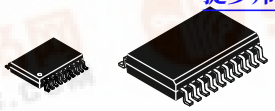


SLAS268E–MAY 2000–REVISED MARCH 2004

8-CHANNEL, 12-/10-/8-BIT, 2.7-V TO 5.5-V LOW POWER DIGITAL-TO-ANALOG CONVERTER WITH POWER DOWN

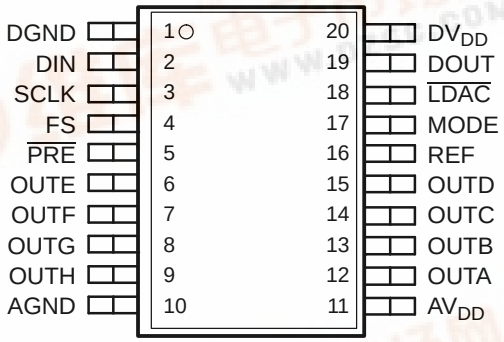
FEATURES

- Eight Voltage Output DACs in One Package
  - TLV5610 . . . 12-Bit
  - TLV5608 . . . 10-Bit
  - TLV5629 . . . 8-Bit
- Programmable Settling Time vs Power Consumption
  - 1 µs In Fast Mode
  - 3 µs In Slow Mode
- Compatible With TMS320 and SPI™ Serial Ports
- Monotonic Over Temperature
- Low Power Consumption:
  - 18 mW In Slow Mode at 3-V
  - 48 mW In Fast Mode at 3-V
- Reference Input Buffers
- Power-Down Mode
- Buffered, High Impedance Reference Inputs
- Data Output for Daisy-Chaining

APPLICATIONS

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

DW OR PW PACKAGE
(TOP VIEW)



DESCRIPTION

The TLV5610, TLV5608, and TLV5629 are pin-compatible, eight-channel, 12-/10-/8-bit voltage output DACs each with a flexible 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.

Additional features are a power-down mode, an LDAC input for simultaneous update of all eight DAC outputs, and a data output which can be used to cascade multiple devices.

The resistor string output voltage is buffered by a rail-to-rail output amplifier with a programmable settling time to allow the designer to optimize speed vs power dissipation. The buffered, high-impedance reference input can be connected to the supply voltage.

Implemented with a CMOS process, the DACs are designed for single-supply operation from 2.7 V to 5.5 V. The devices are available in 20-pin SOIC and TSSOP packages.

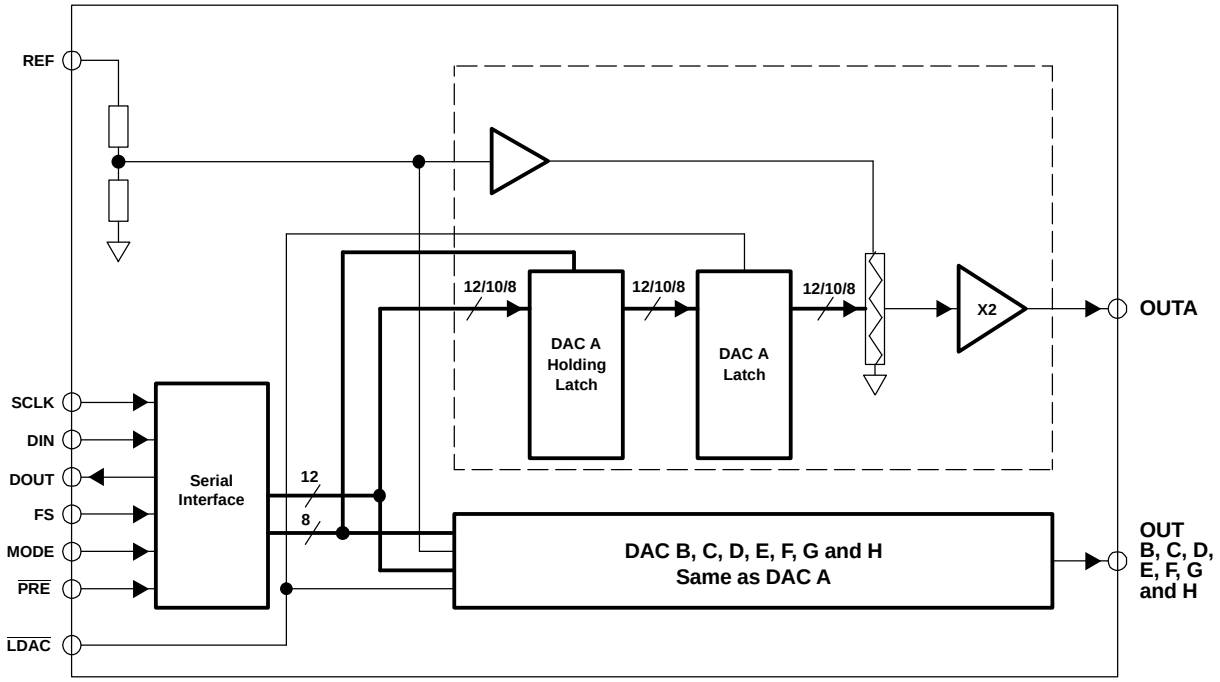
AVAILABLE OPTIONS

T_A	PACKAGE		
	SMALL OUTLINE (DW)	TSSOP (PW)	RESOLUTION
-40°C to 85°C	TLV5610IDW	TLV5610IPW	12
	TLV5608IDW	TLV5608IPW	10
	TLV5629IDW	TLV5629IPW	8

SPI is a trademark of Motorola, Inc.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

