- **12-Bit Voltage Output DAC**
- **Programmable Settling Time vs Power Consumption**
  - **3 μs in Fast Mode**
  - **9 μs in Slow Mode**
- **Ultra Low Power Consumption:**
  - **900 μW Typ in Slow Mode at 3 V**
  - **2.1 mW Typ in Fast Mode at 3 V**
- **Differential Nonlinearity . . . <0.5 LSB Typ**
- **Compatible With TMS320 and SPI Serial Ports**
- **Power-Down Mode (10 nA)**
- **Buffered High-Impedance Reference Input**
- **Voltage Output Range . . . 2 Times the Reference Input Voltage**
- **Monotonic Over Temperature**
- **Available in MSOP Package**

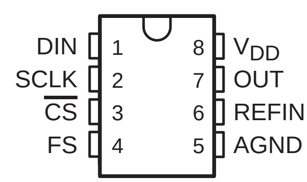
applications

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

description

The TLV5616 is a 12-bit voltage output digital-to-analog converter (DAC) with a flexible 4-wire serial interface. The 4-wire serial interface allows glueless interface to TMS320, SPI, QSPI, and Microwire serial ports. The TLV5616 is programmed with a 16-bit serial string containing 4 control and 12 data bits. Developed for a wide range of supply voltages, the TLV5616 can operate from 2.7 V to 5.5 V.

D, DGK, OR P PACKAGE
(TOP VIEW)



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 settling time of the DAC is programmable to allow the designer to optimize speed versus power dissipation. The settling time is chosen by the control bits within the 16-bit serial input string. A high-impedance buffer is integrated on the REFIN terminal to reduce the need for a low source impedance drive to the terminal.

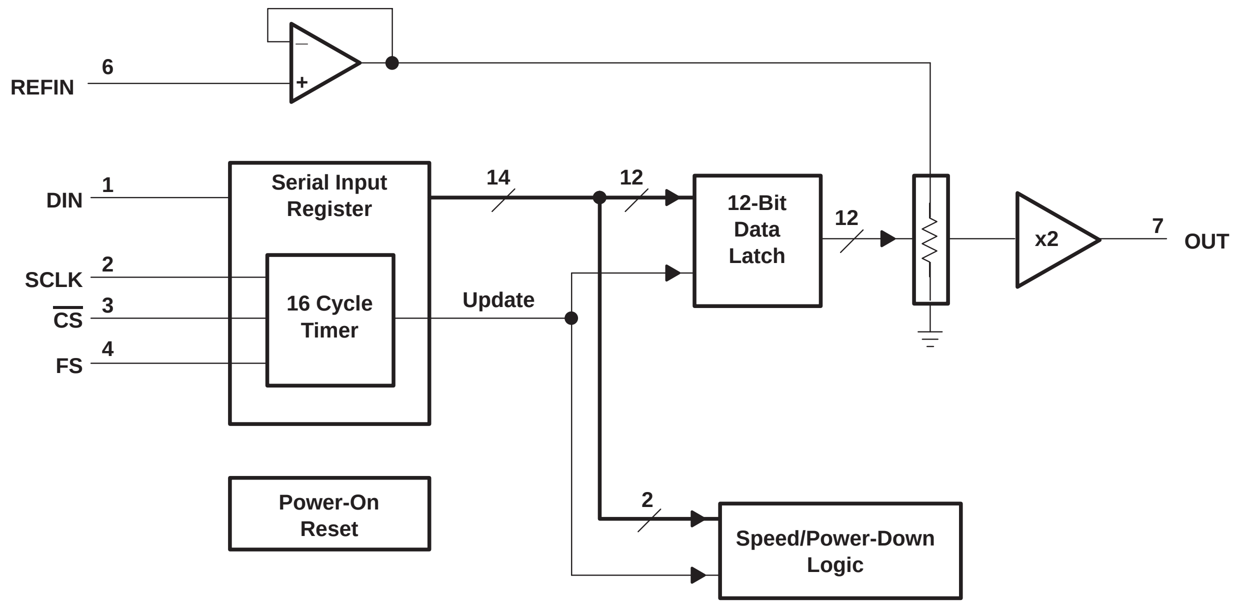
Implemented with a CMOS process, the TLV5616 is designed for single supply operation from 2.7 V to 5.5 V. The device is available in an 8-terminal SOIC package. The TLV5616C is characterized for operation from 0°C to 70°C. The TLV5616I is characterized for operation from −40°C to 85°C.

AVAILABLE OPTIONS

T_A	PACKAGE		
	SMALL OUTLINE† (D)	MSOP (DGK)	PLASTIC DIP (P)
0°C to 70°C	TLV5616CD	TLV5616CDGK	TLV5616CP
−40°C to 85°C	TLV5616ID	TLV5616IDGK	TLV5616IP

† Available in tape and reel as the TLV5616CDR and the TLV5616IDR

functional block diagram



Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
AGND	5		Analog ground
$\overline{CS}$	3	I	Chip select. Digital input used to enable and disable inputs, active low.
DIN	1	I	Serial digital data input
FS	4	I	Frame sync. Digital input used for 4-wire serial interfaces such as the TMS320 DSP interface.
OUT	7	O	DAC analog output
REFIN	6	I	Reference analog input voltage
SCLK	2	I	Serial digital clock input
V_{DD}	8		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: TLV5616C . . . . 0°C to 70°C
TLV5616I . . . . −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

