## *Linear, 32 Taps, 3 Wire Interface, Terminal Voltages ± V$_{CC}$*

The Intersil X9313 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 31 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 or as a two-terminal variable resistor in a wide variety of applications including:

- Control

- Parameter adjustments

- Signal processing

## *Features*

- Solid-state potentiometer

- 3-wire serial interface

- 32 wiper tap points
  - Wiper position stored in nonvolatile memory and recalled on power-up

- 31 resistive elements
  - Temperature compensated
  - End-to-end resistance range ±20%
  - Terminal voltages, -V$_{CC}$ to +V$_{CC}$

- Low power CMOS
  - V$_{CC}$ = 3V or 5V
  - Active current, 3mA max.
  - Standby current, 500µA max.

- High reliability
  - Endurance, 100,000 data changes per bit
  - Register data retention, 100 years

- R$_{TOTAL}$ values = 1kΩ, 10kΩ, 50kΩ

- Packages
  - 8 Ld SOIC, 8 Ld MSOP and 8 Ld PDIP

- Pb-free available (RoHS compliant)

## *Block Diagram*



GENERAL

DETAILED
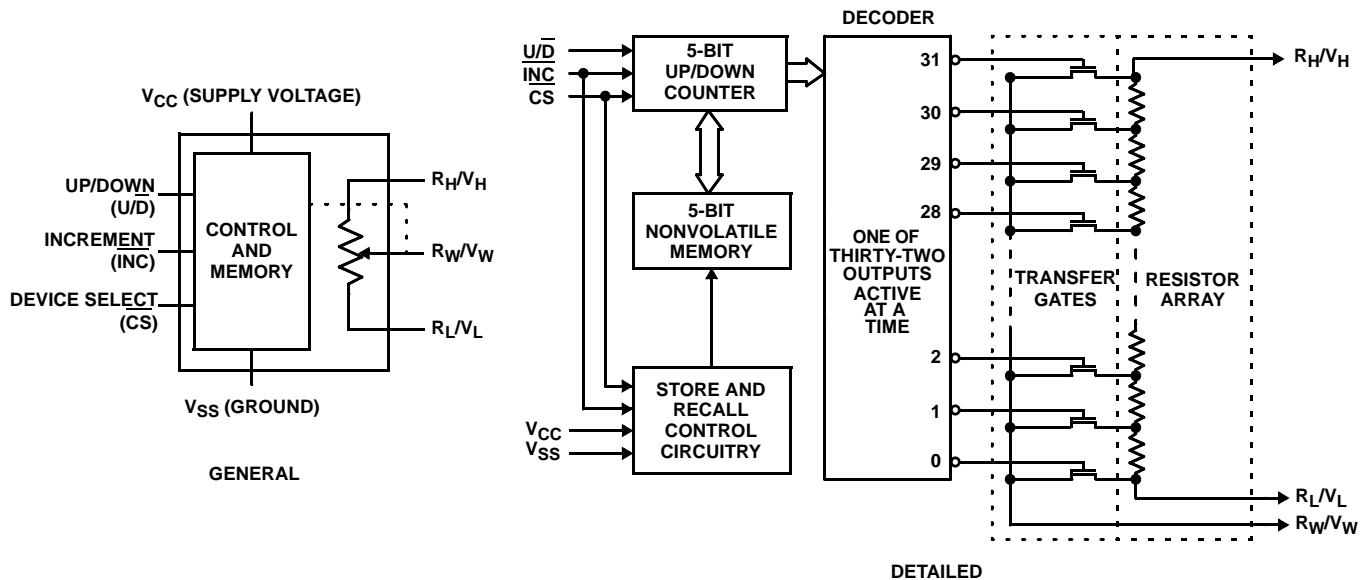
## Ordering Information

| PART NUMBER | PART MARKING | $V_{CC}$ RANGE (V) | $R_{TOTAL}$ (k$\Omega$) | TEMPERATURE RANGE (°C) | PACKAGE | PKG. DWG. # |
|---|---|---|---|---|---|---|
| X9313UMI | 13UI | 4.5 to 5.5 | 50 | -40 to +85 | 8 Ld MSOP | M8.118 |
| X9313UMIZ (Note) | DDB | | | -40 to +85 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313UP | X9313UP | | | 0 to +70 | 8 Ld PDIP | MDP0031 |
| X9313US*, ** | X9313U | | | 0 to +70 | 8 Ld SOIC | MDP0027 |
| X9313USZ* (Note) | X9313U Z | | | 0 to +70 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313USI | X9313U I | | | -40 to +85 | 8 Ld SOIC | MDP0027 |
| X9313USIZ (Note) | X9313U ZI | | | -40 to +85 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313WMZ (Note) | DDF | | 10 | 0 to +70 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313WMI* | 13WI | | | -40 to +85 | 8 Ld MSOP | M8.118 |
| X9313WMIZ* (Note) | DDE | | | -40 to +85 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313WP | X9313WP | | | 0 to +70 | 8 Ld PDIP | MDP0031 |
| X9313WPZ-3 | X9313WP ZD | | | -40 to +85 | 8 Ld PDIP*** (Pb-free) | MDP0031 |
| X9313WPI | X9313WP I | | | -40 to +85 | 8 Ld PDIP | MDP0031 |
| X9313WPIZ | X9313WP ZI | | | -40 to +85 | 8 Ld PDIP*** (Pb-free) | MDP0031 |
| X9313WS*, ** | X9313WS | | | 0 to +70 | 8 Ld SOIC | MDP0027 |
| X9313WSZ*, ** (Note) | X9313W Z | | | 0 to +70 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313WSI*, ** | X9313WS I | | | -40 to +85 | 8 Ld SOIC | MDP0027 |
| X9313WSIZ* (Note) | X9313WS ZI | | | -40 to +85 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313ZM | 313Z | | 1 | 0 to +70 | 8 Ld MSOP | M8.118 |
| X9313ZMZ (Note) | DDJ | | | 0 to +70 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313ZMI*, ** | 13ZI | | | -40 to +85 | 8 Ld MSOP | M8.118 |
| X9313ZMIZ*, ** (Note) | DDH | | | -40 to +85 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313ZP | X9313ZP | | | 0 to +70 | 8 Ld PDIP | MDP0031 |
| X9313ZPI | X9313ZP I | | | -40 to +85 | 8 Ld PDIP | MDP0031 |
| X9313ZPIZ (Note) | X9313ZP ZI | | | -40 to +85 | 8 Ld PDIP*** (Pb-free) | MDP0031 |
