



# ±15V, 128-Tap, Low-Drift Digital Potentiometers

## General Description

The MAX5436–MAX5439 are 128-tap high-voltage ( $\pm 5V$  to  $\pm 15V$ ) digital potentiometers in packages that are half the size of comparable devices in 8-pin SO. They perform the same function as mechanical potentiometers, but replace the mechanics with a simple digital interface. The digital logic is powered by a separate single +2.7V to +5.25V supply voltage ( $V_{CC}$ ). The resistor string uses its own analog supplies ( $V_{DD}$  and  $V_{SS}$ ) that require  $V_{DD} - V_{SS}$  to be greater than 9V and less than 31.5V. This allows for greater flexibility in voltage ranges that can be used with these devices. Examples of analog supply ranges include not only dual voltages of  $\pm 5V$  to  $\pm 15V$ , but single-supply voltages, such as +10V, +15V, +30V, -30V, and more, as long as the ranges of  $V_{DD} - V_{SS}$  and  $V_{CC} - V_{SS}$  are met.

The MAX5437/MAX5439 include an on-chip, high-voltage, uncommitted amplifier, providing additional reductions in board space and cost. Other features include low 35ppm/°C end-to-end and 5ppm/°C ratio-metric resistor temperature coefficients, a 3-wire SPI™/QSPI™/MICROWIRE™-compatible serial interface, and a power-on reset to midscale.

The MAX5436/MAX5438 are available in 10-pin  $\mu$ MAX packages. The MAX5437/MAX5439 are available in 14-pin TSSOP package. Each device is guaranteed over the extended temperature range of -40°C to +85°C.

## Applications

LCD Screen Contrast Adjustment  
Data-Acquisition Systems  
Mechanical Potentiometer Replacement  
Low-Drift Programmable Gain Amplifier  
Audio Volume Control

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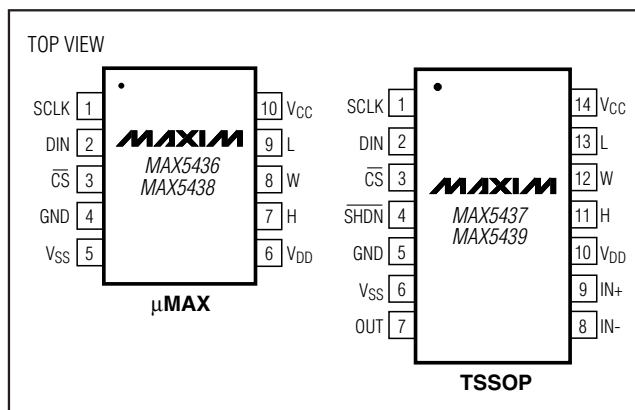
## Features

- ◆ +10V to +30V Single-Supply Operation
- ◆ -28V to -10V Single Negative Supply Operation
- ◆  $\pm 5V$  to  $\pm 15V$  Dual-Supply Operation
- ◆ 128 Tap Positions
- ◆ Uncommitted High-Voltage Amplifier (MAX5437/MAX5439)
- ◆ Low Temperature Coefficient  
35ppm/°C (End-to-End)  
5ppm/°C (Ratiometric)
- ◆ Small-Footprint Packages  
10-Pin  $\mu$ MAX (MAX5436/MAX5438)  
14-Pin TSSOP (MAX5437/MAX5439)
- ◆ Glitchless Switching Between the Resistor Taps
- ◆ 3-Wire SPI/QSPI/MICROWIRE-Compatible Serial Interface
- ◆ 50k $\Omega$ /100k $\Omega$  End-to-End Resistances
- ◆ Power-On Reset: Wiper Goes to Midscale (Position 64)

## Ordering Information

| PART       | TEMP RANGE     | PIN- PACKAGE | RESISTANCE (k $\Omega$ ) |
|------------|----------------|--------------|--------------------------|
| MAX5436EUB | -40°C to +85°C | 10 $\mu$ MAX | 50                       |
| MAX5437EUD | -40°C to +85°C | 14 TSSOP     | 50                       |
| MAX5438EUB | -40°C to +85°C | 10 $\mu$ MAX | 100                      |
| MAX5439EUD | -40°C to +85°C | 14 TSSOP     | 100                      |

## Pin Configurations



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## ABSOLUTE MAXIMUM RATINGS

|                                               |                                                      |
|-----------------------------------------------|------------------------------------------------------|
| V <sub>DD</sub> to GND, V <sub>SS</sub> = GND | -0.3V to +34V                                        |
| V <sub>SS</sub> to GND, V <sub>DD</sub> = GND | -34V to +0.3V                                        |
| V <sub>DD</sub> to V <sub>SS</sub>            | -0.3V to +34V                                        |
| V <sub>DD</sub> to V <sub>CC</sub>            | -6.3V to +28.75V                                     |
| V <sub>CC</sub> to V <sub>SS</sub>            | -0.3V to +34V                                        |
| V <sub>CC</sub> to GND                        | -0.3V to +6V                                         |
| DIN, SCLK, CS, SHDN                           | -0.3V to (V <sub>CC</sub> + 0.3V)                    |
| H, L, W, IN+, IN-, OUT                        | (V <sub>SS</sub> - 0.3V) to (V <sub>DD</sub> + 0.3V) |
| Maximum Continuous Current into H, L, and W   |                                                      |
| MAX5436-MAX5439                               | ±1mA                                                 |

Continuous Power Dissipation (T<sub>A</sub> = +70°C)

10-Pin  $\mu$ MAX (derate 6.94mW/°C above +70°C) .....556mW

14-Pin TSSOP (derate 9.1mW/°C above +70°C) .....727mW

Operating Temperature Range .....-40°C to +85°C

Junction Temperature .....+150°C

Storage Temperature Range .....-65°C to +150°C

Lead Temperature (soldering, 10s) .....+300°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<sub>DD</sub> = +15V, V<sub>SS</sub> = -15V, V<sub>CC</sub> = +5V, V<sub>H</sub> = V<sub>DD</sub>, V<sub>L</sub> = V<sub>SS</sub>, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C, unless otherwise noted.)

