



# 256-Position SPI Compatible Digital Potentiometer

## Preliminary Technical Data

# AD5160

### FEATURES

- 256-Position
- End-to-End Resistance 5k, 10k, 50k, 100k $\Omega$
- Compact SOT23-8 (2.9 x 3mm) Package
- SPI Compatible Interface
- Power ON Reset to Midscale
- Single Supply +2.7V to +5.5V
- Low Temperature Coefficient 35ppm/ $^{\circ}$ C
- Low power,  $I_{DD}=5\mu$ A
- Wide Operating Temperature  $-40^{\circ}$ C to  $+125^{\circ}$ C

### Applications

- Mechanical Potentiometer Replacement in new designs
- Transducer Adjustment of pressure, temperature, position, chemical and optical sensors
- RF Amplifier biasing
- Automotive Electronics Adjustment
- Gain Control and Offset Adjustment

### GENERAL DESCRIPTION

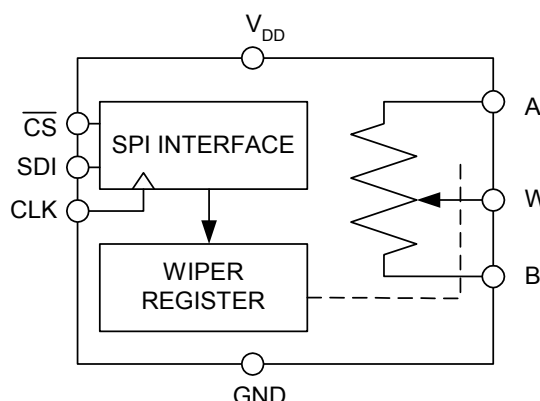
The AD5160 provides a compact 2.9x3mm packaged solution for 256-position adjustment applications.

This device performs the same electronic adjustment function as a mechanical potentiometer or a variable resistor. Available in four different end-to-end resistance values (5k, 10k, 50k, 100k $\Omega$ ) these low temperature coefficient devices are ideal for high accuracy and stability variable resistance adjustments.

The wiper settings are controllable through the SPI compatible digital interface. The resistance between the wiper and either end point of the fixed resistor varies linearly with respect to the digital code transferred into the RDAC latch<sup>1</sup>.

Operating from a 2.7 to 5.5 volt power supply consuming less than 5 $\mu$ A allows for usage in portable battery operated applications.

### FUNCTIONAL DIAGRAM



### PIN CONFIGURATION

|   |                 |                        |   |
|---|-----------------|------------------------|---|
| 1 | W               | A                      | 8 |
| 2 | V <sub>DD</sub> | B                      | 7 |
| 3 | GND             | $\overline{\text{CS}}$ | 6 |
| 4 | CLK             | SDI                    | 5 |

### Notes:

1. The terms digital potentiometers, VR, and RDAC are used interchangeably.

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# PRELIMINARY TECHNICAL DATA

## 256 Position Digital Potentiometer

# AD5160

**AD5160 ELECTRICAL CHARACTERISTICS 5K, 10K, 50K, 100KΩ VERSION** ( $V_{DD} = +5V \pm 10\%$ , or  $+3V \pm 10\%$ ,  $V_A = +V_{DD}$ ,  $V_B = 0V$ ,  $-40^\circ C < T_A < +125^\circ C$  unless otherwise noted.)

