Serial Input, Quad 8-Bit Nonvolatile DACPOT™

FEATURES

- **Four 8-Bit DACS**
  - **Differential Non-linearity - ±0.5LSB max**
  - **Integral Non-Linearity - ±1LSB max**
- **Each DAC has Independent Reference Inputs**
  - **Output Buffer Amplifiers Swing Rail-to-Rail**
  - **Ground to V_{DD} Reference Input Range**
- **Each DAC's Digital Input Data Maintained in Nonvolatile EEPROM**
- **Power-On Reset Reloads Registers with Nonvolatile Data**
- **Simple Serial Interface for Reading and Writing DAC values, SPI™ and QSPI™ compatible.**
- **Fully operational from 2.7V to 5.5V**
- **Low Power: <1mW @ 2.7V**

OVERVIEW

The S9408 DACPOT™ is a serial input, voltage output, quad 8-bit digital to analog converter. The S9408 operates from a single +2.7V to +5.5V supply. Internal precision buffers swing rail-to-rail and the reference input range includes both ground and the positive supply.

The S9408 integrates four 8-bit DACs and their associated circuits which include an enhanced unity-gain operational amplifier output, an 8-bit data latch, an 8-bit nonvolatile register, and an industry-standard serial interface for reading and writing data to the DACs' data latches and registers. The DACs are independently programmable and each has its own electrically isolated Vreference inputs.

FUNCTIONAL BLOCK DIAGRAM

2015 T BD 2.0

Characteristics subject to change without notice

2015 2.2 8/2/00

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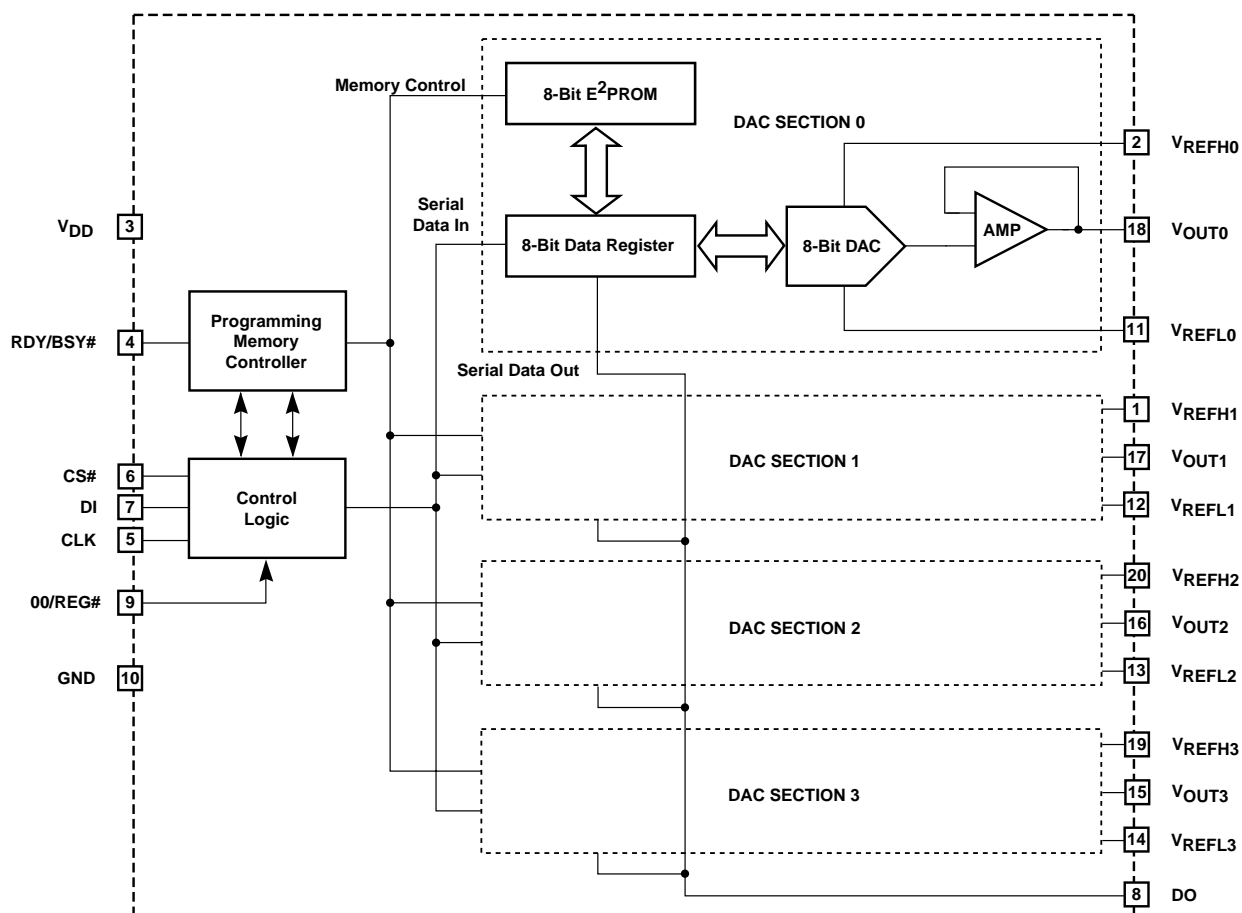
PINOUT and SIGNAL DEFINITION

