

# TLV5618A-EP

## 2.7-V TO 5.5-V LOW-POWER DUAL 12-BIT DIGITAL-TO-ANALOG CONVERTER WITH POWER DOWN

SGLS214 – OCTOBER 2003

### features

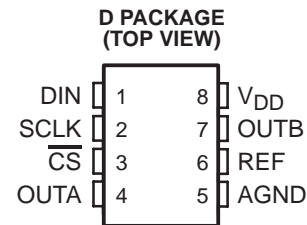
- **Controlled Baseline**
  - One Assembly/Test Site, One Fabrication Site
- **Extended Temperature Performance of –55°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree†**
- **Dual 12-Bit Voltage Output DAC**
- **Programmable Settling Time**
  - 3  $\mu$ s in Fast Mode
  - 10  $\mu$ s in Slow Mode

- **Compatible With TMS320 and SPI Serial Ports**
- **Differential Nonlinearity <0.5 LSB Typ**
- **Monotonic Over Temperature**
- **Direct Replacement for TLC5618A**

### applications

- **Digital Servo Control Loops**
- **Digital Offset and Gain Adjustment**
- **Industrial Process Control**
- **Machine and Motion Control Devices**
- **Mass Storage Devices**

† Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over an extended temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.



### description

The TLV5618A is a dual 12-bit voltage output DAC with a flexible 3-wire serial interface. The serial interface is compatible with TMS320, SPI™, QSPI™, and Microwire™ serial ports. It is programmed with a 16-bit serial string containing 4 control and 12 data bits.

The resistor string output voltage is buffered by an x2 gain rail-to-rail output buffer. The buffer features a Class-AB output stage to improve stability and reduce settling time. The programmable settling time of the DAC allows the designer to optimize speed versus power dissipation.

Implemented with a CMOS process, the device is designed for single supply operation from 2.7 V to 5.5 V. It is available in an 8-pin SOIC package.

The TLV5618AM is characterized for operation from –55°C to 125°C.

### ORDERING INFORMATION

T <sub>A</sub>	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–55°C to 125°C	SOIC (D)	Tape and reel	TLV5618AMDREP	5618ME

‡ Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



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Microwire is a trademark of National Semiconductor Corporation.

**PRODUCTION DATA** information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



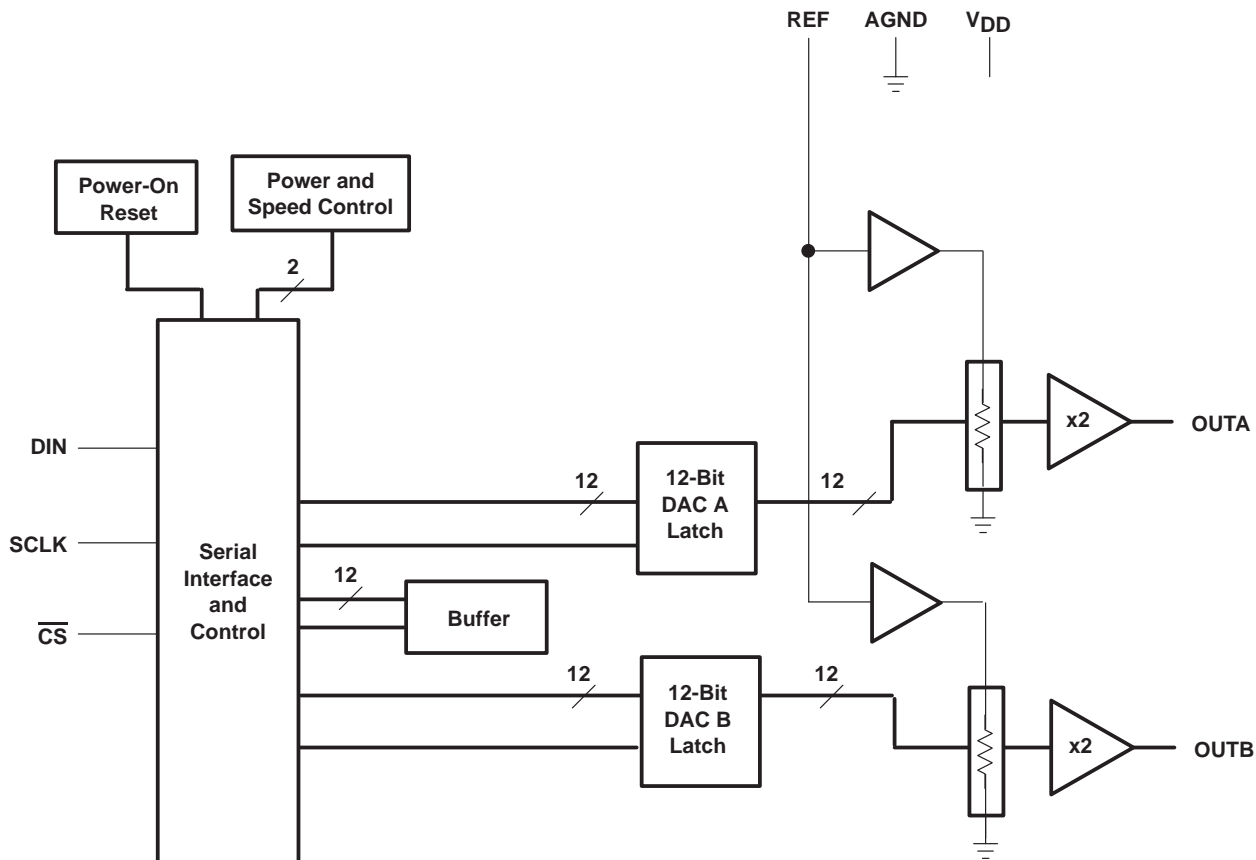
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**functional block diagram**



