ANALOG DEVICES

Nonvolatile Memory Digital Potentiometers

Preliminary Technical Data

AD5231/AD5232/AD5233

FEATURES

Nonvolatile Memory Permanently Stores Wiper Settings
AD5231 Single, 1024 Position Resolution
AD5232 Dual, 256 Position Resolution
AD5233 Quad, 64 Position Resolution
10K, 50K, 100K Ohm Terminal Resistance
Linear or Log taper Settings
Increment/Decrement Commands, Push Button Command
SPI Compatible Serial Data Input with Readback Function
+3 to +5V Single Supply or ±2.5V Dual Supply Operation
User EEMEM nonvolatile memory to store constants

APPLICATIONS

Mechanical Potentiometer Replacement
Instrumentation: Gain, Offset Adjustment
Programmable Voltage to Current Conversion
Programmable Filters, Delays, Time Constants
Line Impedance Matching
Power Supply Adjustment
DIP Switch Setting

GENERAL DESCRIPTION

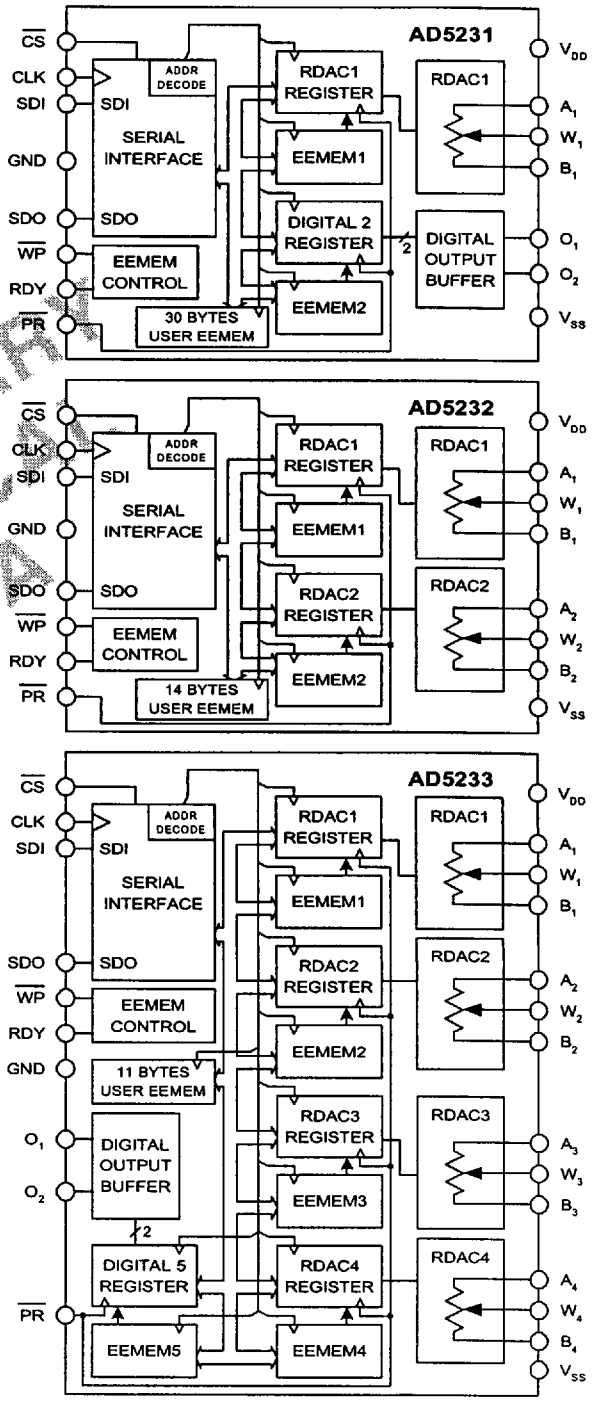
The AD5231/AD5232/AD5233 family provides a single-/dual-/quad-channel, digitally controlled variable resistor (VR) with resolutions of 1024/256/64 positions respectively. These devices perform the same electronic adjustment function as a potentiometer or variable resistor. The AD523X's versatile programming via a Micro Controller allows multiple modes of operation and adjustment.

In the direct program mode a predetermined setting of the RDAC register can be loaded directly from the micro controller. Another key mode of operation allows the RDAC register to be refreshed with the setting previously stored in the EEMEM register. When changes are made to the RDAC register to establish a new wiper position, the value of the setting can be saved into the EEMEM by executing an EEMEM save operation. Once the settings are saved in the EEMEM register these values will always be transferred automatically to the RDAC register to set the wiper position at system power ON. Such operation is enabled by the internal preset strobe and the preset can also be accessed externally.

Another mode of adjustment is the increment and decrement from the present setting of the Wiper position setting (RDAC) register. An internal scratch pad RDAC register can be moved UP or DOWN, one step of the nominal terminal resistance between terminals A-and-B. This linearly changes the wiper to B terminal resistance (R_{WB}) by one position segment of the device's end-to-end resistance (R_{AB}). For non-linear changes in wiper setting a left/right shift command adjusts levels in +/-6dB steps which can be useful for sound and light alarm applications.

