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TLV5638-EP

2.7-V TO 5.5-V LOW-POWER DUAL 12-BIT DIGITAL-TO-ANALOG CONVERTER WITH INTERNAL REFERENCE AND POWER DOWN

SGLS130A – JULY 2002 – REVISED JULY 2003

features

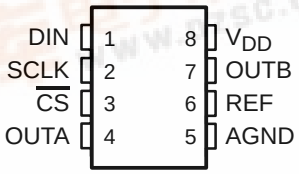
- Controlled Baseline
  - One Assembly/Test Site, One Fabrication Site
- Extended Temperature Performance up to –55°C to 125°C
- Enhanced Diminishing Manufacturing Sources (DMS) Support
- Enhanced Product Change Notification
- Qualification Pedigree†
- Dual 12-Bit Voltage Output DAC
- Programmable Internal Reference
- Programmable Settling Time:
  1 μs in Fast Mode,
  3.5 μs in Slow Mode
- Compatible With TMS320 and SPI™ Serial Ports
- Differential Nonlinearity <0.5 LSB Typ
- Monotonic Over Temperature

† 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.

applications

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

D PACKAGE
(TOP VIEW)



description

The TLV5638 is a dual 12-bit voltage output DAC with a flexible 3-wire serial interface. The serial interface allows glueless interface to TMS320 and 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 a 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 vs power dissipation. With its on-chip programmable precision voltage reference, the TLV5638 simplifies overall system design.

Because of its ability to source up to 1 mA, the reference can also be used as a system reference. 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 to reduce board space.

ORDERING INFORMATION

T_A	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	SOIC – D	Tape and reel	TLV5638QDREP	5638QE
–55°C to 125°C	SOIC – D	Tape and reel	TLV5638MDREP	5638ME

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

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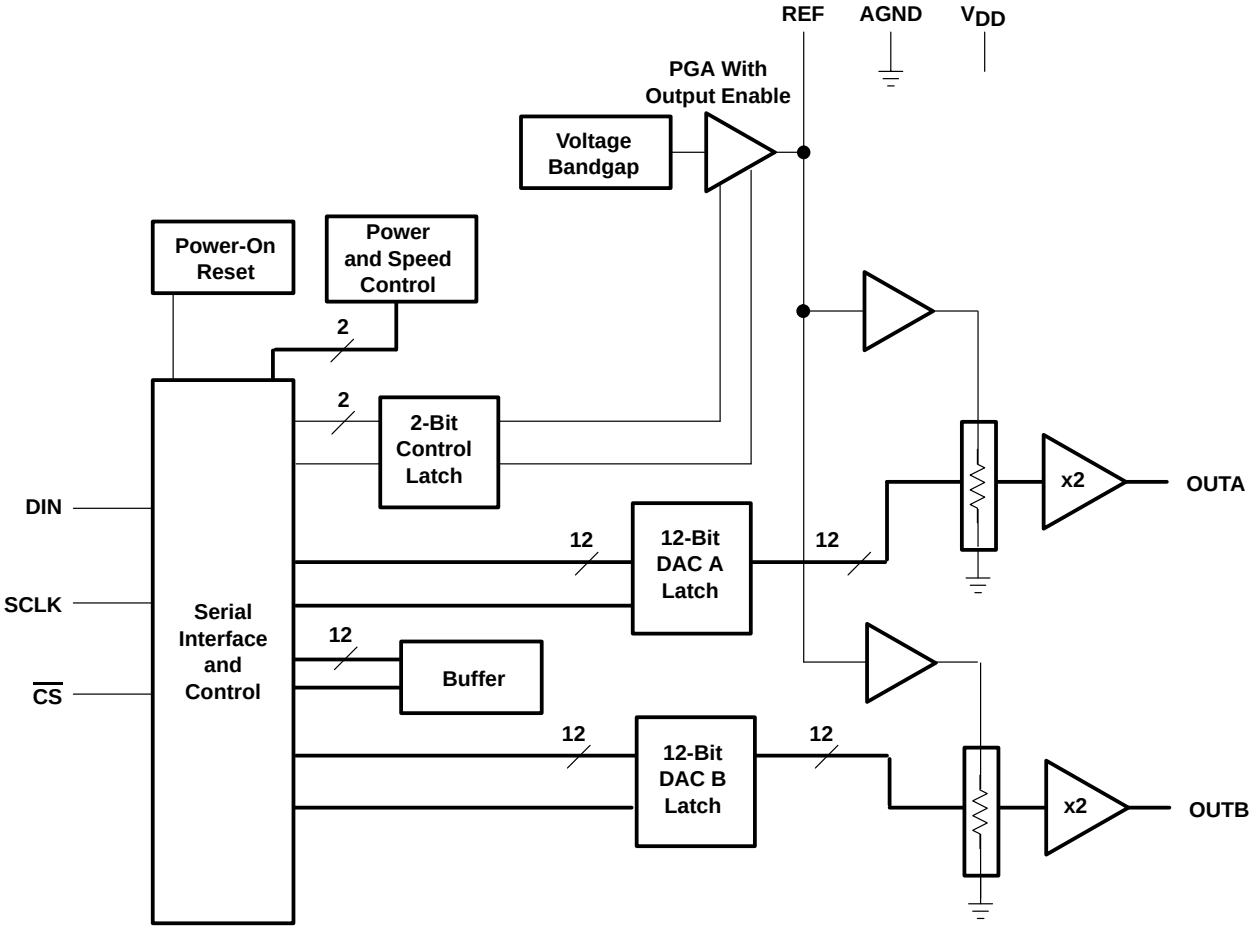
functional block diagram



