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[ON Semiconductor](#)  
[NCV1124DG](#)

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## NCV1124

### Dual Variable-Reluctance Sensor Interface IC

The NCV1124 is a monolithic integrated circuit designed primarily to condition signals from sensors used to monitor rotating parts.

The NCV1124 is a dual channel device. Each of the two identical channels interfaces with a variable-reluctance sensor, and continuously compares the sensor output signal to a user-programmable internal reference. An alternating input signal of appropriate amplitude at IN1 or IN2 will result in a rectangular waveform at the corresponding OUT terminal, suitable for interface to either standard microprocessors or standard logic families.

A diagnostic input, common to both channels, provides a means to test for degradation or loss of the physical connector to both sensors.

#### Typical Applications

- Anti-Skid Braking and Traction Control
- Vehicle Stability Control
- Drive Belt Slippage Detection
- Crankshaft/Camshaft Position Sensing

#### Features

- Two Independent Channels
- Internal Hysteresis
- Built-In Diagnostic Mode
- Designed to Work from a  $5.0\text{ V} \pm 10\%$  Supply
- Site and Control for Automotive Applications
- Pb-Free Packages are Available

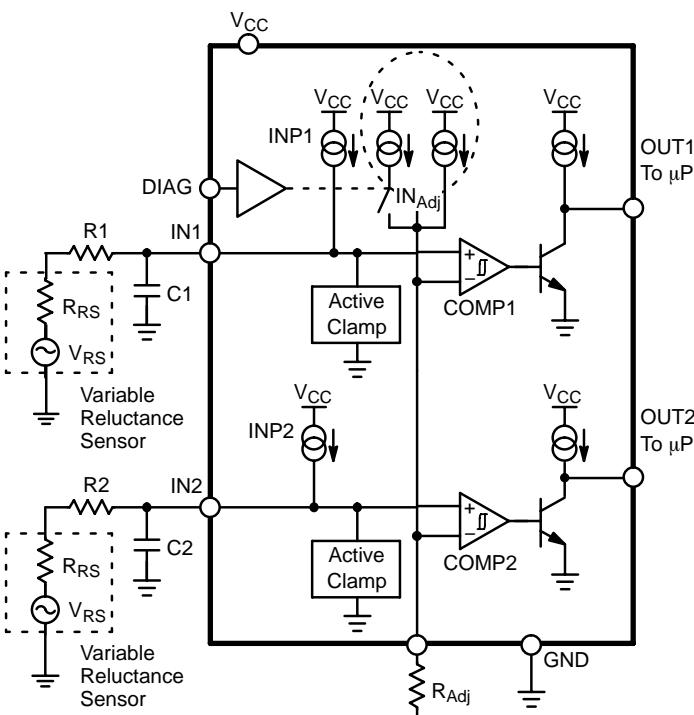


Figure 1. Block Diagram



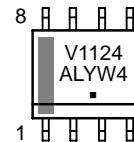
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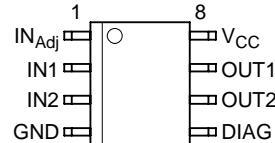
SO-8  
CASE 751

#### MARKING DIAGRAM



V1124 = 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.

## NCV1124

### 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, $R_1 = R_2 = 22\text{ k}\Omega$ )	-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)	240 peak
		°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. 60 second maximum above 183°C.

