

Dual Digitally Controlled Potentiometers (XDCPs™)

FEATURES

- **Dual solid-state potentiometers**
- **Individual Up/Down interfaces**
- **32 wiper tap points per potentiometer**
 - Wiper position stored in nonvolatile memory and recalled on power-up
- **31 resistive elements per potentiometer**
 - Temperature compensated
 - Maximum resistance tolerance of $\pm 25\%$
 - Terminal voltage, 0 to V_{CC}
- **Low power CMOS**
 - $V_{CC} = 2.7\text{ V} - 5.5\text{ V}$.
 - Active current, $200\mu\text{A}$ typical per potentiometer
 - Standby current, $4\mu\text{A}$ max per potentiometer
- **High reliability**
 - Endurance **200,000** data changes per bit
 - Register data retention, **100 years**
- R_{TOTAL} value = $12.5\text{k}\Omega$, $50\text{k}\Omega$
- **Packages**
 - 14 Ld TSSOP
- **Pb-free plus anneal available (RoHS compliant)**

DESCRIPTION

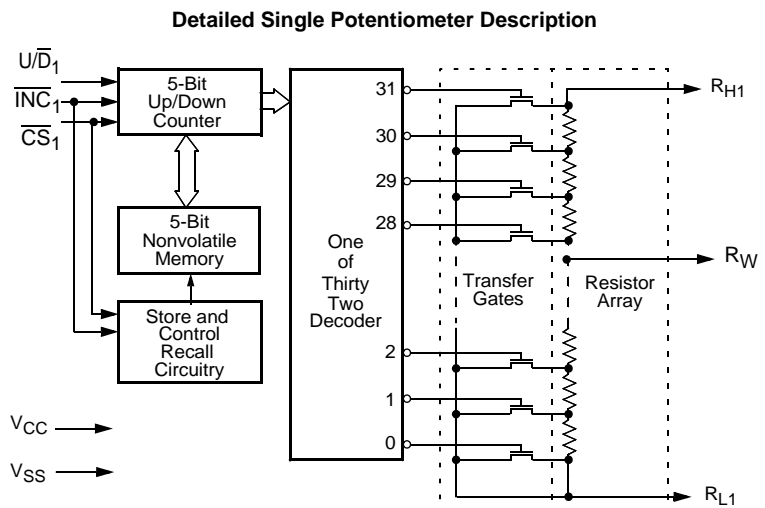
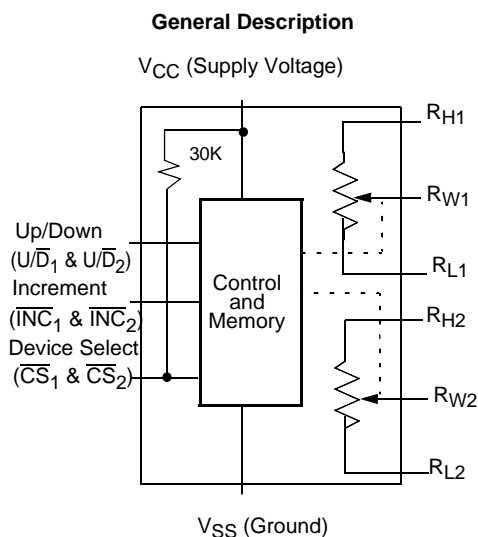
The Intersil X93256 is a dual digitally controlled potentiometer (XDCP). The device consists of two resistor arrays, wiper switches, a control section, and nonvolatile memory. The wiper positions are controlled by individual Up/Down interfaces.

A potentiometer is implemented by a resistor array composed of 31 resistive elements and a wiper switching network. The position of each wiper element is controlled by a set of independent \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.

Each potentiometer is connected as a three-terminal variable resistor and can be used in a wide variety of applications including:

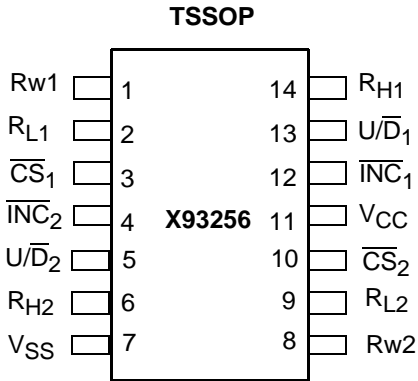
- Bias and Gain Control
- LCD Contrast Adjustment

BLOCK DIAGRAM



X93256

PIN CONFIGURATION



*NC can be left unconnected, or connected to any voltage between V_{SS} and V_{CC}.