| PARAMETER                                 | SYMBOL           | CONDITIONS                                 | MIN  | TYP   | MAX  | UNITS  |
|-------------------------------------------|------------------|--------------------------------------------|------|-------|------|--------|
| DC PERFORMANCE (voltage-divider mode)     |                  |                                            |      |       |      |        |
| Resolution                                | 2 <sup>N</sup>   |                                            | 128  |       |      | Taps   |
| Integral Nonlinearity                     | INL              | (Note 1)                                   |      |       | ±1   | LSB    |
| Differential Nonlinearity                 | DNL              | (Note 1)                                   |      |       | ±1   | LSB    |
| End-to-End Resistor Tempco                | TC <sub>R</sub>  |                                            |      | 35    |      | ppm/°C |
| Ratiometric Resistor Tempco               |                  |                                            |      | 5     |      | ppm/°C |
| Full-Scale Error                          |                  | R <sub>H</sub> L = 50kΩ (MAX5436/MAX5437)  |      | -0.3  |      | LSB    |
| Zero-Scale Error                          |                  | R <sub>H</sub> L = 50kΩ (MAX5436/MAX5437)  |      | +0.3  |      | LSB    |
| Full-Scale Error                          |                  | R <sub>H</sub> L = 100kΩ (MAX5438/MAX5439) |      | -0.15 |      | LSB    |
| Zero-Scale Error                          |                  | R <sub>H</sub> L = 100kΩ (MAX5438/MAX5439) |      | +0.15 |      | LSB    |
| DC PERFORMANCE (variable-resistor mode)   |                  |                                            |      |       |      |        |
| Resolution                                | 2 <sup>N</sup>   |                                            | 128  |       |      | Taps   |
| Integral Nonlinearity                     | INL              | (Note 2)                                   |      |       | ±1   | LSB    |
| Differential Nonlinearity                 | DNL              | (Note 2)                                   |      |       | ±1   | LSB    |
| DC PERFORMANCE (resistor characteristics) |                  |                                            |      |       |      |        |
| Wiper Resistance                          | W <sub>R</sub>   | (Note 3)                                   |      | 0.9   | 2    | kΩ     |
| Wiper Capacitance                         | W <sub>C</sub>   | Midscale                                   |      | 6     |      | pF     |
| End-to-End Resistance                     | R <sub>H</sub> L | MAX5438/MAX5439                            | 75   | 100   | 125  | kΩ     |
|                                           |                  | MAX5436/MAX5437                            | 37.5 | 50    | 62.5 |        |
| DIGITAL INPUTS                            |                  |                                            |      |       |      |        |
| Input High Voltage                        |                  | V <sub>CC</sub> = 4.75V to 5.25V (Note 4)  | 2.4  |       |      | V      |
| Input Low Voltage                         |                  | V <sub>CC</sub> = 4.75V to 5.25V           |      |       | 0.8  | V      |

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = +15V$ ,  $V_{SS} = -15V$ ,  $V_{CC} = +5V$ ,  $V_H = V_{DD}$ ,  $V_L = V_{SS}$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ , unless otherwise noted.)

| PARAMETER                                                  | SYMBOL    | CONDITIONS                                                                                       | MIN          | TYP  | MAX          | UNITS  |
|------------------------------------------------------------|-----------|--------------------------------------------------------------------------------------------------|--------------|------|--------------|--------|
| Input High Voltage                                         |           | $V_{CC} = 2.7V$ to $3.6V$                                                                        | 2.0          |      |              | V      |
| Input Low Voltage                                          |           | $V_{CC} = 2.7V$ to $3.6V$                                                                        |              |      | 0.6          | V      |
| Input Leakage Current                                      |           |                                                                                                  |              |      | ±1.0         | μA     |
| Input Capacitance                                          |           |                                                                                                  |              | 5.0  |              | pF     |
| <b>DYNAMIC CHARACTERISTICS (analog)</b>                    |           |                                                                                                  |              |      |              |        |
| Wiper -3dB Bandwidth                                       | $BW_W$    | $R_{HL} = 50k\Omega$ , midscale, $V_H = 1.5V_{P-P}$ , $C_{WIPER} = 20pF$ , voltage-divider mode  |              | 400  |              | kHz    |
|                                                            |           | $R_{HL} = 100k\Omega$ , midscale, $V_H = 1.5V_{P-P}$ , $C_{WIPER} = 20pF$ , voltage-divider mode |              | 200  |              |        |
| Wiper Settling Time                                        | $t_{IL}$  | $C_{WIPER} = 20pF$ , code 1 to code 127, settle to 0.5LSB                                        |              | 5    |              | μs     |
| <b>AMPLIFIER CHARACTERISTICS (analog)</b>                  |           |                                                                                                  |              |      |              |        |
| Input Bias Current                                         | $I_B$     |                                                                                                  |              | 15   |              | nA     |
| Input Offset Voltage                                       | $V_{OS}$  |                                                                                                  |              | ±6   |              | mV     |
| Offset-Voltage Temperature Drift                           | $V_{OSD}$ |                                                                                                  |              | 10   |              | μV/°C  |
| Input Offset Current                                       | $I_{OS}$  |                                                                                                  |              | 2    |              | nA     |
| Unity-Gain Bandwidth                                       | $UBW_A$   | $C_{LOAD} = 250pF$                                                                               |              | 100  |              | kHz    |
| Slew Rate                                                  | $SR$      |                                                                                                  |              | 0.25 |              | V/μs   |
| Large-Signal Voltage Gain                                  | $A_{VO}$  | $R_{LOAD} = 100k\Omega$ , $V_{OUT} = \pm 14V$                                                    |              | 100  |              | V/mV   |
| Input Noise                                                | $V_N$     | $f = 1kHz$                                                                                       |              | 110  |              | nV/√Hz |
| Input Compliance                                           | $CMR_I$   |                                                                                                  | $V_{SS} + 1$ |      | $V_{DD} - 2$ | V      |
| Output Compliance                                          | $CMR_O$   | $I_{LOAD} = \pm 5mA$                                                                             | $V_{SS} + 1$ |      | $V_{DD} - 1$ | V      |
| DC CMRR                                                    | $CMRR$    |                                                                                                  |              | 68   |              | dB     |
| DC PSRR                                                    | $PSRR$    |                                                                                                  |              | 70   |              | dB     |
| <b>TIMING CHARACTERISTICS (digital)</b> (Note 5, Figure 3) |           |                                                                                                  |              |      |              |        |
| SCLK Clock Frequency                                       | $f_{CLK}$ |                                                                                                  | 0            |      | 10           | MHz    |
| SCLK Clock Period                                          | $t_{CP}$  |                                                                                                  | 100          |      |              | ns     |
| SCLK Pulse Width High                                      | $t_{CH}$  |                                                                                                  | 40           |      |              | ns     |
| SCLK Pulse Width Low                                       | $t_{CL}$  |                                                                                                  | 40           |      |              | ns     |
| $\overline{CS}$ Fall to SCLK Rise Setup Time               | $t_{CSS}$ |                                                                                                  | 40           |      |              | ns     |
| SCLK Rise to $\overline{CS}$ Rise Hold Time                | $t_{CSH}$ |                                                                                                  | 10           |      |              | ns     |
| DIN Setup Time                                             | $t_{DS}$  |                                                                                                  | 40           |      |              | ns     |
| DIN Hold Time                                              | $t_{DH}$  |                                                                                                  | 0            |      |              | ns     |
| SCLK Rise to $\overline{CS}$ Fall Delay                    | $t_{CSO}$ |                                                                                                  | 10           |      |              | ns     |
| $\overline{CS}$ Rise to SCLK Rise Hold                     | $t_{CS1}$ |                                                                                                  | 40           |      |              | ns     |
| $\overline{CS}$ Pulse Width High                           | $t_{CSW}$ |                                                                                                  | 100          |      |              | ns     |
| <b>POWER SUPPLIES</b>                                      |           |                                                                                                  |              |      |              |        |
| Positive Analog Supply Voltage                             | $V_{DD}$  |                                                                                                  | 0            |      | 31.5         | V      |
| Negative Analog Supply Voltage                             | $V_{SS}$  |                                                                                                  | -28.8        |      | 0            | V      |