| X9313ZS*, ** | X9313ZS | | | 0 to +70 | 8 Ld SOIC | MDP0027 |
| X9313ZSZ*, ** (Note) | X9313 Z | | | 0 to +70 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313ZSI* | X9313ZS I | | | -40 to +85 | 8 Ld SOIC | MDP0027 |
| X9313ZSIZ* (Note) | X9313ZS ZI | | | -40 to +85 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313UM-3T1 | 13UD | 3 to 5.5 | 50 | 0 to +70 | 8 Ld MSOP Tape and Reel | M8.118 |
| X9313UMZ-3T1 (Note) | DDD | | | 0 to +70 | 8 Ld MSOP Tape and Reel (Pb-free) | M8.118 |
| X9313UMI-3* | 13UE | | | -40 to +85 | 8 Ld MSOP | M8.118 |
| X9313UMIZ-3* (Note) | 13UEZ | | | -40 to +85 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313US-3*, ** | X9313U D | | | 0 to +70 | 8 Ld SOIC | MDP0027 |
| X9313USZ-3*, ** (Note) | X9313U ZD | | | 0 to +70 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313WM-3* | 13WD | | 10 | 0 to +70 | 8 Ld MSOP | M8.118 |
| X9313WMZ-3* (Note) | DDG | | | 0 to +70 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313WMI-3* | 13WE | | | -40 to +85 | 8 Ld MSOP | M8.118 |
| X9313WMIZ-3* (Note) | 13WEZ | | | -40 to +85 | 8 Ld MSOP (Pb-free) | M8.118 |

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## Ordering Information (Continued)

| PART NUMBER | PART MARKING | V_CC RANGE (V) | R_TOTAL (kΩ) | TEMPERATURE RANGE (°C) | PACKAGE | PKG. DWG. # |
|---|---|---|---|---|---|---|
| X9313WS-3*, ** | X9313W D | 3 to 5.5 | 10 | 0 to +70 | 8 Ld SOIC | MDP0027 |
| X9313WSZ-3* (Note) | X9313W ZD | | | 0 to +70 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313ZM-3* | 13ZD | | 1 | 0 to +70 | 8 Ld MSOP | M8.118 |
| X9313ZMZ-3* (Note) | DDK | | | 0 to +70 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313ZMI-3* | 13ZE | | | -40 to +85 | 8 Ld MSOP | M8.118 |
| X9313ZMIZ-3* (Note) | 13ZEZ | | | -40 to +85 | 8 Ld MSOP (Pb-free) | M8.118 |
| X9313ZP-3 | X9313ZP D | | | 0 to +70 | 8 Ld PDIP | MDP0031 |
| X9313ZPZ-3 (Note) | X9313ZP ZD | | | 0 to +70 | 8 Ld PDIP (Pb-free)*** | MDP0031 |
| X9313ZS-3*, ** | X9313Z D | | | 0 to +70 | 8 Ld SOIC | MDP0027 |
| X9313ZSZ-3* (Note) | X9313Z ZD | | | 0 to +70 | 8 Ld SOIC (Pb-free) | M8.15 |
| X9313ZSI-3* | X9313Z E | | | -40 to +85 | 8 Ld SOIC | MDP0027 |
| X9313ZSIZ-3* (Note) | X9313Z ZE | | | -40 to +85 | 8 Ld SOIC (Pb-free) | M8.15 |

NOTE: 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.

*Add "T1" suffix for tape and reel. Please refer to TB347 for details on reel specifications.
**Add "T2" suffix for tape and reel. Please refer to TB347 for details on reel specifications.
***Pb-free PDIPs can be used for through hole wave solder processing only. They are not intended for use in Reflow solder processing applications.

## Pin Descriptions

### RH/VH and RL/VL

The high (RH/VH) and low (RL/VL) terminals of the X9313 are equivalent to the fixed terminals of a mechanical potentiometer. The terminology of RL/VL and RH/VH references the relative position of the terminal in relation to wiper movement direction selected by the $U/\overline{D}$ input and not the voltage potential on the terminal.

### RW/VW

RW/VW 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 40Ω at $V_{CC}$ = 5V.

