

# Low Noise, Low Power, 32 Taps

## X9316

### E<sup>2</sup>POT™ Nonvolatile Digital Potentiometer

#### FEATURES

- **Low Micropower CMOS**
  - $V_{CC} = 3V$  to  $5.5V$
  - **Active Current,  $50\mu A$  (Increment) Max**
  - **Standby Current,  $400\mu A$  (Store) Max**
- **Low Noise**
- **31 Resistive Elements**
  - **Temperature Compensated**
  - **$\pm 20\%$  End to End Resistance Range**
  - **$-5V$  to  $+5V$**
- **32 Wiper Tap Points**
  - **Wiper Positioned via Three-Wire Interface**
  - **Similar to TTL Up/Down Counter**
  - **Wiper Position Stored in Nonvolatile Memory and Recalled on Power-Up**
- **100 Year Wiper Position Data Retention**
- **X9316Z =  $1K\Omega$**
- **X9316W =  $10K\Omega$**
- **Packages**
  - **14-Lead PDIP**
  - **14-Lead SOIC**

#### DESCRIPTION

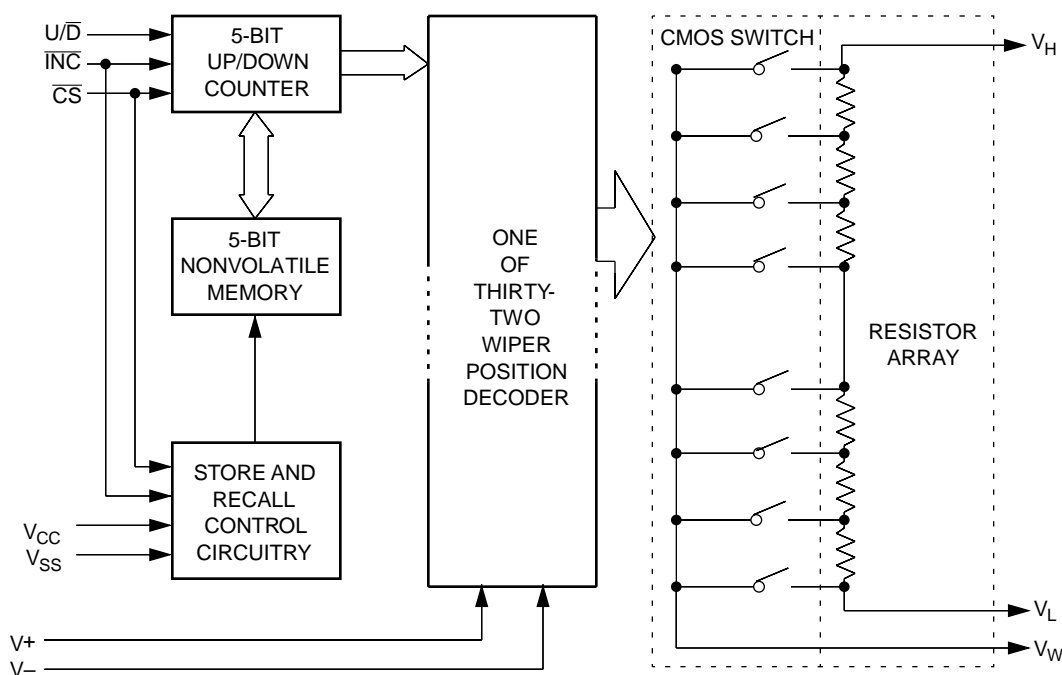
The Xicor X9316 is a solid state "micropower" nonvolatile potentiometer and is ideal for digitally controlled resistance trimming in battery-powered systems.

The X9316 is a resistor array composed of 31 resistive elements. Between each element and at either end are tap points accessible to the wiper element. The position of the wiper element is controlled by the  $\overline{CS}$ , U/D, and INC inputs. The position of the wiper can be stored in nonvolatile memory and then be recalled upon a subsequent power-up operation.

The resolution of the X9316 is equal to the maximum resistance value divided by 31. As an example, for the X9316W ( $10K\Omega$ ) each tap point represents  $323\Omega$ .

All Xicor nonvolatile memories are designed and tested for applications requiring extended endurance and data retention.

#### FUNCTIONAL DIAGRAM



7000 FRM F01

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# X9316

## PIN DESCRIPTIONS

### $V_H$ and $V_L$

The high ( $V_H$ ) and low ( $V_L$ ) terminals of the X9316 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is  $V_-$  and the maximum is  $V_+$ . It should be noted that the terminology of  $V_L$  and  $V_H$  references the relative position of the terminal in relation to wiper movement direction selected by the  $U/\bar{D}$  input and not the voltage potential on the terminal.

### $V_W$

$V_W$  is the wiper terminal, equivalent to the movable terminal of a mechanical potentiometer. The position of the wiper within the array is determined by the control inputs. The wiper terminal series resistance is typically 100 $\Omega$ .

### Up/Down ( $U/\bar{D}$ )

The  $U/\bar{D}$  input controls the direction of the wiper movement and whether the counter is incremented or decremented.

### Increment ( $\bar{INC}$ )

The  $\bar{INC}$  input is negative-edge triggered. Toggling  $\bar{INC}$  will move the wiper and either increment or decrement the counter in the direction indicated by the logic level on the  $U/\bar{D}$  input.

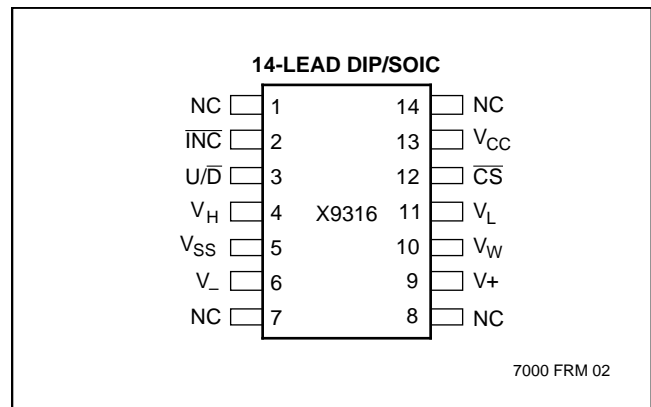
### Chip Select ( $\bar{CS}$ )

The device is selected when the  $\bar{CS}$  input is LOW. The current counter value is stored in nonvolatile memory when  $\bar{CS}$  is returned HIGH while the  $\bar{INC}$  input is also HIGH. After the store operation is complete, the X9316 will be placed in the low power standby mode until the device is selected once again.

### $V_+$ , $V_-$ (Analog positive/negative power supply)

The  $V_+$  and  $V_-$  pins supply an external voltage to the wiper position decoder.