The AD523X are available in the thin TSSOP package. All parts are guaranteed to operate over the extended industrial temperature range of -40°C to +85°C.

FUNCTIONAL BLOCK DIAGRAMS



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AD5231/AD5232/AD5233 - SPECIFICATIONS

ELECTRICAL CHARACTERISTICS 10K , 50K, 100K OHM VERSIONS (V_{DD} = +3V±10% or +5V±10% and V_{SS}=0V, V_A = +V_{DD}, V_B = 0V, -40°C < T_A < +85°C unless otherwise noted.)

Parameter	Symbol	Conditions	Min	Typ[1]	Max	Units
DC CHARACTERISTICS RHEOSTAT MODE Specifications apply to all VRs						
Resistor Differential NL[2]	R-DNL	R_{WB}, V_A=NC	-1	±1/4	+1	LSB
Resistor Nonlinearity[2]	R-INL	R_{WB}, V_A=NC	-1	±1/2	+1	%FS
Nominal resistor tolerance	ΔR	T_A = 25°C, V_{AB} = V_{DD},Wiper (V_W) = No connect	-30		30	%
Resistance Temperature Coefficent	$R_{AB}/\Delta T$	V_{AB} = V_{DD}, Wiper (V_W) = No Connect		500		ppm/°C
Wiper Resistance	R_W	I_W = 1 V/R, V_{DD} = +5V		50	100	Ω
Wiper Resistance	R_W	I_W = 1 V/R, V_{DD} = +3V		200		Ω
DC CHARACTERISTICS POTENTIOMETER DIVIDER MODE Specifications apply to all VRs						
Resolution	N	AD5231/AD5232/AD5233	10 / 8 / 6			Bits
Integral Nonlinearity[3]	INL		1	±1/2	+1	%FS
Differential Nonlinearity[3]	DNL		1	±1/4	+1	LSB
Voltage Divider Temperature Coefficent	$\Delta V_W/\Delta T$	Code = Half-scale		15		ppm/°C
Full-Scale Error	V_{WFSE}	Code = Full-scale	1	-0.3	+0	%FS
Zero-Scale Error	V_{WZSE}	Code = Zero-scale	0	+0.3	+1	%FS
RESISTOR TERMINALS						
Voltage Range[4]	$V_{A,B,W}$		V_{SS}		V_{DD}	V
Capacitance[5] Ax, Bx	$C_{A,B}$	f = 1 MHz, measured to GND, Code = Half-scale		45		pF
Capacitance[5] Wx	C_W	f = 1 MHz, measured to GND, Code = Half-scale		60		pF
Common-mode Leakage Current[6]	I_{CM}	V_A = V_B = V_{DD}/2		0.01	1	µA
DIGITAL INPUTS & OUTPUTS						
Input Logic High	V_{IH}	with respect to GND	0.3•V_{DD}			V
Input Logic Low	V_{IL}	with respect to GND			0.7•V_{DD}	V
Output Logic High	V_{OH}	$R_{PULL-UP}$ = 2.2KΩ to +5V	4.9			V
Output Logic High	V_{OH}	I_{OH} = 40µA, V_{LOGIC} = +5V	4			V
Output Logic Low	V_{OL}	I_{OL} = 1.6mA, V_{LOGIC} = +5V			0.4	V
Input Current	I_{IL}	V_{IN} = 0V or V_{DD}			±1	µA
Input Capacitance[5]	C_{IL}			5		pF
POWER SUPPLIES						
Single-Supply Power Range	V_{DD}	V_{SS} = 0V	2.7		5.5	V
Dual-Supply Power Range	V_{DD}/V_{SS}	V_{SS} = 0V	±2.2		±2.7	V
Positive Supply Current	I_{DD}	V_{IH} = V_{DD} or V_{IL} = GND		2	20	µA
Programming Mode Current	$I_{DD(PG)}$	V_{IH} = V_{DD} or V_{IL} = GND		15		mA
Read Mode Current	$I_{DD(READ)}$	V_{IH} = V_{DD} or V_{IL} = GND		650		µA
Negative Supply Current	I_{SS}	V_{IH} = V_{DD} or V_{IL} = GND, V_{DD} = 2.5V, V_{SS} = -2.5V			10	µA
Power Dissipation[7]	P_{DISS}	V_{IH} = V_{DD} or V_{IL} = GND			0.05	mW
Power Supply Sensitivity	PSS	ΔV_{DD} = +5V ±10%		0.002	0.01	%/%
DYNAMIC CHARACTERISTICS[5, 8]						
Bandwidth 3dB	BW_10K	R = 10KΩ		600		KHz
Total Harmonic Distortion	THD_W	V_A =1Vrms, V_B = 0V, f=1KHz		0.003		%
V_W Settling Time	t_S	V_A= VDD, V_B=0V, 50% of final value				
		For R_{AB} = 10K/50K/100K		1 / 3 / 6		µs
Resistor Noise Voltage	e_{N_WB}	R_{WB} = 5KΩ, f = 1KHz		9		nV√Hz
Crosstalk	C_T	V_A = V_{DD}, V_B = 0V, Measue V_W with adjacent VR making full scale change		-65		dB

AD5231/AD5232/AD5233 - SPECIFICATIONS

ELECTRICAL CHARACTERISTICS 10K , 50K, 100K OHM VERSIONS (V_{DD} = +3V±10% to +5V±10% and V_{SS}=0V, V_A = +V_{DD}, V_B = 0V, -40°C < T_A < +85°C unless otherwise noted.)