Terminal Functions

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

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: TLV5638Q (see Note 1) . . . . . –40°C to 125°C
TLV5638M (see Note 1) . . . . . –55°C to 125°C
Storage temperature range, T_{stg} (see Note 1) . . . . . –65°C to 150°C
Package thermal impedance, θ_{JA}: D package . . . . . 131°C/W
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . . 260°C

† 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.

NOTE 1: Long term high-temperature storage and/or extended use at maximum recommended operating conditions may result in a reduction of overall device life. See 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	V
Power on reset, POR		0.55		2	V
High-level digital input voltage, V_{IH}	V_{DD} = 2.7 V to 5.5 V	2			V
Low-level digital input voltage, V_{IL}	V_{DD} = 2.7 V to 5.5 V			0.8	V
Reference voltage, V_{ref} to REF terminal	V_{DD} = 5 V (see Note 1)	AGND	2.048	V_{DD}–1.5	V
Reference voltage, V_{ref} to REF terminal	V_{DD} = 3 V (see Note 1)	AGND	1.024	V_{DD}–1.5	V
Load resistance, R_L		2			kΩ
Load capacitance, C_L				100	pF
Clock frequency, f_{CLK}				20	MHz
Operating free-air temperature, T_A	TLV5638Q (see Note 2)	–40		125	°C
	TLV5638M (see Note 2)	–55		125	

NOTES: 1. Due to the x2 output buffer, a reference input voltage ≥ (V_{DD}–0.4 V)/2 causes clipping of the transfer function. The output buffer of the internal reference must be disabled, if an external reference is used.
2. Long term high-temperature storage and/or extended use at maximum recommended operating conditions may result in a reduction of overall device life. See www.ti.com/ep_quality for additional information on enhanced plastic packaging.

electrical characteristics over recommended operating conditions, V_{ref} = 2.048 V, V_{ref} = 1.024 V (unless otherwise noted)

power supply

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
I_{DD}	Power supply current	No load, All inputs = AGND or V_{DD}, DAC latch = 0x800	V_{DD} = 5 V, Int. ref.	Fast		4.3	7	mA
				Slow		2.2	3.6	
			V_{DD} = 3 V, Int. ref.	Fast		3.8	6.3	mA
				Slow		1.8	3.0	
			V_{DD} = 5 V, Ext. ref.	Fast		3.9	6.3	mA
				Slow		1.8	3.0	
			V_{DD} = 3 V, Ext. ref.	Fast		3.5	5.7	mA
				Slow		1.5	2.6	
	Power-down supply current					0.01	10	μA
PSRR	Power supply rejection ratio	Zero scale, See Note 2				–65		dB
		Full scale, See Note 3				–65		

NOTES: 3. Power supply rejection ratio at zero scale is measured by varying V_{DD} and is given by:
$PSRR = 20 \log [(E_{ZS}(V_{DD}max) – E_{ZS}(V_{DD}min))/V_{DD}max]$
4. Power supply rejection ratio at full scale is measured by varying V_{DD} and is given by:
$PSRR = 20 \log [(E_G(V_{DD}max) – E_G(V_{DD}min))/V_{DD}max]$

static DAC specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Resolution		12			bits
INL	Integral nonlinearity, end point adjusted	See Note 4		±1.7	±6	LSB
DNL	Differential nonlinearity	See Note 5		±0.4	±1	LSB
E_{ZS}	Zero-scale error (offset error at zero scale)	See Note 6			±24	mV
E_{ZS} TC	Zero-scale-error temperature coefficient	See Note 7		10		ppm/°C
E_G	Gain error	See Note 8			±0.6	% full scale V
E_G T_C	Gain error temperature coefficient	See Note 9		10		ppm/°C

NOTES: 5. 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. Tested from code 32 to 4095.
6. 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.
7. Zero-scale error is the deviation from zero voltage output when the digital input code is zero.
8. Zero-scale-error temperature coefficient is given by: E_{ZS} TC = $[E_{ZS}(T_{max}) – E_{ZS}(T_{min})]/V_{ref} \times 10^6/(T_{max} – T_{min})$.
9. Gain error is the deviation from the ideal output ($2V_{ref}$ – 1 LSB) with an output load of 10 kΩ excluding the effects of the zero-error.
10. Gain temperature coefficient is given by: E_G TC = $[E_G(T_{max}) – E_G(T_{min})]/V_{ref} \times 10^6/(T_{max} – T_{min})$.

