19-1896; Rev 0; 1/01

MAXIM

256-Tap, µPoT, Low-Drift, Digital Potentiometer

General Description

The MAX5402 µPoT™ digital potentiometer is a 256-tap variable resistor with 10kΩ total resistance in a tiny 8-pin µMAX package. This device functions as a mechanical potentiometer, consisting of a fixed resistor string with a digitally controlled wiper contact. It operates from +2.7V to +5.5V single-supply voltages and uses an ultra-low 0.1µA supply current. This device also provides glitchless switching between resistor taps, as well as a convenient power-on reset (POR) that sets the wiper to the midscale position at power-up. A low 5ppm/°C ratiometric temperature coefficient makes it ideal for applications requiring low drift.

The MAX5402 serves well in applications requiring digitally controlled resistors, including adjustable voltage references and programmable gain amplifiers (PGAs). A nominal end-to-end resistor temperature coefficient of 35ppm/°C makes this part suitable for use as a variable resistor in applications such as low-tempco adjustable gain and other circuit configurations. This device is guaranteed over the extended industrial temperature range (-40°C to +85°C).

Features

- **Small Footprint, 8-Pin µMAX Package**
- **Ultra-Low 100nA Supply Current**
- **+2.7V to +5.5V Single-Supply Operation**
- **256 Tap Positions**
- **Low Ratiometric Temperature Coefficient 5ppm/°C**
- **Low End-to-End Resistor Temperature Coefficient 35ppm/°C**
- **Power-On Reset: Wiper Goes to Midscale (Position 128)**
- **Glitchless Switching Between the Resistor Taps**
- **3-Wire SPI™-Interface Compatible**
- **10kΩ Resistor Value**

Applications

Mechanical Potentiometer Replacement

Low-Drift PGAs

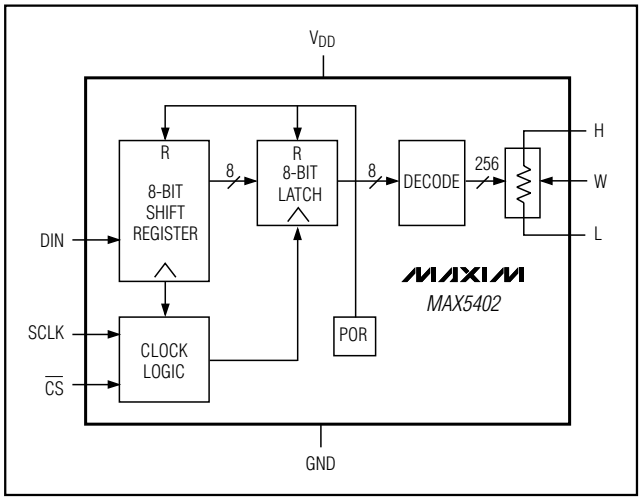
Adjustable Voltage References

Ordering Information

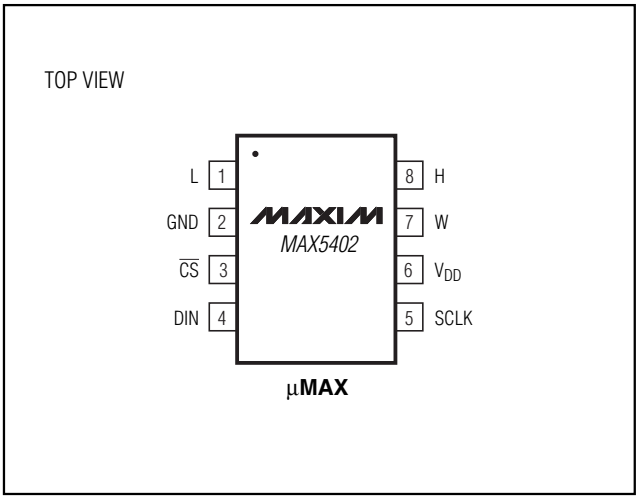
PART	TEMP. RANGE	PIN-PACKAGE	R (kΩ)
MAX5402EUA	-40°C to +85°C	8 µMAX	10

µPoT is a trademark of Maxim Integrated Products.
SPI is a trademark of Motorola, Inc.

