



# DAC7613

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## 12-Bit, Voltage Output DIGITAL-TO-ANALOG CONVERTER

### FEATURES

- **LOW POWER:** 1.8mW
- **UNIPOLAR OR BIPOLAR OPERATION**
- **SETTLING TIME:** 10 $\mu$ s to 0.012%
- **12-BIT LINEARITY AND MONOTONICITY:** -40°C to +85°C
- **DATA READBACK**
- **DOUBLE-BUFFERED DATA INPUTS**
- **24-LEAD SSOP PACKAGE**

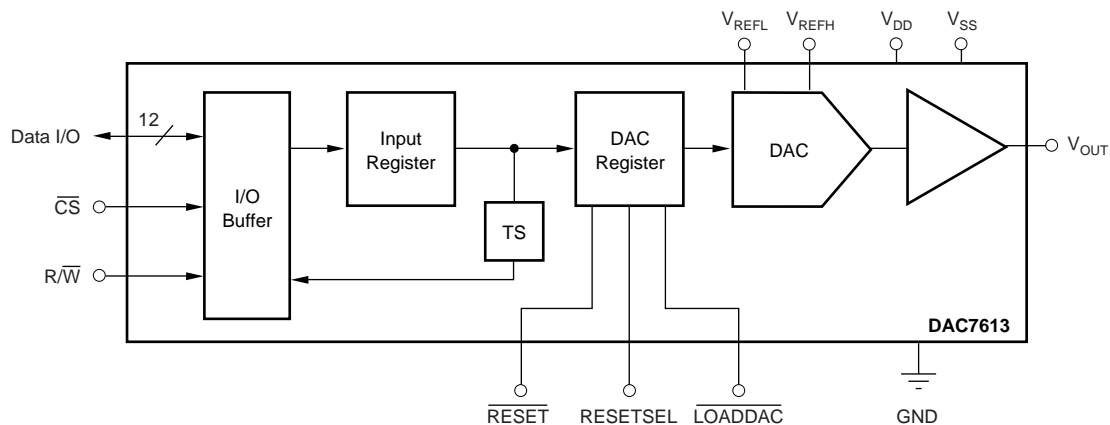
### APPLICATIONS

- **PROCESS CONTROL**
- **CLOSED-LOOP SERVO-CONTROL**
- **MOTOR CONTROL**
- **DATA ACQUISITION SYSTEMS**

### DESCRIPTION

The DAC7613 is a 12-bit, voltage output digital-to-analog converter with guaranteed 12-bit monotonic performance over the specified temperature range. The DAC7613 accepts a 12-bit parallel input data, has double-buffered DAC input logic and provides a readback mode of the internal input register. An asynchronous reset clears all registers to a mid-scale code of 800<sub>H</sub> or to a zero-scale of 000<sub>H</sub>. The DAC7613 can operate from a single +5V supply or from +5V and -5V supplies.

Low power and small size makes the DAC7613 ideal for data acquisition systems and closed-loop servo-control. The DAC7613 is available in a plastic SSOP-24 package, and offers guaranteed specifications over the -40°C to +85°C temperature range.