† 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}	V_{DD} = 5 V	4.5	5	5.5	V
	V_{DD} = 3 V	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			V
Low-level digital input voltage, V_{IL}	DV_{DD} = 2.7 V			0.6	V
	DV_{DD} = 5.5 V			1	V
Reference voltage, V_{ref} to REFIN terminal	V_{DD} = 5 V (see Note 1)	AGND	2.048	V_{DD}−1.5	V
Reference voltage, V_{ref} to REFIN terminal	V_{DD} = 3 V (see Note 1)	AGND	1.024	V_{DD}−1.5	V
Load resistance, R_L		2	10		kΩ
Load capacitance, C_L				100	pF
Clock frequency, f_{CLK}				20	MHz
Operating free-air temperature, T_A	TLV5616C	0		70	°C
	TLV5616I	−40		85	°C

NOTE 1: Due to the x2 output buffer, a reference input voltage ≥ $V_{DD/2}$ causes clipping of the transfer function.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

power supply

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
I_{DD}	Power supply current		V_{DD} = 5 V, VREF = 2.048 V, No load, All inputs = AGND or V_{DD}, DAC latch = 0x800	Fast		0.9	1.35	mA
				Slow		0.4	0.6	mA
			V_{DD} = 3 V, VREF = 1.024 V No load, All inputs = AGND or V_{DD}, DAC latch = 0x800	Fast		0.7	1.1	mA
				Slow		0.3	0.45	mA
	Power down supply current (see Figure 12)					10		nA
PSRR	Power supply rejection ratio	Zero scale	See Note 2			−80		dB
		Full scale	See Note 3			−80		dB
	Power on threshold voltage, POR					2		V

NOTES: 2. Power supply rejection ratio at zero scale is measured by varying V_{DD} and is given by:
$PSRR = 20 \log [(E_{ZS}(V_{DD}max) - E_{ZS}(V_{DD}min))/V_{DD}max]$
3. Power supply rejection ratio at full scale is measured by varying V_{DD} and is given by:
$PSRR = 20 \log [(E_G(V_{DD}max) - E_G(V_{DD}min))/V_{DD}max]$

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted) (continued)

static DAC specifications R_L = 10 kΩ, C_L = 100 pF

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Resolution			12	12	bits
INL	Integral nonlinearity	See Note 4		± 1.9	±4	LSB
DNL	Differential nonlinearity	See Note 5		± 0.5	± 1	LSB
E_{ZS}	Zero-scale error (offset error at zero scale)	See Note 6			±10	mV
	Zero-scale-error temperature coefficient	See Note 7		10		ppm/°C
E_G	Gain error	See Note 8			±0.6	% of FS voltage
	Gain-error temperature coefficient	See Note 9		10		ppm/°C

NOTES: 4. 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 10 to code 4095.
5. The differential nonlinearity (DNL) sometimes referred to as differential error, is the difference between the measured and ideal 1 LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code. Tested from code 10 to code 4095.
6. Zero-scale error is the deviation from zero voltage output when the digital input code is zero.
7. Zero-scale-error temperature coefficient is given by: E_{ZS} TC = [E_{ZS} (T_{max}) − E_{ZS} (T_{min})]/V_{ref} × 10^6/(T_{max} − T_{min}).
8. 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.
9. Gain temperature coefficient is given by: E_G TC = [E_G(T_{max}) − E_G (T_{min})]/V_{ref} × 10^6/(T_{max} − T_{min}).

output specifications

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_O	Voltage output range	R_L = 10 kΩ	0		AV_{DD}−0.1	V
	Output load regulation accuracy	R_L = 2 kΩ, vs 10 kΩ		0.1	±0.25	% of FS voltage

reference input (REF)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_I	Input voltage range			0		V_{DD}−1.5	V
R_I	Input resistance				10		MΩ
C_I	Input capacitance				5		pF
	Reference input bandwidth	REFIN = 0.2 V_{pp} + 1.024 V dc	Slow		525		kHz
			Fast		1.3		MHz
	Reference feed through	REFIN = 1 V_{pp} at 1 kHz + 1.024 V dc (see Note 10)			−75		dB

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

digital inputs

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{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			3		pF

operating characteristics over recommended operating free-air temperature range (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, See Note 11	Fast		3	5.5	µs
			Slow		9	20	
$t_{s(CC)}$	Output settling time, code to code	R_L = 10 kΩ, C_L = 100 pF, See Note 12	Fast		1		µs
			Slow		2		µs
SR	Slew rate	R_L = 10 kΩ, C_L = 100 pF, See Note 13	Fast		3.6		V/µs
			Slow		0.9		
	Glitch energy	Code transition from 0x7FF to 0x800			10		nV−s
S/N	Signal to noise	fs = 400 KSPS, fout = 1.1 kHz, R_L = 10 kΩ, C_L = 100 pF, BW = 20 kHz			74		dB
S/(N+D)	Signal to noise + distortion				66		dB
THD	Total harmonic distortion				−68		dB
	Spurious free dynamic range				70		dB

NOTES: 11. Settling time is the time for the output signal to remain within ±0.5 LSB of the final measured value for a digital input code change of 0x080 to 0x3FF or 0x3FF to 0x080. Not tested, ensured by design.
12. Settling time is the time for the output signal to remain within ± 0.5 LSB of the final measured value for a digital input code change of one count. Code change from 0x1FF to 0x200. Not tested, ensured by design.
13. 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
$t_{su(CS-FS)}$	Setup time, $\overline{CS}$ low before FS↓	10			ns
$t_{su(FS-CK)}$	Setup time, FS low before first negative SCLK edge	8			ns
$t_{su(C16-FS)}$	Setup time, sixteenth negative edge after FS low on which bit D0 is sampled before rising edge of FS	10			ns
$t_{su(C16-CS)}$	Setup time, sixteenth positive SCLK edge (first positive after D0 is sampled) before $\overline{CS}$ rising edge. If FS is used instead of the sixteenth positive edge to update the DAC, then the setup time is between the FS rising edge and $\overline{CS}$ rising edge.	10			ns
t_{wH}	Pulse duration, SCLK high	25			ns
t_{wL}	Pulse duration, SCLK low	25			ns
$t_{su(D)}$	Setup time, data ready before SCLK falling edge	8			ns
$t_{h(D)}$	Hold time, data held valid after SCLK falling edge	5			ns
$t_{wH(FS)}$	Pulse duration, FS high	20			ns

