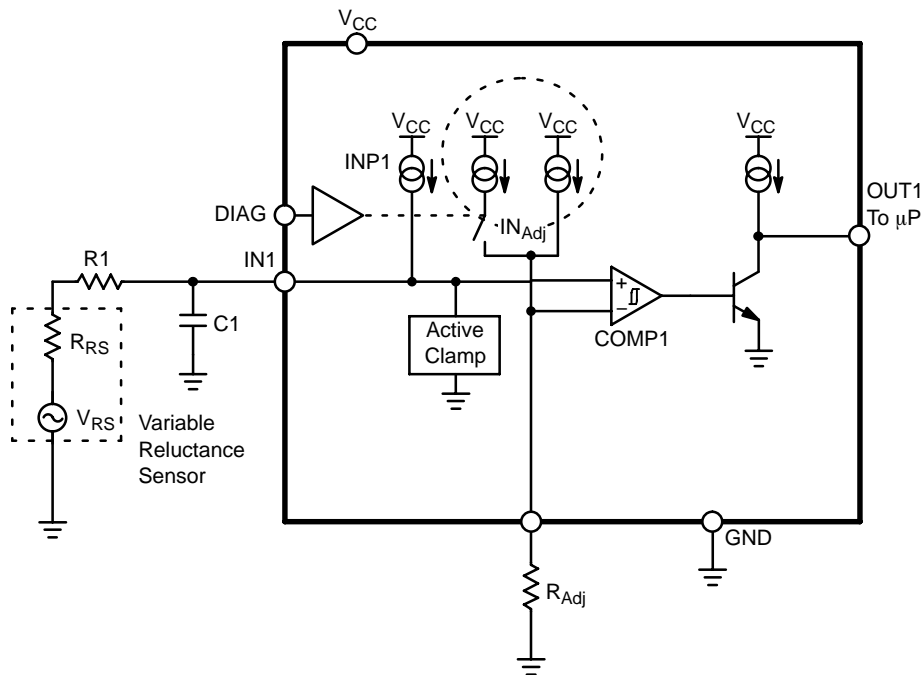


Figure 2. Application Diagram

## THEORY OF OPERATION

## NORMAL OPERATION

Figure 2 shows one channel of the CS1124 along with the necessary external components. Both channels share the  $IN_{Adj}$  pin as the negative input to a comparator. A brief description of the components is as follows:

$V_{RS}$  – Ideal sinusoidal, ground referenced, sensor output – amplitude usually increases with frequency, depending on loading.

$R_{RS}$  – Source impedance of sensor.

$R1/R_{Adj}$  – External resistors for current limiting and biasing.

$INP1/IN_{Adj}$  – Internal current sources that determine trip points via  $R1/R_{Adj}$ .

**COMP1** – Internal comparator with built-in hysteresis set at 160 mV.

**OUT1** – Output 0 V – 5.0 V square wave with the same frequency as  $V_{RS}$ .

By inspection, the voltage at the (+) and (–) terminals of COMP1 with  $V_{RS} = 0V$  are:

$$V^+ = INP1(R1 + R_{RS}) \quad (1)$$

$$V^- = IN_{Adj} \times R_{Adj} \quad (2)$$

As  $V_{RS}$  begins to rise and fall, it will be superimposed on the DC biased voltage at  $V^+$ .

$$V^+ = INP1(R1 + R_{RS}) + V_{RS} \quad (3)$$

To get comparator COMP1 to trip, the following condition is needed when crossing in the positive direction,

$$V^+ > V^- + V_{HYS} \quad (4)$$

( $V_{HYS}$  is the built-in hysteresis set to 160 mV), or when crossing in the negative direction,

$$V^+ < V^- - V_{HYS} \quad (5)$$

Combining equations 2, 3, and 4, we get:

$$INP1(R1 + R_{RS}) + V_{RS} > IN_{Adj} \times R_{Adj} + V_{HYS} \quad (6)$$

therefore,

$$V_{RS(+TRP)} < IN_{Adj} \times R_{Adj} - INP1(R1 + R_{RS}) + V_{HYS} \quad (7)$$

It should be evident that tripping on the negative side is:

$$V_{RS(-TRP)} < IN_{Adj} \times R_{Adj} - INP1(R1 + R_{RS}) - V_{HYS} \quad (8)$$

In normal mode,

$$INP1 = IN_{Adj} \quad (9)$$

We can now re-write equation (7) as:

$$V_{RS(+TRP)} > INP1(R_{Adj} - R1 - R_{RS}) + V_{HYS} \quad (10)$$

By making

$$R_{Adj} = R1 + R_{RS} \quad (11)$$

you can detect signals with as little amplitude as  $V_{HYS}$ .