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# SPECIFICATION

At  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ,  $V_{DD} = +5\text{V}$ ,  $V_{SS} = -5\text{V}$ ,  $V_{REFH} = +2.5\text{V}$ , and  $V_{REFL} = -2.5\text{V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	DAC7613E			DAC7613EB			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>ACCURACY</b>								
Linearity Error <sup>(1)</sup>	$V_{SS} = 0\text{V}$ or $-5\text{V}$			$\pm 2$			$\pm 1$	LSB <sup>(2)</sup>
Differential Linearity Error	$V_{SS} = 0\text{V}$ or $-5\text{V}$			$\pm 1$			$\pm 1$	LSB
Monotonicity	$T_{MIN}$ to $T_{MAX}$	12			*			Bits
Zero-Scale Error	Code = $000_H$			$\pm 4$			*	LSB
Zero-Scale Drift			2	5		*	*	ppm/ $^{\circ}\text{C}$
Full-Scale Error	Code = $FFF_H$			$\pm 4$			*	LS
Zero-Scale Error	Code = $00A_H$ , $V_{SS} = 0\text{V}$			$\pm 8$			*	LSB
Zero-Scale Drift	$V_{SS} = 0\text{V}$		5	10		*	*	ppm/ $^{\circ}\text{C}$
Full-Scale Error	Code = $FFF_H$ , $V_{SS} = 0\text{V}$			$\pm 8$			*	LSB
Power Supply Rejection			30			*	*	ppm/V
<b>ANALOG OUTPUT</b>								
Voltage Output <sup>(3)</sup>	$V_{REFL} = 0\text{V}$ , $V_{SS} = 0\text{V}$ $V_{SS} = -5\text{V}$	0 $V_{REFL}$ -1.25		$V_{REFH}$ $V_{REFH}$ +1.25	*		*	V V mA
Output Current							*	
Load Capacitance	No Oscillation		100			*	*	pF
Short-Circuit Current			+5, -15			*	*	mA
Short-Circuit Duration			Indefinite			*	*	
<b>REFERENCE INPUT</b>								
$V_{REFH}$ Input Range	$V_{SS} = 0\text{V}$ or $-5\text{V}$	$V_{REFL} + 1.25$		+2.5	*		*	V
$V_{REFL}$ Input Range	$V_{SS} = 0\text{V}$	0		$V_{REFH} - 1.25$	*		*	V
$V_{REFL}$ Input Range	$V_{SS} = -5\text{V}$	-2.5		$V_{REFH} - 1.25$	*		*	V
<b>DYNAMIC PERFORMANCE</b>								
Settling Time <sup>(4)</sup>	To $\pm 0.012\%$		5	10		*	*	$\mu\text{s}$
Output Noise Voltage	0Hz to 1MHz		40			*	*	nV/ $\sqrt{\text{Hz}}$
<b>DIGITAL INPUT/OUTPUT</b>								
Logic Family			CMOS			*		
Logic Levels								
$V_{IH}$	$I_{IH} \leq \pm 10\mu\text{A}$	$0.7 V_{DD}$		$V_{DD} + 0.3$	*		*	V
$V_{IL}$	$I_{IL} \leq \pm 10\mu\text{A}$	-0.3		$0.3 V_{DD}$	*		*	V
$V_{OH}$	$I_{OH} = -0.8\text{mA}$	3.6		$V_{DD}$	*		*	V
$V_{OL}$	$I_{OL} = 1.6\text{mA}$	0.0		0.4	*		*	V
Data Format			Straight Binary			*		
<b>POWER SUPPLY REQUIREMENTS</b>								
$V_{DD}$		4.75		5.25	*		*	V
$V_{SS}$	If $V_{SS} \neq 0\text{V}$	-5.25		-4.75	*		*	V
$I_{DD}$			0.35	0.5		*	*	mA
$I_{SS}$		-0.65	-0.45		*	*	*	mA
Power Dissipation	$V_{SS} = -5\text{V}$		4	5.75		*	*	mW
	$V_{SS} = 0\text{V}$		1.8	2.5		*	*	mW
<b>TEMPERATURE RANGE</b>								
Specified Performance		-40		+85	*		*	$^{\circ}\text{C}$

NOTES: (1) If  $V_{SS} = 0\text{V}$ , specification applies at code  $00A_H$  and above. (2) LSB means Least Significant Bit, when  $V_{REFH}$  equals +2.5V and  $V_{REFL}$  equals -2.5V, then one LSB equals 1.22mV. (3) Ideal output voltage, does not take into account zero or full-scale error. (4) If  $V_{SS} = -5\text{V}$ , full-scale 5V step. If  $V_{SS} = 0\text{V}$ , full-scale positive 2.5V step and negative step from code  $FFF_H$  to  $00A_H$ .

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## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

$V_{DD}$ to $V_{SS}$ .....	-0.3V to 11V
$V_{DD}$ to GND .....	-0.3V to 5.5V
$V_{REFL}$ to $V_{SS}$ .....	-0.3V to ( $V_{DD} - V_{SS}$ )
$V_{DD}$ to $V_{REFH}$ .....	-0.3V to ( $V_{DD} - V_{SS}$ )
$V_{REFH}$ to $V_{REFL}$ .....	-0.3V to ( $V_{DD} - V_{SS}$ )
Digital Input Voltage to GND .....	-0.3V to $V_{DD} + 0.3V$
Digital Output Voltage to GND .....	-0.3V to $V_{DD} + 0.3V$
Maximum Junction Temperature .....	+150°C
Operating Temperature Range .....	-40°C to +85°C
Storage Temperature Range .....	-65°C to +150°C
Lead Temperature (soldering, 10s) .....	+300°C

NOTE: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.



## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

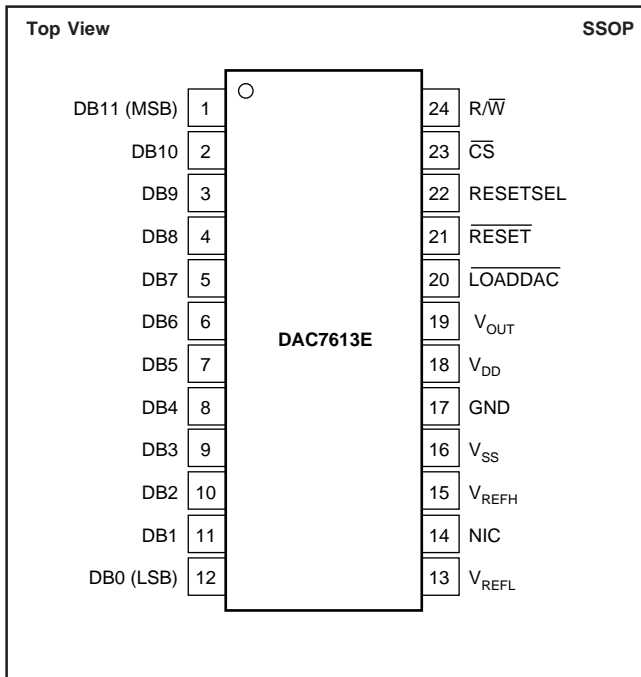
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## PACKAGE/ORDERING INFORMATION

