Digital Potentiometer
AS1500/AS1501/AS1502/AS1503

DATASHEET

Key Features

- 256-Position
- Available in four Resistance values
  - AS1500 resistance 10kOhms
  - AS1501 resistance 20kOhms
  - AS1502 resistance 50kOhms
  - AS1503 resistance 100kOhms
- Power Shutdown —Less than 1 µA
- 3-Wire SPI-Compatible Serial Data Input
- 10 MHz Update Data Loading Rate
- 2.7 V to 5.5 V Single-Supply Operation
- Temperature Range –40°C to +125°C
- Package SO-8
- Compatible to AD8400

General Description

The AS1500 is a digital potentiometer with 256 programmable steps. The values of the resistor can be controlled via 3 wire serial interface capable to handle programming rates up to 10MHz. The AS1500 is available in four different resistor values. The AS1500 incorporates a 10kΩ, the AS1501 a 20kΩ, the AS1502 a 50kΩ and the AS1503 a 100kΩ fixed resistor. The wiper contact taps the fixed resistor at points determined by the 8-bit digital code word. The resistance between the wiper and the endpoint of the resistor is linear. The switching action is performed in a way that no glitches occur. Furthermore the AS150x product family includes a shutdown mode, where it consumes less than 1µA. The AS150x is available in an 8-pin SOIC package. All parts are guaranteed to operate over the extended industrial temperature range of –40°C to +125°C.

Applications

- Line Impedance Matching
- Volume Control, Panning
- Mechanical Potentiometer Replacement
- Power Supply Adjustment
- Programmable Filters, Delays, Time Constants

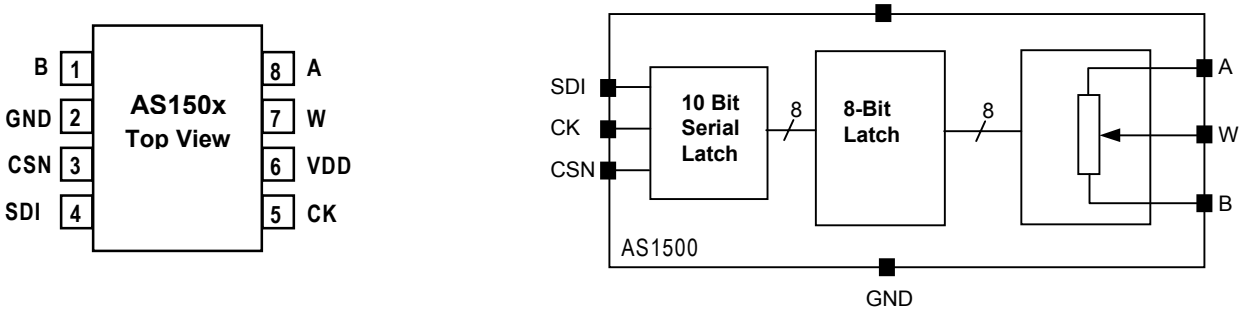


Figure 1 Pinout andfunctional Block Diagram of Digital Potentiometer AS150x family

ABSOLUTE MAXIMUM RATINGS

(TA = 25°C, unless otherwise noted.)

Parameter	Limits
VDD to GND	–0.3V, +7V
VA, VB, VW to GND	0V, VDD
AX – BX, AX – WX, BX – WX	±20mA
Digital Input and Output Voltage to GND	0V, +7V
Operating Temperature Range	–40°C to +125°C
Maximum Junction Temperature (TJ max)	150°C
Storage Temperature	–65°C to +150°C
Package body temperature [1]	260°C
Package Power Dissipation	(TJ max – TA) / θJA
ESD [2]	1kV

Table 1: Absolute Maximum Ratings

Pin	Name	Description
1	B	Terminal B RDAC
2	GND	Ground
3	CSN	Chip Select Input, Active Low. When CS returns high, data in the serial input register is loaded into the DAC register.
4	SDI	Serial Data Input
5	CK	Serial Clock Input, Positive Edge Triggered.
6	VDD	Positive power supply, specified for operation at both 3V and 5V.
7	W	Wiper RDAC
8	A	Terminal A RDAC

Table 2: Pin Function Description

[1] The reflow peak soldering temperature (body temperature) is specified according IPC/JEDEC J-STD-020C “Moisture/Reflow Sensitivity Classification for non hermetic Solid State Surface Mount Devices”.

