



# Low-Power Digital Potentiometers

MAX5160/MAX5161

## General Description

The MAX5160/MAX5161 linear-taper digital potentiometers perform the same function as a mechanical potentiometer or a variable resistor. They consist of a fixed resistor and a wiper contact with 32 tap points that are digitally controlled by three lines for the 8-pin MAX5160 or by two lines for the 6-pin MAX5161.

These parts are ideal for applications requiring digitally controlled resistors. Three resistance values are available for each part type: 50k $\Omega$ , 100k $\Omega$ , and 200k $\Omega$ . A nominal resistor temperature coefficient of 50ppm/ $^{\circ}$ C end-to-end and only 5ppm/ $^{\circ}$ C ratiometric makes the MAX5160 ideal for applications requiring a low-temperature-coefficient variable resistor, such as low-tempco, adjustable-gain circuit configurations.

The MAX5160 is available in an 8-pin  $\mu$ MAX package, and the MAX5161 is available in a 6-pin SOT23 package. Both devices are guaranteed over the extended-industrial temperature range ( $-40^{\circ}$ C to  $+85^{\circ}$ C).

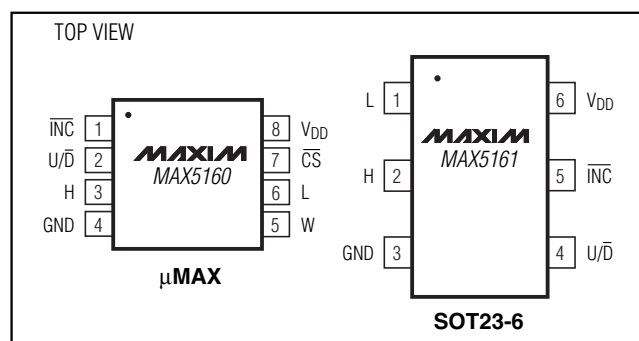
## Applications

LCD Screen Adjustment  
Volume Control  
Mechanical Potentiometer Replacement

## Selector Guide

| PART        | TOP MARK | R (k $\Omega$ ) |
|-------------|----------|-----------------|
| MAX5160NEUA | —        | 200             |
| MAX5160MEUA | —        | 100             |
| MAX5160LEUA | —        | 50              |
| MAX5161NEZT | AAAC     | 200             |
| MAX5161MEZT | AAAB     | 100             |
| MAX5161LEZT | AAAA     | 50              |

## Pin Configurations



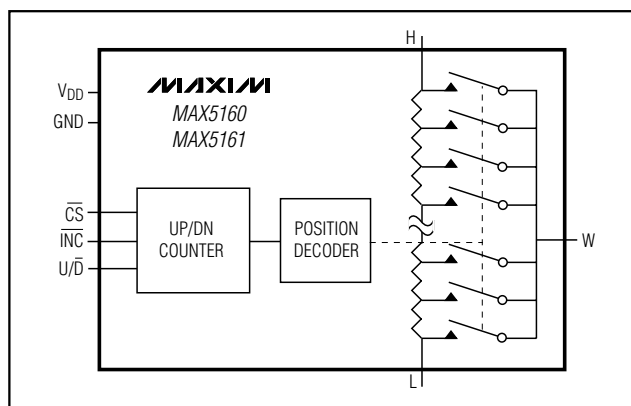
## Features

- ◆ 32 Tap Positions
- ◆ 50k $\Omega$ , 100k $\Omega$ , and 200k $\Omega$  Resistance Values
- ◆ 400 $\Omega$  Wiper Resistance
- ◆  $\pm 25\%$  Resistance Tolerance
- ◆ 3-Wire Serial Data Input
- ◆  $\pm 1$ LSB DNL
- ◆  $\pm 0.5$ LSB INL
- ◆ 100nA Supply Current
- ◆ +2.7V to +5.5V Single-Supply Operation
- ◆ Power-On Reset: Wiper Goes to Midscale (position 16)
- ◆  $\pm 2$ kV ESD Protection
- ◆ Small-Footprint Packages
  - 6-Pin SOT23 (MAX5161)
  - 8-Pin  $\mu$ MAX (MAX5160)
- ◆ Glitchless Switching Between the Resistor Taps

