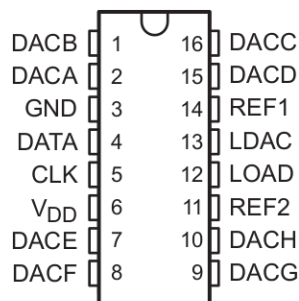


# TLV5628C, TLV5628I OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

SLAS108A – JANUARY 1995 – REVISED NOVEMBER 1995

- Eight 8-Bit Voltage Output DACs
- 3-V Single Supply Operation
- Serial Interface
- High-Impedance Reference Inputs
- Programmable for 1 or 2 Times Output Range
- Simultaneous Update Facility
- Internal Power-On Reset
- Low Power Consumption
- Half-Buffered Output

DW OR N PACKAGE  
(TOP VIEW)



## applications

- Programmable Voltage Sources
- Digitally Controlled Amplifiers/Attenuators
- Mobile Communications
- Automatic Test Equipment
- Process Monitoring and Control
- Signal Synthesis

## description

The TLV5628C and TLV5628I are octal 8-bit voltage output digital-to-analog converters (DACs) with buffered reference inputs (high impedance). The DACs produce an output voltage that varies between one or two times the reference voltages and GND, and the DACs are monotonic. The device is simple to use, running from a single supply of 3 to 3.6 V. A power-on reset function is incorporated to ensure repeatable start-up conditions.

Digital control of the TLV5628C and TLV5628I is over a simple 3-wire serial bus that is CMOS compatible and easily interfaced to all popular microprocessor and microcontroller devices. The 12-bit command word comprises 8 bits of data, 3 DAC select bits and a range bit, the latter allowing selection between the times 1 or times 2 output range. The DAC registers are double buffered, allowing a complete set of new values to be written to the device, then all DAC outputs are updated simultaneously through control of the LDAC terminal. The digital inputs feature Schmitt triggers for high noise immunity.

The 16-terminal small-outline D package allows digital control of analog functions in space-critical applications. The TLV5628C is characterized for operation from 0°C to 70°C. The TLV5628I is characterized for operation from –40°C to 85°C. The TLV5628C and TLV5628I do not require external trimming.

AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGE	
	SMALL OUTLINE (DW)	PLASTIC DIP (N)
0°C to 70°C	TLV5628CDW	TLV5628CN
–40°C to 85°C	TLV5628IDW	TLV5628IN



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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.

 **TEXAS  
INSTRUMENTS**

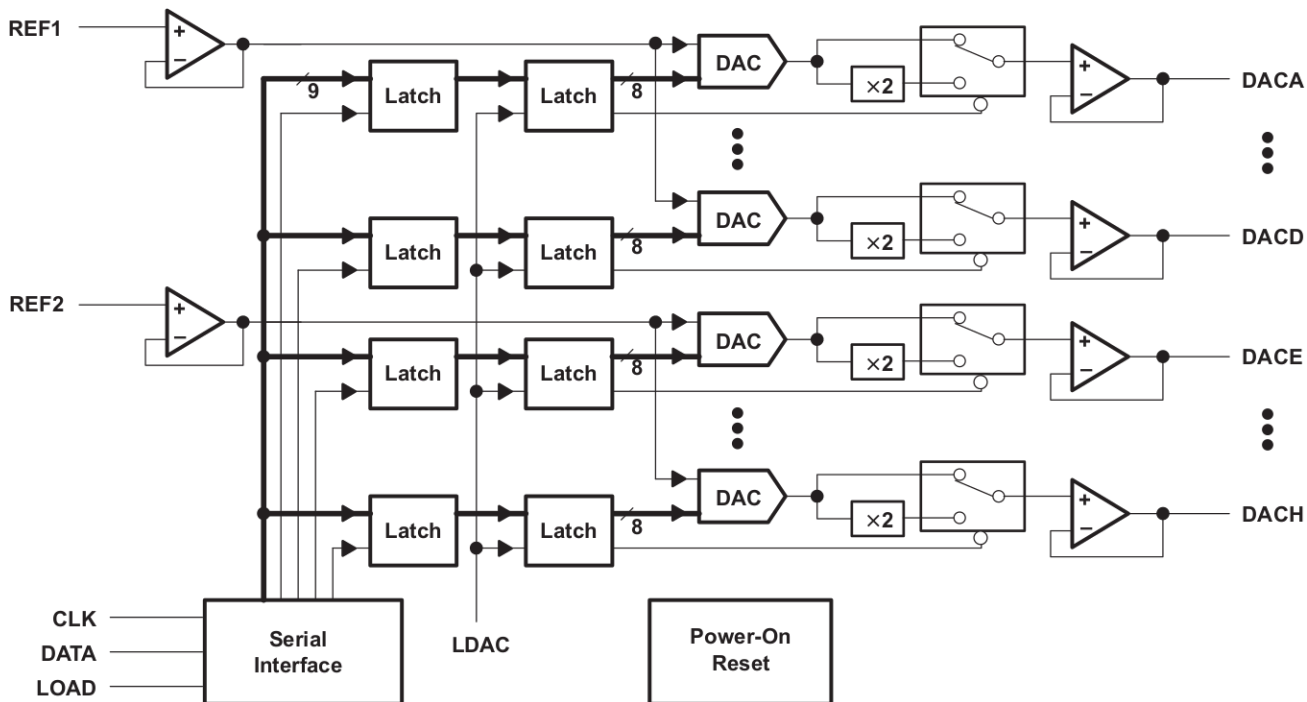
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## OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

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## functional block diagram



## Terminal Functions

TERMINAL NAME NO.		I/O	DESCRIPTION
CLK	5	I	Serial-interface clock, data enters on the negative edge
DACA	2	O	DACA analog output
DACB	1	O	DACB analog output
DACC	16	O	DACC analog output
DACD	15	O	DACD analog output
DACE	7	O	DACE analog output
DACF	8	O	DACF analog output
DACG	9	O	DACG analog output
DACH	10	O	DACH analog output
DATA	4	I	Serial-interface digital data input
GND	3	I	Ground return and reference terminal
LDAC	13	I	DAC-update latch control
LOAD	12	I	Serial-interface load control
REF1	14	I	Reference voltage input to DACA
REF2	11	I	Reference voltage input to DACB
V <sub>DD</sub>	6	I	Positive supply voltage

## detailed description

The TLV5628 is implemented using eight resistor-string DACs. The core of each DAC is a single resistor with 256 taps, corresponding to the 256 possible codes listed in Table 1. One end of each resistor string is connected to the GND terminal and the other end is fed from the output of the reference input buffer. Monotonicity is maintained by use of the resistor strings. Linearity depends upon the matching of the resistor elements and upon the performance of the output buffer. Because the inputs are buffered, the DACs always present a high-impedance load to the reference sources. There are two input reference terminals; REF1 is used for DACA through DACD and REF2 is used by DACE through DACH.