Functional Diagram



Pin Configuration



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ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND .....-0.3V to +6V
DIN, SCLK, $\overline{CS}$ to GND .....-0.3V to +6V
H, L, W to GND .....-0.3V to (V_{DD} + 0.3)
Maximum Continuous Current into Pins H, L, and W 1mA
Continuous Power Dissipation (T_A = +70°C)
8-Pin µMAX (derate 4.1mW/°C above +70°C) 330mW

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_{DD} = +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 (Voltage-Divider Mode)						
Resolution	N		8			Bits
Integral Nonlinearity (Notes 1, 2)	INL				±1/2	LSB
Differential Nonlinearity (Notes 1, 2)	DNL				±1	LSB
End-to-End Resistor Tempco	TC_R			35		ppm/°C
Ratiometric Resistor Tempco				5		ppm/°C
Full-Scale Error				-6		LSB
Zero-Scale Error				+6		LSB
DC PERFORMANCE (Variable-Resistor Mode)						
Resolution	N		8			Bits
Integral Nonlinearity (Notes 1, 3)	INL	V_{DD} = +5V			±1	LSB
		V_{DD} = +3V			±3	LSB
Differential Nonlinearity (Notes 1, 3)	DNL	V_{DD} = +5V			±1/2	LSB
		V_{DD} = +3V			±1/2	LSB
DC PERFORMANCE (Resistor Characteristics)						
Wiper Resistance (Note 4)	R_W	V_{DD} = +5V		275		Ω
		V_{DD} = +3V			550	Ω
Wiper Capacitance	C_W			46		pF
End-to-End Resistance	R_{HL}		7.5	10	12.5	kΩ
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					±1.0	µA
Input Capacitance				5		pF
TIMING CHARACTERISTICS (ANALOG)						
Wiper-Settling Time	t_S	To 50% of final value from code 0 to code 128		100		ns
TIMING CHARACTERISTICS (DIGITAL) (Note 5) (Figure 2)						
SCLK Clock Period	t_{CP}		100			ns
SCLK Pulse Width High	t_{CH}		40			ns

ELECTRICAL CHARACTERISTICS (continued)

(V_{DD} = +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
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}			0			ns
DIN Setup Time	t_{DS}			40			ns
DIN Hold Time	t_{DH}			0			ns
SCLK Rise to $\overline{CS}$ Fall Delay	t_{CS0}			10			ns
$\overline{CS}$ Rise to SCLK Rise Hold	t_{CS1}			40			ns
$\overline{CS}$ Pulse Width High	t_{CSW}			100			ns
POWER SUPPLIES							
Supply Voltage	V_{DD}			2.7		5.5	V
Supply Current	I_{DD}	$\overline{CS}$ = SCLK = DIN = V_{DD}	V_{DD} = +5V		0.8	5	µA
			V_{DD} = +2.7V		0.1		µA

Note 1: Linearity is defined in terms of the H-to-L code-dependent resistance.

Note 2: The DNL and INL are measured with the potentiometer configured as a voltage-divider with H = V_{DD} and L = 0. The wiper terminal is unloaded and measured with an ideal voltmeter.

Note 3: The DNL and INL are measured with the potentiometer configured as a variable resistor. H is unconnected and L = 0. The wiper terminal is driven with a source current of 200µA at V_{DD} = +3V and 400µA at V_{DD} = +5V.

Note 4: The wiper resistance is the worst value measured, injecting a current, I_W = V_{DD}/R_{HL} into terminal W.

Note 5: Digital timing is guaranteed by design.

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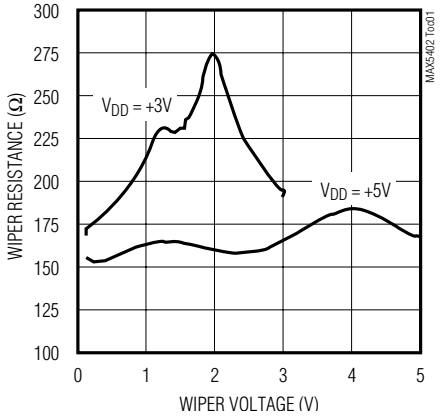
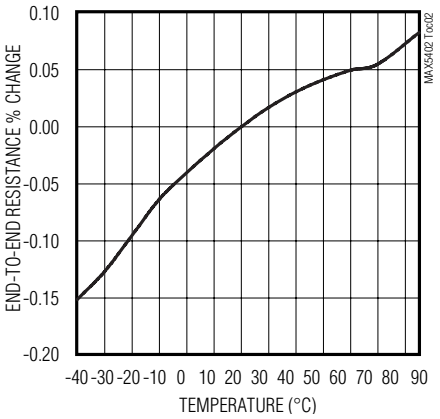
Typical Operating Characteristics

(T_A = +25°C, unless otherwise noted.)

