**NOT RECOMMENDED FOR NEW DESIGNS**
**NO RECOMMENDED REPLACEMENT**
**contact our Technical Support Center at**
**1-888-INTERSIL or www.intersil.com/tsc**

# X93154

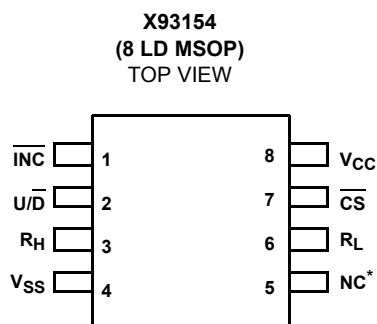Low Noise, Low Power, 32 Taps Digitally Controlled Potentiometer (XDCP™)

The Intersil X93154 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. 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 during a subsequent power-up operation.

The device is connected as a two-terminal variable resistor and can be used in a wide variety of applications including:

- Bias and Gain Control
- LCD Contrast Adjustment

## Pinout

**X93154**
**(8 LD MSOP)**
TOP VIEW

| | | |
|---|---|---|
| $\overline{INC}$ | 1 | 8 $V_{CC}$ |
| U/$\overline{D}$ | 2 | 7 $\overline{CS}$ |
| $R_H$ | 3 | 6 $R_L$ |
| $V_{SS}$ | 4 | 5 NC* |

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

## 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
  - Maximum Resistance Tolerance of ±30%
  - Terminal Voltage, 0 to $V_{CC}$

- Low Power CMOS
  - $V_{CC}$ = 3V ±10%
  - Active Current, 250µA max.
  - Standby Current, 1µA max.

- High Reliability
  - Endurance 200,000 Data Changes per Bit
  - Register Data Retention, 100 years

- $R_{TOTAL}$ Value = 50kΩ

- Package
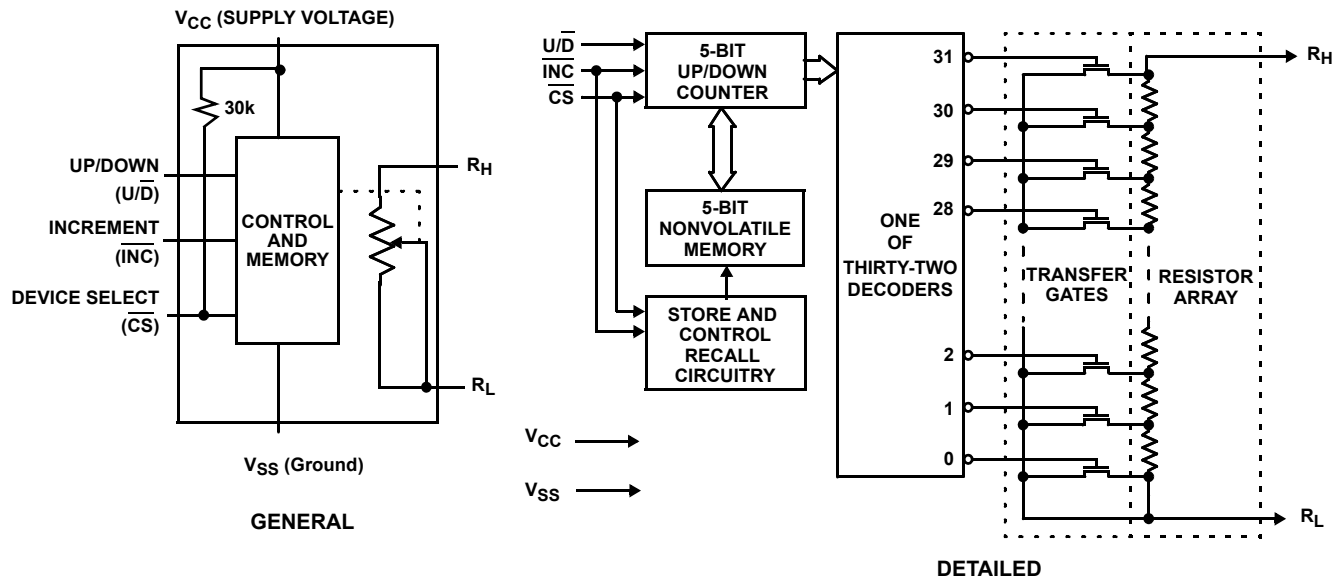  - 8 Ld MSOP

- Pb-free (RoHS Compliant)