[2] HBM MIL-Std883E 3015.7methods.

AS1500 / AS1501 – SPECIFICATIONS

VDD = 3V±10% or 5V±10%, V_A = VDD, V_B = 0V, –40°C ≤ T_A ≤ +125°C unless otherwise noted.

ELECTRICAL CHARACTERISTICS – 10k and 20k VERSIONS

Parameter	Symbol	Conditions	Min	Typ[3]	Max	Unit
DC CHARACTERISTICS RHEOSTAT MODE						
Nominal Resistance[4]	R_{AB}	T_A = 25°C, VDD = 5V, AS1500, Version: 10kΩ	8	10	12	kΩ
		T_A = 25°C, VDD = 5V, AS1501, Version: 20kΩ	16	20	24	kΩ
Resistance Tempco[5]	$\Delta R_{AB}/\Delta T$	V_{AB} = VDD, Wiper = No Connect		500		ppm/°C
Wiper Resistance	R_W	VDD = 5V	20	100	200	Ω
Resistor Differential NL[6]	R-DNL	R_{WB}, VDD = 5V, V_A = No Connect	–1	±1/4	+1	LSB
Resistor Integral NL	R-INL	R_{WB}, VDD = 5V, V_A = No Connect	–2	±1/2	+2	LSB
DC CHARACTERISTICS POTENTIOMETER DIVIDER						
Resolution	N			8		Bits
Integral Nonlinearity	INL	VDD = 5.5V T_A = 25°C	–2	±1/2	+2	LSB
		VDD = 2.7V T_A = 25°C	–2	±1/2	+2	LSB
Differential Nonlinearity	DNL	VDD = 5.5V T_A = 25°C	–1	±1/4	+1	LSB
		VDD = 2.7V T_A = 25°C	–1	±1/4	+1	LSB
Voltage Divider Tempco	$\Delta V_W/\Delta T$	Code = 80_H		15		ppm/°C
Full-Scale Error	V_{WFSE}	Code = FF_H, VDD = 5.5V	–4	–2.8	0	LSB
Zero-Scale Error	V_{WZSE}	Code = 00_H, VDD = 5.5V	0	1.3	2	LSB
RESISTOR TERMINALS						
Voltage Range[7]	$V_{A, B, W}$		0		VDD	V
Capacitance[8] Ax, Bx	$C_{A, B}$	f =1MHz, Measured to GND, Code = 80_H		75		pF
Capacitance Wx	C_W	f =1MHz, Measured to GND, Code = 80_H		120		pF
DIGITAL INPUTS AND OUTPUTS						
Input Logic High	V_{IH}	VDD = 5V	2.4			V
Input Logic Low	V_{IL}	VDD = 5V			0.8	V
Input Logic High	V_{IH}	VDD = 3V	2.1			V
Input Logic Low	V_{IL}	VDD = 3V			0.6	V
Input Current	I_{IH}, I_{IL}	V_{IN} = 5V or 0V, VDD = 5V			±1	µA
Input Capacitance	C_{IL}			5		pF
POWER SUPPLIES						
Power Supply Range	VDD		2.7		5.5	V
Supply Current (CMOS)	IDD	V_{IH} = VDD or V_{IL} = 0V, VDD = 5.5V		0.1	1	µA
Supply Current (TTL)[9]	IDD	V_{IH} = 2.4V or 0.8V, VDD = 5.5V		0.9	4	mA
Power Dissipation (CMOS)[10]	P_{DISS}	V_{IH} = VDD or V_{IL} = 0V, VDD = 5.5V			27.5	µW
Power Supply Suppression Ratio	PSSR	VDD = 5V + 0.5V_P sine wave @ 1kHz, AS1500, Version: 10kΩ		-54	-25	dB
		VDD = 5V + 0.5V_P sine wave @ 1kHz, AS1501, Version: 20kΩ		-52	-25	dB
DYNAMIC CHARACTERISTICS[11]						
Bandwidth –3dB	BW_10k	R_{WB} = 10kΩ, VDD = 5V		1000		kHz
Bandwidth –3dB	BW_20k	R_{WB} = 20kΩ, VDD = 5V		500		kHz
Total Harmonic Distortion	THD_W	V_A = 1V_{RMS} + 2V_{DC}, V_B = 2V_{DC}, f = 1kHz		0.003		%
V_W Settling Time	t_S_10k	R_{WB} = 5kΩ, V_A = VDD, V_B = 0V, ±1% Error Band		2		µs
	t_S_20k	R_{WB} = 10kΩ, V_A = VDD, V_B = 0V, ±1% Error Band		4		µs
Resistor Noise Voltage	e_{NWB}_10k	R_{WB} = 5kΩ, f =1kHz		9		nV/ √ Hz
	e_{NWB}_20k	R_{WB} = 10kΩ, f =1kHz		13		nV/ √ Hz