FUNCTIONAL BLOCK DIAGRAM



Terminal Functions

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
AGND	10	I	Analog ground
AV_{DD}	11	I	Analog power supply
DGND	1	I	Digital ground
DIN	2	I	Digital serial data input
DOUT	19	O	Digital serial data output
DV_{DD}	20	I	Digital power supply
FS	4	I	Frame sync input
$\overline{\text{LDAC}}$	18	I	Load DAC. The DAC outputs are only updated, if this signal is low. It is an asynchronous input.
MODE	17	I	DSP/µC mode pin. High = µC mode, NC = DSP mode.
$\overline{\text{PRE}}$	5	I	Preset input
REF	16	I	Voltage reference input
SCLK	3	I	Serial clock input
OUTA-OUTH	6-9, 12-15	O	DAC outputs A, B, C, D, E, F, G and H

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)(1)

	UNIT
Supply voltage (AV_{DD}, DV_{DD} to GND)	7 V
Reference input voltage	- 0.3 V to AV_{DD} + 0.3 V
Digital input voltage range	- 0.3 V to DV_{DD} + 0.3 V
Operating free-air temperature range, T_A	-40°C to 85°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

(1) 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, AV_{DD}, DV_{DD}	5-V operation	4.5	5	5.5	V
	3-V operation	2.7	3	3.3	V
High-level digital input voltage, V_{IH}	DV_{DD} = 2.7 V	2			V
	DV_{DD} = 5.5 V	2.4			
Low-level digital input voltage, V_{IL}	DV_{DD} = 2.7 V			0.6	V
	DV_{DD} = 5.5 V			1	
Reference voltage, V_{ref}	AV_{DD} = 5 V	GND	4.096	AV_{DD}	V
	AV_{DD} = 3 V	GND	2.048	AV_{DD}	V
Load resistance, R_L		2			kΩ
Load capacitance, C_L				100	pF
Clock frequency, f_{CLK}				30	MHz
Operating free-air temperature, T_A		-40		85	°C

ELECTRICAL CHARACTERISTICS

over recommended operating free-air temperature range, supply voltages, and reference voltages (unless otherwise noted)

POWER SUPPLY							
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I_{DD}	Power supply current	No load, V_{ref} = 4.096 V, All inputs = DV_{DD} or GND	Fast		16	21	mA
			Slow		6	8	
	Power down supply current				0.1		µA
POR	Power on threshold				2		V
PSRR	Power supply rejection ratio	Full scale (1)			-60		dB

(1) Power supply rejection ratio at full scale is measured by varying AV_{DD} and is given by:
PSRR = 20 log [($E_G(AV_{DD}max)$ - $E_G(AV_{DD}min)$)/$V_{DD}max$]

ELECTRICAL CHARACTERISTICS (CONTINUED)

over recommended operating free-air temperature range, supply voltages, and reference voltages (unless otherwise noted)

STATIC DAC SPECIFICATIONS

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
Resolution		TLV5610				12		Bits
		TLV5608				10		
		TLV5629				8		
Integral nonlinearity (INL)		TLV5610	V_{ref} = 2 V, 4V	Code 40 to 4095		±2	±6	LSB
		TLV5608		Code 20 to 1023		±0.5	±2	
		TLV5629		Code 6 to 255		±0.3	±1	
Differential nonlinearity (DNL)		TLV5610	V_{ref} = 2 V, 4V	Code 40 to 4095		±0.5	±1	LSB
		TLV5608		Code 20 to 1023		±0.1	±1	
		TLV5629		Code 6 to 255		±0.1	±1	
E_{ZS}	Zero-scale error (offset error at zero scale)						±30	mV
E_{ZS} TC	Zero-scale-error temperature coefficient					30		µV/°C
E_G	Gain error						±0.6	% of FS voltage
E_G TC	Gain error temperature coefficient					10		ppm/°C

OUTPUT SPECIFICATIONS

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_O	Voltage output range	R_L = 10 kΩ	0		AV_{DD}-0.4	V
	Output load regulation accuracy	R_L = 2 kΩ vs 10 kΩ			±0.3	% of FS voltage

REFERENCE INPUT

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_I	Reference input voltage			0		AV_{DD}	V
R_i	Reference input resistance				100		kΩ
C_i	Reference input capacitance				5		pF
	Reference input bandwidth	V_{ref} = 0.4 V_{pp} + 2.048 V dc, Input code = 0x800	Fast		2.2		MHz
			Slow		1.9		
	Reference feedthrough	V_{ref} = 2 V_{pp} at 1 kHz + 2.048 V dc(1)			-84		dB

DIGITAL INPUT

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

DIGITAL OUTPUT

V_{OH}	High-level digital output voltage	R_L= 10 kΩ	2.6			V
V_{OL}	Low-level digital output voltage	R_L= 10 kΩ			0.4	V
	Output voltage rise time	R_L= 10 kΩ, C_L = 20 pF, Includes propogation delay		7	20	ns

(1) Reference feedthrough is measured at the DAC output with an input code = 0x000.