PARAMETER MEASUREMENT INFORMATION

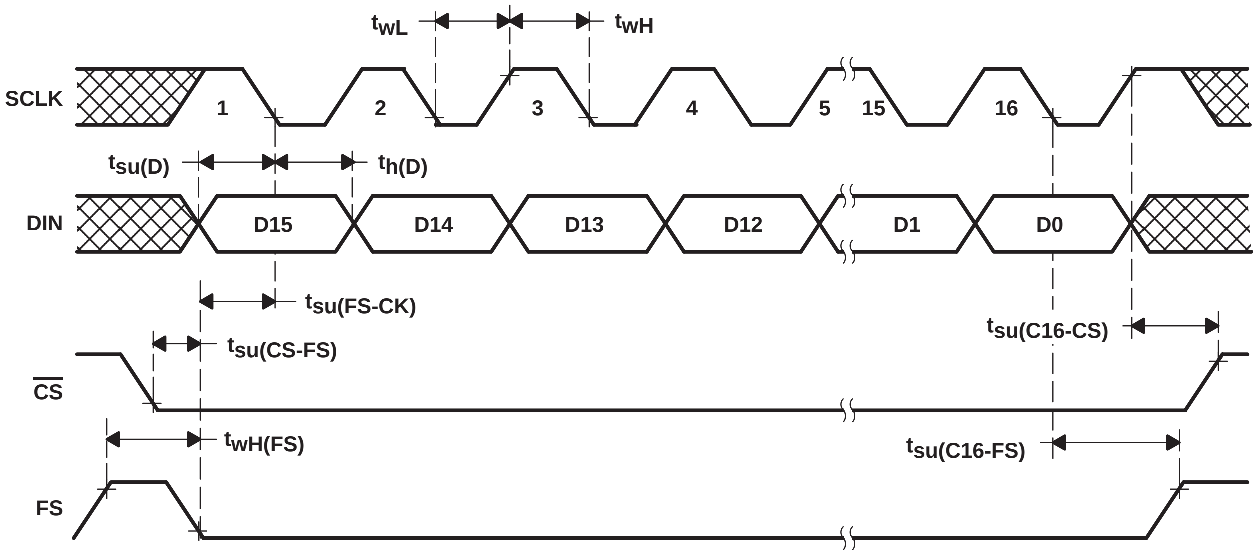


Figure 1. Timing Diagram

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE
vs
LOAD CURRENT

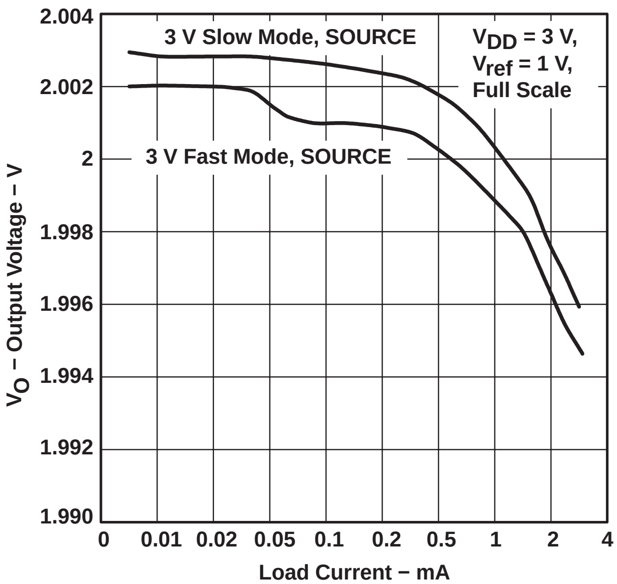


Figure 2

OUTPUT VOLTAGE
vs
LOAD CURRENT

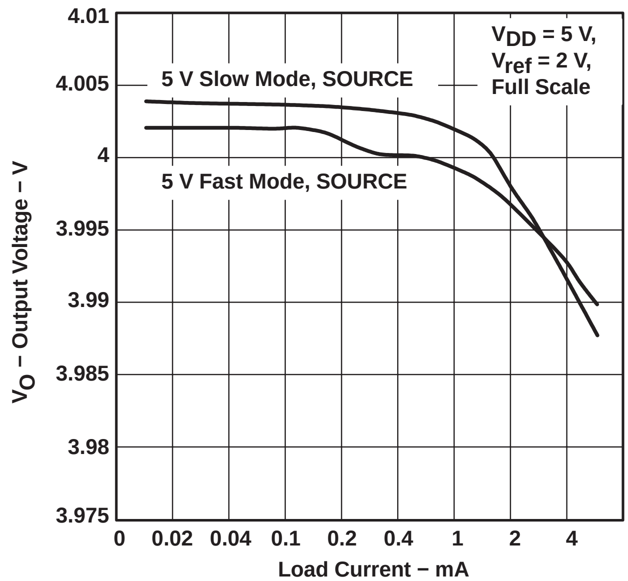


Figure 3

OUTPUT VOLTAGE
vs
LOAD CURRENT

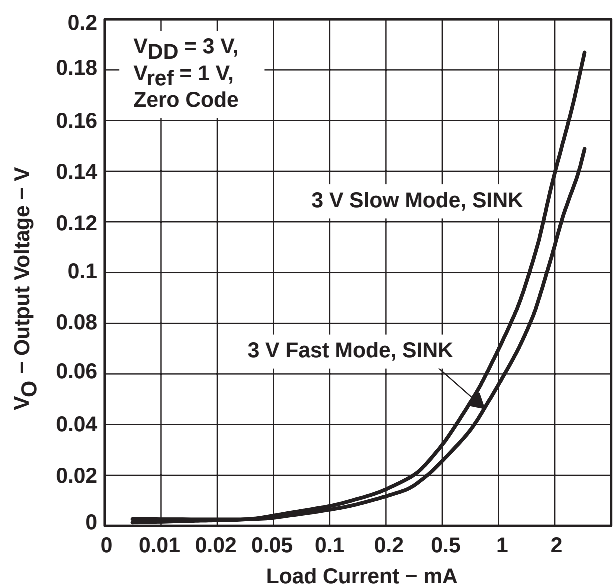


Figure 4

OUTPUT VOLTAGE
vs
LOAD CURRENT

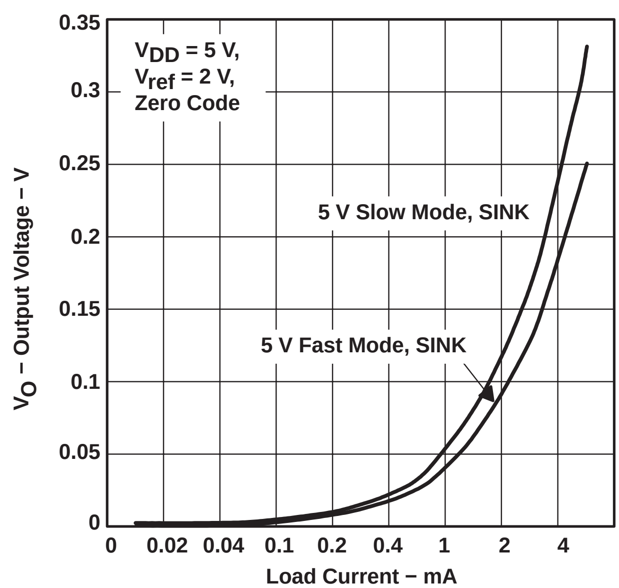


Figure 5

TYPICAL CHARACTERISTICS

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

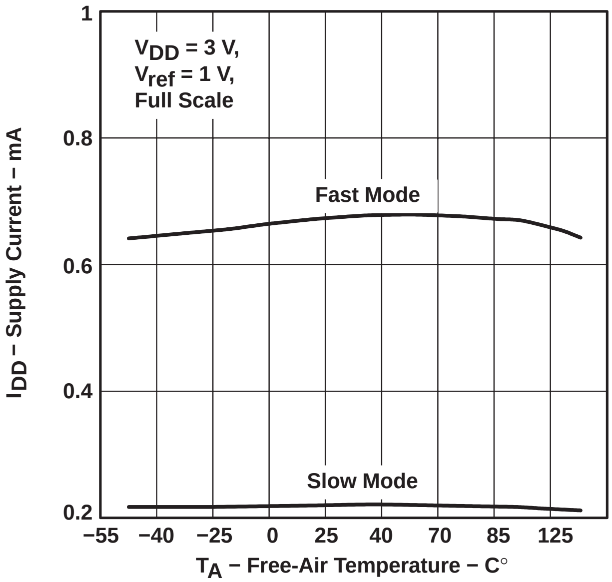


Figure 6

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