## Ordering Information

| PART        | TEMP. RANGE                        | PIN-PACKAGE | R (k $\Omega$ ) |
|-------------|------------------------------------|-------------|-----------------|
| MAX5160NEUA | $-40^{\circ}$ C to $+85^{\circ}$ C | 8 $\mu$ MAX | 200             |
| MAX5160MEUA | $-40^{\circ}$ C to $+85^{\circ}$ C | 8 $\mu$ MAX | 100             |
| MAX5160LEUA | $-40^{\circ}$ C to $+85^{\circ}$ C | 8 $\mu$ MAX | 50              |
| MAX5161NEZT | $-40^{\circ}$ C to $+85^{\circ}$ C | 6 SOT23     | 200             |
| MAX5161MEZT | $-40^{\circ}$ C to $+85^{\circ}$ C | 6 SOT23     | 100             |
| MAX5161LEZT | $-40^{\circ}$ C to $+85^{\circ}$ C | 6 SOT23     | 50              |

## Functional Diagram



# Low-Power Digital Potentiometers

## ABSOLUTE MAXIMUM RATINGS

|                                                                    |                             |
|--------------------------------------------------------------------|-----------------------------|
| $V_{DD}$ to GND .....                                              | -0.3V to +6V                |
| $\overline{CS}$ , $\overline{INC}$ , $U/\overline{D}$ to GND ..... | -0.3V to +6V                |
| H, L, W to GND .....                                               | -0.3V to ( $V_{DD}$ + 0.3V) |
| Input and Output Latchup Immunity .....                            | $\pm 200$ mA                |
| Maximum Continuous Current into H, L, and W<br>MAX516__E__ .....   | $\pm 1$ mA                  |

|                                                                                         |                                             |
|-----------------------------------------------------------------------------------------|---------------------------------------------|
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )                              |                                             |
| 6-Pin SOT23 (derate 6.25mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) .....          | 500mW                                       |
| 8-Pin $\mu\text{MAX}$ (derate 4.1mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) ..... | 330mW                                       |
| Operating Temperature Range .....                                                       | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |
| Storage Temperature Range .....                                                         | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temperature (soldering, 10s) .....                                                 | $+300^\circ\text{C}$                        |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