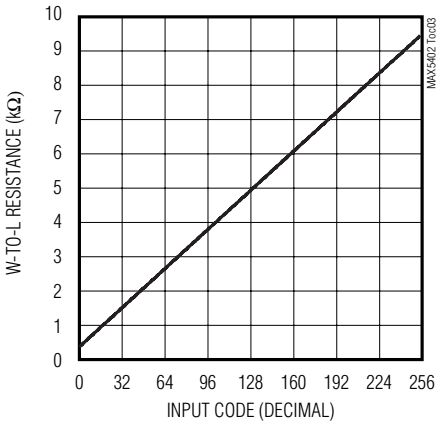
WIPER RESISTANCE vs. WIPER VOLTAGE



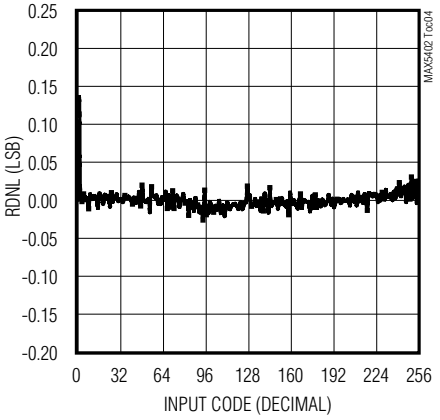
END-TO-END RESISTANCE % CHANGE vs. TEMPERATURE



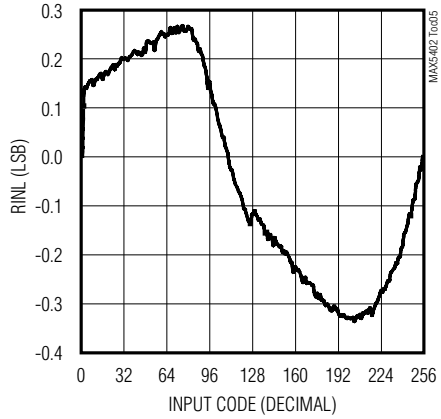
RESISTANCE vs. INPUT CODE



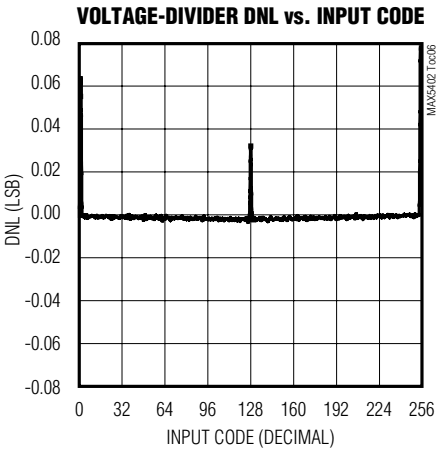
VARIABLE RESISTOR DNL vs. INPUT CODE



VARIABLE RESISTOR INL vs. INPUT CODE



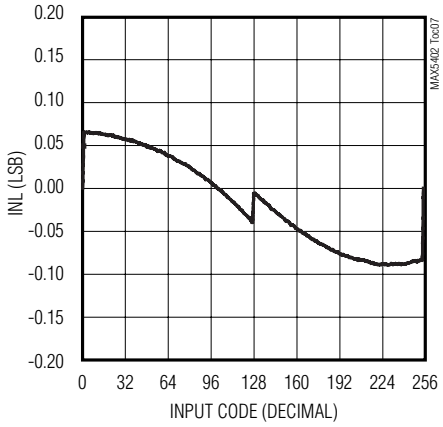
VOLTAGE-DIVIDER DNL vs. INPUT CODE



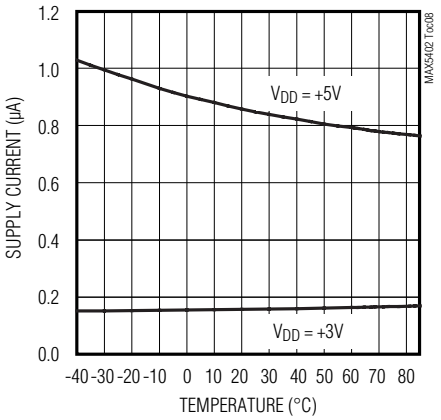
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