Each DAC output is buffered by a configurable-gain output amplifier, which can be programmed to times 1 or times 2 gain.

On power-up, the DACs are reset to CODE 0.

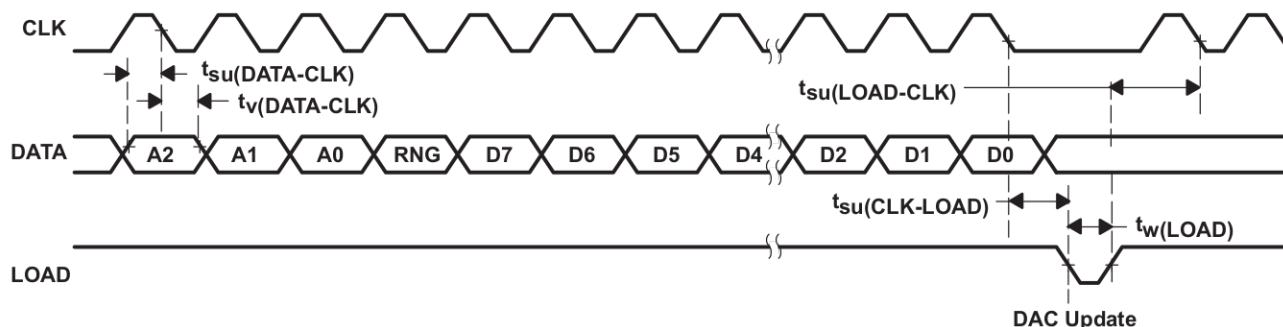
Each output voltage is given by:

$$V_O(\text{DACA|B|C|D|E|F|G|H}) = \text{REF} \times \frac{\text{CODE}}{256} \times (1 + \text{RNG bit value})$$

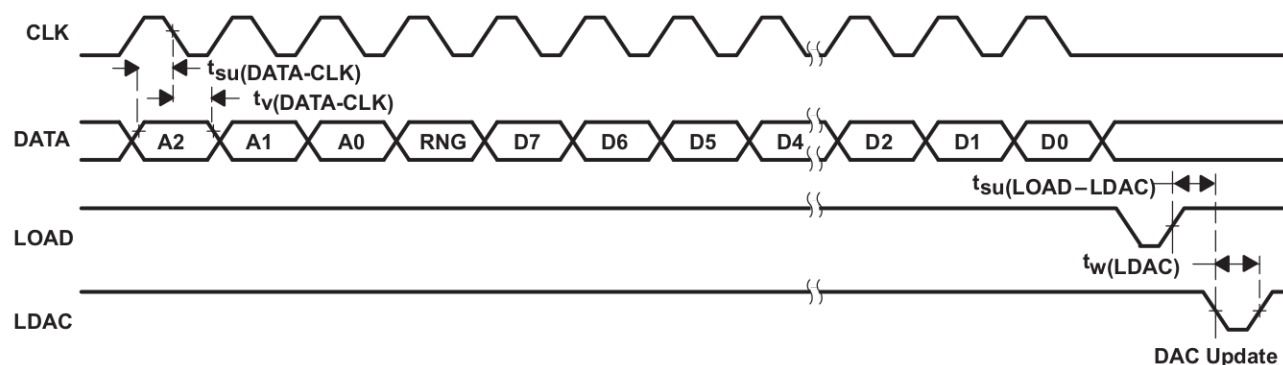
where CODE is in the range of 0 to 255 and the range (RNG) bit is a 0 or 1 within the serial-control word.

## data interface

With LOAD high, data is clocked into the DATA terminal on each falling edge of CLK. Once all data bits have been clocked in, LOAD is pulsed low to transfer the data from the serial-input register to the selected DAC as shown in Figure 1. When LDAC is low, the selected DAC output voltage is updated and LOAD goes low. When LDAC is high during serial programming, the new value is stored within the device and can be transferred to the DAC output at a later time by pulsing LDAC low as shown in Figure 2. Data is entered MSB first. Data transfers using two 8 clock cycle periods are shown in Figures 3 and 4.



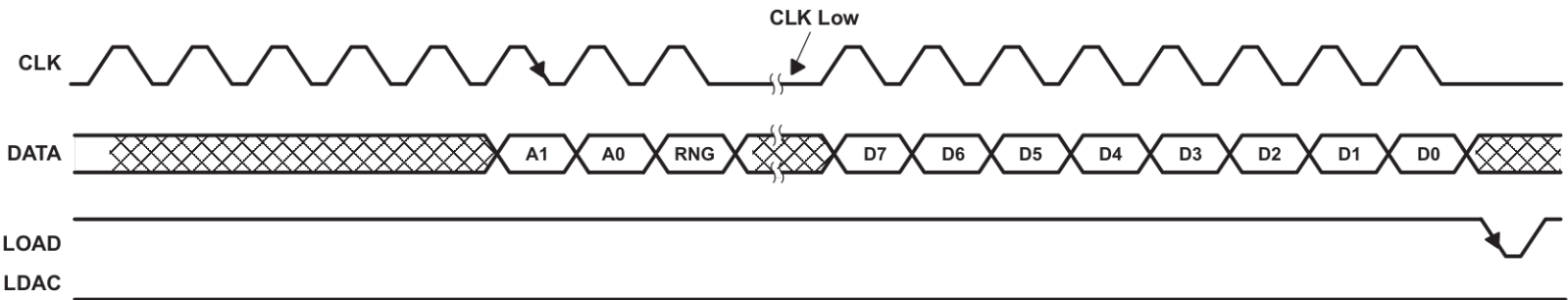
**Figure 1. LOAD-Controlled Update (LDAC = Low)**



