- **Four 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**

D OR N PACKAGE
(TOP VIEW)

GND	1	14	V_{DD}
REFA	2	13	LDAC
REFB	3	12	DACA
REFC	4	11	DACB
REFD	5	10	DACC
DATA	6	9	DACD
CLK	7	8	LOAD
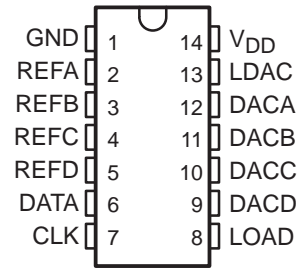
applications

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

description

The TLV5620C and TLV5620I are quadruple 8-bit voltage output digital-to-analog converters (DACs) with buffered reference inputs (high impedance). The DACs produce an output voltage that ranges between either one or two times the reference voltages and GND; and, the DACs are monotonic. The device is simple to use, because it runs from a single supply of 3 V to 3.6 V. A power-on reset function is incorporated to ensure repeatable start-up conditions.

Digital control of the TLV5620C and TLV5620I is over a simple three-wire serial bus that is CMOS compatible and easily interfaced to all popular microprocessor and microcontroller devices. The 11-bit command word comprises eight bits of data, two 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 update simultaneously through control of LDAC. The digital inputs feature Schmitt triggers for high noise immunity.

The 14-terminal small-outline (SO) package allows digital control of analog functions in space-critical applications. The TLV5620C is characterized for operation from 0°C to 70°C. The TLV5620I is characterized for operation from −40°C to 85°C. The TLV5620C and TLV5620I do not require external trimming.

AVAILABLE OPTIONS

	PACKAGE	
T_A	SMALL OUTLINE (D)	PLASTIC DIP (N)
0°C to 70°C	TLV5620CD	TLV5620CN
−40°C to 85°C	TLV5620ID	TLV5620IN

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functional block diagram
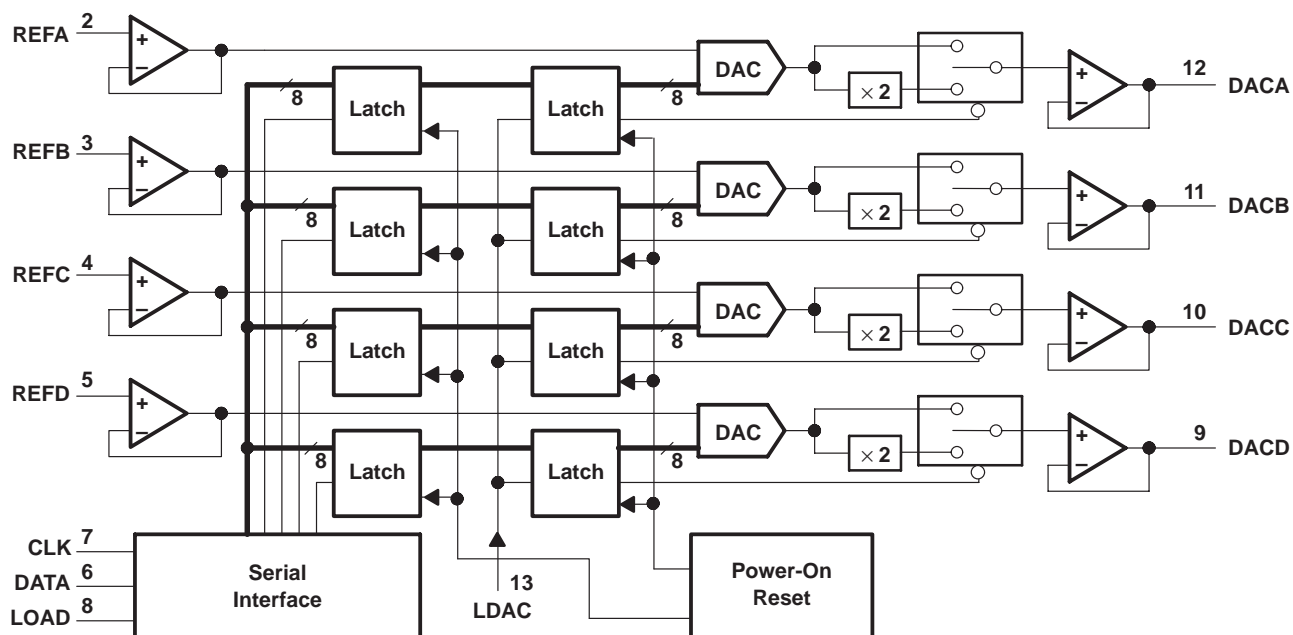
Terminal Functions