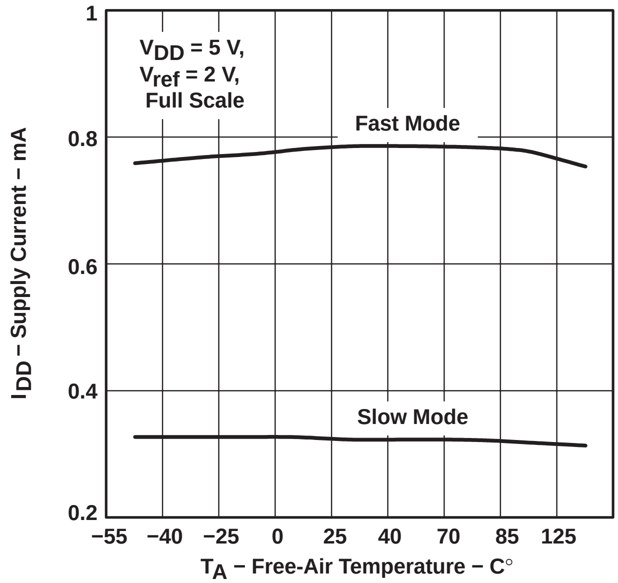


Figure 7

TOTAL HARMONIC DISTORTION vs FREQUENCY

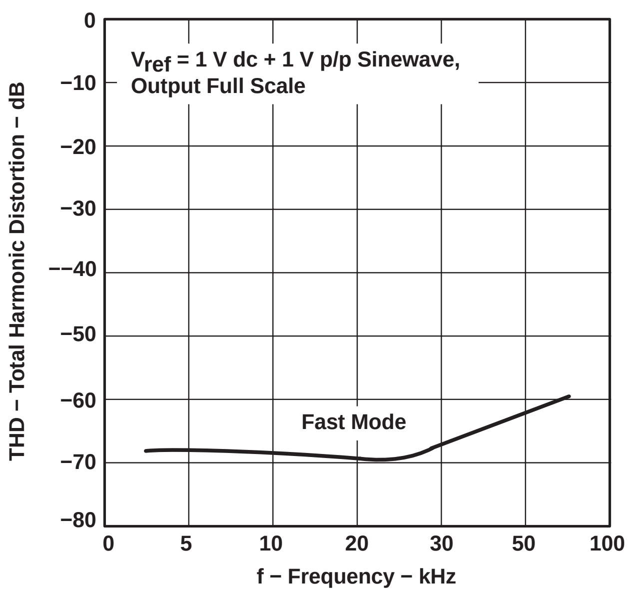


Figure 8

TOTAL HARMONIC DISTORTION vs FREQUENCY

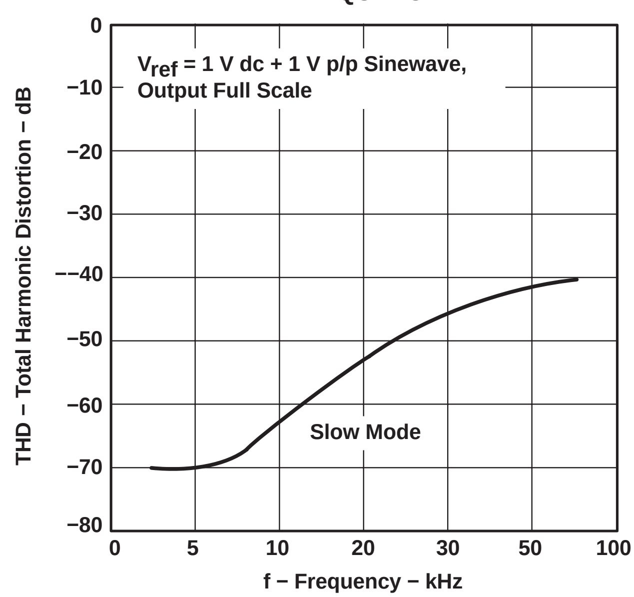


Figure 9

TYPICAL CHARACTERISTICS

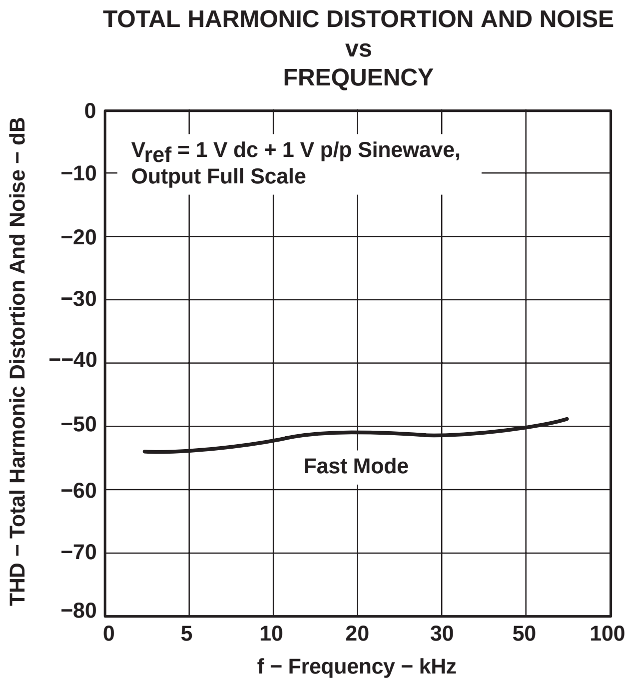


Figure 10

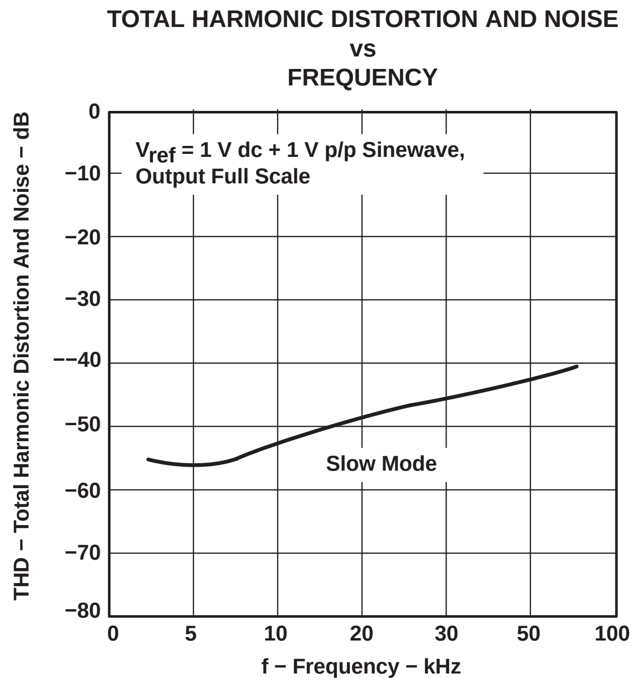


Figure 11

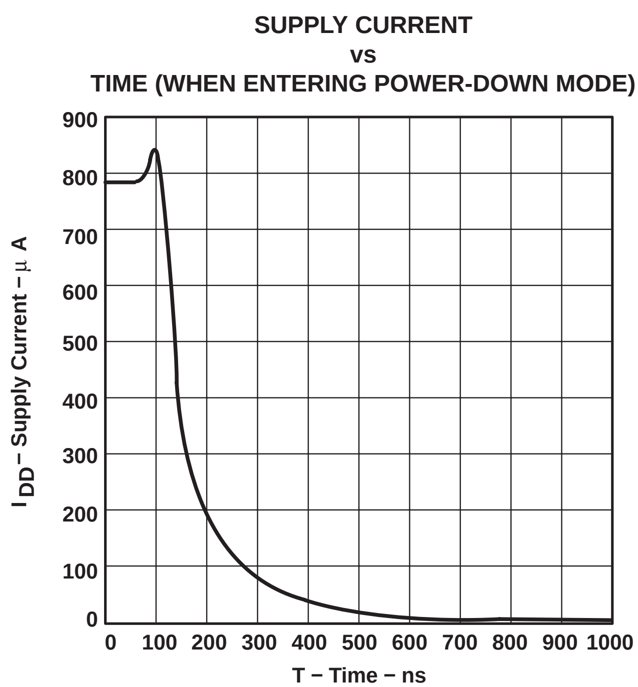


Figure 12

TYPICAL CHARACTERISTICS

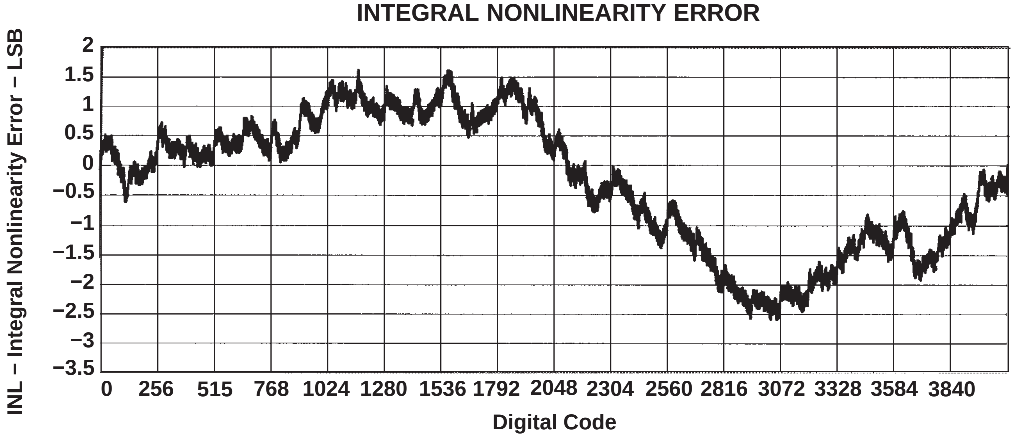


Figure 13

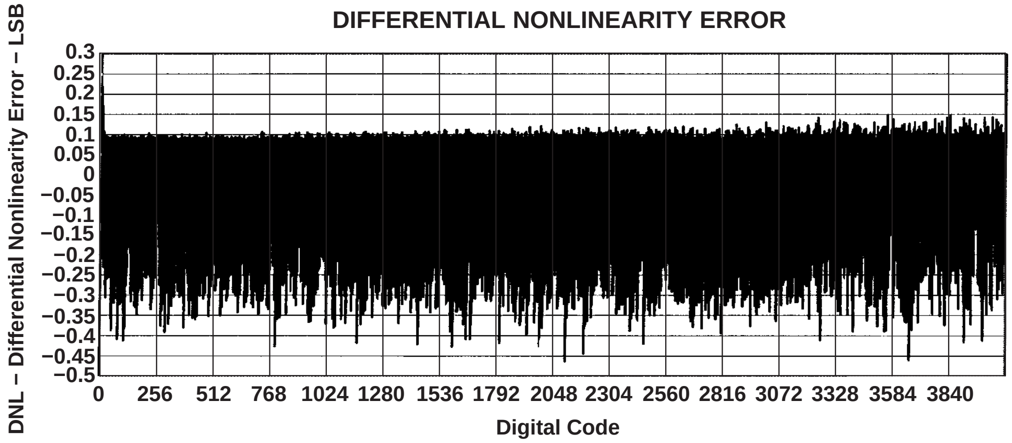


Figure 14

APPLICATION INFORMATION

general function