## PIN CONFIGURATION



## PIN NAMES

| Symbol      | Description             |
|-------------|-------------------------|
| $V_H$       | High Terminal           |
| $V_W$       | Wiper Terminal          |
| $V_L$       | Low Terminal            |
| $V_{SS}$    | Ground                  |
| $V_{CC}$    | Supply Voltage          |
| $U/\bar{D}$ | Up/Down Input           |
| $\bar{INC}$ | Increment Input         |
| $\bar{CS}$  | Chip Select Input       |
| $V_+$       | Positive Analog Voltage |
| $V_-$       | Negative Analog Voltage |

7000 FRM T01.1

# X9316

## DEVICE OPERATION

There are three sections of the X9316: the input control, counter and decode section; the nonvolatile memory; and the resistor array. The input control section operates just like an up/down counter. The output of this counter is decoded to turn on a single electronic switch connecting a point on the resistor array to the wiper output. Under the proper conditions the contents of the counter can be stored in nonvolatile memory and retained for future use. The resistor array is comprised of 31 individual resistors connected in series. At either end of the array and between each resistor is an electronic switch that transfers the potential at that point to the wiper.

The  $\overline{INC}$ ,  $U/\overline{D}$  and  $\overline{CS}$  inputs control the movement of the wiper along the resistor array. With  $\overline{CS}$  set LOW the X9316 is selected and enabled to respond to the  $U/\overline{D}$  and  $\overline{INC}$  inputs. HIGH to LOW transitions on  $\overline{INC}$  will increment or decrement (depending on the state of the  $U/\overline{D}$  input) a seven bit counter. The output of this counter is decoded to select one of thirty two wiper positions along the resistive array.

The wiper, when at either fixed terminal, acts like its mechanical equivalent and does not move beyond the last position. That is, the counter does not wrap around when clocked to either extreme.

The value of the counter is stored in nonvolatile memory whenever  $\overline{CS}$  transitions HIGH while the  $\overline{INC}$  input is also HIGH.

When the X9316 is powered-down, the last counter position stored will be maintained in the nonvolatile memory. When power is restored, the contents of the memory are recalled and the counter is reset to the value last stored.

## Operation Notes

The system may select the X9316, move the wiper and deselect the device without having to store the latest wiper position in nonvolatile memory. The wiper movement is performed as described above; once the new position is reached, the system would keep  $\overline{INC}$  LOW while taking  $\overline{CS}$  HIGH. The new wiper position would be maintained until changed by the system or until a power-up/down cycle recalled the previously stored data.

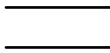


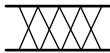

This would allow the system to always power-up to a pre-set value stored in nonvolatile memory; then during system operation minor adjustments could be made. The adjustments might be based on user preference, system parameter changes due to temperature drift, etc...

The state of  $U/\overline{D}$  may be changed while  $\overline{CS}$  remains LOW. This allows the host system to enable the X9316 and then move the wiper up and down until the proper trim is attained.

## $T_{IW}/R_{TOTAL}$

The electronic switches on the X9316 operate in a "make before break" mode when the wiper changes tap positions. If the wiper is moved several positions multiple taps are connected to the wiper for  $t_{IW}$  ( $\overline{INC}$  to  $V_W$  change). The  $R_{TOTAL}$  value for the device can temporarily be reduced by a significant amount if the wiper is moved several positions.

## SYMBOL TABLE

| WAVEFORM   | INPUTS                      | OUTPUTS                       |
|--|-----------------------------|-------------------------------|
|  | Must be steady              | Will be steady                |
|  | May change from Low to High | Will change from Low to High  |
|  | May change from High to Low | Will change from High to Low  |
|  | Don't Care: Changes Allowed | Changing: State Not Known     |
|  | N/A                         | Center Line is High Impedance |

# X9316

## ABSOLUTE MAXIMUM RATINGS\*

Temperature under Bias ..... -65°C to +135°C  
 Storage Temperature ..... -65°C to +150°C  
 Voltage on  $\overline{CS}$ ,  $\overline{INC}$ ,  $U/\overline{D}$  and  $V_{CC}$   
 with Respect to  $V_{SS}$  ..... -1V to +7V  
 Voltage on  $V_H$  and  $V_L$  Referenced to  $V_{SS}$   
 $\Delta V = |V_H - V_L|$   
 X9316Z ..... 4V  
 X9316W ..... 10V  
 Lead Temperature (Soldering 10 seconds) ..... 300°C  
 Wiper Current .....  $\pm 1$  mA

## ANALOG CHARACTERISTICS

### Electrical Characteristics

End-to-End Resistance Tolerance .....  $\pm 20\%$   
 Power Rating at 25°C  
 X9316Z ..... 16mW  
 X9316W ..... 10mW  
 Wiper Current .....  $\pm 1$  mA Max.  
 Typical Wiper Resistance ..... 100 $\Omega$  at 1mA  
 Typical Noise .....  $< -140$  dB $\sqrt{\text{Hz}}$  Ref: 1V

### Resolution

Resistance ..... 3%

### Linearity

Absolute Linearity<sup>(1)</sup> .....  $\pm 1.0$  MI<sup>(2)</sup>  
 Relative Linearity<sup>(3)</sup> .....  $\pm 0.2$  MI<sup>(2)</sup>

## \*COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and the functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### Temperature Coefficient

(-40°C to +85°C) ..... +300 ppm/°C Typical  
 Ratiometric Temperature Coefficient .....  $\pm 20$  ppm

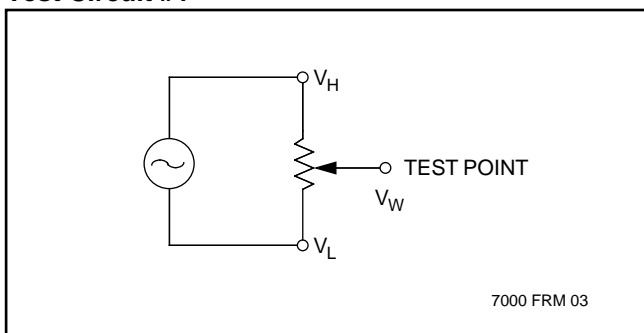
### Wiper Adjustability

Unlimited Wiper Adjustment (Non-Store operation)  
 Wiper Position Store Operations ..... 100,000