| Parameter                                                                     | Symbol                | Conditions                                                        | Min      | Typ <sup>1</sup> | Max      | Units           |
|-------------------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------|----------|------------------|----------|-----------------|
| DC CHARACTERISTICS RHEOSTAT MODE                                              |                       |                                                                   |          |                  |          |                 |
| Resistor Differential Nonlinearity <sup>2</sup>                               | R-DNL                 | $R_{WB}$ , $V_A = \text{No Connect}$                              | -1       | $\pm 0.25$       | +1       | LSB             |
| Resistor Integral Nonlinearity <sup>2</sup>                                   | R-INL                 | $R_{WB}$ , $V_A = \text{No Connect}$                              | -2       | $\pm 0.5$        | +2       | LSB             |
| Nominal Resistor Tolerance <sup>3</sup>                                       | $\Delta R_{AB}$       | $T_A = 25^\circ C$                                                | -30      |                  | 30       | %               |
| Resistance Temperature Coefficient                                            | $R_{AB}/\Delta T$     | $V_{AB} = V_{DD}$ , Wiper = No Connect                            |          | 35               |          | ppm/ $^\circ C$ |
| Wiper Resistance                                                              | $R_W$                 | $V_{DD} = +5V$                                                    |          | 50               | 100      | $\Omega$        |
| DC CHARACTERISTICS POTENTIOMETER DIVIDER MODE Specifications apply to all VRs |                       |                                                                   |          |                  |          |                 |
| Resolution                                                                    | N                     |                                                                   | 8        |                  |          | Bits            |
| Differential Nonlinearity <sup>4</sup>                                        | DNL                   |                                                                   | -1       | $\pm 1/4$        | +1       | LSB             |
| Integral Nonlinearity <sup>4</sup>                                            | INL                   |                                                                   | -2       | $\pm 1/2$        | +2       | LSB             |
| Voltage Divider Temperature Coefficient                                       | $\Delta V_W/\Delta T$ | Code = 80 <sub>H</sub>                                            |          | 5                |          | ppm/ $^\circ C$ |
| Full-Scale Error                                                              | $V_{WFSE}$            | Code = FF <sub>H</sub>                                            | -1.5     | -0.5             | +0       | LSB             |
| Zero-Scale Error                                                              | $V_{WZSE}$            | Code = 00 <sub>H</sub>                                            | 0        | +0.5             | +1.5     | LSB             |
| RESISTOR TERMINALS                                                            |                       |                                                                   |          |                  |          |                 |
| Voltage Range <sup>5</sup>                                                    | $V_{A,B,W}$           |                                                                   | $V_{SS}$ |                  | $V_{DD}$ | V               |
| Capacitance <sup>6</sup> A, B                                                 | $C_{A,B}$             | $f = 1 \text{ MHz}$ , measured to GND, Code = 80 <sub>H</sub>     |          | 45               |          | pF              |
| Capacitance <sup>6</sup> W                                                    | $C_W$                 | $f = 1 \text{ MHz}$ , measured to GND, Code = 80 <sub>H</sub>     |          | 60               |          | pF              |
| Shutdown Supply Current <sup>7</sup>                                          | $I_{DD\_SD}$          | $V_{DD} = 5.5V$                                                   |          | 0.01             | 5        | $\mu A$         |
| Common-Mode Leakage                                                           | $I_{CM}$              | $V_A = V_B = V_{DD}/2$                                            |          | 1                |          | nA              |
| DIGITAL INPUTS & OUTPUTS                                                      |                       |                                                                   |          |                  |          |                 |
| Input Logic High                                                              | $V_{IH}$              |                                                                   | 2.4      |                  |          | V               |
| Input Logic Low                                                               | $V_{IL}$              |                                                                   |          |                  | 0.8      | V               |
| Input Logic High                                                              | $V_{IH}$              | $V_{DD} = +3V$                                                    | 2.1      |                  |          | V               |
| Input Logic Low                                                               | $V_{IL}$              | $V_{DD} = +3V$                                                    |          |                  | 0.6      | V               |
| Input Current                                                                 | $I_{IL}$              | $V_{IN} = 0V$ or $+5V$                                            |          |                  | $\pm 1$  | $\mu A$         |
| Input Capacitance <sup>6</sup>                                                | $C_{IL}$              |                                                                   |          | 5                |          | pF              |
| POWER SUPPLIES                                                                |                       |                                                                   |          |                  |          |                 |
| Logic Supply                                                                  | $V_{LOGIC}$           |                                                                   | 2.7      |                  | 5.5      | V               |
| Power Supply Range                                                            | $V_{DD\_RANGE}$       | $V_{SS} = 0V$                                                     | -0.3     |                  | 5.5      | V               |
| Supply Current                                                                | $I_{DD}$              | $V_{IH} = +5V$ or $V_{IL} = 0V$                                   |          | 5                |          | $\mu A$         |
| Power Dissipation <sup>8</sup>                                                | $P_{DISS}$            | $V_{IH} = +5V$ or $V_{IL} = 0V$ , $V_{DD} = +5V$                  |          |                  | 0.2      | mW              |
| Power Supply Sensitivity                                                      | PSS                   | $\Delta V_{DD} = +5V \pm 10\%$ , Code = Midscale                  | -0.01    | 0.001            | +0.01    | %/%             |
| DYNAMIC CHARACTERISTICS <sup>6, 9</sup>                                       |                       |                                                                   |          |                  |          |                 |
| Bandwidth -3dB                                                                | BW_10K                | $R_{AB} = 10K\Omega$ , Code = 80 <sub>H</sub>                     |          | 600              |          | KHz             |
| Bandwidth -3dB                                                                | BW_50K                | $R_{AB} = 50K\Omega$ , Code = 80 <sub>H</sub>                     |          | 100              |          | KHz             |
| Total Harmonic Distortion                                                     | THD <sub>W</sub>      | $V_A = 1V_{rms}$ , $V_B = 0V$ , $f = 1KHz$ , $R_{AB} = 10K\Omega$ |          | 0.003            |          | %               |
| $V_W$ Settling Time (10K $\Omega$ /50K $\Omega$ )                             | $t_S$                 | $V_A = 5V$ , $V_B = 0V$ , $\pm 1$ LSB error band                  |          | 2/9              |          | $\mu s$         |
| Resistor Noise Voltage Density                                                | $e_{N\_WB}$           | $R_{WB} = 5K\Omega$ , $RS = 0$                                    |          | 9                |          | nV/ $\sqrt{Hz}$ |