Parameter	Symbol	Conditions	Min	Typ[1]	Max	Units
INTERFACE TIMING CHARACTERISTICS applies to all parts(Notes 5, 9)						
Clock Cycle Time	t_1		20			ns
Input Clock Pulse Width	t_2, t_3	Clock level high or low	10			ns
$\overline{CS}$ Setup Time	t_4		10			ns
Data Setup Time	t_5	From Positive CLK transition	5			ns
Data Hold Time	t_6	From Positive CLK transition	5			ns
CLK Shutdown Time	t_7		0			ns
$\overline{CS}$ Rise to Clock Rise Setup	t_8		10			ns
$\overline{CS}$ High Pulse Width	t_9		10			ns
CLK to SDO Propagation Delay[10]	t_{10}	R_L = 1KΩ, C_L < 20pF	1		25	ns
Store to Nonvolatile EEMEM Save Time[11]	t_{12}	Applies to Command 2_H, 3_H			25	ms
$\overline{CS}$ to SDO - SPI line acquire	t_{13}					ns
$\overline{CS}$ to SDO - SPI line release	t_{14}					ns
RDY Rise to $\overline{CS}$ Fall	t_{15}					ns
Startup Time	t_{16}					ms
CLK Setup Time	t_{17}	For 1 CLK period (t_4 - t_3 = 1 CLK period)				ns
Preset Pulse Width (Asynchronous)	t_{PR}		50			ns

NOTES:

1. Typicals represent average readings at +25°C and V_{DD} = +5V.
2. 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. I_W = V_{DD}/R for both V_{DD}=+3V or V_{DD}=+5V.
3. 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 ±1LSB maximum are Guaranteed Monotonic operating conditions.
4. Resistor terminals A,B,W have no limitations on polarity with respect to each other.
5. Guaranteed by design and not subject to production test.
6. Common mode leakage current is a measure of the DC leakage from any terminals A,B,W to a common mode bias level of V_{DD} / 2.
7. P_{DISS} is calculated from (I_{DD} x V_{DD}=+5V).
8. All dynamic characteristics use V_{DD} = +5V.
9. See timing diagram for location of measured values. All input control voltages are specified with t_R=t_F=2.5ns(10% to 90% of 3V) and timed from a voltage level of 1.5V. Switching characteristics are measured using both V_{DD} = +3V or +5V.
10. Propagation delay depends on value of V_{DD}, R_{PULL_UP}, and C_L see applications text.
11. Low only for instruction commands 8, 9,10, 2, 3: CMD_8 ~ 1ms; CMD_9,10 ~0.1ms; CMD_2,3 ~20ms

Timing Diagram

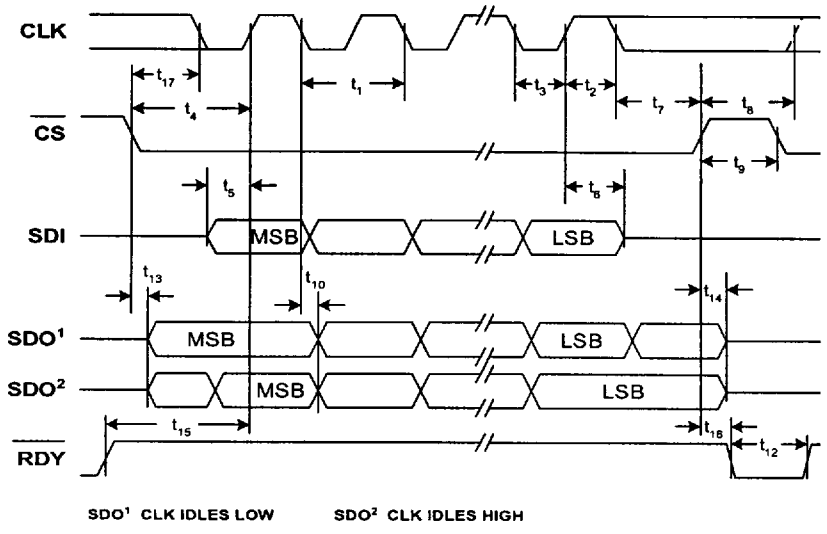


Figure 1. Timing Diagram

Absolute Maximum Rating (T_A = +25°C, unless otherwise noted)