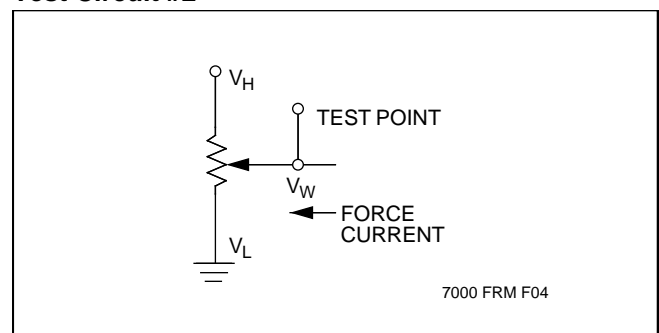
### Physical Characteristics

Marking Includes  
 Manufacturer's Trademark  
 Resistance Value or Code  
 Date Code

Test Circuit #1



Test Circuit #2



- Notes:** (1) Absolute Linearity is utilized to determine actual wiper voltage versus expected voltage  
 $= (V_{w(n)}(\text{actual}) - V_{w(n)}(\text{expected})) = \pm 1$  MI Maximum.  
 (2) 1 MI = Minimum Increment =  $R_{TOT}/31$ .  
 (3) Relative Linearity is a measure of the error in step size between taps =  $V_{w(n+1)} - [V_{w(n)} + \text{MI}] = +0.2$  MI.

# X9316

## RECOMMENDED OPERATING CONDITIONS

| Temperature | Min.  | Max.  |
|-------------|-------|-------|
| Commercial  | 0°C   | +70°C |
| Industrial  | -40°C | +85°C |

7000 FRM T02

| Supply Voltage | Limits  |
|----------------|---------|
| X9316          | 5V ±10% |

7000 FRM T03.1

## D.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified.)

| Symbol                         | Parameter   | Limits           |         |                     | Units | Test Conditions   |
|--------------------------------|---|------------------|---------|---------------------|-------|---|
|                                |   | Min.             | Typ.(4) | Max.                |       |   |
| I <sub>CC</sub>                | V <sub>CC</sub> Active Current (Increment)                                  |                  |         | 50                  | μA    | $\overline{CS} = V_{IL}$ , $U/\overline{D} = V_{IL}$ or $V_{IH}$ and $\overline{INC} = 0.4V/2.4V$ @ max. t <sub>CYC</sub> |
|                                | V <sub>CC</sub> Active Current (Store)                                      |                  |         | 400                 | μA    |   |
| I <sub>SB</sub>                | Standby Supply Current  |                  |         | 1                   | μA    | $\overline{CS} = V_{CC} - 0.3V$ , $U/\overline{D}$ and $\overline{INC} = V_{SS}$ or $V_{CC} - 0.3V$                       |
| I <sub>V+</sub> <sup>(5)</sup> | V+ Supply Current   |                  |         | 400                 | μA    | $\overline{CS} = V_{IL}$ , $U/\overline{D} = V_{IL}$ or $V_{IH}$ and $\overline{INC} = 0.4V/2.4V$ @ max. t <sub>CYC</sub> |
| I <sub>V-</sub> <sup>(5)</sup> | V- Supply Current   |                  |         | 400                 | μA    | $\overline{CS} = V_{IL}$ , $U/\overline{D} = V_{IL}$ or $V_{IH}$ and $\overline{INC} = 0.4V/2.4V$ @ max. t <sub>CYC</sub> |
| I <sub>LI</sub>                | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ Input Leakage Current |                  |         | ±10                 | μA    | V <sub>IN</sub> = V <sub>SS</sub> to V <sub>CC</sub>  |
| V <sub>IH</sub>                | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ Input HIGH Voltage    | 2                |         | V <sub>CC</sub> + 1 | V     |   |
| V <sub>IL</sub>                | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ Input LOW Voltage     | -1               |         | 0.8                 | V     |   |
| R <sub>W</sub>                 | Wiper Resistance  |                  | 100     | 200                 | Ω     | Max. Wiper Current ±1mA   |
| V <sub>VH</sub>                | VH Terminal Voltage   | V <sub>-</sub>   |         | V <sub>+</sub>      | V     |   |
| V <sub>VL</sub>                | VL Terminal Voltage   | V <sub>-</sub>   |         | V <sub>+</sub>      | V     |   |
| V+                             | Analog Positive Power Supply  | V <sub>CC</sub>  |         | V <sub>CC</sub>     | V     |   |
| V-                             | Analog Negative Power Supply  | -V <sub>CC</sub> |         | 0                   | V     |   |
| C <sub>IN</sub> <sup>(5)</sup> | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ Input Capacitance     |                  |         | 10                  | pF    | V <sub>CC</sub> = 5V, V <sub>IN</sub> = V <sub>SS</sub> , T <sub>A</sub> = 25°C   |

7000 FRM T04.1

## STANDARD PARTS

| Part Number | Maximum Resistance | Wiper Increments | Minimum Resistance |
|-------------|--------------------|------------------|--------------------|
| X9316Z      | 1KΩ                | 32.3Ω            | 100Ω               |
| X9316W      | 10KΩ               | 323Ω             | 100Ω               |

7000 FRM T05

**Notes:** (4) Typical values are for T<sub>A</sub> = 25°C and nominal supply voltage.

(5) This parameter is periodically sampled and not 100% tested.

# X9316

## A.C. CONDITIONS OF TEST

|                           |          |
|---------------------------|----------|
| Input Pulse Levels        | 0V to 3V |
| Input Rise and Fall Times | 10ns     |
| Input Reference Levels    | 1.5V     |

7000 FRM T06

## MODE SELECTION

| $\overline{CS}$ | $\overline{INC}$ | $U/\overline{D}$ | Mode                        |
|-----------------|------------------|------------------|-----------------------------|
| L               |                  | H                | Wiper Up                    |
| L               |                  | L                | Wiper Down                  |
|                 | H                | X                | Store Wiper Position        |
| H               | X                | X                | Standby                     |
|                 | L                | X                | No Store, Return to Standby |