ELECTRICAL CHARACTERISTICS (CONTINUED)

over recommended operating free-air temperature range, supply voltages, and reference voltages (unless otherwise noted)

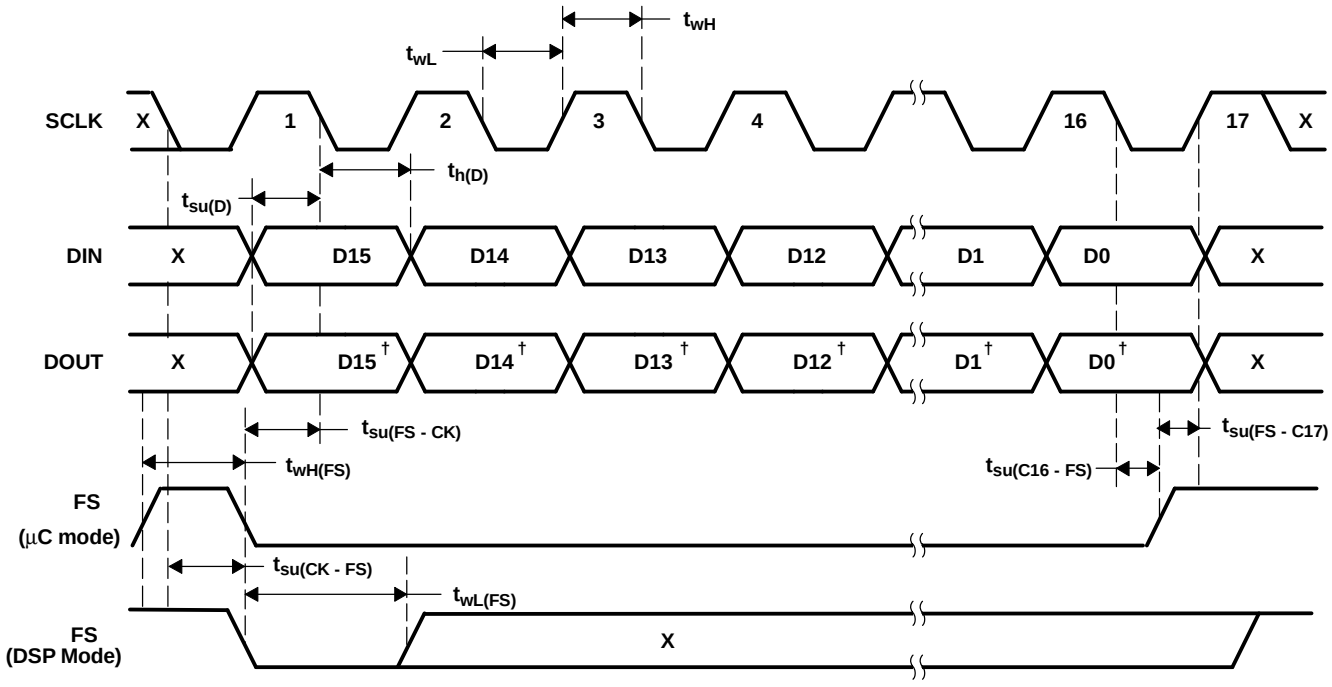
ANALOG OUTPUT DYNAMIC PERFORMANCE							
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{s(FS)}$	Output settling time (full scale)	R_L = 10 kΩ, C_L = 100 pF(1)	Fast		1	3	µs
			Slow		3	7	
$t_{s(CC)}$	Output settling time, code to code	R_L = 10 kΩ, C_L = 100 pF(2)	Fast		0.5	1	µs
			Slow		1	2	
SR	Slew rate	R_L = 10 kΩ, C_L = 100 pF(3)	Fast	4	10		V/µs
			Slow	1	3		
	Glitch energy	See note (4)			4		nV-s
	Channel crosstalk	10 kHz sine, 4 V_{PP}			-90		dB

(1) 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 0x80 to 0xFFF and 0xFFF to 0x080, respectively. Assured by design; not tested.
(2) 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. The max time applies to code changes near zero scale or full scale. Assured by design; not tested.
(3) Slew rate determines the time it takes for a change of the DAC output from 10% to 90% full scale voltage.
(4) Code transition: TLV5610 - 0x7FF to 0x800, TLV5608 - 0x7FC to 0x800, TLV5629 - 0x7F0 to 0x800

TIMING REQUIREMENTS

DIGITAL INPUTS					
		MIN	NOM	MAX	UNIT
$t_{su(FS-CK)}$	Setup time, FS low before next negative SCLK edge	8			ns
$t_{su(C16-FS)}$	Setup time, 16th negative edge after FS low on which bit D0 is sampled before rising edge of FS. µC mode only	10			ns
$t_{su(FS-C17)}$	µC mode, setup time, FS high before 17th positive SCLK.	10			ns
$t_{su(CK-FS)}$	DSP mode, setup time, SLCK low before FS low.	5			ns
$t_{wL(LDAC)}$	$\overline{\text{LDAC}}$ duration low	10			ns
t_{wH}	SCLK pulse duration high	16			ns
t_{wL}	SCLK pulse duration low	16			
$t_{su(D)}$	Setup time, data ready before SCLK falling edge	8			ns
$t_{h(D)}$	Hold time, data held valid after SCLK falling edge	5			ns
$t_{wH(FS)}$	FS duration high	10			ns
$t_{wL(FS)}$	FS duration low	10			ns
t_s	Settling time	See AC specs			