A design example is given in the applications section.

## OPEN SENSOR PROTECTION

The CS1124 has a DIAG pin that when pulled high (5.0 V), will increase the  $IN_{Adj}$  current source by roughly 50%.

Equation (7) shows that a larger  $V_{RS(+TRP)}$  voltage will be needed to trip comparator COMP1. However, if no  $V_{RS}$  signal is present, then we can use equations 1, 2, and 4 (equation 5 does not apply in this mode) to get:

$$INP1(R1 + R_{RS}) > INP1 \times K_I \times R_{Adj} + V_{HYS} \quad (12)$$

Since  $R_{RS}$  is the only unknown variable we can solve for  $R_{RS}$ .

$$R_{RS} = \frac{INP1 \times K_I \times R_{Adj} + V_{HYS}}{INP1} - R1 \quad (13)$$

Equation (13) shows that if the output switches states when entering the diag mode with  $V_{RS} = 0$ , the sensor impedance must be greater than the above calculated value. This can be very useful in diagnosing intermittent sensor.

## INPUT PROTECTION

As shown in Figure 2, an active clamp is provided on each input to limit the voltage on the input pin and prevent substrate current injection. The clamp is specified to handle  $\pm 12$  mA. This puts an upper limit on the amplitude of the sensor output. For example, if  $R1 = 20$  k, then

$$V_{RS(MAX)} = 20 \text{ k} \times 12 \text{ mA} = 240 \text{ V}$$

Therefore, the  $V_{RS(pk-pk)}$  voltage can be as high as 480 V.

The CS1124 will *typically* run at a frequency up to 1.8 MHz if the input signal does not activate the positive or negative input clamps. Frequency performance will be lower when the positive or negative clamps are active. *Typical* performance will be up to a frequency of 680 kHz with the clamps active.

CIRCUIT DESCRIPTION

Figure 3 shows the part operating near the minimum input thresholds. As the sin wave input threshold is increased, the low side clamps become active (Figure 4). Increasing the amplitude further (Figure 5), the high-side clamp becomes active. These internal clamps allow for voltages up to -250 V and 250 V on the sensor side of the setup (with  $R1 = R2 = 22\text{ k}$ ) (reference the diagram page 1).

Figure 6 shows the effect using the diagnostic (DIAG) function has on the circuit. The input threshold (negative) is switched from a threshold of -160 mV to +160 mV when DIAG goes from a low to a high. There is no hysteresis when DIAG is high.