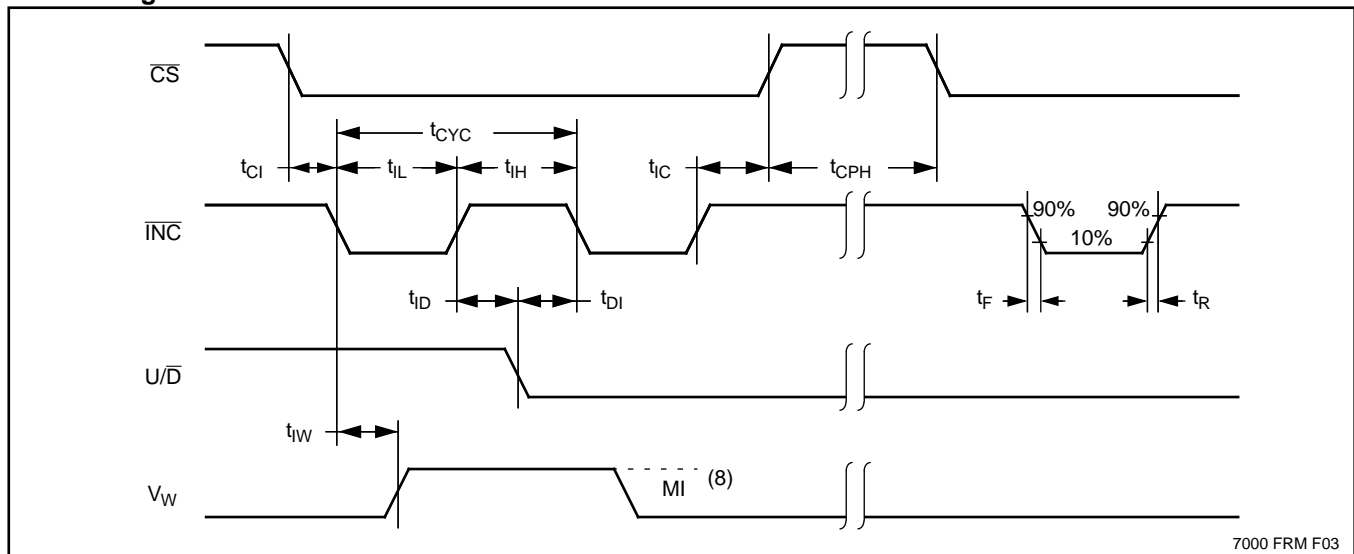
7000 FRM T07

## A.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

| Symbol             | Parameter  | Limits |         |      | Units       |
|--------------------|--|--------|---------|------|-------------|
|                    |  | Min.   | Typ.(6) | Max. |             |
| $t_{CI}$           | $\overline{CS}$ to $\overline{INC}$ Setup                | 100    |         |      | ns          |
| $t_{ID}$           | $\overline{INC}$ HIGH to $U/\overline{D}$ Change         | 100    |         |      | ns          |
| $t_{DI}$           | $U/\overline{D}$ to $\overline{INC}$ Setup               | 2.9    |         |      | $\mu$ s     |
| $t_{IL}$           | $\overline{INC}$ LOW Period                              | 1      |         |      | $\mu$ s     |
| $t_{IH}$           | $\overline{INC}$ HIGH Period                             | 1      |         |      | $\mu$ s     |
| $t_{IC}$           | $\overline{INC}$ Inactive to $\overline{CS}$ Inactive    | 1      |         |      | $\mu$ s     |
| $t_{CPH1}$         | $\overline{CS}$ Deselect Time (STORE)                    | 10     |         |      | ms          |
| $t_{CPH2}$         | $\overline{CS}$ Deselect Time (NO STORE)                 | 100    |         |      | ns          |
| $t_{IW}$           | $\overline{INC}$ to $V_W$ Change                         |        | 1       | 5    | $\mu$ s     |
| $t_{CYC}$          | $\overline{INC}$ Cycle Time                              | 4      |         |      | $\mu$ s     |
| $t_R, t_F^{(7)}$   | $\overline{CS}, \overline{INC}$ Input Rise and Fall Time |        |         | 500  | $\mu$ s     |
| $t_{PU}^{(7)}$     | Power up to Wiper Stable                                 |        |         | 5    | $\mu$ s     |
| $t_R V_{CC}^{(7)}$ | $V_{CC}$ Power-up Rate                                   | 0.2    |         | 50   | mV/ $\mu$ s |
| $t_{WR}$           | Store Cycle  |        | 5       | 10   | ms          |

7000 FRM T08.1

## A.C. Timing



7000 FRM F03

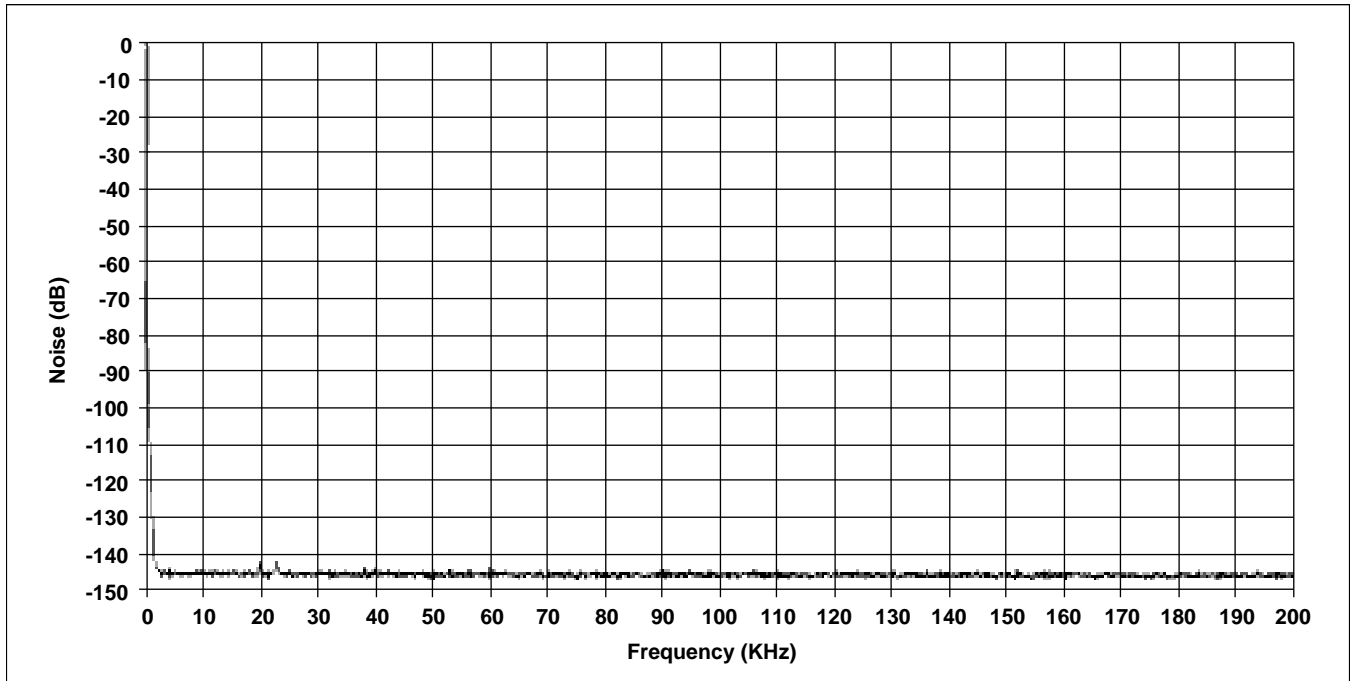
**Notes:** (6) Typical values are for  $T_A = 25^\circ\text{C}$  and nominal supply voltage.

