



# WM2637 Dual 10-Bit Serial Input Voltage Output DAC with Internal Reference

Production Data, Rev 1.0, July 1999

## FEATURES

- Dual 10-bit voltage output DAC
- Single 2.7V to 5.5V supply
- DNL  $\pm 0.1$  LSBs, INL  $\pm 0.4$  LSBs
- Internal programmable voltage reference
- Low power consumption:
  - 5.5 mW, slow mode - 5V supply
  - 3.3 mW, slow mode - 3V supply
- TMS320, (Q) SPI™, and Microwire™ compatible serial interface
- Programmable settling time of 1 $\mu$ s or 3.5 $\mu$ s typical
- Power down mode 10nA

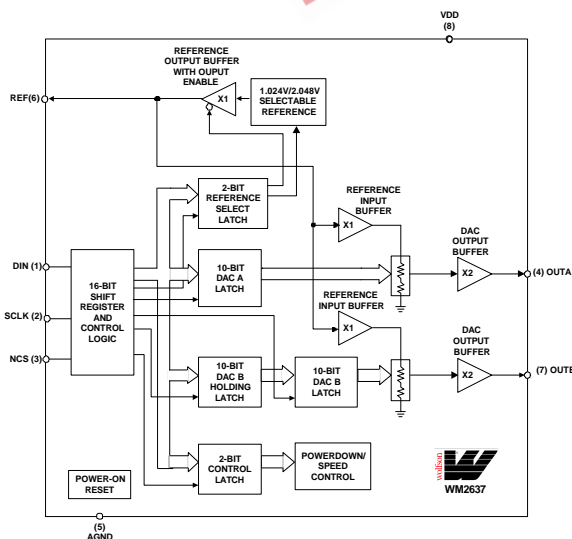
## APPLICATIONS

- Battery powered test instruments
- Digital offset and gain adjustment
- Battery operated/remote industrial controls
- Machine and motion control devices
- Wireless telephone and communication systems
- Speech synthesis
- Arbitrary waveform generation

## ORDERING INFORMATION

DEVICE	TEMP. RANGE	PACKAGE
WM2637CD	0° to 70°C	8-pin SOIC
WM2637ID	-40° to 85°C	8-pin SOIC

## BLOCK DIAGRAM



## DESCRIPTION

The WM2637 is a dual 10-bit voltage output, resistor string, digital-to-analogue converter. A software controlled power down mode is provided that reduces current consumption to 10nA.

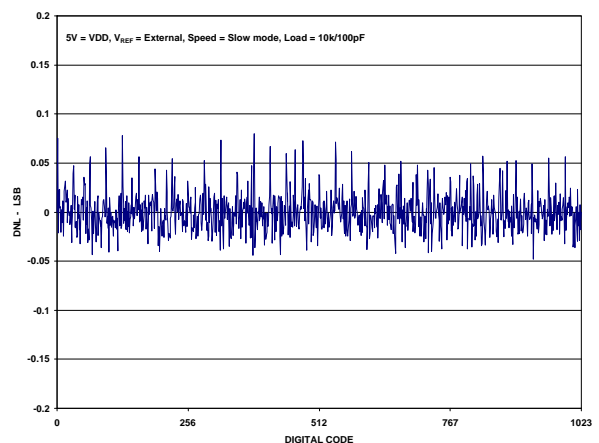
The WM2637 features an internal programmable voltage reference simplifying overall system design. A reference voltage may also be supplied externally.

The device has been designed to interface efficiently to industry standard microprocessors and DSPs, including the TMS320 family. The WM2637 is programmed with a 16-bit serial word comprising of a latch address, mode DAC control bits and DAC or control data.

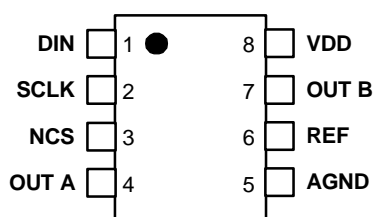
Excellent performance is delivered with a typical DNL of 0.1 LSBs. The programmable settling time allows the designer to optimize speed versus power consumption. The output stage is buffered by a x2 gain near rail-to-rail amplifier.

The device is available in an 8-pin SOIC package ideal for space-critical applications. Commercial temperature (0° to 70°C) and industrial temperature (-40° to 85°C) variants are supported.