( $V_{DD} = +2.7\text{V}$  to  $+5.5\text{V}$ ,  $V_H = V_{DD}$ ,  $V_L = 0$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ . Typical values are at  $V_{DD} = +5\text{V}$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                                                    | SYMBOL            | CONDITIONS                                                                                                  |                         | MIN                   | TYP  | MAX  | UNITS  |
|--------------------------------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|------|------|--------|
| DC PERFORMANCE                                               |                   |                                                                                                             |                         |                       |      |      |        |
| Resolution                                                   |                   |                                                                                                             |                         | 3                     |      |      | %      |
| Integral Nonlinearity (Note 1)                               | INL               |                                                                                                             |                         | ±1/2                  |      |      | LSB    |
| Differential Nonlinearity (Note 1)                           | DNL               |                                                                                                             |                         | ±1                    |      |      | LSB    |
| End-to-End Resistor Tempco                                   | TCR               |                                                                                                             |                         | 50                    |      |      | ppm/°C |
| Ratiometric Resistor Tempco                                  |                   |                                                                                                             |                         | 5                     |      |      | ppm/°C |
| Full-Scale Error                                             |                   |                                                                                                             |                         | -0.1                  |      |      | LSB    |
| Zero-Scale Error                                             |                   |                                                                                                             |                         | +0.1                  |      |      | LSB    |
| Wiper Resistance                                             | R <sub>W</sub>    |                                                                                                             |                         | 400                   | 1700 |      | Ω      |
| Wiper Capacitance                                            | C <sub>W</sub>    |                                                                                                             |                         | 10                    |      |      | pF     |
| End-to-End Resistance                                        | HL                | MAX516_NE__                                                                                                 |                         | 150                   | 200  | 250  | kΩ     |
|                                                              |                   | MAX516_ME__                                                                                                 |                         | 75                    | 100  | 125  |        |
|                                                              |                   | MAX516_LE__                                                                                                 |                         | 37.5                  | 50   | 62.5 |        |
| DIGITAL INPUTS                                               |                   |                                                                                                             |                         |                       |      |      |        |
| Input High Voltage                                           | V <sub>IH</sub>   |                                                                                                             |                         | 0.7 × V <sub>DD</sub> |      |      | V      |
| Input Low Voltage                                            | V <sub>IL</sub>   |                                                                                                             |                         | 0.3 × V <sub>DD</sub> |      |      | V      |
| Input Leakage Current                                        |                   |                                                                                                             |                         | ±1                    |      |      | μA     |
| Input Capacitance                                            |                   |                                                                                                             |                         | 5                     |      |      | pF     |
| TIMING CHARACTERISTICS (Figure 6)                            |                   |                                                                                                             |                         |                       |      |      |        |
| $\overline{\text{CS}}$ to $\overline{\text{INC}}$ Setup Time | t <sub>CI</sub>   |                                                                                                             |                         | 25                    |      |      | ns     |
| $\overline{\text{CS}}$ to $\overline{\text{INC}}$ Hold Time  | t <sub>IC</sub>   |                                                                                                             |                         | 0                     |      |      | ns     |
| $\overline{\text{INC}}$ Low Period                           | t <sub>IL</sub>   |                                                                                                             |                         | 25                    |      |      | ns     |
| $\overline{\text{INC}}$ High Period                          | t <sub>IH</sub>   |                                                                                                             |                         | 25                    |      |      | ns     |
| U/ $\overline{\text{D}}$ to $\overline{\text{INC}}$ Hold     | t <sub>ID</sub>   |                                                                                                             |                         | 0                     |      |      | ns     |
| U/ $\overline{\text{D}}$ to $\overline{\text{INC}}$ Setup    | t <sub>DI</sub>   |                                                                                                             |                         | 50                    |      |      | ns     |
| Wiper-Settling Time                                          | t <sub>IW</sub>   |                                                                                                             |                         | 1                     |      |      | μs     |
| $\overline{\text{INC}}$ Frequency                            | f <sub>IMAX</sub> |                                                                                                             |                         | 7                     |      |      | MHz    |
| POWER SUPPLIES                                               |                   |                                                                                                             |                         |                       |      |      |        |
| Supply Voltage                                               | V <sub>DD</sub>   |                                                                                                             |                         | 2.7                   |      | 5.5  | V      |
| Supply Current                                               | I <sub>DD</sub>   | $\overline{\text{CS}} = \overline{\text{INC}} = \text{U}/\overline{\text{D}} = \text{V}_{\text{DD}}$ or GND | V <sub>DD</sub> = +5V   | 0.6                   | 10   |      | μA     |
|                                                              |                   |                                                                                                             | V <sub>DD</sub> = +2.7V | 135                   |      |      | nA     |