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

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

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

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

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

The device is selected when the $\overline{CS}$ input is LOW. The current counter value is stored in nonvolatile memory when $\overline{CS}$ is returned HIGH while the $\overline{INC}$ input is also HIGH. After the store operation is complete, the X9313 will be placed in the low power standby mode until the device is selected once again.
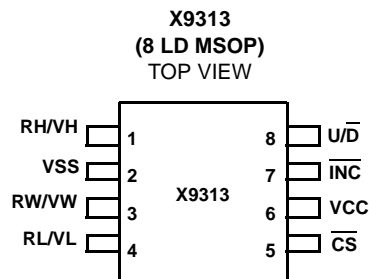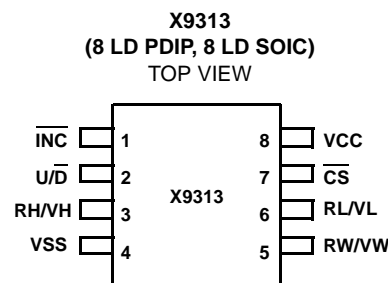
## Pinouts

**X9313**
**(8 LD PDIP, 8 LD SOIC)**
TOP VIEW

| | | |
|---|---|---|
| $\overline{INC}$ | 1 | 8 VCC |
| U/$\overline{D}$ | 2 | 7 $\overline{CS}$ |
| RH/VH | 3 | 6 RL/VL |
| VSS | 4 | 5 RW/VW |

**X9313**
**(8 LD MSOP)**
TOP VIEW

| | | |
|---|---|---|
| RH/VH | 1 | 8 U/$\overline{D}$ |
| VSS | 2 | 7 $\overline{INC}$ |
| RW/VW | 3 | 6 VCC |
| RL/VL | 4 | 5 $\overline{CS}$ |

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**TABLE 1. PIN NAMES**

| SYMBOL | DESCRIPTION |
|---|---|
| RH/VH | High terminal |
| RW/VW | Wiper terminal |
| RL/VL | Low terminal |
| VSS | Ground |
| VCC | Supply voltage |
| U/$\overline{\text{D}}$ | Up/Down control input |
| INC | Increment control input |
| CS | Chip Select control input |

## Principles of Operation

There are three sections of the X9313: 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 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 $t_{IW}$ (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 $\overline{\text{INC}}$, 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 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 U/$\overline{\text{D}}$ 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 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 X9313, 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 previously described 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 power-up/down cycle recalled the previously stored data.
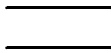
This procedure allows the system to always power-up to a preset value stored in nonvolatile memory; then during system operation, minor adjustments could be made. The adjustments might be based on user preference, system parameter changes due to temperature drift, etc.

The state of 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.

**TABLE 2. MODE SELECTION**

| $\overline{\text{CS}}$ | $\overline{\text{INC}}$ | U/$\overline{\text{D}}$ | 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 |
| \⌐ | L | H | Wiper up (not recommended) |
| \⌐ | L | L | Wiper down (not recommended) |

## 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 |

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## 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 $V_H$, $V_L$, $V_W$
  with respect to $V_{SS}$. . . . . . . . . . . . . . . . . . . . . . . . . . . -6V to +7V
$\Delta V = |V_H - V_L|$:
  X9313Z . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .4V
  X9313W, X9313U . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .10V
$I_W$ (10s) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .±8.8mA
ESD Rating
  Human Body Model . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2.0kV
  Machine Model. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .200V

## Recommended Operating Conditions

Temperature:
  Commercial. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0°C to +70°C
  Industrial . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .-40°C to +85°C
Supply Voltage (VCC):
  X9313 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .5V ±10%
  X9313-3 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3V to 5.5V
Max Wiper current . . . . . . . . . . . . . . . . . . . . . . . . . . . . .±4.4mA
Power rating:
  $R_{TOTAL} \geq 10k\Omega$ . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .10mW
  $R_{TOTAL}$ 1k$\Omega$. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .16mW
Pb-free reflow profile . . . . . . . . . . . . . . . . . . . . . . . . .see link below
  http://www.intersil.com/pbfree/Pb-FreeReflow.asp
Pb-free PDIPs can be used for through hole wave solder processing
only. They are not intended for use in Reflow solder processing
applications

*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 Characteristics    Over recommended operating conditions, unless otherwise stated.

| SYMBOL | PARAMETER | TEST CONDITIONS | LIMITS | | | UNIT |
| | | | MIN | TYP | MAX | |
|---|---|---|---|---|---|---|
| | End-to-End Resistance Tolerance | | | | ±20 | % |
| $V_{VH}$ | $V_H$ Terminal Voltage | | $-V_{CC}$ | | $+V_{CC}$ | V |
| $V_{VL}$ | $V_L$ Terminal Voltage | | $-V_{CC}$ | | $+V_{CC}$ | V |
| $R_W$ | Wiper Resistance | $I_W = (V_H - V_L)/R_{TOTAL}$, $V_{CC} = 5V$ | | 40 | 100 | Ω |
| $I_W$ | Wiper Current | | | | ±4.4 | mA |
| | Noise (Note 5) | Ref: 1kHz | | -120 | | dBV |
| | Resolution | | | 3 | | % |
| | Absolute Linearity (Note 1) | $R_{W(n)(actual)}$ - $R_{W(n)(expected)}$ | | | ±1 | MI (Note 3) |
| | Relative Linearity (Note 2) | $R_{W(n+1)}$ - $(R_{W(n)}+MI)$ | | | ±0.2 | MI (Note 3) |
| | $R_{TOTAL}$ Temperature Coefficient (Note 5) | | | ±300 | | ppm/°C |
| | Ratiometric Temperature Coefficient (Note 5) | | | ±20 | | ppm/°C |
| $C_H/C_L/C_W$ (Note 5) | Potentiometer Capacitances | See Circuit #3 | | 10/10/25 | | pF |

NOTES:

1. Absolute linearity is utilized to determine actual wiper voltage versus expected voltage = $(V_{W(n)(actual)}$ - $V_{W(n)(expected)}) = ±1$ MI maximum.