### ELECTRICAL CHARACTERISTICS (4.5 V < $V_{CC}$ < 5.5 V, $-40^\circ\text{C} < T_A < 125^\circ\text{C}$ , $V_{DIAG} = 0$ ; unless otherwise specified.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
<b><math>V_{CC}</math> SUPPLY</b>					
Operating Current Supply	$V_{CC} = 5.0\text{ V}$	-	-	5.0	mA
<b>Sensor Inputs</b>					
Input Threshold – Positive	$V_{DIAG} = \text{Low}$ $V_{DIAG} = \text{High}$	135 135	160 160	185 185	mV mV
Input Threshold – Negative	$V_{DIAG} = \text{Low}$ $V_{DIAG} = \text{High}$	-185 135	-160 160	-135 185	mV mV
Input Bias Current (INP1, INP2)	$V_{IN} = 0.336\text{ V}$	-16	-11	-6.0	$\mu\text{A}$
Input Bias Current (DIAG)	$V_{DIAG} = 0\text{ V}$	-	-	1.0	$\mu\text{A}$
Input Bias Current Factor ( $K_i$ ) ( $IN_{Adj} = INP \times K_i$ )	$V_{IN} = 0.336\text{ V}$ , $V_{DIAG} = \text{Low}$ $V_{IN} = 0.336\text{ V}$ , $V_{DIAG} = \text{High}$	- 152	100 155	- 157	%INP %INP
Bias Current Matching	INP1 or INP2 to $IN_{Adj}$ , $V_{IN} = 0.336\text{ V}$	-1.0	0	1.0	$\mu\text{A}$
Input Clamp – Negative	$I_{IN} = -50\text{ }\mu\text{A}$ $I_{IN} = -12\text{ mA}$	-0.5 -0.5	-0.25 -0.30	0 0	V V
Input Clamp – Positive	$I_{IN} = +12\text{ mA}$	5.0	7.0	9.8	V
Output Low Voltage	$I_{OUT} = 1.6\text{ mA}$	-	0.2	0.4	V
Output High Voltage	$I_{OUT} = -1.6\text{ mA}$	$V_{CC} - 0.5$	$V_{CC} - 0.2$	-	V
Mode Change Time Delay	-	0	-	20	$\mu\text{s}$
Input to Output Delay	$I_{OUT} = 1.0\text{ mA}$	-	1.0	20	$\mu\text{s}$
Output Rise Time	$C_{LOAD} = 30\text{ pF}$	-	0.5	2.0	$\mu\text{s}$
Output Fall Time	$C_{LOAD} = 30\text{ pF}$	-	0.05	2.0	$\mu\text{s}$
Open–Sensor Positive Threshold	$V_{DIAG} = \text{High}$ , $R_{IN(Adj)} = 40\text{ k}\Omega$ . Note 2	29.4	54	86.9	$\text{k}\Omega$
<b>Logic Inputs</b>					
DIAG Input Low Threshold	-	-	-	$0.2 \times V_{CC}$	V
DIAG Input High Threshold	-	$0.7 \times V_{CC}$	-	-	V
DIAG Input Resistance	$V_{IN} = 0.3 \times V_{CC}$ , $V_{CC} = 5.0\text{ V}$ $V_{IN} = V_{CC}$ , $V_{CC} = 5.0\text{ V}$	8.0 8.0	22 22	70 70	$\text{k}\Omega$ $\text{k}\Omega$

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

## NCV1124

### PACKAGE PIN DESCRIPTION

PIN # SO-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 <sup>†</sup>
NCV1124DG	SO-8 NB (Pb-Free)	98 Units / Rail
NCV1124DR2G	SO-8 NB (Pb-Free)	2500 Units / Tape & Reel

<sup>†</sup>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.