Ordering Information

| PART NUMBER | PART MARKING | R _{TOTAL} (kΩ) | TEMPERATURE RANGE (°C) | PACKAGE | PKG. DWG. # |
|-----------------------------|--------------|-------------------------|------------------------|-------------------------------|-------------|
| X93256UV14I-2.7* | X93256UVG | 50 | -40 to 85 | 14 Ld TSSOP (4.4mm) | MDP0044 |
| X93256UV14IZ-2.7* (Note) | X93256UZG | 50 | -40 to 85 | 14 Ld TSSOP (4.4mm) (Pb-free) | MDP0044 |
| X93256WV14I-2.7* | X93256WVG | 12.5 | -40 to 85 | 14 Ld TSSOP (4.4mm) | MDP0044 |
| X93256WV14IZ-2.7* (Note) | X93256WZG | 12.5 | -40 to 85 | 14 Ld TSSOP (4.4mm) (Pb-free) | MDP0044 |

*Add "T1" suffix for tape and reel.

NOTE: Intersil Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are 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.

PIN DESCRIPTIONS

| TSSOP | Symbol | Brief Description |
|-------|--------------------|--|
| 1 | R _{W1} | R _{W1} . The R _{W1} pin of the X93256 is the wiper terminal of the first potentiometer which is equivalent to the movable terminal of a mechanical potentiometer. |
| 2 | R _{L1} | R_{L1} . The R _{H1} and R _{L1} pins of the X93256 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V _{SS} and the maximum is V _{CC} . The terminology of R _{H1} and R _{L1} references the relative position of the terminal in relation to wiper movement direction selected by the U/ \bar{D} input. |
| 3 | \overline{CS}_1 | Chip Select 1 (\overline{CS}_1) . The first potentiometer is selected when the \overline{CS}_1 input is LOW. The current counter value is stored in nonvolatile memory when \overline{CS}_1 is returned HIGH while the \overline{INC}_1 input is also HIGH. After the store operation is complete, the first potentiometer of the X93256 will be placed in the low power standby mode until the first potentiometer is selected once again. |
| 4 | \overline{INC}_2 | Increment 2 (\overline{INC}_2) . The \overline{INC}_2 input is negative-edge triggered. Toggling \overline{INC}_2 will move the wiper of the second potentiometer and either increment or decrement the counter in the direction indicated by the logic level on the U/ \bar{D}_2 input. |
| 5 | U/ \bar{D}_2 | Up/Down 2 (U/\bar{D}_2) . The U/ \bar{D}_2 input controls the direction of the second potentiometer wiper movement and whether the counter for the second potentiometer is incremented or decremented. |
| 6 | R _{H2} | R_{H2} . The R _{H2} and R _{L2} pins of the X93256 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V _{SS} and the maximum is V _{CC} . The terminology of R _{H2} and R _{L2} references the relative position of the wiper terminal for the second potentiometer in relation to the wiper movement direction selected by the U/ \bar{D}_2 input. |
| 7 | V _{SS} | Ground. |
| 8 | R _{W2} | R _{W2} . The R _{W2} pin of the X93256 is the wiper terminal of the second potentiometer which is equivalent to the movable terminal of a mechanical potentiometer. |
| 9 | R _{L2} | R_{L2} . The R _{H2} and R _{L2} pins of the X93256 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V _{SS} and the maximum is V _{CC} . The terminology of R _{H2} and R _{L2} references the relative position of the wiper terminal for the second potentiometer in relation to the wiper movement direction selected by the U/ \bar{D}_2 input. |
| 10 | \overline{CS}_2 | Chip Select 2 (\overline{CS}_2) . The second potentiometer is selected when the \overline{CS}_2 input is LOW. The current counter value is stored in nonvolatile memory when \overline{CS}_2 is returned HIGH while the \overline{INC}_2 input is also HIGH. After the store operation is complete, the second potentiometer of the X93256 will be placed in the low power standby mode until the second potentiometer is selected once again. |
| 11 | V _{CC} | Supply Voltage. |
| 12 | \overline{INC}_1 | Increment 1 (\overline{INC}_1) . The \overline{INC}_1 input is negative-edge triggered. Toggling \overline{INC}_1 will move the wiper of the first potentiometer and either increment or decrement the counter in the direction indicated by the logic level on the U/ \bar{D}_1 input. |
| 13 | U/ \bar{D}_1 | Up/Down 1 (U/\bar{D}_1) . The U/ \bar{D}_1 input controls the direction of the first potentiometer wiper movement and whether the counter for the first potentiometer is incremented or decremented. |
| 14 | R _{H1} | R_{H1} . The R _{H1} and R _{L1} pins of the X93256 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V _{SS} and the maximum is V _{CC} . The terminology of R _{H1} and R _{L1} references the relative position of the wiper terminal for the first potentiometer in relation to the wiper movement direction selected by the U/ \bar{D}_1 input. |