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{DD} = +15V$ ,  $V_{SS} = -15V$ ,  $V_{CC} = +5V$ ,  $V_H = V_{DD}$ ,  $V_L = V_{SS}$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = +25^{\circ}C$ , unless otherwise noted.)

| PARAMETER                                           | SYMBOL   | CONDITIONS                                                     | MIN  | TYP | MAX  | UNITS   |
|-----------------------------------------------------|----------|----------------------------------------------------------------|------|-----|------|---------|
| Analog Supply Separation                            | $V_{DS}$ | $V_{DD} - V_{SS}$                                              | 9.0  |     | 31.5 | V       |
| Digital Supply Voltage                              | $V_{CC}$ |                                                                | 2.70 |     | 5.25 | V       |
| Digital Supply to Negative Analog Supply Separation | $V_{CS}$ | $V_{CC} - V_{SS}$                                              | 2.7  |     | 31.5 | V       |
| Power-On Reset Threshold                            | POR      |                                                                |      | 1.6 |      | V       |
| Digital Supply Current                              | $I_{CC}$ | (Note 4)                                                       |      | 30  | 50   | $\mu A$ |
| Positive Analog Supply Current                      | $I_{DD}$ | MAX5436/MAX5438<br>$\overline{SHDN} = GND$ for MAX5437/MAX5439 |      | 30  | 60   | $\mu A$ |
|                                                     |          | $\overline{SHDN} = V_{CC}$                                     |      | 105 | 215  |         |
| Negative Analog Supply Current                      | $I_{SS}$ | MAX5436/MAX5438<br>$\overline{SHDN} = GND$ for MAX5437/MAX5439 |      | 55  | 110  | $\mu A$ |
|                                                     |          | $\overline{SHDN} = V_{CC}$                                     |      | 130 | 250  |         |

**Note 1:** The DNL and INL are measured with the potentiometer configured as a voltage-divider with  $H = V_{DD}$  and  $L = V_{SS}$ . The wiper terminal is unloaded.

**Note 2:** The DNL and INL are measured with the potentiometer configured as a variable resistor.  $H$  is unconnected and  $L = V_{SS}$ . The wiper terminal is driven with a source current of  $80\mu A$  for the  $50k\Omega$  configuration and  $40\mu A$  for the  $100k\Omega$  configuration.

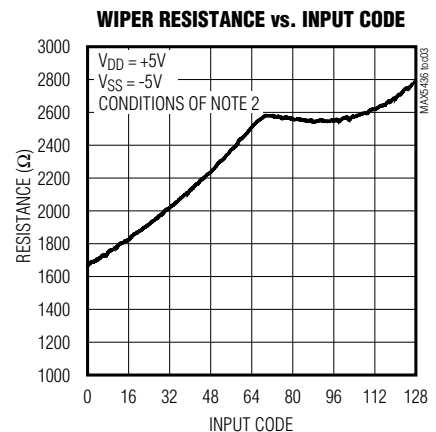
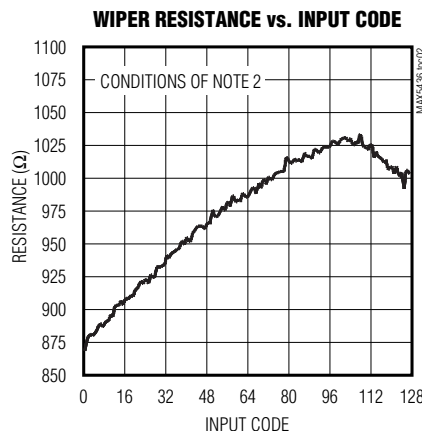
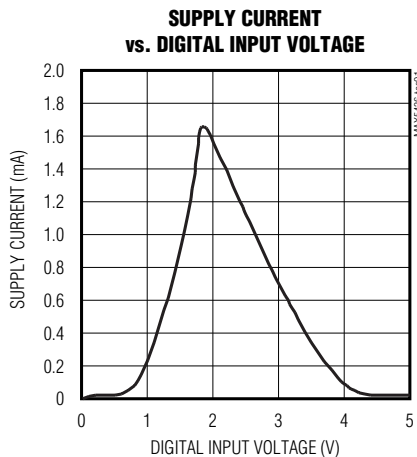
**Note 3:** The wiper resistance is measured assuming the source currents given in Note 2.

**Note 4:** The device draws current in excess of the specified supply current when the digital inputs are driven with voltages between  $(V_{CC} - 0.5V)$  and  $(GND + 0.5V)$ . See Supply Current vs. Digital Input Voltage in the *Typical Operating Characteristics* section.