The TLV5616 is a 12-bit single supply DAC based on a resistor string architecture. The device consists of a serial interface, 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) is given by:

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

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

serial interface

Explanation of data transfer: First, the device has to be enabled with $\overline{CS}$ set to low. Then, a falling edge of FS 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 FS rises, the content of the shift register is moved to the DAC latch which updates the voltage output to the new level.

The serial interface of the TLV5616 can be used in two basic modes:

- Four wire (with chip select)
- Three wire (without chip select)

Using chip select (four wire mode), it is possible to have more than one device connected to the serial port of the data source (DSP or microcontroller). The interface is compatible with the TMS320 family. Figure 15 shows an example with two TLV5616s connected directly to a TMS320 DSP.

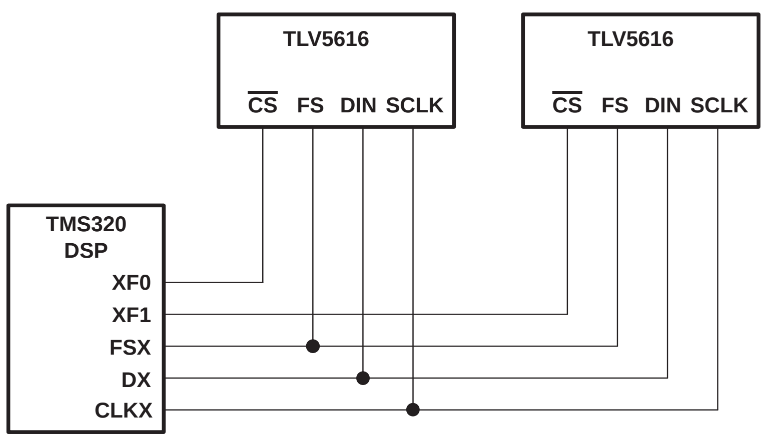


Figure 15. TMS320 Interface

APPLICATION INFORMATION

serial interface (continued)

If there is no need to have more than one device on the serial bus, then $\overline{CS}$ can be tied low. Figure 16 shows an example of how to connect the TLV5616 to a TMS320, SPI, or Microwire port using only three pins.

