

X9116

Low Noise, Low Power, Low Cost Digitally Controlled Potentiometer (XDCP™)

FN8160  
Rev 3.00  
February 3, 2011

The Intersil X9116 is a digitally controlled nonvolatile potentiometer designed to be used in trimmer applications. The pot consists of 15 equal resistor segments that connect to the wiper pin through programmable CMOS switches. The tap position is programmed through a 3-wire up/down serial port. The last position of the wiper is stored in a nonvolatile memory location which is recalled at the time of power up of the device.

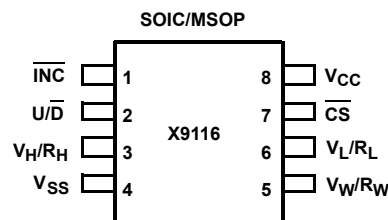
The wiper moves through sequential tap positions with inputs on the serial port. A falling edge on INC (bar) causes the tap position to increment one position up or down based on whether the U/D (bar) pin is held high or low.

The X9116 can be used in many applications requiring a variable resistance. In many cases it can replace a mechanical trimmer and offers many advantages such as temperature and time stability as well as the reliability of a solid state solution.

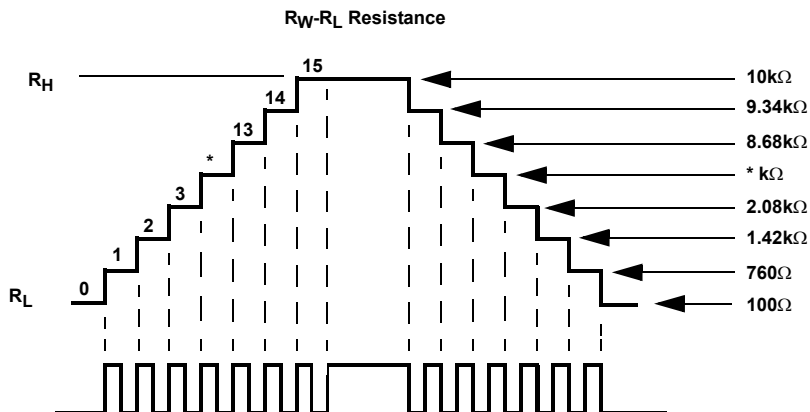
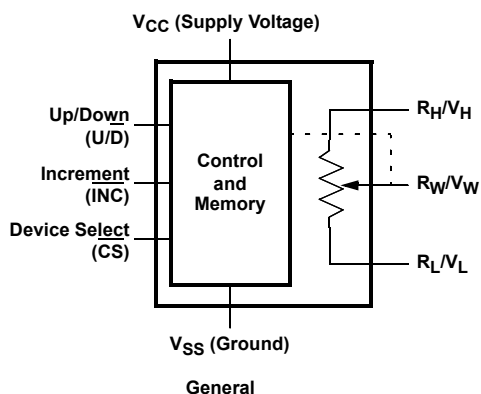
**Features**

- Solid-state nonvolatile
- 16 wiper taps
- 3-wire up/down serial interface
- $V_{CC} = 2.7V$  and  $5V$
- Active current  $< 50\mu A$  max.
- Standby current  $< 5\mu A$  max.
- $R_{TOTAL} = 10k\Omega$
- Packages: 8 Ld MSOP, 8 Ld SOIC
- Pb-free plus anneal available (RoHS compliant)