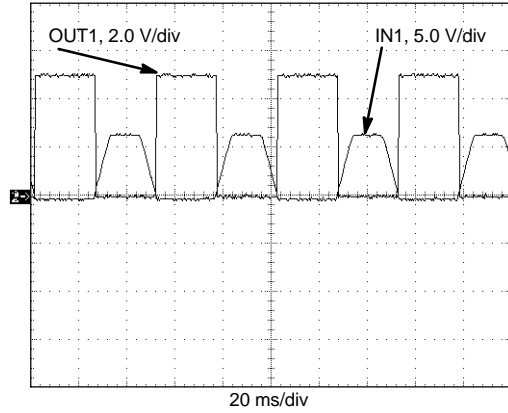


Figure 5. Low- and High-Side Clamps

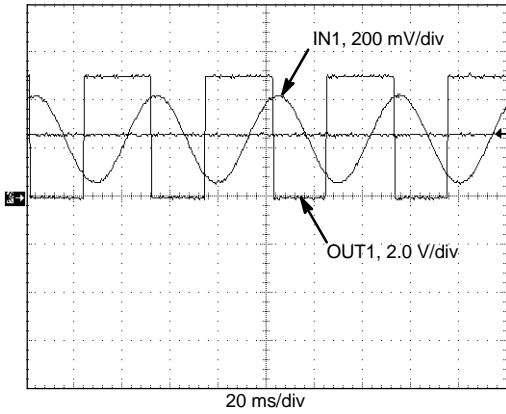


Figure 3. Minimum Threshold Operation

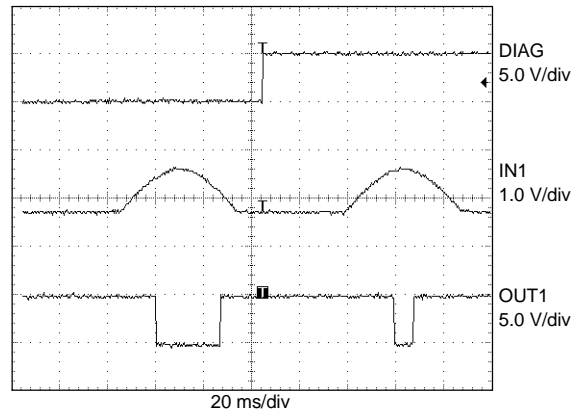


Figure 6. Diagnostic Operation

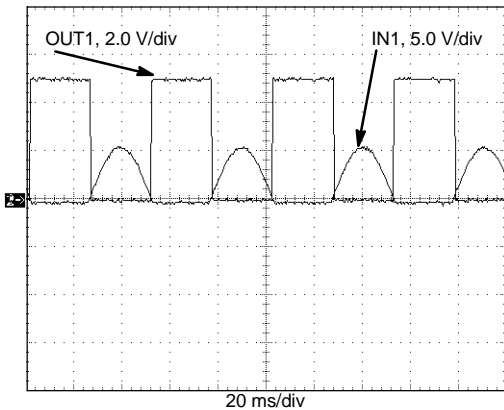


Figure 4. Low-Side Clamp

## APPLICATION INFORMATION

Referring to Figure 2, the following will be a design example given these system requirements:

$$R_{RS} = 1.5 \text{ k}\Omega \text{ (} > 12 \text{ k}\Omega \text{ is considered open)}$$

$$V_{RS(\text{MAX})} = 120 \text{ V}_{\text{pk}}$$

$$V_{RS(\text{MIN})} = 250 \text{ mV}_{\text{pk}}$$

$$F_{VRS} = 10 \text{ kHz @ } V_{RS(\text{MIN})} = 40 \text{ V}_{\text{pk-pk}}$$

### 1. Determine tradeoff between R1 value and power rating. (use 1/2 watt package)

$$P_D = \frac{\left(\frac{120}{\sqrt{2}}\right)^2}{R_1} < 1/2 \text{ W}$$

Set  $R_1 = 15 \text{ k}$ . (The clamp current will then be  $120/15 \text{ k} = 8.0 \text{ mA}$ , which is less than the  $12 \text{ mA}$  limit.)

### 2. Determine $R_{\text{Adj}}$

Set  $R_{\text{Adj}}$  as close to  $R_1 + R_{RS}$  as possible.

Therefore,  $R_{\text{Adj}} = 17 \text{ k}$ .

### 3. Determine $V_{RS(+TRP)}$ using equation (7).

$$V_{RS(+TRP)} = 11\mu\text{A} \times 17 \text{ k} - 11\mu\text{A}(15 \text{ k} + 1.5 \text{ k}) + 160 \text{ mV}$$

$$V_{RS(+TRP)} = 166 \text{ mV typical} \\ \text{(easily meets 250 mV minimum)}$$

### 4. Calculate worst case $V_{RS(+TRP)}$

Examination of equation (7) and the spec reveals the worst case trip voltage will occur when:

$$V_{\text{HYS}} = 180 \text{ mV}$$

$$I_{N_{\text{Adj}}} = 16 \mu\text{A}$$

$$I_{N_{P1}} = 15 \mu\text{A}$$

$$R_1 = 14.25 \text{ k (5\% low)}$$

$$R_{\text{Adj}} = 17.85 \text{ k (5\% High)}$$

$$V_{RS(+)}_{\text{MAX}} = 16 \mu\text{A}(17.85 \text{ k}) \\ - 15\mu\text{A}(14.25 \text{ k} + 1.5 \text{ k}) + 180 \text{ mV} \\ = 229 \text{ mV}$$

which is still less than the  $250 \text{ mV}$  minimum amplitude of the input.

### 5. Calculate C1 for low pass filtering

Since the sensor guarantees  $40 \text{ V}_{\text{pk-pk}} @ 10 \text{ kHz}$ , a low pass filter using  $R_1$  and  $C_1$  can be used to eliminate high frequency noise without affecting system performance.

$$\text{Gain Reduction} = \frac{0.29 \text{ V}}{20 \text{ V}} = 0.0145 = -36.7 \text{ dB}$$

Therefore, a cut-off frequency,  $f_c$ , of  $145 \text{ Hz}$  could be used.

$$C_1 \leq \frac{1}{2\pi f_c R_1} \leq 0.07 \mu\text{F}$$

Set  $C_1 = 0.047 \mu\text{F}$ .