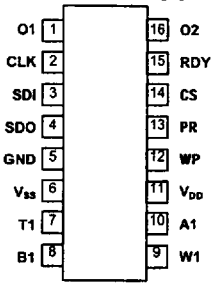
V_{DD} to GND ..... -0.3, +7V
V_{SS} to GND ..... 0V, -7V
V_{DD} to V_{SS} ..... +7V
V_A, V_B, V_W to GND ..... V_{SS}, V_{DD}
$A_X - B_X$, $A_X - W_X$, $B_X - W_X$ ..... ±20mA
O_x to GND ..... 0V, V_{DD}
Digital Inputs & Output Voltage to GND ..... 0V, +7V
Operating Temperature Range ..... -40°C to +85°C
Maximum Junction Temperature ($T_{J\,MAX}$) ..... +150°C
Storage Temperature ..... -65°C to +150°C
Lead Temperature (Soldering, 10 sec) ..... +300°C
Package Power Dissipation ..... $(T_{JMAX} - T_A) / \theta_{JA}$
Thermal Resistance θ_{JA},
TSSOP-16 ..... 150°C/W
TSSOP-24 ..... 128°C/W

Ordering Guide

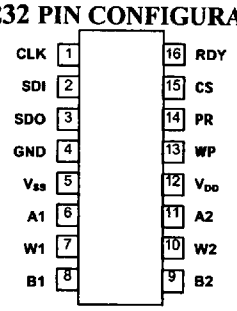
Model	#CHs/ k Ohm	Temp Range	Package Description	Package Option
AD5231BRU10	X1/10	-40/+85°C	TSSOP-16	RU-16
AD5231BRU50	X1/50	-40/+85°C	TSSOP-16	RU-16
AD5231BRU100	X1/100	-40/+85°C	TSSOP-16	RU-16
AD5232BRU10	X2/10	-40/+85°C	TSSOP-16	RU-16
AD5232BRU50	X2/50	-40/+85°C	TSSOP-16	RU-16
AD5232BRU100	X2/100	-40/+85°C	TSSOP-16	RU-16
AD5233BRU10	X4/10	-40/+85°C	TSSOP-24	RU-24
AD5233BRU50	X4/50	-40/+85°C	TSSOP-24	RU-24
AD5233BRU100	X4/100	-40/+85°C	TSSOP-24	RU-24

The AD5231/AD5232/AD5233 contains x,xxx transistors.
Die size: x' mil x y' mil, z' sq. mil

AD5231 PIN CONFIGURATION



AD5232 PIN CONFIGURATION



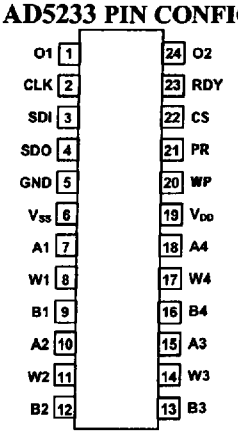
AD5231 PIN FUNCTION DESCRIPTION

#	Name	Description
1	O1	Non-Volatile Digital Output #1, ADDR(O1) = 1H, data bit position D0
2	CLK	Serial Input Register clock pin. Shifts in one bit at a time on positive clock CLK edges.
3	SDI	Serial Data Input Pin.
4	SDO	Serial Data Output Pin. Open Drain Output requires external pull-up resistor. Commands 9 & 10 activate the SDO output. See Instruction operation Truth Table.
5	GND	Ground pin, logic ground reference
6	V_{SS}	Negative Supply. Connect to zero volts for single supply applications.
7	T1	Used as digital input during factory test mode. Leave pin floating or connect to V_{DD} or V_{SS}.
8	B1	B terminal of RDAC1.
9	W1	Wiper terminal of RDAC1, ADDR(RDAC1)= 0_H
10	A1	A terminal of RDAC1.
11	V_{DD}	Positive Power Supply Pin. Should be ≥ the input-logic HIGH voltage.
12	$\overline{WP}$	Write Protect Pin. Prevents any changes to the present EEMEM contents when active low.
13	$\overline{PR}$	Hardware over ride preset pin. Refreshes the scratch pad register with current contents of the EEMEM register. Factory default loads midscale 200_H.
14	$\overline{CS}$	Serial Register chip select active low. When $\overline{CS}$ returns to logic high, the internal circuitry decodes the instruction word placed into the serial register.
15	RDY	Ready. Active-high open drain output. Identifies completion of commands 2, 3, 8, 9, 10.
16	O2	Non-Volatile Digital Output #2, ADDR(O2) = 1H, data bit position D1.

AD5232 PIN FUNCTION DESCRIPTION

#	Name	Description
1	CLK	Serial Input Register clock pin. Shifts in one bit at a time on positive clock edges.
2	SDI	Serial Data Input Pin. Shifts in one bit at a time on positive clock CLK edges.
3	SDO	Serial Data Output Pin. Open Drain Output requires external pull-up resistor. Commands 9 & 10 activate the SDO output. See Instruction operation Truth Table.
4	GND	Ground pin, logic ground reference
5	V_{SS}	Negative Supply. Connect to zero volts for single supply applications.
6	A1	A terminal of RDAC1.
7	W1	Wiper terminal of RDAC1, ADDR(RDAC1)= 0_H.
8	B1	B terminal of RDAC1.
9	B2	B terminal of RDAC2.
10	W2	Wiper terminal of RDAC2, ADDR(RDAC3)= 1_H.
11	A2	A terminal of RDAC2.
12	V_{DD}	Positive Power Supply Pin. Should be ≥ the input-logic HIGH voltage.
13	$\overline{WP}$	Write Protect Pin. Prevents any changes to the present EEMEM contents when active low.
14	$\overline{PR}$	Hardware over ride preset pin. Refreshes the scratch pad register with current contents of the EEMEM register. Factory default loads midscale 80_H.
15	$\overline{CS}$	Serial Register chip select active low. When $\overline{CS}$ returns to logic high, the internal circuitry decodes the instruction word placed into the serial register.
16	RDY	Ready. Active-high open drain output. Identifies completion of commands 2, 3, 8, 9, 10.