PARAMETER MEASUREMENT INFORMATION



† Previous input data

Figure 1. Serial Interface Timing

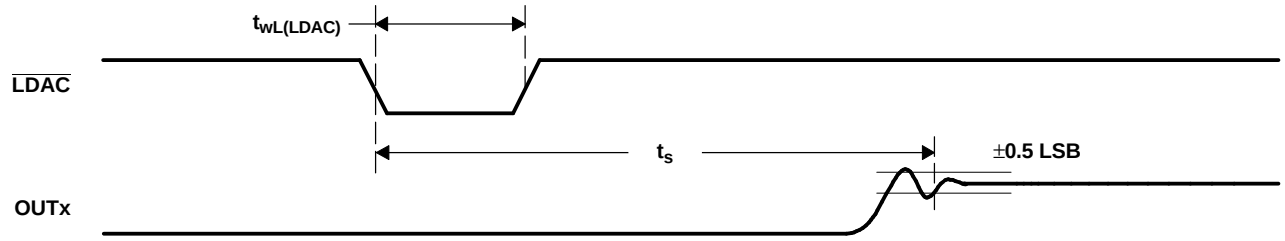


Figure 2. Output Timing

TYPICAL CHARACTERISTICS

OUTPUT LOAD REGULATION

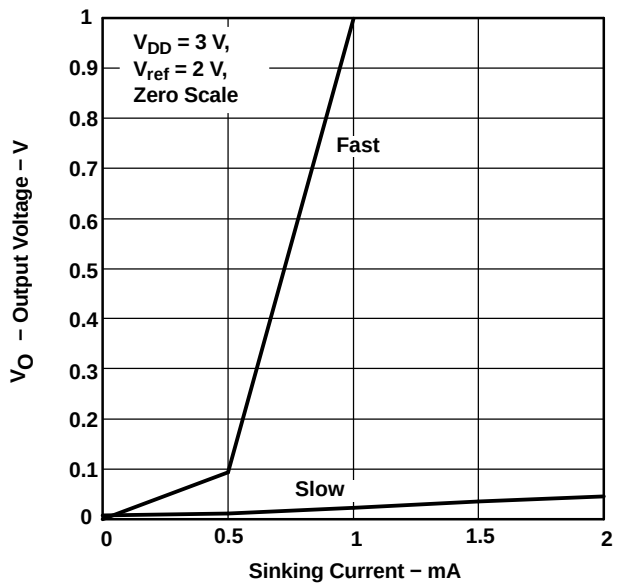


Figure 3.

OUTPUT LOAD REGULATION

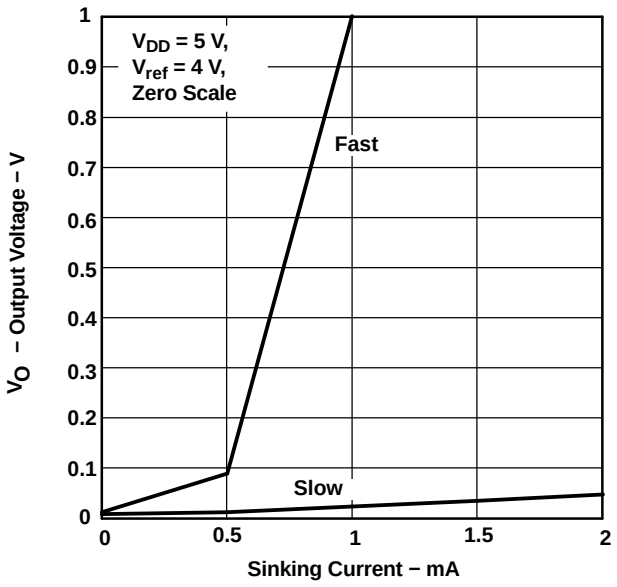


Figure 4.

OUTPUT LOAD REGULATION

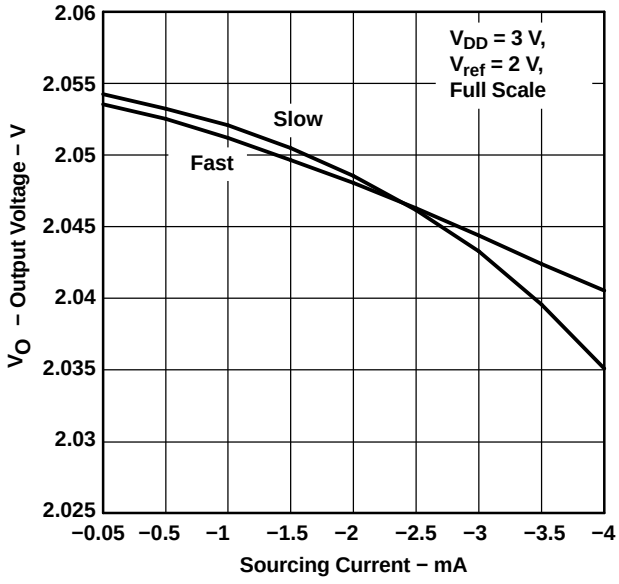


Figure 5.

OUTPUT LOAD REGULATION

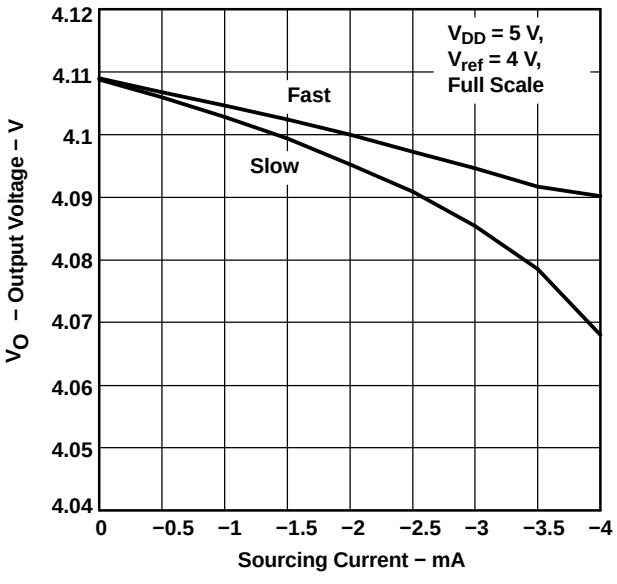


Figure 6.