(7) This parameter is periodically sampled and not 100% tested.

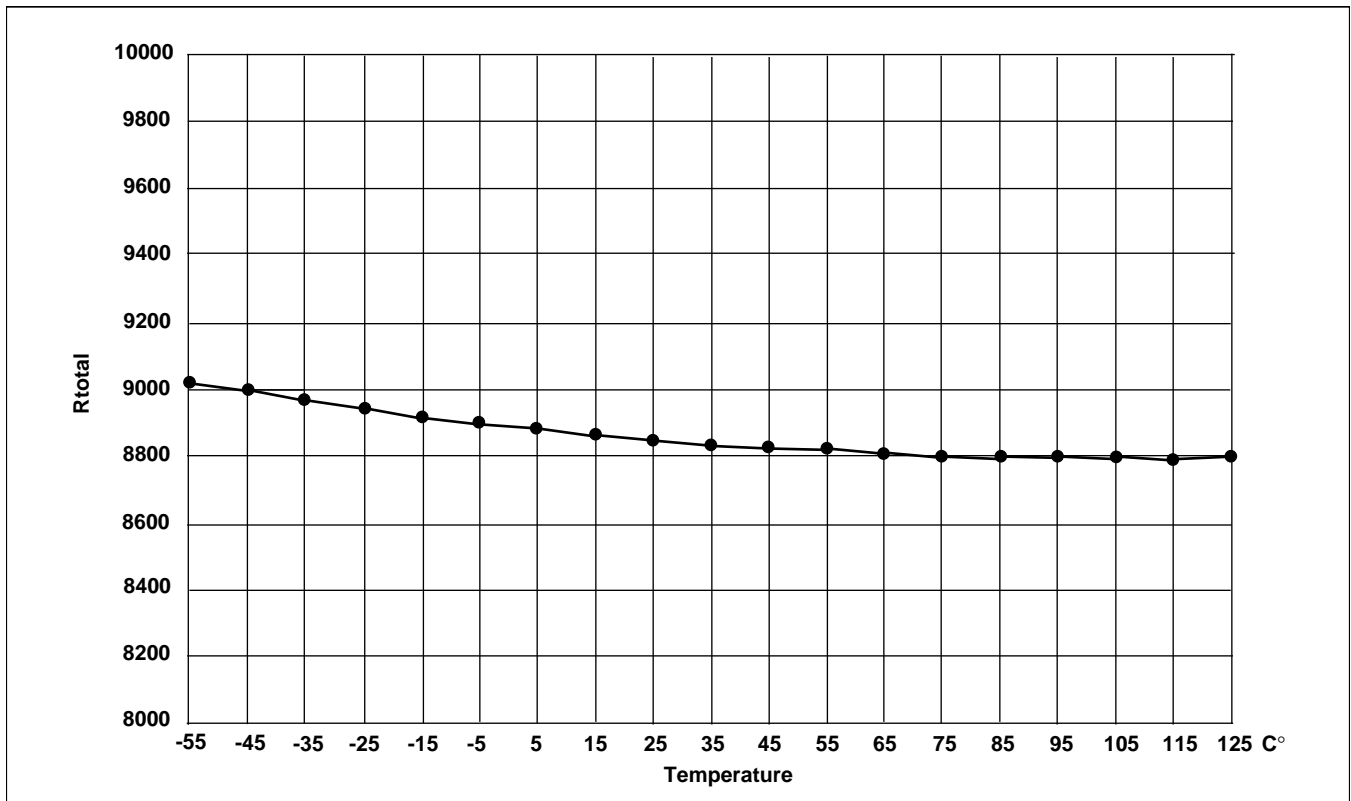
(8) MI in the A.C. timing diagram refers to the minimum incremental change in the  $V_W$  output due to a change in the wiper position.