**Note 5:** Guaranteed by design and characterization.

## Typical Operating Characteristics

( $V_{DD} = +15V$ ,  $V_{SS} = -15V$ ,  $V_{CC} = +5V$ ,  $V_H = V_{DD}$ ,  $V_L = V_{SS}$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)

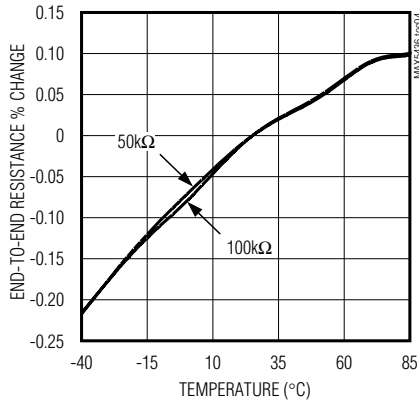


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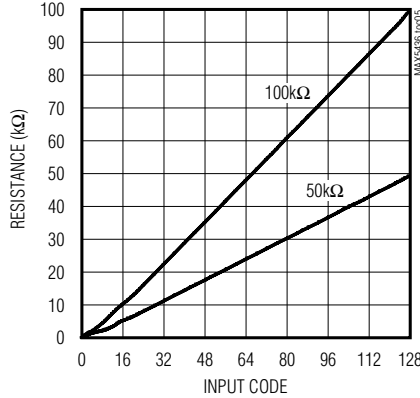
## Typical Operating Characteristics (continued)

( $V_{DD} = +15V$ ,  $V_{SS} = -15V$ ,  $V_{CC} = +5V$ ,  $V_H = V_{DD}$ ,  $V_L = V_{SS}$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

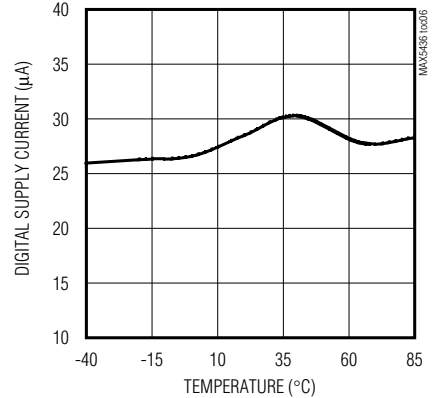
**END-TO-END RESISTANCE % CHANGE  
vs. TEMPERATURE**



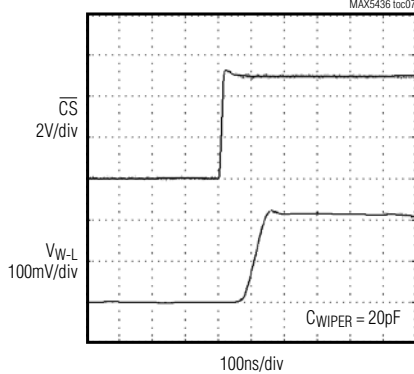
**W-TO-L RESISTANCE CHANGE  
vs. INPUT CODE**



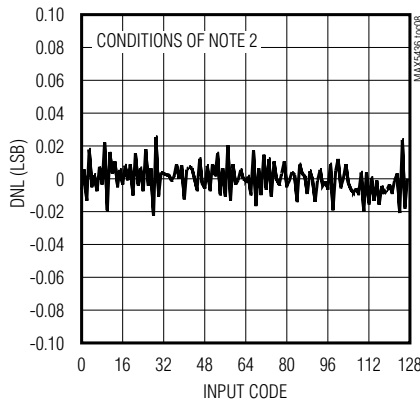
**DIGITAL SUPPLY CURRENT  
vs. TEMPERATURE**



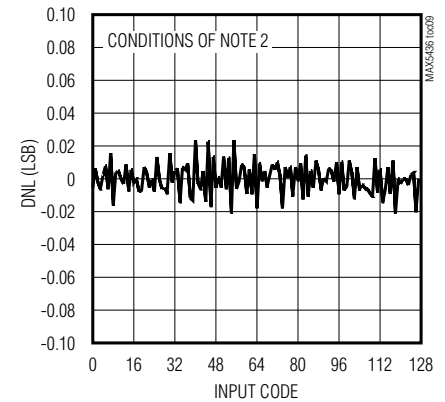
**MIDSCALE SWITCHING TRANSIENT  
(CODE 63 TO CODE 64)**



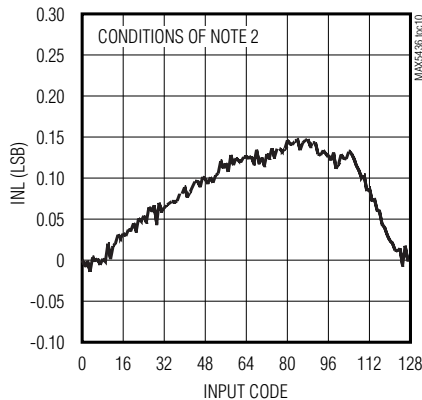
**VARIABLE-RESISTOR DNL  
vs. INPUT CODE (50kΩ)**



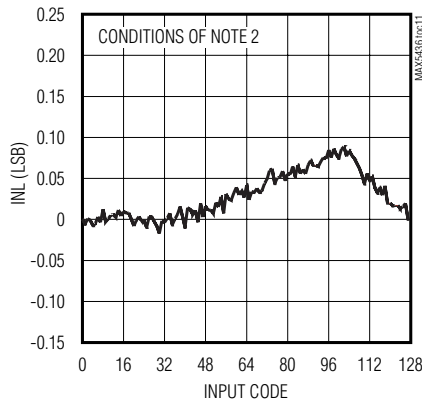
**VARIABLE-RESISTOR DNL  
vs. INPUT CODE (100kΩ)**



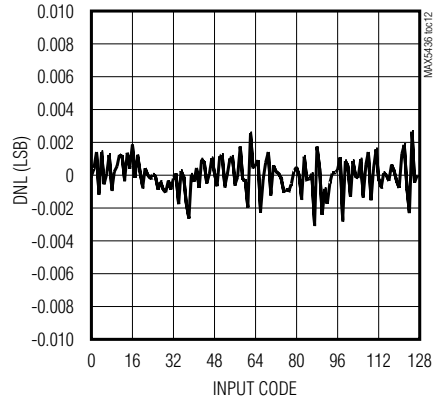
**VARIABLE-RESISTOR INL  
vs. INPUT CODE (50kΩ)**