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
CLK	7	I	Serial interface clock. The input digital data is shifted into the serial interface register on the falling edge of the clock applied to the CLK terminal.
DACA	12	O	DAC A analog output
DACB	11	O	DAC B analog output
DACC	10	O	DAC C analog output
DACD	9	O	DAC D analog output
DATA	6	I	Serial interface digital data input. The digital code for the DAC is clocked into the serial interface register serially. Each data bit is clocked into the register on the falling edge of the clock signal.
GND	1	I	Ground return and reference terminal
LDAC	13	I	Load DAC. When this signal is high, no DAC output updates occur when the input digital data is read into the serial interface. The DAC outputs are only updated when LDAC is taken from high to low.
LOAD	8	I	Serial interface load control. When the LDAC terminal is low, the falling edge of the LOAD signal latches the digital data into the output latch and immediately produces the analog voltage at the DAC output terminal.
REFA	2	I	Reference voltage input to DAC A. This voltage defines the output analog range.
REFB	3	I	Reference voltage input to DAC B. This voltage defines the analog output range.
REFC	4	I	Reference voltage input to DAC C. This voltage defines the analog output range.
REFD	5	I	Reference voltage input to DAC D. This voltage defines the analog output range.
V_{DD}	14	I	Positive supply voltage

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detailed description

The TLV5620 is implemented using four 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 GND 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 segments and upon the performance of the output buffer. Since the inputs are buffered, the DACs always presents a high-impedance load to the reference source.

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:

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

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

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	$(1/256) \times$ REF (1+RNG)
•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•
0	1	1	1	1	1	1	1	$(127/256) \times$ REF (1+RNG)
1	0	0	0	0	0	0	0	$(128/256) \times$ REF (1+RNG)
•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•
1	1	1	1	1	1	1	1	$(255/256) \times$ REF (1+RNG)

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 when 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.

Table 2 lists the 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 2. Serial Input Decode