# X9316

## TYPICAL NOISE

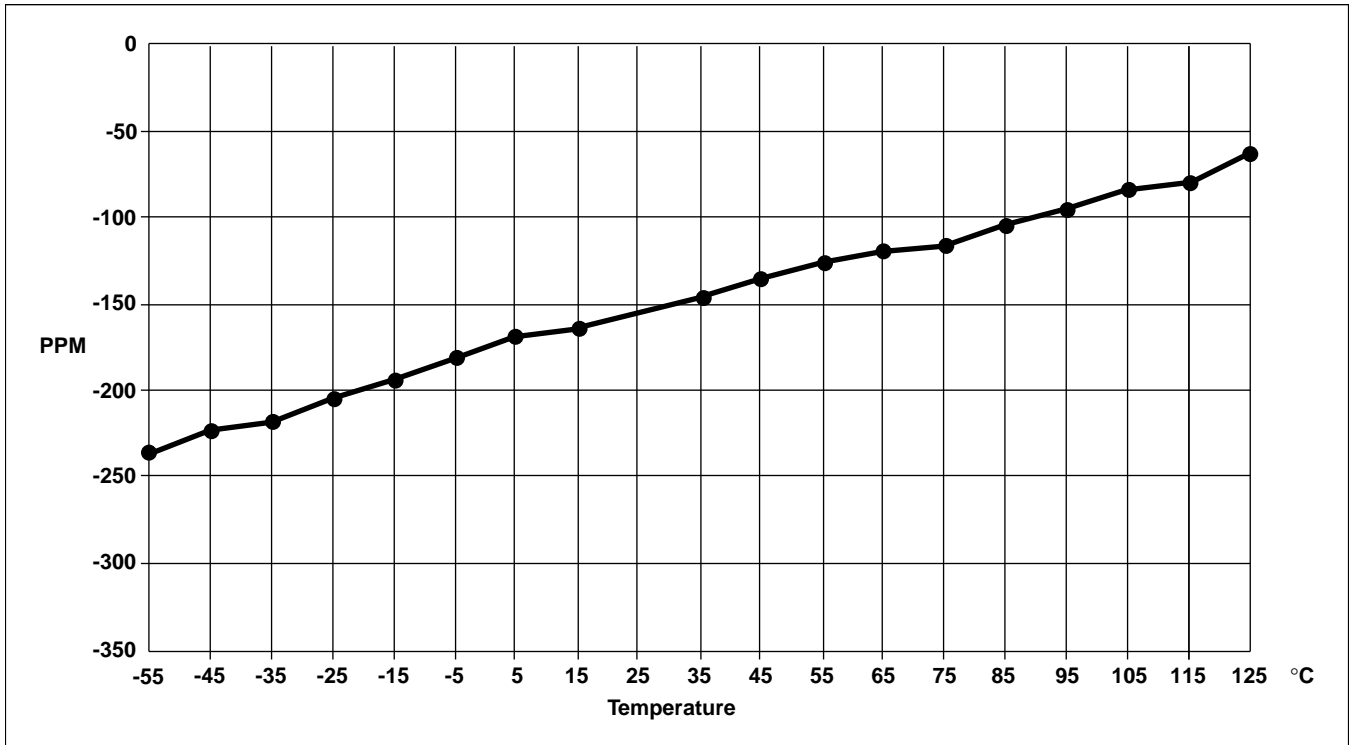


## TYPICAL RTOTAL vs. TEMPERATURE

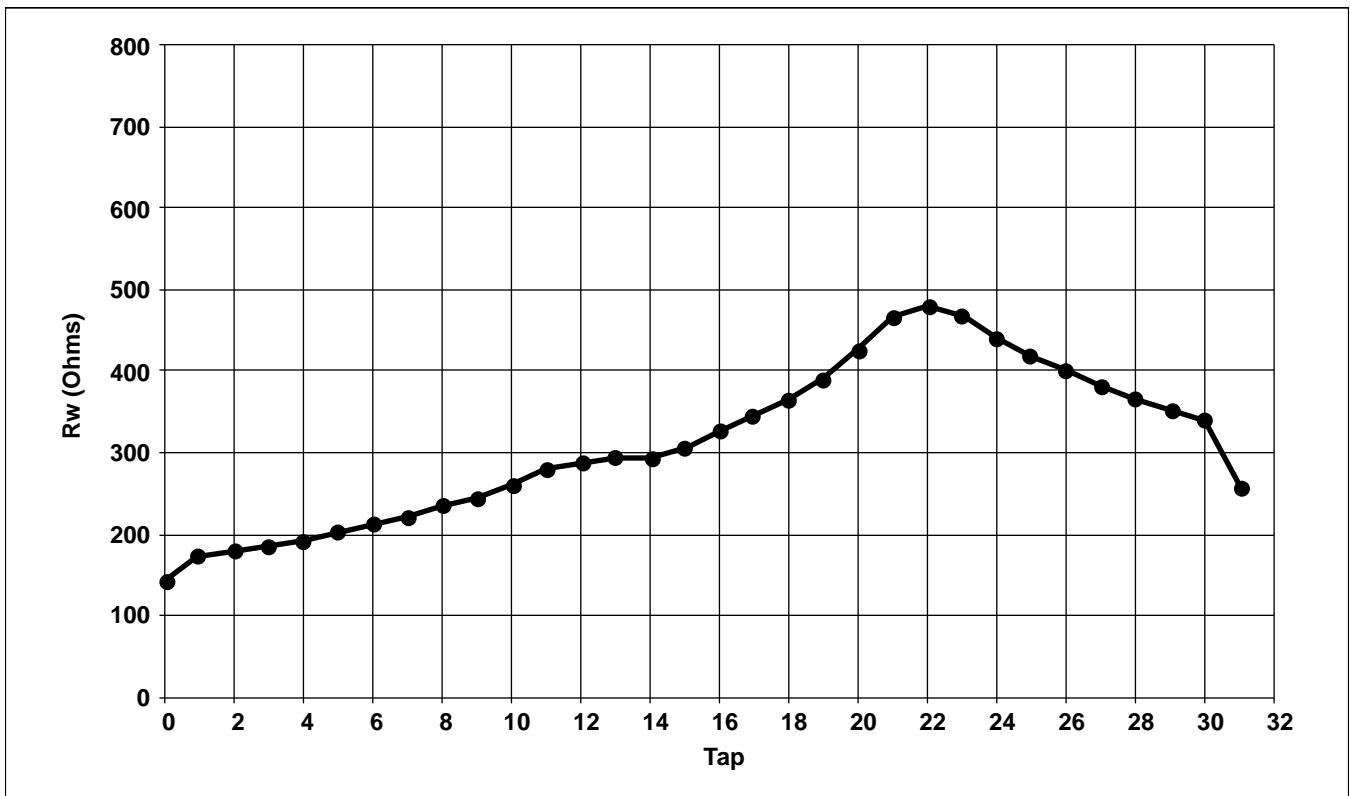


# X9316

## TYPICAL TOTAL RESISTANCE TEMPERATURE COEFFICIENT

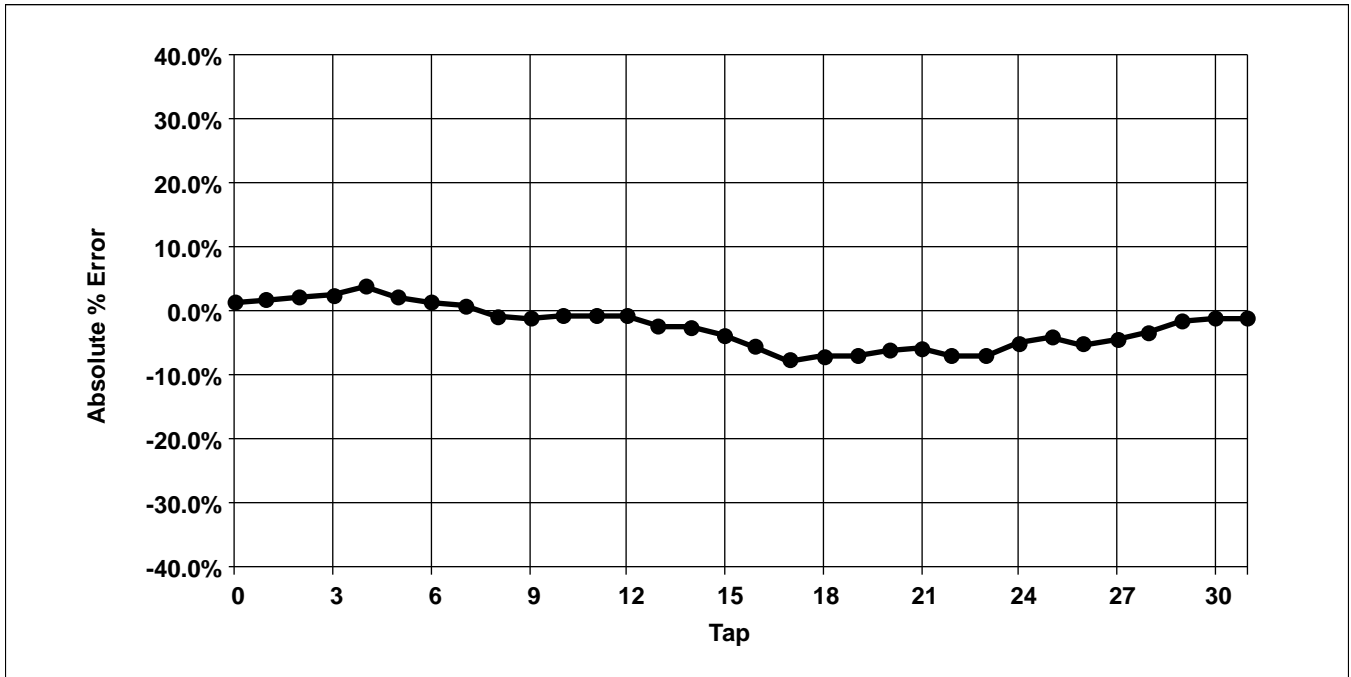


