



# Digitally Controlled Potentiometer (XDCP™)

**X9319**

## FEATURES

- Solid-state potentiometer
- 3-wire serial interface
- Terminal voltage, 0 to +10V
- 100 wiper tap points
  - Wiper position stored in nonvolatile memory and recalled on power-up
- 99 resistive elements
  - Temperature compensated
  - End to end resistance range  $\pm 20\%$
- Low power CMOS
  - $V_{CC} = 5V$
  - Active current, 3mA max.
  - Standby current, 1mA max.
- High reliability
  - Endurance, 100,000 data changes per bit
  - Register data retention, 100 years
- $R_{TOTAL}$  value = 10K $\Omega$  and 50K $\Omega$
- Packages
  - 8-lead SOIC and DIP

## DESCRIPTION

The Xicor X9319 is a digitally controlled potentiometer (XDCP). The device consists of a resistor array, wiper switches, a control section, and nonvolatile memory. The wiper position is controlled by a 3-wire interface.

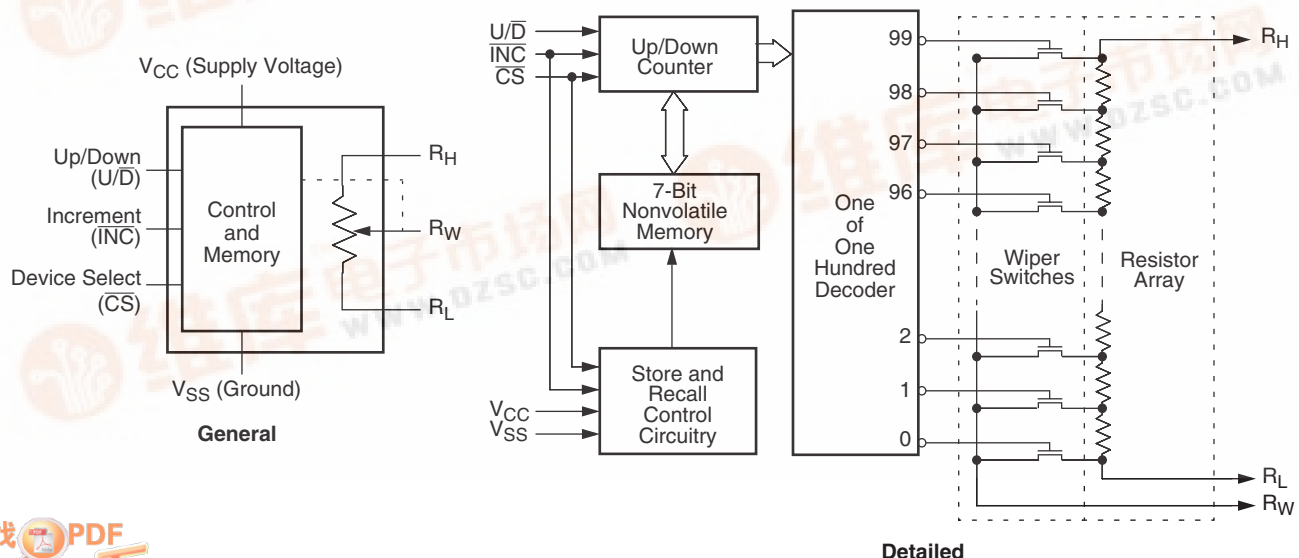
The potentiometer is implemented by a resistor array composed of 99 resistive elements and a wiper switching network. Between each element and at either end are tap points accessible to the wiper terminal. The position of the wiper element is controlled by the  $\overline{CS}$ ,  $U/\overline{D}$ , and  $\overline{INC}$  inputs. The position of the wiper can be stored in nonvolatile memory and then be recalled upon a subsequent power-up operation.

The device can be used as a three-terminal potentiometer for voltage control or as a two-terminal variable resistor for current control in a wide variety of applications.