A1	A0	DAC UPDATED
0	0	DACA
0	1	DACB
1	0	DACC
1	1	DACD

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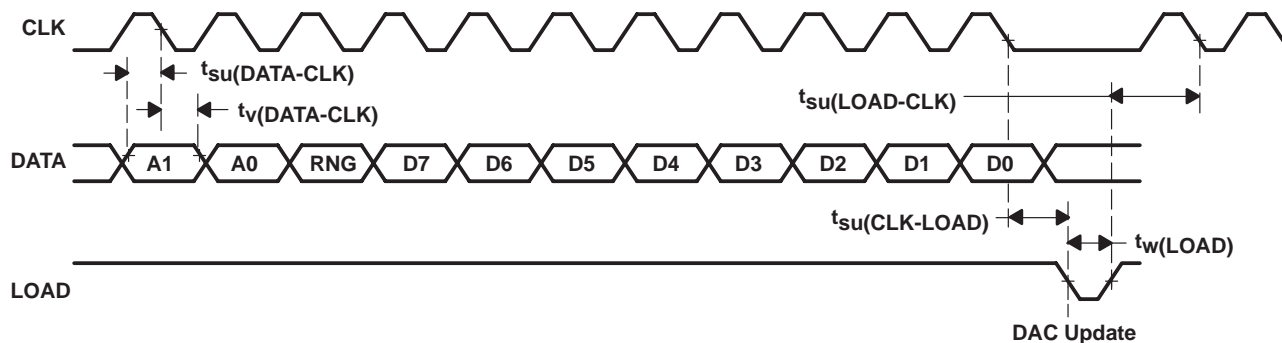
Figure 1. LOAD-Controlled Update (LDAC = Low)
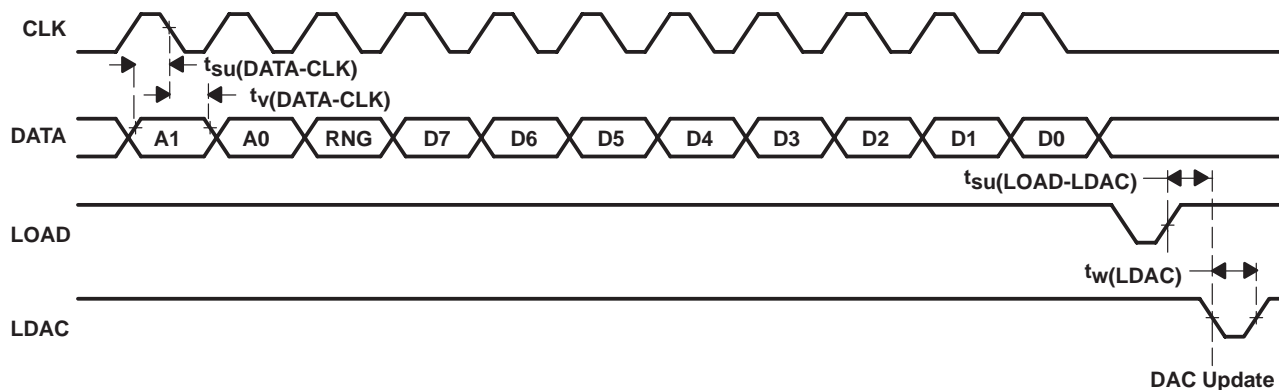
Figure 2. LDAC-Controlled Update

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CLK Low

CLK

DATA · A1 · A0 · RNG · D7 · D6 · D5 · D4 · D3 · D2 · D1 · D0
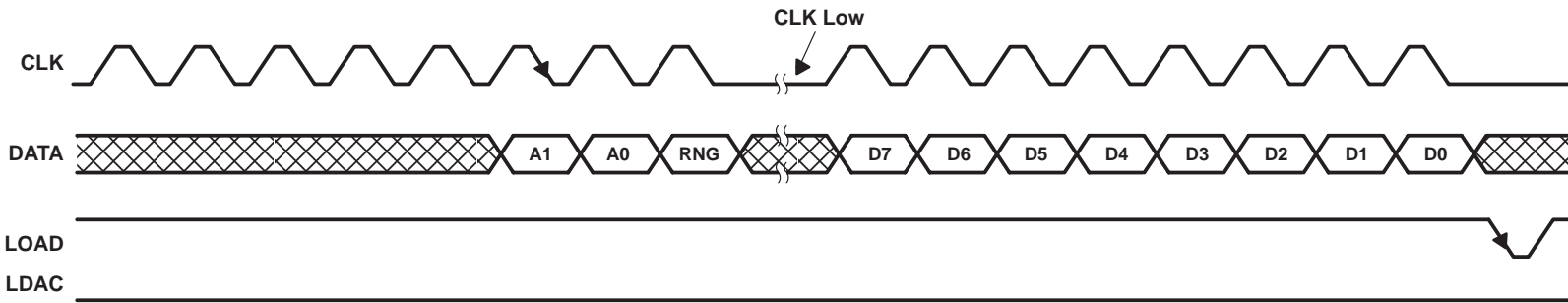
LOAD