**Terminal Functions**

TERMINAL NAME	NO.	I/O/P	DESCRIPTION
AGND	5	P	Ground
$\overline{\text{CS}}$	3	I	Chip select. Digital input active low, used to enable/disable inputs.
DIN	1	I	Digital serial data input
OUTA	4	O	DAC A analog voltage output
OUTB	7	O	DAC B analog voltage output
REF	6	I	Analog reference voltage input
SCLK	2	I	Digital serial clock input
VDD	8	P	Positive power supply

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**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†**

Supply voltage ( $V_{DD}$ to AGND) .....	7 V
Reference input voltage range .....	- 0.3 V to $V_{DD} + 0.3$ V
Digital input voltage range .....	- 0.3 V to $V_{DD} + 0.3$ V
Operating free-air temperature range‡, $T_A$ : TLV5618AM .....	-55°C to 125°C
Storage temperature range‡, $T_{stg}$ .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	260°C
Package thermal impedance, $R_{\theta JA}$ : D package .....	131°C/W

† Stresses beyond those 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 beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

‡ Long term high-temperature storage and/or extended use at maximum recommended operating conditions may result in a reduction of overall device life. See [http://www.ti.com/ep\\_quality](http://www.ti.com/ep_quality) for additional information on enhanced plastic packaging.

**recommended operating conditions**

		MIN	NOM	MAX	UNIT
Supply voltage, $V_{DD}$	$V_{DD} = 5$ V	4.5	5	5.5	V
	$V_{DD} = 3$ V	2.7	3	3.3	
Power on reset		0.55		2	V
High-level digital input voltage, $V_{IH}$	$V_{DD} = 2.7$ V	2			V
	$V_{DD} = 5.5$ V	2.4			
Low-level digital input voltage, $V_{IL}$	$V_{DD} = 2.7$ V			0.6	V
	$V_{DD} = 5.5$ V			1	
Reference voltage, $V_{ref}$ to REF terminal	$V_{DD} = 5$ V (see Note 1)	AGND	2.048	$V_{DD} - 1.5$	V
	$V_{DD} = 3$ V (see Note 1)	AGND	1.024	$V_{DD} - 1.5$	
Load resistance, $R_L$		2			k $\Omega$
Load capacitance, $C_L$				100	pF
Clock frequency, $f_{(CLK)}$				20	MHz
Operating free-air temperature, $T_A$	TLV5618AM	-55		125	°C

NOTE 1: Due to the x2 output buffer, a reference input voltage  $\geq (V_{DD} - 0.4 \text{ V})/2$  causes clipping of the transfer function.



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**electrical characteristics over recommended operating conditions (unless otherwise noted)**

**power supply**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I <sub>DD</sub>	Power supply current	No load, All inputs = AGND or V <sub>DD</sub> , DAC latch = All ones	V <sub>DD</sub> = 2.7 V to 5.5 V	Fast	1.8	2.3	mA
				Slow	0.8	1	
Power down supply current					1		μA
PSRR	Power supply rejection ratio	Zero scale, See Note 2			-65		dB
		Full scale, See Note 3			-65		