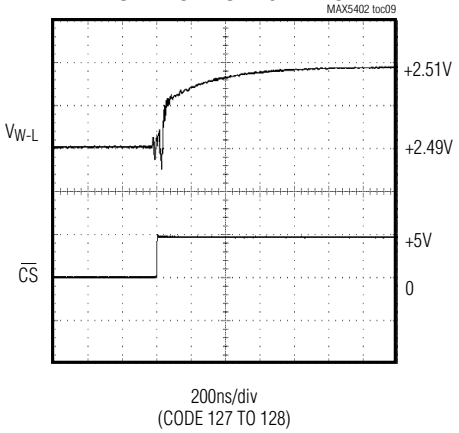
VOLTAGE-DIVIDER INL vs. INPUT CODE



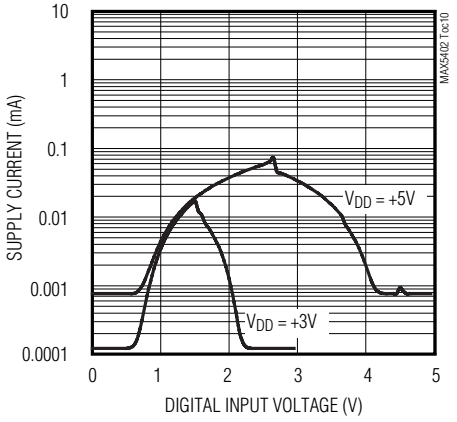
SUPPLY CURRENT vs. TEMPERATURE



TAP-TO-TAP SWITCHING TRANSIENT



INPUT LOGIC VOLTAGE



Pin Description

PIN	NAME	FUNCTION
1	L	Low Terminal of Resistor
2	GND	Ground
3	$\overline{CS}$	Chip Select Input
4	DIN	Serial Data Input
5	SCLK	Serial Clock Input
6	V_{DD}	Power Supply. Bypass with a 0.1µF capacitor to GND.
7	W	Wiper Terminal
8	H	High Terminal of Resistor

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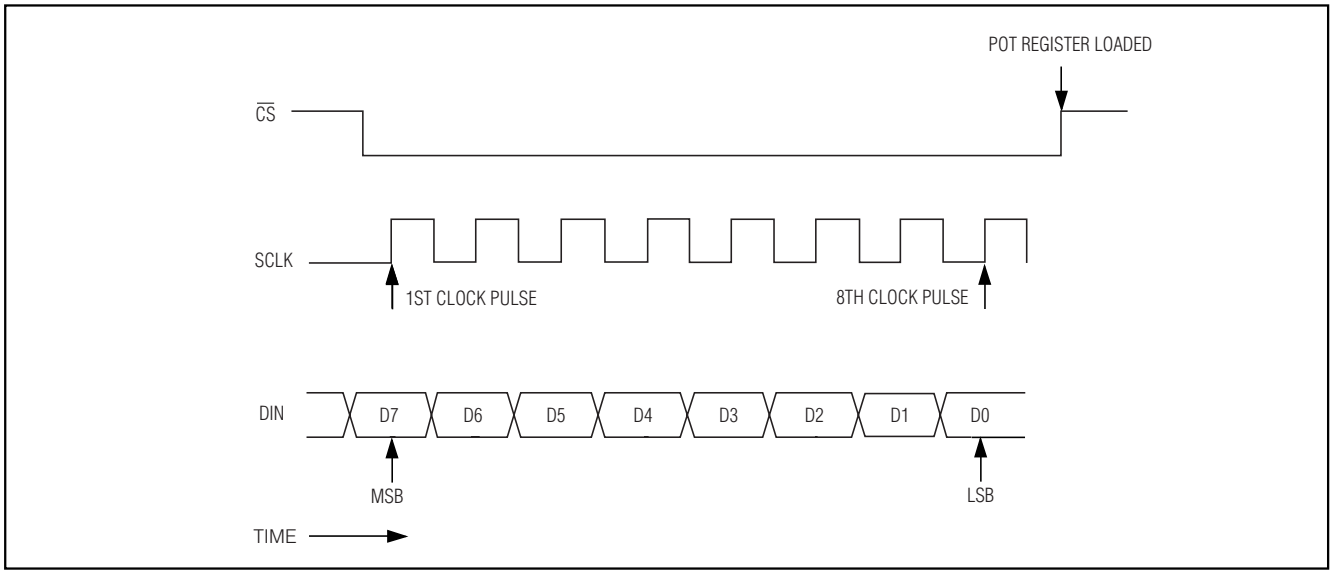