2. Relative linearity is a measure of the error in step size between taps = $R_{W(n+1)}$ - $(R_{W(n)} + MI) = ±0.2$ MI.

3. 1 MI = minimum increment = $R_{TOT}/31$.

## DC Electrical Specifications    Over recommended operating conditions, unless otherwise stated.

| SYMBOL | PARAMETER | TEST CONDITIONS/NOTES | MIN | TYP (Note 4) | MAX | UNIT |
|--------|-----------|----------------------|-----|--------------|-----|------|
| $I_{CC}$ | $V_{CC}$ Active Current | $\overline{CS}$ = $V_{IL}$, U/$\overline{D}$ = $V_{IL}$ or $V_{IH}$ and $\overline{INC}$ = 0.42/2.4V @ max $t_{CYC}$ | | 1 | 3 | mA |
| $I_{SB}$ | Standby Supply Current | $\overline{CS}$ = $V_{CC}$ - 0.3V, U/$\overline{D}$ and $\overline{INC}$ = $V_{SS}$ or $V_{CC}$ - 0.3V | | 200 | 500 | µA |
| $I_{LI}$ | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input Leakage Current | $V_{IN}$ = $V_{SS}$ to $V_{CC}$ | | | ±10 | µA |
| $V_{IH}$ | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input HIGH Current | | 2 | | | V |
| $V_{IL}$ | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input LOW Current | | | | +0.8 | V |
| $C_{IN}$ (Note 5) | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input Capacitance | $V_{CC}$ = 5V, $V_{IN}$ = $V_{SS}$, $T_A$ = +25°C, f = 1MHz | | 10 | | pF |

## Endurance and Data Retention

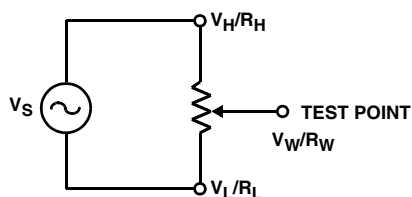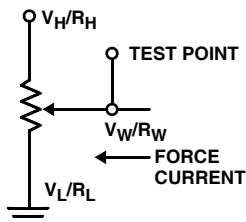| PARAMETER | MIN | UNIT |
|-----------|-----|------|
| Minimum endurance | 100,000 | Data changes per bit per register |
| Data retention | 100 | Years |



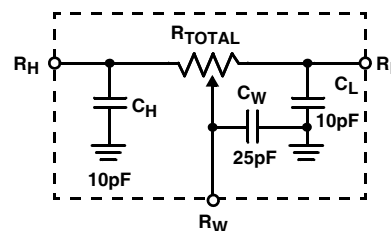FIGURE 1.  TEST CIRCUIT #1



FIGURE 2.  TEST CIRCUIT #2



FIGURE 3.  CIRCUIT #3 SPICE MACRO MODEL

**AC Electrical Specifications**    Over recommended operating conditions, unless otherwise stated.

| SYMBOL | PARAMETER | LIMITS | | | UNIT |
| | | MIN | TYP (Note 4) | 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 | | | µs |
| $t_{IL}$ | $\overline{INC}$ LOW Period | 1 | | | µs |
| $t_{IH}$ | $\overline{INC}$ HIGH Period | 1 | | | µs |
| $t_{IC}$ | $\overline{INC}$ Inactive to $\overline{CS}$ Inactive | 1 | | | µs |
| $t_{CPH}$ | $\overline{CS}$ Deselect Time (STORE) | 20 | | | ms |
| $t_{CPH}$ | $\overline{CS}$ Deselect Time (NO STORE) | 100 | | | ns |
| $t_{IW}$ | $\overline{INC}$ to $V_W$ Change | | 5 | | µs |
| $t_{CYC}$ | $\overline{INC}$ Cycle Time | 2 | | | µs |
| $t_R$, $t_F$ (Note 5) | $\overline{INC}$ Input Rise and Fall Time | | | 500 | µs |
| $t_{PU}$ (Note 5) | Power-up to Wiper Stable | | 10 | | µs |
| $t_R$ $V_{CC}$ (Note 5) | $V_{CC}$ Power-up Rate | 0.2 | | 50 | V/ms |
| $t_{WR}$ (Note 5) | Store Cycle | | 10 | | ms |

NOTES:

4. Typical values are for $T_A$ = +25°C and nominal supply voltage.

5. This parameter is not 100% tested.

## *Power-Up and Power-Down Requirements*

The recommended power-up sequence is to apply $V_{CC}$/$V_{SS}$ first, then the potentiometer voltages. During power-up, the data sheet parameters for the DCP do not fully apply until 1ms after $V_{CC}$ reaches its final value. The $V_{CC}$ ramp specification is always in effect. In order to prevent unwanted tap position changes, or an inadvertent store, bring the $\overline{CS}$ and $\overline{INC}$ high before or concurrently with the VCC pin on power-up.
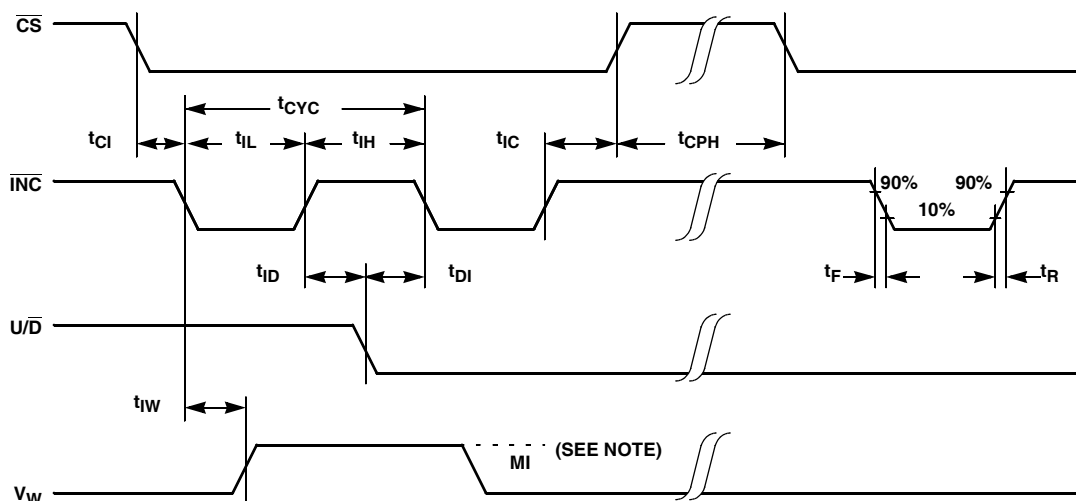


NOTE: MI IN THE AC TIMING DIAGRAM REFERS TO THE MINIMUM INCREMENTAL CHANGE IN THE $V_W$ OUTPUT DUE TO A CHANGE IN THE WIPER POSITION.

**FIGURE 4. AC TIMING DIAGRAM**

## Applications Information

Electronic digitally controlled potentiometers (XDCP) provide three powerful application advantages:

1. The variability and reliability of a solid-state potentiometer.

2. The flexibility of computer-based digital controls.

3. The retentivity of nonvolatile memory used for the storage of multiple potentiometer settings or data.
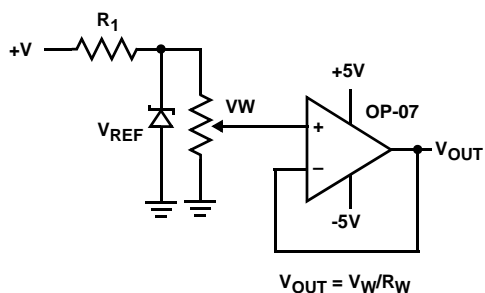
## Basic Configurations of Electronic Potentiometers
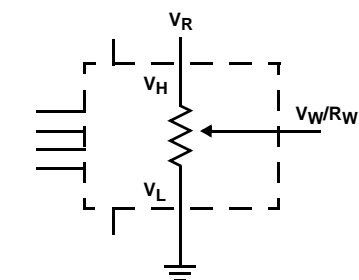


THREE-TERMINAL POTENTIOMETER;
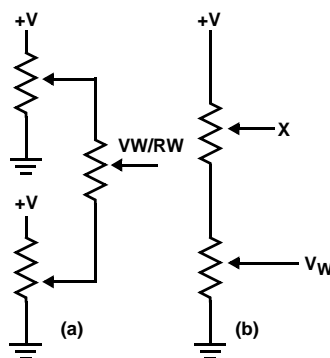VARIABLE VOLTAGE DIVIDER
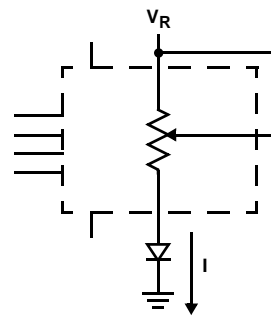
TWO-TERMINAL VARIABLE RESISTOR;
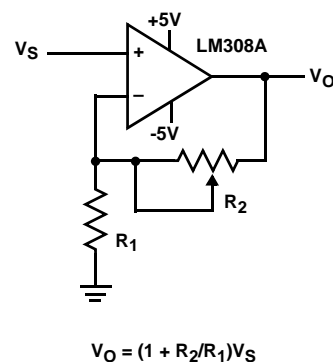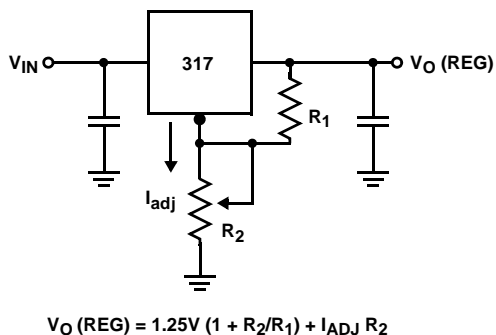VARIABLE CURRENT

## Basic Circuits



BUFFERED REFERENCE VOLTAGE

$V_{OUT} = V_W/R_W$

CASCADING TECHNIQUES

NONINVERTING AMPLIFIER

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

VOLTAGE REGULATOR

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

OFFSET VOLTAGE ADJUSTMENT
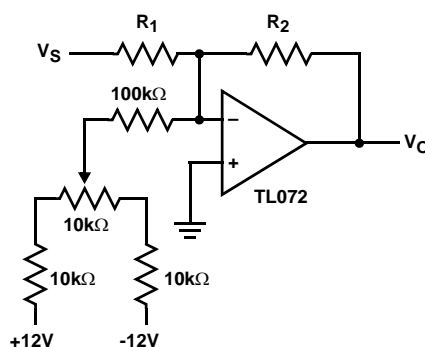
COMPARATOR WITH HYSTERESIS

$V_{UL} = [R_1/(R_1 + R_2)] V_O(max)$
$V_{LL} = [R_1/(R_1 + R_2)] V_O(min)$
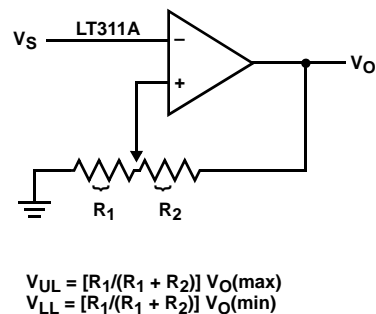
(FOR ADDITIONAL CIRCUITS SEE AN115)