electrical characteristics over recommended operating conditions, V_{ref} = 2.048 V, V_{ref} = 1.024 V (unless otherwise noted) (continued)

output specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_O	Output voltage	R_L = 10 kΩ	0		V_{DD}–0.4	V
	Output load regulation accuracy	V_O = 4.096 V, 2.048 V, R_L = 2 kΩ			±0.25	% full scale V

reference pin configured as output (REF)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{ref(OUTL)}$	Low reference voltage		1.003	1.024	1.045	V
$V_{ref(OUTH)}$	High reference voltage	V_{DD} > 4.75 V	2.027	2.048	2.069	V
$I_{ref(source)}$	Output source current				1	mA
$I_{ref(sink)}$	Output sink current		–1			mA
	Load capacitance				100	pF
PSRR	Power supply rejection ratio			–65		dB

reference pin configured as input (REF)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_I	Input voltage			0		V_{DD}–1.5	V
R_I	Input resistance				10		MΩ
C_I	Input capacitance				5		pF
	Reference input bandwidth	REF = 0.2 V_{pp} + 1.024 V dc	Fast		1.3		MHz
			Slow		525		kHz
	Reference feedthrough	REF = 1 V_{pp} at 1 kHz + 1.024 V dc (see Note 10)			–80		dB

NOTE 11: Reference feedthrough is measured at the DAC output with an input code = 0x000.

digital inputs

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{IH}	High-level digital input current	$V_I = V_{DD}$			1	µA
I_{IL}	Low-level digital input current	V_I = 0 V	–1			µA
C_i	Input capacitance			8		pF

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

analog output dynamic performance

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
$t_{s(FS)}$	Output settling time, full scale	R_L = 10 kΩ, See Note 11	C_L = 100 pF,	Fast		1	3	µs
				Slow		3.5	7	
$t_{s(CC)}$	Output settling time, code to code	R_L = 10 kΩ, See Note 12	C_L = 100 pF,	Fast		0.5	1.5	µs
				Slow		1	2	
SR	Slew rate	R_L = 10 kΩ, See Note 13	C_L = 100 pF,	Fast		12		V/µs
				Slow		1.8		
	Glitch energy	$\overline{DIN}$ = 0 to 1, $\overline{CS}$ = V_{DD}	FCLK = 100 kHz,			5		nV–s
SNR	Signal-to-noise ratio	f_s = 480 kSPS, R_L = 10 kΩ,	f_{out} = 1 kHz, C_L = 100 pF		69	74		dB
S/(N+D)	Signal-to-noise + distortion				58	67		
THD	Total harmonic distortion					–69	–57	
	Spurious free dynamic range				57	72		

NOTES: 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 0x020 to 0xFDF and 0xFDF to 0x020 respectively. Not tested, assured by design.
13. 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.
14. Slew rate determines the time it takes for a change of the DAC output from 10% to 90% full-scale voltage.

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, 16th negative SCLK edge (when D0 is sampled) before $\overline{CS}$ rising edge	10			ns
t_{wH}	SCLK pulse width high	25			ns
t_{wL}	SCLK pulse width low	25			ns
$t_{su(D)}$	Setup time, data ready before SCLK falling edge	10			ns
$t_{h(D)}$	Hold time, data held valid after SCLK falling edge	5			ns