20-Pin PDIP
or 20-Pin SOIC

V_{REFH1}	1	20	V_{REFH2}
V_{REFH0}	2	19	V_{REFH3}
V_{DD}	3	18	V_{OUT0}
RDY/BSY#	4	17	V_{OUT1}
CLK	5	16	V_{OUT2}
CS#	6	15	V_{OUT3}
DI	7	14	V_{REFL3}
DO	8	13	V_{REFL2}
00/REG#	9	12	V_{REFL1}
GND	10	11	V_{REFL0}

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Pin	Name	Function
1, 2 20, 19	V_{REFH}	Vreference High: $V_{REFL} < V_{REFH} - V_{DD}$
3	V_{DD}	Power Supply Voltage
4	RDY/BSY#	Ready/Busy: open drain output indicating status of nonvolatile write operations
5	CLK	Clock Input Pin: used for serial data communication
6	CS#	Chip Select: When high deselects the device and places it in a low power mode
7	DI	Data Input: serial data input pin
8	DO	Data Output: serial data output pin
9	00/REG#	Power On Recall Option Input
10	GND	Power Supply Ground
11, 12 13, 14	V_{REFL}	Vreference Low: $V_{REFH} > V_{REFL} \bullet GND$
15, 16 17, 18	V_{OUT}	DAC Output: buffered D to A converter output

The analog outputs of the S9408 can be programmed to any one of 256 individual voltage steps. Each step value is $1/256^{th}$ of the voltage differential between V_{REFH} and V_{REFL} of the respective DAC. Once programmed these settings can be retained in nonvolatile memory during all power conditions and will be automatically recalled upon a power-up sequence. Each DAC can be independently read without affecting the output voltage during the read cycle. In addition, each output can be adjusted an unlimited number of times without altering the value stored in the nonvolatile memory.

DEVICE OPERATION

Analog Section
The S9804 is an 8-bit, voltage output digital-to-analog converter (DAC). The DAC consists of a resistor network that converts 8-bit digital inputs into equivalent analog output voltages in proportion to the applied reference voltage.

Reference inputs
The voltage differential between the V_{REFL} and V_{REFH} inputs sets the full-scale output voltage for its respective DAC. V_{REFL} must be equal to or greater than ground (positive voltage). V_{REFH} must be greater (more positive) than V_{REFL} and less than or equal to V_{DD}.

Output Buffer Amplifiers
The voltage outputs are precision unity-gain followers that slew up to 1V/µs. The outputs can swing from V_{REFL} to V_{REFH}. With a 0V to 5V output transition the amplifier outputs typically settle to 1LSB in 40µs.

DIGITAL INTERFACE

The S9408 employs a common 4-wire serial interface. It is comprised of a Clock (CLK), Chip Select (CS#), Data In (DI) and Data Out (DO). Data is clocked into the device on the clock's rising edge and out of the device on the clock's falling edge. Data is shifted in and out MSB first. DO only becomes active after the device has been selected and after a valid read command and address has been received.

All data transfers are initiated after CS# goes low and a logic '1' is clocked into the device. This first data transfer is the start bit and must precede all operations. Following the start bit are two command bits used to specify which of four commands to execute. The next two bits are the address bits used to select one of the four DACs. The action of the next eight clock cycles will be dependent upon the command issued.