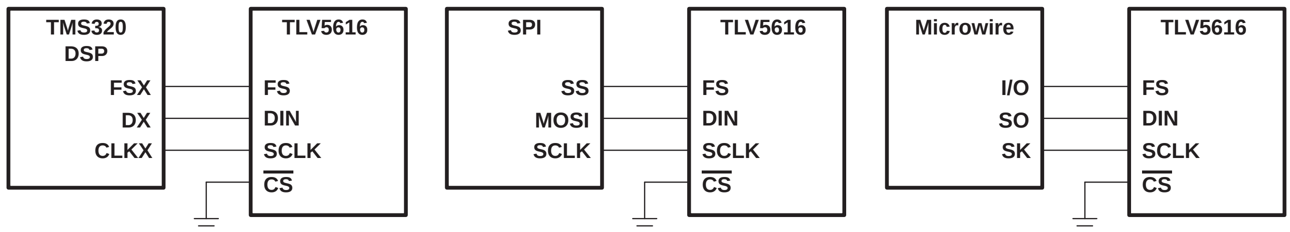


Figure 16. Three-Wire Interface

Notes on SPI and Microwire: Before the controller starts the data transfer, the software has to generate a falling edge on the I/O pin connected to FS. If the word width is 8 bits (SPI and Microwire), two write operations must be performed to program the TLV5616. After the write operation(s), the DAC output is updated automatically on the next positive clock edge following the sixteenth falling clock edge.

serial clock frequency and update rate

The maximum serial clock frequency is given by:

$$f_{SCLKmax} = \frac{1}{t_{wH(min)} + t_{wL(min)}} = 20\ \text{MHz}$$

The maximum update rate is:

$$f_{UPDATEmax} = \frac{1}{16\left(t_{wH(min)} + t_{wL(min)}\right)} = 1.25\ \text{MHz}$$

The maximum update rate is a theoretical value for the serial interface, since the settling time of the TLV5616 has to be considered also.

data format

The 16-bit data word for the TLV5616 consists of two parts:

- Control bits (D15 . . . D12)
- New DAC value (D11 . . . D0)

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	SPD	PWR	X	New DAC value (12 bits)											

X: don’t care
SPD: Speed control bit. 1 → fast mode 0 → slow mode
PWR: Power control bit. 1 → power down 0 → normal operation

In power-down mode, all amplifiers within the TLV5616 are disabled.

APPLICATION INFORMATION

TLV5616 interfaced to TMS320C203 DSP

hardware interfacing

Figure 17 shows an example how to connect the TLV5616 to a TMS320C203 DSP. The serial interface of the TLV5616 is ideally suited to this configuration, using a maximum of four wires to make the necessary connections. In applications where only one synchronous serial peripheral is used, the interface can be simplified even further by pulling $\overline{CS}$ low all the time as shown in the figure.

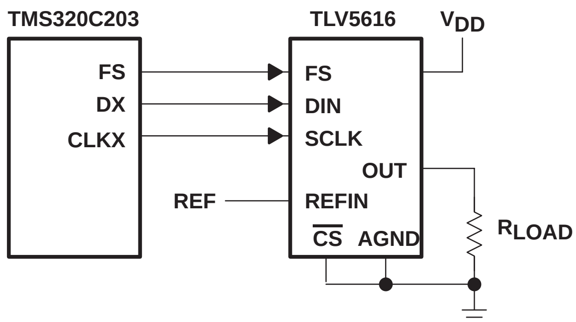


Figure 17. TLV5616 to DSP Interface

software

No setup procedure is needed to access the TLV5616. The output voltage can be set using just a single command.

```
out    data_addr, SDTR
```

where data_addr points to an address location holding the control bits and the 12 data bits providing the output voltage data. SDTR is the address of the transmit FIFO of the synchronous serial port.

The following code shows how to use the timer of the TMS320C203 as a time base to generate a voltage ramp with the TLV5616.

A timer interrupt is generated every 205 µs. The corresponding interrupt service routine increments the output code (stored at 0x0064) for the DAC, adds the DAC control bits to the four most significant bits, and writes the new code to the TLV5616. The resulting period of the saw waveform is:

$$\pi = 4096 \times 205 \text{ E-6 s} = 0.84 \text{ s}$$

```
;*******************************************************************************
;* Title   : Ramp generation with TLV5616                                       *
;* Version : 1.0                                                                *
;* DSP     : TI TMS320C203                                                      *
;* © (1998) Texas Instruments Incorporated                                      *
;*******************************************************************************

;----------- I/O and memory mapped regs ------------
       .include ”regs.asm”
;----------- vectors -------------------------------
       .ps       0h
        b        start
        b        INT1
        b        INT23
        b        TIM_ISR
```

APPLICATION INFORMATION

```
;*************************************************************************************
;* Main Program
;*************************************************************************************
       .ps       1000h
       .entry
start:
; disable interrupts
       setc      INTM        ; disable maskable interrupts
       splk      #0ffffh, IFR
       splk      #0004h, IMR

; set up the timer to interrupt ever 205uS
       splk      #0000h, 60h
       splk      #00FFh, 61h
       out       61h, PRD
       out       60h, TIM
       splk      #0c2fh, 62h
       out       62h, TCR
; Configure SSP to use internal clock, internal frame sync and burst mode
       splk      #0CC0Eh, 63h
       out       63h, SSPCR
       splk      #0CC3Eh, 63h
       out       63h, SSPCR

       splk      #0000h, 64h ; set initial DAC value

; enable interrupts
       clrc      INTM        ; enable maskable interrupts

; loop forever!
next:     idle               ;wait for interrupt
          b      next

; all else fails stop here
done:     b      done        ;hang there

;*************************************************************************************
;* Interrupt Service Routines
;*************************************************************************************
INT1:     ret                ;do nothing and return

INT23:    ret                ;do nothing and return

TIM_ISR:
          lacl   64h         ; restore counter value to ACC
          add    #1h         ; increment DAC value
          and    #0FFFh      ; mask 4 MSBs
          sacl   64h         ; store 12 bit counter value
          or     #4000h      ; set DAC control bits
          sacl   65h         ; store DAC value
          out    65h, SDTR   ; send data

          clrc   intm        ; re-enable interrupts
          ret
.END
```

APPLICATION INFORMATION

TLV5616 interfaced to MCS51® microcontroller

hardware interfacing

Figure 18 shows an example of how to connect the TLV5616 to an MCS51® compatible microcontroller. The serial DAC input data and external control signals are sent via I/O port 3 of the controller. The serial data is sent on the RxD line, with the serial clock output on the TxD line. P3.4 and P3.5 are configured as outputs to provide the chip select and frame sync signals for the TLV5616.