NOTES: 2. Power supply rejection ratio at zero scale is measured by varying V<sub>DD</sub> and is given by:

$$PSRR = 20 \log [(E_{ZS}(V_{DDmax}) - E_{ZS}(V_{DDmin})/V_{DDmax}]$$

3. Power supply rejection ratio at full scale is measured by varying V<sub>DD</sub> and is given by:

$$PSRR = 20 \log [(E_G(V_{DDmax}) - E_G(V_{DDmin})/V_{DDmax}]$$

**static DAC specifications**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Resolution				12			bits
INL	Integral nonlinearity	See Note 4			±2	±4	LSB
DNL	Differential nonlinearity	See Note 5			±0.5	±1	LSB
E <sub>ZS</sub>	Zero-scale error (offset error at zero scale)	See Note 6				±12	mV
E <sub>ZS</sub> (TC)	Zero-scale-error temperature coefficient	See Note 7			3		ppm/°C
E <sub>G</sub>	Gain error	See Note 8	V <sub>DD</sub> = 2.7 V – 5.5 V			±0.6	% full scale V
E <sub>G</sub> (TC)	Gain-error temperature coefficient	See Note 9			1		ppm/°C

NOTES: 4. The relative accuracy of integral nonlinearity (INL), sometimes referred to as linearity error, 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.

5. The differential nonlinearity (DNL), sometimes referred to as differential error, is the difference between the measured and ideal 1-LSB amplitude change of any two adjacent codes.

6. Zero-scale error is the deviation from zero voltage output when the digital input code is zero.

7. Zero-scale-error temperature coefficient is given by:  $E_{ZS} TC = [E_{ZS}(T_{max}) - E_{ZS}(T_{min})]/2V_{ref} \times 10^6/(T_{max} - T_{min})$ .

8. Gain error is the deviation from the ideal output (2V<sub>ref</sub> – 1 LSB) with an output load of 10 kΩ.

9. Gain temperature coefficient is given by:  $E_G TC = [E_G(T_{max}) - E_G(T_{min})]/2V_{ref} \times 10^6/(T_{max} - T_{min})$ .

**output specifications**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V <sub>O</sub>	Output voltage range	R <sub>L</sub> = 10 kΩ		0		V <sub>DD</sub> -0.4	V
Output load regulation accuracy		V <sub>O</sub> = 4.096 V, 2.048 V, R <sub>L</sub> = 2 kΩ to 10 kΩ				±0.29	% FS



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electrical characteristics over recommended operating conditions (unless otherwise noted)  
(continued)

**reference input**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>I</sub>	Input voltage range		0	V <sub>DD</sub> -1.5		V
R <sub>I</sub>	Input resistance			10		MΩ
C <sub>I</sub>	Input capacitance			5		pF
Reference input bandwidth	REF = 0.2 V <sub>pp</sub> + 1.024 V dc	Fast		1.3		MHz
		Slow		525		kHz
Reference feedthrough	REF = 1 V <sub>pp</sub> at 1 kHz + 1.024 V dc (see Note 10)			-80		dB

NOTE 10: Reference feedthrough is measured at the DAC output with an input code = 0x000.

**digital inputs**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I <sub>IH</sub>	High-level digital input current	V <sub>I</sub> = V <sub>DD</sub>			1	μA
I <sub>IL</sub>	Low-level digital input current	V <sub>I</sub> = 0 V	-1			μA
C <sub>i</sub>	Input capacitance			8		pF

**analog output dynamic performance**

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t <sub>s</sub> (FS)	Output settling time, full scale	R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF, See Note 11	Fast		1	3	μs
			Slow		3	10	
t <sub>s</sub> (CC)	Output settling time, code to code	R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF, See Note 12	Fast		1		μs
			Slow		2		
SR	Slew rate	R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF, See Note 13	Fast		3		V/μs
			Slow		0.5		
Glitch energy		DIN = 0 to 1, FCLK = 100 kHz, $\overline{CS} = V_{DD}$			5		nV-s
SNR	Signal-to-noise ratio	f <sub>s</sub> = 102 kSPS, f <sub>out</sub> = 1 kHz, R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF			76		dB
SINAD	Signal-to-noise + distortion				68		
THD	Total harmonic distortion				-68		
SFDR	Spurious free dynamic range				72		

- NOTES: 11. Settling time is the time for the output signal to remain within ±0.5 LSB of the final measured value for a digital input code change of 0x020 to 0xFDF and 0xFDF to 0x020 respectively. Not tested, assured by design.  
12. Settling time is the time for the output signal to remain within ±0.5 LSB of the final measured value for a digital input code change of one count. Not tested, assured by design.  
13. Slew rate determines the time it takes for a change of the DAC output from 10% to 90% of full-scale voltage.