TYPICAL CHARACTERISTICS (CONTINUED)

TLV5610
INTEGRAL NONLINEARITY
vs
CODE

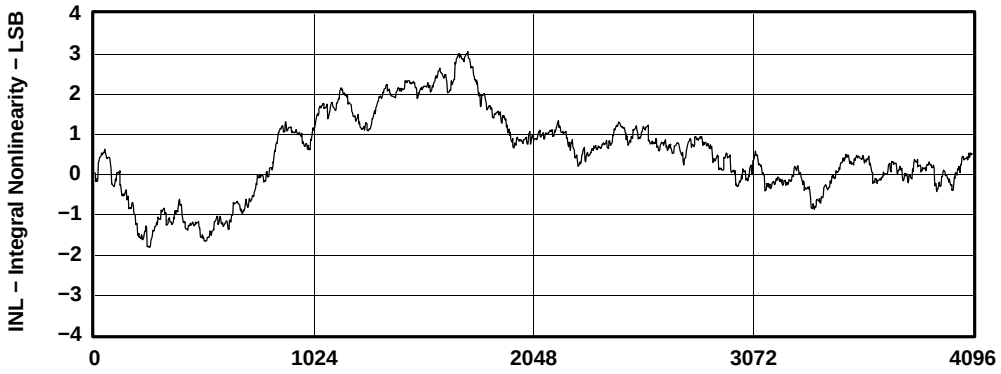


Figure 7.

TLV5610
DIFFERENTIAL NONLINEARITY
vs
CODE

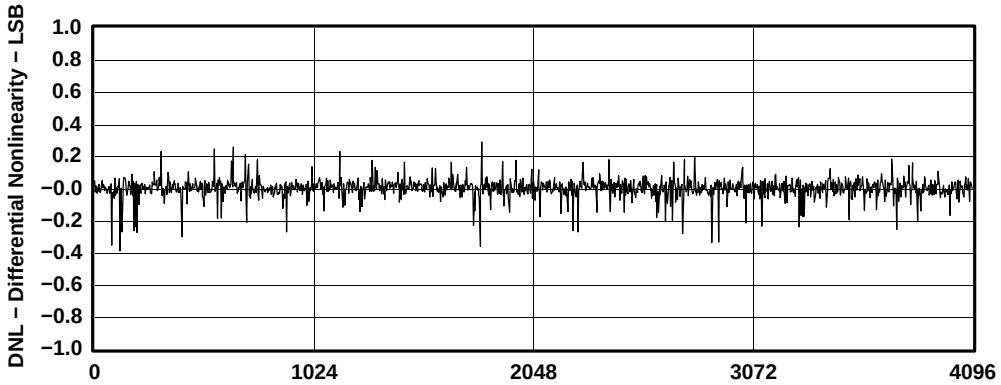


Figure 8.

TYPICAL CHARACTERISTICS (CONTINUED)

TLV5608
INTEGRAL NONLINEARITY
vs
CODE

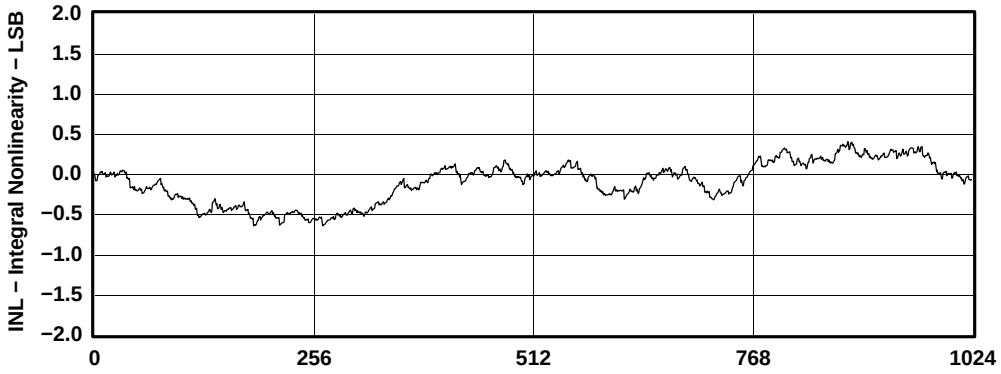


Figure 9.

TLV5608
DIFFERENTIAL NONLINEARITY
vs
CODE

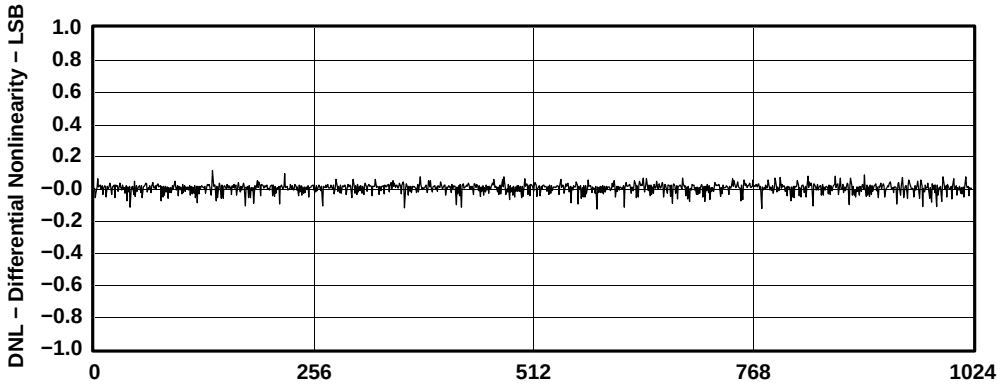


Figure 10.