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} , R_H , R_L and V_{CC}
 with respect to V_{SS} -1V to +6.5V
 Lead temperature (soldering 10 seconds) 300°C
 Maximum reflow temperature (40 seconds) 240°C
 Maximum resistor current 2mA

COMMENT

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

RECOMMENDED OPERATING CONDITIONS

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

| Supply Voltage (V_{CC}) | Limits |
|-----------------------------|--------------------------------|
| X93256 | 2.7V \pm 5.5% ⁽⁷⁾ |

POTENTIOMETER CHARACTERISTICS (Over recommended operating conditions unless otherwise stated.)

| Symbol | Parameter | Limits | | | | Test Conditions/Notes |
|---------------|-------------------------------------|--------|----------|-----------|--------------------|---|
| | | Min. | Typ. | Max. | Unit | |
| R_{TOT} | End to end resistance | 9.375 | 12.5 | 15.625 | k Ω | W option (5) |
| | | 37.5 | 50 | 62.5 | k Ω | U option (5) |
| V_R | R_H , R_L terminal voltages | 0 | | V_{CC} | V | (5) |
| | Power rating | | | 1 | mW ⁽⁷⁾ | $R_{TOTAL} = 50k\Omega$ (5) (6) |
| | Noise | | -120 | | dBV ⁽⁷⁾ | Ref: 1kHz (5) (6) |
| R_W | Wiper Resistance | | | 1100 | Ω | (5) (6) |
| I_W | Wiper Current | | | 0.6 | mA | (5) (6) |
| | Resolution | | 3 | | % | (5) |
| | Absolute linearity ⁽¹⁾ | | | ± 1 | MI ⁽³⁾ | $V_{H(n)(actual)} - V_{H(n)(expected)}$ (5) |
| | Relative linearity ⁽²⁾ | | | ± 0.5 | MI ⁽³⁾ | $V_{H(n+1)} - [V_{H(n)} + MI]$ (5) |
| | R_{TOTAL} temperature coefficient | | ± 35 | | ppm/°C | (5) (6) |
| $C_H/C_L/C_W$ | Potentiometer capacitances | | 10/10/25 | | pF ⁽⁶⁾ | See circuit #2 (5) |

- Notes: (1) Absolute linearity is utilized to determine actual wiper voltage versus expected voltage = $(V_{H(n)(actual)} - V_{H(n)(expected)}) = \pm 1$ MI Maximum. n = 1 .. 29 only.
 (2) Relative linearity is a measure of the error in step size between taps = $V_{H(n+1)} - [V_{H(n)} + MI] = \pm 0.5$ MI, n = 1 .. 29 only.
 (3) 1 MI = Minimum Increment = $R_{TOT}/31$.
 (4) Typical values are for $T_A = 25^\circ C$ and nominal supply voltage.
 (5) This parameter only applies to a single potentiometer.
 (6) Typical parameter is guaranteed by characterization.
 (7) When performing multiple write operations, V_{CC} must not decrease by more than 150mV from it's initial value.