LDAC

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

CLK Low

CLK

DATA · A1 · A0 · RNG · D7 · D6 · D5 · D4 · D3 · D2 · D1 · D0

LOAD
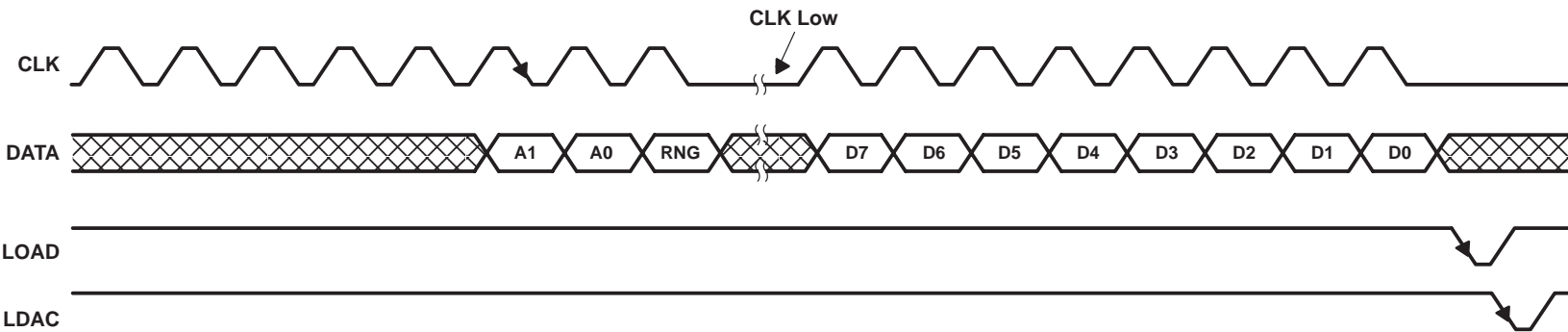
LDAC

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

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linearity, offset, and gain error using single-end supplies

When an amplifier is operated from a single supply, the voltage offset can still be either positive or negative. With a positive offset voltage, 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, therefore, 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 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 5.
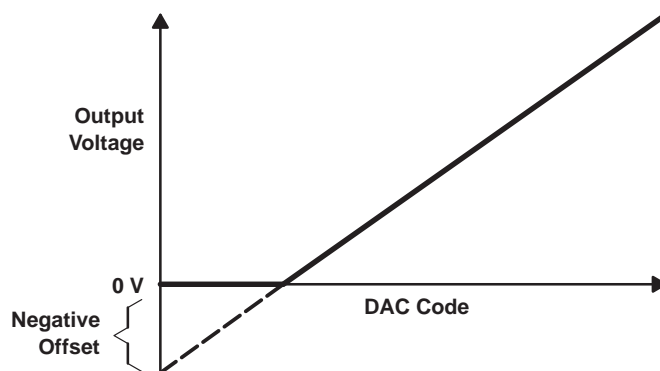

**Figure 5. Effect of Negative Offset (Single Supply)**

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 ground.

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

equivalent inputs and outputs

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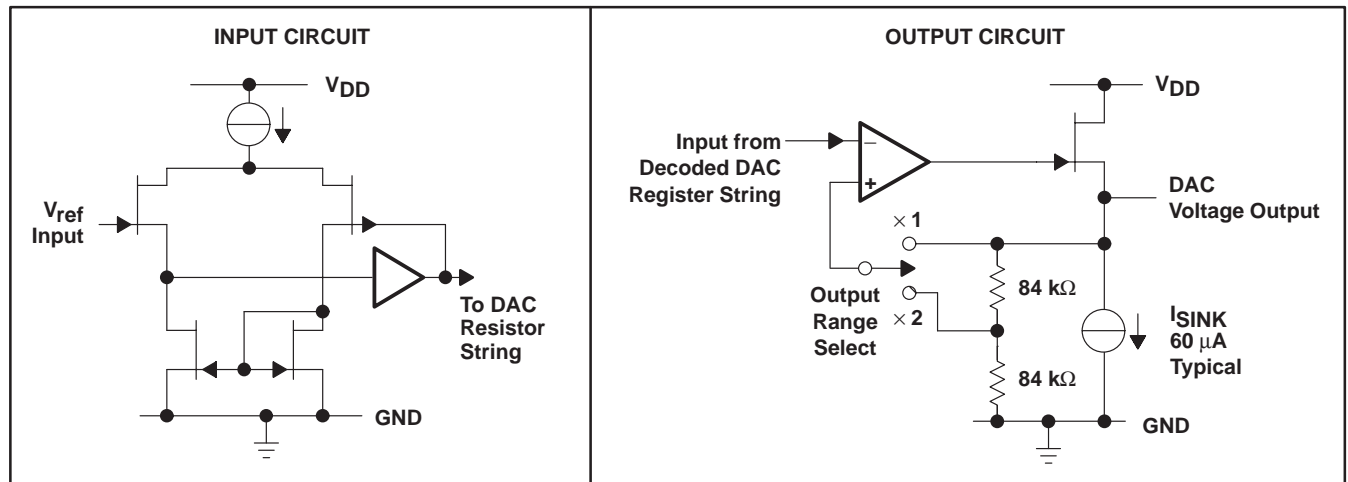
absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage (V_{DD} – GND) . . . . 7 V