## Ordering Information

| PART NUMBER (Notes 1, 2, 3) | PART MARKING | $V_{CC}$ LIMITS (V) | $R_{TOTAL}$ (kΩ) | TEMP RANGE (°C) | PACKAGE (Pb-free) | PKG. DWG. # |
|---|---|---|---|---|---|---|
| X93154UM8IZ-3 | AIW | 3 ±10% | 50 | -40 to +85 | 8 Ld MSOP | M8.118 |

NOTES:

1. Add "T1" 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 product information page for X93154. For more information on MSL, please see tech brief TB363.

## Block Diagram



GENERAL

DETAILED

## Pin Descriptions

| MSOP | SYMBOL | BRIEF DESCRIPTION |
|---|---|---|
| 1 | $\overline{INC}$ | **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. |
| 2 | U/$\overline{D}$ | **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. |
| 3 | $R_H$ | **$R_H$**. The $R_H$ and $R_L$ pins of the X93154 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 U/$\overline{D}$ input. |
| 4 | $V_{SS}$ | Ground. |
| 5 | NC | **No Connection** (or can be connected to any voltage between $V_{SS}$ and $V_{CC}$). |
| 6 | $R_L$ | **$R_L$**. The $R_H$ and $R_L$ pins of the X93154 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 U/$\overline{D}$ input. |
| 7 | $\overline{CS}$ | **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 X93154 will be placed in the low power standby mode until the device is selected once again. |
| 8 | $V_{CC}$ | Supply Voltage. |

## Absolute Maximum Ratings

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
Maximum Resistor Current . . . . . . . . . . . . . . . . . . . . . . . . . . . 2mA

## Thermal Information

Storage Temperature . . . . . . . . . . . . . . . . . . . . . . . . . -65°C to +150°C
Temperature Under Bias . . . . . . . . . . . . . . . . . . . . . . . -65°C to +135°C
Pb-Free Reflow Profile. . . . . . . . . . . . . . . . . . . . . . . . . . . see TB493

## Recommended Operating Conditions

Temperature Range, Industrial. . . . . . . . . . . . . . . . . .-40°C to +85°C
Supply Voltage, $V_{CC}$ . . . . . . . . . . . . . . . . . . . . . . . .3V ±10% (Note 4)

*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.*

NOTE:

4. When performing multiple write operations, $V_{CC}$ must not decrease by more than 150mV from its initial value.

## Potentiometer Specifications    Across recommended operating conditions unless otherwise stated.

| SYMBOL | PARAMETER | TEST CONDITIONS/NOTES | MIN (Note 10) | TYP (Note 8) | MAX (Note 10) | UNIT |
|---|---|---|---|---|---|---|
| $R_{TOT}$ | End-to-End Resistance | | 35 | 50 | 65 | kΩ |
| $V_R$ | $R_H$, $R_L$ Terminal Voltages | | 0 | | $V_{CC}$ | V |
| | Power Rating | $R_{TOTAL}$ = 50kΩ | | | 1 | mW (Note 9) |
| | Noise | Ref: 1kHz | | -120 | | dBV (Note 9) |
| $R_W$ | Wiper Resistance | (Note 9) | | | 1000 | Ω |
| $I_W$ | Wiper Current | (Note 9) | | | 0.6 | mA |
| | Resolution | | | 3 | | % |
| | Absolute Linearity (Note 5) | $V_{H(n)(actual)}$-$V_{H(n)(expected)}$ | | | ±1 | MI (Note 7) |
| | Relative Linearity (Note 6) | $V_{H(n+1)}$-[$V_{H(n)+MI}$] | | | ±0.5 | MI (Note 7) |
| | $R_{TOTAL}$ Temperature Coefficient | (Note 9) | | ±35 | | ppm/°C |
| $C_H$/$C_L$/$C_W$ | Potentiometer Capacitances | See "Circuit #2 SPICE Macro Model" on page 4 | | 10/10/25 | | pF (Note 9) |