## TYPICAL WIPER RESISTANCE

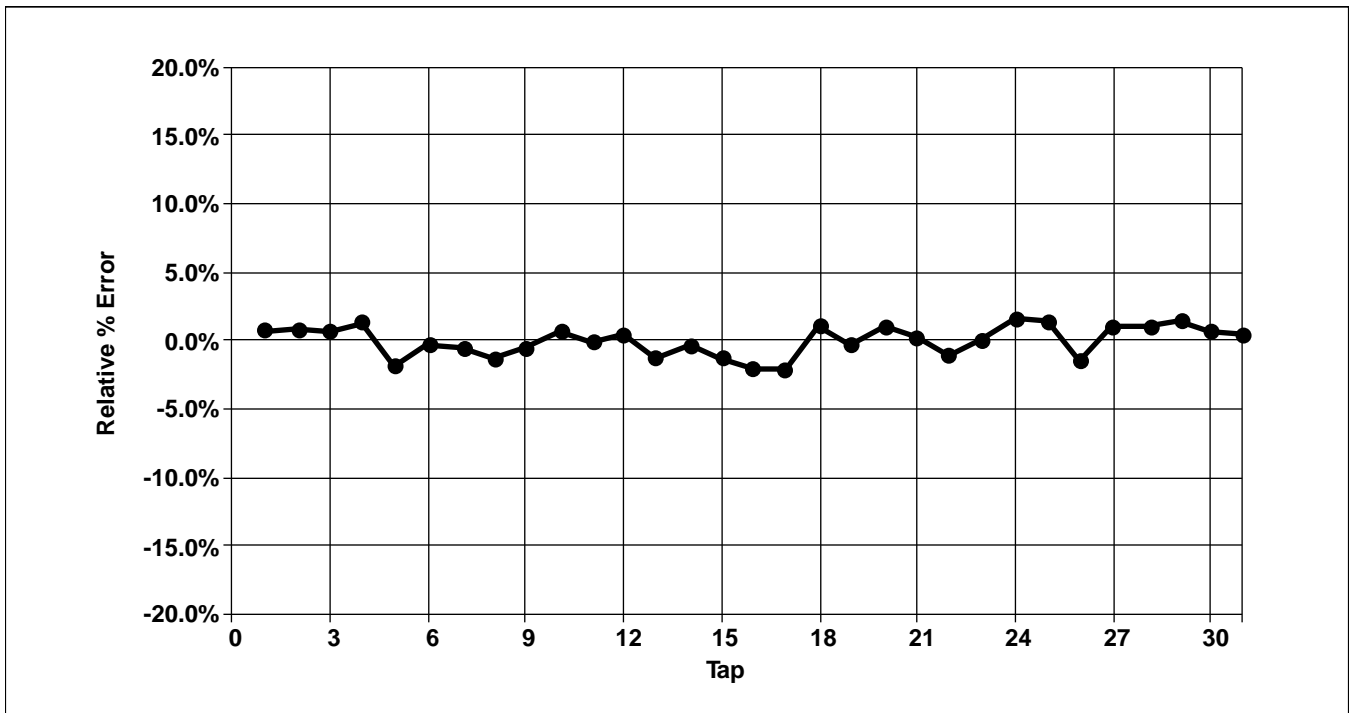




TYPICAL ABSOLUTE % ERROR PER TAP POSITION

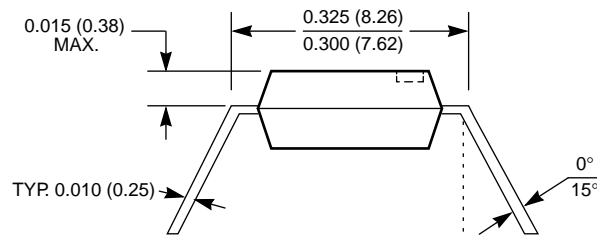
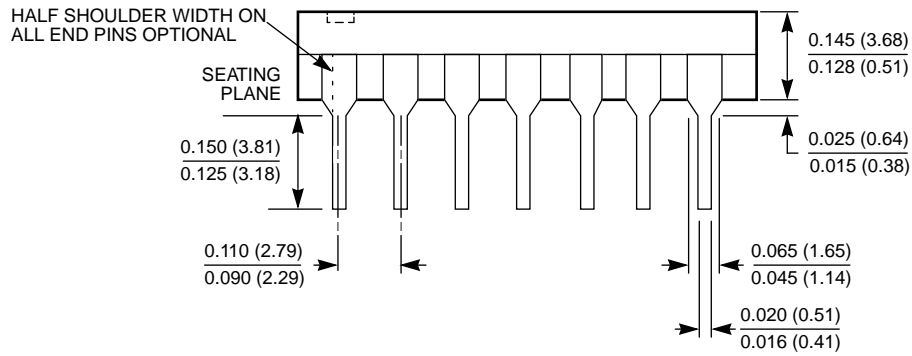
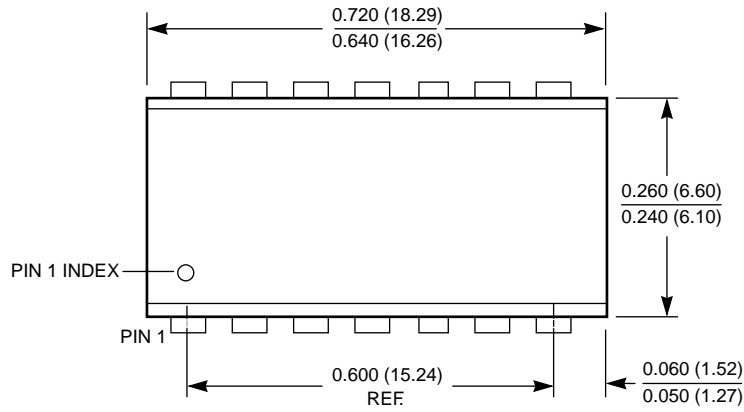