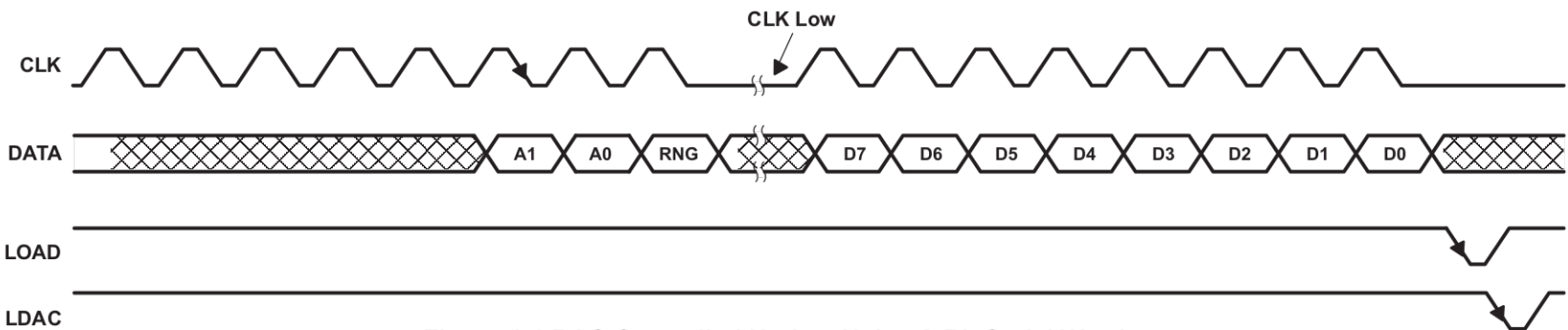
**Figure 2. LDAC-Controlled Update**

**TLV5628C, TLV5628I**  
**OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS**

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**Figure 3. Load Controlled Update Using 8-Bit Serial Word (LDAC = Low)**



**Figure 4. LDAC Controlled Update Using 8-Bit Serial Word**

**data interface (continued)**

Table 2 lists the A2, A1, and A0 bits and the selection of the updated DACs. The RNG bit controls the DAC output range. When RNG = low, the output range is between the applied reference voltage and GND, and when RNG = high, the range is between twice the applied reference voltage and GND.

**Table 1. Ideal Output Transfer**

D7	D6	D5	D4	D3	D2	D1	D0	OUTPUT VOLTAGE
0	0	0	0	0	0	0	0	GND
0	0	0	0	0	0	0	1	$(1/256) \times \text{REF} (1+\text{RNG})$
•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•
0	1	1	1	1	1	1	1	$(127/256) \times \text{REF} (1+\text{RNG})$
1	0	0	0	0	0	0	0	$(128/256) \times \text{REF} (1+\text{RNG})$
•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•
1	1	1	1	1	1	1	1	$(255/256) \times \text{REF} (1+\text{RNG})$

**Table 2. Serial Input Decode**

A2	A1	A0	DAC UPDATED
0	0	0	DACA
0	0	1	DACB
0	1	0	DACC
0	1	1	DACD
1	0	0	DACE
1	0	1	DACF
1	1	0	DACG
1	1	1	DACH

# TLV5628C, TLV5628I

## OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

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### linearity, offset, and gain error

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, with a negative voltage offset, attempts to drive the output to a negative voltage. However, since the most negative supply rail is ground, the output cannot drive to a negative voltage.

So when the output offset voltage is negative, the output voltage remains at 0 volts until the input code value produces a sufficient output voltage to overcome the inherent negative offset voltage resulting in the transfer function shown in Figure 5.

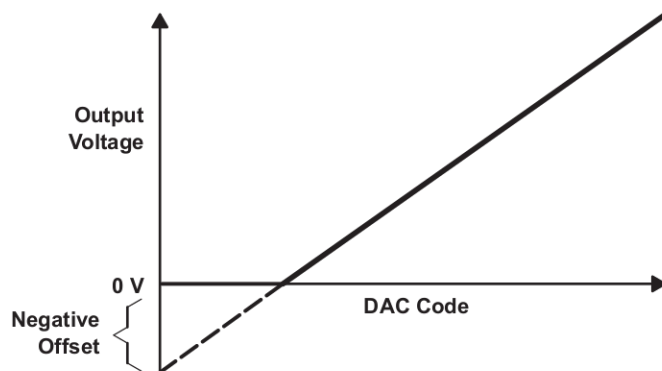


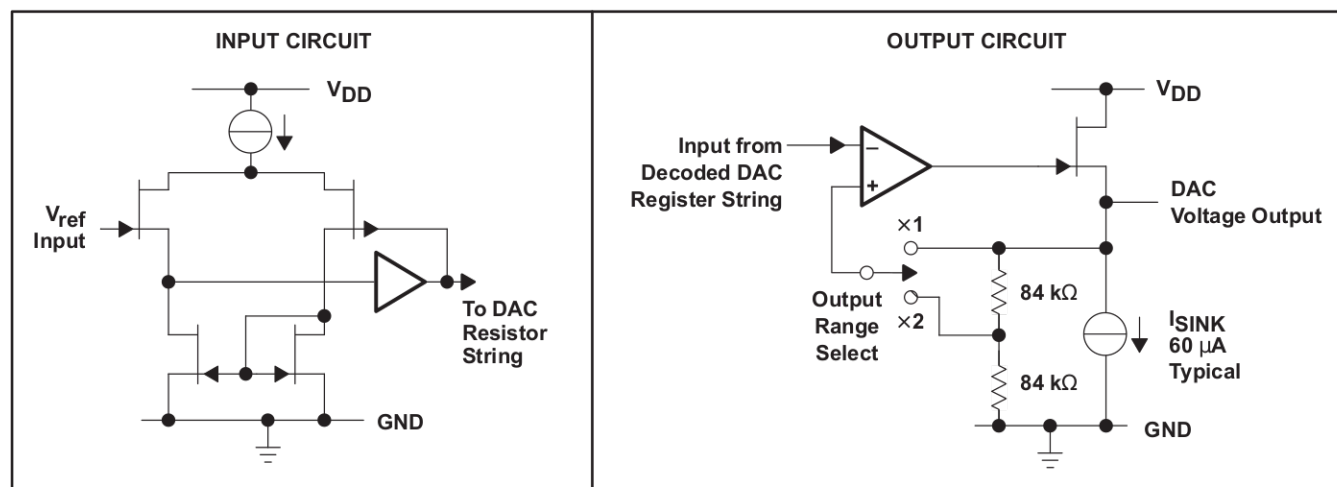
Figure 5. Effect of Negative Offset (Single Supply)