PRODUCT	MAXIMUM LINEARITY ERROR (LSB)	MAXIMUM DIFFERENTIAL LINEARITY ERROR (LSB)	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFICATION TEMPERATURE RANGE	ORDERING NUMBER <sup>(1)</sup>	TRANSPORT MEDIA
DAC7613E	±2	±1	SSOP-24	338	-40°C to +85°C	DAC7613E	Rails
"	"	"	"	"	"	DAC7613E/1K	Tape and Reel
DAC7613EB	±1	±1	SSOP-24	338	-40°C to +85°C	DAC7613EB	Rails
"	"	"	"	"	"	DAC7613EB/1K	Tape and Reel

NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /1K indicates 1000 devices per reel). Ordering 1000 pieces of "DAC7613E/1K" will get a single 1000-piece Tape and Reel.

## PIN CONFIGURATION

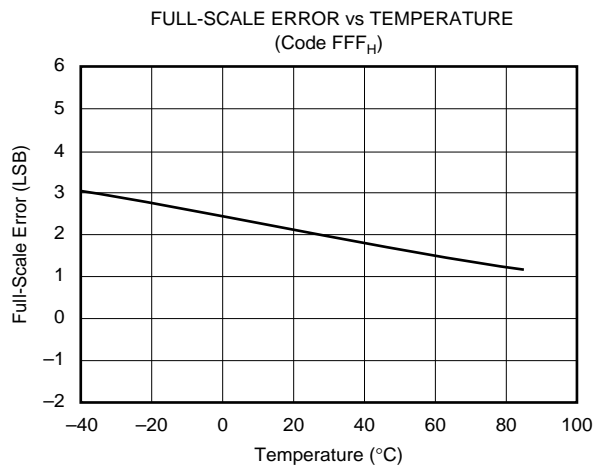
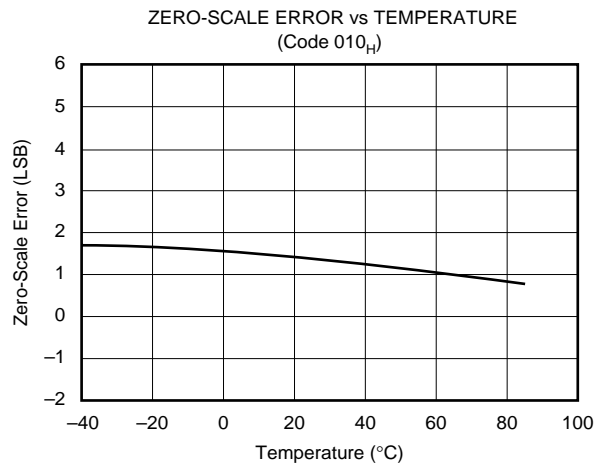
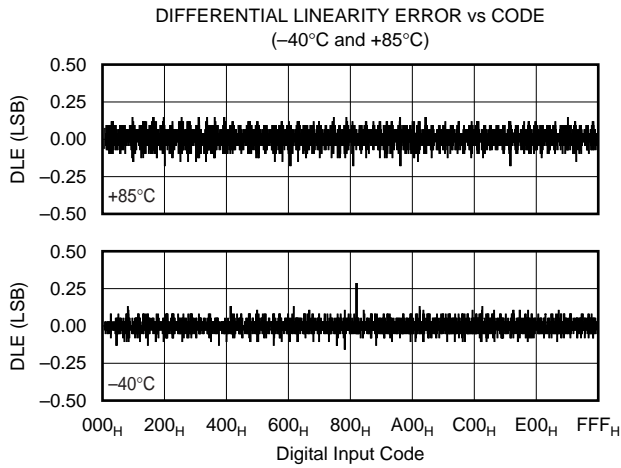
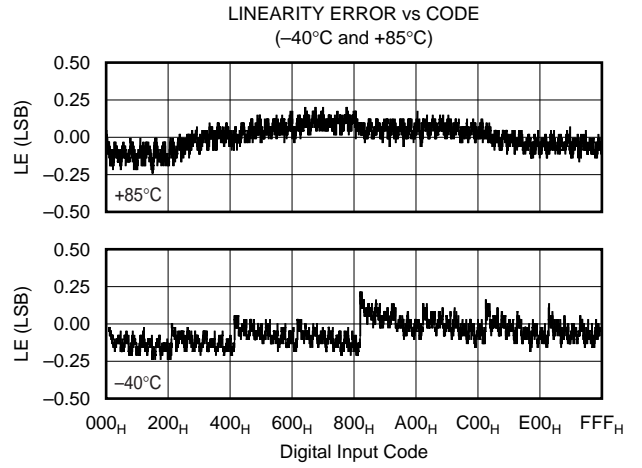
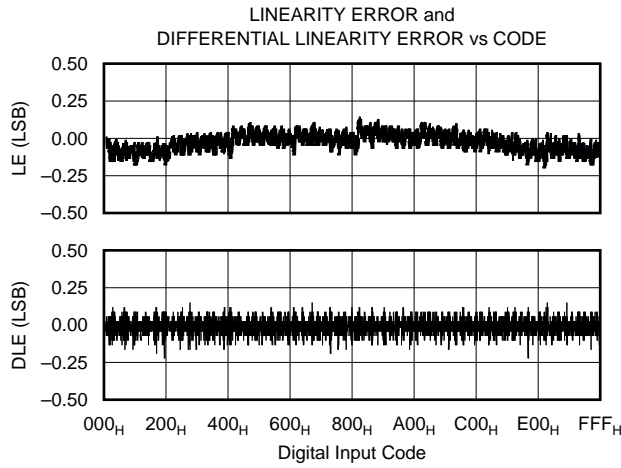