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**digital input timing requirements**

		MIN	NOM	MAX	UNIT
$t_{su}(CS-CK)$	Setup time, $\overline{CS}$ low before first negative SCLK edge	10			ns
$t_{su}(C16-CS)$	Setup time, 16 <sup>th</sup> negative SCLK edge before $\overline{CS}$ rising edge	10			ns
$t_w(H)$	SCLK pulse width high	25			ns
$t_w(L)$	SCLK pulse width low	25			ns
$t_{su}(D)$	Setup time, data ready before SCLK falling edge	8			ns
$t_h(D)$	Hold time, data held valid after SCLK falling edge	10			ns
$t_h(CSH)$	Hold time, $\overline{CS}$ high between cycles	$V_{DD} = 5\text{ V}$	25		ns
		$V_{DD} = 3\text{ V}$	50		

**timing requirements**

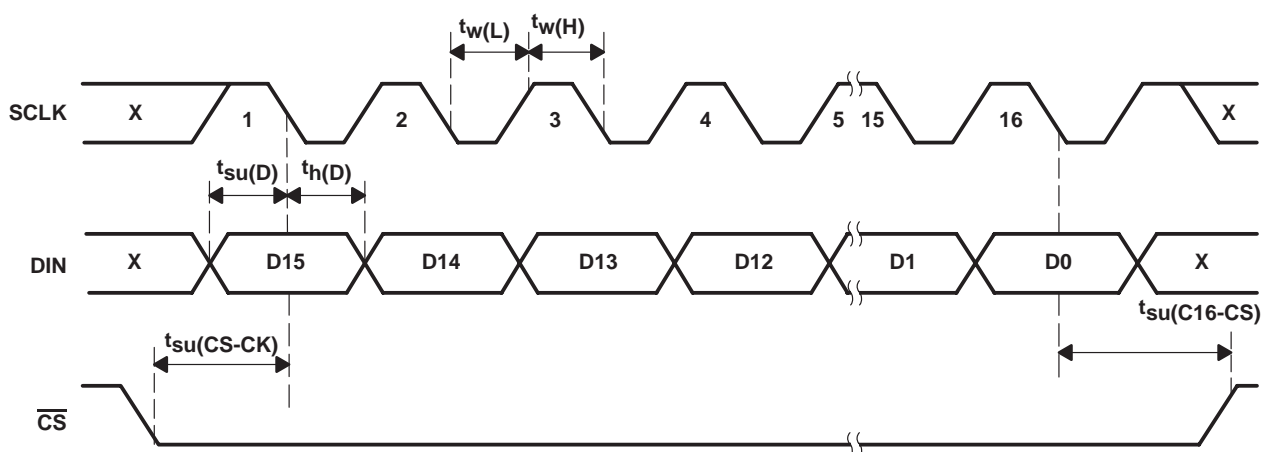
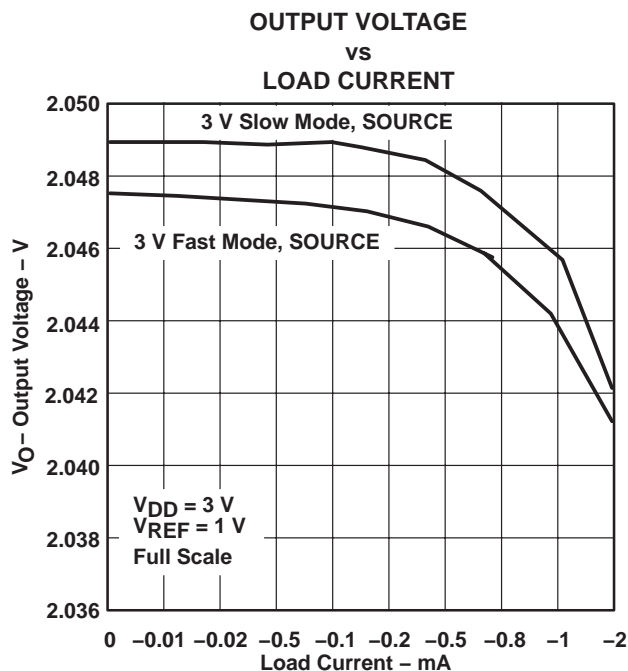
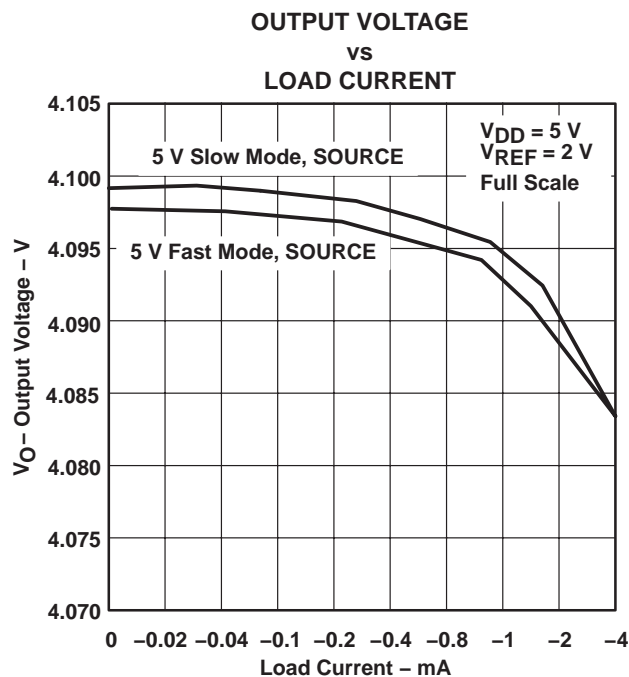