The negative offset error produces a breakpoint, not a linearity error. The transfer function would follow the dotted line if the output buffer could drive to a negative voltage.

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 is 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. The linearity in the unipolar mode is measured between full scale code and the lowest code which produces a positive output voltage.

The code is calculated from the maximum specification for the negative offset.

### equivalent inputs and outputs



# TLV5628C, TLV5628I

## OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

Supply voltage ( $V_{DD} - GND$ )	7 V
Digital input voltage range, $V_{ID}$	$GND - 0.3 V$ to $V_{DD} + 0.3 V$
Reference input voltage range	$GND - 0.3 V$ to $V_{DD} + 0.3 V$
Operating free-air temperature range, $T_A$ : TLV5628C	0°C to 70°C
TLV5628I	–40°C to 85°C
Storage temperature range, $T_{stg}$	–50°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	230°C

<sup>†</sup> 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.

### recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, V <sub>DD</sub>		2.7	3.3	5.25	V
High-level digital input voltage, V <sub>IH</sub>		0.8 V <sub>DD</sub>			V
Low-level digital input voltage, V <sub>IL</sub>		0.8			V
Reference voltage, V <sub>ref</sub> [A B C D E F G H], X1 gain		V <sub>DD</sub> –1.5			V
Load resistance, R <sub>L</sub>		10			kΩ
Setup time, data input, t <sub>su</sub> (DATA-CLK) (see Figures 1 and 2)		50			ns
Valid time, data input valid after CLK↓, t <sub>v</sub> (DATA-CLK) (see Figures 1 and 2)		50			ns
Setup time, CLK eleventh falling edge to LOAD, t <sub>su</sub> (CLK-LOAD) (see Figure 1)		50			ns
Setup time, LOAD↑ to CLK↓, t <sub>su</sub> (LOAD-CLK) (see Figure 1)		50			ns
Pulse duration, LOAD, t <sub>w</sub> (LOAD) (see Figure 1)		250			ns
Pulse duration, LDAC, t <sub>w</sub> (LDAC) (see Figure 2)		250			ns
Setup time, LOAD↑ to LDAC↓, t <sub>su</sub> (LOAD-LDAC) (see Figure 2)		0			ns
CLK frequency		1			MHz
Operating free-air temperature, T <sub>A</sub>	TLV5628C	0		70	°C
	TLV5628I	–40		85	°C





# TLV5628C, TLV5628I

## OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

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**electrical characteristics over recommended operating free-air temperature range,  
V<sub>DD</sub> = 3 V to 3.6 V, V<sub>ref</sub> = 2 V, ×1 gain output range (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I <sub>IH</sub>	High-level digital input current	V <sub>I</sub> = V <sub>DD</sub>			±10	μA
I <sub>IL</sub>	Low-level digital input current	V <sub>I</sub> = 0 V			±10	μA
I <sub>O(sink)</sub>	Output sink current	Each DAC output	20			μA
I <sub>O(source)</sub>	Output source current		1			mA
C <sub>i</sub>	Input capacitance			15		pF
	Reference input capacitance			15		
I <sub>DD</sub>	Supply current	V <sub>DD</sub> = 3.3 V			4	mA
I <sub>ref</sub>	Reference input current	V <sub>DD</sub> = 3.3 V, V <sub>ref</sub> = 1.5 V			±10	μA
E <sub>L</sub>	Linearity error (end point corrected)	V <sub>ref</sub> = 1.25 V, ×2 gain (see Note 1)			±1	LSB
E <sub>D</sub>	Differential linearity error	V <sub>ref</sub> = 1.25 V, ×2 gain (see Note 2)			±0.9	LSB
E <sub>ZS</sub>	Zero-scale error	V <sub>ref</sub> = 1.25 V, ×2 gain (see Note 3)	0		30	mV
	Zero-scale error temperature coefficient	V <sub>ref</sub> = 1.25 V, ×2 gain (see Note 4)		10		μV/°C
E <sub>FS</sub>	Full-scale error	V <sub>ref</sub> = 1.25 V, ×2 gain (see Note 5)			±60	mV
	Full-scale error temperature coefficient	V <sub>ref</sub> = 1.25 V, ×2 gain (see Note 6)		±25		μV/°C
PSRR	Power supply sensitivity	See Notes 7 and 8		0.5		mV/V

- NOTES: 1. Integral nonlinearity (INL) is the maximum deviation of the output from the line between zero-scale and full scale (excluding the effects of zero code and full-scale errors).
2. Differential nonlinearity (DNL) 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.
3. Zero-scale error is the deviation from zero voltage output when the digital input code is zero.
4. Zero-scale error temperature coefficient is given by:  $ZSETC = [ZSE(T_{max}) - ZSE(T_{min})]/V_{ref} \times 10^6/(T_{max} - T_{min})$ .
5. Full-scale error is the deviation from the ideal full-scale output (V<sub>ref</sub> – 1 LSB) with an output load of 10 kΩ.
6. Full-scale temperature coefficient is given by:  $FSETC = [FSE(T_{max}) - FSE(T_{min})]/V_{ref} \times 10^6/(T_{max} - T_{min})$ .
7. Zero-scale error rejection ratio (ZSE-RR) is measured by varying the V<sub>DD</sub> voltage from 4.5 V to 5.5 V dc and measuring the effect of this signal on the zero-code output voltage.
8. Full-scale error rejection ratio (FSE-RR) is measured by varying the V<sub>DD</sub> voltage from 3 V to 3.6 V dc and measuring the effect of this signal on the full-scale output voltage.