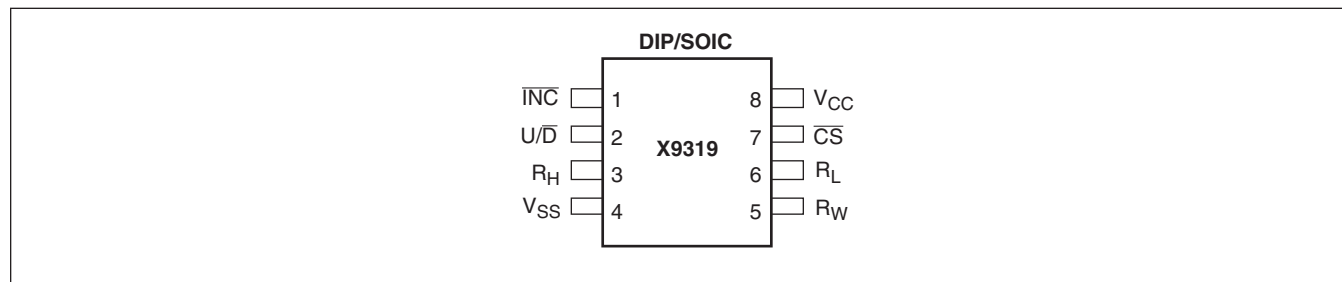
## APPLICATIONS

- LCD bias control
- DC bias adjustment
- Gain and offset trim
- Laser diode bias control
- Voltage regulator output control

## BLOCK DIAGRAM



## PIN CONFIGURATION



## ORDERING INFO

| Ordering Number | RTOTAL       | Package            | Operating Temperature Range |
|-----------------|--------------|--------------------|-----------------------------|
| X9319WS8        | 10K $\Omega$ | 8-lead SOIC        | 0°C to 70°C                 |
| X9319WS8I       | 10K $\Omega$ | 8-lead SOIC        | -40°C to +85°C              |
| X9319WP8        | 10K $\Omega$ | 8-lead Plastic DIP | 0°C to 70°C                 |
| X9319WP8I       | 10K $\Omega$ | 8-lead Plastic DIP | -40°C to +85°C              |
| X9319US8        | 50K $\Omega$ | 8-lead SOIC        | 0°C to 70°C                 |
| X9319US8I       | 50K $\Omega$ | 8-lead SOIC        | -40°C to +85°C              |
| X9319UP8        | 50K $\Omega$ | 8-lead Plastic DIP | 0°C to 70°C                 |
| X9319UP8I       | 50K $\Omega$ | 8-lead Plastic DIP | -40°C to +85°C              |

## PIN DESCRIPTIONS

| DIP/<br>SOIC | Symbol                         | Brief Description   |
|--------------|--------------------------------|---|
| 1            | $\overline{\text{INC}}$        | <b>Increment.</b> Toggling $\overline{\text{INC}}$ while $\overline{\text{CS}}$ is low moves the wiper either up or down.                     |
| 2            | $\text{U}/\overline{\text{D}}$ | <b>Up/Down.</b> The $\text{U}/\overline{\text{D}}$ input controls the direction of the wiper movement.  |
| 3            | $R_H$                          | The high terminal is equivalent to one of the fixed terminals of a mechanical potentiometer.  |
| 4            | $V_{SS}$                       | <b>Ground.</b>  |
| 5            | $R_W$                          | The wiper terminal is equivalent to the movable terminal of a mechanical potentiometer.   |
| 6            | $R_L$                          | The low terminal is equivalent to one of the fixed terminals of a mechanical potentiometer.   |
| 7            | $\overline{\text{CS}}$         | <b>Chip Select.</b> The device is selected when the $\overline{\text{CS}}$ input is LOW, and de-selected when $\overline{\text{CS}}$ is high. |
| 8            | $V_{CC}$                       | <b>Supply Voltage.</b>  |

**ABSOLUTE MAXIMUM RATINGS**

Junction 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  
 $R_H$ ,  $R_W$ ,  $R_L$  to ground ..... +12V  
 Lead temperature (soldering 10 seconds).....300°C  
 $I_W$  (10 seconds) .....  $\pm 6$ mA

**COMMENT**

Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only; 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.