AD5233 PIN CONFIGURATION



AD5233 PIN FUNCTION DESCRIPTION

#	Name	Description
1	O1	Non-Volatile Digital Output #1, ADDR(O1) = 4H, data bit position D0.
2	CLK	Serial Input Register clock pin. Shifts in one bit at a time on positive clock CLK edges.
3	SDI	Serial Data Input Pin.
4	SDO	Serial Data Output Pin. Open Drain Output requires external pull-up resistor. Commands 9 & 10 activate the SDO output. See Instruction operation Truth Table.
5	GND	Ground pin, logic ground reference.
6	V_{SS}	Negative Supply. Connect to zero volts for single supply applications.
7	A1	A terminal of RDAC1.
8	W1	Wiper terminal of RDAC1, ADDR(RDAC1) = 0_H.
9	B1	B terminal of RDAC1.
10	A2	A terminal of RDAC2.
11	W2	Wiper terminal of RDAC2, ADDR(RDAC2) = 1_H.
12	B2	B terminal of RDAC2.
13	B3	B terminal of RDAC3.
14	W3	Wiper terminal of RDAC3, ADDR(RDAC3) = 2_H.
15	A3	A terminal of RDAC3.
16	B4	B terminal of RDAC4.
17	W4	Wiper terminal of RDAC4, ADDR(RDAC4) = 3_H.
18	A4	A terminal of RDAC4.
19	V_{DD}	Positive Power Supply Pin. Should be ≥ the input-logic HIGH voltage.
20	$\overline{WP}$	Write Protect Pin. Prevents any changes to the present EEMEM contents when active low.
21	$\overline{PR}$	Hardware over ride preset pin. Refreshes the scratch pad register with current contents of the EEMEM register. Factory default loads midscale 20_H.
22	$\overline{CS}$	Serial Register chip select active low. When $\overline{CS}$ returns to logic high, the internal circuitry decodes the instruction word placed into the serial register.
23	RDY	Ready. Active-high open drain output. Identifies completion of commands 2, 3, 8, 9, 10.
24	O2	Non-Volatile Digital Output #2, ADDR(O2) = 4_H, data bit position D1.

OPERATIONAL OVERVIEW

The AD5231/32/33 digital potentiometer family is designed to operate as a true variable resistor replacement device for analog signals that remain within the terminal voltage range of $V_{SS}<V_{TERM}<V_{DD}$. The basic voltage range is limited to a $|V_{DD}-V_{SS}| < 5.5V$.

Control of the digital potentiometer allows both scratch pad register (RDAC register) changes to be made, as well as, 100,000 times of nonvolatile electrically erasable memory (EEMEM) register operations. The EEMEM update process takes approximately 20.2ms, during this time the shift register is locked preventing any changes from taking place. The RDY pin flags the completion of this EEMEM save. The EEMEM retention is designed to last 10 years without refresh.

The scratch pad register can be changed incrementally by using the software controlled Increment/Decrement instruction or the Shift Left/Right instruction command. Once an Increment, Decrement or Shift command has been loaded into the shift register subsequent $\overline{CS}$ strobes will repeat this command. This is useful for push button control applications. Alternately the scratch pad register can be programmed with any position value using the standard SPI serial interface mode by loading the representative data word. The scratch pad register can be loaded with the current contents of the nonvolatile EEMEM register under program control. At system power ON, the default value of the scratch pad memory is the value previously saved in the EEMEM register. The factory EEMEM preset value is midscale.

A serial data output pin is available for daisy chaining and for readout of the internal register contents. The serial input data register uses a 16 or 24-bit instruction/address/data WORD. The write-protect ($\overline{WP}$) pin provides a hardware EEMEM protection feature disabling any changes of the present EEMEM contents.

SERIAL DATA INTERFACE

The AD523X family contains a four-wire SPI compatible digital interface (SDI, SDO, $\overline{CS}$, and CLK). Key features of this interface include:

- Independently Programmable Read & Write to all registers
- Direct parallel refresh of all RDAC wiper registers from corresponding EEMEM registers
- Increment & Decrement instructions for each RDAC wiper register
- Left & right Bit Shift of all RDAC wiper registers to achieve 6dB level changes
- Permanent storage of the present scratch pad RDAC register values into the corresponding EEMEM register
- Extra bytes of user addressable electrical-erasable memory

The serial interface contains three different word formats to support the single AD5231, dual AD5232, and the quad AD5233 digital potentiometer devices. The AD5232 and AD5233 use a 16-bit serial data word loaded MSB first, while the AD5231 uses a 24-bit serial word loaded MSB first. The format of the SPI compatible word is shown in Table 1 and 2. The Command Bits (Cx) control the operation of the digital potentiometer according to the command instructions shown in Table 3, 4, and 5. The Address Bits (Ax) determine which register is activated. The Data Bits (Dx) are the values that are loaded into the decoded register. The last instruction executed prior to a period of no programming activity should be the NOP instruction. This will place the internal logic circuitry in a minimum power dissipation state.