Digital input voltage range . . . . GND – 0.3 V to V_{DD} + 0.3 V

Reference input voltage range, V_{ID} . . . . GND – 0.3 V to V_{DD} + 0.3 V

Operating free-air temperature range, T_A: TLV5620C . . . . 0°C to 70°C

                                    TLV5620I . . . . –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 . . . . 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.

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}		2.7	3.3	5.25	V
High-level input voltage, V_{IH}		0.8 V_{DD}			V
Low-level input voltage, V_{IL}				0.8	V
Reference voltage, V_{ref} [A|B|C|D], x1 gain				$V_{DD}-1.5$	V
Load resistance, R_L		10			kΩ
Setup time, data input, $t_{su(DATA-CLK)}$ (see Figures 1 and 2)		50			ns
Valid time, data input valid after CLK↓, $t_{v(DATA-CLK)}$ (see Figures 1 and 2)		50			ns
Setup time, CLK eleventh falling edge to LOAD, $t_{su(CLK-LOAD)}$ (see Figure 1)		50			ns
Setup time, LOAD↑ to CLK↓, $t_{su(LOAD-CLK)}$ (see Figure 1)		50			ns
Pulse duration, LOAD, $t_{w(LOAD)}$ (see Figure 1)		250			ns
Pulse duration, LDAC, $t_{w(LDAC)}$ (see Figure 2)		250			ns
Setup time, LOAD↑ to LDAC↓, $t_{su(LOAD-LDAC)}$ (see Figure 2)		0			ns
CLK frequency				1	MHz
Operating free-air temperature, T_A	TLV5620C	0		70	°C
	TLV5620I	–40		85	

electrical characteristics over recommended operating free-air temperature range, V_{DD} = 3 V to 3.6 V, V_{ref} = 2 V, $\times$ 1 gain output range (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{IH}	High-level input current	$V_I = V_{DD}$			±10	μA
I_{IL}	Low-level input current	$V_I = 0$ V			±10	μA
$I_{O(sink)}$	Output sink current	Each DAC output	20			μA
$I_{O(source)}$	Output source current		1			mA
C_i	Input capacitance			15		pF
	Reference input capacitance			15		
I_{DD}	Supply current	V_{DD} = 3.3 V			2	mA
I_{ref}	Reference input current	V_{DD} = 3.3 V, V_{ref} = 1.5 V			±10	μA
E_L	Linearity error (end point corrected)	V_{ref} = 1.25 V, $\times$ 2 gain, See Note 1			±1	LSB
E_D	Differential linearity error	V_{ref} = 1.25 V, $\times$ 2 gain, See Note 2			±0.9	LSB
E_{ZS}	Zero-scale error	V_{ref} = 1.25 V, $\times$ 2 gain, See Note 3	0		30	mV
	Zero-scale error temperature coefficient	V_{ref} = 1.25 V, $\times$ 2 gain, See Note 4		10		μV/°C
E_{FS}	Full-scale error	V_{ref} = 1.25 V, $\times$ 2 gain, See Note 5			±60	mV
	Full-scale error temperature coefficient	V_{ref} = 1.25 V, $\times$ 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 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} × 10^6/(T_{max} − T_{min}).
5.   Full-scale error is the deviation from the ideal full-scale output (V_{ref} − 1 LSB) with an output load of 10 kΩ.
6.   Full-scale error temperature coefficient is given by: FSETC = [FSE(T_{max}) − FSE (T_{min})]/V_{ref} × 10^6/(T_{max} − T_{min}).
7.   Zero-scale error rejection ratio (ZSE-RR) is measured by varying the V_{DD} 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 varing the V_{DD} 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_{DD} = 3 V to 3.6 V, V_{ref} = 2 V, $\times$ 1 gain output range (unless otherwise noted)