Table 3: Electrical Characteristics – 10k and 20k Versions

[3] Typicals represent average readings at 25°C and VDD = 5V.

[4] Wiper is not connected. I_{AB} = 350µA for the 10kΩ version and 175µA for the 20kΩ version.

[5] All Tempcos are guaranteed by design and not subject to production test.

[6] Terminal A is not connected. I_W = 350µA for the 10kΩ version and 175µA for the 20kΩ version.

[7] Resistor terminals A, B, W have no limitations on polarity with respect to each other.

[8] All capacitances are guaranteed by design and not subject to production test. Resistor-terminal capacitance tests are measured with 2.5V bias on the measured terminal. The remaining resistor terminals are left open circuit.

[9] Worst-case supply current consumed when input logic level at 2.4V, standard characteristic of CMOS logic.

[10] P_{DISS} is calculated from (IDD×VDD). CMOS logic level inputs result in minimum power dissipation.

[11] All dynamic characteristics are guaranteed by design and not subject to production test. All dynamic characteristics use VDD=5V.

AS1502 / AS1503 – SPECIFICATIONS

VDD = 3V±10% or 5V±10%, V_A = VDD, V_B = 0V, –40°C ≤ T_A ≤ +125°C unless otherwise noted.

ELECTRICAL CHARACTERISTICS – 50k and 100k VERSIONS

Parameter	Symbol	Conditions	Min	Typ[12]	Max	Unit
DC CHARACTERISTICS RHEOSTAT MODE						
Nominal Resistance[13]	R_{AB}	T_A = 25°C, VDD = 5V, AS1502, Version: 50kΩ	40	50	60	kΩ
		T_A = 25°C, VDD = 5V, AS1503, Version: 100kΩ	80	100	120	kΩ
Resistance Tempco[14]	$\Delta R_{AB}/\Delta T$	V_{AB} = VDD, Wiper = No Connect		500		ppm/°C
Wiper Resistance	R_W	VDD = 5V	20	100	200	Ω
Resistor Differential NL[15]	R-DNL	R_{WB}, VDD = 5V, V_A = No Connect	–1	±1/4	+1	LSB
Resistor Integral NL	R-INL	R_{WB}, VDD = 5V, V_A = No Connect	–2	±1/2	+2	LSB
DC CHARACTERISTICS POTENTIOMETER DIVIDER						
Resolution	N			8		Bits
Integral Nonlinearity	INL	VDD = 5.5V T_A = 25°C	–4	±1	+4	LSB
		VDD = 2.7V T_A = 25°C	–4	±1	+4	LSB
Differential Nonlinearity	DNL	VDD = 5.5V T_A = 25°C	–1	±1/4	+1	LSB
		VDD = 2.7V T_A = 25°C	–1	±1/4	+1	LSB
Voltage Divider Tempco	$\Delta V_W/\Delta T$	Code = 80_H		15		ppm/°C
Full-Scale Error	V_{WFSE}	Code = FF_H, VDD = 5.5V	–1	–0.25	0	LSB
Zero-Scale Error	V_{WZSE}	Code = 00_H, VDD = 5.5V	0	0.1	1	LSB
RESISTOR TERMINALS						
Voltage Range[16]	$V_{A, B, W}$		0		VDD	V
Capacitance[17] Ax, Bx	$C_{A, B}$	f = 1MHz, Measured to GND, Code = 80_H		15		pF