PARAMETER MEASUREMENT INFORMATION

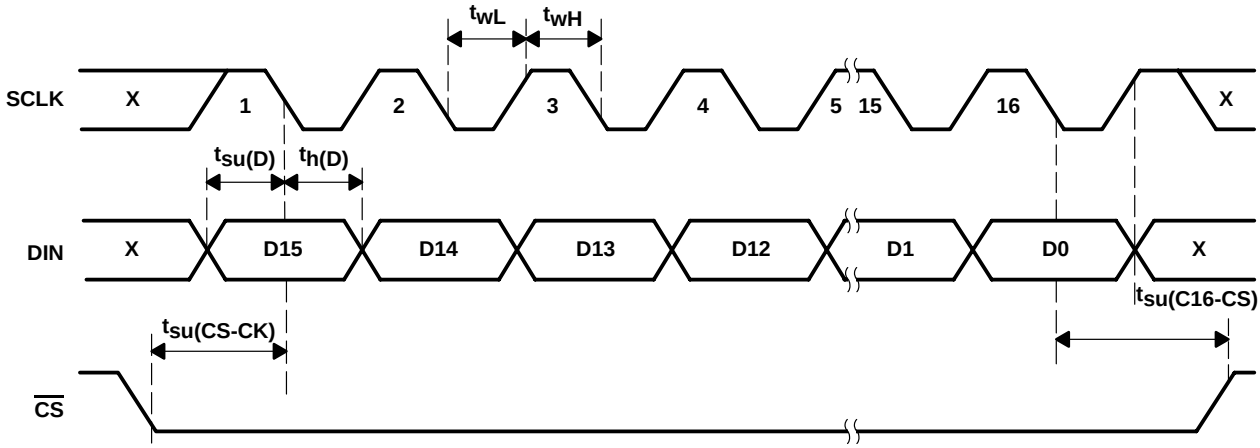


Figure 1. Timing Diagram

TYPICAL CHARACTERISTICS

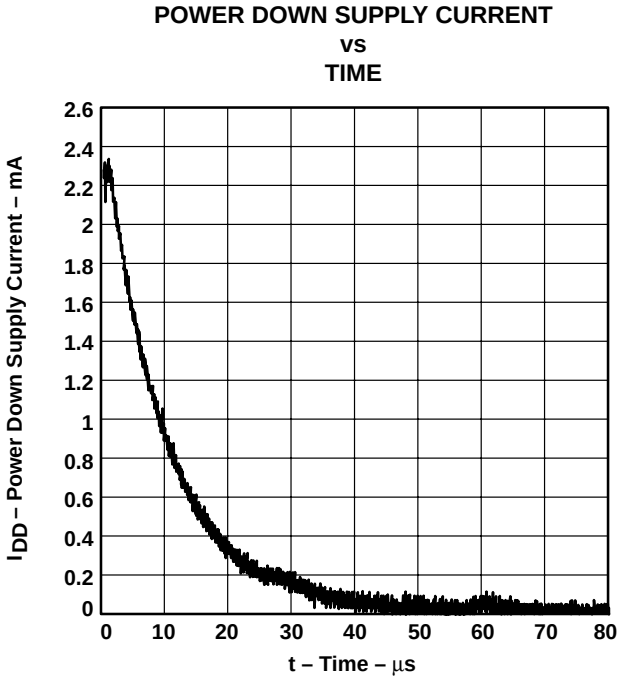


Figure 2

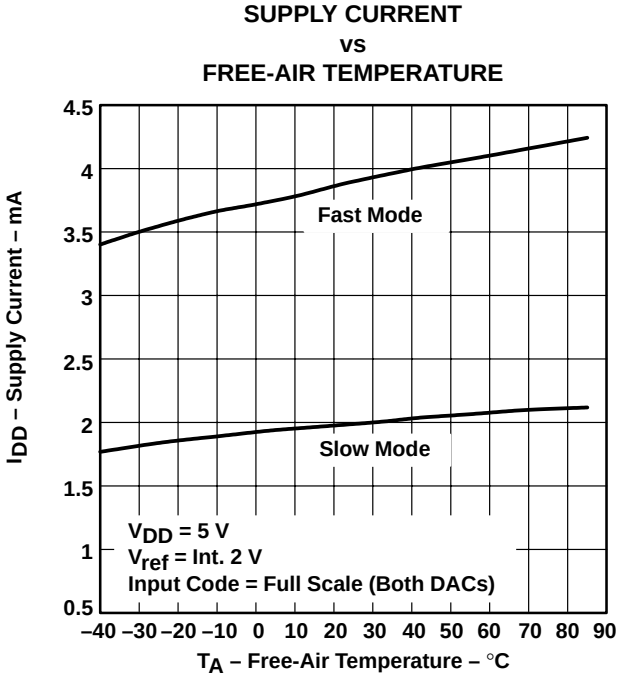


Figure 3

TYPICAL CHARACTERISTICS

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

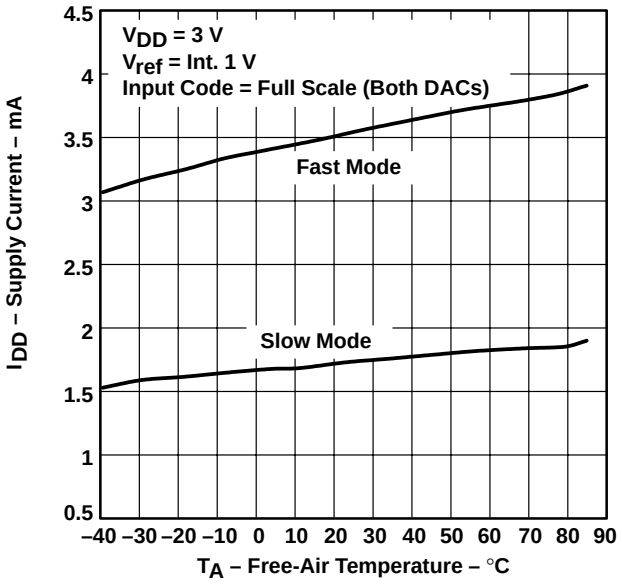


Figure 4

OUTPUT VOLTAGE vs LOAD CURRENT

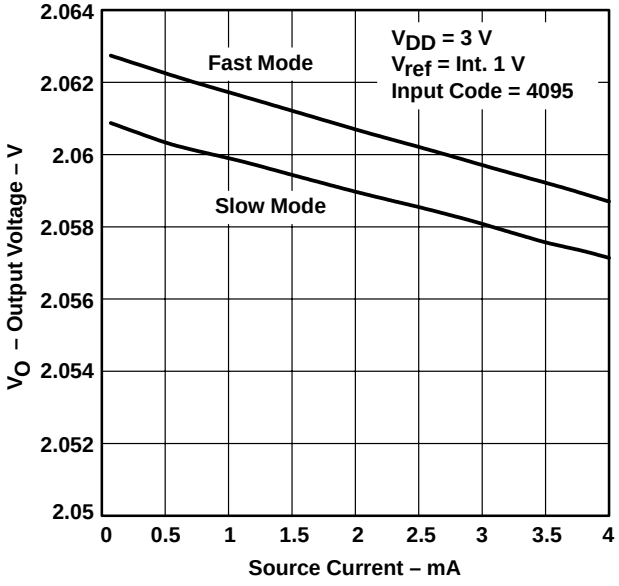


Figure 5

OUTPUT VOLTAGE vs LOAD CURRENT

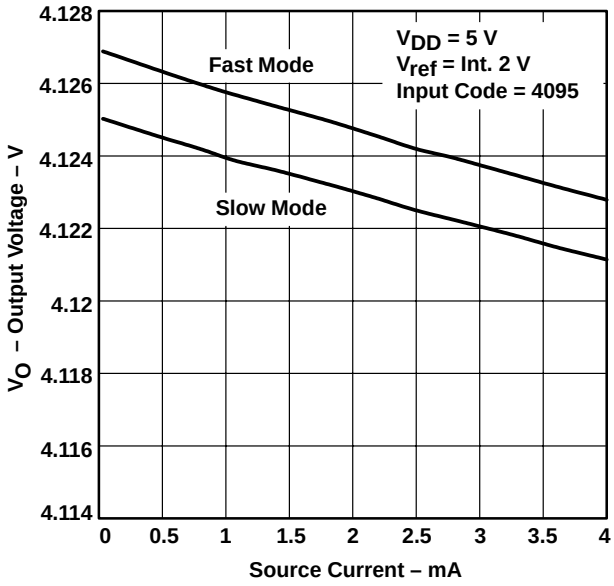


Figure 6

OUTPUT VOLTAGE vs LOAD CURRENT

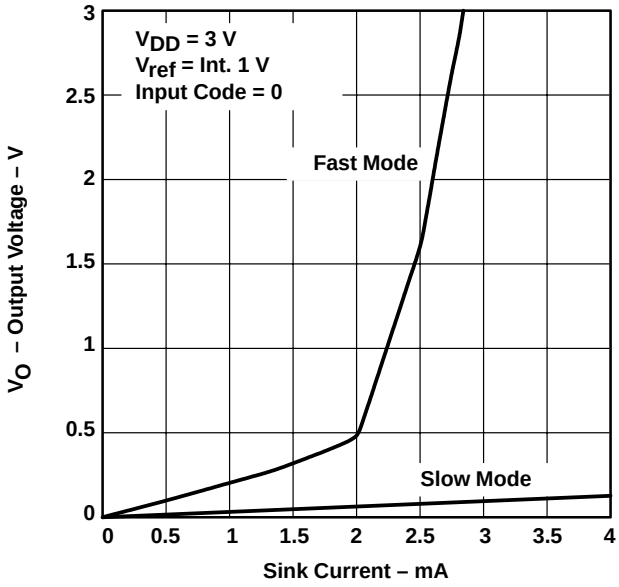


Figure 7

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE
vs
LOAD CURRENT

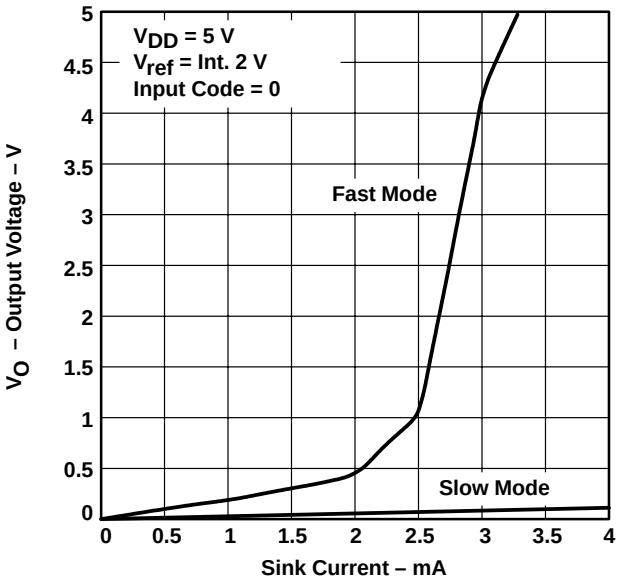


Figure 8

TOTAL HARMONIC DISTORTION AND NOISE
vs
FREQUENCY

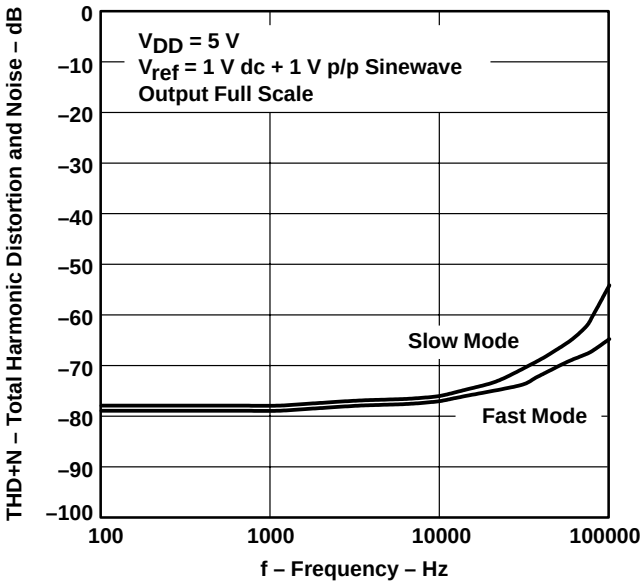


Figure 9

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

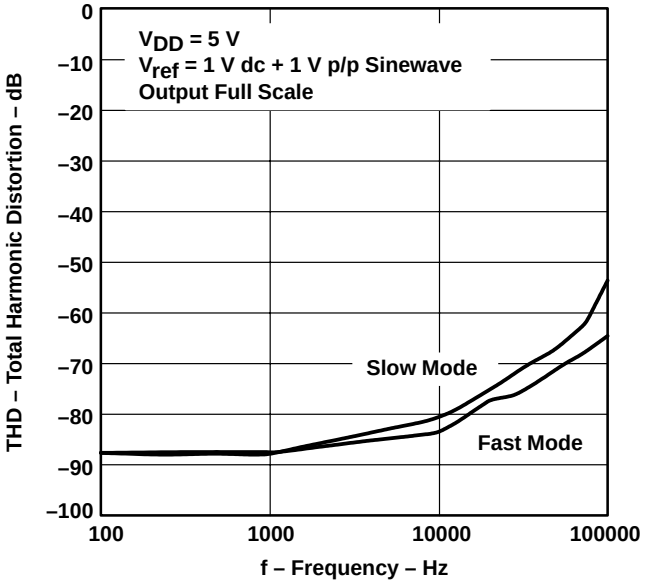


Figure 10

TYPICAL CHARACTERISTICS

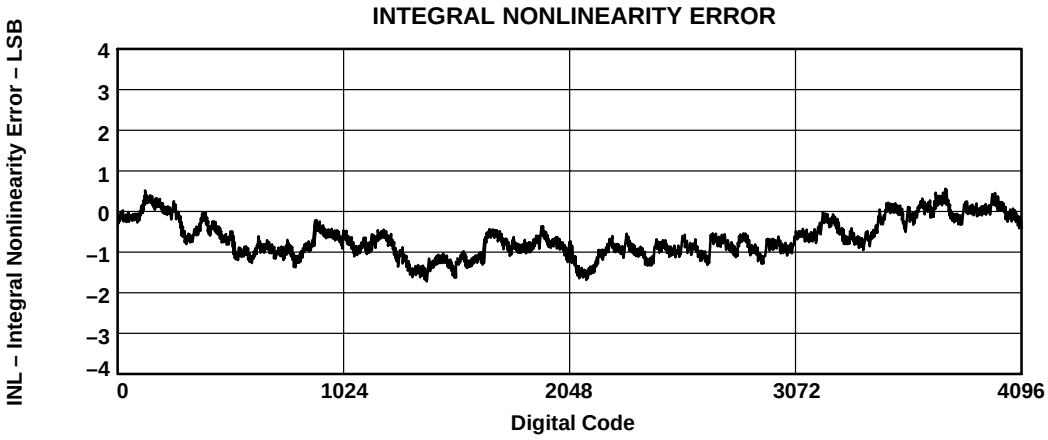


Figure 11

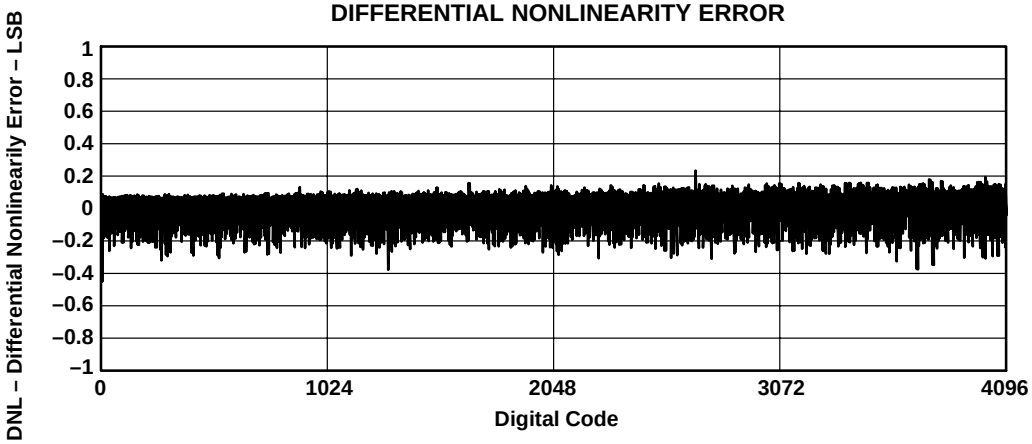


Figure 12

APPLICATION INFORMATION

general function

The TLV5638 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 programmable internal reference, a resistor string, and a rail-to-rail output buffer.

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

$$2 \text{ REF } \frac{\text{CODE}}{\text{0x1000}} \text{ [V]}$$