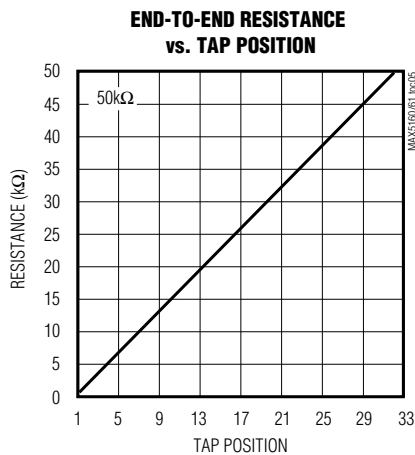
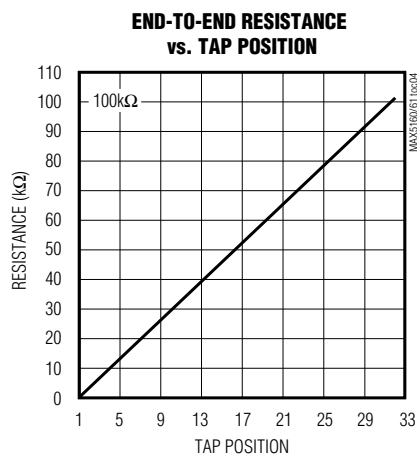
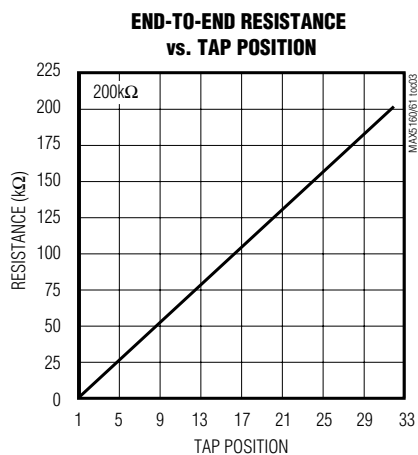
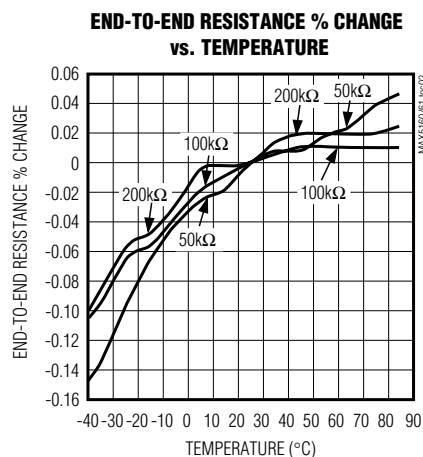
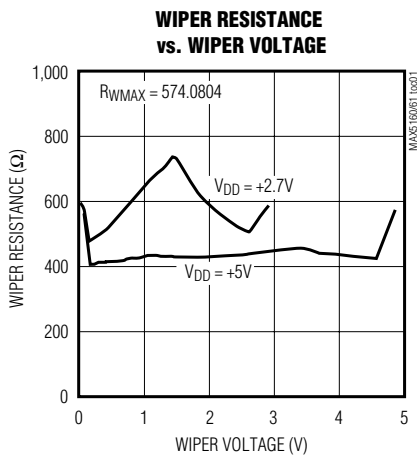
**Note 1:** For the MAX5160, linearity is defined in terms of H to L code-dependent resistance.

# Low-Power Digital Potentiometers

## Typical Operating Characteristics

( $V_{DD} = +5V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

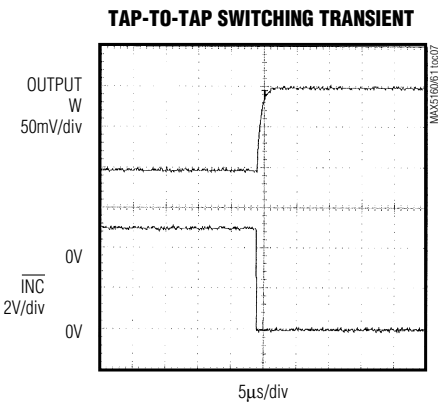
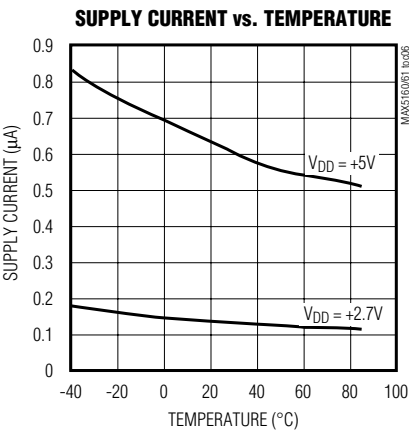
MAX5160/MAX5161



# Low-Power Digital Potentiometers

## Typical Operating Characteristics (continued)

(V<sub>DD</sub> = +5V, T<sub>A</sub> = +25°C, unless otherwise noted.)