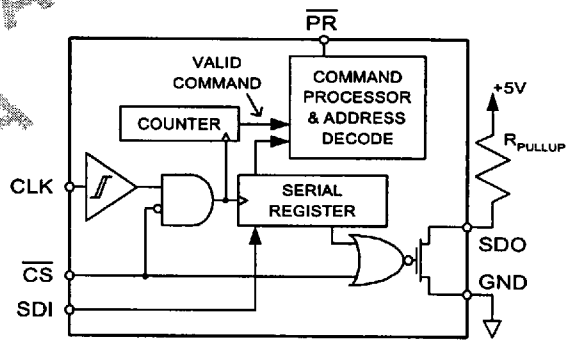


Figure 2. Equivalent Digital Input-Output Logic

The equivalent serial data input and output logic is shown in figure 2. The open drain output SDO is disabled whenever chip select $\overline{CS}$ is logic high. The SPI interface can be used in two slave modes CPHA=1, CPOL=1 and CPHA=0, CPOL=0. CPHA and CPOL refer to the control bits, which dictate SPI timing in the following microprocessors/MicroConverters: ADuC812/824, M68HC11, and MC68HC16R1/916R1.

Table 1. AD5232 & AD5233 16-bit Serial Data Word

	MSB															LSB
AD5232	C3	C2	C1	C0	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0
AD5233	C3	C2	C1	C0	A3	A2	A1	A0	X	X	D5	D4	D3	D2	D1	D0

Table 2. AD5231 24-bit Serial Data Word

	MSB																							LSB
AD5231	C3	C2	C1	C0	A3	A2	A1	A0	X	X	X	X	X	X	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

Command bits are identified as Cx, address bits are Ax, and data bits are Dx. Command instruction codes are defined in tables 3, 4, & 5.

Table 3. AD5231 Instruction/Operation Truth Table

Inst No.	Instruction Byte 1 B15 •••••••••••••••• B8 C3 C2 C1 C0 A3 A2 A1 A0	Data Byte 1 B15 •••• B8 X ••• D9 D8	Data Byte 0 B7 ••• B0 D7 ••• D0	Operation
0	0 0 0 0 X X X X	X ••• X X	X ••• X	NOP: Do nothing
1	0 0 0 1 << ADDR >>	X ••• X X	X ••• X	Write contents of EEMEM(ADDR) to RDAC(ADDR) Register
2	0 0 1 0 << ADDR >>	X ••• X X	X ••• X	SAVE WIPER SETTING: Write contents of RDAC(ADDR) to EEMEM(ADDR)
3	0 0 1 1 << ADDR >>	X ••• D9 D8	D7 ••• D0	Write contents of Serial Register Data Byte 0 & 1 to EEMEM(ADDR)
4	0 1 0 0 << ADDR >>	X ••• X X	X ••• X	DEC 6dB: Right Shift contents of RDAC(ADDR), LSB rolls over to MSB position
5	0 1 0 1 X X X X	X ••• X X	X ••• X	DEC All 6dB: Right Shift contents of all RDAC Registers, LSB rolls over to MSB position
6	0 1 1 0 << ADDR >>	X ••• X X	X ••• X	Decrement contents of RDAC(ADDR) by One, does not roll over at zero-scale
7	0 1 1 1 X X X X	X ••• X X	X ••• X	Decrement contents of all RDAC Registers by One, does not rollover at zero-scale
8	1 0 0 0 0 0 0 0	X ••• X X	X ••• X	RESET: Load all RDACs with their corresponding EEMEM previously-saved values
9	1 0 0 1 << ADDR >>	X ••• X X	X ••• X	Write contents of EEMEM(ADDR) to Serial Register Data Byte 0 & 1
10	1 0 1 0 << ADDR >>	X ••• X X	X ••• X	Write contents of RDAC(ADDR) to Serial Register Data Byte 0 & 1
11	1 0 1 1 << ADDR >>	X ••• D9 D8	D7 ••• D0	Write contents of Serial Register Data Byte 0 &1 to RDAC(ADDR)
12	1 1 0 0 << ADDR >>	X ••• X X	X ••• X	INC 6dB: Left Shift contents of RDAC(ADDR), stops at all ones
13	1 1 0 1 X X X X	X ••• X X	X ••• X	INC All 6dB: Left Shift contents of all RDAC Registers, stops at all ones
14	1 1 1 0 << ADDR >>	X ••• X X	X ••• X	Increment contents of RDAC(ADDR) by One, does not rollover at full-scale
15	1 1 1 1 X X X X	X ••• X X	X ••• X	Increment contents of all RDAC Registers by One, does not rollover at full-scale

NOTES:

1. The SDO output shifts-out the last 16-bits of data clocked into the serial register for daisy chain operation. Exception, following Instruction #9 or #10 the selected internal register data will be present in data byte 0 & 1. Instructions following #9 & #10 must be a full 24-bit data word to completely clock out the contents of the serial register.
2. The RDAC register is a volatile scratch pad register that is refreshed at power ON from the corresponding non-volatile EEMEM register.
3. The increment, decrement and shift commands ignore the contents of the shift register Data Byte 0.
4. Execution of the Operation column noted in the table takes place when the $\overline{CS}$ strobe returns to logic high.