**Pinout**



**Block Diagram**



## Ordering Information

| PART NUMBER<br>(BRAND) (Notes 1, 2, 3) | PART MARKING | V <sub>CC</sub> LIMITS<br>(V) | R <sub>TOTAL</sub><br>(kΩ) | TEMP. RANGE<br>(°C) | PACKAGE<br>(Pb-free) | PKG.<br>DWG. # |
|--|--------------|-------------------------------|----------------------------|---------------------|----------------------|----------------|
| X9116WM8Z                              | AKY          | 5V ±10%                       | 10                         | 0 to +70            | 8 Ld MSOP            | M8.118         |
| X9116WM8IZ                             | DCG          |                               |                            | -40 to +85          | 8 Ld MSOP            | M8.118         |
| X9116WS8Z                              | X9116W Z     |                               |                            | 0 to +70            | 8 Ld SOIC            | M8.15          |
| X9116WS8IZ                             | X9116W ZI    |                               |                            | -40 to +85          | 8 Ld SOIC            | M8.15          |
| X9116WM8Z-2.7                          | AOJ          | 2.7-5.5                       |                            | 0 to +70            | 8 Ld MSOP            | M8.118         |
| X9116WM8IZ-2.7                         | AKS          |                               |                            | -40 to +85          | 8 Ld MSOP            | M8.118         |
| X9116WS8Z-2.7                          | X9116W ZF    |                               |                            | 0 to +70            | 8 Ld SOIC            | M8.15          |
| X9116WS8IZ-2.7                         | X9116W G     |                               |                            | -40 to +85          | 8 Ld SOIC            | M8.15          |

### NOTES:

1. Add "T\*" suffix for tape and reel. Please refer to [TB347](#) for details on reel specifications.
2. These Intersil Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
3. For Moisture Sensitivity Level (MSL), please see device information page for [X9116](#). For more information on MSL please see techbrief [TB363](#).

## Pin Descriptions

### V<sub>H</sub>/R<sub>H</sub> and V<sub>L</sub>/R<sub>L</sub>

The high (V<sub>H</sub>/R<sub>H</sub>) and low (V<sub>L</sub>/R<sub>L</sub>) terminals of the X9116 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V<sub>SS</sub> and the maximum is V<sub>CC</sub>.

### V<sub>W</sub>/R<sub>W</sub>

R<sub>W</sub>/R<sub>W</sub> is the wiper terminal and is 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 200Ω to 400Ω depending upon V<sub>CC</sub>.

### Up/Down (U/D)

The U/D input controls the direction of the wiper movement and whether the counter is incremented (up) or decremented (down).

### Increment (INC)

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

### Chip Select (CS)

The device is selected when the CS input is LOW. The current counter value is stored in nonvolatile memory when CS is returned HIGH while the INC input is also HIGH. After the store operation is complete the X9116 will be placed in the low power standby mode until the device is selected once again.

## Pin Descriptions

| SYMBOL                         | DESCRIPTION             |
|--------------------------------|-------------------------|
| V <sub>W</sub> /R <sub>W</sub> | Wiper Terminal          |
| V <sub>L</sub> /R <sub>L</sub> | Low Terminal            |
| V <sub>SS</sub>                | Ground                  |
| V <sub>CC</sub>                | Supply Voltage          |
| U/D                            | Up/Down Control Input   |
| INC                            | Increment Control Input |
| CS                             | Chip Select Input       |

## Pin Descriptions

| SYMBOL                         | DESCRIPTION   |
|--------------------------------|---------------|
| V <sub>H</sub> /R <sub>H</sub> | High Terminal |

### Principles of Operation

There are three sections of the X9116: 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 15 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 pin.

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 electronic switches on the device 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  $t_{1W}$  (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.

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

### Instructions and Programming

The  $\overline{INC}$ ,  $\overline{U/D}$  and  $\overline{CS}$  inputs control the movement of the wiper along the resistor array. With  $\overline{CS}$  set LOW, the device is selected and enabled to respond to the  $\overline{U/D}$  and  $\overline{INC}$  inputs. HIGH to LOW transitions on  $\overline{INC}$  will increment or decrement (depending on the state of the  $\overline{U/D}$  input) a four bit counter. The output of this counter is decoded to select one of 16 wiper positions along the resistive array.

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

The system may select the X9116, move the wiper, and deselect the device without having to store the latest wiper position in nonvolatile memory. After the wiper movement is performed as described above and once the new position is reached, the system must keep  $\overline{INC}$  LOW while taking  $\overline{CS}$  HIGH. The new wiper position will be maintained until changed by the system or until a power-up/down cycle recalls the previously stored data.

This procedure allows the system to always power-up to a preset 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  $\overline{U/D}$  may be changed while  $\overline{CS}$  remains LOW. This allows the host system to enable the device and then move the wiper up and down until the proper trim is attained.