	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output slew rate	C_L = 100 pF R_L = 10 kΩ		1		V/μs
Output settling time	To ±0.5 LSB, C_L = 100 pF, R_L = 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-DACD		−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 between a LOAD falling edge and the DAC output reaching full-scale voltage within $\pm$ 0.5 LSB starting from an initial output voltage equal to zero.
10.   Reference feedthrough is measured at any DAC output with an input code = 00 hex with a V_{ref} input = 1 V dc + 1 V_{PP} 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_{ref} input = 1 V dc + 1 V_{PP} at 10 kHz.
12.   Reference bandwidth is the −3 dB bandwidth with an input at V_{ref} = 1.25 V dc + 2 V_{PP} and with a digital input code of full-scale.
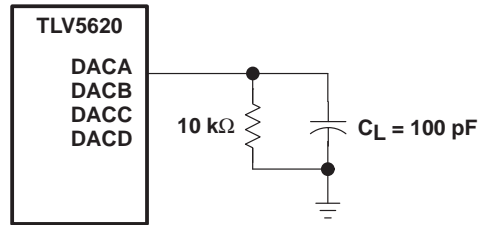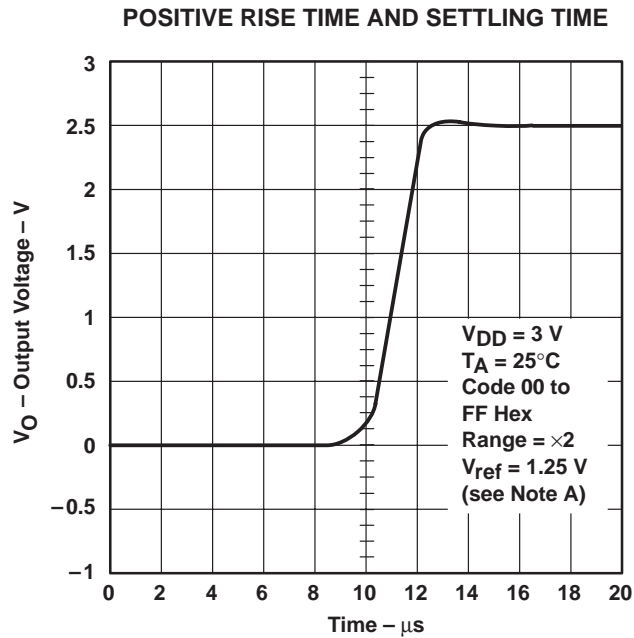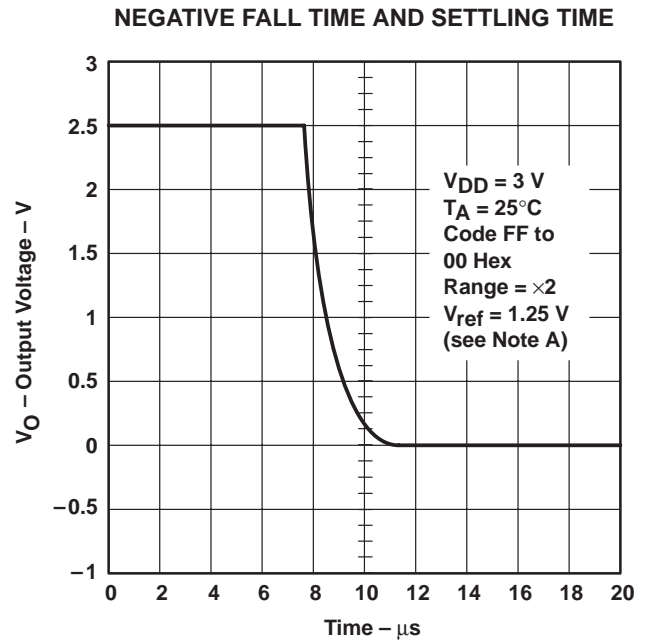