Table 4. AD5232 Instruction/Operation Truth Table

Inst No.	Instruction Byte 1 B15 •••••••••••••••• B8								Data Byte 0 B7 •••••••••••••••• B0								Operation
	C3	C2	C1	C0	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
0	0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	NOP: Do nothing
1	0	0	0	1	<<	ADDR		>>	X	X	X	X	X	X	X	X	Write contents of EEMEM(ADDR) to RDAC(ADDR) Register
2	0	0	1	0	<<	ADDR		>>	X	X	X	X	X	X	X	X	SAVE WIPER SETTING: Write contents of RDAC(ADDR) to EEMEM(ADDR)
3	0	0	1	1	<<	ADDR		>>	D7	D6	D5	D4	D3	D2	D1	D0	Write contents of Serial Register Data Byte 0 to EEMEM(ADDR)
4	0	1	0	0	<<	ADDR		>>	X	X	X	X	X	X	X	X	DEC 6dB: Right Shift contents of RDAC(ADDR), LSB rolls over to MSB position
5	0	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	DEC All 6dB: Right Shift contents of all RDAC Registers, LSB rolls over to MSB position
6	0	1	1	0	<<	ADDR		>>	X	X	X	X	X	X	X	X	Decrement contents of RDAC(ADDR) by One, does not roll over at zero-scale
7	0	1	1	1	X	X	X	X	X	X	X	X	X	X	X	X	Decrement contents of all RDAC Registers by One, does not rollover at zero-scale
8	1	0	0	0	0	0	0	0	X	X	X	X	X	X	X	X	RESET: Load all RDACs with their corresponding EEMEM previously-saved values
9	1	0	0	1	<<	ADDR		>>	X	X	X	X	X	X	X	X	Write contents of EEMEM(ADDR) to Serial Register Data Byte 0
10	1	0	1	0	<<	ADDR		>>	X	X	X	X	X	X	X	X	Write contents of RDAC(ADDR) to Serial Register Data Byte 0
11	1	0	1	1	<<	ADDR		>>	D7	D6	D5	D4	D3	D2	D1	D0	Write contents of Serial Register Data Byte 0 to RDAC(ADDR)
12	1	1	0	0	<<	ADDR		>>	X	X	X	X	X	X	X	X	INC 6dB: Left Shift contents of RDAC(ADDR), stops at all ones
13	1	1	0	1	X	X	X	X	X	X	X	X	X	X	X	X	INC All 6dB: Left Shift contents of all RDAC Registers, stops at all ones
14	1	1	1	0	<<	ADDR		>>	X	X	X	X	X	X	X	X	Increment contents of RDAC(ADDR) by One, does not rollover at full-scale
15	1	1	1	1	X	X	X	X	X	X	X	X	X	X	X	X	Increment contents of all RDAC Registers by One, does not rollover at full-scale

NOTES:

1. The SDO output shifts-out the last 8-bits of data clocked into the serial register for daisy chain operation. Exception, following Instruction #9 or #10 the selected internal register data will be present in data byte 0. Instructions following #9 & #10 must be a full 16-bit data word to completely clock out the contents of the serial register.
2. The RDAC register is a volatile scratch pad register that is refreshed at power ON from the corresponding non-volatile EEMEM register.
3. The increment, decrement and shift commands ignore the contents of the shift register Data Byte 0.
4. Execution of the Operation column noted in the table takes place when the $\overline{CS}$ strobe returns to logic high.