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| Parameter                                                          | Symbol           | Conditions              | Min | Typ <sup>1</sup> | Max | Units |
|--------------------------------------------------------------------|------------------|-------------------------|-----|------------------|-----|-------|
| INTERFACE TIMING CHARACTERISTICS applies to all parts (Notes 6,10) |                  |                         |     |                  |     |       |
| Input Clock Pulse Width                                            | $t_{CH}, t_{CL}$ | Clock level high or low |     | 20               |     | ns    |
| Data Setup Time                                                    | $t_{DS}$         |                         |     | 5                |     | ns    |
| Data Hold Time                                                     | $t_{DH}$         |                         |     | 5                |     | ns    |
| $\overline{CS}$ Setup Time                                         | $t_{CSS}$        |                         |     | 15               |     | ns    |
| $\overline{CS}$ High Pulse Width                                   | $t_{CSW}$        |                         |     | 40               |     | ns    |
| CLK Fall to $\overline{CS}$ Fall Hold Time                         | $t_{CSH0}$       |                         |     | 0                |     | ns    |
| CLK Fall to $\overline{CS}$ Rise Hold Time                         | $t_{CSH}$        |                         |     | 0                |     | ns    |
| $\overline{CS}$ Rise to Clock Rise Setup                           | $t_{CS1}$        |                         |     | 10               |     | ns    |

### NOTES:

- Typicals represent average readings at  $+25^\circ C$  and  $V_{DD} = +5V$ .
- Resistor position nonlinearity error R-INL is the deviation from an ideal value measured between the maximum resistance and the minimum resistance wiper positions. R-DNL measures the relative step change from ideal between successive tap positions. Parts are guaranteed monotonic.
- $V_{AB} = V_{DD}$ , Wiper ( $V_W$ ) = No connect
- INL and DNL are measured at  $V_W$  with the RDAC configured as a potentiometer divider similar to a voltage output D/A converter.  $V_A = V_{DD}$  and  $V_B = 0V$ . DNL specification limits of  $\pm 1LSB$  maximum are Guaranteed Monotonic operating conditions.
- Resistor terminals A,B,W have no limitations on polarity with respect to each other.
- Guaranteed by design and not subject to production test.
- Measured at the A terminal. A terminal is open circuited in shutdown mode.
- $P_{DISS}$  is calculated from  $(I_{DD} \times V_{DD})$ . CMOS logic level inputs result in minimum power dissipation
- All dynamic characteristics use  $V_{DD} = +5V$ .
- See timing diagram for location of measured values. All input control voltages are specified with  $t_R = t_F = 2ns$  (10% to 90% of  $+3V$ ) and timed from a voltage level of 1.5V. Switching characteristics are measured using  $V_{LOGIC} = +5V$ .
- The AD5160 contains 2532 transistors. Die Size: 30.7mil x 76.8 mil, 2358sq. mil.
- See timing diagram for location of measured values.

### CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD5160 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



# 256 Position Digital Potentiometer

# AD5160

**ABSOLUTE MAXIMUM RATINGS<sup>1</sup>** ( $T_A = +25^\circ\text{C}$ , unless otherwise noted)

|                                                                  |                                             |
|------------------------------------------------------------------|---------------------------------------------|
| $V_{DD}$ to GND .....                                            | -0.3, +7V                                   |
| $V_A, V_B, V_W$ to GND .....                                     | $V_{DD}$                                    |
| $I_{MAX}$ .....                                                  | $\pm 20\text{mA}^2$                         |
| Digital Inputs & Output Voltage to GND .....                     | 0V, +7V                                     |
| Operating Temperature Range .....                                | $-40^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Maximum Junction Temperature ( $T_{JMAX}$ ) .....                | $+150^\circ\text{C}$                        |
| Storage Temperature .....                                        | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temperature (Soldering, 10 sec) .....                       | $+300^\circ\text{C}$                        |
| Thermal Resistance <sup>3</sup> $\theta_{JA}$ ,<br>SOT23-8 ..... | $230^\circ\text{C/W}$                       |

## NOTES

- Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
- Maximum terminal current is bounded by the maximum current handling of the switches, maximum power dissipation of the package, and maximum applied voltage across any two of the A, B, and W terminals at a given resistance
- Package Power Dissipation ( $T_{JMAX} - T_A$ ) /  $\theta_{JA}$

## ORDERING GUIDE

| Model#       | $R_{AB}$<br>( $\Omega$ ) | Package<br>Description | Package<br>Option | Brand |
|--------------|--------------------------|------------------------|-------------------|-------|
| AD5160BRJ5   | 5K                       | SOT23-8                | RJ-8              | D08   |
| AD5160BRJ10  | 10K                      | SOT23-8                | RJ-8              | D09   |
| AD5160BRJ50  | 50K                      | SOT23-8                | RJ-8              | D0A   |
| AD5160BRJ100 | 100K                     | SOT23-8                | RJ-8              | D0B   |

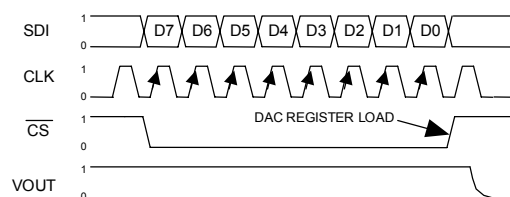
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## 256 Position Digital Potentiometer