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PARAMETER MEASUREMENT INFORMATION

Figure 6. Slew, Settling Time, and Linearity Measurements

TYPICAL CHARACTERISTICS

POSITIVE RISE TIME AND SETTLING TIME

NOTE A: Rise time = 2.05 µs, positive slew rate = 0.96 V/µs, settling time = 4.5 µs.

Figure 7

NEGATIVE FALL TIME AND SETTLING TIME

NOTE A: Fall time = 4.25 µs, negative slew rate = 0.46 V/µs, settling time = 8.5 µs.

Figure 8

TYPICAL CHARACTERISTICS

DAC OUTPUT VOLTAGE
vs
OUTPUT LOAD

V_{DD} = 3 V,
V_{ref} = 1.5 V,
Range = 2x

Figure 9

DAC OUTPUT VOLTAGE
vs
OUTPUT LOAD

V_{DD} = 3 V,
V_{ref} = 1.5 V,
Range = 1x

Figure 10

SUPPLY CURRENT
vs
TEMPERATURE

Range = ×2
Input Code = 255
V_{DD} = 3 V
V_{ref} = 1.25 V
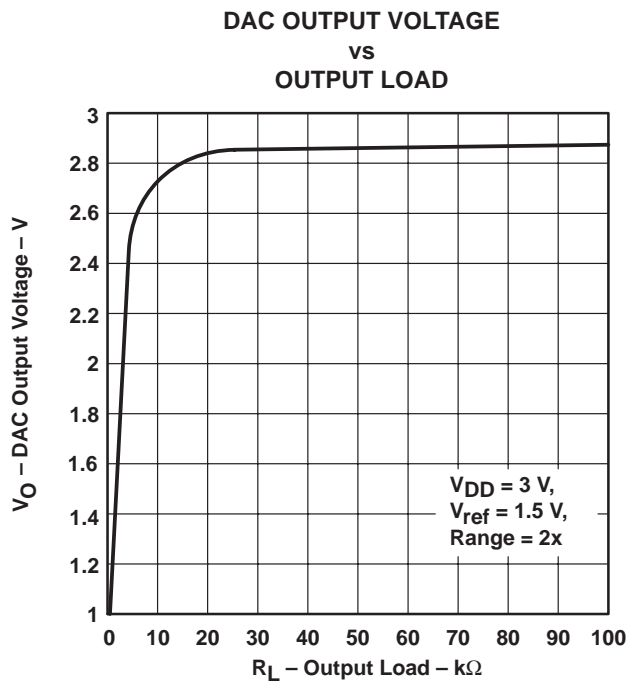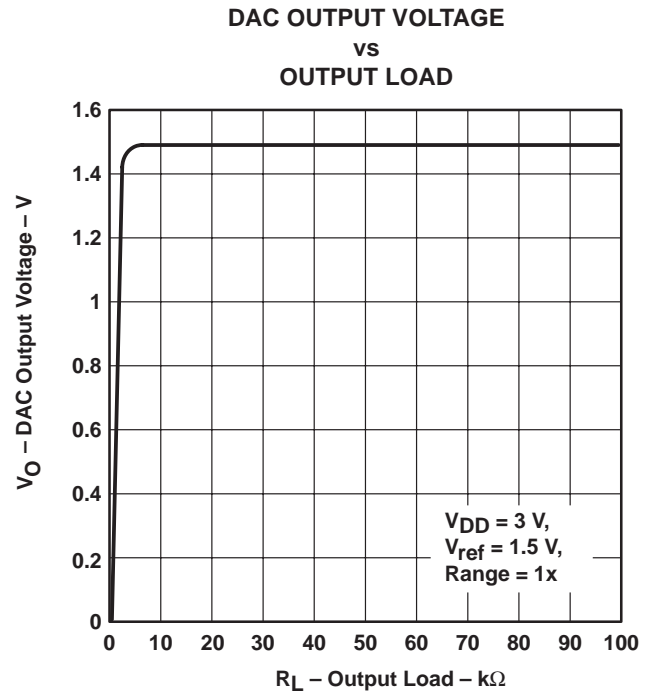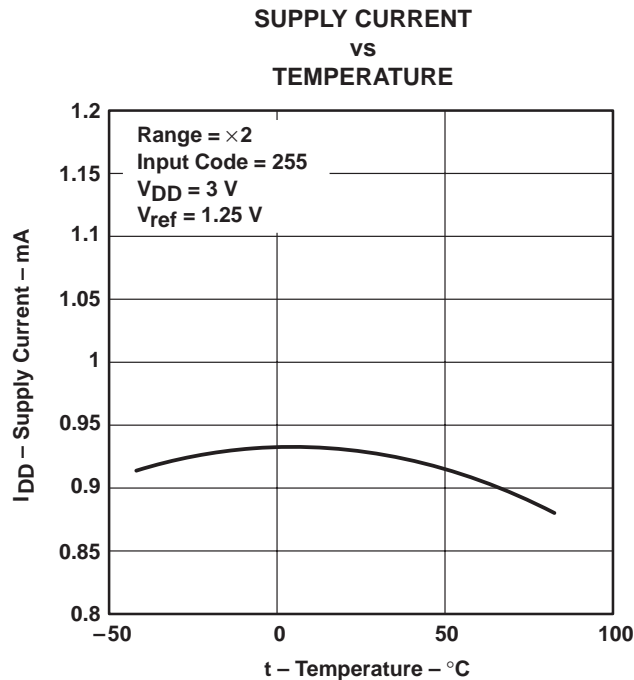
Figure 11

APPLICATION INFORMATION
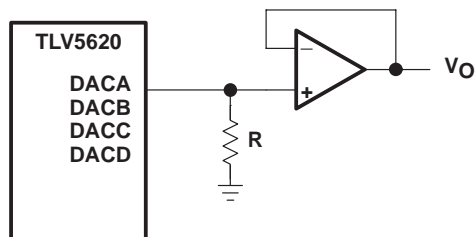
NOTE A: Resistor R $\geq$ 10 kΩ

Figure 12. Output Buffering Scheme

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]	Op Temp (°C)	Top-Side Markings [4]	Samples
TLV5620CD	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TLV5620C	Samples
TLV5620CDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TLV5620C	Samples
TLV5620CDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TLV5620C	Samples
TLV5620CDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TLV5620C	Samples
TLV5620CN	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	TLV5620CN	Samples
TLV5620CNE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	TLV5620CN	Samples
TLV5620ID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TLV5620I	Samples
TLV5620IDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TLV5620I	Samples
TLV5620IDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TLV5620I	Samples
TLV5620IDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TLV5620I	Samples
TLV5620IN	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	TLV5620IN	Samples
TLV5620INE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	TLV5620IN	Samples

[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.
OBSOLETE: TI has discontinued the production of the device.

[2] 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)

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

[4] Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

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PACKAGE MATERIALS INFORMATION

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS

A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

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
TLV5620IDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

PACKAGE MATERIALS INFORMATION

TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV5620IDR	SOIC	D	14	2500	367.0	367.0	38.0

IMPORTANT NOTICE

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		