Where REF is the reference voltage and CODE is the digital input value in the range 0x000 to 0xFFF. A power on reset initially puts the internal latches to a defined state (all bits zero).

APPLICATION INFORMATION

serial interface

A falling edge of $\overline{CS}$ 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 $\overline{CS}$ 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 13 shows examples of how to connect the TLV5638 to TMS320, SPI™, and Microwire™.

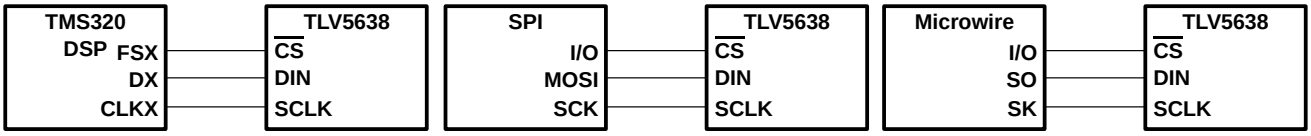


Figure 13. Three-Wire Interface

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 FS. If the word width is 8 bits (SPI™ and Microwire™), two write operations must be performed to program the TLV5638. After the write operation(s), the holding registers or the control register are updated automatically on the 16th positive clock edge.

serial clock frequency and update rate

The maximum serial clock frequency is given by:

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

The maximum update rate is:

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

Note, that the maximum update rate is just a theoretical value for the serial interface, as the settling time of the TLV5638 has to be considered, too.

APPLICATION INFORMATION

data format

The 16-bit data word for the TLV5638 consists of two parts:

- Program bits (D15..D12)
- New data (D11..D0)

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
R1	SPD	PWR	R0	12 Data bits											