Capacitance Wx	C_W	f = 1MHz, Measured to GND, Code = 80_H		80		pF
DIGITAL INPUTS AND OUTPUTS						
Input Logic High	V_{IH}	VDD = 5V	2.4			V
Input Logic Low	V_{IL}	VDD = 5V			0.8	V
Input Logic High	V_{IH}	VDD = 3V	2.1			V
Input Logic Low	V_{IL}	VDD = 3V			0.6	V
Input Current	I_{IH}, I_{IL}	V_{IN} = 5V or 0V, VDD = 5V			±1	µA
Input Capacitance	C_{IL}			5		pF
POWER SUPPLIES						
Power Supply Range	VDD		2.7		5.5	V
Supply Current (CMOS)	IDD	V_{IH} = VDD or V_{IL} = 0V, VDD = 5.5V		0.1	1	µA
Supply Current (TTL)[18]	IDD	V_{IH} = 2.4V or 0.8V, VDD = 5.5V		0.9	4	mA
Power Dissipation (CMOS)[19]	P_{DISS}	V_{IH} = VDD or V_{IL} = 0V, VDD = 5.5V			27.5	µW
Power Supply Suppression Ratio	PSSR	VDD = 5V + 0.5V_P sine wave @ 1kHz; AS1502, Version: 50kΩ		-43	tbd.	dB
		VDD = 5V + 0.5V_P sine wave @ 1kHz; AS1503, Version: 100kΩ		-48	tbd.	dB
DYNAMIC CHARACTERISTICS[20]						
Bandwidth –3dB	BW_50k	R_{WB} = 50kΩ, VDD = 5V		220		kHz
Bandwidth –3dB	BW_100k	R_{WB} = 100kΩ, VDD = 5V		110		kHz
Total Harmonic Distortion	THD_W	V_A = 1V_{RMS} + 2V_{DC}, V_B = 2V_{DC}, f = 1kHz		0.003		%
V_W Settling Time	t_S_50k	R_{WB} = 50kΩ, V_A = VDD, V_B = 0V, ±1% Error Band		9		µs
	t_S_100k	R_{WB} = 100kΩ, V_A = VDD, V_B = 0V, ±1% Error Band		18		µs
Resistor Noise Voltage	e_{NWB}_50k	R_{WB} = 50kΩ, f = 1kHz		20		nV/ √ Hz
	e_{NWB}_100k	R_{WB} = 100kΩ, f = 1kHz		29		nV/ √ Hz

Table 4: Electrical Characteristics – 50k and 100k Versions

[12] Typicals represent average readings at 25°C and VDD = 5V.
[13] Wiper is not connected. I_{AB} = 70µA for the 50kΩ version and 35µA for the 100kΩ version.
[14] All Tempcos are guaranteed by design and not subject to production test.
[15] Terminal A is not connected. I_W = 70µA for the 50kΩ version and 35µA for the 100kΩ version.
[16] Resistor terminals A, B, W have no limitations on polarity with respect to each other.
[17] All capacitances are guaranteed by design and not subject to production test. Resistor-terminal capacitance tests are measured with 2.5V bias on the measured terminal. The remaining resistor terminals are left open circuit.
[18] Worst-case supply current consumed when input logic level at 2.4V, standard characteristic of CMOS logic.
[19] P_{DISS} is calculated from (IDD×VDD). CMOS logic level inputs result in minimum power dissipation.
[20] All dynamic characteristics are guaranteed by design and not subject to production test. All dynamic characteristics use VDD=5V.