Figure 1. Serial Interface Timing Diagram

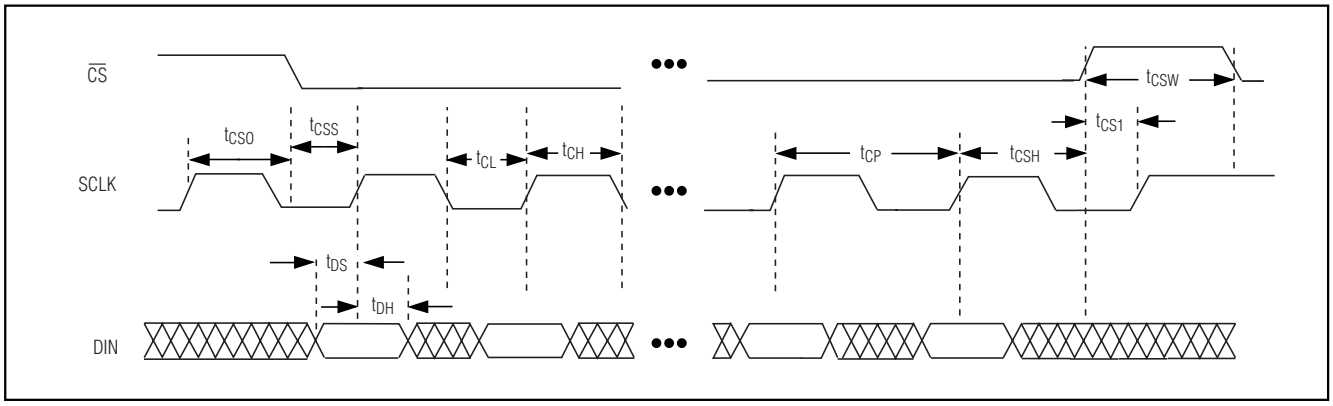

Figure 2. Detailed Serial Interface Timing Diagram

Detailed Description

The MAX5402 consists of 255 fixed resistors in series between pins H and L. The potentiometer wiper (pin W) can be programmed to access any one of the 256 different tap points on the resistor string. The MAX5402 has an SPI-compatible 3-wire serial data interface to control the wiper tap position. This write-only interface contains three inputs: Chip Select ($\overline{CS}$), Data In (DIN), and Data Clock (SCLK). When $\overline{CS}$ is taken low, data from the DIN pin is synchronously loaded into the 8-bit serial shift register on the rising edge of each SCLK pulse (Figure 1). The MSB is shifted in first, as shown in Figure 3. Note that if $\overline{CS}$ is not kept low during the entire data stream, the data will be corrupted and the device will need to be reloaded. After all 8 data bits have been loaded into the shift register, they are latched into the decoder once $\overline{CS}$ is taken high. The decoder switches the potentiometer wiper to the tap position that corresponds to the 8-bit input data. Each resistor cell is 10kΩ/255 or 39.2Ω for the MAX5402.

The MAX5402 features POR circuitry. This sets the wiper to the midscale position at power-up by loading a binary value of 128 into the 8-bit latch. The MAX5402 can be used as a variable resistor by connecting pin W to either pin H or L.

Data Word							
B0 (D7)	**B1** (D6)	**B2** (D5)	**B3** (D4)	**B4** (D3)	**B5** (D2)	**B6** (D1)	**B7** (D0)
(MSB) First Bit In							(LSB) Last Bit In

Figure 3. Serial Data Format

Applications Information

The MAX5402 is intended for a variety of circuits where accurate, fine-tuned adjustable resistance is required, such as in adjustable voltage or adjustable gain circuit configurations. The MAX5402 is used in either a potentiometer divider or a variable resistor configuration.