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

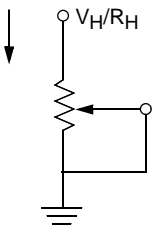
| Symbol | Parameter | Limits | | | Unit | Test Conditions |
|-----------------------------------|--|-----------------------|---------|-----------------------|------|---|
| | | Min. | Typ.(4) | Max. | | |
| I _{CC1} | V _{CC} active current (Increment) | | 50 | 250 | μA | $\overline{CS} = V_{IL}, U/\overline{D} = V_{IL} \text{ or } V_{IH} \text{ and } \overline{INC} = 0.4V @ \text{max. } t_{CYC} V_{CC} = 3V$ |
| | | | 200 | 300 | | $\overline{CS} = V_{IL}, U/\overline{D} = V_{IL} \text{ or } V_{IH} \text{ and } \overline{INC} = 0.4V @ \text{max. } t_{CYC} V_{CC} = 5V$ |
| I _{CC2} | V _{CC} active current (Store) (EEPROM Store) | | | 600 | μA | $\overline{CS} = V_{IH}, U/\overline{D} = V_{IL} \text{ or } V_{IH} \text{ and } \overline{INC} = V_{IH} @ \text{max. } t_{WR} V_{CC} = 3V$ |
| | | | | 1400 | μA | $\overline{CS} = V_{IH}, U/\overline{D} = V_{IL} \text{ or } V_{IH} \text{ and } \overline{INC} = V_{IH} @ \text{max. } t_{WR} V_{CC} = 5V$ |
| I _{SB} | Standby supply current | | | 1 | μA | $\overline{CS} = V_{CC} - 0.3V, U/\overline{D} \text{ and } \overline{INC} = V_{SS} \text{ or } V_{CC} - 0.3V V_{CC} = 3V$ |
| | | | | 4 | μA | $\overline{CS} = V_{CC} - 0.3V, U/\overline{D} \text{ and } \overline{INC} = V_{SS} \text{ or } V_{CC} - 0.3V V_{CC} = 5V$ |
| I _{LI} | CS input leakage current | | | ±1 | μA | V _{IN} = V _{CC} ⁽⁵⁾ |
| I _{LI} | CS input leakage current | 60 | 100 | 150 | μA | V _{CC} = 3V, $\overline{CS} = 0$ ⁽⁵⁾ |
| I _{LI} | CS input leakage current | 120 | 200 | 250 | μA | V _{CC} = 5V, $\overline{CS} = 0$ ⁽⁵⁾ |
| I _{LI} | $\overline{INC}, U/\overline{D}$ input leakage current | | | ±1 | μA | V _{IN} = V _{SS} to V _{CC} ⁽⁵⁾ |
| V _{IH} | $\overline{CS}, \overline{INC}, U/\overline{D}$ input HIGH voltage | V _{CC} x 0.7 | | V _{CC} + 0.5 | V | (5) |
| V _{IL} | $\overline{CS}, \overline{INC}, U/\overline{D}$ input LOW voltage | -0.5 | | V _{CC} x 0.1 | V | (5) |
| C _{IN} ⁽⁵⁾⁽⁷⁾ | $\overline{CS}, \overline{INC}, U/\overline{D}$ input capacitance | | | 10 | pF | V _{CC} = 3V, V _{IN} = V _{SS} , T _A = 25°C, f = 1MHz ⁽⁶⁾ |

ENDURANCE AND DATA RETENTION

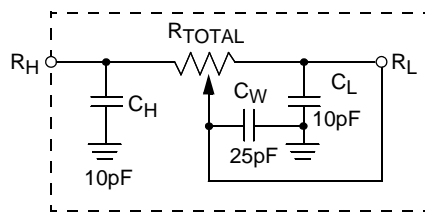
| Parameter | Min. | Unit |
|-------------------|---------|----------------------|
| Minimum endurance | 200,000 | Data changes per bit |
| Data retention | 100 | Years |

Test Circuit #1

Test Point



Circuit #2 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 |

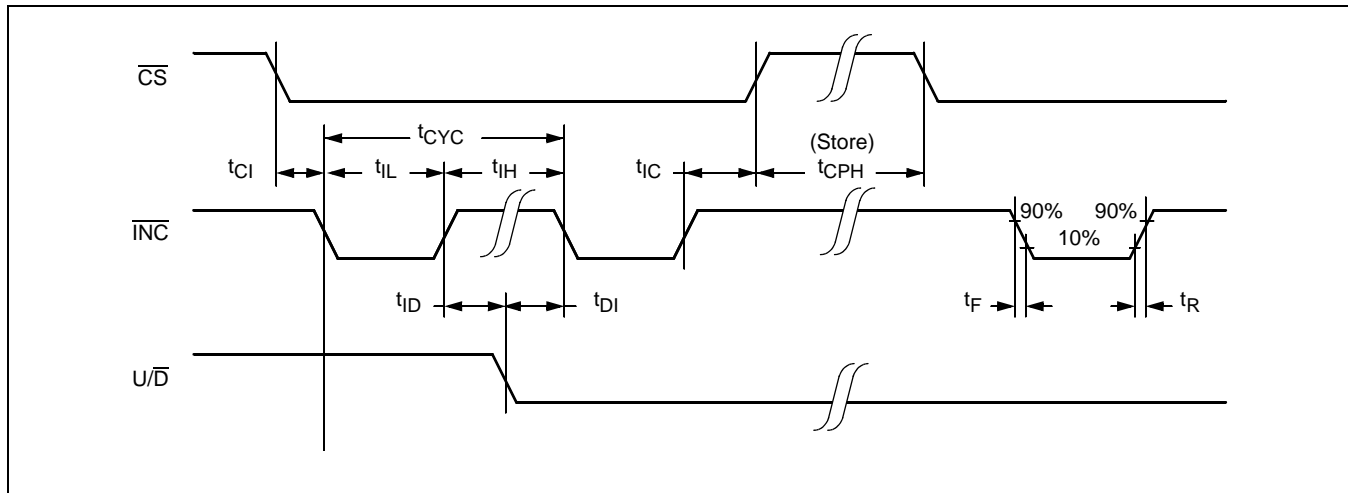
A.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