## DC Electrical Specifications   Across recommended operating conditions, unless otherwise specified.

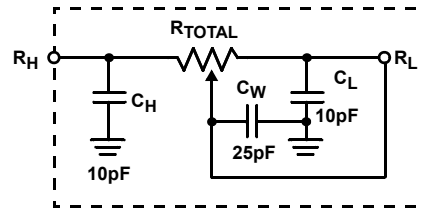| SYMBOL | PARAMETER | TEST CONDITIONS | MIN (Note 10) | TYP (Note 8) | MAX (Note 10) | UNIT |
|---|---|---|---|---|---|---|
| $I_{CC1}$ | $V_{CC}$ Active Current (Increment) | $\overline{CS}$ = $V_{IL}$, U/$\overline{D}$ = $V_{IL}$ or $V_{IH}$ and $\overline{INC}$ = 0.4V at max. $t_{CYC}$ | | 50 | 250 | µA |
| $I_{CC2}$ | $V_{CC}$ Active Current (Store) (EEPROM Store) | $\overline{CS}$ = $V_{IH}$, U/$\overline{D}$ = $V_{IL}$ or $V_{IH}$ and $\overline{INC}$ = $V_{IH}$ at max. $t_{WR}$ | | | 600 | µA |
| $I_{SB}$ | Standby Supply Current | $\overline{CS}$ = $V_{CC}$ - 0.3V, U/$\overline{D}$ and $\overline{INC}$ = $V_{SS}$ or $V_{CC}$ - 0.3V | | | 1 | µA |
| $I_{LI}$ | CS | $V_{IN}$ = $V_{CC}$ | | | ±1 | µA |
| $I_{LI}$ | CS | $V_{CC}$ = 3V, $\overline{CS}$ = 0 | 60 | 100 | 150 | µA |
| $I_{LI}$ | $\overline{INC}$, U/$\overline{D}$ Input Leakage Current | $V_{IN}$ = $V_{SS}$ to $V_{CC}$ | | | ±1 | µA |
| $V_{IH}$ | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input HIGH Voltage | | $V_{CC}$ x 0.7 | | $V_{CC}$ + 0.5 | V |
| $V_{IL}$ | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input LOW Voltage | | -0.5 | | $V_{CC}$ x 0.1 | V |
| $C_{IN}$ (Note 9) | $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input Capacitance | $V_{CC}$ = 3V, $V_{IN}$ = $V_{SS}$, $T_A$ = +25°C, f = 1MHz | | | 10 | pF |

## Endurance and Data Retention

| PARAMETER | MIN | UNIT |
|---|---|---|
| Minimum endurance | 200,000 | Data changes per bit |
| Data retention | 100 | Years |

### *Test Circuit #1*



TEST POINT

$V_H/R_H$
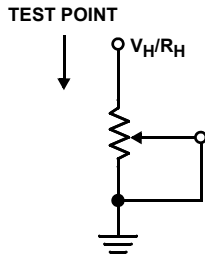
### *Circuit #2 SPICE Macro Model*



### AC Conditions of Test

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

## AC Electrical Specifications  Across recommended operating conditions unless otherwise specified.

| SYMBOL | PARAMETER | MIN (Note 10) | TYP (Note 8) | MAX (Note 10) | UNIT |
|---|---|---|---|---|---|
| $t_{CI}$ | $\overline{CS}$ 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 | | | 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 (No Store) | 250 | | | ns |
| $t_{CPH}$ | $\overline{CS}$ Deselect Time (Store) | 10 | | | ms |
| $t_{CYC}$ | $\overline{INC}$ Cycle Time | 2 | | | µs |
| $t_R$, $t_F$ (Note 9) | $\overline{INC}$ Input Rise and Fall Time | | | 500 | µs |
| $t_R$ $V_{CC}$ (Note 9) | $V_{CC}$ Power-up Rate | 1.0 | | 50 | V/ms |
| $t_{WR}$ | Store Cycle | | 5 | 10 | ms |

NOTES:

5. Absolute linearity is utilized to determine actual wiper voltage versus expected voltage = ($V_{H(n)}$(actual)-$V_{H(n)}$(expected)) = ±1 MI Maximum. n = 1... 29 only.

6. Relative linearity is a measure of the error in step size between taps = $V_{H(n+1)}$-[$V_{H(n)}$ + MI] = ±0.5 MI, n = 1 .. 29 only.

7. 1 MI = Minimum Increment = $R_{TOT}$/31.

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

9. Limits established by characterization and are not production tested.

10. Parts are 100% tested at +25°C. Over-temperature limits established by characterization and are not production tested.