# Mini Small Outline Plastic Packages (MSOP)



**TOP VIEW**

**SIDE VIEW**

**END VIEW**
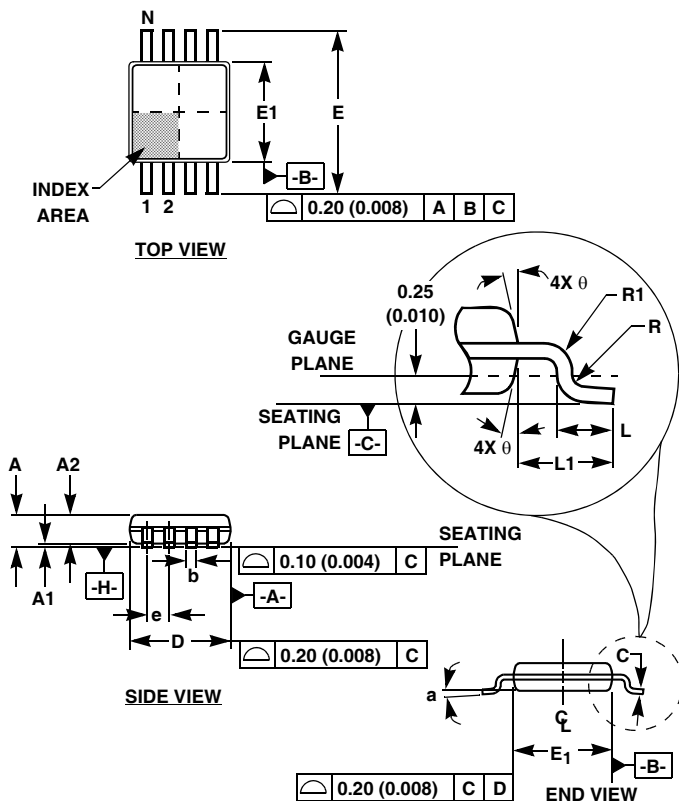
**M8.118 (JEDEC MO-187AA)**
**8 LEAD MINI SMALL OUTLINE PLASTIC PACKAGE**

| SYMBOL | INCHES | | MILLIMETERS | | NOTES |
|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | |
| A | 0.037 | 0.043 | 0.94 | 1.10 | - |
| A1 | 0.002 | 0.006 | 0.05 | 0.15 | - |
| A2 | 0.030 | 0.037 | 0.75 | 0.95 | - |
| b | 0.010 | 0.014 | 0.25 | 0.36 | 9 |
| c | 0.004 | 0.008 | 0.09 | 0.20 | - |
| D | 0.116 | 0.120 | 2.95 | 3.05 | 3 |
| E1 | 0.116 | 0.120 | 2.95 | 3.05 | 4 |
| e | 0.026 BSC | | 0.65 BSC | | - |
| E | 0.187 | 0.199 | 4.75 | 5.05 | - |
| L | 0.016 | 0.028 | 0.40 | 0.70 | 6 |
| L1 | 0.037 REF | | 0.95 REF | | - |
| N | 8 | | 8 | | 7 |
| R | 0.003 | - | 0.07 | - | - |
| R1 | 0.003 | - | 0.07 | - | - |
| 0 | 5° | 15° | 5° | 15° | - |
| α | 0° | 6° | 0° | 6° | - |

Rev. 2 01/03

NOTES:

1. These package dimensions are within allowable dimensions of JEDEC MO-187BA.

2. Dimensioning and tolerancing per ANSI Y14.5M-1994.

3. Dimension "D" does not include mold flash, protrusions or gate burrs and are measured at Datum Plane. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.

4. Dimension "E1" does not include interlead flash or protrusions and are measured at Datum Plane. -H- Interlead flash and protrusions shall not exceed 0.15mm (0.006 inch) per side.

5. Formed leads shall be planar with respect to one another within 0.10mm (0.004) at seating Plane.

6. "L" is the length of terminal for soldering to a substrate.

7. "N" is the number of terminal positions.

8. Terminal numbers are shown for reference only.

9. Dimension "b" does not include dambar protrusion. Allowable dambar protrusion shall be 0.08mm (0.003 inch) total in excess of "b" dimension at maximum material condition. Minimum space between protrusion and adjacent lead is 0.07mm (0.0027 inch).