## TYPICAL PERFORMANCE



## PIN CONFIGURATION



## PIN DESCRIPTION

PIN NO	NAME	TYPE	DESCRIPTION
1	DIN	Digital input	Serial data input.
2	SCLK	Digital input	Serial clock input.
3	NCS	Digital input	Chip select. This pin is active low.
4	OUTA	Analogue output	DAC A analogue output.
5	AGND	Supply	Analogue ground.
6	REF	Analogue I/O	Reference voltage input/output.
7	OUTB	Analogue output	DAC B analogue output
8	VDD	Supply	Positive power supply.

## ABSOLUTE MAXIMUM RATINGS

Absolute Maximum Ratings are stress ratings only. Permanent damage to the device may be caused by continuously operating at or beyond these limits. Device functional operating limits and guaranteed performance specifications are given under Electrical Characteristics at the test conditions specified.



ESD Sensitive Device. This device is manufactured on a CMOS process. It is therefore generically susceptible to damage from excessive static voltages. Proper ESD precautions must be taken during handling and storage of this device.

CONDITION	MIN	MAX
Supply voltage, VDD to AGND		7V
Digital input voltage	-0.3V	VDD + 0.3V
Reference input voltage	-0.3V	VDD + 0.3V
Operating temperature range, T <sub>A</sub>	WM2637CD	0°C
	WM2637ID	-40°C
Storage temperature	-65°C	150°C
Lead temperature 1.6mm (1/16 inch) soldering for 10 seconds		260°C

## RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply voltage	VDD		2.7		5.5	V
High-level digital input voltage	V <sub>IH</sub>	VDD = 5V	2			V
Low-level digital input voltage	V <sub>IL</sub>	VDD = 5V			0.8	V
Reference voltage to REF	V <sub>REF</sub>				VDD - 1.5	V
Load resistance	R <sub>L</sub>		2			kΩ
Load capacitance	C <sub>L</sub>				100	
Serial Clock Rate	F <sub>SCLK</sub>				20	
Operating free-air temperature	T <sub>A</sub>	WM2637CD	0		70	°C
		WM2637ID	-40		85	°C

**Note:** Reference voltages greater than  $V_{DD}/2$  will cause saturation for large DAC codes.

## ELECTRICAL CHARACTERISTICS

### Test Conditions:

$R_L = 10k\Omega$ ,  $C_L = 100pF$ .  $V_{DD} = 5V \pm 10\%$ ,  $V_{REF} = 2.048V$  and  $V_{DD} = 3V \pm 10\%$ ,  $V_{REF} = 1.024V$  over recommended operating free-air temperature range (unless noted otherwise)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>Static DAC Specifications</b>						
Resolution			10			bits
Integral non-linearity	INL	See Note 1		$\pm 0.4$	$\pm 1.0$	LSB
Differential non-linearity	DNL	See Note 2		$\pm 0.1$	$\pm 0.5$	LSB
Zero code error	ZCE	See Note 3			$\pm 24$	mV
Gain error	GE	See Note 4			$\pm 0.6$	% FSR
D.c. power supply rejection ratio	DC PSRR	See Note 5		0.5		mV/V
Zero code error temperature coefficient		See Note 6		10		ppm/ $^{\circ}C$
Gain error temperature coefficient		See Note 6		10		ppm/ $^{\circ}C$
<b>DAC Output Specifications</b>						
Output voltage range			0		$V_{DD} - 0.1$	V
Output load regulation		2k $\Omega$ to 10k $\Omega$ load See Note 7		$\pm 0.1$	$\pm 0.25$	%
<b>Power Supplies</b>						
Active supply current	$I_{DD}$	No load, $V_{IH} = V_{DD}$ , $V_{IL} = 0V$ $V_{DD} = 5V$ , $V_{REF} = 2.048V$ , Internal Slow Fast $V_{DD} = 5V$ , $V_{REF} = 2.048V$ , External Slow Fast $V_{DD} = 3V$ , $V_{REF} = 1.024V$ , Internal Slow Fast $V_{DD} = 3V$ , $V_{REF} = 1.024V$ , External Slow Fast See Note 8		2.0 4.2 1.7 3.8 1.7 3.7 1.4 3.4	2.5 5.0 2.1 4.6 2.2 4.6 1.8 4.2	mA mA mA mA mA mA mA mA
Power down supply current		No load, all digital inputs 0V or VDD See Note 9		0.01	10	$\mu A$
<b>Dynamic DAC Specifications</b>						
Slew rate		DAC code 32 to 1023, 10%-90% Slow Fast See Note 10		1.5 8.0		V/ $\mu s$ V/ $\mu s$
Settling time		DAC code 32 to 1023 Slow Fast See Note 11		3.5 1.0		$\mu s$ $\mu s$
Glitch energy		Code 511 to 512		10		nV-s
Signal to noise ratio	SNR	$f_s = 400ksps$ , $f_{OUT} = 1kHz$ , BW = 20kHz See Note 12	53	56		dB
Signal to noise and distortion ratio	SNRD	$f_s = 400ksps$ , $f_{OUT} = 1kHz$ , BW = 20kHz	50	54		dB