**VARIABLE-RESISTOR INL  
vs. INPUT CODE (100kΩ)**



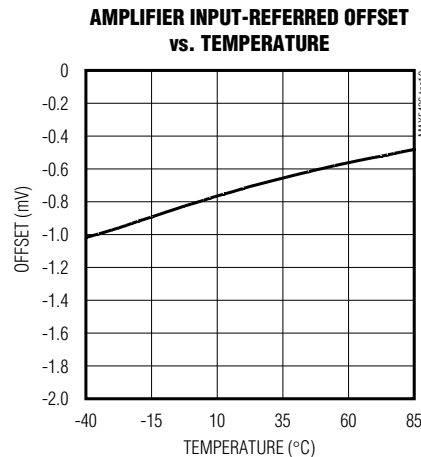
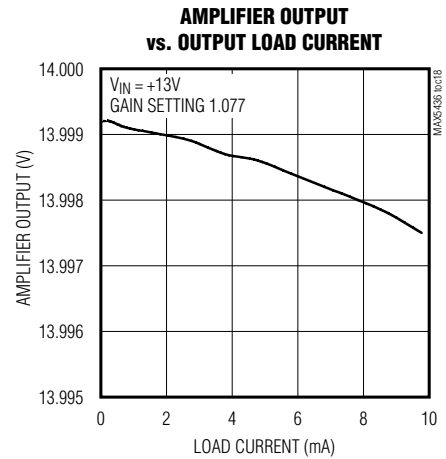
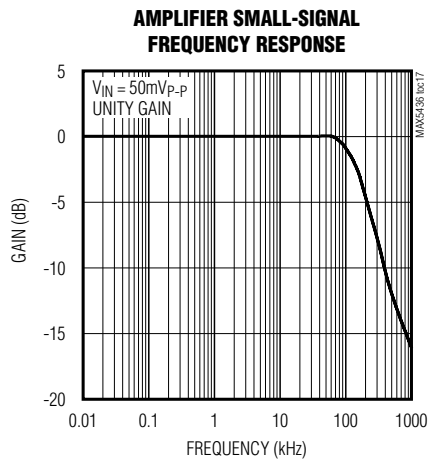
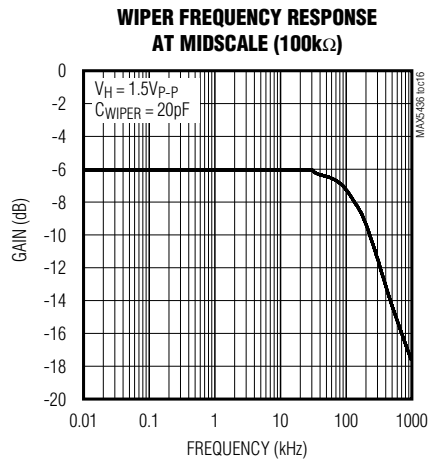
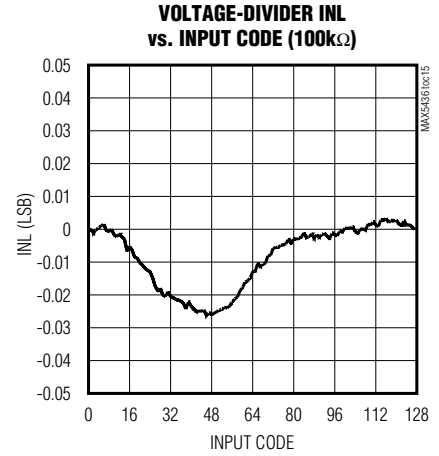
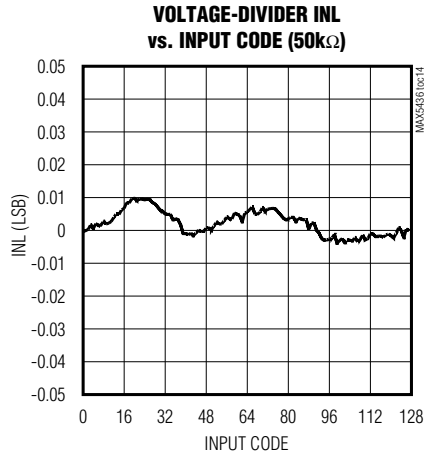
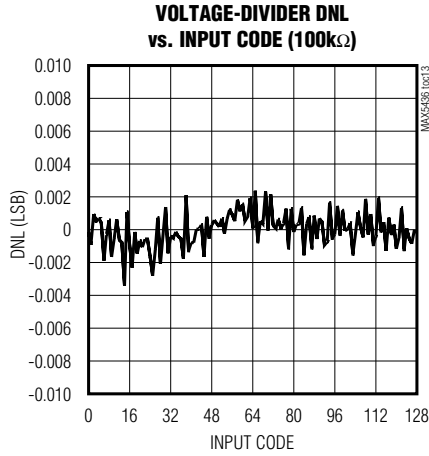
**VOLTAGE-DIVIDER DNL  
vs. INPUT CODE (50kΩ)**



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## Typical Operating Characteristics (continued)

( $V_{DD} = +15V$ ,  $V_{SS} = -15V$ ,  $V_{CC} = +5V$ ,  $V_H = V_{DD}$ ,  $V_L = V_{SS}$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



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## Pin Description

| PIN                 |                     | NAME                     | DESCRIPTION                                                   |
|---------------------|---------------------|--------------------------|---------------------------------------------------------------|
| MAX5436/<br>MAX5438 | MAX5437/<br>MAX5439 |                          |                                                               |
| 1                   | 1                   | SCLK                     | Serial Clock Input                                            |
| 2                   | 2                   | DIN                      | Serial Data Input                                             |
| 3                   | 3                   | $\overline{\text{CS}}$   | Chip Select                                                   |
| —                   | 4                   | $\overline{\text{SHDN}}$ | Amplifier Shutdown                                            |
| 4                   | 5                   | GND                      | Analog and Digital Ground                                     |
| 5                   | 6                   | V <sub>SS</sub>          | Negative Analog Supply. Bypass with a 0.1μF capacitor to GND. |
| —                   | 7                   | OUT                      | Amplifier Output                                              |
| —                   | 8                   | IN <sup>-</sup>          | Amplifier Negative Input                                      |
| —                   | 9                   | IN <sup>+</sup>          | Amplifier Positive Input                                      |
| 6                   | 10                  | V <sub>DD</sub>          | Positive Analog Supply. Bypass with a 0.1μF capacitor to GND. |
| 7                   | 11                  | H                        | High Terminal of Resistor                                     |
| 8                   | 12                  | W                        | Wiper Terminal of Resistor                                    |
| 9                   | 13                  | L                        | Low Terminal of Resistor                                      |
| 10                  | 14                  | V <sub>CC</sub>          | Digital Supply. Bypass with a 0.1μF capacitor to GND.         |