**POTENTIOMETER CHARACTERISTICS**

( $V_{CC} = 5V \pm 10\%$ ,  $T_A$  = Full Operating Temperature Range unless otherwise stated)

| Symbol                       | Parameter  | Limits   |                     |      |                   | Test Conditions/Notes               |
|------------------------------|--|----------|---------------------|------|-------------------|-------------------------------------|
|                              |  | Min.     | Typ. <sup>(4)</sup> | Max. | Unit              |                                     |
|                              | End to end resistance tolerance                        | -20      |                     | +20  | %                 | See ordering information for values |
| $V_{RH/RL}$                  | $R_H/R_L$ terminal voltage                             | $V_{SS}$ |                     | 10   | V                 | $V_{SS} = 0V$                       |
|                              | Power rating   |          |                     | 25   | mW                |                                     |
| $R_W$                        | Wiper resistance                                       |          | 40                  | 200  | $\Omega$          | $I_W = 1mA$                         |
| $I_W$                        | Wiper current <sup>(5)</sup>                           | -3.0     |                     | +3.0 | mA                | See test circuit                    |
|                              | Noise <sup>(7)</sup>                                   |          | -120                |      | dBV               | Ref: 1kHz                           |
|                              | Resolution   |          | 1                   |      | %                 |                                     |
|                              | Absolute linearity <sup>(1)</sup>                      | -1       |                     | +1   | MI <sup>(3)</sup> | $V(RH) = 10V$ ,<br>$V(RL) = 0V$     |
|                              | Relative linearity <sup>(2)</sup>                      | -0.2     |                     | +0.2 | MI <sup>(3)</sup> |                                     |
|                              | $R_{TOTAL}$ temperature coefficient <sup>(5)</sup>     |          | $\pm 300$           |      | ppm/°C            |                                     |
|                              | Ratiometric temperature coefficient <sup>(5),(6)</sup> | -20      |                     | +20  | ppm/°C            |                                     |
| $C_H/C_L/C_W$ <sup>(5)</sup> | Potentiometer capacitances                             |          | 10/10/25            |      | pF                | See equivalent circuit              |
| $V_{CC}$                     | Supply Voltage   | 4.5      |                     | 5.5  | V                 |                                     |

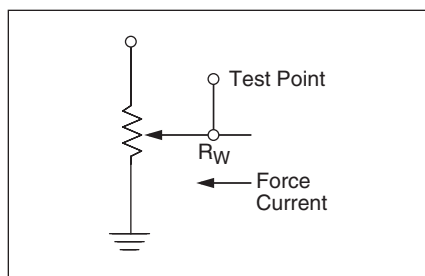
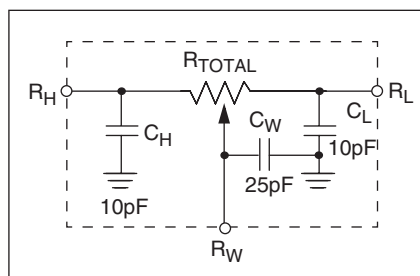
**D.C. OPERATING CHARACTERISTICS**(V<sub>CC</sub> = 5V ±10%, T<sub>A</sub> = Full Operating Temperature Range unless otherwise stated)

| Symbol              | Parameter   | Limits |         |                     | Unit | Test Conditions  |
|---------------------|---|--------|---------|---------------------|------|--|
|                     |   | Min.   | Typ.(4) | Max.                |      |  |
| I <sub>CC</sub>     | V <sub>CC</sub> active current (Increment)                                  |        | 1       | 3                   | mA   | $\overline{CS} = V_{IL}$ , $U/\overline{D} = V_{IL}$ or $V_{IH}$ and $\overline{INC} = 0.4V/2.4V$ @ min. $t_{CYC}$<br>R <sub>L</sub> , R <sub>H</sub> , R <sub>W</sub> not connected |
| I <sub>SB</sub>     | Standby supply current  |        | 300     | 1000                | μA   | $\overline{CS} \geq 2.4V$ , $U/\overline{D}$ and $\overline{INC} = 0.4V$<br>R <sub>L</sub> , R <sub>H</sub> , R <sub>W</sub> not connected   |
| I <sub>LI</sub>     | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ input leakage current | -10    |         | +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    |  |
| C <sub>IN</sub> (5) | $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ input capacitance     |        |         | 10                  | pF   | V <sub>CC</sub> = 5V, V <sub>IN</sub> = V <sub>SS</sub> , T <sub>A</sub> = 25°C, f = 1MHz  |