Figure 1. Timing Diagram

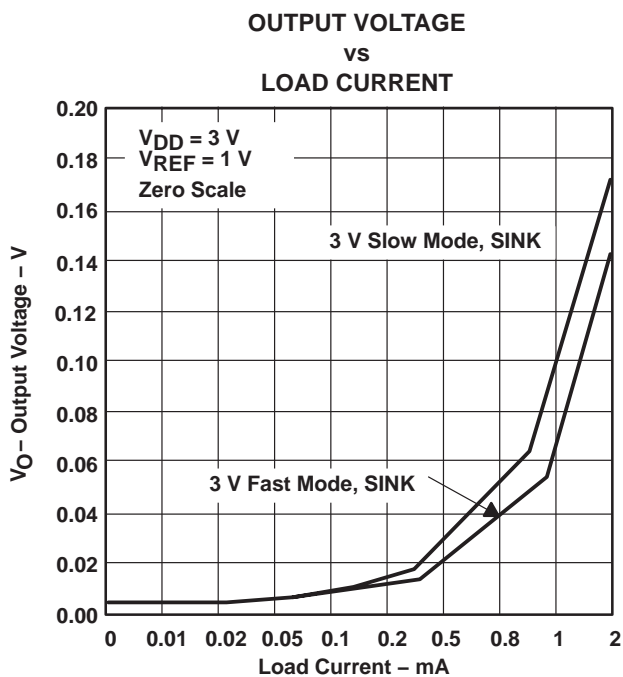
**TYPICAL CHARACTERISTICS**



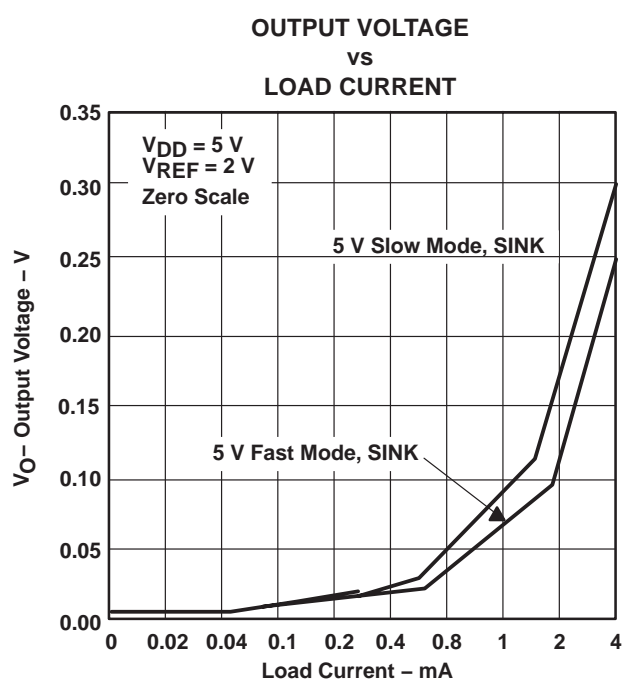
**Figure 2**



**Figure 3**



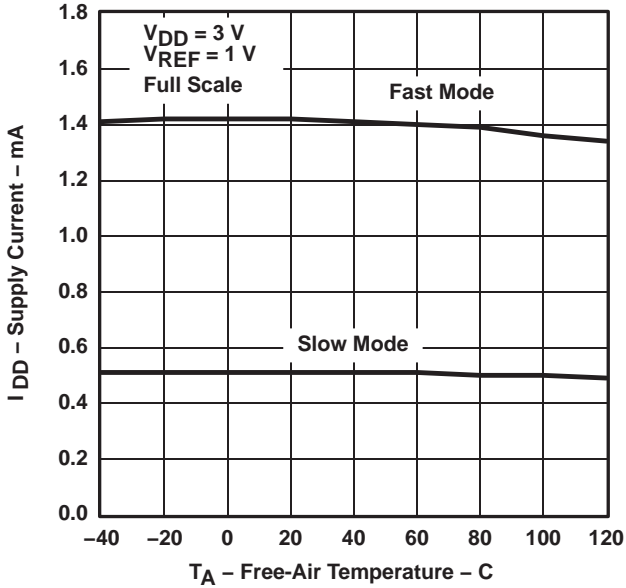
**Figure 4**



**Figure 5**

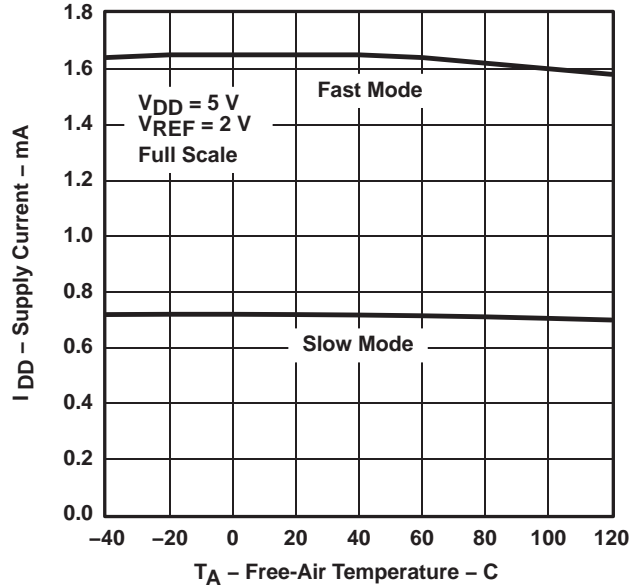
**TYPICAL CHARACTERISTICS**

**SUPPLY CURRENT**  
**vs**  
**FREE-AIR TEMPERATURE**



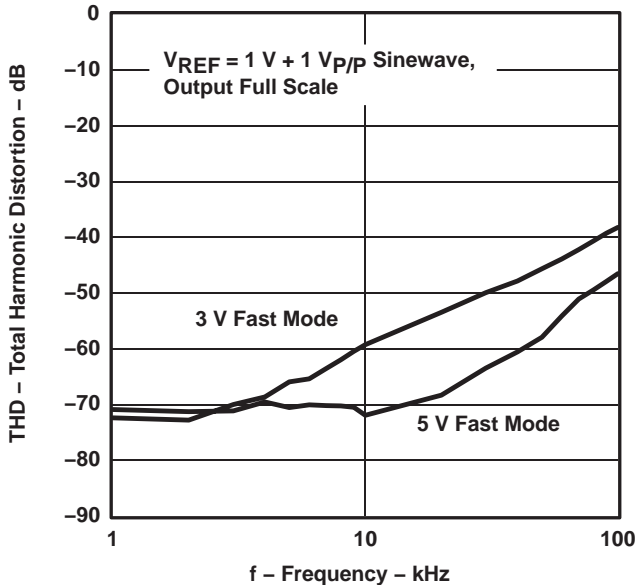
**Figure 6**

**SUPPLY CURRENT**  
**vs**  
**FREE-AIR TEMPERATURE**



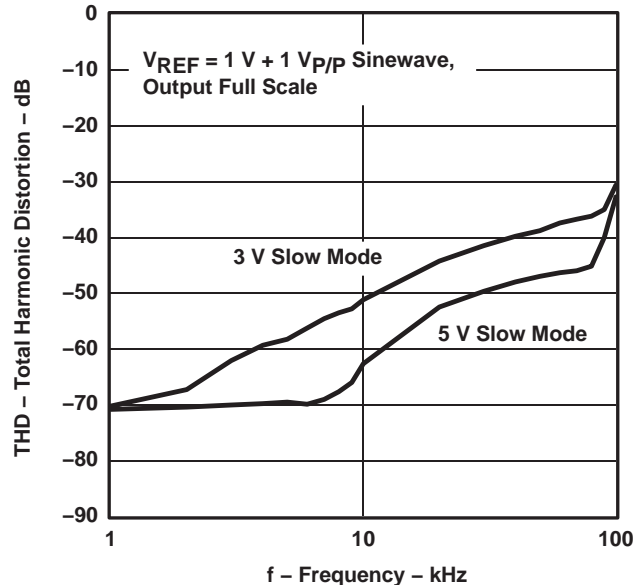
**Figure 7**

**TOTAL HARMONIC DISTORTION**  
**vs**  
**FREQUENCY**



**Figure 8**

**TOTAL HARMONIC DISTORTION**  
**vs**  
**FREQUENCY**



**Figure 9**



TYPICAL CHARACTERISTICS