AS150x – SPECIFICATIONS

(VDD = 3V±10% or 5V±10%, VA = VDD, VB = 0V, –40°C≤TA≤+125°C unless otherwise noted.)

ELECTRICAL CHARACTERISTICS–ALL VERSIONS

Parameter	Sym-bol	Conditions	Min	Typ [21]	Max	Unit
SWITCHING CHARACTERISTICS [22, 23]						
Input Clock Pulsewidth	t_{CH}, t_{CL}	Clock Level High or Low	50			ns
Data Setup Time	t_{DS}		5			ns
Data Hold Time	t_{DH}		5			ns
CSN Setup Time	t_{CSS}		10			ns
CSN High Pulsewidth	t_{CSW}		10			ns
CK Fall to CSN Rise Hold Time	t_{CSH}		0			ns
CSN Rise to Clock Rise Setup	t_{CS1}		10			ns

Table 5: Switching Characteristics

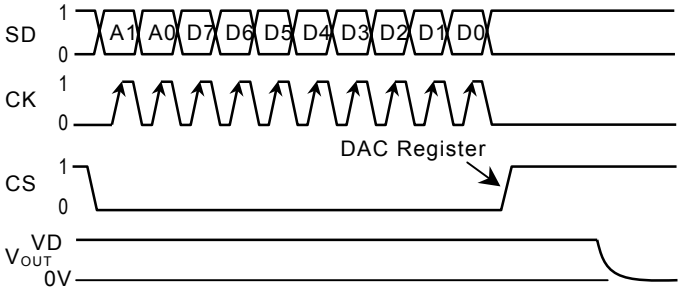


Figure 2: Timing Diagram

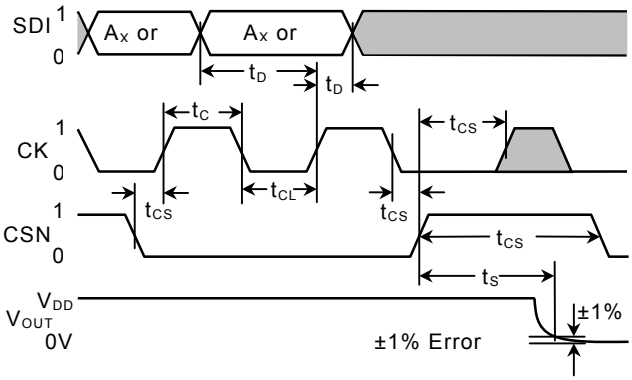


Figure 3: Detailed Timing Diagram

Detailed Description

Serial-Programming

Programming of the AS150x is done via the 3 wire serial interface. The three input signals are serial data input (SDI), clock(CK) and chip select (CS). A programming sequence consists of 10-bit, where the last eight bit contain the code word for the resistor value. The first two bits A1 and A0 have to be low(see Table). The data is shifted into the internal 10 Bit register with the rising edge of the CK signal. With the rising edge of the CSN signal the data becomes valid and the resistance is updated (see figure 2). A detailed block diagram is shown in figure 3.

A1	A0	D7	D6	D5	D4	D3	D2	D1	D0
0	0	MSB			Data				LSB

Table 6: Serial data format (16 bits)

Rheostat Operation

The digital potentiometer family AS150x offers nominal resistor values of 10kΩ, 20 kΩ, 50kΩ and 100kΩ. The resistor has 256 contact points where the wiper can access the resistor. The 8-bit code word determines the position of the wiper and is decoded through an internal logic. The lowest code 00h is related to the terminal B. The resistance is then only determined by the wiper resistance (100Ω). The resistance for the next code 01h is the nominal resistor RAB (10kΩ, 20 kΩ, 50kΩ or 100kΩ) divided through 256 plus the wiper resistor. In case of AS1501 (10kΩ) the total resistance is 39Ω+100Ω=139Ω. Accordingly the resistor for code 02h is 78Ω+100Ω=178Ω. The last code 255h does not connect to terminal A directly (see Figure 5). So the maximum value is 10000Ω - 39Ω +100Ω = 10061Ω. The general formula for the calculation of the resistance R_{WB} is:

$$R_{WB}(Dx) = (Dx)/256 \cdot R_{AB} + R_W$$

where R_{AB} is the nominal resistance between terminal A and B, R_W is the wiper resistance and D_X is the 8-Bit Code word. In Table 7 the resistor values between the wiper and terminal B for AS1501 are given for specific codes D_X. In the zero-scale condition the wiper resistance of 100Ω remains present.