## PIN DESCRIPTIONS

PIN	LABEL	DESCRIPTION
1	DB11	Data Bit 11, MSB
2	DB10	Data Bit 10
3	DB9	Data Bit 9
4	DB8	Data Bit 8
5	DB7	Data Bit 7
6	DB6	Data Bit 6
7	DB5	Data Bit 5
8	DB4	Data Bit 4
9	DB3	Data Bit 3
10	DB2	Data Bit 2
11	DB1	Data Bit 1
12	DB0	Data Bit 0, LSB
13	V <sub>REFL</sub>	Reference Input Voltage Low. Sets minimum output voltage for the DAC.
14	NIC	Not Internally Connected
15	V <sub>REFH</sub>	Reference Input Voltage High. Sets maximum output voltage for the DAC.
16	V <sub>SS</sub>	Negative Analog Supply Voltage, 0V or -5V nominal.
17	GND	Ground
18	V <sub>DD</sub>	Positive Power Supply
19	V <sub>OUT</sub>	DAC Voltage Output
20	LOADDAC	The selected DAC register becomes transparent when $\overline{\text{LOADDAC}}$ is LOW. It is in the latched state when $\overline{\text{LOADDAC}}$ is HIGH.
21	RESET	Asynchronous Reset Input. Sets the DAC register to either zero-scale (000 <sub>H</sub> ) or mid-scale (800 <sub>H</sub> ) when LOW. RESETSEL determines which code is active.
22	RESETSEL	When LOW, a LOW on $\overline{\text{RESET}}$ will cause the DAC register to be set to code 000 <sub>H</sub> . When RESETSEL is HIGH, a LOW on $\overline{\text{RESET}}$ will set the registers to code 800 <sub>H</sub> .
23	CS	Chip Select. Active LOW.
24	R/W	Enabled by $\overline{\text{CS}}$ . Controls data read and write from the input register.