## Detailed Description

### Digital Interface Operation

The MAX5436–MAX5439 use a 3-wire SPI/QSPI/MICROWIRE-compatible serial data interface to control the wiper position. This write-only interface contains three inputs: chip select ( $\overline{\text{CS}}$ ), data in (DIN), and serial clock (SCLK). When  $\overline{\text{CS}}$  is taken low, data from DIN is synchronously loaded into the serial shift register on the rising edge of each SCLK pulse (Figure 2). The 8-bit data word requires 8 clock pulses to input the serial data. Note that the first bit of the data word, D7, is unused and should be ignored. Therefore, the second rising edge of SCLK loads the MSB. After all the data bits have been shifted in, they are latched into the potentiometer control register when  $\overline{\text{CS}}$  transitions from low to high, the wiper position is then updated. Note that if  $\overline{\text{CS}}$  is not kept low during the entire data stream, the data will be corrupted and the device will need to be reloaded.

## Applications Information

### Power-Up Sequencing

The MAX5436–MAX5439 have been designed so that any of the supplies can turn on first without causing any unwanted crowbar currents to flow. Note that both digital and analog supplies are required to power up the wiper and uncommitted amplifier (MAX5437/MAX5439 only).

### Adjustable Gain Amplifier

The MAX5436/MAX5438 are used with the MAX427 to make a digitally adjustable gain circuit as shown in Figure 4. The normal feedback resistor is replaced with the MAX5436/MAX5438 in a variable-resistor configuration so that the gain of the circuit can be digitally controlled. The MAX5437/MAX5439 can use the internal high-voltage amplifier to make this digitally adjustable gain circuit.

### LCD Biasing Control Applications

The MAX5436–MAX5439 are ideal for LCDs that require separate voltage for contrast control in addition to the main supply voltage. Figure 5a shows the MAX5436–MAX5439 being used for LCD contrast control along with the MAX629, which provides the LCD supply voltage. A similar circuit with an additional buffer circuit is shown in Figure 5b.

# ±15V, 128-Tap, Low-Drift Digital Potentiometers

| DATA WORD        |       |    |    |    |    |    |                 |
|------------------|-------|----|----|----|----|----|-----------------|
| D7               | D6    | D5 | D4 | D3 | D2 | D1 | D0              |
| Don't Care       | (MSB) |    |    |    |    |    | (LSB)           |
| First Bit Loaded |       |    |    |    |    |    | Last Bit Loaded |