[21] Typicals represent average readings at 25°C and VDD=5V.

[22] Guaranteed by design and not subject to production test. Resistor-terminal capacitance tests are measured with 2.5V bias on the measured terminal. The remaining resistor terminals are left open circuit.

[23] See timing diagram for location of measured values. All input control voltages are specified with $t_R = t_F$ = 1ns (10% to 90% of VDD) and timed from a voltage level of 1.6V. Switching characteristics are measured using VDD=3V or 5V. To avoid false clocking, a minimum input logic slew rate of 1V/µs should be maintained.

D_X (Dec)	R_{WB} (Ω)	Output State
255	10061	Full Scale
128	5100	Midscale
1	139	1 LSB
0	100	Zero-Scale (Wiper Contact Resistance)

Table 7: RDAC-Codes WB

The maximum current through the wiper and terminal B is 5mA. If the current exceeds this limit the internal switches can degrade or even be damaged. As a mechanical potentiometer the resistance R_{WA} and R_{WB} are totally symmetrical. The relation between them is shown in Figure 4.

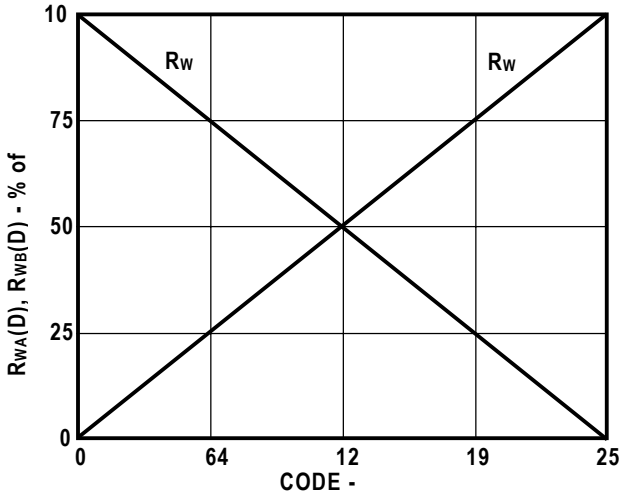


Figure 4: R_{WA} and R_{WB} versa Code

The resistance RWA is the complimentary resistor to RWB and can be controlled digitally as well. RWA starts at the maximum value of the nominal resistance and is reduced with increasing 8-Bit code words. The formula to calculate RWA is given below:

$$R_{WA}(Dx) = (256 - Dx)/256 \cdot R_{AB} + R_W$$

where R_{AB} is the nominal resistance between terminal A and B, R_W is the wiper resistance and D_X is the 8-Bit Code word. In Table 8 the resistor values between the wiper and terminal B for AS1501 are given for specific codes D_X.

D_X (Dec)	R_{WA} (Ω)	Output State
255	89	Full Scale
128	5050	Midscale
1	10011	1 LSB
0	10050	Zero-Scale

Table 8: RDAC-Codes WA

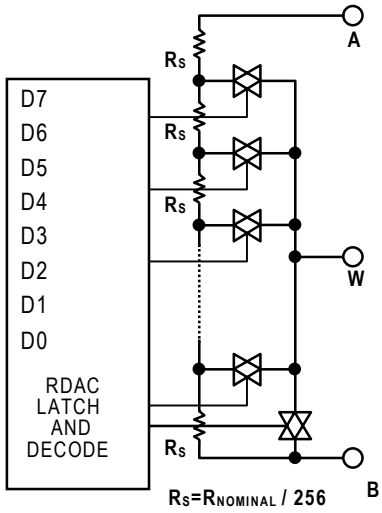


Figure 5: Equivalent RDAC Circuit

Voltage Output Operation

The AS150x family can easily used in an voltage output mode, where the output voltage is proportional to an applied voltage to a given terminal. When 5V are applied to terminal A and B is set to ground the ouput voltage at the wiper starts at zero volts up to 1LSB less then 5V. One LSB of voltage corresponds to the voltage applied at terminal AB divided through 256 steps of possible wiper settings. The formula is given by