Table 5. AD5233 Instruction/Operation Truth Table

Inst No.	Instruction Byte 1 B15 •••••••••••••••• B8 C3 C2 C1 C0 A3 A2 A1 A0	Data Byte 0 B7 •••••••••••••••• B0 D7 D6 D5 D4 D3 D2 D1 D0	Operation
0	0 0 0 0 X X X X	X X X X X X X X	NOP: Do nothing
1	0 0 0 1 << ADDR >>	X X X X X X X X	Write contents of EEMEM(ADDR) to RDAC(ADDR) Register
2	0 0 1 0 << ADDR >>	X X X X X X X X	SAVE WIPER SETTING: Write contents of RDAC(ADDR) to EEMEM(ADDR)
3	0 0 1 1 << ADDR >>	D7 D6 D5 D4 D3 D2 D1 D0	Write contents of Serial Register Data Byte 0 to EEMEM(ADDR)
4	0 1 0 0 << ADDR >>	X X X X X X X X	DEC 6dB: Right Shift contents of RDAC(ADDR), LSB rolls over to MSB position
5	0 1 0 1 X X X X	X X X X X X X X	DEC All 6dB: Right Shift contents of all RDAC Registers, LSB rolls over to MSB position
6	0 1 1 0 << ADDR >>	X X X X X X X X	Decrement contents of RDAC(ADDR) by One, does not roll over at zero-scale
7	0 1 1 1 X X X X	X X X X X X X X	Decrement contents of all RDAC Registers by One, does not rollover at zero-scale
8	1 0 0 0 0 0 0 0	X X X X X X X X	RESET: Load all RDACs with their corresponding EEMEM previously-saved values
9	1 0 0 1 << ADDR >>	X X X X X X X X	Write contents of EEMEM(ADDR) to Serial Register Data Byte 0
10	1 0 1 0 << ADDR >>	X X X X X X X X	Write contents of RDAC(ADDR) to Serial Register Data Byte 0
11	1 0 1 1 << ADDR >>	D7 D6 D5 D4 D3 D2 D1 D0	Write contents of Serial Register Data Byte 0 to RDAC(ADDR)
12	1 1 0 0 << ADDR >>	X X X X X X X X	INC 6dB: Left Shift contents of RDAC(ADDR), stops at all ones
13	1 1 0 1 X X X X	X X X X X X X X	INC All 6dB: Left Shift contents of all RDAC Registers, stops at all ones
14	1 1 1 0 << ADDR >>	X X X X X X X X	Increment contents of RDAC(ADDR) by One, does not rollover at full-scale
15	1 1 1 1 X X X X	X X X X X X X X	Increment contents of all RDAC Registers by One, does not rollover at full-scale

NOTES:

1. The SDO output shifts-out the last 8-bits of data clocked into the serial register for daisy chain operation. Exception, following Instruction #9 or #10 the selected internal register data will be present in data byte 0. Instructions following #9 & #10 must be a full 16-bit data word to completely clock out the contents of the serial register. The wiper only has 64 positions that correspond to the lower 6-bits of register data.
2. The RDAC register is a volatile scratch pad register that is refreshed at power ON from the corresponding non-volatile EEMEM register.
3. The increment, decrement and shift commands ignore the contents of the shift register Data Byte 0.
4. Execution of the Operation column noted in the table takes place when the $\overline{CS}$ strobe returns to logic high.

Latched Digital Outputs

A pair of digital outputs, O1 & O2, are available in the AD5231, and the AD5233 parts that provide a nonvolatile logic 0 or logic 1 setting. O1 & O2 are standard CMOS logic outputs shown in figure 2A. These outputs are ideal to replace functions often provided by DIP switches. In addition, they can be used to drive other standard CMOS logic controlled parts that need an occasional setting change.

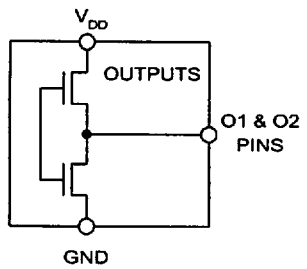


Figure 2A. Logic Outputs O1 & O2.

Detail Potentiometer Operation

The actual structure of the RDAC is designed to emulate the performance of a mechanical potentiometer. The RDAC contains a string of connected resistor segments, with an array of analog switches that act as the wiper connection to several points along the resistor array. The number of points is the resolution of the device. For example, the AD5232 has 256 connection points allowing it to provide better than 0.5% set-ability resolution. Figure 3 provides an equivalent diagram of the connections between the three terminals that make up one channel of the RDAC. The SW_A and SW_B will always be ON while one of the switches SW(0) to SW(2^N-1) will be ON one at a time depending upon the resistance step decoded from the Data Bits. Note there are two 50 ohm wiper resistances, R_W. The resistance contributed by R_W must be accounted for in the output resistance. At terminals A-to-wiper, R_W is the sum of the resistances of SW_A and SW_X. Similarly, R_W is the sum of the resistances SW_B and SW_X at terminals B-to-Wiper.

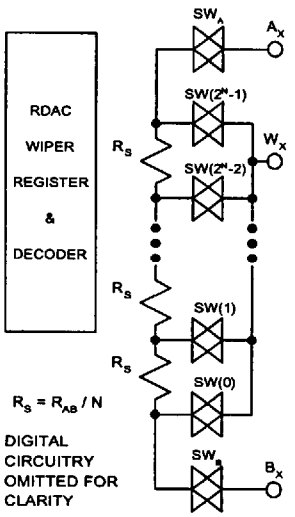
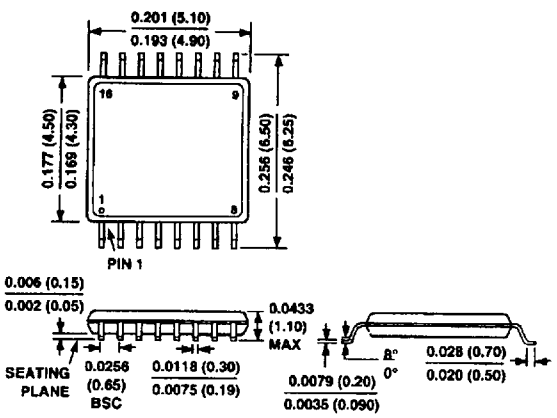


Figure 3. Equivalent RDAC structure

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm)

16-Lead TSSOP (RU-16)



24-Lead Thin Surface Mount TSSOP Package (RU-24)