**ENDURANCE AND DATA RETENTION**(V<sub>CC</sub> = 5V ±10%, T<sub>A</sub> = Full Operating Temperature Range)

| Parameter         | Min.    | Unit                 |
|-------------------|---------|----------------------|
| Minimum endurance | 100,000 | Data changes per bit |
| Data retention    | 100     | Years                |

- Notes:** (1) Absolute linearity is utilized to determine actual wiper voltage versus expected voltage =  $[V(R_{W(n)}(\text{actual})) - V(R_{W(n)}(\text{expected}))]/MI$   
 $V(R_{W(n)}(\text{expected})) = n(V(R_H) - V(R_L))/99 + V(R_L)$ , with n from 0 to 99.  
(2) Relative linearity is a measure of the error in step size between taps =  $[V(R_{W(n+1)}) - (V(R_{W(n)}) - MI)]/MI$   
(3) 1 MI = Minimum Increment =  $[V(R_H) - V(R_L)]/99$ .  
(4) Typical values are for T<sub>A</sub> = 25°C and nominal supply voltage.  
(5) Guaranteed by device characterization.  
(6) Ratiometric temperature coefficient =  $(V(R_W)_{T1(n)} - V(R_W)_{T2(n)})/[V(R_W)_{T1(n)}(T1 - T2) \times 10^6]$ , with T1 & T2 being 2 temperatures, and n from 0 to 99.  
(7) Measured with wiper at tap position 31, R<sub>L</sub> grounded, using test circuit.

**Test Circuit****Equivalent Circuit****A.C. CONDITIONS OF TEST**

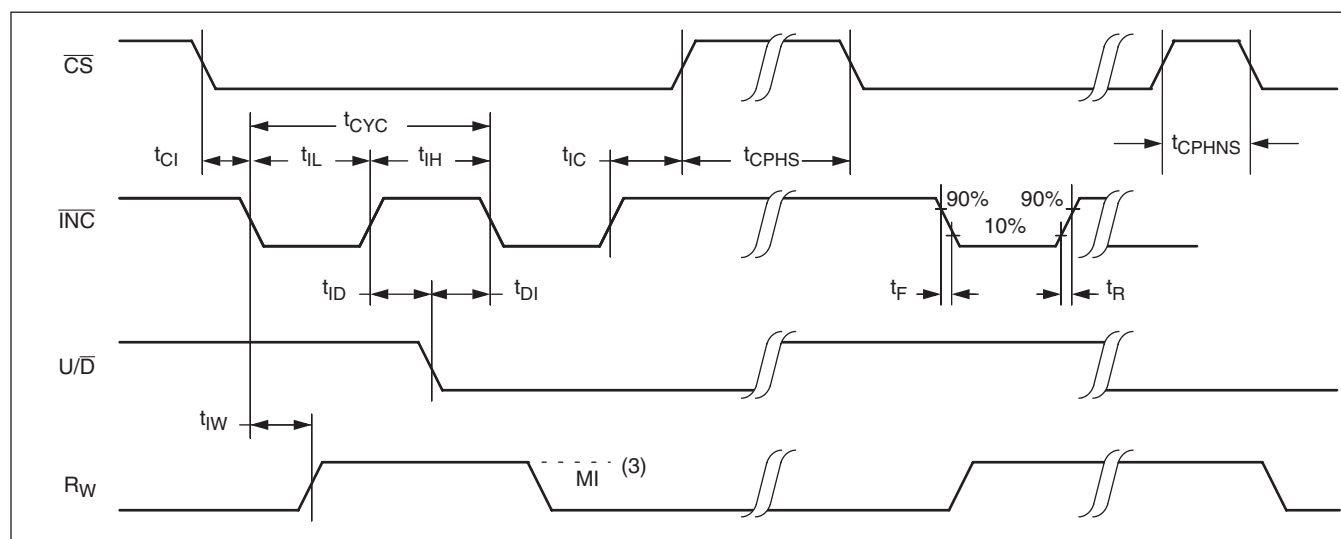
|                           |              |
|---------------------------|--------------|
| Input pulse levels        | 0.8V to 2.0V |
| Input rise and fall times | 10ns         |
| Input reference levels    | 1.4V         |