### Mode Selection

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

### 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 |

**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/D, $V_H/R_H$ , $V_L/R_L$<br>and $V_{CC}$ with Respect to $V_{SS}$ | -1V to +7V  |
| $\Delta V =  V_H/R_H - V_L/R_L $  | 5.5V  |
| Pb-Free Reflow Profile  | see link below<br><a href="http://www.intersil.com/pbfree/Pb-FreeReflow.asp">http://www.intersil.com/pbfree/Pb-FreeReflow.asp</a> |
| $I_W$ (10 seconds)  | $\pm 10.0$ mA   |

**Recommended Operating Conditions**

|                                    |            |                |
|------------------------------------|------------|----------------|
| Temperature Range                  | Commercial | 0°C to +70°C   |
|                                    | Industrial | -40°C to +85°C |
| Supply Voltage ( $V_{CC}$ ) Limits | X9116      | 5V $\pm$ 10%   |
|                                    | X9116-2.7  | 2.7V to 5.5V   |

**CAUTION:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

**Potentiometer Specifications** Over recommended operating conditions unless otherwise stated. **Boldface limits apply over the operating temperature range, -40°C to +85°C or 0°C to +70°C.**

| SYMBOL        | PARAMETER                           | TEST CONDITIONS/NOTES                                 | MIN<br>(Note 10)           | TYP      | MAX<br>(Note 10)           | UNIT        |
|---------------|-------------------------------------|---|----------------------------|----------|----------------------------|-------------|
| $R_{TOTAL}$   | End to end resistance variation     |   | <b>-20</b>                 |          | <b>+20</b>                 | %           |
| $V_{VH}$      | $V_H/R_H$ terminal voltage          | $V_{SS} = 0V$   | <b><math>V_{SS}</math></b> |          | <b><math>V_{CC}</math></b> | V           |
| $V_{VL}$      | $V_L/R_L$ terminal voltage          | $V_{SS} = 0V$   | <b><math>V_{SS}</math></b> |          | <b><math>V_{CC}</math></b> | V           |
|               | Power rating                        | $R_{TOTAL} = 10k\Omega$                               |                            |          | <b>10</b>                  | mW          |
| $R_W$         | Wiper resistance                    | $I_W = 1mA, V_{CC} = 5V$                              |                            | 200      | <b>400</b>                 | $\Omega$    |
| $R_W$         | Wiper resistance                    | $I_W = 1mA, V_{CC} = 2.7V$                            |                            | 400      | <b>1000</b>                | $\Omega$    |
| $I_W$         | Wiper current                       |   | <b>-5.0</b>                |          | <b>+5.0</b>                | mA          |
|               | Noise                               | Ref: 1kHz   |                            | -120     |                            | dBV         |
|               | Resolution                          |   |                            | 6        |                            | %           |
|               | Absolute linearity (Note 4)         | $V_{W(n)}(\text{actual}) - V_{W(n)}(\text{expected})$ | <b>-1</b>                  |          | <b>+1</b>                  | MI (Note 6) |
|               | Relative linearity (Note 5)         | $V_{W(n+1)} - [V_{W(n)} + MI]$                        | <b>-0.2</b>                |          | <b>+0.2</b>                | MI (Note 6) |
|               | $R_{TOTAL}$ temperature coefficient |   |                            |          | $\pm 300$                  | ppm/°C      |
|               | Ratiometric temperature coefficient |   |                            |          | $\pm 20$                   | ppm/°C      |
| $C_H/C_L/C_W$ | Potentiometer capacitances          | See "Circuit #3 SPICE Macro Model" on page 5          |                            | 10/10/25 |                            | pF          |

**NOTES:**

- 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.
- Relative linearity is a measure of the error in step size between taps =  $V_{W(n+1)} - [V_{W(n)} + MI] \pm 0.2$  MI.
- 1 MI = Minimum Increment =  $R_{TOT}/15$ .