$$V_W(Dx) = (Dx)/256 \cdot V_{AB} + V_B$$

where V_{AB} is the voltage applied between terminal A and B, V_W is the voltage at the wiper, D_X is the 8-Bit Code word and V_B is the voltage at terminal B. The temperature drift is significant better than in Rheostat mode, since the temperature coefficient is determined by the internal resistor ratio. Therefore the temperature drift is only 15ppm/°C.

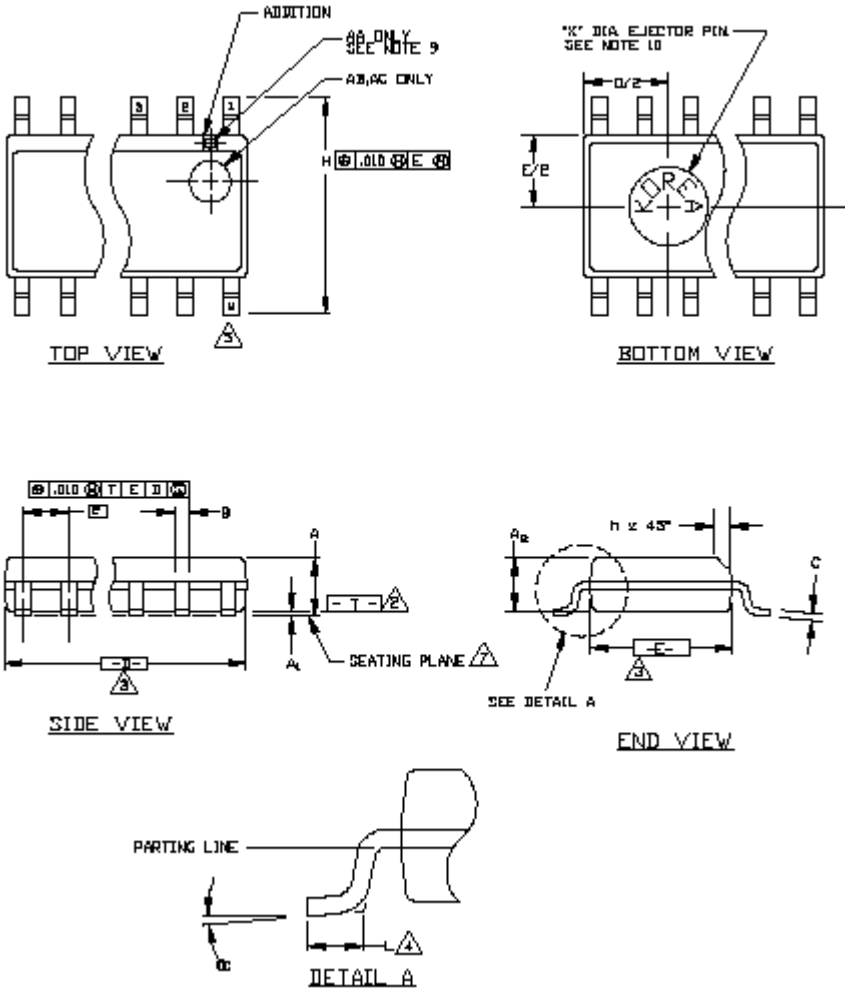
Applications

The digital potentiometer can replace in many applications the analog trimming potentiometer. The digital potentiometer is not sensitive to vibrations and shocks. It has an extremely small form-factor and can be adjusted very fast (e.g. AS1500 has an update rate of 600kHz) Furthermore the temperature drift, resolution and noise are significant better and cannot be achieved with a mechanical trimming potentiometer. Due to the programmability the resistor settings can be stored in the system memory, so that after a power down the exact settings can be recalled easily.