**A.C. OPERATING CHARACTERISTICS**(V<sub>CC</sub> = 5V ±10%, T<sub>A</sub> = Full Operating Temperature Range unless otherwise stated)

| Symbol   | Parameter   | Limits |                     |      | Unit |
|--|---|--------|---------------------|------|------|
|  |   | Min.   | Typ. <sup>(4)</sup> | Max. |      |
| t <sub>CI</sub>                                | $\overline{CS}$ to $\overline{INC}$ setup             | 100    |                     |      | ns   |
| t <sub>ID</sub> <sup>(5)</sup>                 | $\overline{INC}$ HIGH to U/ $\overline{D}$ change     | 100    |                     |      | ns   |
| t <sub>DI</sub> <sup>(5)</sup>                 | U/ $\overline{D}$ to $\overline{INC}$ setup           | 1      |                     |      | μs   |
| t <sub>IL</sub>                                | $\overline{INC}$ LOW period                           | 1      |                     |      | μs   |
| t <sub>IH</sub>                                | $\overline{INC}$ HIGH period                          | 1      |                     |      | μs   |
| t <sub>IC</sub>                                | $\overline{INC}$ inactive to $\overline{CS}$ inactive | 1      |                     |      | μs   |
| t <sub>CPHS</sub>                              | $\overline{CS}$ deselect time (STORE)                 | 20     |                     |      | ms   |
| t <sub>CPHNS</sub> <sup>(5)</sup>              | $\overline{CS}$ deselect time (NO STORE)              | 1      |                     |      | μs   |
| t <sub>IW</sub> <sup>(5)</sup>                 | $\overline{INC}$ to R <sub>W</sub> change             |        | 100                 | 500  | μs   |
| t <sub>CYC</sub>                               | $\overline{INC}$ cycle time                           | 4      |                     |      | μs   |
| t <sub>R</sub> , t <sub>F</sub> <sup>(5)</sup> | $\overline{INC}$ input rise and fall time             |        |                     | 500  | μs   |
| t <sub>PU</sub> <sup>(5)</sup>                 | Power up to wiper stable                              |        |                     | 500  | μs   |
| t <sub>R</sub> V <sub>CC</sub> <sup>(5)</sup>  | V <sub>CC</sub> power-up rate                         | 0.2    |                     | 50   | V/ms |

**POWER UP AND DOWN REQUIREMENTS**

In order to prevent unwanted tap position changes, or an inadvertant store, bring the  $\overline{CS}$  and  $\overline{INC}$  high before or concurrently with the V<sub>CC</sub> pin on powerup. The potentiometer voltages must be applied after this sequence is completed. During power-up, the data sheet parameters for the DCP do not fully apply until 1 millisecond after V<sub>CC</sub> reaches its final value. The V<sub>CC</sub> ramp spec is always in effect.

**A.C. TIMING**

## PIN DESCRIPTIONS

### $R_H$ and $R_L$

The high ( $R_H$ ) and low ( $R_L$ ) terminals of the X9319 are equivalent to the fixed terminals of a mechanical potentiometer. The terminology of  $R_L$  and  $R_H$  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.

### $R_W$

$R_W$  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  $40\Omega$ .

### 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.

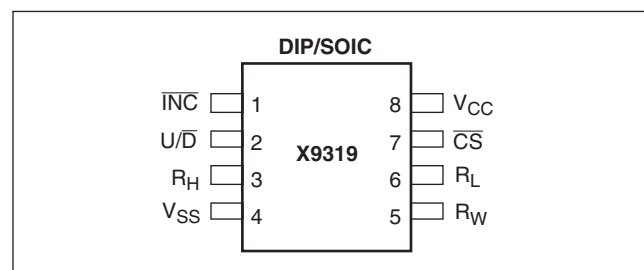
### Increment ( $\bar{INC}$ )

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 X9319 will be placed in the low power standby mode until the device is selected once again.