INTEGRAL NONLINEARITY ERROR  
vs  
DIGITAL CODE

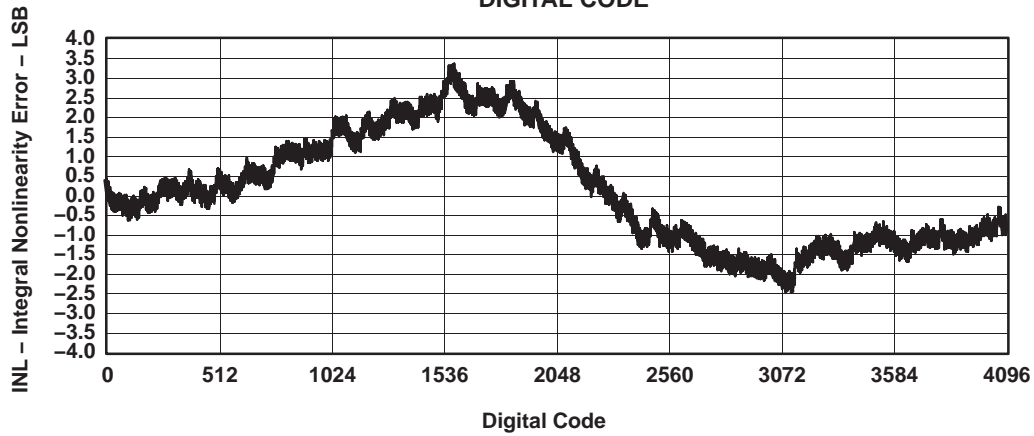


Figure 10

DIFFERENTIAL NONLINEARITY ERROR  
vs  
DIGITAL CODE

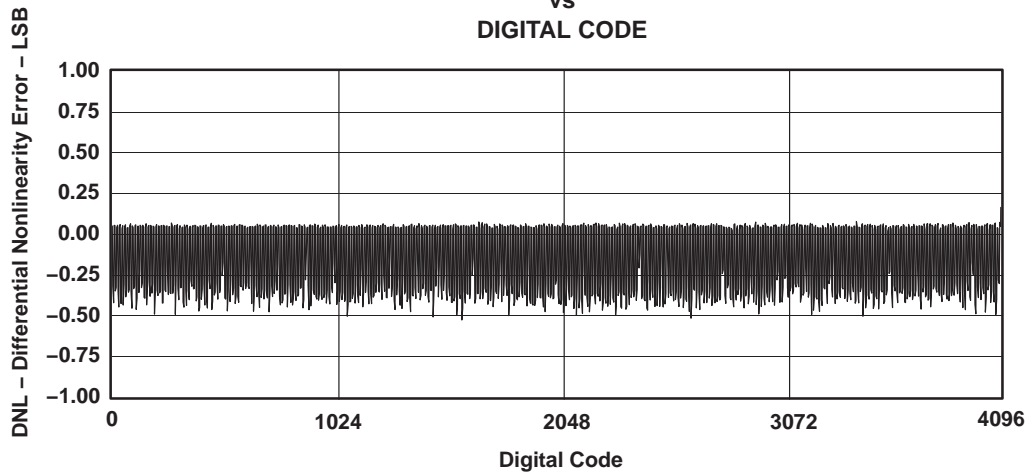


Figure 11

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**APPLICATION INFORMATION**

**general function**

The TLV5618A is a dual 12-bit, single-supply DAC, based on a resistor-string architecture. It consists of a serial interface, a speed and power down control logic, a resistor string, and a rail-to-rail output buffer.

The output voltage (full scale determined by the reference) is given by:

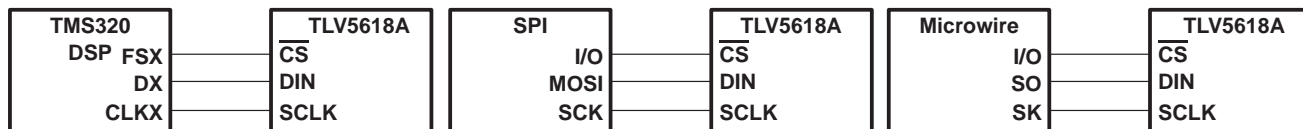
$$2 \text{ REF } \frac{\text{CODE}}{2^n} \text{ [V]}$$

Where REF is the reference voltage and CODE is the digital input value within the range of 0<sub>10</sub> to 2<sup>n</sup>-1, where n=12 (bits). The 16-bit data word, consisting of control bits and the new DAC value, is illustrated in the *data format* section. A power-on reset initially resets the internal latches to a defined state (all bits zero).

**serial interface**

A falling edge of  $\overline{\text{CS}}$  starts shifting the data bit-per-bit (starting with the MSB) to the internal register on the falling edges of SCLK. After 16 bits have been transferred or  $\overline{\text{CS}}$  rises, the content of the shift register is moved to the target latches (DAC A, DAC B, BUFFER, CONTROL), depending on the control bits within the data word.