Start	C_1	C_0	A_1	A_0	Command
1	0	0	A	A	NV Write Enable
1	0	1	A	A	Write — Data In
1	1	0	A	A	Read — Data Out
1	1	1	A	A	Recall

TABLE 1. COMMAND FORMAT

Internally there are four DACs and associated with each are two registers. There is one data register that is used by the DAC to hold the digital value it converts. There is also one nonvolatile register that holds the default value that can be recalled into the data register during power-up or by executing the Recall command.

READ
Read operations are initiated by taking CS# low and clocking in a start bit followed by the read command and the address of the data register to be read. The next eight clocks will output on the DO pin the contents of the selected data register. This read will not affect the contents of the register or the output of the DAC. Refer to Figure 1 for an illustration of the sequence of bus conditions for a read operation.
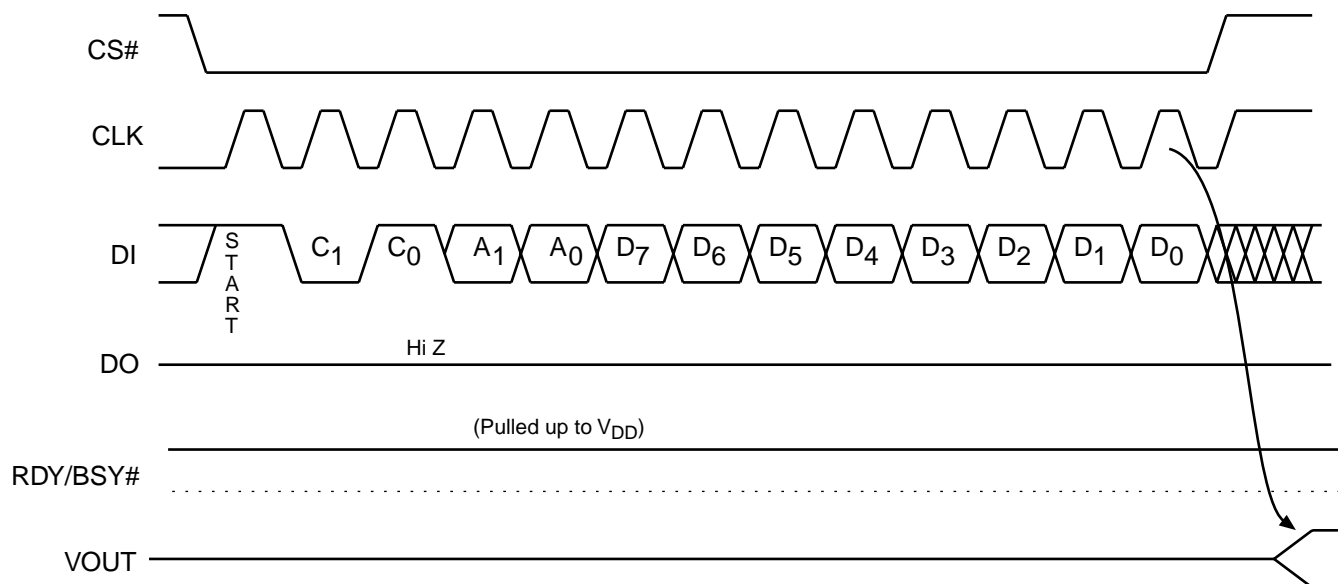
WRITE
Write operations are initiated by taking CS# low and clocking in a start bit followed by the write command and the address of the data register to be written. This action is followed by the host clocking eight bits of data into the register, MSB first. The output of the selected DAC will change as the last bit is clocked into the device. At this point the clock counter will reset the command register, requiring a full sequence to be initiated in order to write to the DAC again.