TYPICAL CHARACTERISTICS (CONTINUED)

TLV5629
INTEGRAL NONLINEARITY
vs
CODE

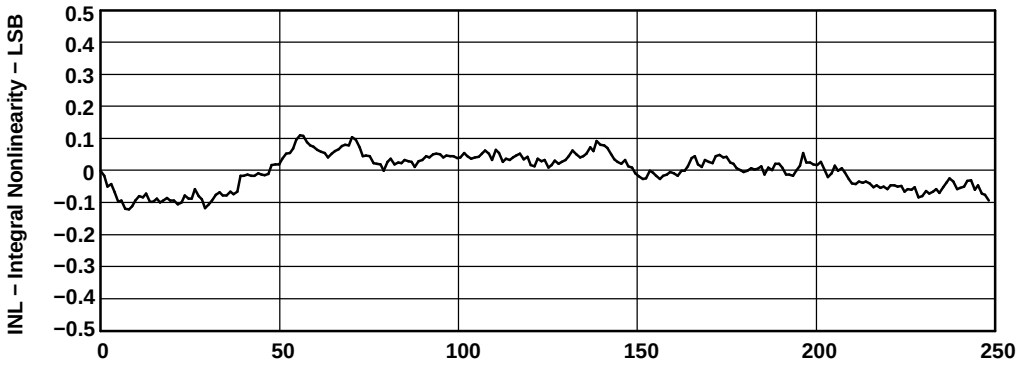


Figure 11.

TLV5629
DIFFERENTIAL NONLINEARITY
vs
CODE

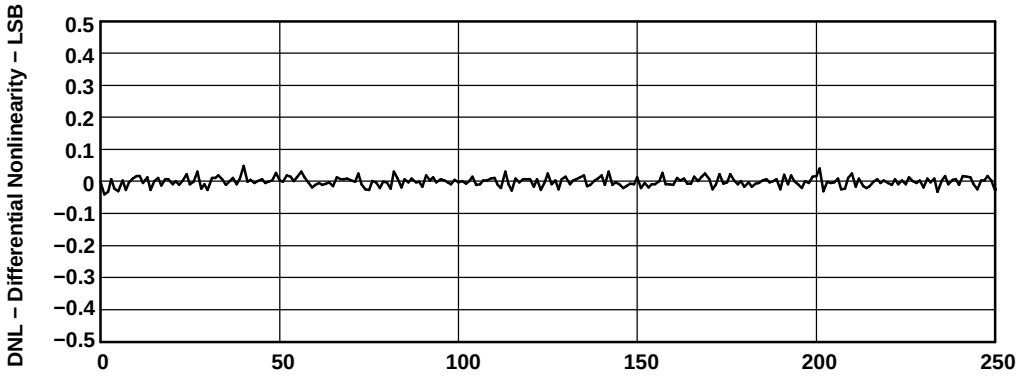


Figure 12.

APPLICATION INFORMATION

GENERAL FUNCTION

The TLV5610, TLV5608, and TLV5629 are 8-channel, 12-bit, single-supply DACs, based on a resistor string architecture. They consist of a serial interface, a speed and power-down control logic, a reference input buffer, a resistor string, and a rail-to-rail output buffer.

The output voltage (full scale determined by external reference) for each channel is given by:

$$\text{REF}\ \frac{\text{CODE}}{\text{0x1000}}\ [\text{V}] \quad (1)$$

where REF is the reference voltage and CODE is the digital input value. The input range is 0x000 to 0xFFF for the TLV5610, 0x000 to 0xFFC for the TLV5608, and 0x000 to 0xFF0 for the TLV5629. A power-on-reset initially puts the internal latches to a defined state (all bits zero).

SERIAL INTERFACE

A falling edge of FS starts shifting the data on DIN starting with the MSB to the internal register on the falling edges of SCLK. After 16 bits have been transferred, the content of the shift register is moved to one of the DAC holding registers, depending on the address bits within the data word. A logic 0 on the $\overline{\text{LDAC}}$ pin is required to transfer the content of the DAC holding register to the DAC latch and to update the DAC outputs. $\overline{\text{LDAC}}$ is an asynchronous input. It can be held low if a simultaneous update of all eight channels is not needed.

For daisy-chaining, DOUT provides the data sampled on DIN with a delay of 16 clock cycles.

