19-1435; Rev 2a; 2/01

MAXIM

Low-Power Digital Potentiometers

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: 50kΩ, 100kΩ, and 200kΩ. A nominal resistor temperature coefficient of 50ppm/°C end-to-end and only 5ppm/°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 µMAX package, and the MAX5161 is available in a 6-pin SOT23 package. Both devices are guaranteed over the extended-industrial temperature range (-40°C to +85°C).

Applications

LCD Screen Adjustment

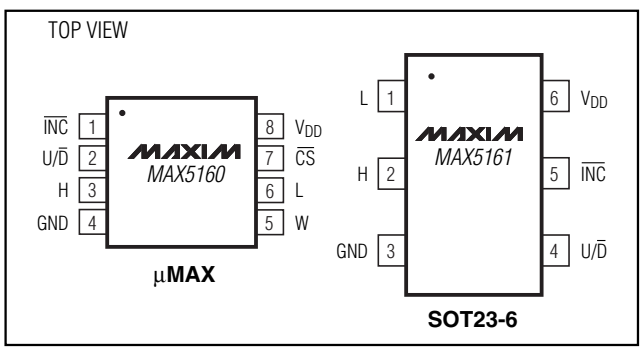
Volume Control

Mechanical Potentiometer Replacement

Selector Guide

PART	TOP MARK	R (kΩ)
MAX5160NEUA	—	200
MAX5160MEUA	—	100
MAX5160LEUA	—	50
MAX5161NEZT	AAAC	200
MAX5161MEZT	AAAB	100
MAX5161LEZT	AAAA	50

Pin Configurations



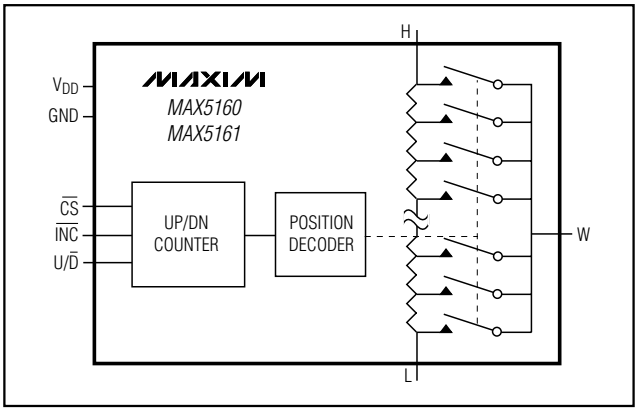
Features

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

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	R (kΩ)
MAX5160NEUA	-40°C to +85°C	8 µMAX	200
MAX5160MEUA	-40°C to +85°C	8 µMAX	100
MAX5160LEUA	-40°C to +85°C	8 µMAX	50
MAX5161NEZT	-40°C to +85°C	6 SOT23	200
MAX5161MEZT	-40°C to +85°C	6 SOT23	100
MAX5161LEZT	-40°C to +85°C	6 SOT23	50

Functional Diagram



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 .....±200mA
Maximum Continuous Current into H, L, and W
MAX516_ _ E_ _.....±1mA

Continuous Power Dissipation (T_A = +70°C)
6-Pin SOT23 (derate 6.25mW/°C above +70°C).....500mW
8-Pin µMAX (derate 4.1mW/°C above +70°C) 330mW
Operating Temperature Range ..... -40°C to +85°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_{DD} = +2.7V to +5.5V, V_H = V_{DD}, V_L = 0, T_A = T_{MIN} to T_{MAX}. Typical values are at V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