Adjustable Current to Voltage Converter

Figure 4 shows the MAX5402 used with a MAX4250 low-noise op amp to precisely tune a current-to-voltage converter. Pins H and W of the MAX5402 are connected to the node between R3 and R2, and pin L is connected to ground.

Adjustable Gain Amplifier

The MAX5402 is used again with the MAX4250 to make a digitally adjustable gain circuit as shown in Figure 5. The normal feedback resistor is replaced with the MAX5402 in a variable resistor configuration, so that the gain of the circuit can be digitally controlled.

Adjustable Voltage Reference

In Figure 6, the MAX5402 is shown with the MAX6160 to make an adjustable voltage reference. In this circuit, the H pin of the MAX5402 is connected to the OUT pin of the MAX6160, the L pin of the MAX5402 is connected to GND, and the W pin of the MAX5402 is connected to the ADJ pin of the MAX6160. The MAX5402 allows precise tuning of the voltage reference output. A low 5ppm/°C ratiometric tempco allows a very stable adjustable voltage overtemperature.

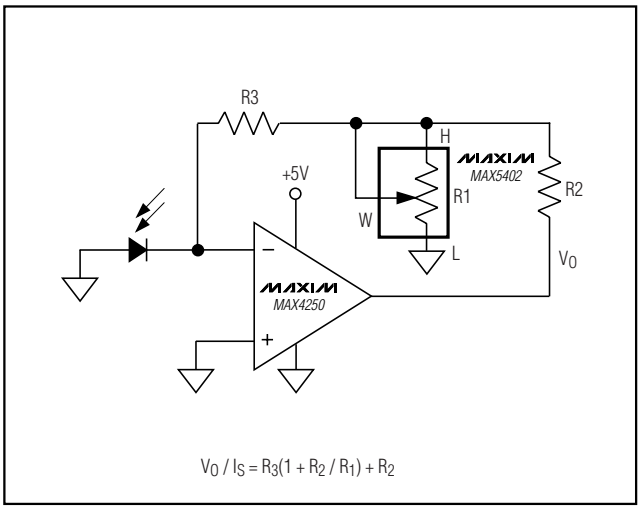

Figure 4. I to V Converter

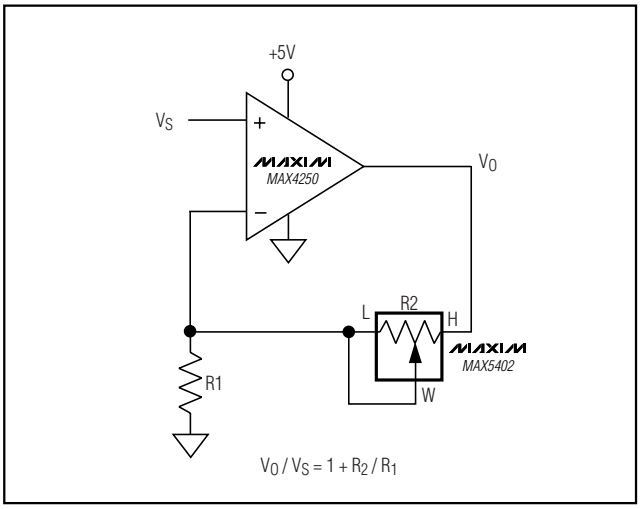

Figure 5. Noninverting Amplifier

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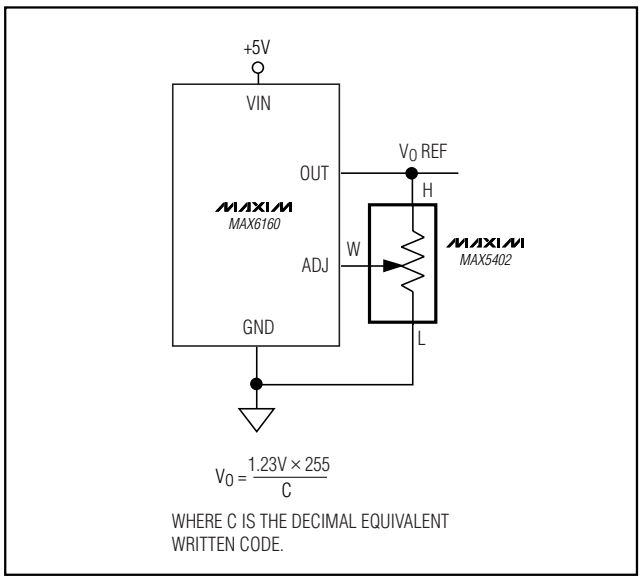