**Test Conditions:**

$R_L = 10k\Omega$ ,  $C_L = 100pF$ .  $V_{DD} = 5V \pm 10\%$ ,  $V_{REF} = 2.048V$  and  $V_{DD} = 3V \pm 10\%$ ,  $V_{REF} = 1.024V$  over recommended operating free-air temperature range (unless noted otherwise)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
		See Note 12				
Total harmonic distortion	THD	$f_s = 400kps$ , $f_{OUT} = 1kHz$ , BW = 20kHz See Note 12		-61	-50	dB
Spurious free dynamic range	SPFDR	$f_s = 400kps$ , $f_{OUT} = 1kHz$ , BW = 20kHz See Note 12	51	62		dB
<b>Reference Configured As Input</b>						
Reference input resistance	$R_{REFIN}$			10		M $\Omega$
Reference input capacitance	$C_{REFIN}$			55		pF
Reference feedthrough		$V_{REF} = 1V_{PP}$ at 1kHz + 1.024V dc, DAC code 0		-60		dB
Reference input bandwidth		$V_{REF} = 0.2V_{PP} + 1.024V$ dc DAC code 1024 Slow Fast		1.0 1.0		MHz MHz
<b>Reference Configured As Output</b>						
Low reference voltage	$V_{REFOUTL}$		1.003	1.024	1.045	V
High reference voltage	$V_{REFOUTH}$	$V_{DD} > 4.75V$	2.027	2.048	2.069	V
Output source current	$I_{REFSRC}$				1	mA
Output sink current	$I_{REFSNK}$		-1			mA
Load Capacitance					100	pF
PSRR				-48		dB
<b>Digital Inputs</b>						
High level input current	$I_{IH}$	Input voltage = VDD			1	$\mu A$
Low level input current	$I_{IL}$	Input voltage = 0V			-1	$\mu A$
Input capacitance	$C_I$			8		pF

**Notes:**

- Integral non-linearity (INL)** is the maximum deviation of the output from the line between zero and full scale (excluding the effects of zero code and full scale errors).
- Differential non-linearity (DNL)** is the difference between the measured and ideal 1LSB amplitude change of any adjacent two codes. A guarantee of monotonicity means the output voltage changes in the same direction (or remains constant) as a change in digital input code.
- Zero code error** is the voltage output when the DAC input code is zero.
- Gain error** is the deviation from the ideal full scale output excluding the effects of zero code error.
- Power supply rejection ratio** is measured by varying VDD from 4.5V to 5.5V and measuring the proportion of this signal imposed on the zero code error and the gain error.
- Zero code error** and **Gain error** temperature coefficients are normalised to full scale voltage.
- Output load regulation** is the difference between the output voltage at full scale with a 10k $\Omega$  load and 2k $\Omega$  load. It is expressed as a percentage of the full scale output voltage with a 10k $\Omega$  load.
- $I_{DD}$  is measured while continuously writing code 1512 to the DAC. For  $V_{IH} < V_{DD} - 0.7V$  and  $V_{IL} > 0.7V$  supply current will increase.
- Typical supply current** in power down mode is 10nA. Production test limits are wider for speed of test.
- Slew rate** results are for the lower value of the rising and falling edge slew rates
- Settling time** is the time taken for the signal to settle to within 0.5LSB of the final measured value for both rising and falling edges. Limits are ensured by design and characterisation, but are not production tested.
- SNR, SNRD, THD** and **SPFDR** are measured on a synthesised sinewave at frequency  $f_{OUT}$  generated with a sampling frequency  $f_s$ .