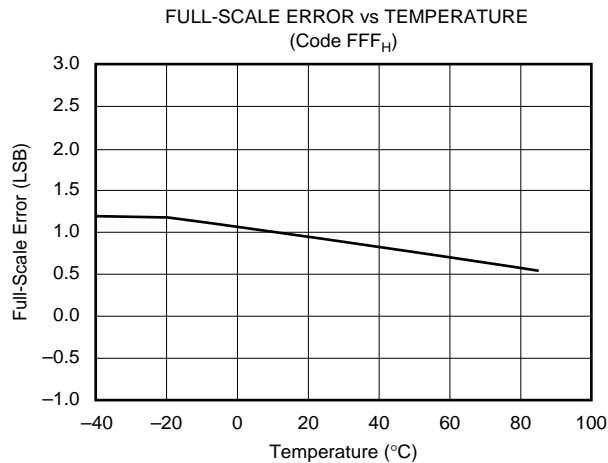
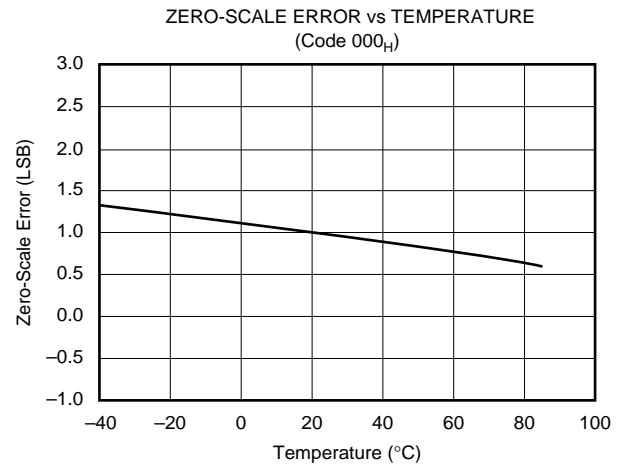
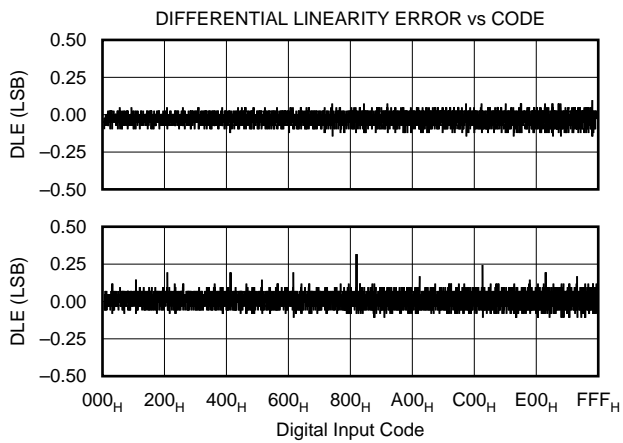
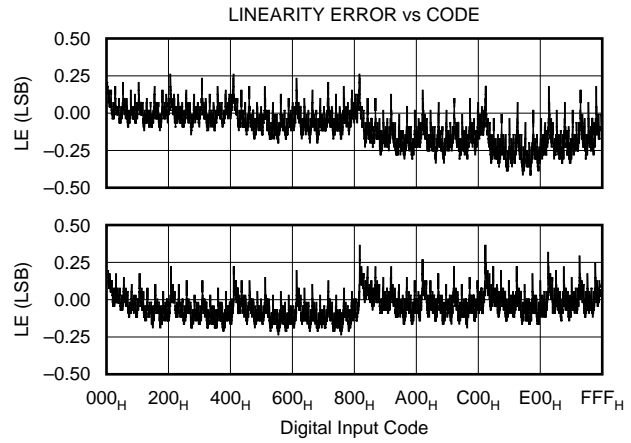
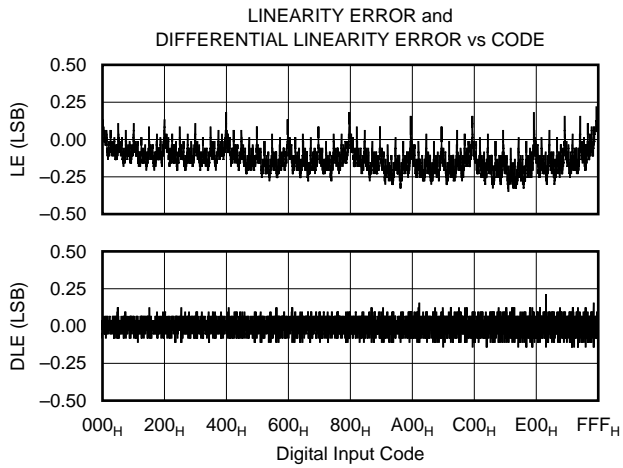
# TYPICAL PERFORMANCE CURVES: $V_{SS} = 0V$

At  $T_A = +25^\circ C$ ,  $V_{DD} = +5V$ ,  $V_{REFH} = +2.5V$ , and  $V_{REFL} = 0V$ , representative unit, unless otherwise specified.



# TYPICAL PERFORMANCE CURVES: $V_{SS} = -5V$

At  $T_A = +25^\circ C$ ,  $V_{DD} = +5V$ ,  $V_{REFH} = +2.5V$ , and  $V_{REFL} = 0V$ , representative unit, unless otherwise specified.



# THEORY OF OPERATION

The DAC7613 is a 12-bit, voltage output Digital-to-Analog Converter (DAC). The architecture is a classic R-2R ladder configuration followed by an operational amplifier that serves as a buffer. The minimum voltage output (“zero-scale”) and maximum voltage output (“full-scale”) are set by the external voltage references ( $V_{REFL}$  and  $V_{REFH}$ , respectively). The digital input is a 12-bit parallel word and the DAC input

register offers a readback capability. The converter can be powered from a single +5V supply or a dual  $\pm 5V$  supply. The device offers a reset function which immediately sets the DAC output voltage and DAC register to mid-scale (code 800<sub>H</sub>) or to zero-scale (code 000<sub>H</sub>), depending on the status of the reset selection. See Figures 1 and 2 for the basic operation of the DAC7613.