## PIN CONFIGURATION



## PIN NAMES

| Symbol      | Description               |
|-------------|---------------------------|
| $R_H$       | High terminal             |
| $R_W$       | Wiper terminal            |
| $R_L$       | Low terminal              |
| $V_{SS}$    | Ground                    |
| $V_{CC}$    | Supply voltage            |
| $U/\bar{D}$ | Up/Down control input     |
| $\bar{INC}$ | Increment control input   |
| $\bar{CS}$  | Chip select control input |

## PRINCIPLES OF OPERATION

There are three sections of the X9319: the control section, the nonvolatile memory, and the resistor array. The 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. The contents of the counter can be stored in nonvolatile memory and retained for future use. The resistor array is comprised of 99 individual resistors connected in series. Electronic switches at either end of the array and between each resistor provide an electrical connection to the wiper pin,  $R_W$ .

The wiper acts like its mechanical equivalent and does not move beyond the first or 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  $t_{1W}$  ( $\bar{INC}$  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  $\overline{\text{INC}}$ ,  $\text{U}/\overline{\text{D}}$  and  $\overline{\text{CS}}$  inputs control the movement of the wiper along the resistor array. With  $\overline{\text{CS}}$  set LOW the device is selected and enabled to respond to the  $\text{U}/\overline{\text{D}}$  and  $\overline{\text{INC}}$  inputs. HIGH to LOW transitions on  $\overline{\text{INC}}$  will increment or decrement (depending on the state of the  $\text{U}/\overline{\text{D}}$  input) the seven bit counter. The output of this counter is decoded to select one of one hundred wiper positions along the resistive array.

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

The system may select the X9319, 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  $\overline{\text{INC}}$  LOW while taking  $\overline{\text{CS}}$  HIGH. The new wiper position will be maintained until changed by the system or until a powerup/down cycle recalled 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  $\text{U}/\overline{\text{D}}$  may be changed while  $\overline{\text{CS}}$  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.

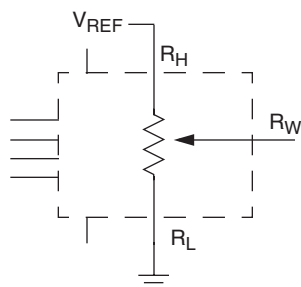
## MODE SELECTION

| $\overline{\text{CS}}$  | $\overline{\text{INC}}$  | $\text{U}/\overline{\text{D}}$ | Mode                                       |
|---|--|--------------------------------|--|
| L   |  | H                              | Wiper up                                   |
| L   |  | L                              | Wiper down                                 |
|  | H  | X                              | Store wiper position to nonvolatile memory |
| H   | X  | X                              | Standby                                    |
|  | L  | X                              | No store, return to standby                |
|  | L  | H                              | Wiper Up (not recommended)                 |
|  | L  | L                              | Wiper Down (not recommended)               |

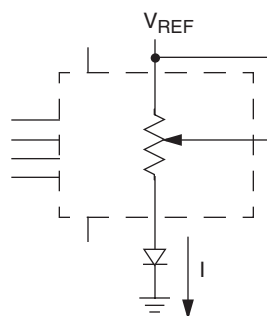
## APPLICATIONS INFORMATION

Electronic digitally controlled (XDCP) potentiometers provide three powerful application advantages; (1) the variability and reliability of a solid-state potentiometer, (2) the flexibility of computer-based digital controls, and (3) the retentivity of nonvolatile memory used for the storage of multiple potentiometer settings or data.

### Basic Configurations of Electronic Potentiometers



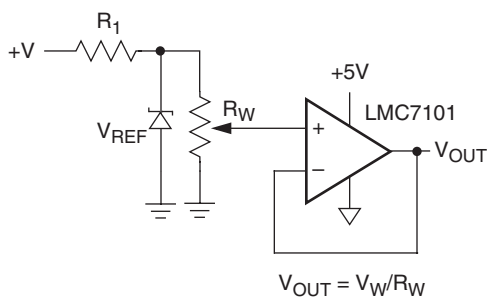
Three terminal potentiometer;  
variable voltage divider