## SERIAL INTERFACE

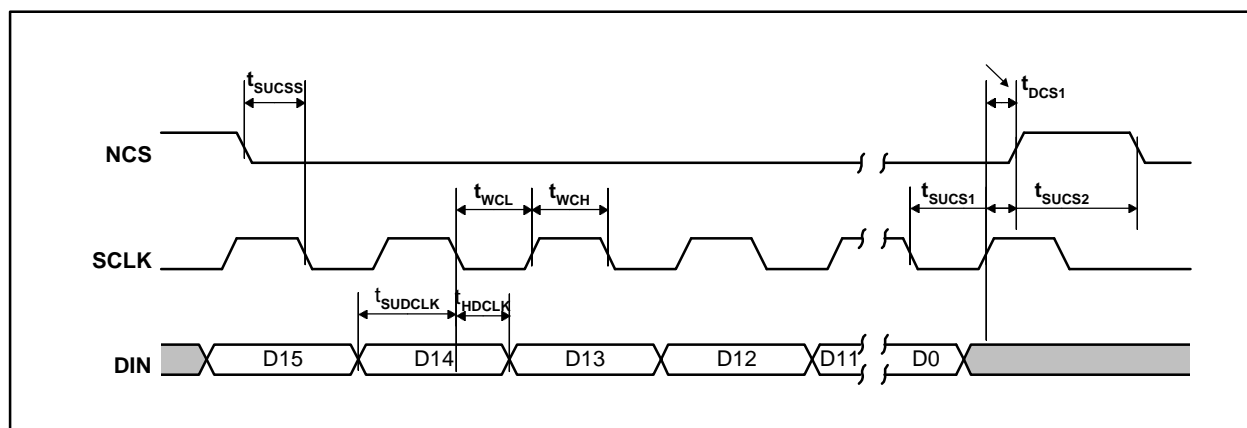


Figure 1 Timing Diagram

## Test Conditions:

$R_L = 10k\Omega$ ,  $C_L = 100pF$ .  $V_{DD} = 5V \pm 10\%$ ,  $V_{REF} = 2.048V$  and  $V_{DD} = 3V \pm 10\%$ ,  $V_{REF} = 1.024V$  over recommended operating free-air temperature range (unless noted otherwise)

SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{sucss}$	Setup time NCS low before SCLK low	10			ns
$t_{sucs1}$	Setup time, rising edge of SCLK to rising edge of NCS, external end of write	10			ns
$t_{sucs2}$	Setup time, rising edge of SCLK to falling edge of NCS, start of next write cycle	5			ns
$t_{wcl}$	Pulse duration, SCLK high	25			ns
$t_{wch}$	Pulse duration, SCLK low	25			ns
$t_{sudclk}$	Setup time, data ready before SCLK falling edge	10			ns
$t_{hdclk}$	Hold time, data held valid after SCLK falling edge	5			ns