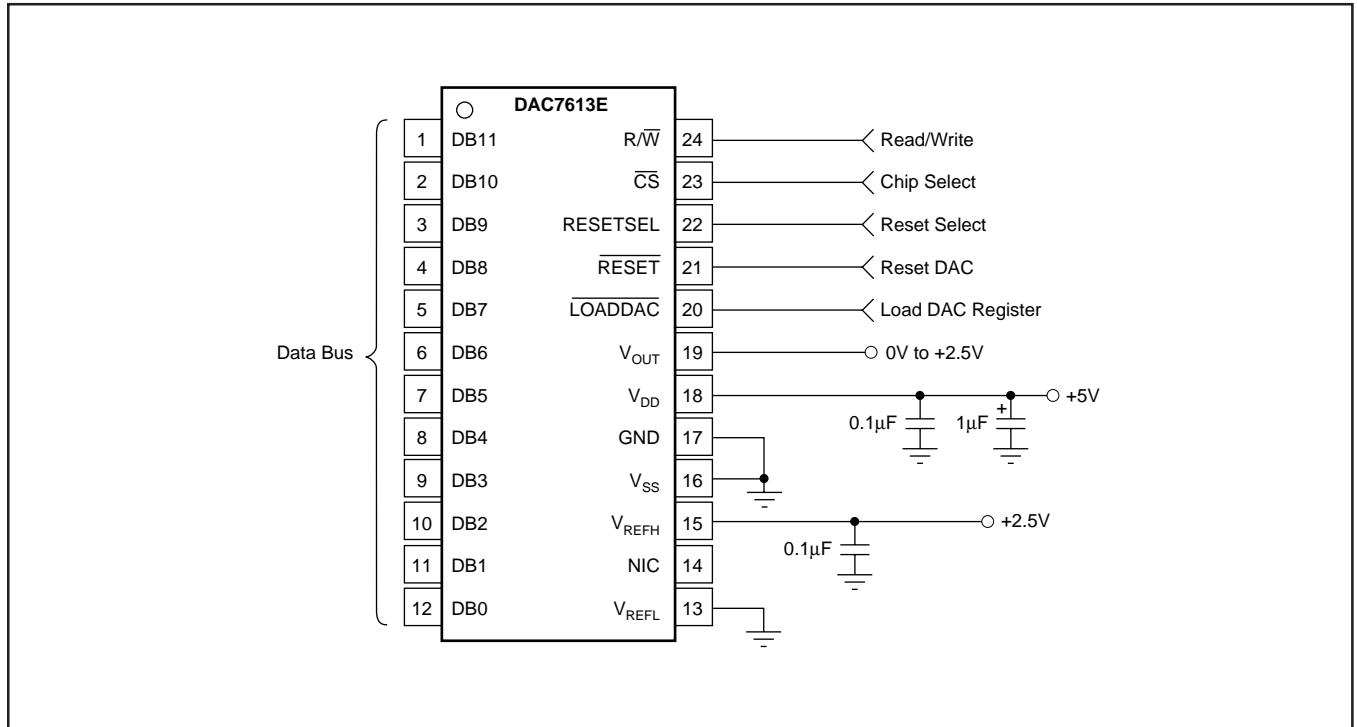


FIGURE 1. Basic Single-Supply Operation of the DAC7613.