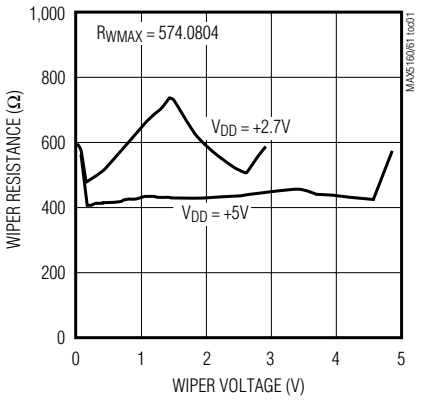
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DC PERFORMANCE							
Resolution					3		%
Integral Nonlinearity (Note 1)	INL					±1/2	LSB
Differential Nonlinearity (Note 1)	DNL					±1	LSB
End-to-End Resistor Tempco	TC_R				50		ppm/°C
Ratiometric Resistor Tempco					5		ppm/°C
Full-Scale Error						-0.1	LSB
Zero-Scale Error						+0.1	LSB
Wiper Resistance	R_W				400	1700	Ω
Wiper Capacitance	C_W				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_{IH}			0.7 × V_{DD}			V
Input Low Voltage	V_{IL}					0.3 × V_{DD}	V
Input Leakage Current						±1	µA
Input Capacitance					5		pF
TIMING CHARACTERISTICS (Figure 6)							
$\overline{CS}$ to $\overline{INC}$ Setup Time	t_{CI}			25			ns
$\overline{CS}$ to $\overline{INC}$ Hold Time	t_{IC}			0			ns
$\overline{INC}$ Low Period	t_{IL}			25			ns
$\overline{INC}$ High Period	t_{IH}			25			ns
U/$\overline{D}$ to $\overline{INC}$ Hold	t_{ID}			0			ns
U/$\overline{D}$ to $\overline{INC}$ Setup	t_{DI}			50			ns
Wiper-Settling Time	t_{IW}				1		µs
$\overline{INC}$ Frequency	f_{IMAX}					7	MHz
POWER SUPPLIES							
Supply Voltage	V_{DD}			2.7		5.5	V
Supply Current	I_{DD}	$\overline{CS}$ = $\overline{INC}$ = U/$\overline{D}$ = V_{DD} or GND	V_{DD} = +5V		0.6	10	µA
			V_{DD} = +2.7V		135		nA

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

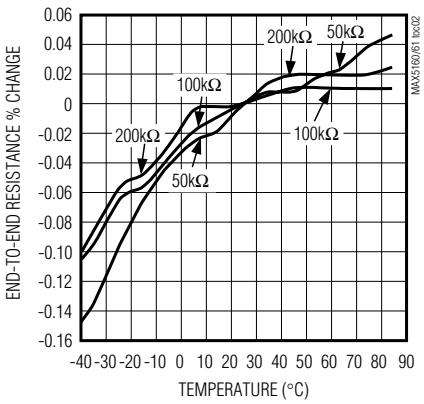
Typical Operating Characteristics

(V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

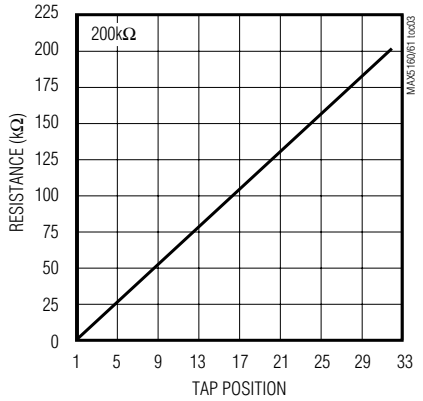
WIPER RESISTANCE vs. WIPER VOLTAGE



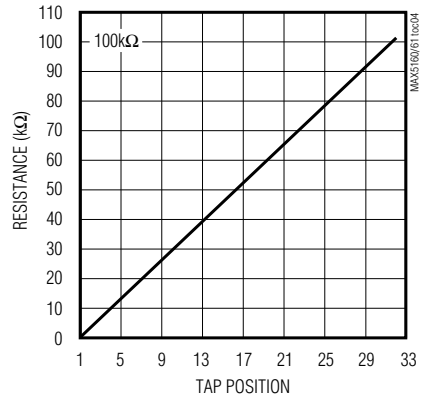
END-TO-END RESISTANCE % CHANGE vs. TEMPERATURE