Figure 12 shows examples of how to connect the TLV5618A to TMS320, SPI, and Microwire.



**Figure 12. Three-Wire Interface**

Notes on SPI and Microwire: Before the controller starts the data transfer, the software has to generate a falling edge on the pin connected to  $\overline{\text{CS}}$ . If the word width is 8 bits (SPI and Microwire) two write operations must be performed to program the TLV5618A. After the write operation(s), the holding registers or the control register are updated automatically on the next positive clock edge following the 16<sup>th</sup> falling clock edge.

**serial clock frequency and update rate**

The maximum serial clock frequency is given by:

$$f_{\text{sclkmax}} = \frac{1}{t_{\text{whmin}} + t_{\text{wlmin}}} = 20 \text{ MHz}$$

The maximum update rate is:

$$f_{\text{updatemax}} = \frac{1}{16 (t_{\text{whmin}} + t_{\text{wlmin}})} = 1.25 \text{ MHz}$$

Note that the maximum update rate is just a theoretical value for the serial interface, as the settling time of the TLV5618A should also be considered.



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**APPLICATION INFORMATION**

**examples of operation (continued)**

Both outputs are updated on the rising clock edge after D0 from the DAC A data word is sampled.

- Set power-down mode:

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

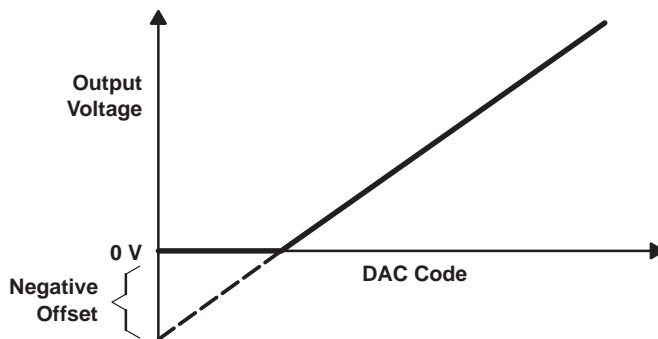
X = Don't care

**linearity, offset, and gain error using single ended supplies**

When an amplifier is operated from a single supply, the voltage offset can still be either positive or negative. With a positive offset, the output voltage changes on the first code change. With a negative offset, the output voltage may not change with the first code, depending on the magnitude of the offset voltage.

The output amplifier attempts to drive the output to a negative voltage. However, because the most negative supply rail is ground, the output cannot drive below ground and clamps the output at 0 V.

The output voltage then remains at zero until the input code value produces a sufficient positive output voltage to overcome the negative offset voltage, resulting in the transfer function shown in Figure 13.



**Figure 13. Effect of Negative Offset (Single Supply)**

This offset error, not the linearity error, produces this breakpoint. The transfer function would have followed the dotted line if the output buffer could drive below the ground rail.

For a DAC, linearity is measured between zero-input code (all inputs 0) and full-scale code (all inputs 1) after offset and full scale are adjusted out or accounted for in some way. However, single supply operation does not allow for adjustment when the offset is negative due to the breakpoint in the transfer function. So the linearity is measured between full-scale code and the lowest code that produces a positive output voltage.

## APPLICATION INFORMATION

### definitions of specifications and terminology

#### integral nonlinearity (INL)

The relative accuracy or integral nonlinearity (INL), sometimes referred to as linearity error, 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 nonlinearity (DNL)

The differential nonlinearity (DNL), sometimes referred to as differential error, is the difference between the measured and ideal 1 LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code.

#### zero-scale error ( $E_{ZS}$ )

Zero-scale error is defined as the deviation of the output from 0 V at a digital input value of 0.

#### gain error ( $E_G$ )

Gain error is the error in slope of the DAC transfer function.

#### total harmonic distortion (THD)

THD is the ratio of the rms value of the first six harmonic components to the value of the fundamental signal. The value for THD is expressed in decibels.

#### signal-to-noise ratio + distortion (S/N+D)

S/N+D is the ratio of the rms value of the output signal to the rms sum of all other spectral components below the Nyquist frequency, including harmonics but excluding dc. The value for S/N+D is expressed in decibels.

#### spurious free dynamic range (SFDR)

Spurious free dynamic range is the difference between the rms value of the output signal and the rms value of the largest spurious signal within a specified bandwidth. The value for SFDR is expressed in decibels.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TLV5618AMDREP	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5618AMDREPG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
V62/04646-01XE	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

<sup>(1)</sup> 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.

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

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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- Catalog: [TLV5618A](#)
- Military: [TLV5618AM](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications

**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
TLV5618AMDREP	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV5618AMDREP	SOIC	D	8	2500	346.0	346.0	29.0



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