> **NOTE:** This write operation does not affect the contents of the nonvolatile register. Therefore, the nonvolatile register can contain the power-on default settings (e.g. volume), and the write DAC command can be used to make situational adjustments.
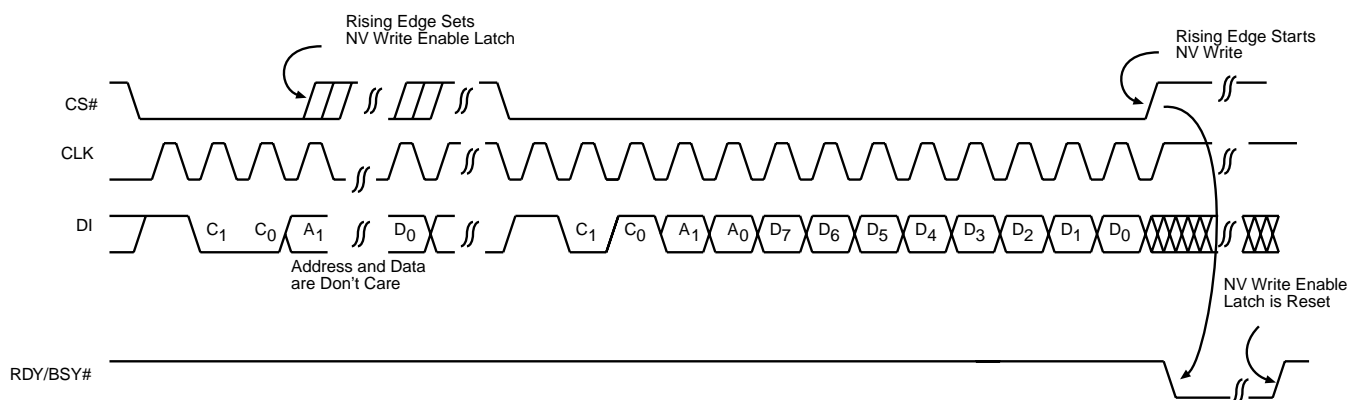
Refer to Figure 2 for an illustration of the sequence of bus conditions for a write operation.
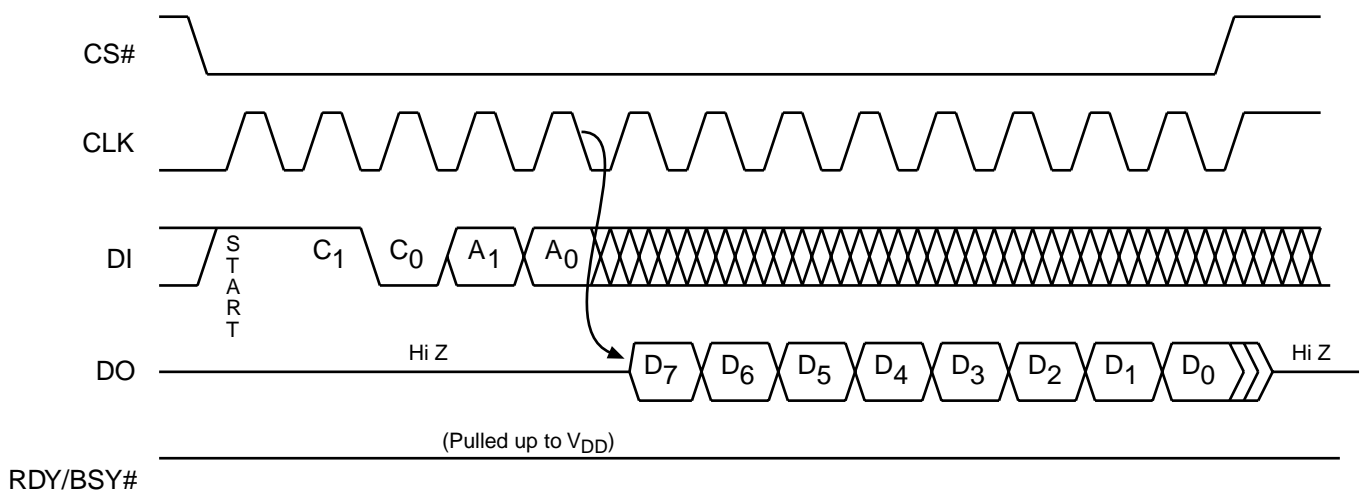
FIGURE 1. READ SEQUENCE

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FIGURE 2. WRITE SEQUENCE

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FIGURE 3. NONVOLATILE WRITE SEQUENCE

NONVOLATILE WRITE

A nonvolatile write is a two step operation: it is initiated by taking CS# low and clocking in a start bit followed by the NV Enable command. At this point the host can take CS# back high or continue clocking in data. This data is don't care and will be ignored by the S9408. If any command other than write follows NV enable the NV latch will be cleared.