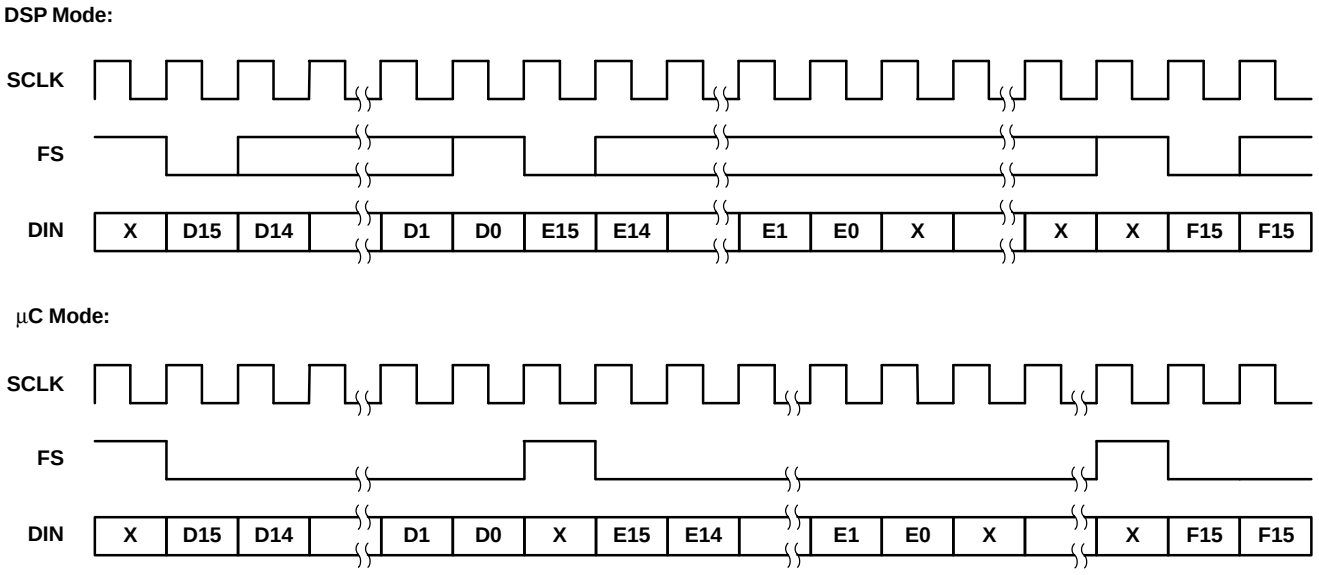


Figure 13. Data Sampled on DIN

Difference between DSP mode (MODE = N.C. or 0) and µC (MODE = 1) mode:

- In µC mode, FS needs to be held low until all 16 data bits have been transferred. If FS is driven high before the 16th falling clock edge, the data transfer is cancelled. The DAC is updated after a rising edge on FS.
- In DSP mode, FS needs to stay low for 20 ns and can go high before the 16th falling clock edge.
- In DSP mode there needs to be one falling SCLK edge before FS goes low to start the write (DIN) cycle. This extra falling SCLK edge has to happen at least 5 ns before FS goes low, $t_{su(CK-FS)} \geq 5$ ns.
- In µC mode, the extra falling SCLK edge is not necessary. However, if it does happen, the extra negative SCLK edge is not allowed to occur within 10 ns after FS goes HIGH to finish the WRITE cycle ($t_{su(FS-C17)}$).

APPLICATION INFORMATION (continued)

SERIAL CLOCK FREQUENCY AND UPDATE RATE

The maximum serial clock frequency is given by:

$$f_{sclkmax} = \frac{1}{t_{whmin} + t_{wlmin}} = 30\ MHz \quad (2)$$

The maximum update rate is:

$$f_{updatemax} = \frac{1}{16\left(t_{whmin} + t_{wlmin}\right)} = 1.95\ MHz \quad (3)$$

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

DATA FORMAT

The 16-bit data word consists of two parts:

- Address bits (D150D12)
- Data bits (D110D0)

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
A3	A2	A1	A0	DATA											

Register Map

A3	A2	A1	A0	FUNCTION
0	0	0	0	DAC A
0	0	0	1	DAC B
0	0	1	0	DAC C
0	0	1	1	DAC D
0	1	0	0	DAC E
0	1	0	1	DAC F
0	1	1	0	DAC G
0	1	1	1	DAC H
1	0	0	0	CTRL0
1	0	0	1	CTRL1
1	0	1	0	Preset
1	0	1	1	Reserved
1	1	0	0	DAC A and $\overline{B}$
1	1	0	1	DAC C and $\overline{D}$
1	1	1	0	DAC E and $\overline{F}$
1	1	1	1	DAC G and $\overline{H}$

DAC A-H AND TWO-CHANNEL REGISTERS

Writing to DAC A-H sets the output voltage of channel A-H. It is possible to automatically generate the complement of one channel by writing to one of the four two-channel registers (DAC A and B etc.).

The TLV5610 decodes all 12 data bits. The TLV5608 decodes D11 to D2 (D1 and D0 are ignored). The TLV5629 decodes D11 to D4 (D3 to D0 are ignored).

PRESET

The outputs of all DAC channels can be driven to a predefined value stored in the Preset register by driving the PRE input low. The PRE input is asynchronous to the clock.

CTRL0

D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	PD	DO	X	X	IM

PD	: Full device power down	0 = normal	1 = power down
DO	: Digital output enable	0 = disable	1 = enable
IM	: Input mode	0 = straight binary	1 = twos complement
X	: Reserved		

If DOUT is enabled, the data input on DIN is output on DOUT with a 16-cycle delay. That makes it possible to daisy-chain multiple DACs on one serial bus.