## Pin Description

| PIN     |         | NAME                           | FUNCTION                                                                                                                                                                                                                           |
|---------|---------|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAX5160 | MAX5161 |                                |                                                                                                                                                                                                                                    |
| 1       | 5       | $\overline{\text{INC}}$        | Wiper Increment Control Input. With $\overline{\text{CS}}$ low, a high-to-low transition increments ( $\text{U}/\overline{\text{D}}$ high) or decrements ( $\text{U}/\overline{\text{D}}$ low) the wiper position.                 |
| 2       | 4       | $\text{U}/\overline{\text{D}}$ | Up/Down Control Input. With $\overline{\text{CS}}$ low, a high-to-low $\overline{\text{INC}}$ transition increments ( $\text{U}/\overline{\text{D}}$ high) or decrements ( $\text{U}/\overline{\text{D}}$ low) the wiper position. |
| 3       | 2       | H                              | High Terminal of Resistor                                                                                                                                                                                                          |
| 4       | 3       | GND                            | Ground                                                                                                                                                                                                                             |
| 5       | —       | W                              | Wiper Terminal of Resistor                                                                                                                                                                                                         |
| 6       | 1       | L                              | Low Terminal of Resistor                                                                                                                                                                                                           |
| 7       | —       | $\overline{\text{CS}}$         | Chip-Select Input. Drive low to change the wiper position through $\overline{\text{INC}}$ and $\text{U}/\overline{\text{D}}$ .                                                                                                     |
| 8       | 6       | V <sub>DD</sub>                | Power Supply                                                                                                                                                                                                                       |



# Low-Power Digital Potentiometers

## Alternative Positive LCD Bias Control

Alternatively, use an op amp to provide buffering and gain to the output of the MAX5160/MAX5161. Connect the MAX5160 to the positive input of a noninverting op amp (Figure 3) to select a portion of the input signal by digitally controlling the wiper terminal. Figure 4 shows a similar circuit for the MAX5161.

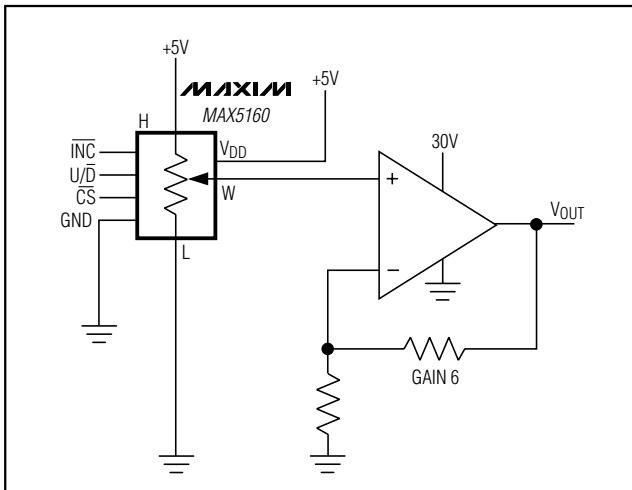


Figure 3. MAX5160 Positive LCD Bias Control

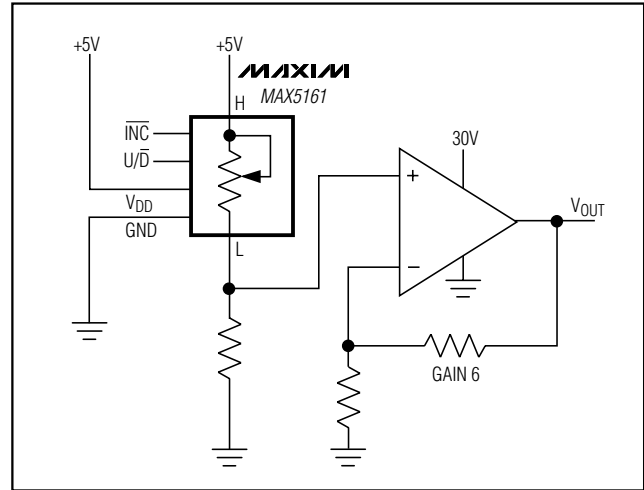


Figure 4. MAX5161 Positive LCD Bias Control

## Adjustable Gain

Figure 5 shows how to use the MAX5161 to digitally adjust the gain of a noninverting op amp configuration. Connect the MAX5161 in series with a resistor to ground to form the adjustable gain control of a noninverting amplifier. The MAX5160/MAX5161 have a low 5ppm/°C ratiometric tempco that allows for a very stable adjustable gain configuration over temperature.