All analog signals must remain within 0 to VDD range. For standard potentiometer applications the wiper output can be used directly. In the case of a low impedance load a buffer shall be used.

Package Information

The AS150x family is offered in a 8-pin SOIC package:



2. DIMENSIONING & TOLERANCES PER ANSI.Y14.5M - 1982.
3. 'T' IS A REFERENCE DATUM.
4. 'D' & 'E' ARE REFERENCE DATUMS AND DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS, BUT DOES INCLUDE MOLD MISMATCH AND ARE MEASURED AT THE MOLD PARTING LINE. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 INCHES PER SIDE.
5. 'L' IS THE LENGTH OF TERMINAL FOR SOLDERING TO A SUBSTRATE.
6. 'N' IS THE NUMBER OF TERMINAL POSITIONS.
7. TERMINAL POSITIONS ARE SHOWN FOR REFERENCE ONLY.
8. FORMED LEADS SHALL BE PLANAR WITH RESPECT TO ONE ANOTHER WITHIN .003 INCHES AT SEATING PLANE.
9. THE APPEARANCE OF PIN #1 I.D ON THE 8 LD IS OPTIONAL, ROUND TYPE ON SINGLE LEADFRAME AND RECTANGULAR TYPE ON MATRIX LEADFRAME.
10. COUNTRY OF ORIGIN LOCATION AND EJECTOR PIN ON PACKAGE BOTTOM IS OPTIONAL AND DEPEND ON ASSEMBLY LOCATION.
11. CONTROLLING DIMENSION: INCHES.

Package Dimensions in Inch and mm (values for N = 8 Pin package are valid):

SYMBOL	COMMON DIMENSIONS			NOTE	VARI-ATIONS	D			N
	MIN.	NOM.	MAX.			MIN.	NOM.	MAX.	
A	.061	.064	.068		AA	.189	.194	.196	8
A_1	.004	.006	.0098		AB	.337	.342	.344	14
A_2	.055	.058	.061		AC	.386	.391	.393	16
B	.0138	.016	.0192						
C	.0075	.008	.0098						
D	SEE VARIATIONS			3					
E	.150	.155	.157						
e	.050 BSC								
H	.230	.236	.244						
h	.010	.013	.016						
L	.016	.025	.035						
N	SEE VARIATIONS			5					
α	0°	5°	8°						
X	.085	.093	.100						

THIS TABLE IN MILLIMETERS

SYMBOL	COMMON DIMENSIONS			NOTE	VARI-ATIONS	D			N
	MIN.	NOM.	MAX.			MIN.	NOM.	MAX.	
A	1.55	1.63	1.73		AA	4.80	4.93	4.98	8
A_1	0.127	0.15	0.25		AB	8.58	8.69	8.74	14
A_2	1.40	1.47	1.55		AC	9.80	9.93	9.98	16
B	0.35	0.41	0.49						
C	0.19	0.20	0.25						
D	SEE VARIATIONS			3					
E	3.81	3.94	3.99						
e	1.27 BSC								
H	5.84	5.99	6.20						
h	0.25	0.33	0.41						
L	0.41	0.64	0.89						
N	SEE VARIATIONS			5					
α	0°	5°	8°						
X	2.16	2.36	2.54						

Ordering Information

Part	Resistor	Pin Package	Delivery Form
AS1500	10kΩ	8-pin SOIC	Tubes
AS1501	20kΩ	8-pin SOIC	Tubes
AS1502	50kΩ	8-pin SOIC	Tubes
AS1503	100kΩ	8-pin SOIC	Tubes
AS1500-T	10kΩ	8-pin SOIC	T&R
AS1501-T	20kΩ	8-pin SOIC	T&R
AS1502-T	50kΩ	8-pin SOIC	T&R
AS1503-T	100kΩ	8-pin SOIC	T&R

For Pb-free package use suffix '-Z'

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