### 6. Calculate the minimum $R_{RS}$ that will be indicated as an open circuit. (DIAG = 5.0 V)

Rearranging equation (7) gives

$$R_{RS} = \frac{\left[ V_{\text{HYS}} + [I_{N_{P1}} \times K_I \times R_{\text{Adj}}] - V_{RS(+TRP)} \right]}{I_{N_{P1}}} - R_1$$

But,  $V_{RS} = 0$  during this test, so it drops out.

Using the following as worst case Low and High:

	Worst Case Low ( $R_{RS}$ )	Worst Case High ( $R_{RS}$ )
$I_{N_{\text{Adj}}}$	$23.6 \mu\text{A} = 15 \mu\text{A} \times 1.57$	$10.7 \mu\text{A} = 7.0 \mu\text{A} \times 1.53$
$R_{\text{Adj}}$	16.15 k	17.85 k
$V_{\text{HYS}}$	135 mV	185 mV
$I_{N_{P1}}$	16 $\mu\text{A}$	6.0 $\mu\text{A}$
$R_1$	15.75 k	14.25 k
$K_I$	1.57	1.53

$$R_{RS} = \frac{135 \text{ mV} + 23.6 \mu\text{A} \times 16.15 \text{ k}}{16 \mu\text{A}} - 15.75 \text{ k} \\ = 16.5 \text{ k}$$

Therefore,

$$R_{RS(\text{MIN})} = 16.5 \text{ k (meets 12 k system spec)}$$

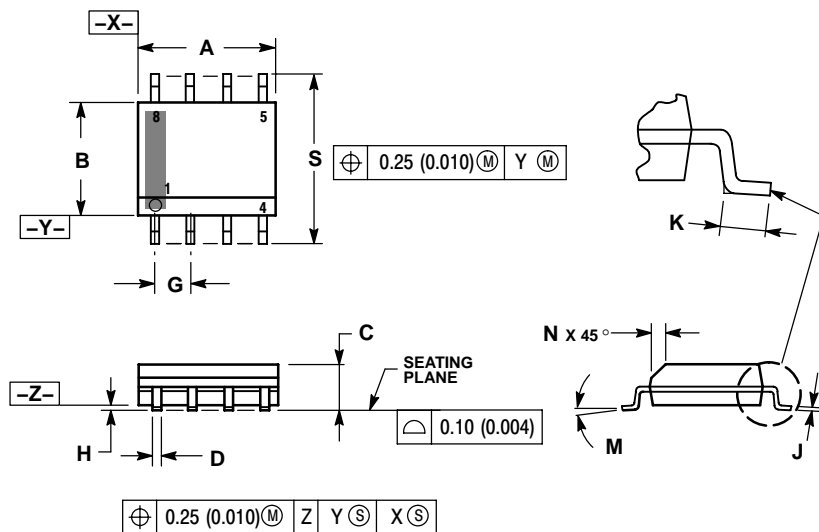
and,

$$R_{RS(\text{MAX})} = \frac{185 \text{ mV} + 10.7 \mu\text{A} \times 17.85 \text{ k}}{6.0 \mu\text{A}} - 14.25 \text{ k} \\ = 48.4 \text{ k}$$

# CS1124

## PACKAGE DIMENSIONS

SOIC-8 NB  
CASE 751-07  
ISSUE AG

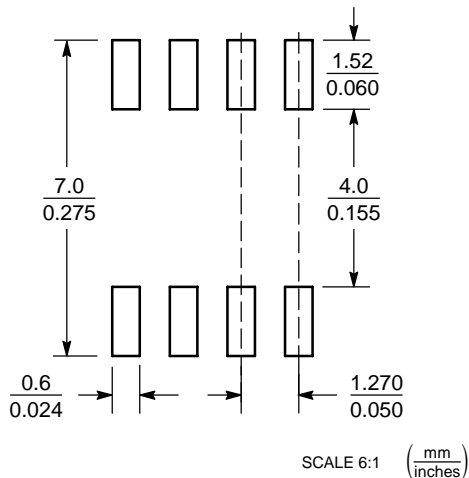


**NOTES:**

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751-01 THRU 751-06 ARE OBSOLETE. NEW STANDARD IS 751-07.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0°	8°	0°	8°
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

### SOLDERING FOOTPRINT\*



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

### PACKAGE THERMAL DATA

Parameter		SOIC-8NB	Unit
R <sub>θJC</sub>	Typical	45	°C/W
R <sub>θJA</sub>	Typical	165	°C/W

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