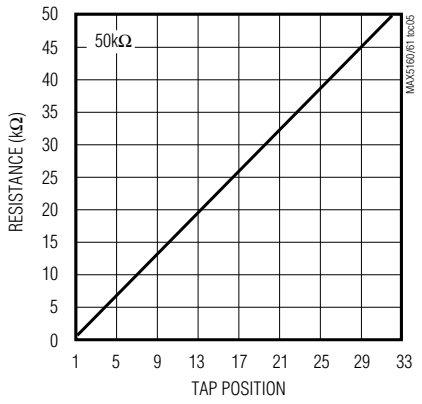
END-TO-END RESISTANCE vs. TAP POSITION



END-TO-END RESISTANCE vs. TAP POSITION



END-TO-END RESISTANCE vs. TAP POSITION

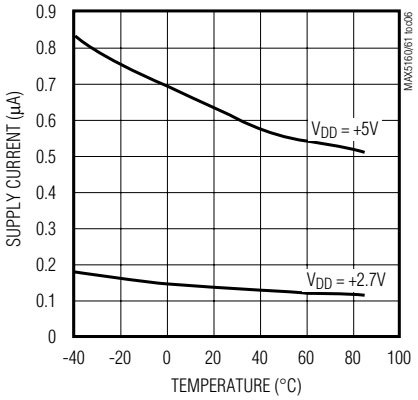


Low-Power Digital Potentiometers

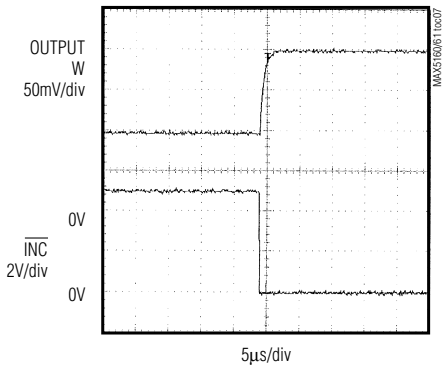
Typical Operating Characteristics (continued)

(V_{DD} = +5V, T_A = +25°C, unless otherwise noted.)

SUPPLY CURRENT vs. TEMPERATURE



TAP-TO-TAP SWITCHING TRANSIENT



Pin Description

PIN		NAME	FUNCTION
MAX5160	MAX5161		
1	5	$\overline{INC}$	Wiper Increment Control Input. With $\overline{CS}$ low, a high-to-low transition increments (U/$\overline{D}$ high) or decrements (U/$\overline{D}$ low) the wiper position.
2	4	U/$\overline{D}$	Up/Down Control Input. With $\overline{CS}$ low, a high-to-low $\overline{INC}$ transition increments (U/$\overline{D}$ high) or decrements (U/$\overline{D}$ 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	—	$\overline{CS}$	Chip-Select Input. Drive low to change the wiper position through $\overline{INC}$ and U/$\overline{D}$.
8	6	V_{DD}	Power Supply

Detailed Description

The MAX5160/MAX5161 consist of resistor arrays with thirty-one resistive elements. Thirty-two tap points are accessible to the wiper along the resistor string between H and L. Logic inputs $\overline{CS}$, U/$\overline{D}$, and $\overline{INC}$ determine the position of the wiper. With $\overline{CS}$ low and U/$\overline{D}$ high, a high-to-low transition on $\overline{INC}$ increments the internal counter, increasing the resistance between W and L. When both $\overline{CS}$ and U/$\overline{D}$ are low, a high-to-low $\overline{INC}$ transition decrements the internal counter, decreasing the resistance between W and L. At either end (maximum or minimum positions), additional transitions in the direction of the end points will not change the counter value (the counter will not wrap around).

The H and L terminals of the MAX5160 are similar to the two end terminals of a mechanical potentiometer. The tap W is equivalent to the variable tap (wiper) of the potentiometer.

The MAX5161 is similar to the MAX5160 except that $\overline{CS}$ internally connects to ground and the wiper terminal (W) is shorted to the high terminal (H). The MAX5161 acts as a variable resistor (a potentiometer with the wiper and one end terminal shorted together).

The MAX5160/MAX5161 feature power-on reset circuitry that sets the wiper position to midscale at power-up.

Applications Information

The MAX5160/MAX5161 are intended for circuits requiring digitally controlled adjustable voltage or adjustable gain, such as LCD contrast control, where voltage biasing adjusts the display contrast.

Controlling a Switch-Mode LCD Bias Generator

Figure 1 shows an application where the MAX5161 is used with a MAX1771 to make an adjustable positive LCD-bias circuit. The output of the MAX1771 is a positive voltage that is digitally controlled through the MAX5160/MAX5161. Similarly, Figure 2 shows the application of the MAX5161 in a digitally controlled negative LCD-bias circuit along with the MAX774/MAX775/MAX776.