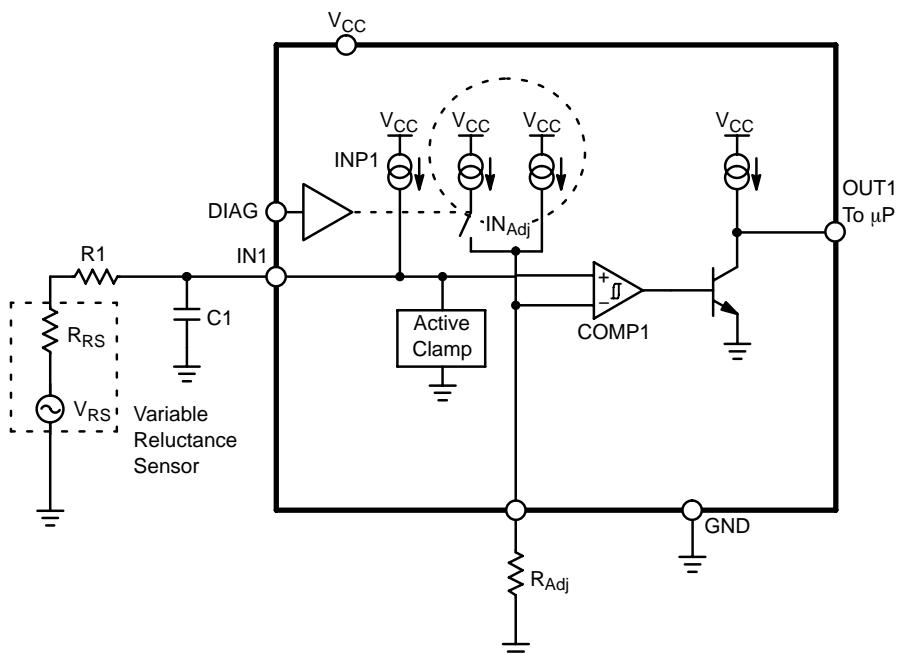


Figure 2. Application Diagram

## NCV1124

### THEORY OF OPERATION

#### NORMAL OPERATION

Figure 2 shows one channel of the NCV1124 along with the necessary external components. Both channels share the IN<sub>Adj</sub> pin as the negative input to a comparator. A brief description of the components is as follows:

**V<sub>RS</sub>** – Ideal sinusoidal, ground referenced, sensor output – amplitude usually increases with frequency, depending on loading.

**R<sub>RS</sub>** – Source impedance of sensor.

**R<sub>1</sub>/R<sub>Adj</sub>** – External resistors for current limiting and biasing.

**INP1/IN<sub>Adj</sub>** – Internal current sources that determine trip points via R<sub>1</sub>/R<sub>Adj</sub>.

**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<sub>RS</sub>.

By inspection, the voltage at the (+) and (–) terminals of COMP1 with V<sub>RS</sub> = 0V are:

$$V^+ = INP1(R1 + RRS) \quad (1)$$

$$V^- = INAdj \times RAdj \quad (2)$$

As V<sub>RS</sub> begins to rise and fall, it will be superimposed on the DC biased voltage at V<sup>+</sup>.

$$V^+ = INP1(R1 + RRS) + VRS \quad (3)$$

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

$$V^+ > V^- + VHYS \quad (4)$$

(V<sub>HYS</sub> is the built-in hysteresis set to 160 mV), or when crossing in the negative direction,

$$V^+ < V^- - VHYS \quad (5)$$

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

$$INP1(R1 + RRS) + VRS > INAdj \times RAdj + VHYS \quad (6)$$

therefore,

$$VRS(+TRP) < INAdj \times RAdj - INP1(R1 + RRS) + VHYS \quad (7)$$

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

$$VRS(-TRP) < INAdj \times RAdj - INP1(R1 + RRS) - VHYS \quad (8)$$

In normal mode,

$$INP1 = INAdj \quad (9)$$

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

$$VRS(+TRP) > INP1(RAdj - R1 - RRS) + VHYS \quad (10)$$

By making

$$RAdj = R1 + RRS \quad (11)$$

you can detect signals with as little amplitude as V<sub>HYS</sub>.

A design example is given in the applications section.

#### OPEN SENSOR PROTECTION

The NCV1124 has a DIAG pin that when pulled high (5.0 V), will increase the IN<sub>Adj</sub> current source by roughly 50%.

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

$$INP1(R1 + RRS) > INP1 \times K_I \times RAdj + VHYS \quad (12)$$

Since R<sub>RS</sub> is the only unknown variable we can solve for R<sub>RS</sub>,

$$RRS = \frac{INP1 \times K_I \times RAdj + VHYS}{INP1} - R1 \quad (13)$$

Equation (13) shows that if the output switches states when entering the diag mode with V<sub>RS</sub> = 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 R<sub>1</sub> = 20 k, then

$$VRS(MAX) = 20 k \times 12 mA = 240 V$$

Therefore, the V<sub>RS(pk-pk)</sub> voltage can be as high as 480 V.