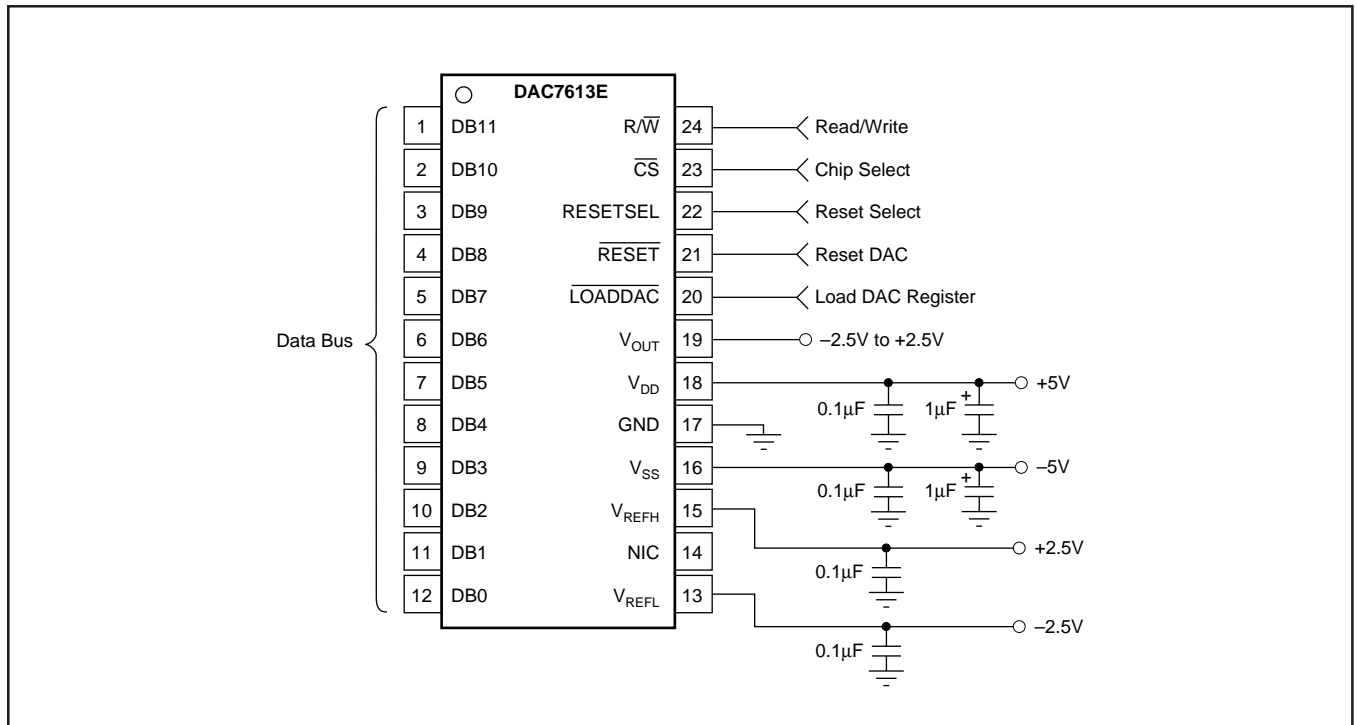


FIGURE 2. Basic Dual-Supply Operation of the DAC7613.

## ANALOG OUTPUTS

When  $V_{SS} = -5V$  (dual supply operation), the output amplifier can swing to within 2.25V of the supply rails, guaranteed over the  $-40^{\circ}C$  to  $+85^{\circ}C$  temperature range. With  $V_{SS} = 0V$  (single-supply operation), the output can swing to ground. Note that the settling time of the output op amp will be longer with voltages very near ground. Additionally, care must be taken when measuring the zero-scale error when  $V_{SS} = 0V$ . Since the output voltage cannot swing below ground, the output voltage may not change for the first few digital input codes (000<sub>H</sub>, 001<sub>H</sub>, 002<sub>H</sub>, etc.) if the output amplifier has a negative offset.

The behavior of the output amplifier can be critical in some applications. Under short-circuit conditions (DAC output shorted to ground), the output amplifier can sink a great deal more current than it can source. See the Specifications table for more details concerning short-circuit current.

## REFERENCE INPUTS

The reference inputs,  $V_{REFL}$  and  $V_{REFH}$ , can be any voltage between  $V_{SS} + 2.25V$  and  $V_{DD} - 2.25V$  provided that  $V_{REFH}$  is at least 1.25V greater than  $V_{REFL}$ . The minimum output of each DAC is equal to  $V_{REFL}$  plus a small offset voltage (essentially, the offset of the output op amp). The maximum output is equal to  $V_{REFH}$  plus a similar offset voltage. Note that  $V_{SS}$  (the negative power supply) must either be connected to ground or must be in the range of  $-4.75V$  to  $-5.25V$ . The voltage on  $V_{SS}$  sets several bias points within the converter. If  $V_{SS}$  is not in one of these two configurations, the bias values may be in error and proper operation of the device is not guaranteed.

The current into the  $V_{REFH}$  input depends on the DAC output voltages and can vary from a few microamps to approximately 0.1 milliamp. The  $V_{REFH}$  source will not be required to sink current, only source it. Bypassing the reference voltage or voltages with at least a 0.1 $\mu F$  capacitor placed as close to the DAC7613 package is strongly recommended.

## DIGITAL INTERFACE

Table I shows the basic control logic for the DAC7613. Note that the internal register is level triggered and not edge triggered. When the appropriate signal is LOW, the register becomes transparent. When this signal is returned HIGH, the digital word currently in the register is latched. The first register (the input register) is triggered via the R/W, and CS inputs. The second register (the DAC register) is transparent when  $\overline{LOADDAC}$  input is pulled LOW.

The double-buffered architecture is mainly designed so that the DAC input register can be written at any time and then the DAC voltage updated by pulling  $\overline{LOADDAC}$  LOW.

R/W	CS	RST	LOADDAC	INPUT REGISTER	DAC REGISTER	MODE
L	L	H	L	Write	Write	Write
L	L	H	H	Write	Hold	Write Input
H	L	H	H	Read	Hold	Read Input
X	H	H	L	Hold	Update	Update
X	H	H	H	Hold	Hold	Hold
X	H	L	X	Hold	Reset	Reset

X = Don't Care.

TABLE I. DAC7613 Control Logic Truth Table.



## DIGITAL TIMING

Figure 3 and Table II provide detailed timing for the digital interface of the DAC7613.

## DIGITAL INPUT CODING

The DAC7613 input data is in Straight Binary format. The output voltage is given by the following equation:

$$V_{OUT} = V_{REFL} + \frac{(V_{REFH} - V_{REFL}) \cdot N}{4096} \quad (1)$$

where N is the digital input code. This equation does not include the effects of offset (zero-scale) or gain (full-scale) errors.