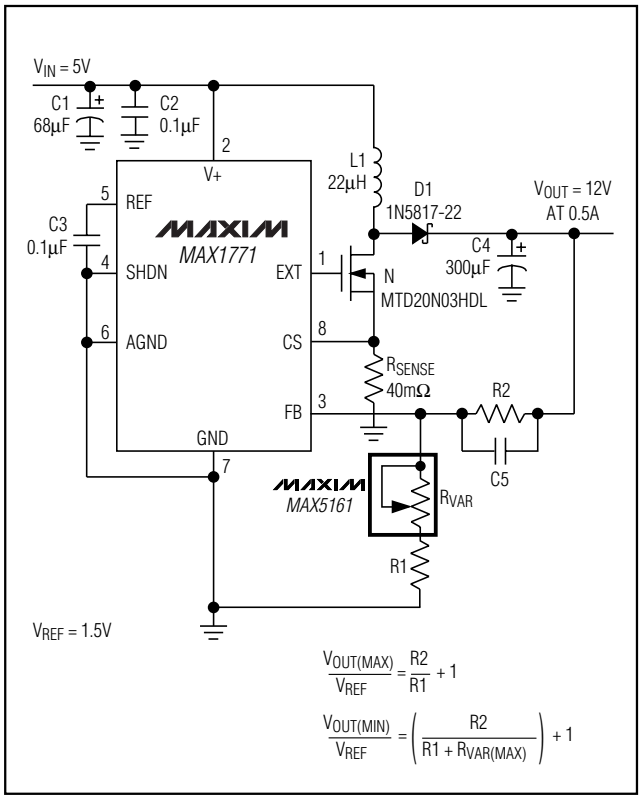


Figure 1. Adjustable Positive LCD Bias

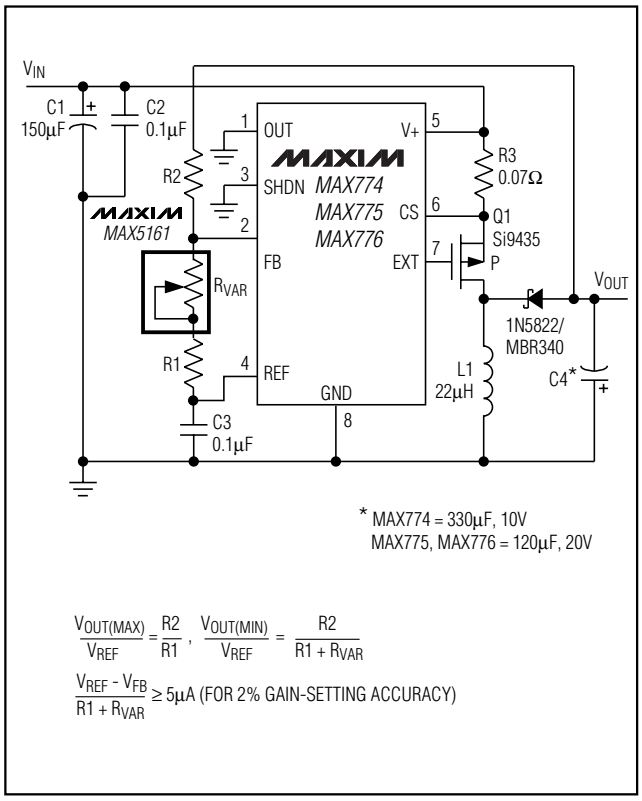


Figure 2. Adjustable Negative LCD Bias

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.

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.