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**DC Electrical Specifications** Over recommended operating conditions unless otherwise specified. **Boldface limits apply over the operating temperature range, -40°C to +85°C or 0°C to +70°C.**

| SYMBOL           | PARAMETER   | TEST CONDITIONS  | MIN (Note 10) | TYP (Note 7) | MAX (Note 10)               | UNIT |
|------------------|---|--|---------------|--------------|-----------------------------|------|
| I <sub>CC1</sub> | V <sub>CC</sub> active current (Increment)                                  | $\overline{CS} = V_{IL}$ , $U/\overline{D} = V_{IL}$ or $V_{IH}$ and $\overline{INC} = 0.4V/2.4V$ @ max t <sub>CYC</sub> |               |              | <b>150</b>                  | μA   |
| I <sub>CC2</sub> | V <sub>CC</sub> active current (Store) (EEPROM Store)                       | $\overline{CS} = V_{IH}$ , $U/\overline{D} = V_{IL}$ or $V_{IH}$ and $\overline{INC} = V_{IH}$ @ max t <sub>WR</sub>     |               |              | <b>400</b>                  | μA   |
| I <sub>SB</sub>  | Standby supply current  | $\overline{CS} = V_{CC} - 0.3V$ , $U/\overline{D}$ and $\overline{INC} = V_{SS}$ or $V_{CC} - 0.3V$                      |               |              | <b>5</b>                    | μA   |
| I <sub>LI</sub>  | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ input leakage current | V <sub>IN</sub> = V <sub>SS</sub> to V <sub>CC</sub>   |               |              | <b>±10</b>                  | μA   |
| V <sub>IH</sub>  | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ input HIGH voltage    |  | <b>2V</b>     |              | <b>V<sub>CC</sub> + 0.5</b> | V    |
| V <sub>IL</sub>  | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ input LOW voltage     |  | <b>-0.5</b>   |              | <b>0.8</b>                  | V    |
| C <sub>IN</sub>  | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ input capacitance     | V <sub>CC</sub> = 5V, V <sub>IN</sub> = V <sub>SS</sub> , T <sub>A</sub> = +25°C, f = 1MHz                               |               | 10           |                             | pF   |

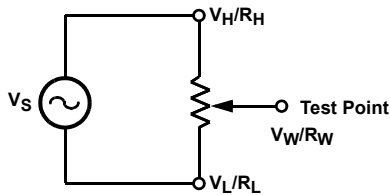
NOTES:

7. Typical values are for T<sub>A</sub> = +25°C and nominal supply voltage.

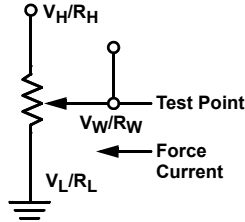
**Endurance and Data Retention**

| PARAMETER         | MIN     | UNIT                 |
|-------------------|---------|----------------------|
| Minimum endurance | 100,000 | Data changes per bit |
| Data retention    | 100     | Years                |

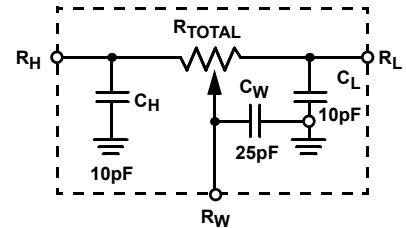
**Test Circuit #1**



**Test Circuit #2**



**Circuit #3 SPICE Macro Model**



**A.C. Conditions of Test**

|                           |          |
|---------------------------|----------|
| Input pulse levels        | 0V to 3V |
| Input rise and fall times | 10ns     |
| Input reference levels    | 1.5V     |