TYPICAL RELATIVE % ERROR PER TAP POSITION



**PACKAGING INFORMATION**

**14-LEAD PLASTIC DUAL IN-LINE PACKAGE TYPE P**



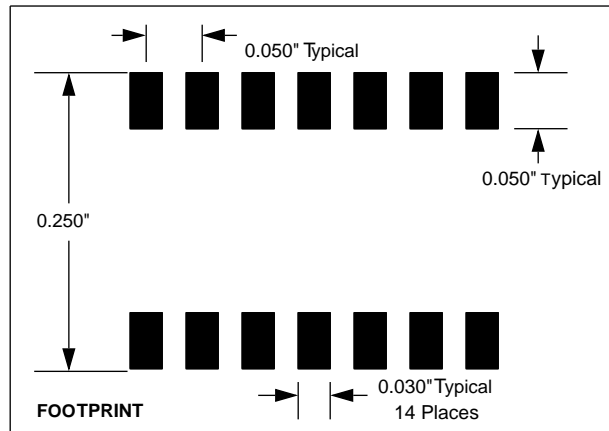
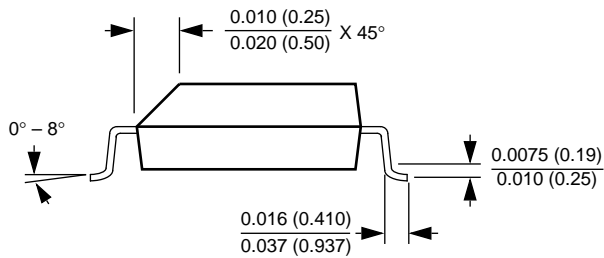
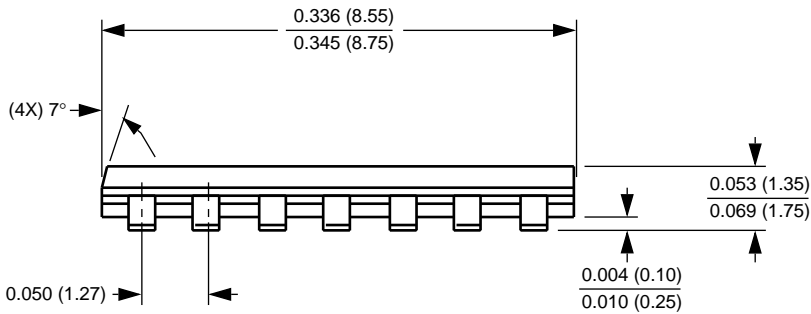
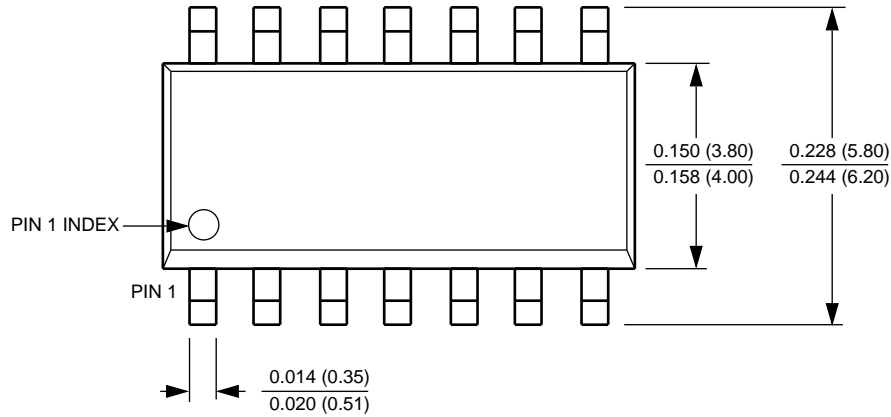
**NOTE:**

- 1. ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)**
- 2. PACKAGE DIMENSIONS EXCLUDE MOLDING FLASH**

3926 FHD F46

PACKAGING INFORMATION

14-LEAD PLASTIC SMALL OUTLINE GULL WING PACKAGE TYPE S



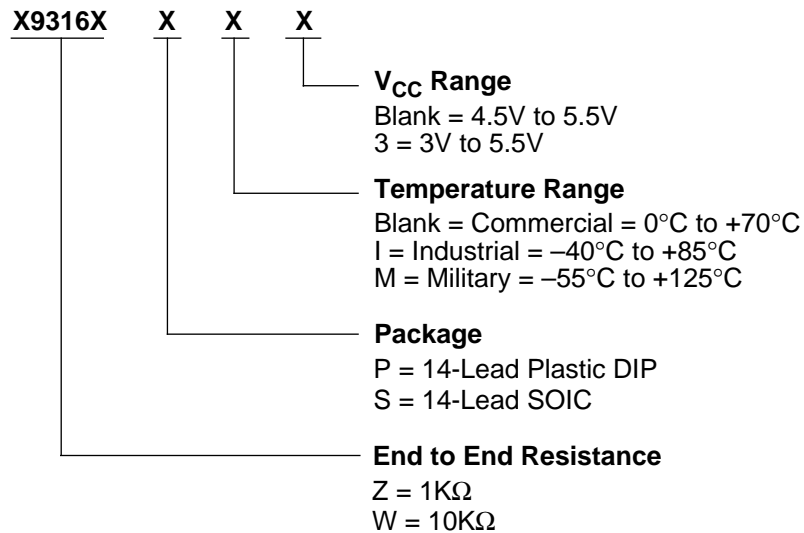
NOTE: ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)

7000 FRM 05

# X9316

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## ORDERING INFORMATION



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### LIMITED WARRANTY

Devices sold by Xicor, Inc. are covered by the warranty and patent indemnification provisions appearing in its Terms of Sale only. Xicor, Inc. makes no warranty, express, statutory, implied, or by description regarding the information set forth herein or regarding the freedom of the described devices from patent infringement. Xicor, Inc. makes no warranty of merchantability or fitness for any purpose. Xicor, Inc. reserves the right to discontinue production and change specifications and prices at any time and without notice.

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### U.S. PATENTS

Xicor products are covered by one or more of the following U.S. Patents: 4,263,664; 4,274,012; 4,300,212; 4,314,265; 4,326,134; 4,393,481; 4,404,475; 4,450,402; 4,486,769; 4,488,060; 4,520,461; 4,533,846; 4,599,706; 4,617,652; 4,668,932; 4,752,912; 4,829, 482; 4,874, 967; 4,883, 976. Foreign patents and additional patents pending.

### LIFE RELATED POLICY

In situations where semiconductor component failure may endanger life, system designers using this product should design the system with appropriate error detection and correction, redundancy and back-up features to prevent such an occurrence.

Xicor's products are not authorized for use in critical components in life support devices or systems.

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.