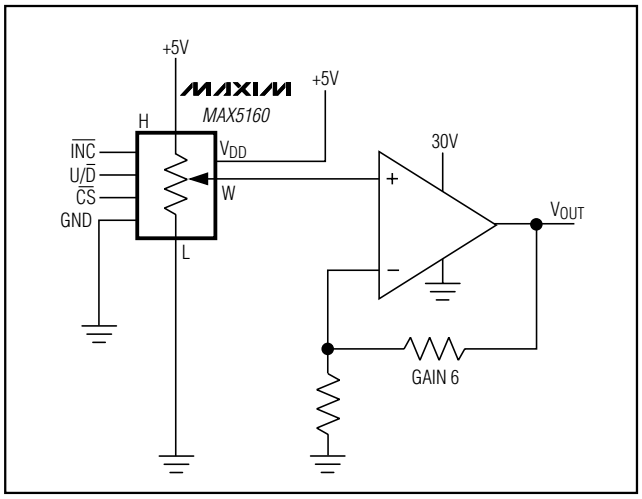


Figure 3. MAX5160 Positive LCD Bias Control

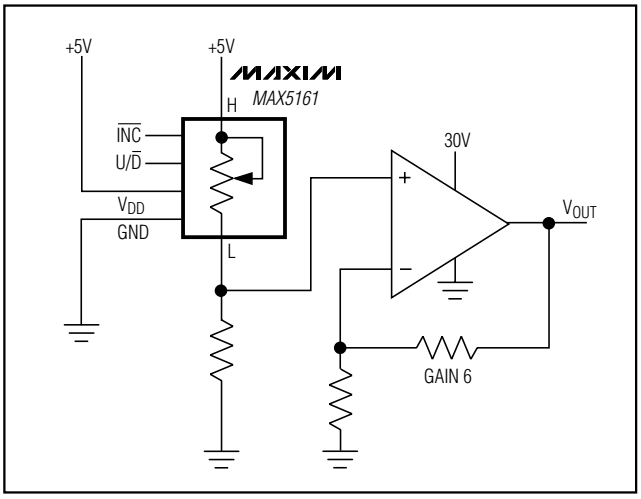


Figure 4. MAX5161 Positive LCD Bias Control

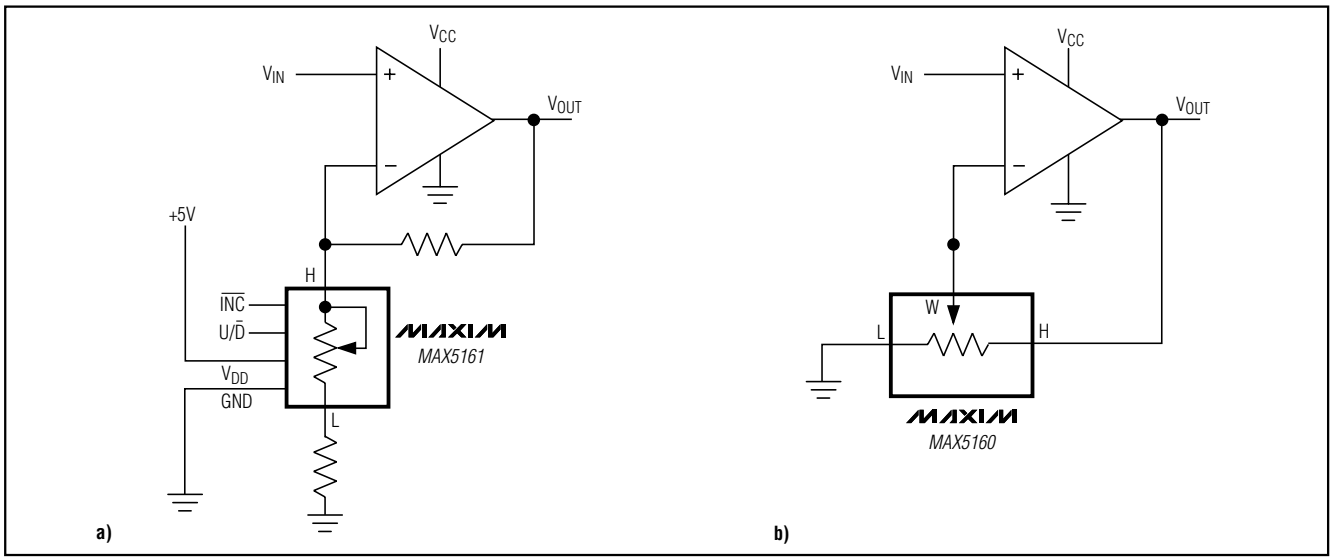


Figure 5. Adjustable Gain Circuit: a) MAX5161; b) MAX5160

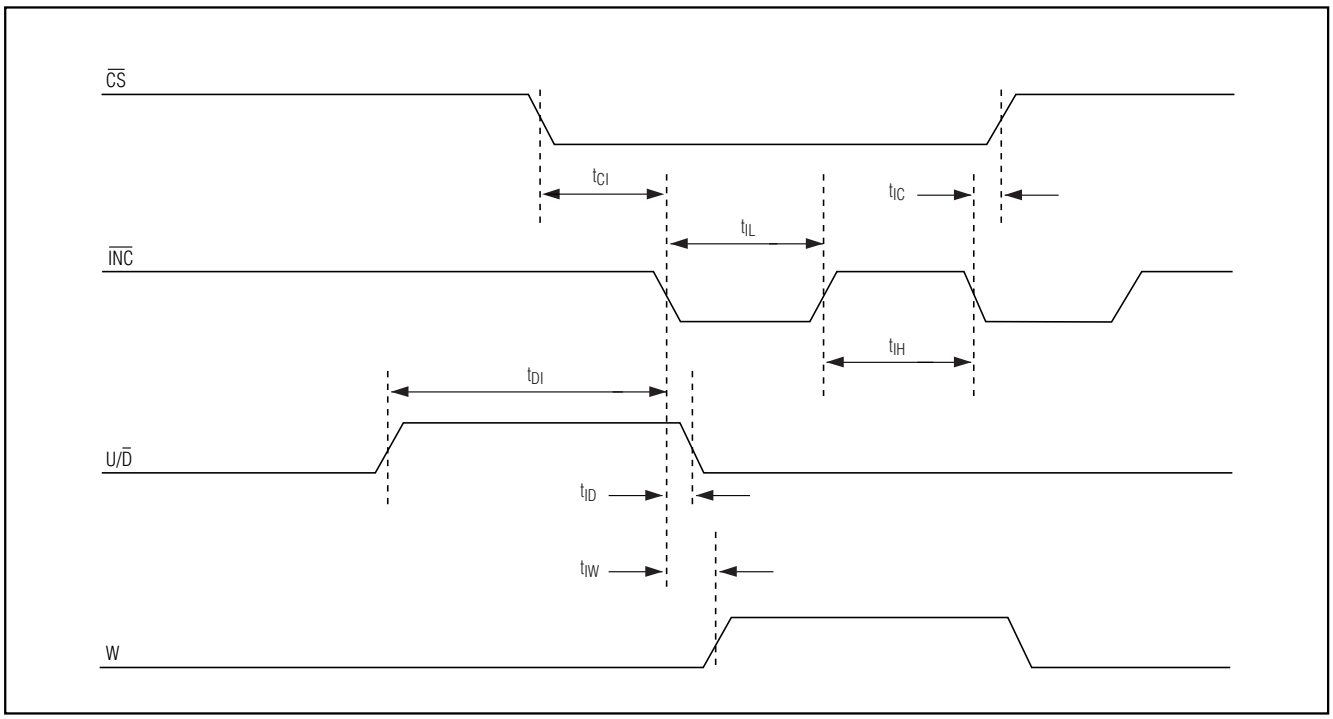


Figure 6. Serial-Interface Timing Diagram

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*

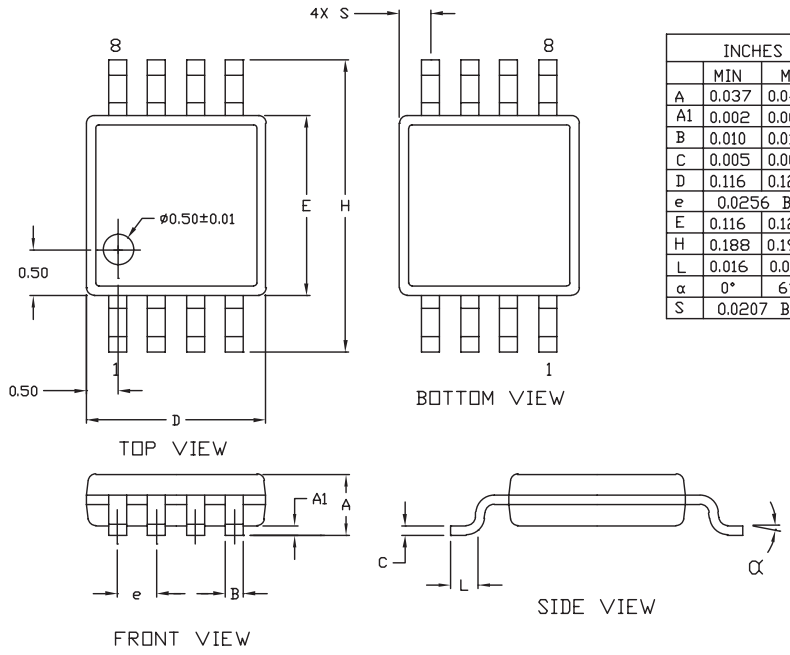
Chip Information

TRANSISTOR COUNT: 969

Low-Power Digital Potentiometers

Package Information

8LUMAXD.EPS



	INCHES		MILLIMETERS		JEDEC INCHES		JEDEC MILLIMETERS	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
A	0.037	0.043	0.94	1.10	---	0.043	---	1.10
A1	0.002	0.006	0.05	0.15	0.002	0.006	0.05	0.15
B	0.010	0.014	0.25	0.36	0.010	0.016	0.25	0.40
C	0.005	0.007	0.13	0.18	0.005	0.009	0.13	0.23
D	0.116	0.120	2.95	3.05	0.114	0.122	2.9	3.1
e	0.0256 BSC		0.65 BSC		0.0256 BSC		0.64 BSC	
E	0.116	0.120	2.95	3.05	0.114	0.122	2.9	3.1
H	0.188	0.198	4.78	5.03	0.193 BSC		4.9 BSC	
L	0.016	0.026	0.41	0.66	0.016	0.027	0.40	0.70
α	0°	6°	0°	6°	0°	6°	0°	6°
S	0.0207 BSC		0.5250 BSC					