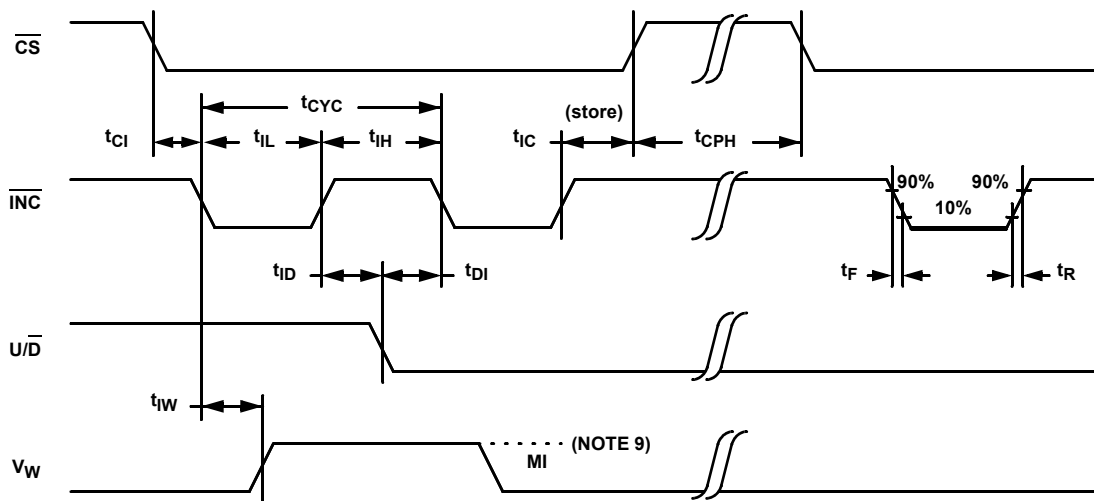
**DC Electrical Specifications** Over recommended operating conditions unless otherwise specified. **Boldface limits apply over the operating temperature range, -40°C to +85°C or 0°C to +70°C.**

| SYMBOL       | PARAMETER   | MIN<br>(Note 10) | TYP<br>(NOTE 8) | MAX<br>(Note 10) | UNIT        |
|--------------|---|------------------|-----------------|------------------|-------------|
| $t_{CI}$     | $\overline{CS}$ to $\overline{INC}$ setup             | <b>100</b>       |                 |                  | ns          |
| $t_{ID}$     | $\overline{INC}$ HIGH to $U/\overline{D}$ change      | <b>100</b>       |                 |                  | ns          |
| $t_{DI}$     | $U/\overline{D}$ to $\overline{INC}$ setup            | <b>2.9</b>       |                 |                  | $\mu$ s     |
| $t_{IL}$     | $\overline{INC}$ LOW period                           | <b>1</b>         |                 |                  | $\mu$ s     |
| $t_{IH}$     | $\overline{INC}$ HIGH period                          | <b>1</b>         |                 |                  | $\mu$ s     |
| $t_{IC}$     | $\overline{INC}$ inactive to $\overline{CS}$ inactive | <b>1</b>         |                 |                  | $\mu$ s     |
| $t_{CPH}$    | $\overline{CS}$ deselect time (STORE)                 | <b>10</b>        |                 |                  | ms          |
| $t_{IW}$     | $\overline{INC}$ to $V_W$ change                      |                  | 1               | <b>5</b>         | $\mu$ s     |
| $t_{CYC}$    | $\overline{INC}$ cycle time                           | <b>4</b>         |                 |                  | $\mu$ s     |
| $t_R, t_F$   | $\overline{INC}$ input rise and fall time             |                  |                 | <b>500</b>       | $\mu$ s     |
| $t_{PU}$     | Power up to wiper stable                              |                  |                 | <b>5</b>         | $\mu$ s     |
| $t_R V_{CC}$ | $V_{CC}$ Power-up rate                                | <b>15</b>        |                 | <b>50</b>        | mV/ $\mu$ s |
| $t_{WR}$     | Store cycle   |                  | 5               | <b>10</b>        | ms          |

### Power Up and Down Requirements

There are no restrictions on the power-up or power-down conditions of  $V_{CC}$  and the voltages applied to the potentiometer pins provided that  $V_{CC}$  is always more positive than or equal to  $V_H$ ,  $V_L$ , and  $V_W$ , i.e.,  $V_{CC} \geq V_H, V_L, V_W$ . The  $V_{CC}$  ramp rate spec is always in effect.