TYPICAL PERFORMANCE GRAPHS

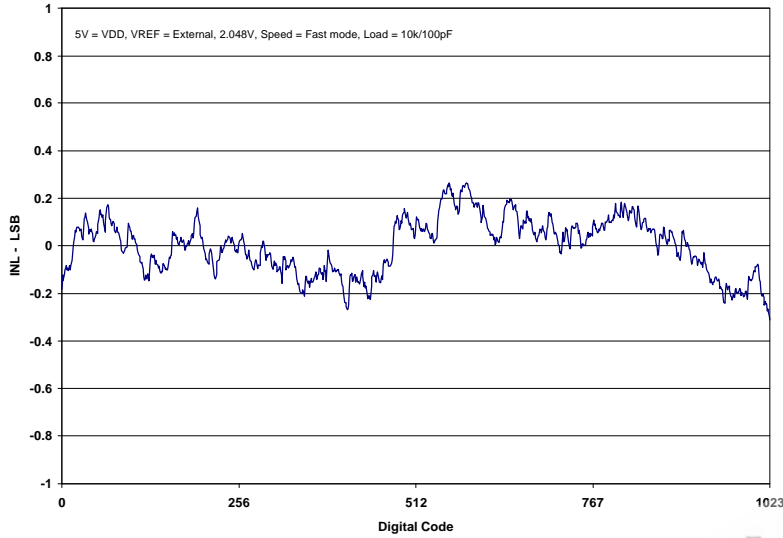


Figure 2 Integral Non-Linearity

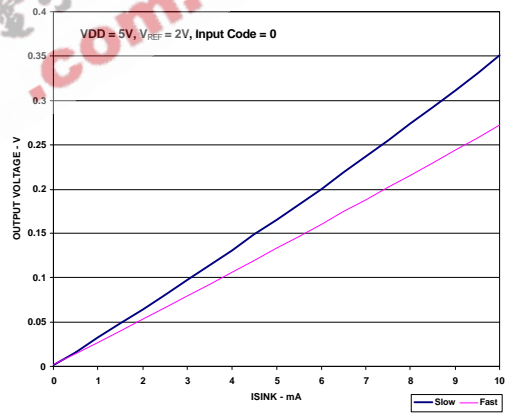
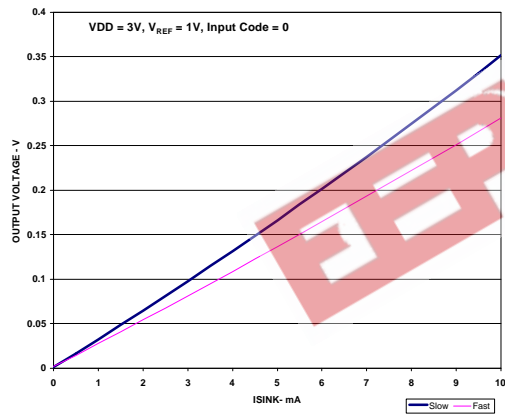


Figure 3 Sink Current VDD = 3V

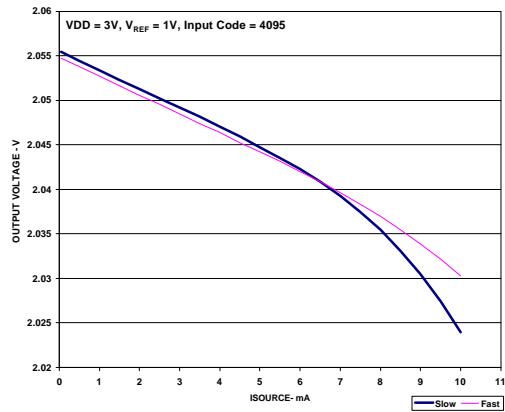


Figure 4 Sink Current VDD = 5V

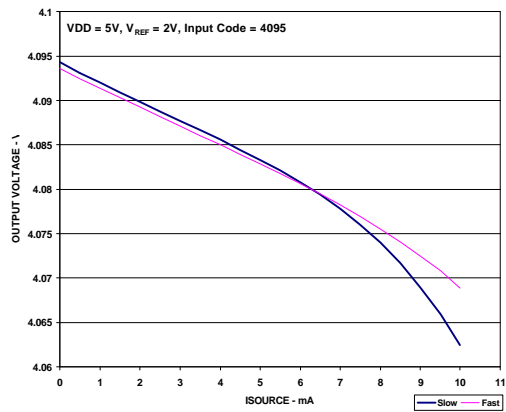


Figure 5 Source Current VDD = 3V

Figure 6 Source Current VDD = 5V

## DEVICE DESCRIPTION

### GENERAL FUNCTION

The device uses a resistor string network buffered with an op amp to convert 10-bit digital data to analogue voltage levels (see Block Diagram). The output voltage is determined by the reference input voltage and the input code according to the following relationship:

$$\text{Output voltage} = 2(V_{\text{REF}}) \frac{\text{code}}{1024}$$

INPUT			OUTPUT
11	1111	1111	$2(V_{\text{REF}}) \frac{1023}{1024}$
	:		:
10	0000	0001	$2(V_{\text{REF}}) \frac{513}{1024}$
10	0000	0000	$2(V_{\text{REF}}) \frac{512}{1024} = V_{\text{REF}}$
01	1111	1111	$2(V_{\text{REF}}) \frac{511}{1024}$
	:		:
00	0000	0001	$2(V_{\text{REF}}) \frac{1}{1024}$
0000	0000	0000	0V

**Table 1 Binary Code Table (0V to 2VREF Output), Gain = 2**

### POWER ON RESET

An internal power-on-reset circuit resets the DAC registers to all 0s on power-up.

### BUFFER AMPLIFIER

The output buffer has a near rail-to-rail output with short circuit protection and can reliably drive a 2kΩ load with a 100pF load capacitance.

### SERIAL INTERFACE

When chip select (NCS) is low, the input data is read into a 16-bit shift register with the input data clocked in most significant bit first. The falling edge of the SCLK input shifts the data into the input register. After 16 bits have been transferred, the next rising edge on SCLK or NCS then transfers the data to the DAC latch. When NCS is high, input data cannot be clocked into the input register (see Table 2).