| Symbol | Parameter | Limits | | | Unit |
|--------------------|---|--------|---------------------|--------|---------|
| | | 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 | 100 | | | ns |
| t_{IL} | \overline{INC} LOW period | 1 | | | μ s |
| t_{IH} | \overline{INC} HIGH period | 1 | | | μ s |
| t_{IC} | \overline{INC} Inactive to \overline{CS} inactive | 1 | | | μ s |
| t_{CPH} | \overline{CS} Deselect time (NO STORE) | 250 | | | ns |
| t_{CPH} | \overline{CS} Deselect time (STORE) | 10 | | | ms |
| t_{CYC} | \overline{INC} cycle time | 2 | | | μ s |
| $t_R, t_F^{(6)}$ | \overline{INC} input rise and fall time | | | 500 | μ s |
| $t_R V_{CC}^{(6)}$ | V_{CC} power-up rate | 0.2 | | 10,000 | V/ms |
| t_{WR} | Store cycle | | 5 | 10 | 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 and V_L , i.e., $V_{CC} \geq V_H, V_L$. The V_{CC} ramp rate spec is always in effect.

A.C. TIMING



PIN DESCRIPTIONS

(In the text, \overline{CS} , \overline{INC} , $\overline{U/D}$, R_H , R_W , and R_L are used to refer to either \overline{CS}_1 or \overline{CS}_2 , etc. Note: These signals can be applied independently or at the same time.)

R_H and R_L

The R_H and R_L pins of the X93256 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V_{SS} and the maximum is V_{CC} . The terminology of R_H and R_L references the relative position of the terminal in relation to wiper movement direction selected by the $\overline{U/D}$ input per potentiometer.

R_W

The R_W pin of the X93256 is the wiper terminal of the potentiometer which is equivalent to the movable terminal of a mechanical potentiometer

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

The $\overline{U/D}$ input controls the direction of a single potentiometer's 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 pertaining potentiometer's counter in the direction indicated by the logic level on the pertaining potentiometer's $\overline{U/D}$ input.

Chip Select (\overline{CS})

A potentiometer is selected when the pertaining \overline{CS} input is LOW. Its current counter value is stored in nonvolatile memory when the pertaining \overline{CS} is returned HIGH while the pertaining \overline{INC} input is also HIGH. After the store operation is complete the affected potentiometer will be placed in the low power standby mode until the potentiometer is selected once again.

PRINCIPLES OF OPERATION

There are multiple sections for each potentiometer in the X93256: an input control, a counter and decode section; the nonvolatile memory; and a resistor array. Each 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. Each 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 connection at that point to the wiper.

Each 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.

If the wiper is moved several positions, multiple taps are connected to the wiper for t_{1W} (INC to V_W change). The 2-terminal resistance value for the device can temporarily change 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 for each potentiometer. When power is restored, the contents of the memory are recalled and each wiper is set to the value last stored.

INSTRUCTIONS AND PROGRAMMING

The \overline{INC} , U/\overline{D} and \overline{CS} inputs control the movement of the pertaining wiper along the resistor array. With \overline{CS} set LOW the pertaining potentiometer 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 five 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 each \overline{CS} transitions HIGH while the pertaining \overline{INC} input is also HIGH. In order to avoid an accidental store during power-up, each \overline{CS} must go HIGH with V_{CC} during initial power-up. When left open, each \overline{CS} pin is internally pulled up to V_{CC} by an internal 30K resistor.