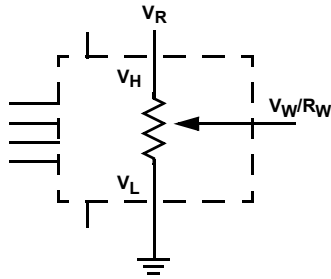
### A.C. Timing



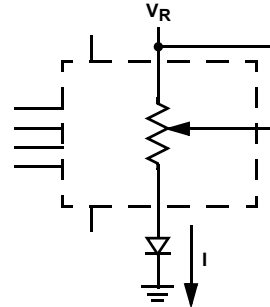
#### NOTES:

- Typical values are for  $T_A = +25^\circ\text{C}$  and nominal supply voltage.
- 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.
- Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design.

**Basic Configurations of Electronic Potentiometers**



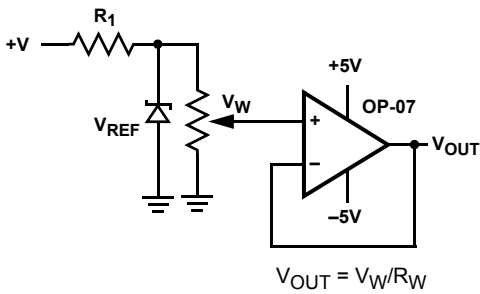
THREE-TERMINAL POTENTIOMETER;  
VARIABLE VOLTAGE DIVIDER



TWO-TERMINAL VARIABLE RESISTOR;  
VARIABLE CURRENT

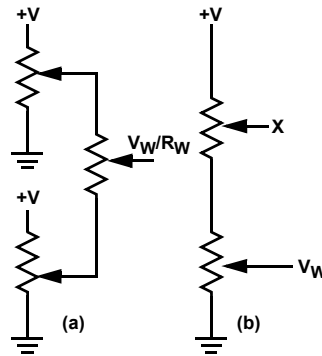
**Basic Circuits**

BUFFERED REFERENCE VOLTAGE

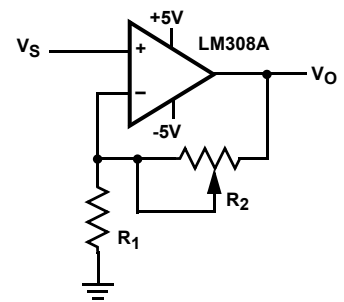


$$V_{OUT} = V_W/R_W$$

CASCADING TECHNIQUES

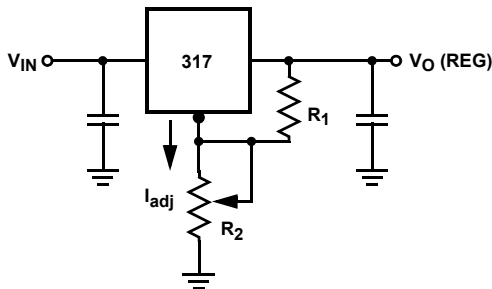


NONINVERTING AMPLIFIER



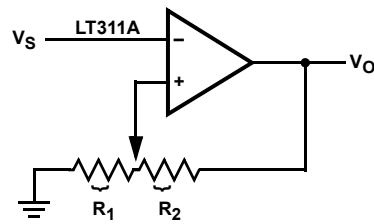
$$V_O = (1+R_2/R_1)V_S$$

VOLTAGE REGULATOR