CTRL1

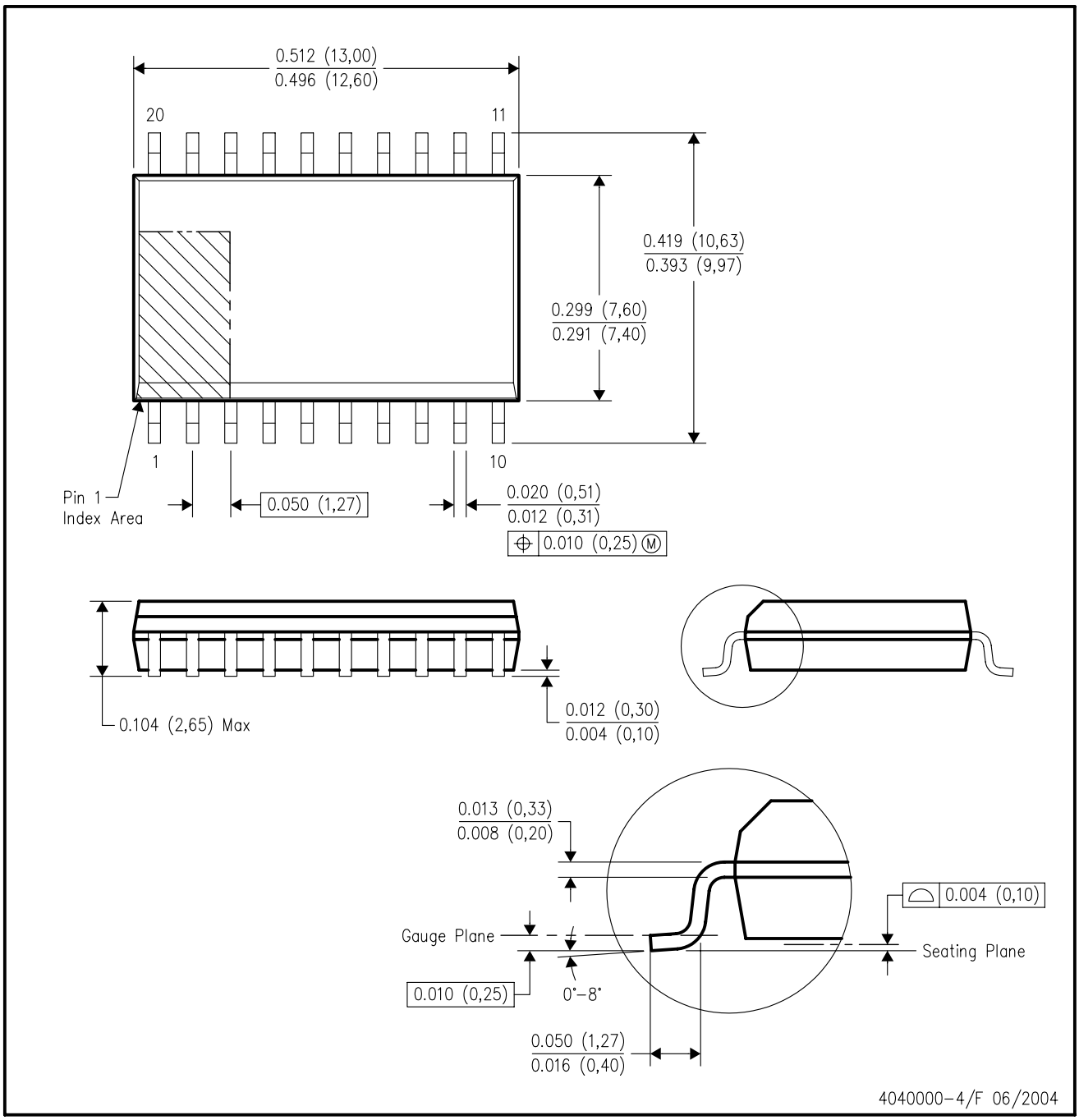
D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	P_{GH}	P_{EF}	P_{CD}	P_{AB}	S_{GH}	S_{EF}	S_{CD}	S_{AB}

P_{XY}	: Power down DAC_{XY}	0 = normal	1 = power down
S_{XY}	: Speed DAC_{XY}	0 = slow	1 = fast
XY	: DAC pair AB, CD, EF, or GH		

In power-down mode, the amplifiers of the selected DAC pair within the device are disabled and the total power consumption of the device is significantly reduced. Power-down mode of a specific DAC pair can be selected by setting the PXY bit within the data word to 1.

There are two settling time modes: fast and slow. Fast mode of a DAC pair is selected by setting S_{XY} to 1 and slow mode is selected by setting S_{XY} to 0.

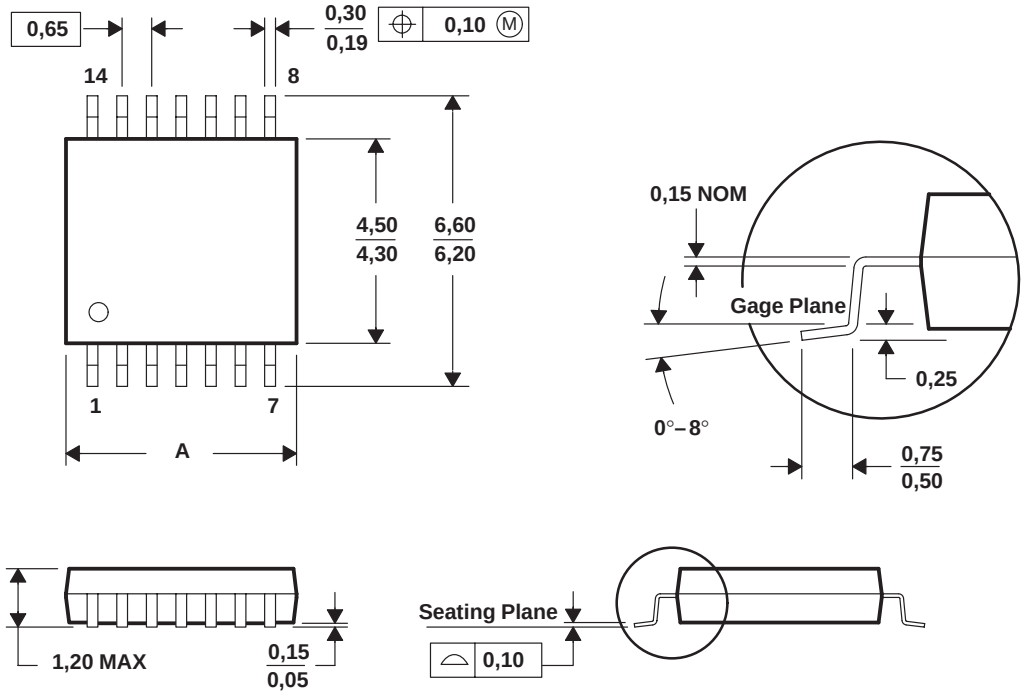
DW (R–PDSO–G20) PLASTIC SMALL–OUTLINE PACKAGE



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–013 variation AC.

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

14 PINS SHOWN



DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265