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15MM (.006").
3. CONTROLLING DIMENSION: MILLIMETERS.
4. MEETS JEDEC MO-187.

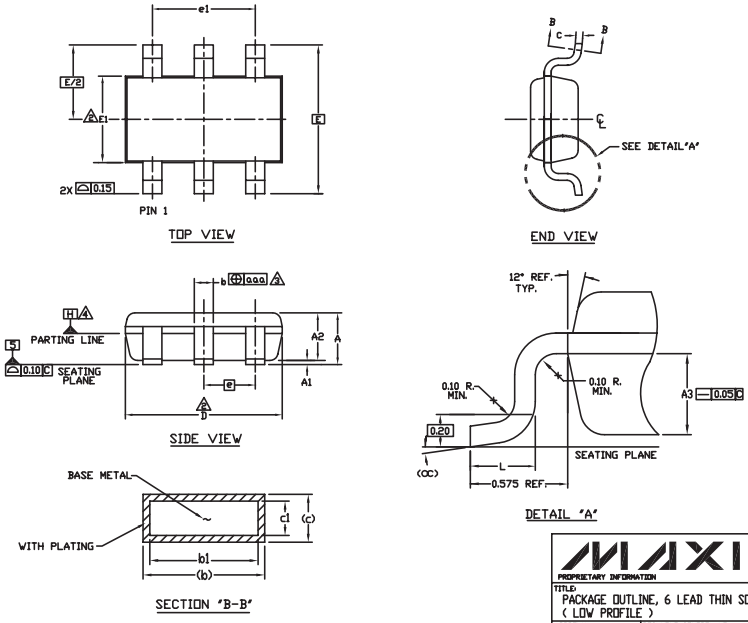
MAXIM
PROPRIETARY INFORMATION

TITLE:
PACKAGE OUTLINE, 8L uMAX

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0036	I	1/1

Package Information (continued)

6 LEAD THIN SOT23.EPS



PROPRIETARY INFORMATION	
TITLE: PACKAGE OUTLINE, 6 LEAD THIN SOT23, (LOW PROFILE)	
APPROVAL	DOCUMENT CONTROL NO. 21-0114 / REV A / 1/2

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.

2. "D" AND "E1" ARE REFERENCE DATUM AND DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS, AND ARE MEASURED AT THE BOTTOM PARTING LINE. MOLD FLASH OR PROTRUSION SHALL NOT EXCEED 0.15mm ON "D" AND 0.25mm ON "E" PER SIDE.

3. THE LEAD WIDTH DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.07mm TOTAL IN EXCESS OF THE LEAD WIDTH DIMENSION AT MAXIMUM MATERIAL CONDITION.

4. DATUM PLANE "H" LOCATED AT MOLD PARTING LINE AND COINCIDENT WITH LEAD, WHERE LEAD EXITS PLASTIC BODY AT THE BOTTOM OF PARTING LINE.

5. THE LEAD TIPS MUST LINE WITHIN A SPECIFIED TOLERANCE ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL LINES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; AND THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED. FORMED LEADS SHALL BE PLANAR WITH RESPECT TO ONE ANOTHER WITH 0.10mm AT SEATING PLANE.

6. THIS PART IS COMPLIANT WITH JEDEC SPECIFICATION MO-193 EXCEPT FOR THE "e" DIMENSION WHICH IS 0.95mm INSTEAD OF 1.00mm. THIS PART IS IN FULL COMPLIANCE TO EIAJ SPECIFICATION SC-74.

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	
cc	0°	4°	8°
aaa		0.20	

PROPRIETARY INFORMATION	
TITLE: PACKAGE OUTLINE, 6 LEAD THIN SOT23, (LOW PROFILE)	
APPROVAL	DOCUMENT CONTROL NO. 21-0114 / REV A / 2/2