### SERIAL CLOCK AND UPDATE RATE

Figure 1 shows the device timing. The maximum serial rate is:

$$f_{\text{SCLKmax}} = \frac{1}{t_{\text{WCHmin}} + t_{\text{WCLmin}}} = 20\text{MHz}$$

The digital update rate is limited to an 800ns period, or 1.25MHz frequency. However, the DAC settling time to 10 bits limits the update rate for large input step transitions.

### SOFTWARE CONFIGURATION OPTIONS

The 16 bits of data can be transferred with the sequence shown in Table 2. D11-D2 contains the 10-bit data word. D15-D12 hold the programmable options which are summarized Table 3

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
R1	SPD	PWD	R0	New DAC value or control register value										x	x

**Table 2 Serial Word Format**

### PROGRAMMABLE SETTling TIME

Settling time is a software selectable 1 $\mu$ s or 3.5 $\mu$ s typical, to within  $\pm 0.5$ LSB of final value. This is controlled by the value of D14. A ONE defines a settling time of 1 $\mu$ s, a ZERO defines a settling time of 3.5 $\mu$ s.

### PROGRAMMABLE POWER DOWN

The power down function is controlled by D13. A ZERO configures the device as active, or fully powered up, a ONE configures the device into power down mode. When the power down function is released the device reverts back to the DAC code set prior to power down.

### REGISTER ADDRESSING

A separate internal control register is available. This is accessed from the register access bits R1 (Bit D15) and R0 (Bit D12).

R1 (BIT D15)	R0 (BIT D12)	REGISTER
0	0	Write data to DAC B and BUFFER
0	1	Write data to BUFFER
1	0	Write data to DAC A and update DAC B with BUFFER content
1	1	Write data to control register

**Table 3 Programmable Options**

The contents of the control register, shown below in Table 4, are used to program the internal reference function

D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
x	x	x	x	x	x	x	x	x	X	REF1	REF0

**Table 4 Control Register Contents**

### PROGRAMMABLE INTERNAL REFERENCE

The reference can be sourced internally or externally under software control. If an external reference voltage is applied to the REF pin, the device must be configured to accept this.

If an external reference is selected, the reference voltage input is buffered which makes the DAC input resistance independent of code. The REF pin has an input resistance of 10M $\Omega$  and an input capacitance of typically 55pF. The reference voltage determines the DAC full-scale output.

If an internal reference is selected, a voltage of 1.024V or 2.048V is available. The internal reference can source up to 1mA and can therefore be used as an external system reference.

REF1 (BIT D1)	REF0 (BIT D0)	REGISTER
0	0	External
0	1	1.024V
1	0	2.048V
1	1	External

**Table 5 Internal Reference Options**

#### Examples:

- Set internal reference voltage to 2.048V

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
1	x	0	1	x	x	x	x	x	x	x	x	x	x	1	0

- Write new DAC A value and update DAC A output

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	x	0	0	New DAC A output value										x	x



## FUNCTION OF THE LATCH CONTROL BITS (D15 AND D12)

### PURPOSE AND USE OF THE DOUBLE BUFFER

Normally only one DAC output can change after a write. The double buffer allows both DAC outputs to change after a single write. This is achieved by the two following steps.

1. A double buffer only write is executed to store the new DAC B data without changing the DAC A and B outputs.
2. Following the previous step, a write to latch A is executed. This writes the serial interface register (SIR) data to latch A and also writes the double buffer contents to latch B. Thus both DACs receive their new data at the same time and so both DAC outputs begin to change at the same time.

Unless a double buffer only write is issued, the latch B and double buffer contents are identical. Thus, following a write to latch A or B with another write to latch A does not change the latch B contents.

Three data transfer options are possible. All transfers occur immediately after NCS goes high (or on the sixteenth positive SCLK edge, whichever is earlier) and are described in the following sections).

### LATCH A WRITE, LATCH B UPDATE (D15 = HIGH, D12 = LOW)

The serial interface register (SIR) data are written to latch A and the double buffer latch contents are written to latch B. The double buffer contents are unaffected. This program bit condition allows simultaneous output updates of both DACs.