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
$t_{RCS}$	$\overline{CS}$ LOW for Read	200			ns
$t_{RDS}$	$R/\overline{W}$ HIGH to $\overline{CS}$ LOW	10			ns
$t_{RDH}$	$R/\overline{W}$ HIGH after $\overline{CS}$ HIGH	0			ns
$t_{DZ}$	$\overline{CS}$ HIGH to Data Bus in High Impedance		100		ns
$t_{CSD}$	$\overline{CS}$ LOW to Data Bus Valid		100	160	ns
$t_{WCS}$	$\overline{CS}$ LOW for Write	50			ns
$t_{WS}$	$R/\overline{W}$ LOW to $\overline{CS}$ LOW	0			ns
$t_{WH}$	$R/\overline{W}$ LOW after $\overline{CS}$ HIGH	5			ns
$t_{DS}$	Data Valid to $\overline{CS}$ HIGH	0			ns
$t_{DH}$	Data Valid after $\overline{CS}$ HIGH	5			ns
$t_{LWD}$	$\overline{LOADDAC}$ LOW	50			ns
$t_{RESET}$	RESET LOW	50			ns

TABLE II. Timing Specifications ( $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ).

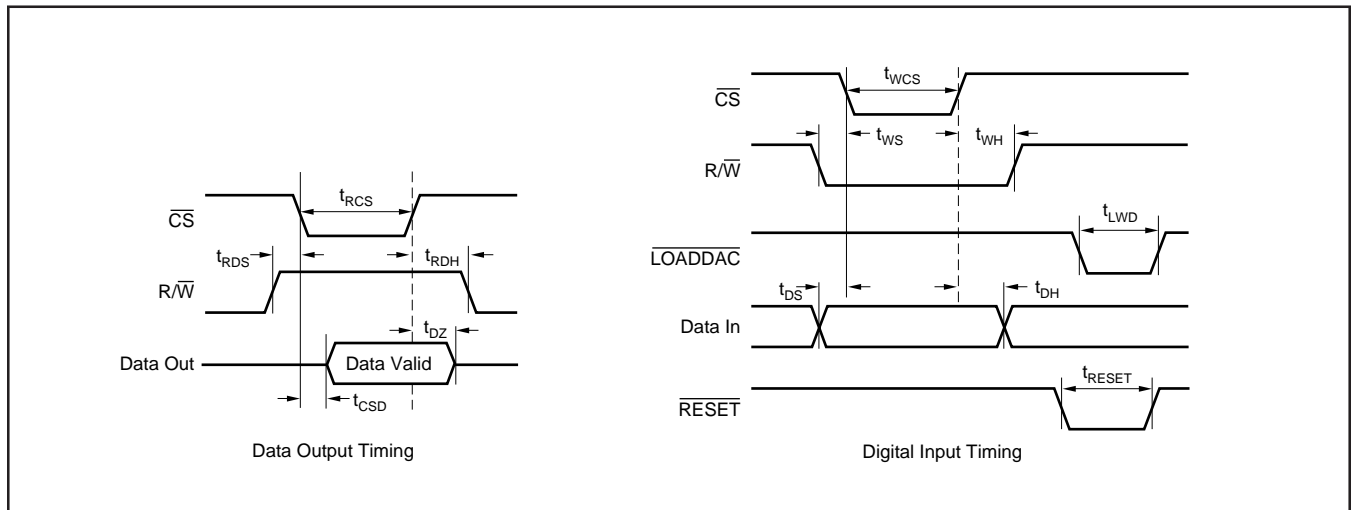


FIGURE 3. Digital Input and Output Timing.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
DAC7613E	ACTIVE	SSOP	DB	24	60	RoHS & Green	Call TI	Level-3-260C-168 HR	-40 to 85	DAC7613E	<a href="#">Samples</a>
DAC7613E/1K	ACTIVE	SSOP	DB	24	1000	RoHS & Green	Call TI	Level-3-260C-168 HR	-40 to 85	DAC7613E	<a href="#">Samples</a>
DAC7613EB	ACTIVE	SSOP	DB	24	60	RoHS & Green	Call TI	Level-3-260C-168 HR	-40 to 85	DAC7613E B	<a href="#">Samples</a>
DAC7613EB/1K	ACTIVE	SSOP	DB	24	1000	RoHS & Green	Call TI	Level-3-260C-168 HR	-40 to 85	DAC7613E B	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
DAC7613E/1K	SSOP	DB	24	1000	330.0	16.4	8.2	8.8	2.5	12.0	16.0	Q1
DAC7613EB/1K	SSOP	DB	24	1000	330.0	16.4	8.2	8.8	2.5	12.0	16.0	Q1

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DAC7613E/1K	SSOP	DB	24	1000	346.0	346.0	33.0
DAC7613EB/1K	SSOP	DB	24	1000	346.0	346.0	33.0

**TUBE**


\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
DAC7613E	DB	SSOP	24	60	530	10.2	4000	NA
DAC7613EB	DB	SSOP	24	60	530	10.2	4000	NA

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