## AC Timing
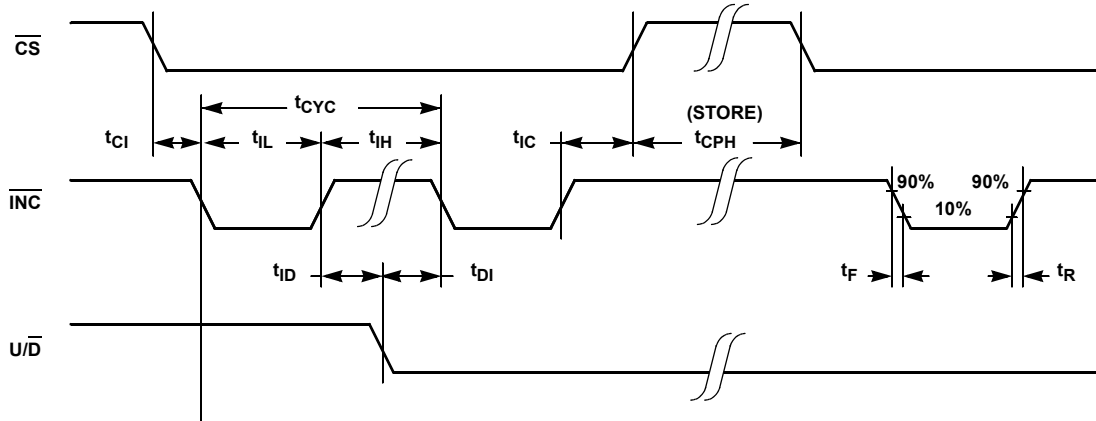


## Power-Up and Power-Down Requirements

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 specification is always in effect.

## Pin Descriptions

### $R_H$ and $R_L$

The $R_H$ and $R_L$ pins of the X93154 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 U/$\overline{D}$ input.

### 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 X93154 will be placed in the low power standby mode until the device is selected once again.

## Pin Names

| SYMBOL | DESCRIPTION |
|--------|-------------|
| $R_H$ | High terminal |
| $R_L$ | Low terminal |
| $V_{SS}$ | Ground |
| $V_{CC}$ | Supply voltage |
| U/$\overline{D}$ | Up/Down control input |
| $\overline{INC}$ | Increment control input |
| $\overline{CS}$ | Chip Select control input |

## Principles of Operation

There are three sections of the X93154: 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 connection 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.

If the wiper is moved several positions, multiple taps are connected to the wiper for $t_{IW}$ (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. 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 $\overline{INC}$, U/$\overline{D}$ 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 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 5-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 $\overline{CS}$ transitions HIGH while the $\overline{INC}$ input is also HIGH. In order to avoid an accidental store during power-up, $\overline{CS}$ must go HIGH with $V_{CC}$ during initial power-up. When performing multiple write operations, $V_{CC}$ must not decrease by more than 150mV from its initial value. When left open, the $\overline{CS}$ pin is internally pulled up to $V_{CC}$ by an internal 30k resistor.

The system may select the X93154, 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 $\overline{INC}$ 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 the wiper up and down until the proper trim is attained.
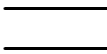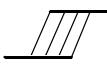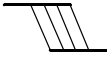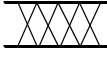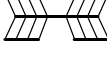
### Mode Selection

| $\overline{CS}$ | $\overline{INC}$ | U/$\overline{D}$ | MODE |
|---|---|---|---|
| L | ╲ | H | Wiper Up |

## Mode Selection

| $\overline{CS}$ | $\overline{INC}$ | U/$\overline{D}$ | MODE |
|---|---|---|---|
| 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 |