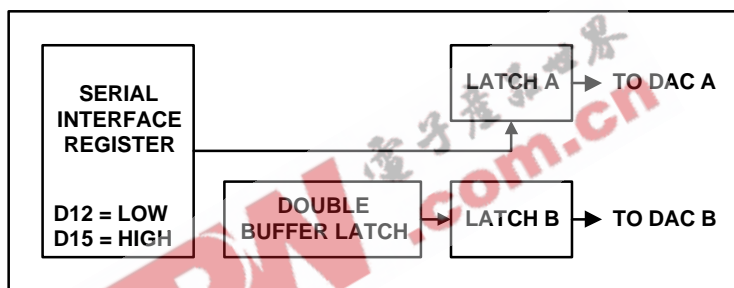


Figure 7 Latch A Write, Latch B Update

### LATCH B AND DOUBLE BUFFER 1 WRITE (D15 = LOW, D12 = LOW)

The SIR data are written to both latch B and the double buffer. Latch A is unaffected.

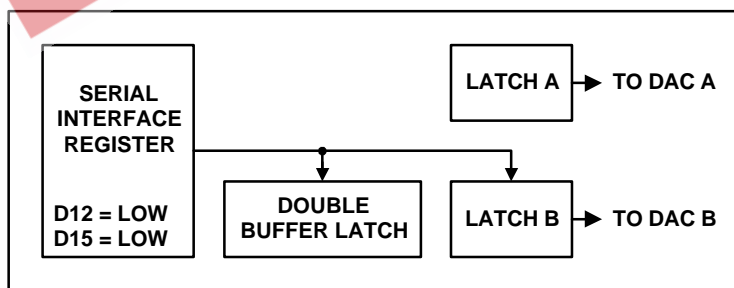
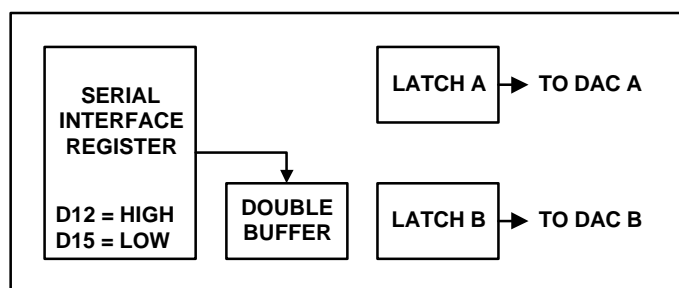


Figure 8 Latch B and Double Buffer Write

**DOUBLE BUFFER ONLY WRITE (D15 = LOW, D12 = HIGH)**

The SIR data are written to the double buffer only. Latch A and B contents are unaffected.



**Figure 9 Double Buffer Only Write**

**OPERATIONAL EXAMPLES**

## 1. changing the latch A data from zero to full code

Assuming that latch A starts at zero code (e.g. after power up), the latch can be filled with 1s by writing (bit D15 on the left, D0 on the right)

```
1X00 1111 1111 11xx
```

to the serial interface. Bit D14 can be zero to select slow mode or one to select fast mode.

The latch B contents and DAC B output are not changed by this write unless the double buffer contents are different from the latch B contents. This can only be true if the last write was a double buffer-only write.

## 2. changing the latch B data from zero to full code

Assuming that latch B starts at zero code (e.g. after power up), the latch can be filled with 1s by writing (bit D15 on the left, D0 on the right)

```
0X00 1111 1111 11xx
```

to the serial interface. Bit D14 can be zero to select slow mode or one to select fast mode. The data (bits D2 to D11) are written to both the double buffer and latch B.

The latch A contents and the DAC A output are not changed by this write.

## 3. double buffered change of both DAC outputs

Assuming that DACs A and B start at zero code (e.g. after power up), if DAC A is to be driven to mid-scale and DAC B to full-scale, and if the outputs are to begin rising at the same time, this can be achieved as follows:

First,

```
0d01 1111 1111 11xx
```

is written (bit D15 on the left, D0 on the right) to the serial interface. This loads the full-scale code into the double buffer but does not change the latch B contents and the DAC B output voltage. The latch A contents and the DAC A output are also unaffected by this write operation.