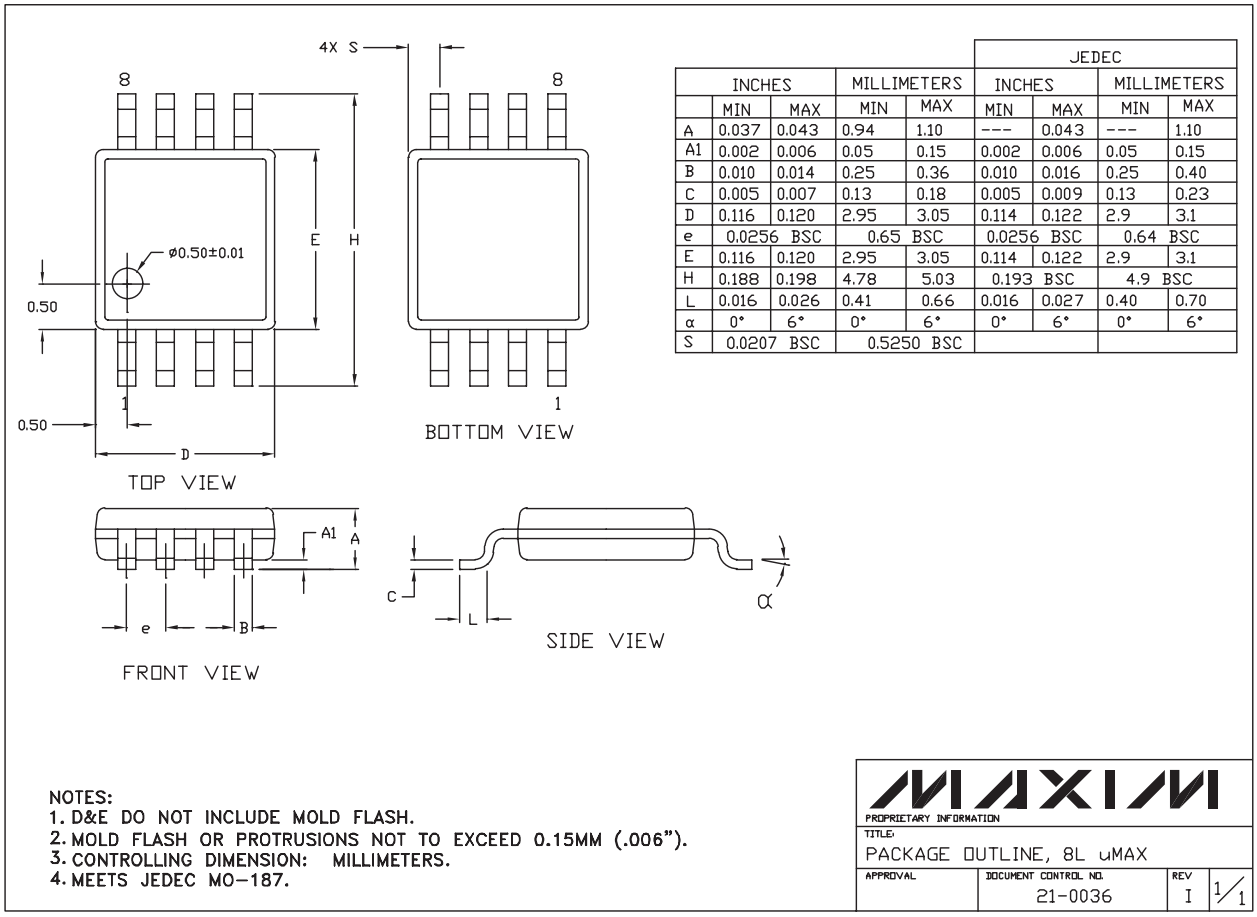
Figure 6. Adjustable Voltage Reference

Chip Information

TRANSISTOR COUNT: 3475

PROCESS: BiCMOS

Package Information



	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