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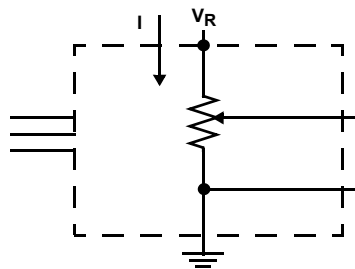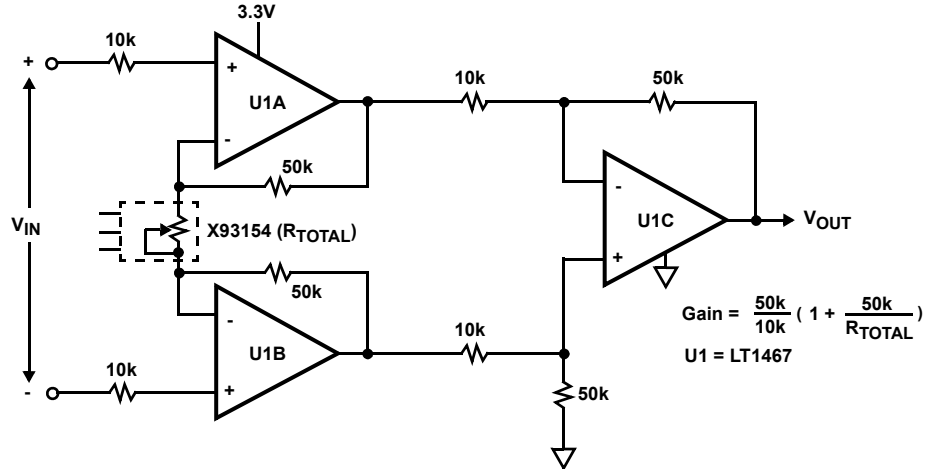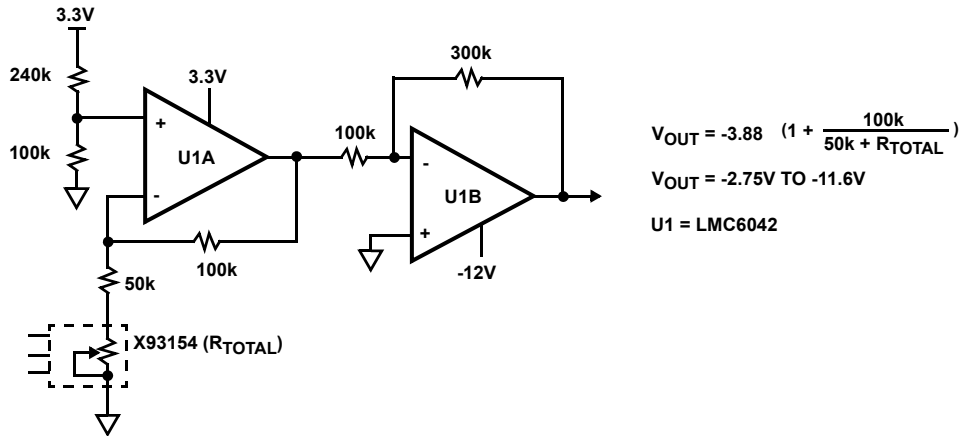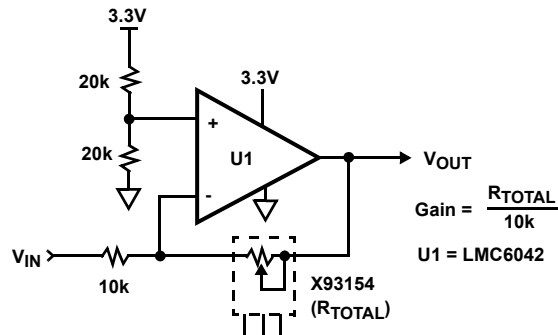