10. Datums -A- and -B- to be determined at Datum plane -H-.

11. Controlling dimension: MILLIMETER. Converted inch dimensions are for reference only.

## *Small Outline Plastic Packages (SOIC)*
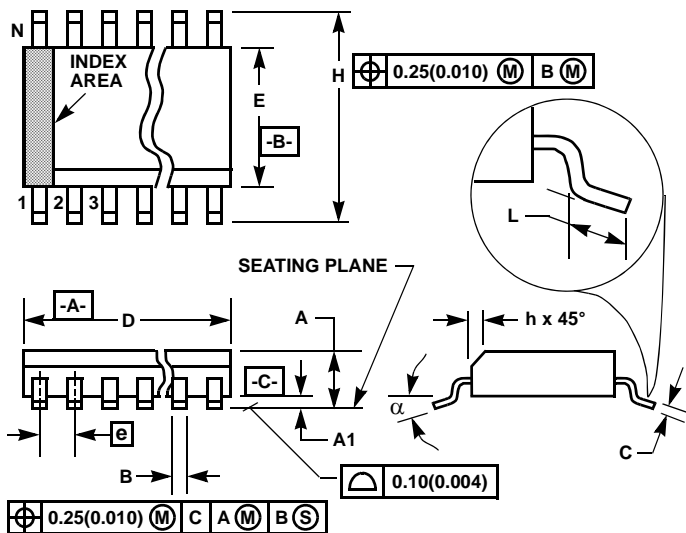


**M8.15** (JEDEC MS-012-AA ISSUE C)
**8 LEAD NARROW BODY SMALL OUTLINE PLASTIC PACKAGE**

| SYMBOL | INCHES | | MILLIMETERS | | NOTES |
|--------|--------|--------|-------------|--------|-------|
| | MIN | MAX | MIN | MAX | |
| A | 0.0532 | 0.0688 | 1.35 | 1.75 | - |
| A1 | 0.0040 | 0.0098 | 0.10 | 0.25 | - |
| B | 0.013 | 0.020 | 0.33 | 0.51 | 9 |
| C | 0.0075 | 0.0098 | 0.19 | 0.25 | - |
| D | 0.1890 | 0.1968 | 4.80 | 5.00 | 3 |
| E | 0.1497 | 0.1574 | 3.80 | 4.00 | 4 |
| e | 0.050 BSC | | 1.27 BSC | | - |
| H | 0.2284 | 0.2440 | 5.80 | 6.20 | - |
| h | 0.0099 | 0.0196 | 0.25 | 0.50 | 5 |
| L | 0.016 | 0.050 | 0.40 | 1.27 | 6 |
| N | 8 | | 8 | | 7 |
| $\alpha$ | 0° | 8° | 0° | 8° | - |

Rev. 1 6/05

NOTES:

1. Symbols are defined in the "MO Series Symbol List" in Section 2.2 of Publication Number 95.

2. Dimensioning and tolerancing per ANSI Y14.5M-1982.

3. Dimension "D" 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.

4. Dimension "E" does not include interlead flash or protrusions. Inter-lead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.

5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.

6. "L" is the length of terminal for soldering to a substrate.

7. "N" is the number of terminal positions.