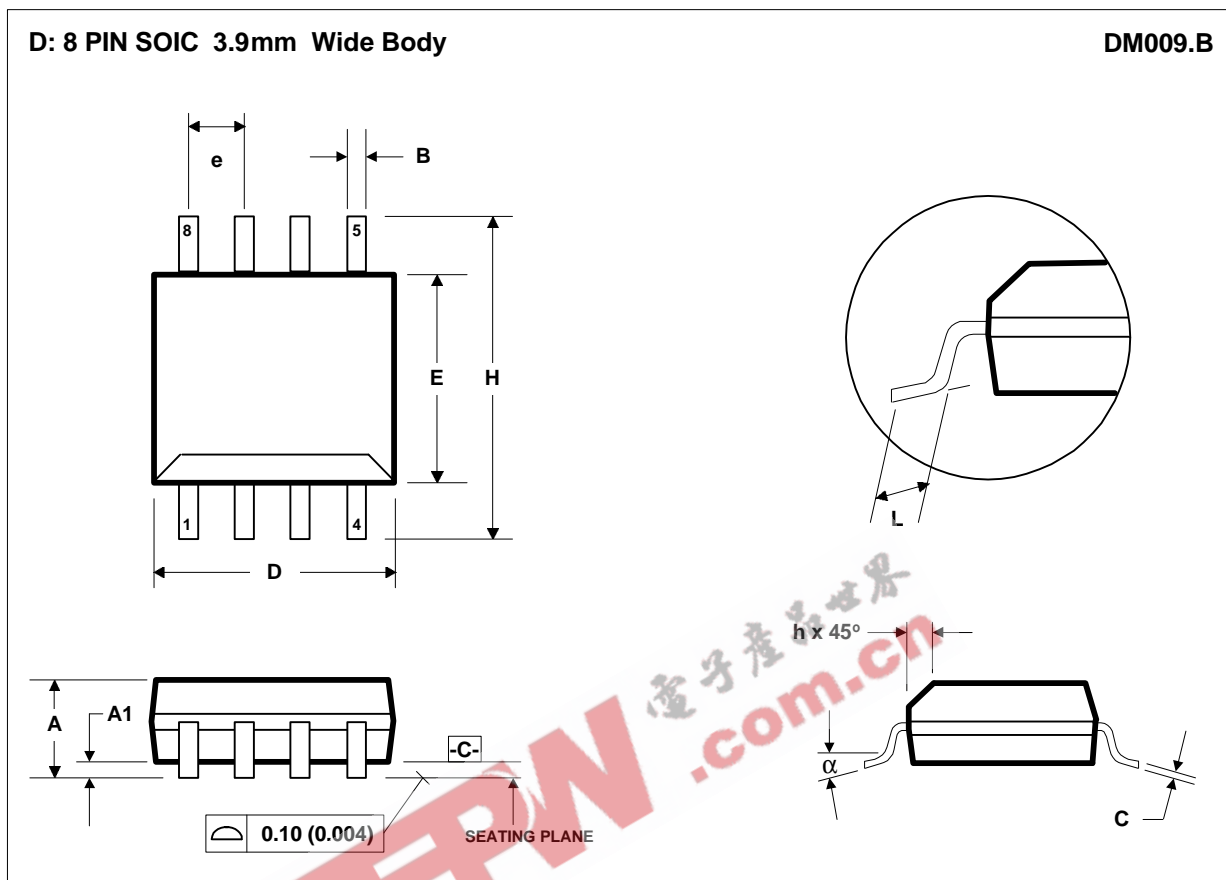
Changing from fast to slow to fast mode changes the supply current which can glitch the outputs, and so D14 (designated by d in the above data word) should be set to maintain the speed mode set by the previous write.

Next,

```
1d00 1000 0000 00xx
```

is written (bit D15 on the left, D0 on the right) to the serial interface. This writes the mid-scale code (1000000000) to latch A and also copies the full-scale code from the double buffer to latch B. Both DAC outputs thus begin to rise after the second write.

PACKAGE DIMENSIONS



Symbols	Dimensions (mm)		Dimensions (Inches)	
	MIN	MAX	MIN	MAX
A	1.35	1.75	0.0532	0.0688
A <sub>1</sub>	0.10	0.25	0.0040	0.0098
B	0.33	0.51	0.0130	0.0200
C	0.19	0.25	0.0075	0.0098
D	4.80	5.00	0.1890	0.1968
e	1.27 BSC		0.050 BSC	
E	3.80	4.00	0.1497	0.1574
h	0.25	0.50	0.0099	0.0196
H	5.80	6.20	0.2284	0.2440
L	0.40	1.27	0.0160	0.0500
α	0°	8°	0°	8°
<b>REF:</b>	<b>JEDEC.95, MS-012</b>			

- NOTES:  
 A. ALL LINEAR DIMENSIONS ARE IN MILLIMETERS (INCHES).  
 B. THIS DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE.  
 C. BODY DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSION, NOT TO EXCEED 0.25MM (0.010IN).  
 D. MEETS JEDEC.95 MS-012, VARIATION = AA. REFER TO THIS SPECIFICATION FOR FURTHER DETAILS.