Two terminal variable resistor;  
variable current

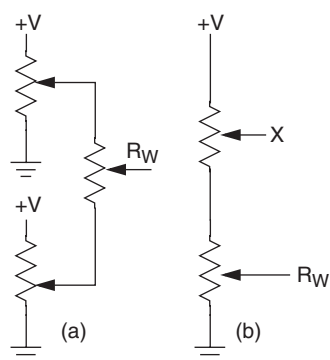
### Basic Circuits

#### Buffered Reference Voltage

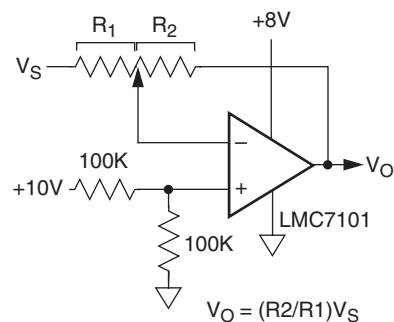


$$V_{OUT} = V_W / R_W$$

#### Cascading Techniques

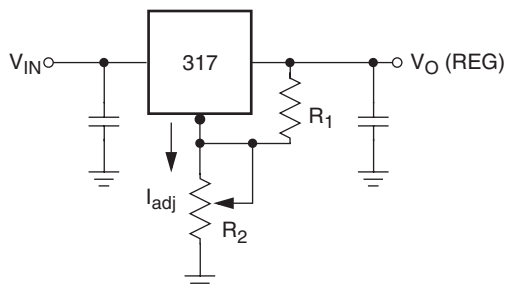


#### Single Supply Inverting Amplifier



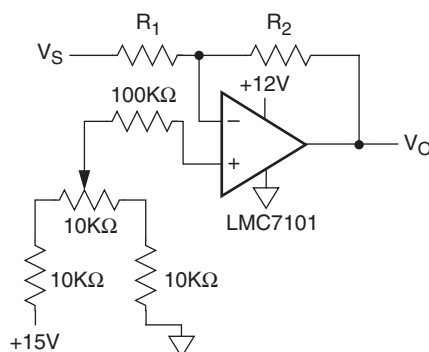
$$V_O = (R_2/R_1)V_S$$

#### Voltage Regulator

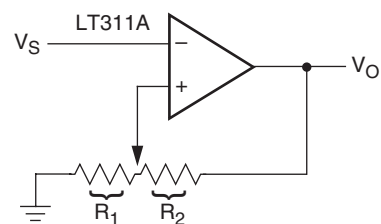


$$V_O (REG) = 1.25V (1 + R_2/R_1) + I_{adj} R_2$$

#### Offset Voltage Adjustment



#### Comparator with Hysteresis



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