**FIGURE 1. TWO TERMINAL VARIABLE RESISTOR. VARIABLE CURRENT**

## Low Voltage High Impedance Instrumentation Amplifier



$$\text{Gain} = \frac{50k}{10k} \left( 1 + \frac{50k}{R_{TOTAL}} \right)$$

U1 = LT1467

## Micro-Power LCD Contrast Control



$$V_{OUT} = -3.88 \left( 1 + \frac{100k}{50k + R_{TOTAL}} \right)$$

$$V_{OUT} = -2.75V \text{ TO } -11.6V$$

U1 = LMC6042

## Single Supply Variable Gain Amplifier



$$\text{Gain} = \frac{R_{TOTAL}}{10k}$$

U1 = LMC6042

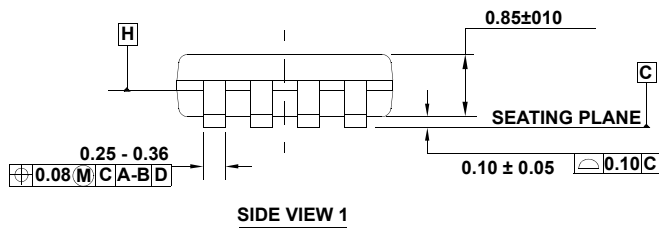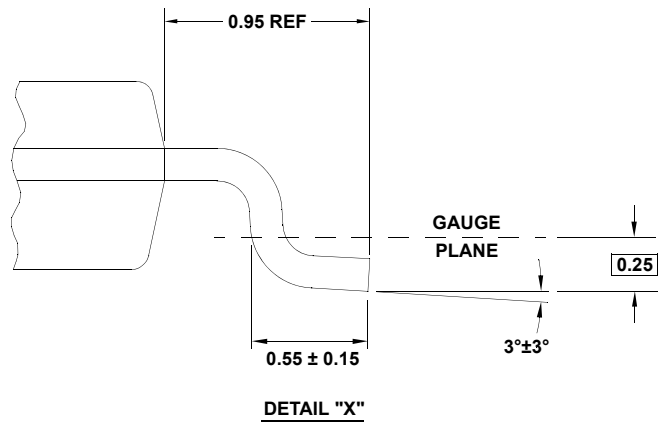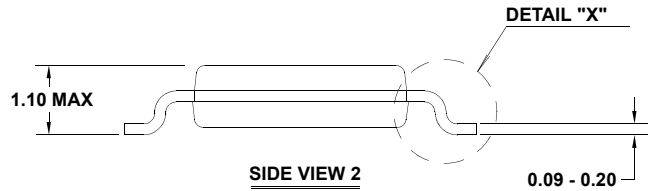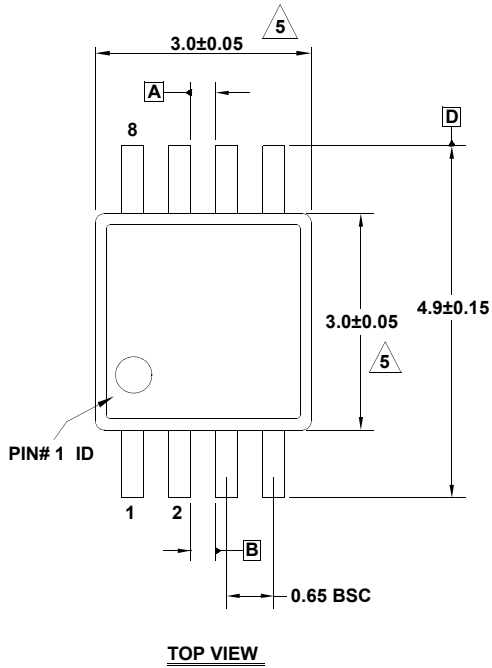For additional products, see www.intersil.com/en/products.html

For information regarding Intersil Corporation and its products, see www.intersil.com

# Package Outline Drawing

## M8.118

**8 LEAD MINI SMALL OUTLINE PLASTIC PACKAGE**

**Rev 4, 7/11**

3.0±0.05

A

8

D

3.0±0.05

4.9±0.15

PIN# 1 ID

1    2

B

0.65 BSC

**TOP VIEW**

1.10 MAX

**SIDE VIEW 2**

DETAIL "X"

0.09 - 0.20

0.95 REF

GAUGE
PLANE

0.25

0.55 ± 0.15

3°±3°

**DETAIL "X"**

H

0.85±010

C

SEATING PLANE

0.25 - 0.36

0.10 ± 0.05    ⌒ 0.10 C

⊕ 0.08 Ⓜ C A-B D

**SIDE VIEW 1**

(5.80)

(4.40)

(3.00)

(0.65)

(0.40)

(1.40)

**TYPICAL RECOMMENDED LAND PATTERN**
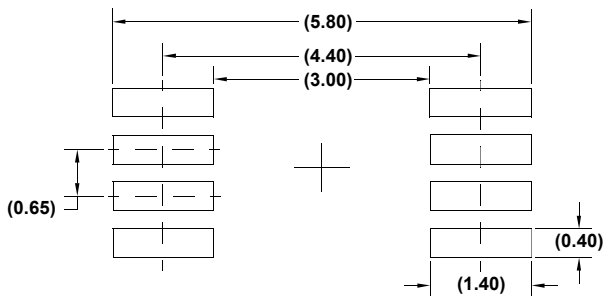
**NOTES:**

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.