SPD: Speed control bit 1 → fast mode 0 → slow mode
PWR: Power control bit 1 → power down 0 → normal operation

The following table lists the possible combination of the register select bits:

register select bits

R1	R0	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

The meaning of the 12 data bits depends on the register. If one of the DAC registers or the BUFFER is selected, then the 12 data bits determine the new DAC value:

data bits: DAC A, DAC B and BUFFER

D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
New DAC Value											

If control is selected, then D1, D0 of the 12 data bits are used to program the reference voltage:

data bits: CONTROL

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

X: don't care

REF1 and REF0 determine the reference source and, if internal reference is selected, the reference voltage.

reference bits

REF1	REF0	REFERENCE
0	0	External
0	1	1.024 V
1	0	2.048 V
1	1	External

CAUTION:
If external reference voltage is applied to the REF pin, external reference MUST be selected.

APPLICATION INFORMATION

Examples of operation:

- Set DAC A output, select fast mode, select internal reference at 2.048 V:

  1. Set reference voltage to 2.048 V (CONTROL register):

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

  2. 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
1	1	0	0	New DAC A output value											

  The DAC A output is updated on the rising clock edge after D0 is sampled.

  To output data consecutively using the same DAC configuration, it is not necessary to program the CONTROL register again.

- Set DAC B output, select fast mode, select external reference:

  3. Select external reference (CONTROL register):

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

  4. Write new DAC B value to BUFFER and update DAC B output:

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	1	0	0	New BUFFER content and DAC B output value											

  The DAC A output is updated on the rising clock edge after D0 is sampled.

  To output data consecutively using the same DAC configuration, it is not necessary to program the CONTROL register again.

- Set DAC A value, set DAC B value, update both simultaneously, select slow mode, select internal reference at 1.024 V:

  1. Set reference voltage to 1.024 V (CONTROL register):

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

  2. Write data for DAC B to BUFFER:

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	1	New DAC B value											

  3. Write new DAC A value and update DAC A and B simultaneously:

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
1	0	0	0	New DAC A value											

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.

To output data consecutively using the same DAC configuration, it is not necessary to program the CONTROL register again.

- 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 14.