**operating characteristics over recommended operating free-air temperature range,  
V<sub>DD</sub> = 3 V to 3.6 V, V<sub>ref</sub> = 2 V, ×1 gain output range (unless otherwise noted)**

	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output slew rate	C <sub>L</sub> = 100 pF, R <sub>L</sub> = 10 kΩ		1		V/μs
Output settling time	To 0.5 LSB, C <sub>L</sub> = 100 pF, R <sub>L</sub> = 10 kΩ, See Note 9		10		μs
Large-signal bandwidth	Measured at –3 dB point		100		kHz
Digital crosstalk	CLK = 1-MHz square wave measured at DACA-DACH		–50		dB
Reference feedthrough	See Note 10		–60		dB
Channel-to-channel isolation	See Note 11		–60		dB
Reference input bandwidth	See Note 12		100		kHz

- NOTES: 9. 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 00 hex to FF hex or FF hex to 00 hex. For TLC5628C V<sub>DD</sub> = 5 V, V<sub>ref</sub> = 2 V and range = ×2. For TLC5628I V<sub>DD</sub> = 3 V, V<sub>ref</sub> = 1.25 V and range = ×2.
10. Reference feedthrough is measured at any DAC output with an input code = 00 hex with a V<sub>ref</sub> input = 1 V dc + 1 V<sub>pp</sub> at 10 kHz.
11. Channel-to-channel isolation is measured by setting the input code of one DAC to FF hex and the code of all other DACs to 00 hex with V<sub>ref</sub> input = 1 V dc + 1 V<sub>pp</sub> at 10 kHz.
12. Reference bandwidth is a –3 dB bandwidth with an input at V<sub>ref</sub> = 1.25 V dc + 2 V<sub>pp</sub> and with a full-scale digital input code.





## PARAMETER MEASUREMENT INFORMATION

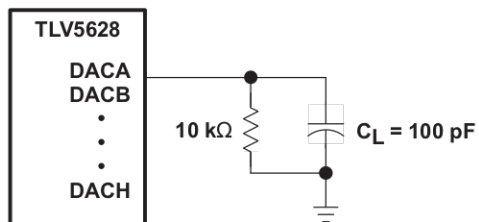
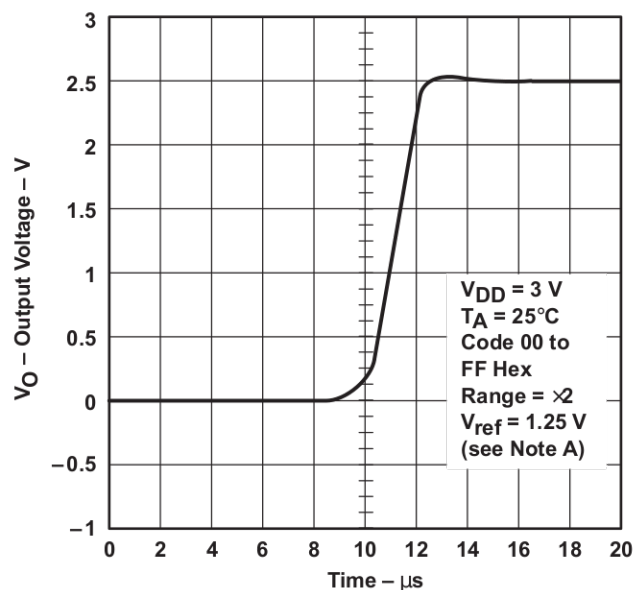


Figure 6. Slewing Settling Time and Linearity Measurements

## TYPICAL CHARACTERISTICS

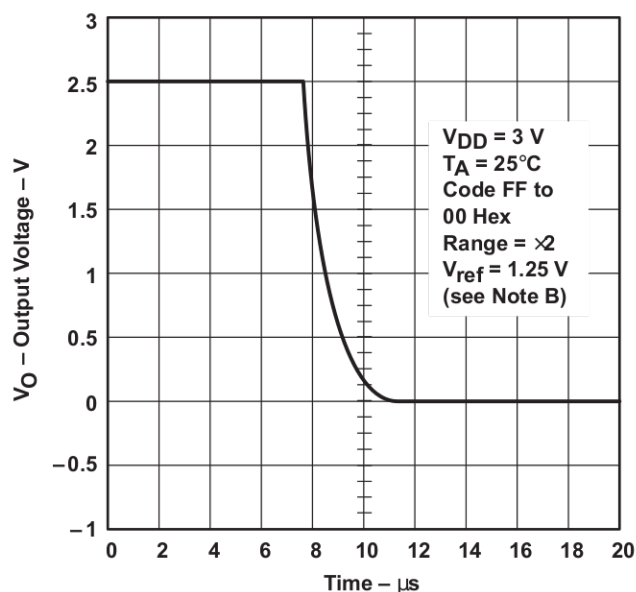
### POSITIVE RISE TIME AND SETTling TIME



NOTE A: Rise time = 2.05  $\mu$ s, positive slew rate = 0.96 V/ $\mu$ s, settling time = 4.5  $\mu$ s.

Figure 7

### NEGATIVE FALL TIME AND SETTling TIME



NOTE B: Fall time = 4.25  $\mu$ s, negative slew rate = 0.46 V/ $\mu$ s, settling time = 8.5  $\mu$ s.