$$V_O (REG) = 1.25V (1+R_2/R_1)+I_{adj} R_2$$

COMPARATOR WITH HYSTERESIS



$$V_{UL} = \{R_1/(R_1+R_2)\} V_O(max)$$

$$V_{LL} = \{R_1/(R_1+R_2)\} V_O(min)$$

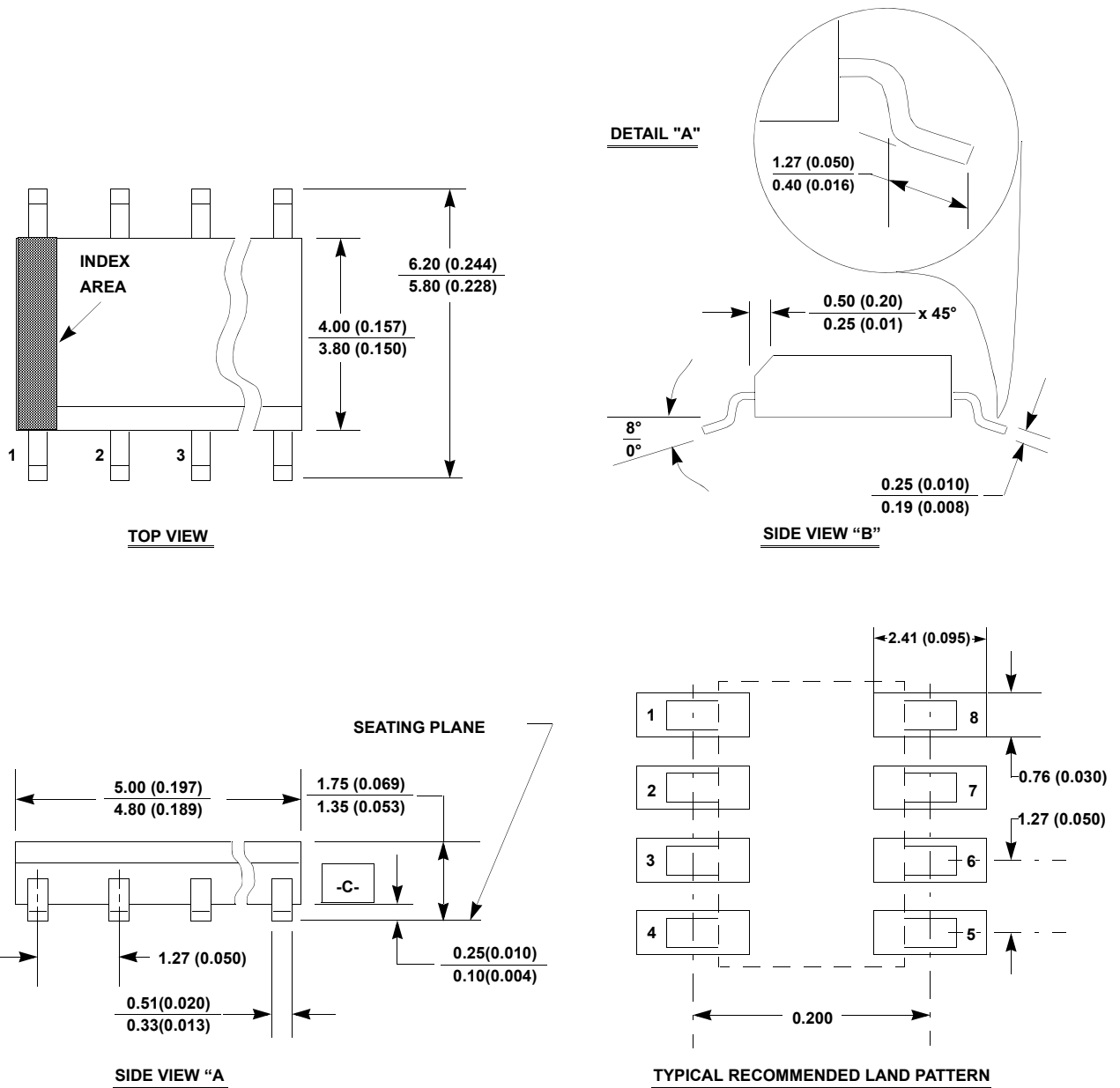
(FOR ADDITIONAL CIRCUITS, SEE AN115)

# Package Outline Drawing

## M8.15

8 LEAD NARROW BODY SMALL OUTLINE PLASTIC PACKAGE

Rev 2, 11/10



**NOTES:**

1. Dimensioning and tolerancing per ANSI Y14.5M-1982.
2. Package length does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
3. Package width does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
4. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
5. Terminal numbers are shown for reference only.
6. The lead width as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch).
7. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.
8. This outline conforms to JEDEC publication MS-012-AA ISSUE C.