Next, the host takes CS# low again and issues a write command and address and then clocks in the eight data

bits to be programmed. The host will then bring CS# HIGH and the data will be latched into the data register and a nonvolatile write operation will commence.

The status of the nonvolatile write can be monitored on the RDY/BSY# pin. A logic low indicates the write is still in progress and the S9408 will not be accessible to the host; a logic high indicates the write has completed and the S9408 is ready for the next command. Refer to Figure 3 for an illustration of the sequence of bus conditions for a nonvolatile write operation.

2015 2.2 8/2/00

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RECALL COMMAND

The recall command will retrieve data from the selected nonvolatile register and write it into the data register of the associated DAC. This operation is initiated by taking CS# low and clocking in a start bit followed by the recall command and the address of the nonvolatile register to be recalled. The eight bits of data are don't care, so CS# can be taken high any time after the address bits are clocked in. Refer to Figure 4 for an illustration of the sequence of bus conditions for a Recall operation.

Power-on recall

Whenever the S9408 is powered on the DAC output values will be returned to the selected default setting. The default setting can be the nonvolatile register contents or all zeroes. The state of the 00/REG# pin will determine which operation will be performed. If it is tied to ground (or left floating) the nonvolatile register contents will be re-called. Conversely, if it is tied to V_{DD} the S9408 will recall zeroes.
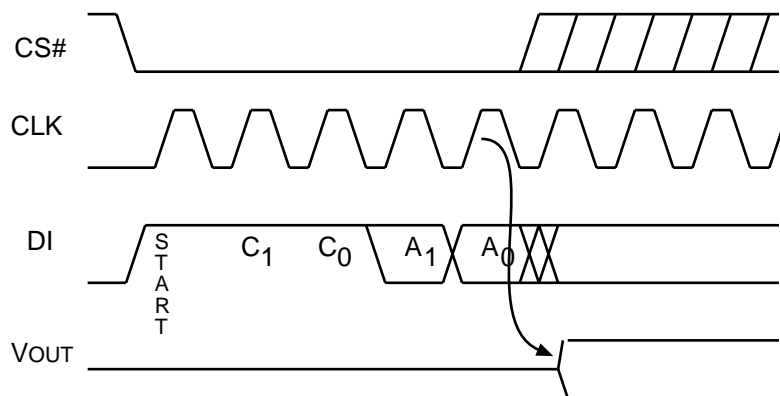
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FIGURE 4. RECALL COMMAND SEQUENCE

ABSOLUTE MAXIMUM RATINGS

V_{DD} to GND .... -0.5V to +7V
Digital Inputs to GND .... -0.5V to V_{DD}+0.5V
Analog Inputs to GND .... -0.5V to V_{DD}+0.5V
Digital Outputs to GND .... -0.5V to V_{DD}+0.5V
Analog Outputs to GND .... -0.5V to V_{DD}+0.5V
Temperature Under Bias .... -55°C to +125°C
Storage Temperature .... -65°C to +150°C
Lead Soldering (10 Sec Max) .... 300°C

Stresses 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 outside those listed in the operational sections of this specification is not implied. Exposure to any absolute maximum rating for extended periods may affect device performance and reliability.

RECOMMENDED OPERATING CONDITIONS

Condition	Min	Max
Temperature	-40°C	+85°C
V_{DD}	+2.7V	+5.5V

2015 PGM T2 1.2

RELIABILITY CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

Symbol	Parameter	Min	Max	Unit
V_{ZAP}	ESD Susceptibility	2000		V
I_{LTH}	Latch-up	100		mA
T_{DR}	Data Retention	100		Years
N_{END}	Endurance	1,000,000		Storage Cycles

DC ELECTRICAL CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{DD}	Supply current during store (note 1)	CS = V_{IL}		1.8	3.0	mA
I_{SB}	Standby supply current	CS = V_{IH}		260	500	µA
I_{IH}	Input leakage current	$V_{IN} = V_{DD}$		<1	10	µA
I_{IL}	Input leakage current	$V_{IN} = 0V$		<1	−10	µA
V_{IH}	High level input voltage		2		V_{DD}	V
V_{IL}	Low level input voltage		0		0.8	V
V_{OH}	High level output voltage	IOH = −400µA	$V_{DD} - 0.3$			V
V_{OL}	Low level output voltage	IOL = 1mA, V_{DD} = 5V; IOL = 0.4mA, V_{DD} = 2.7V			0.4	V

Note 1: I_{DD} is the supply current drawn while the EEPROM is being updated.