Figure 8

# TLV5628C, TLV5628I OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

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## TYPICAL CHARACTERISTICS

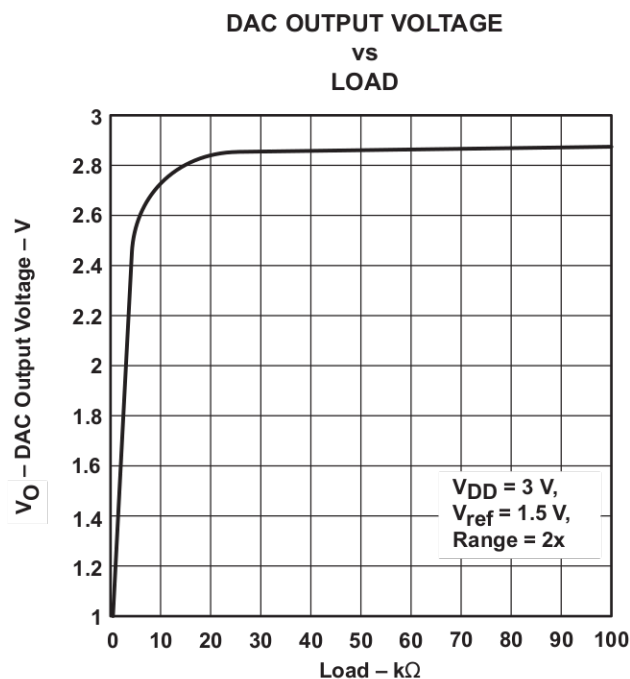


Figure 9

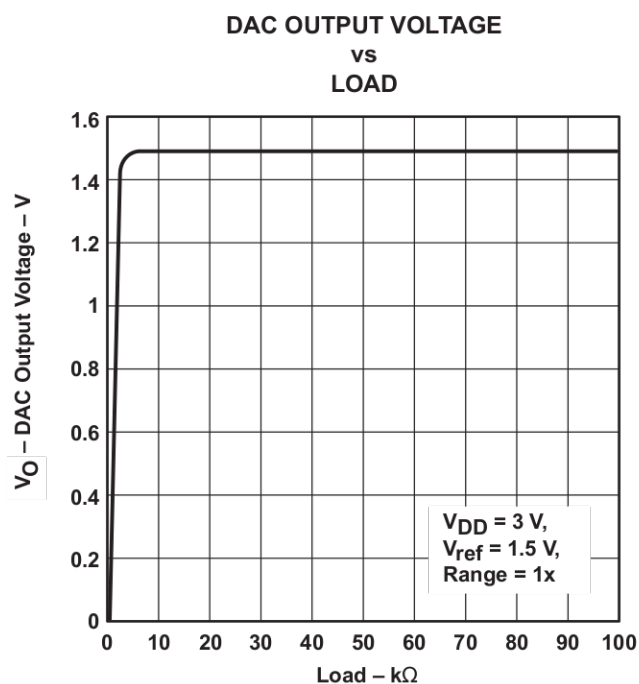


Figure 10

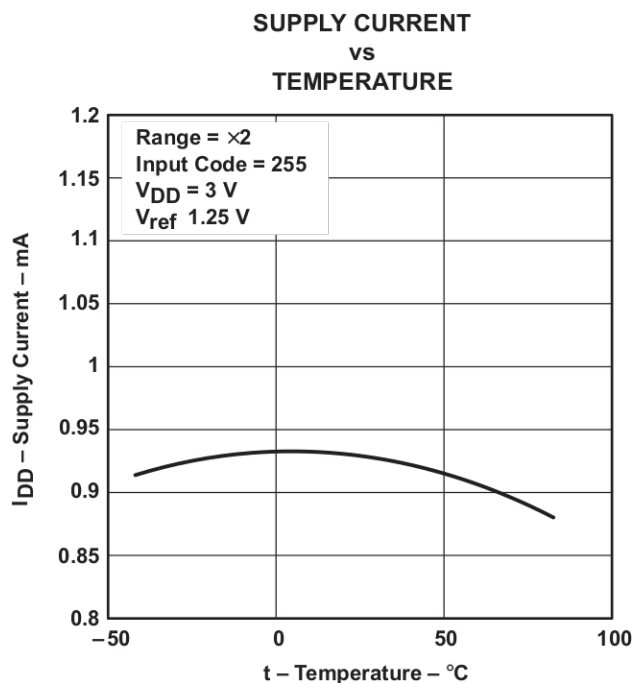
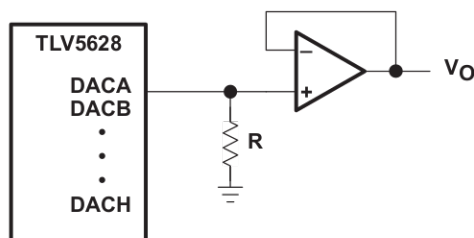