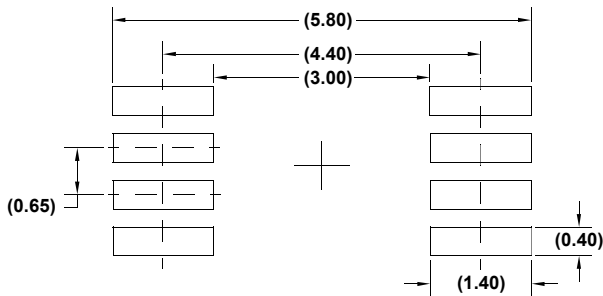
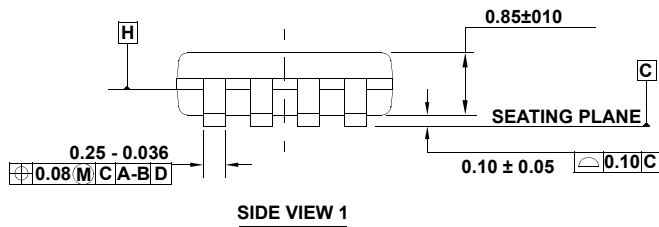
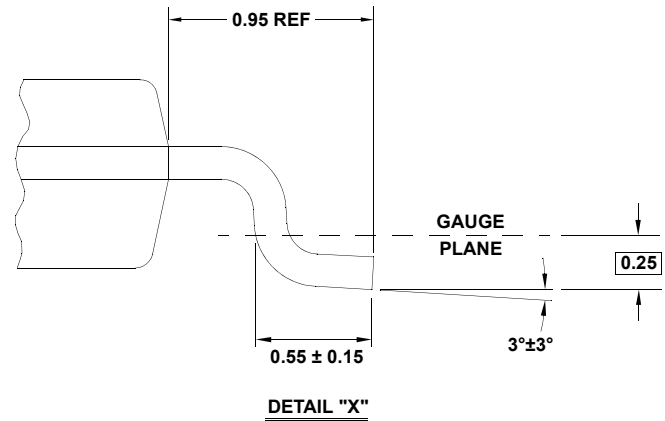
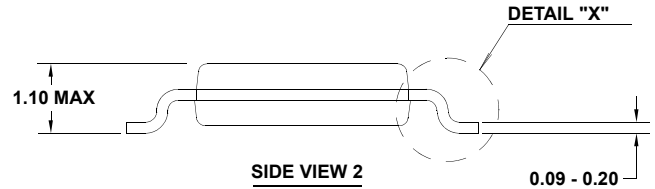
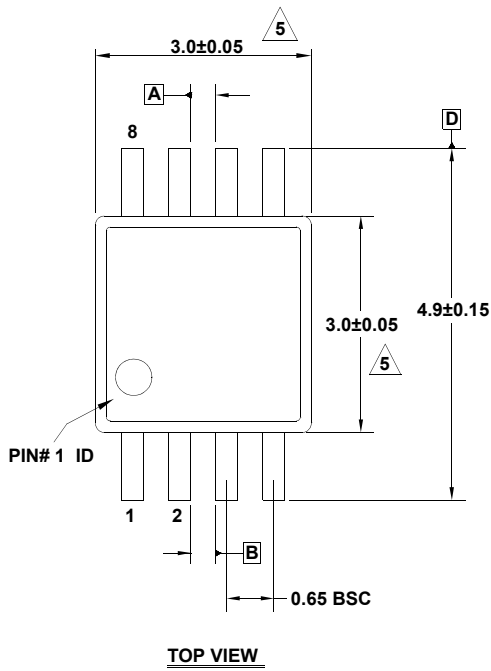


# Package Outline Drawing

## M8.118

8 LEAD MINI SMALL OUTLINE PLASTIC PACKAGE

Rev 3, 3/10



**NOTES:**

1. Dimensions are in millimeters.
2. Dimensioning and tolerancing conform to JEDEC MO-187-AA and AMSEY14.5m-1994.
3. Plastic or metal protrusions of 0.15mm max per side are not included.
4. Plastic interlead protrusions of 0.15mm max per side are not included.
5. Dimensions are measured at Datum Plane "H".
6. Dimensions in ( ) are for reference only.