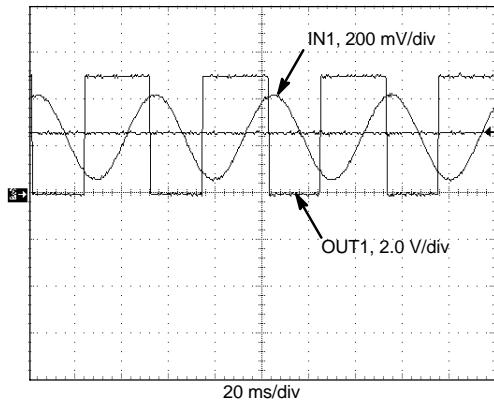
The NCV1124 will *typically* run at a frequency up to 1.8 MHz if the input signal does not activate the positive or negative input clamps. Frequency performance will be lower when the positive or negative clamps are active. *Typical* performance will be up to a frequency of 680 kHz with the clamps active.

## NCV1124

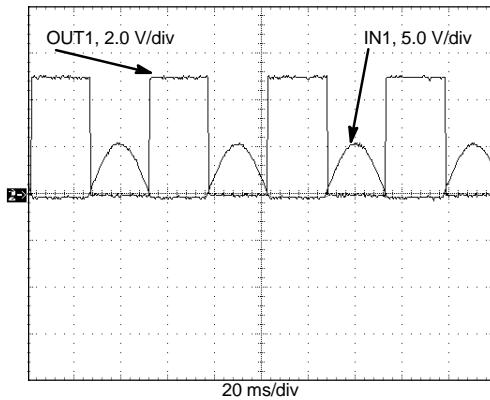
### CIRCUIT DESCRIPTION

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  $R1 = R2 = 22$  k) (reference the diagram page 1).

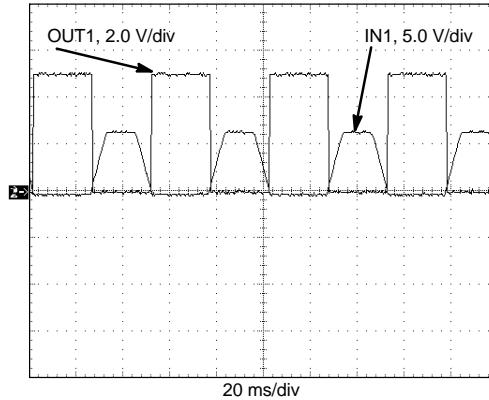
Figure 6 shows the effect using the diagnostic (DIAG) function has on the circuit. The input threshold (negative) is switched from a threshold of  $-160$  mV to  $+160$  mV when DIAG goes from a low to a high. There is no hysteresis when DIAG is high.



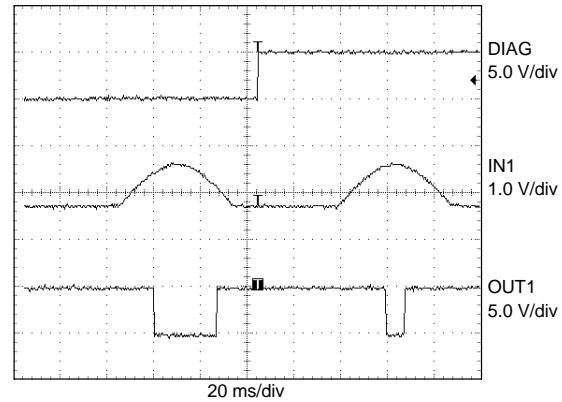
**Figure 3. Minimum Threshold Operation**



**Figure 4. Low-Side Clamp**



**Figure 5. Low- and High-Side Clamps**



**Figure 6. Diagnostic Operation**

## NCV1124

### APPLICATION INFORMATION

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

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

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

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

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

#### 1. Determine tradeoff between $R_1$ value and power rating. (use 1/2 watt package)

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

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 $R_{Adj}$

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

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

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

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

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

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

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

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

$$IN_{Adj} = 16 \mu\text{A}$$

$$INP1 = 15 \mu\text{A}$$

$$R1 = 14.25 \text{ k (5\% low)}$$

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

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

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  $40 \text{ V}_{pk-pk} @ 10 \text{ kHz}$ , a low pass filter using  $R1$  and  $C1$  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.