Figure 11

## APPLICATION INFORMATION



NOTE A: Resistor  $R \geq 10 \text{ k}\Omega$

**Figure 12. Output Buffering Scheme**

# TLV5628C, TLV5628I

## OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

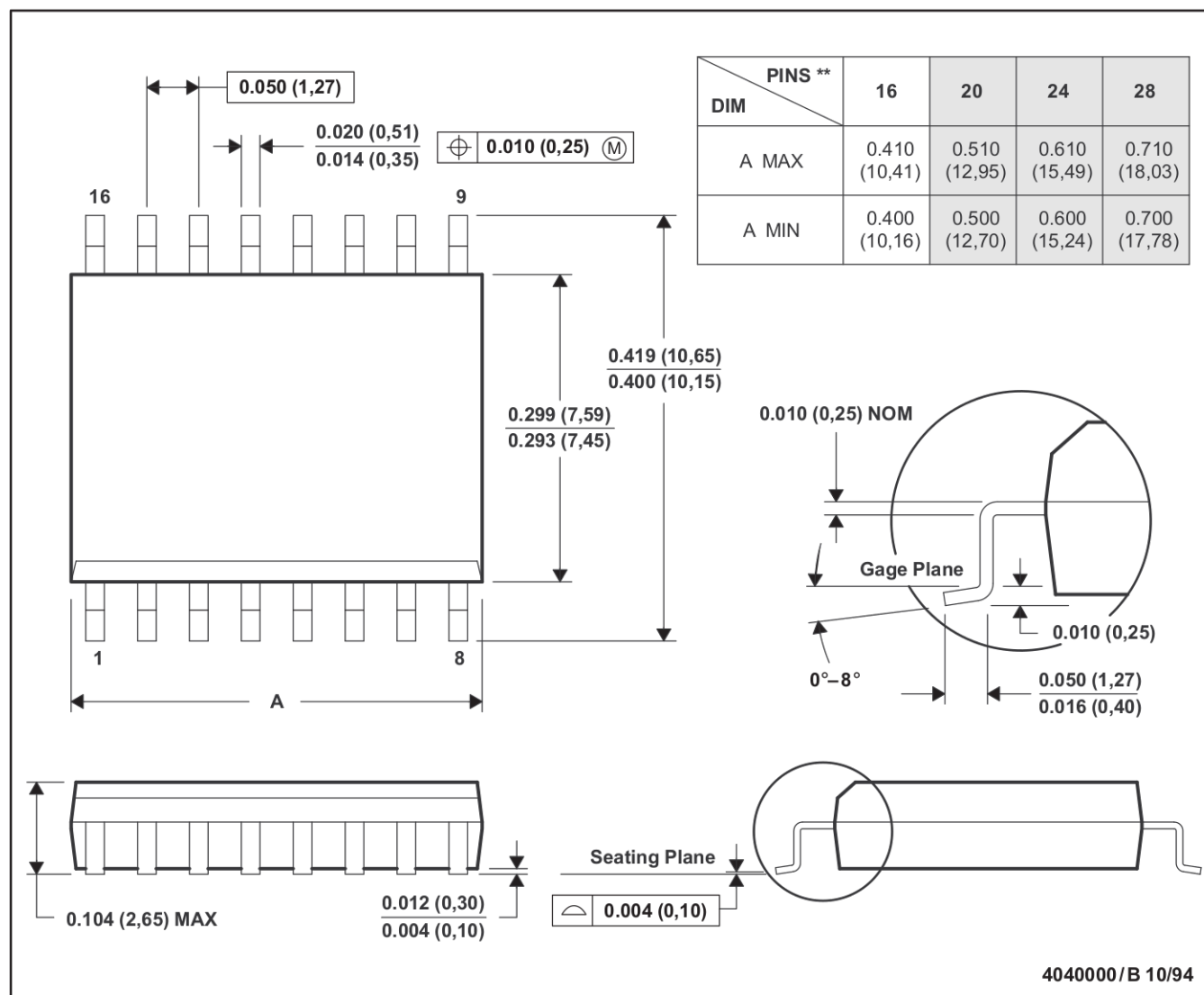
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### MECHANICAL DATA

DW (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

16 PIN SHOWN



- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
  - Falls within JEDEC MS-013

# TLV5628C, TLV5628I

## OCTAL 8-BIT DIGITAL-TO-ANALOG CONVERTERS

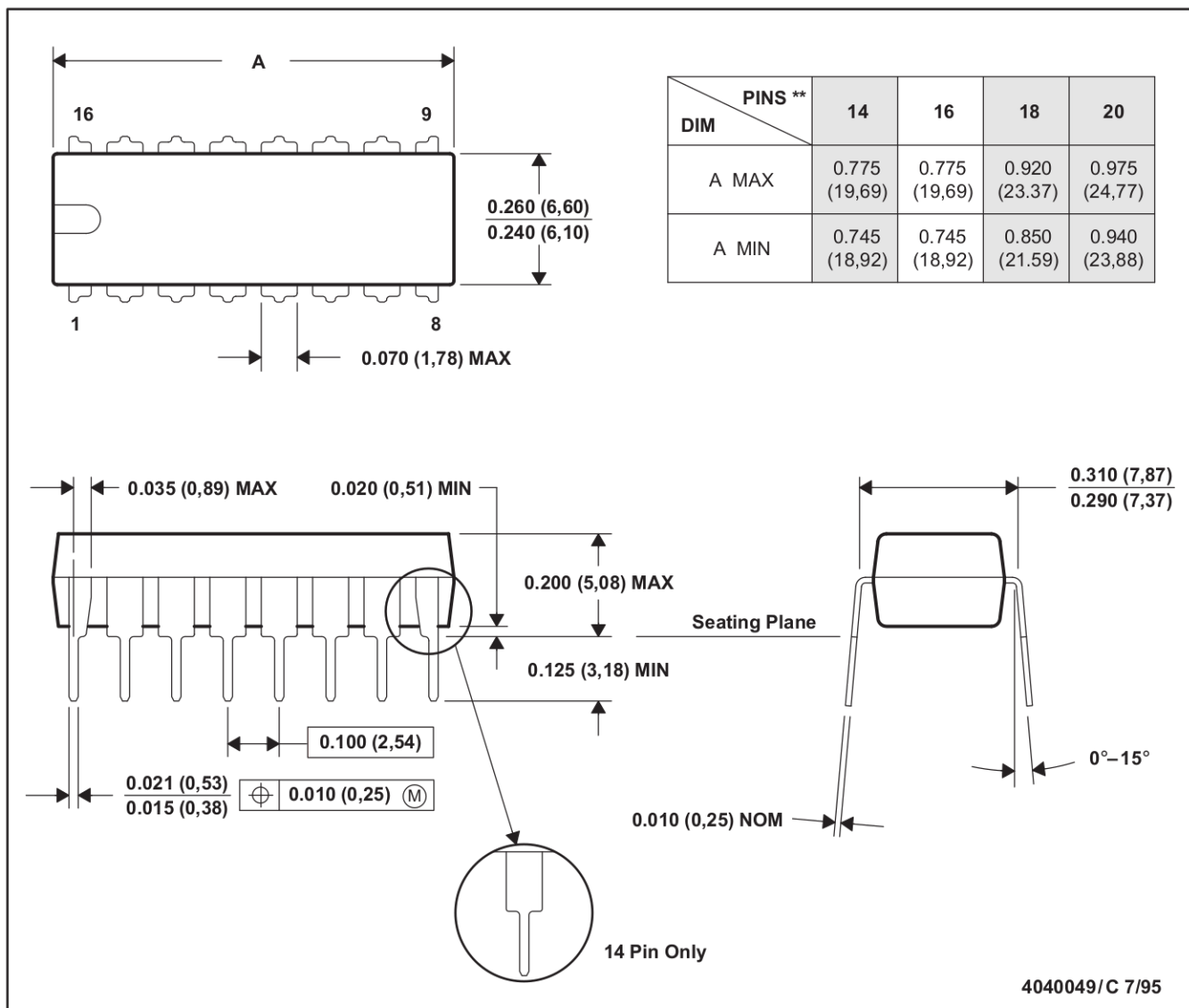
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### MECHANICAL DATA