## Serial Interface

Figure 6 is the serial-interface timing diagram.

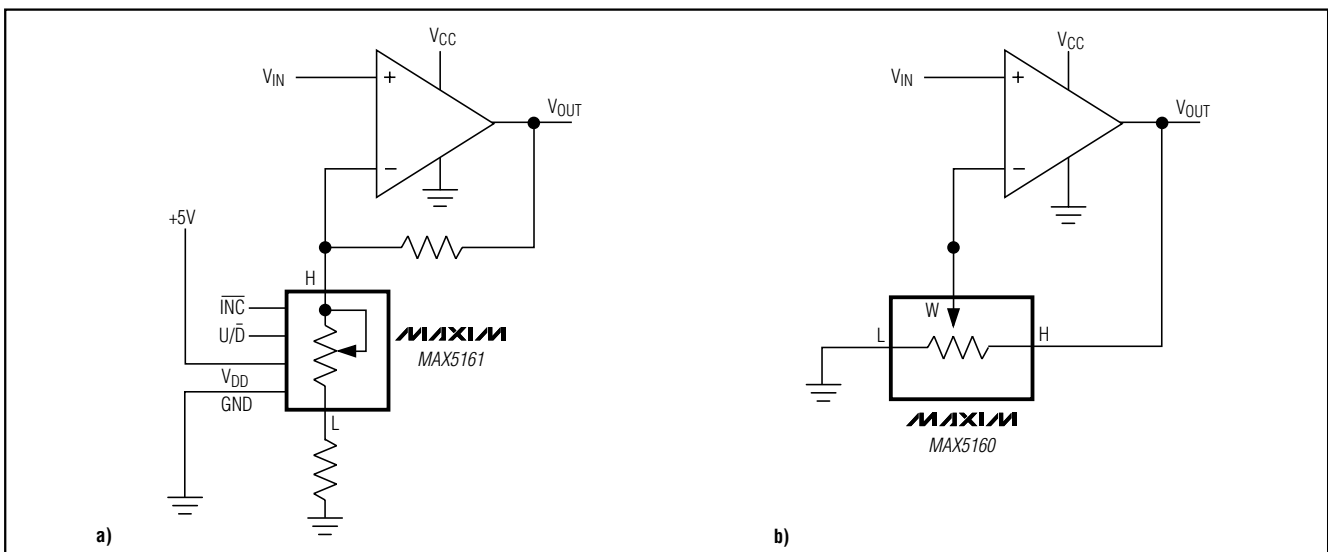


Figure 5. Adjustable Gain Circuit: a) MAX5161; b) MAX5160

# Low-Power Digital Potentiometers

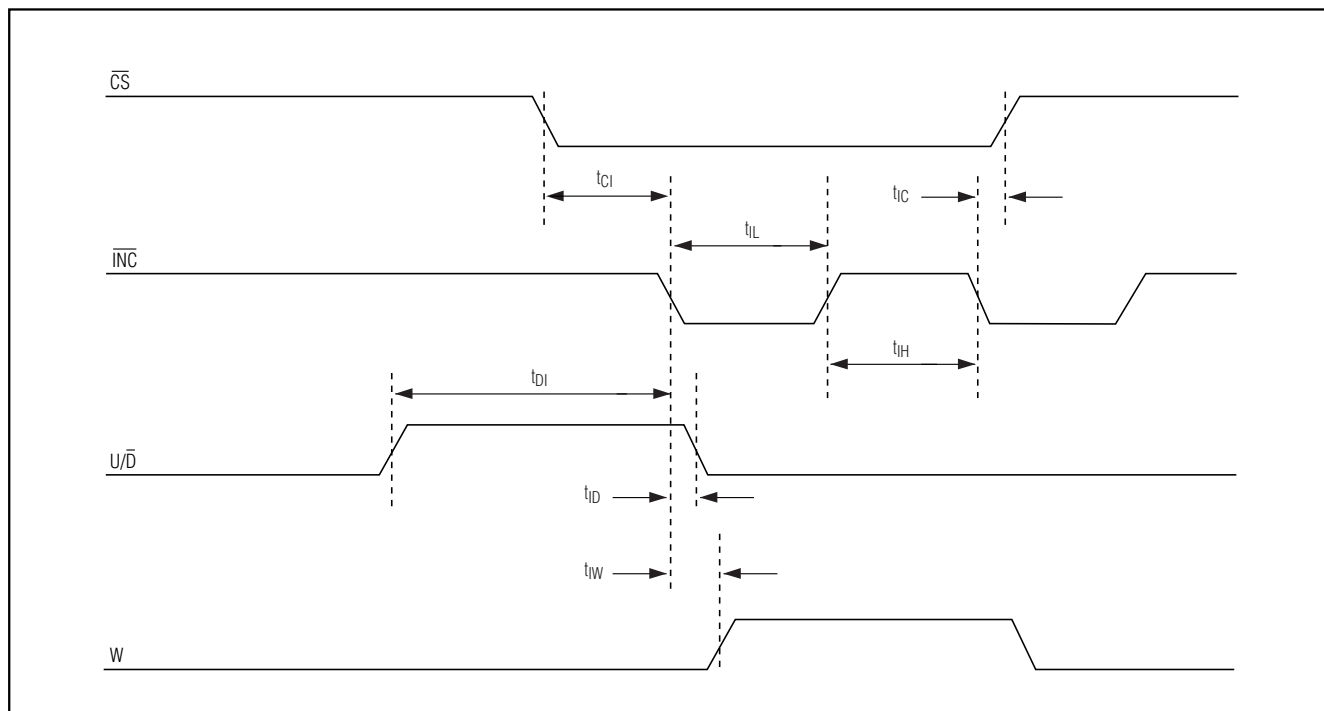


Figure 6. Serial-Interface Timing Diagram

## Truth Table

| $\overline{CS}$ | $U/\overline{D}$ | $\overline{INC}$ | $R_W$ |
|-----------------|------------------|------------------|-------|
| H               | xx-X             | X                | O     |
| L               | L                | ↑                | O     |
| L               | H                | ↑                | O     |
| L               | L                | ↓                | —     |
| L               | H                | ↓                | +     |