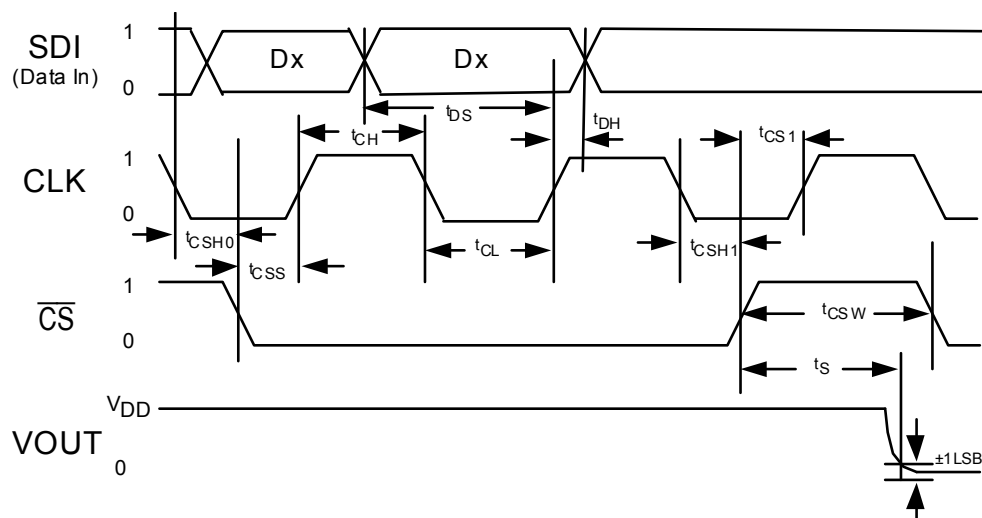
# AD5160

**TABLE 1: AD5160 Serial-Data Word Format**

| B7    | B6 | B5 | B4 | B3 | B2 | B1 | B0    |
|-------|----|----|----|----|----|----|-------|
| D7    | D6 | D5 | D4 | D3 | D2 | D1 | D0    |
| MSB   |    |    |    |    |    |    | LSB   |
| $2^7$ |    |    |    |    |    |    | $2^0$ |



**Figure 1A. AD5160 Timing Diagram**( $V_A = 5V$ ,  $V_B = 0V$ ,  $V_W = V_{OUT}$ )



**Figure 1B. Detail Timing Diagram**( $V_A = 5V$ ,  $V_B = 0V$ ,  $V_W = V_{OUT}$ )

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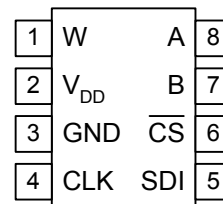
## 256 Position Digital Potentiometer

# AD5160

**TABLE 2:** AD5160 PIN Descriptions

| Pin | Name                   | Description                                                                                     |
|-----|------------------------|-------------------------------------------------------------------------------------------------|
| 1   | V <sub>W</sub>         | W Terminal                                                                                      |
| 2   | V <sub>DD</sub>        | Positive Power Supply                                                                           |
| 3   | GND                    | Ground                                                                                          |
| 4   | CLK                    | Serial Clock Input, positive edge triggered                                                     |
| 5   | SDI                    | Serial Data Input                                                                               |
| 6   | $\overline{\text{CS}}$ | Chip Select Input, Active Low. When CS returns high, data will be loaded into the DAC register. |
| 7   | V <sub>B</sub>         | B Terminal                                                                                      |
| 8   | V <sub>A</sub>         | A Terminal                                                                                      |

### PIN CONFIGURATION



# PRELIMINARY TECHNICAL DATA

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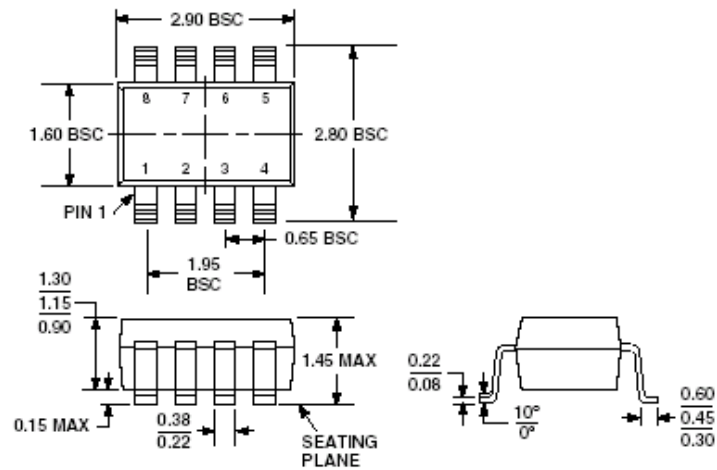
# AD5160

### OUTLINE DIMENSIONS

#### 8-Lead Plastic Surface-Mount Package [SOT-23]

RJ-8

Dimensions shown in millimeters



COMPLIANT TO JEDEC STANDARDS MO-178BA