8. Terminal numbers are shown for reference only.

9. The lead width "B", 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).

10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

## *Small Outline Package Family (SO)*
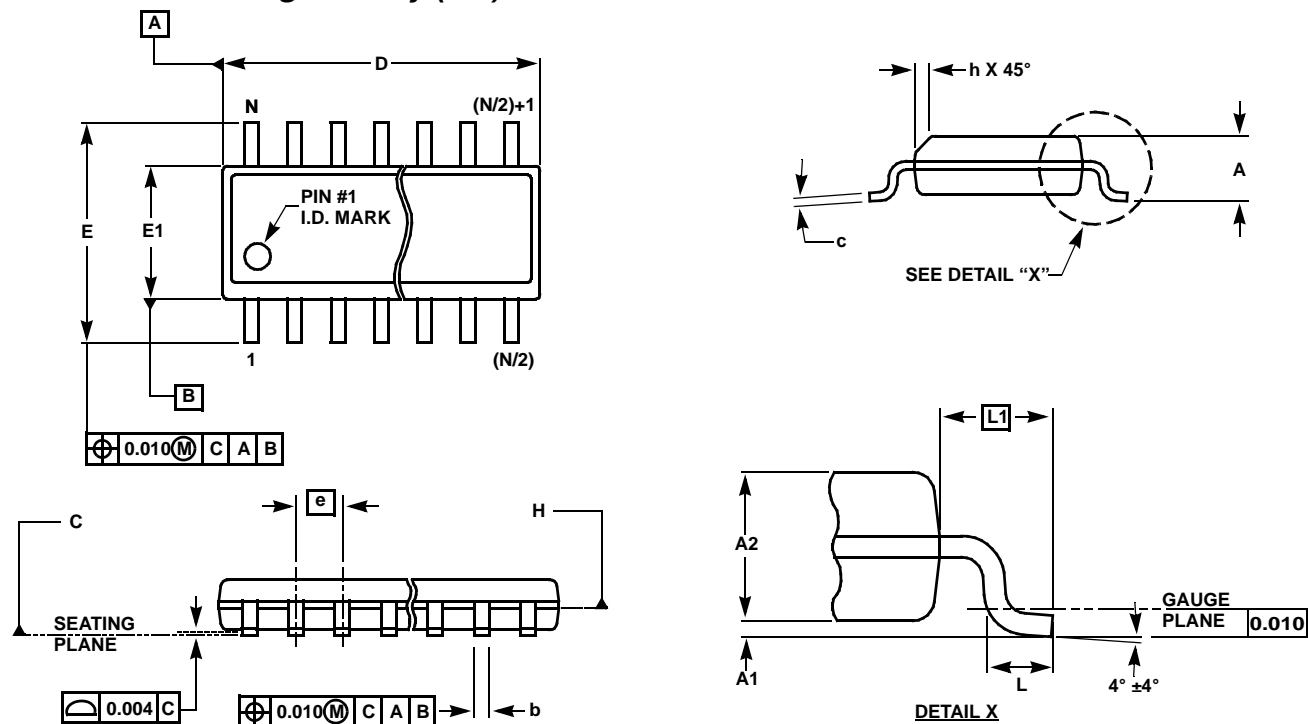


## MDP0027

**SMALL OUTLINE PACKAGE FAMILY (SO)**

| SYMBOL | INCHES | | | | | | | TOLERANCE | NOTES |
|--------|--------|--------|------------------|---------------------------|------------------|------------------|------------------|-----------|-------|
| | SO-8 | SO-14 | SO16 (0.150") | SO16 (0.300") (SOL-16) | SO20 (SOL-20) | SO24 (SOL-24) | SO28 (SOL-28) | | |
| A | 0.068 | 0.068 | 0.068 | 0.104 | 0.104 | 0.104 | 0.104 | MAX | - |
| A1 | 0.006 | 0.006 | 0.006 | 0.007 | 0.007 | 0.007 | 0.007 | ±0.003 | - |
| A2 | 0.057 | 0.057 | 0.057 | 0.092 | 0.092 | 0.092 | 0.092 | ±0.002 | - |
| b | 0.017 | 0.017 | 0.017 | 0.017 | 0.017 | 0.017 | 0.017 | ±0.003 | - |
| c | 0.009 | 0.009 | 0.009 | 0.011 | 0.011 | 0.011 | 0.011 | ±0.001 | - |
| D | 0.193 | 0.341 | 0.390 | 0.406 | 0.504 | 0.606 | 0.704 | ±0.004 | 1, 3 |
| E | 0.236 | 0.236 | 0.236 | 0.406 | 0.406 | 0.406 | 0.406 | ±0.008 | - |
| E1 | 0.154 | 0.154 | 0.154 | 0.295 | 0.295 | 0.295 | 0.295 | ±0.004 | 2, 3 |
| e | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | Basic | - |
| L | 0.025 | 0.025 | 0.025 | 0.030 | 0.030 | 0.030 | 0.030 | ±0.009 | - |
| L1 | 0.041 | 0.041 | 0.041 | 0.056 | 0.056 | 0.056 | 0.056 | Basic | - |
| h | 0.013 | 0.013 | 0.013 | 0.020 | 0.020 | 0.020 | 0.020 | Reference | - |
| N | 8 | 14 | 16 | 16 | 20 | 24 | 28 | Reference | - |

Rev. M 2/07

NOTES:

1. Plastic or metal protrusions of 0.006" maximum per side are not included.

2. Plastic interlead protrusions of 0.010" maximum per side are not included.

3. Dimensions "D" and "E1" are measured at Datum Plane "H".

4. Dimensioning and tolerancing per ASME Y14.5M-1994

## Plastic Dual-In-Line Packages (PDIP)
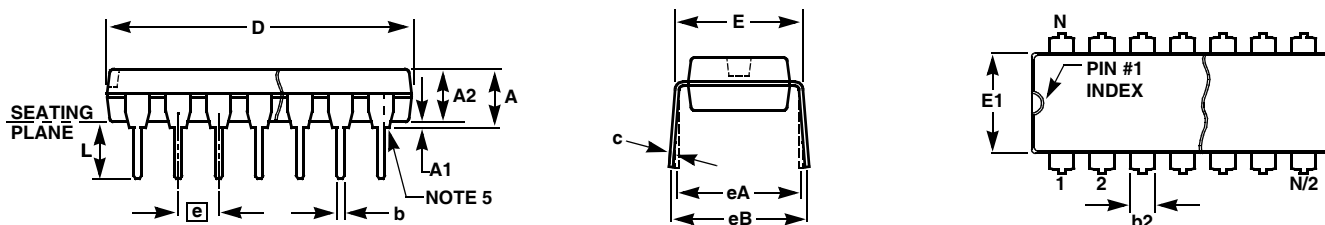


### MDP0031
**PLASTIC DUAL-IN-LINE PACKAGE**

| SYMBOL | INCHES | | | | | TOLERANCE | NOTES |
|---|---|---|---|---|---|---|---|
| | PDIP8 | PDIP14 | PDIP16 | PDIP18 | PDIP20 | | |
| A | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | MAX | |
| A1 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | MIN | |
| A2 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | ±0.005 | |
| b | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | ±0.002 | |
| b2 | 0.060 | 0.060 | 0.060 | 0.060 | 0.060 | +0.010/-0.015 | |
| c | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | +0.004/-0.002 | |
| D | 0.375 | 0.750 | 0.750 | 0.890 | 1.020 | ±0.010 | 1 |
| E | 0.310 | 0.310 | 0.310 | 0.310 | 0.310 | +0.015/-0.010 | |
| E1 | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | ±0.005 | 2 |
| e | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | Basic | |
| eA | 0.300 | 0.300 | 0.300 | 0.300 | 0.300 | Basic | |
| eB | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | ±0.025 | |
| L | 0.125 | 0.125 | 0.125 | 0.125 | 0.125 | ±0.010 | |
| N | 8 | 14 | 16 | 18 | 20 | Reference | |

Rev. C 2/07

NOTES:

1. Plastic or metal protrusions of 0.010" maximum per side are not included.

2. Plastic interlead protrusions of 0.010" maximum per side are not included.

3. Dimensions E and eA are measured with the leads constrained perpendicular to the seating plane.

4. Dimension eB is measured with the lead tips unconstrained.

5. 8 and 16 lead packages have half end-leads as shown.

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