X = Don't care

O = Previous state

+ = Increment

— = Decrement

↓ = High-to-Low Transition

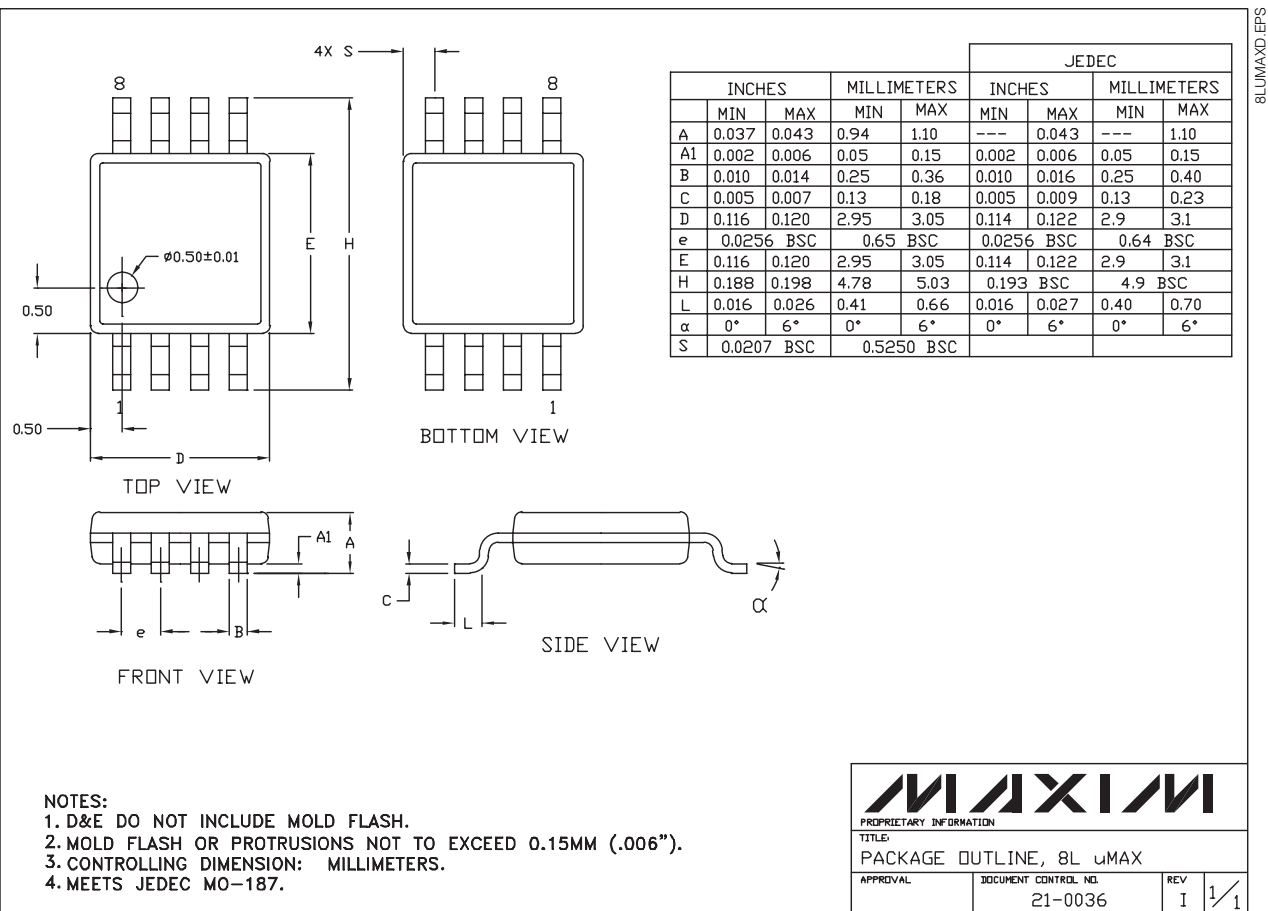
↑ = Low-to-High Transition

## Chip Information

TRANSISTOR COUNT: 969

# Low-Power Digital Potentiometers

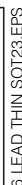
## Package Information





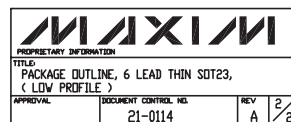
# MAX5160/MAX5161

## S LEAD THIN SOT23 EPS



1. ALL DIMENSIONS ARE IN MILLIMETERS.

- | SYMBOLS |          |       |      |
|---------|----------|-------|------|
|         | MIN      | NOM   | MAX  |
| A       | —        | —     | 1.10 |
| A1      | 0.05     | 0.075 | 0.10 |
| A2      | 0.85     | 0.88  | 0.90 |
| A3      | 0.50 BSC |       |      |
| b       | 0.30     | —     | 0.45 |
| b1      | 0.25     | 0.35  | 0.40 |
| c       | 0.15     | —     | 0.20 |
| c1      | 0.12     | 0.127 | 0.15 |
| D       | 2.80     | 2.90  | 3.00 |
| E       | 2.75 BSC |       |      |
| E1      | 1.55     | 1.60  | 1.65 |
| L       | 0.30     | 0.40  | 0.50 |
| e1      | 1.90 BSC |       |      |
| e       | 0.95 BSC |       |      |
| OC      | 0°       | 4°    | 8°   |
| aaa     | 0.20     |       |      |



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