Figure 1. Serial Data Format

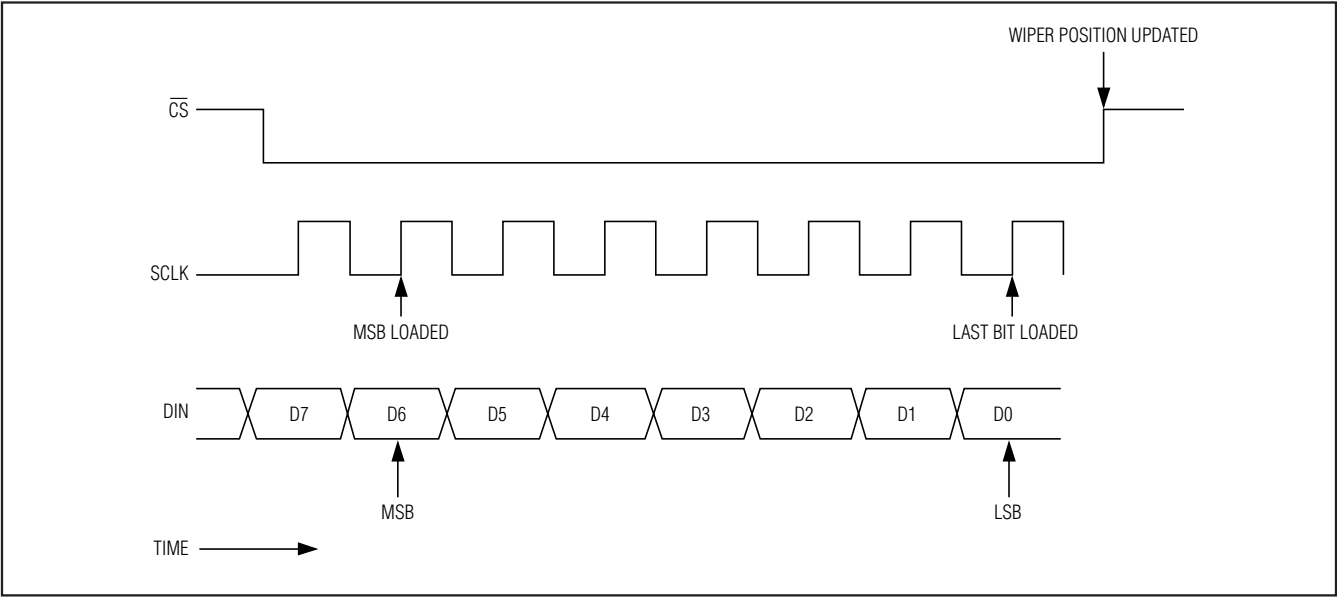


Figure 2. Serial Interface Timing Diagram

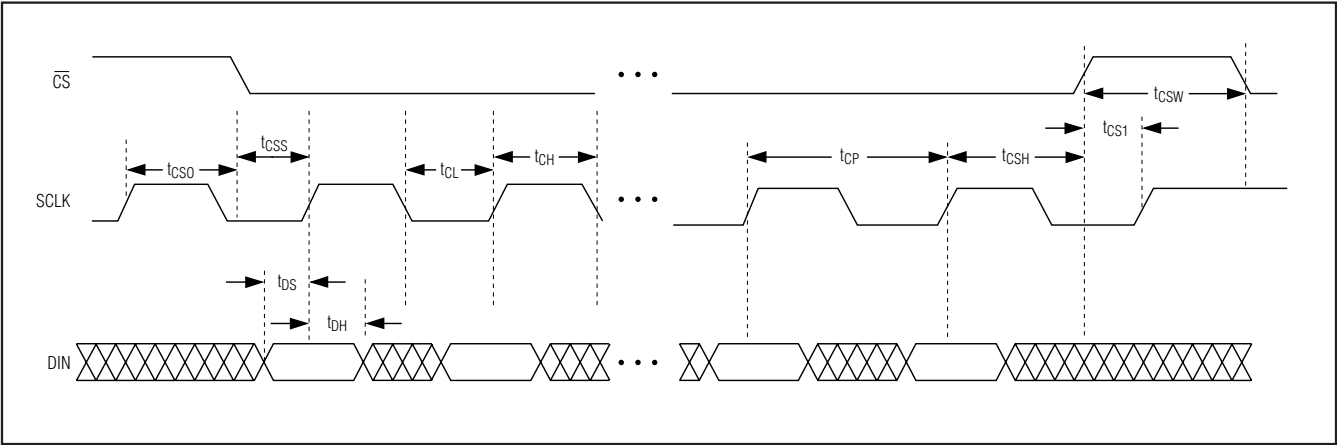


Figure 3. Detailed Serial-Interface Timing Diagram



# **±15V, 128-Tap, Low-Drift Digital Potentiometers**

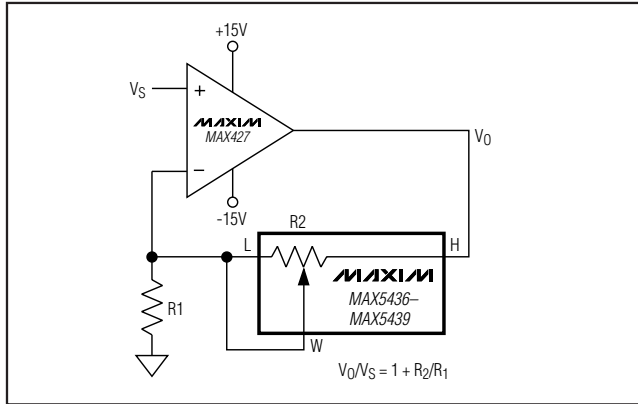


Figure 4. Noninverting Amplifier

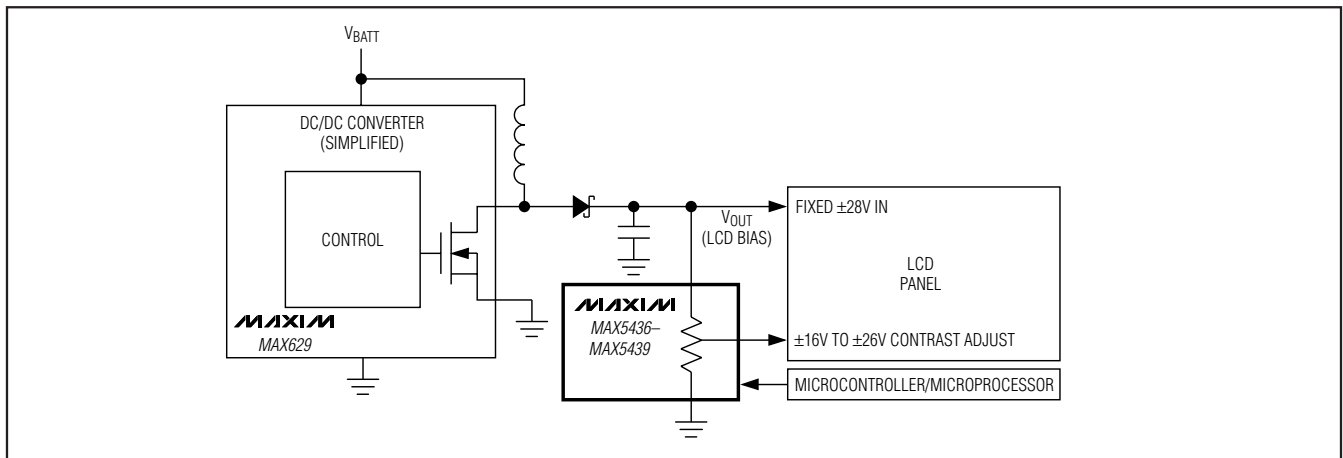


Figure 5a. Simplified LCD Contrast Control Circuit

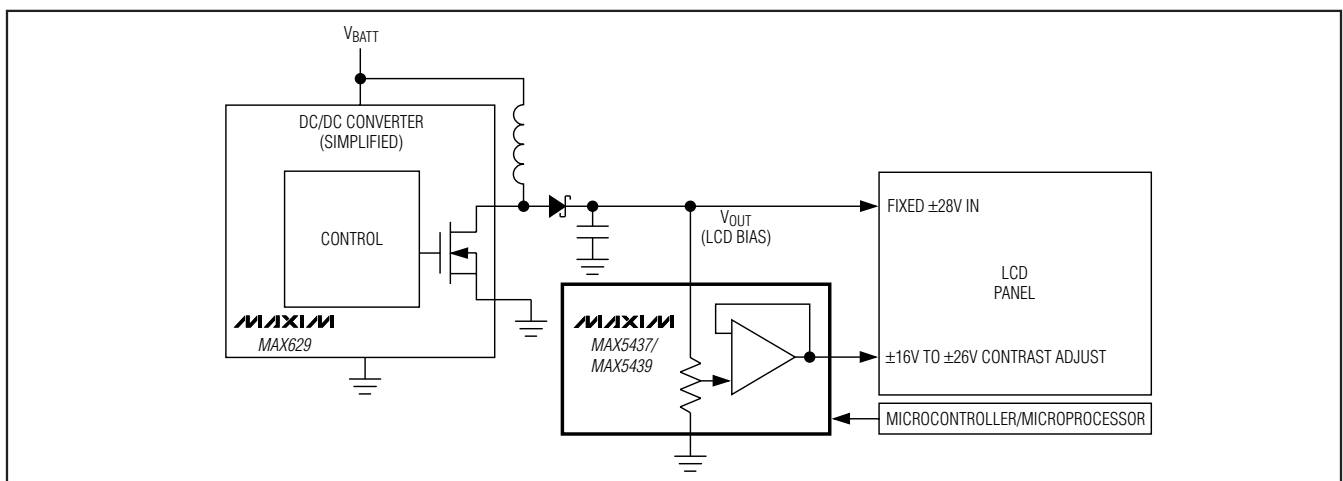
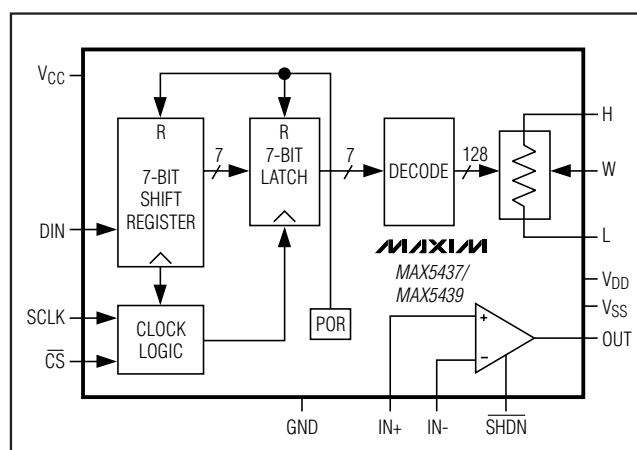