$$C1 \leq \frac{1}{2\pi f_C R1} \leq 0.07 \mu\text{F}$$

$$\text{Set } C1 = 0.047 \mu\text{F}.$$

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

Rearranging equation (7) gives

$$R_{RS} = \frac{\left[ V_{HYS} + [INP1 \times K_I \times R_{Adj}] \right] - V_{RS(+TRP)}}{INP1} - R1$$

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 ( $R_{RS}$ )
$IN_{Adj}$	$23.6 \mu\text{A} = 15 \mu\text{A} \times 1.57$	$10.7 \mu\text{A} = 7.0 \mu\text{A} \times 1.53$
$R_{Adj}$	$16.15 \text{ k}$	$17.85 \text{ k}$
$V_{HYS}$	$135 \text{ mV}$	$185 \text{ mV}$
$INP1$	$16 \mu\text{A}$	$6.0 \mu\text{A}$
$R1$	$15.75 \text{ k}$	$14.25 \text{ k}$
$K_I$	$1.57$	$1.53$

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

Therefore,

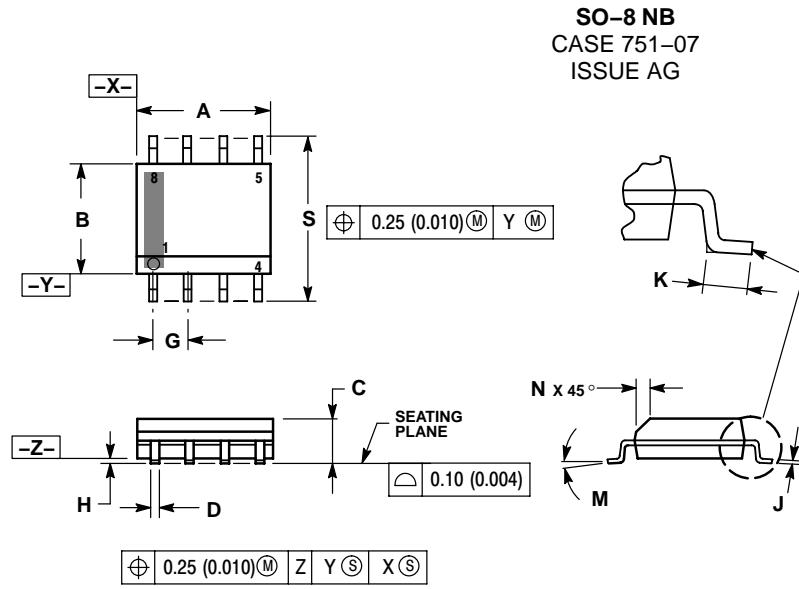
$$R_{RS(MIN)} = 16.5 \text{ k} \text{ (meets 12 k system spec)}$$

and,

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

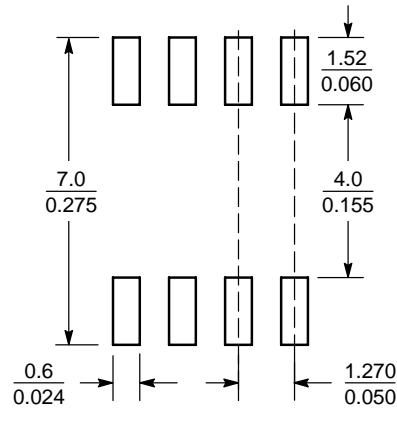
## NCV1124

### PACKAGE DIMENSIONS



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\*



SCALE 6:1 (mm  
inches)

\*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	SO-8NB	Unit
$R_{\theta JC}$	Typical	45
$R_{\theta JA}$	Typical	165

**NCV1124**

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