The system may select the X93256, move any 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 recalled the previously stored data. In order to recall the stored position of the wiper on power-up, the \overline{CS} pin must be held HIGH.

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, or other system trim requirements.

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

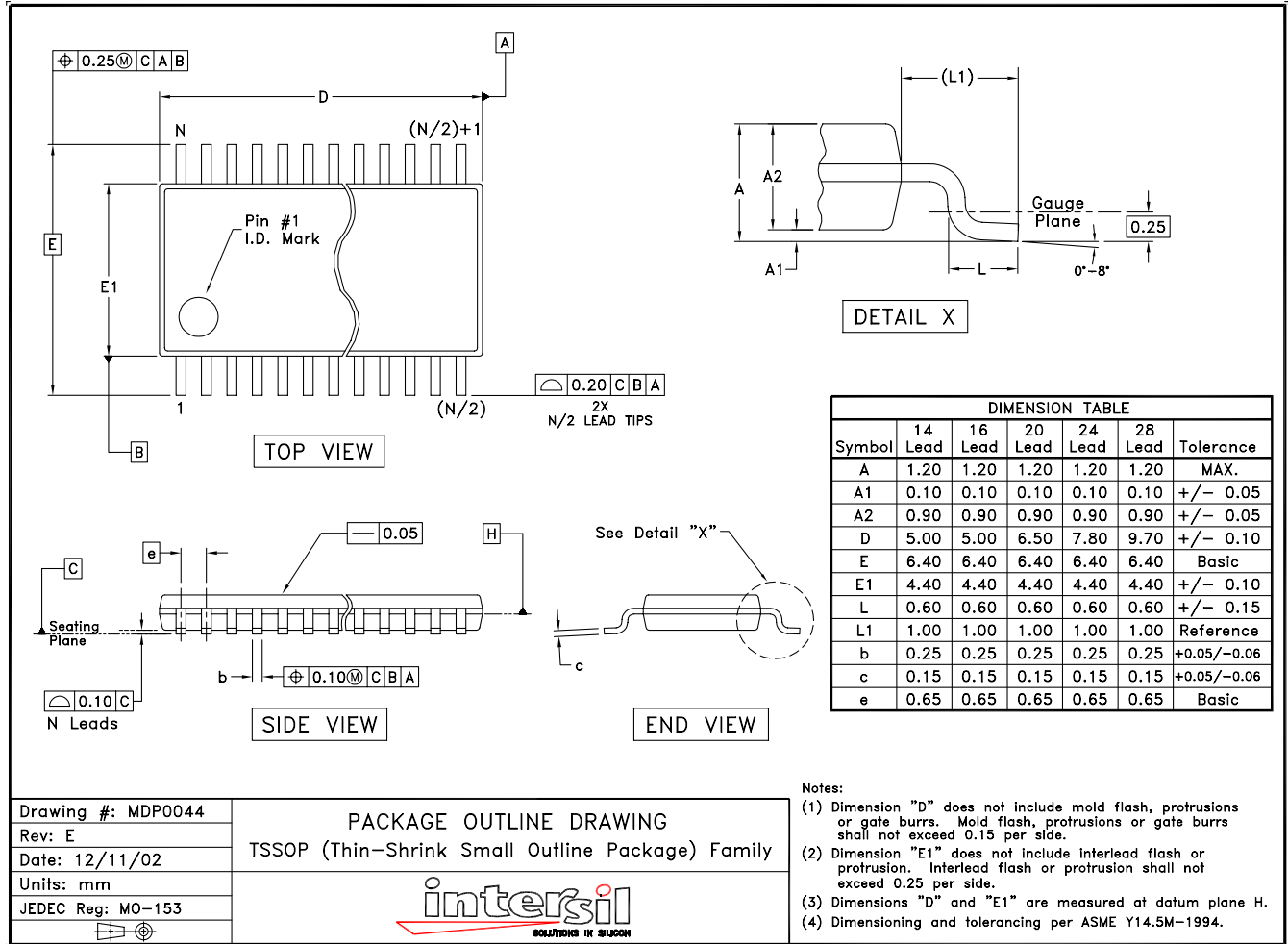
MODE SELECTION

| \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 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 |

Packaging Information



| |
|--------------------|
| Drawing #: MDP0044 |
| Rev: E |
| Date: 12/11/02 |
| Units: mm |
| JEDEC Reg: MO-153 |

PACKAGE OUTLINE DRAWING
TSSOP (Thin-Shrink Small Outline Package) Family

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