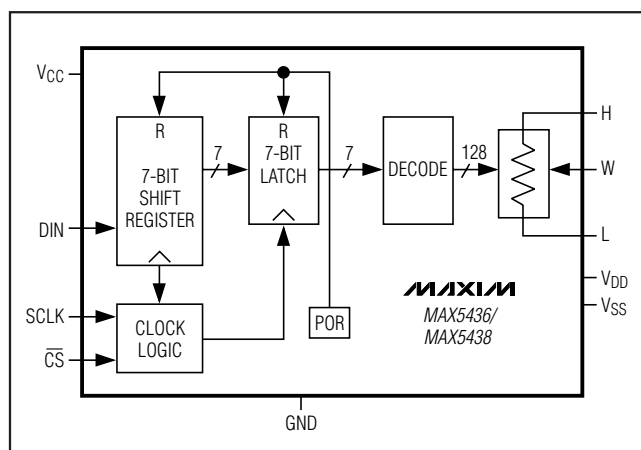


Figure 5b. Simplified LCD Contrast Control Circuit with Buffer

# ±15V, 128-Tap, Low-Drift Digital Potentiometers

## Functional Diagrams



## Chip Information

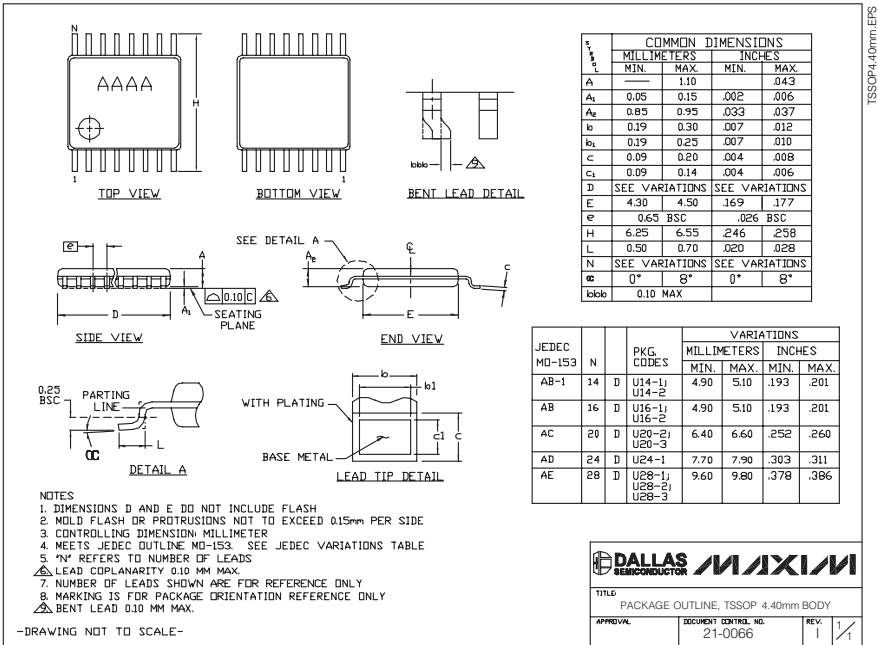
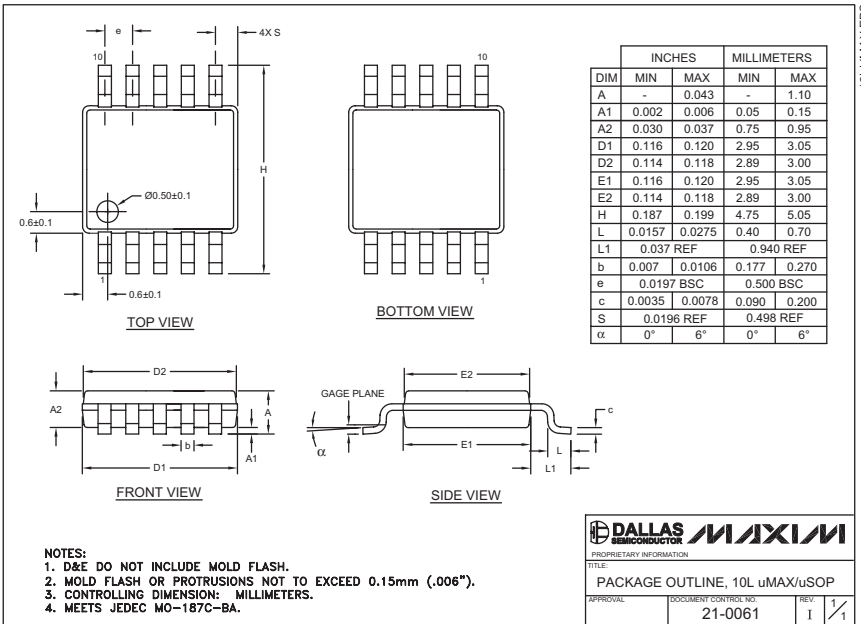
TRANSISTOR COUNT: 2556

PROCESS: BiCMOS

# ±15V, 128-Tap, Low-Drift Digital Potentiometers

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



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