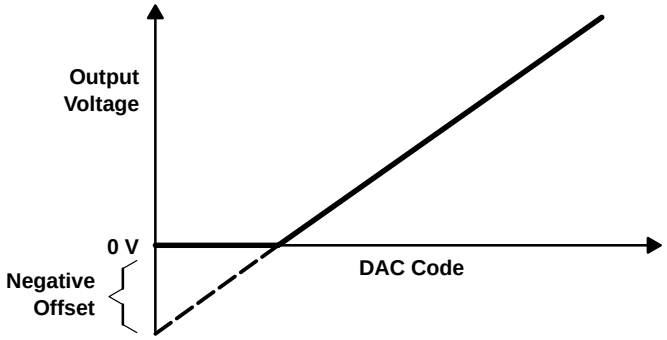


Figure 14. Effect of Negative Offset (Single Supply)

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)

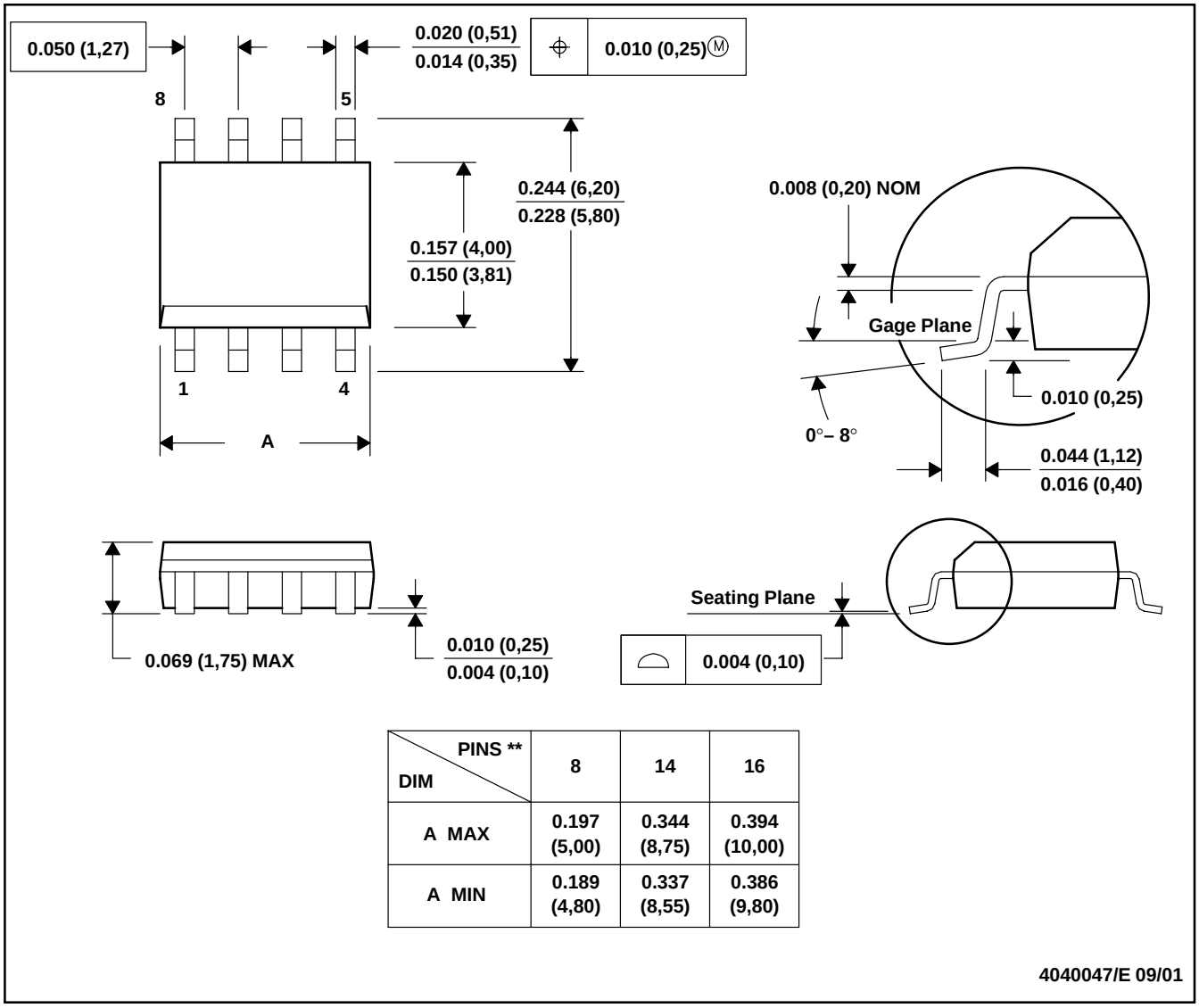
S/N+D is the ratio of the rms value of the output signal to the rms sum of all other spectral components below the Nyquist frequency, including harmonics but excluding dc. The value for S/N+D is expressed in decibels.

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.

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN



DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

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