AC ELECTRICAL CHARACTERISTICS

V_{DD} = +4.5V to +5.5V, V_{REFH} = V_{DD}, V_{REFL} = 0V, T_A = -40°C to +85°C, unless otherwise specified

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
f_C	Clock Frequency		DC		1	MHz
t_{WH}	Minimum CLK High Time		500			ns
t_{WL}	Minimum CLK Low Time		300			ns
t_{CS}	Minimum CS High Time		150			ns
t_{CSS}	CS Setup Time		100			ns
t_{CSH}	CS Hold Time	C_L = 100pF	0			ns
t_{SU}	Data In Setup Time	See Note 1	50			ns
t_H	Data In Hold Time		50			ns
t_V	Output Valid Time				150	ns
t_{HO}	Data Out Hold Time		0			ns
t_{DIS}	Output Disable Time			400		ns
t_{BUSY}	Write Cycle Time			3.3	5	ms

Notes: 1. All timing measurements are defined at the point of signal crossing $V_{DD}/2$.

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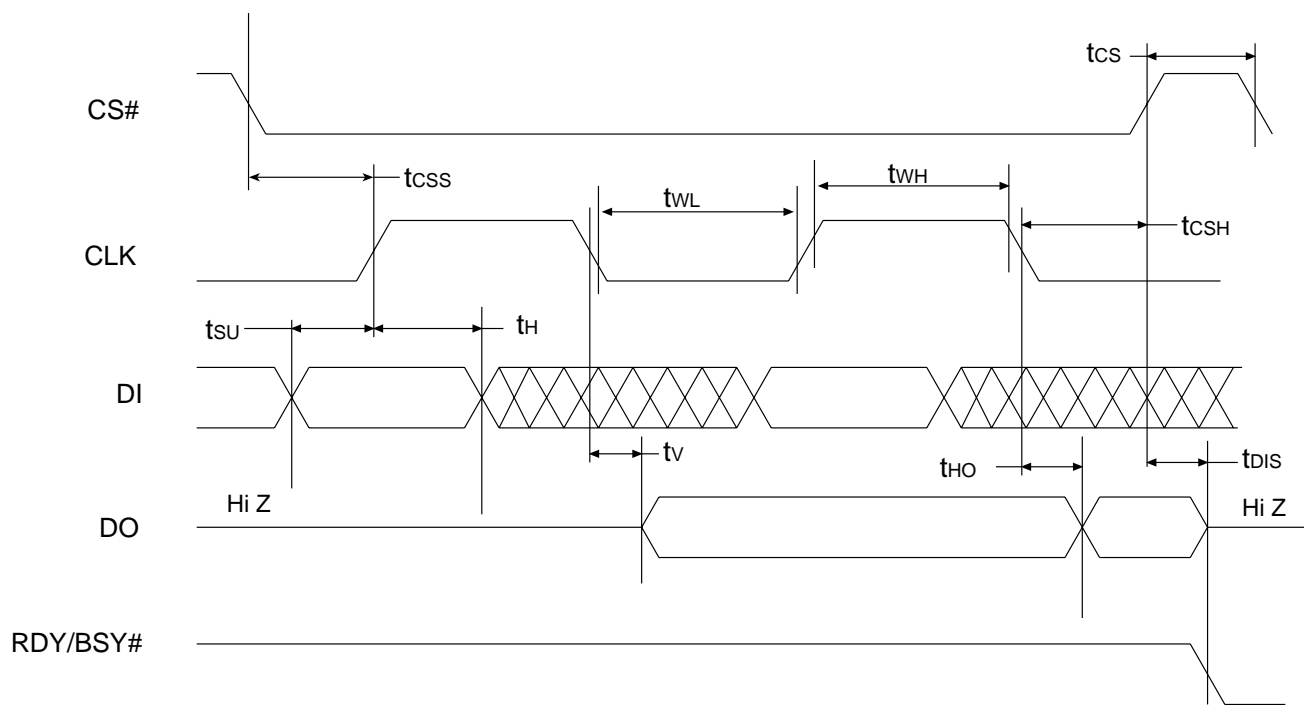
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FIGURE 5. AC TIMING DIAGRAM
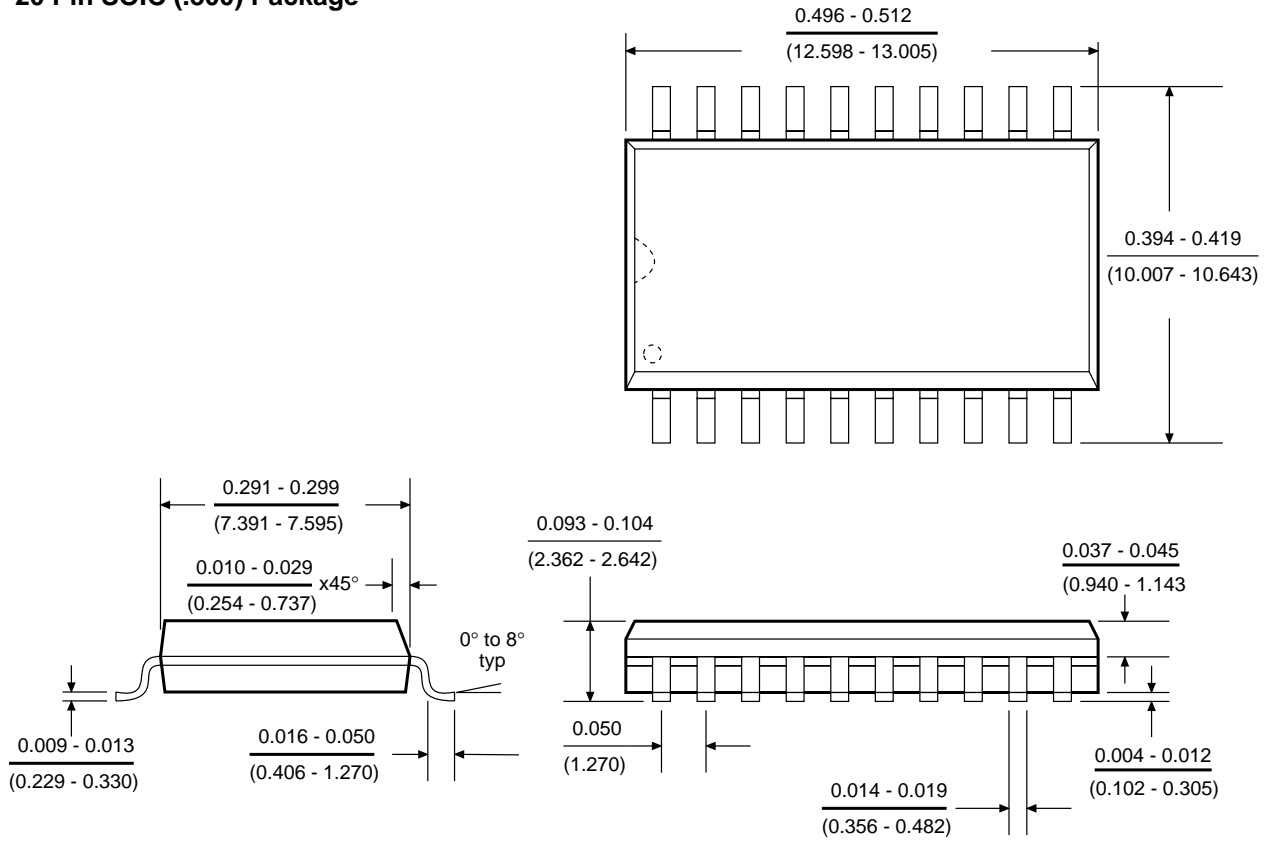
DAC DC ELECTRICAL CHARACTERISTICS

V_{DD} = 2.7V to 5.5V, V_{REFH} = V_{DD}, V_{REFL} = 0V, T_A = -40°C to +85°C, unless otherwise specified