N (R-PDIP-T\*\*)

PLASTIC DUAL-IN-LINE PACKAGE

16 PIN SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001 (20-pin package is shorter than MS-001)

## 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>
TLV5628CDW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628CDWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628CDWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628CDWRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628CN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPD	N / A for Pkg Type
TLV5628CNE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPD	N / A for Pkg Type
TLV5628IDW	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628IDWG4	ACTIVE	SOIC	DW	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628IDWR	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628IDWRG4	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5628IN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPD	N / A for Pkg Type
TLV5628INE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPD	N / A for Pkg Type

<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)

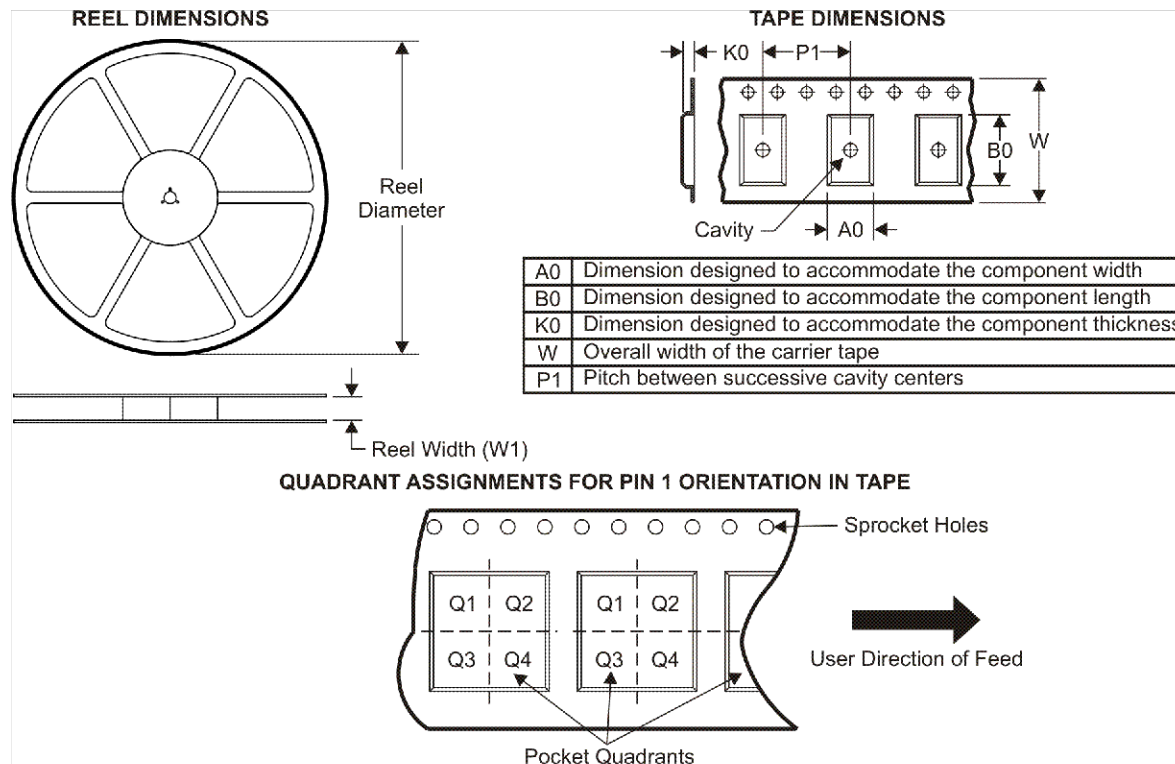
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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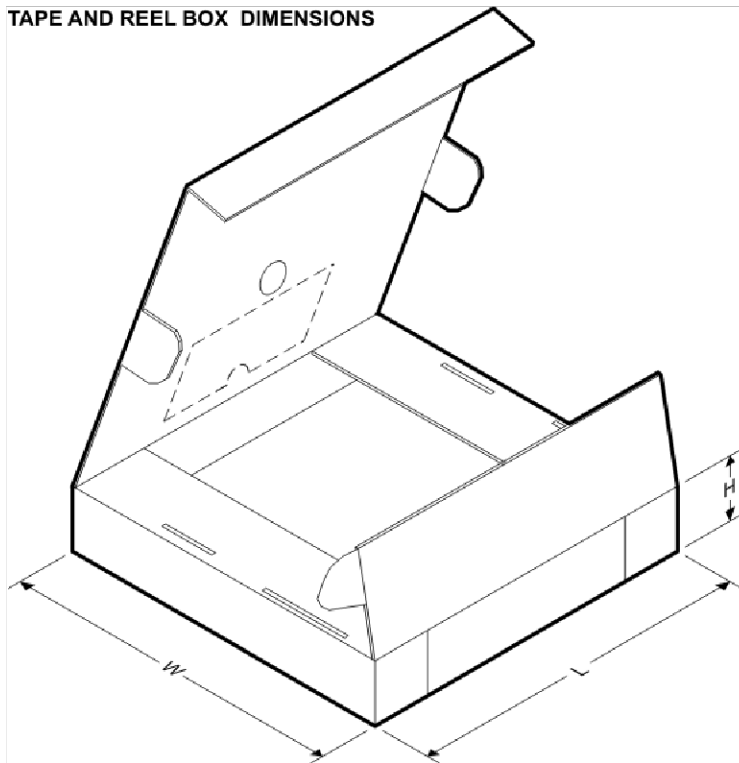
**TAPE AND REEL INFORMATION**



\*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
TLV5628CDWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	12.0	16.0	Q1
TLV5628IDWR	SOIC	DW	16	2000	330.0	16.4	10.75	10.7	2.7	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)
TLV5628CDWR	SOIC	DW	16	2000	346.0	346.0	33.0
TLV5628IDWR	SOIC	DW	16	2000	346.0	346.0	33.0

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