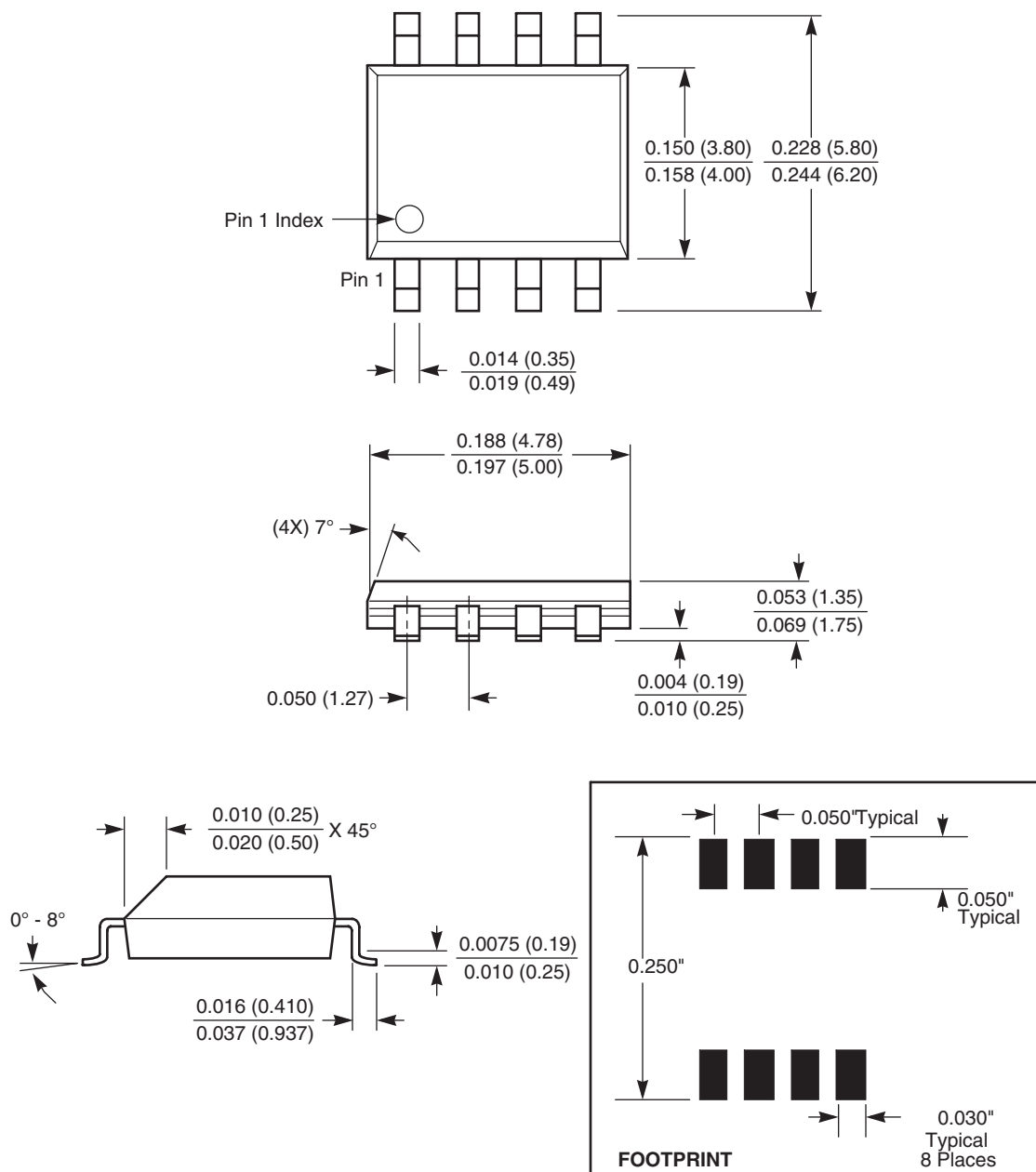
$$V_{LL} = \{R_1/(R_1+R_2)\} V_O(min)$$

(for additional circuits see AN115)



## PACKAGING INFORMATION

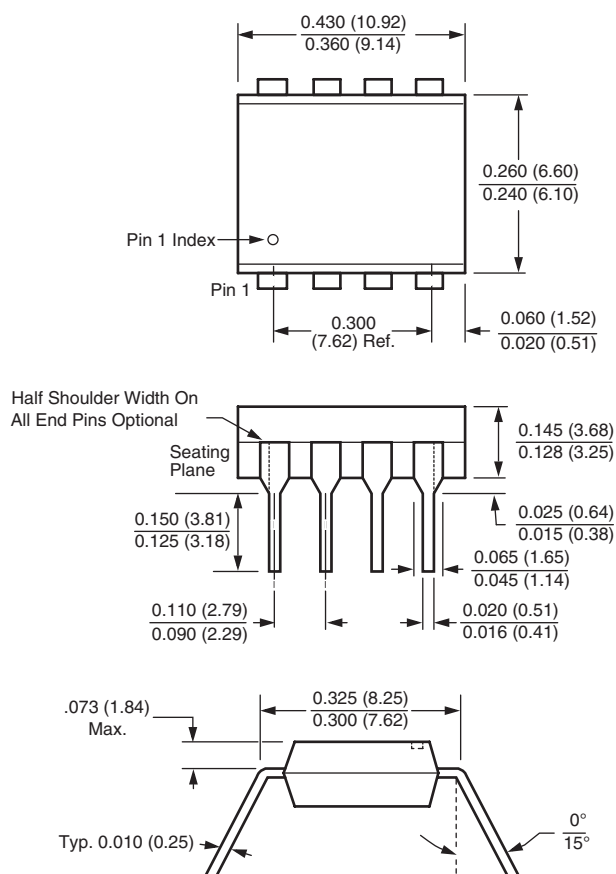
## 8-Lead Plastic Small Outline Package, Type S (8-lead SOIC)



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

## PACKAGING INFORMATION

## 8-Lead Plastic, DIP, Package Code P8



## NOTE:

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

## LIMITED WARRANTY

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## 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.