Property	Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Accuracy	INL	Integral non-linearity	I_{LOAD} = 100µA		0.5	±1	LSB
	DNL	Differential non-linearity	I_{LOAD} = 100µA (note 1)		0.1	±0.5	LSB
References	V_{REFH}	Input voltage		V_{REFL}		V_{DD}	V
	V_{REFL}	Input voltage		GND		V_{REFh}	V
	R_{IN}	V_{REFH} to V_{REFL} resistance			40k		Ω
	TCR_{IN}	Temp. coefficient of R_{IN}			300	600	ppm/ºC
	ΔR_{IN}	Input resistance match			±0.5	±1	%
Analog Output	G_{EFS}	Full-scale gain error	D = FF_{HEX}			±1	LSB
	$V_{OUT}ZS$	Output offset voltage	D = 00_{HEX}	0	2.5	5	mV
	TCV_{OUT}	V_{OUT} temp. coeffiecient	V_{DD} = 5V, I_{LOAD} = 50µA (note 1)			50	µV/ºC
	I_L	Amp output load current		−200		1000	µA
	R_{OUT}	Amp output resistance	I_{LOAD} = 100µA 5V 3V		10 20		Ω Ω
	PSRR	Power supply rejection	I_{LOAD} = 10µA			1	LSB/V
	t_S	DAC settling time to 1LSB	10pF 5V 10pF 3V		36 27		µs µs
	e_N	Amp output noise	f = 1kHz, V_{DD} = 5V		90		nV√Hz
	THD	Total harmonic distortion	V_{REFH} = 2.5V, V_{DD} = 5V, f = 1kHz, V_{IN} = $1V_{RMS}$		0.08		%
	BW	Bandwidth −3dB	V_{REFH} = 2.5V, V_{DD} = 5V, V_{IN} = $100mV_{RMS}$		300		kHz

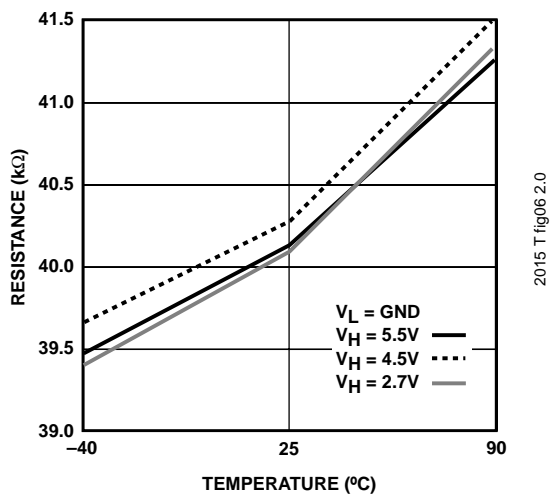Note 1: Guaranteed but not tested

20 Pin SOIC (.300) Package

0.496 - 0.512
(12.598 - 13.005)

0.394 - 0.419
(10.007 - 10.643)

0.291 - 0.299
(7.391 - 7.595)

0.010 - 0.029
(0.254 - 0.737) x45°

0° to 8°
typ

0.093 - 0.104
(2.362 - 2.642)

0.037 - 0.045
(0.940 - 1.143

0.009 - 0.013
(0.229 - 0.330)

0.016 - 0.050
(0.406 - 1.270)

0.050
(1.270)

0.014 - 0.019
(0.356 - 0.482)

0.004 - 0.012
(0.102 - 0.305)

20pn SOIC ILL.1

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V_L = GND
V_H = 5.5V
V_H = 4.5V
V_H = 2.7V

**FIGURE 6. VL to VH END-TO-END RESISTANCE
        OVER TEMPERATURE**

ORDERING INFORMATION

S9408   **P**

Base Part Number —————   —— **Package**
P = 20 Pin PDIP **∗**
S = 20 Pin SOIC
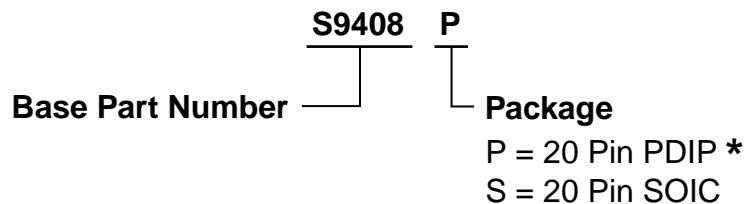
∗ Special order

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