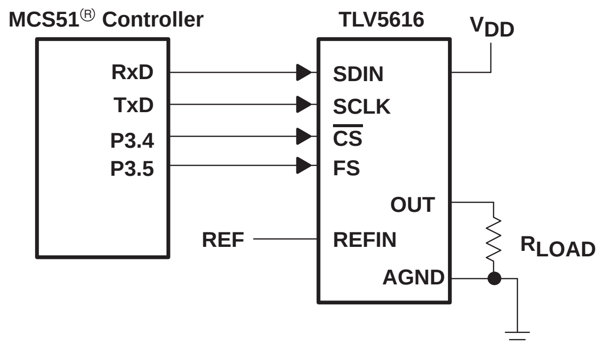


Figure 18. TLV5616 to MCS51® Controller Interface

software

The example program puts out a sine wave on the OUT pin.

The on-chip timer is used to generate interrupts at a fixed frequency. The related interrupt service routine fetches and writes the next sample to the DAC. The samples are stored in a lookup table, which describes one full period of a sine wave.

The serial port of the controller is used in mode 0, which transmits 8 bits of data on RxD, accompanied by a synchronous clock on TxD. Two writes concatenated together are required to write a complete word to the TLV5616. The CS and FS signals are provided in the required fashion through control of I/O port 3, which has bit addressable outputs.

```
;***************************************************************************************
;* Title   : Ramp generation with TLV5616                                              *
;* Version : 1.0                                                                       *
;* MCU     : INTEL MCS51®                                                              *
;* © (1998) Texas Instruments Incorporated                                             *
;***************************************************************************************

;---------------------------------------------------------------------------------------
; Program function declaration
;---------------------------------------------------------------------------------------

NAME   GENSINE

MAIN   SEGMENT       CODE
ISR    SEGMENT       CODE
SINTBL SEGMENT       CODE
VAR1   SEGMENT       DATA
STACK  SEGMENT       IDATA

;---------------------------------------------------------------------------------------
; Code start at address 0, jump to start
;---------------------------------------------------------------------------------------

   CSEG AT  0
```

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APPLICATION INFORMATION

```
   LJMP      start     ; Execution starts at address 0 on power-up.
;------------------------------------------------------------------------------------------
; Code in the timer0 interrupt vector
;------------------------------------------------------------------------------------------
   CSEG AT  0BH

   LJMP      timer0isr ; Jump vector for timer 0 interrupt is 000Bh
;------------------------------------------------------------------------------------------
; Define program variables
;------------------------------------------------------------------------------------------
   RSEG      VAR1

rolling_ptr: DS  1
;------------------------------------------------------------------------------------------
; Interrupt service routine for timer 0 interrupts
;------------------------------------------------------------------------------------------
   RSEG      ISR

timer0isr:

   PUSH      PSW
   PUSH      ACC

   CLR       T0                ; set CSB low
   CLR          T1             ; set FS low

   ; The signal to be output on the dac is a sine function. One cycle of a sine wave is
   ; held in a table @ sinevals as 32 samples of msb, lsb pairs (64 bytes). The pointer,
   ; rolling_ptr, rolls round the table of samples incrementing by 2 bytes (1 sample) on
   ; each interrupt (at the end of this routine).

   MOV       DPTR,#sinevals  ; set DPTR to the start of the table of sine signal values
   MOV       A,rolling_ptr   ; ACC loaded with the pointer into the sine table

   MOVC      A,@A+DPTR       ; get msb from the table
   ORL       A, #00H         ; set control bits
   MOV       SBUF,A          ; send out msb of data word

   MOVA,rolling_ptr; move rolling pointer in to ACC
   INC       A               ; increment ACC holding the rolling pointer
   MOVC      A,@A+DPTR       ; which is the lsb of this sample, now in ACC
MSB_TX:
   JNB       TI, MSB_TX      ; wait for transmit to complete
   CLR       TI              ; clear for new transmit
   MOV       SBUF,A          ; and send out the lsb
LSB_TX:
   JNB       TI, LSB_TX      ; wait for lsb transmit to complete
   SETB      T1              ; set FS = 1
   CLR       TI              ; clear for new transmit

   MOV   A,rolling_ptr       ; load ACC with rolling pointer
   INC   A                   ; increment the ACC twice, to get next sample
   INC   A
   ANL   A,#03FH             ; wrap back round to 0 if >64
   MOV   rolling_ptr,A       ; move value held in ACC back to the rolling pointer

   SETB  T0                  ; CSB high

   POP   ACC
   POP   PSW

   RETI
;----------------------------------------------------------------------------------
; Set up stack
;----------------------------------------------------------------------------------
```

APPLICATION INFORMATION

```
   RSEG   STACK
   DS     10h                 ; 16 Byte Stack!
;-----------------------------------------------------------------------------
; Main Program
;-----------------------------------------------------------------------------
   RSEG   MAIN

start:
   MOV    SP,#STACK-1   ; first set Stack Pointer

   CLR    A
   MOV    SCON,A        ; set serial port 0 to mode 0
   MOV    TMOD,#02H     ; set timer 0 to mode 2 - auto-reload
   MOV    TH0,#0C8H     ; set TH0 for 16.67 kHs interrupts

   SETB   T1            ; set FS = 1
   SETB   T0            ; set CSB = 1

   SETB   ET0           ; enable timer 0 interrupts
   SETB   EA            ; enable all interrupts

   MOV    rolling_ptr,A       ; set rolling pointer to 0
   SETB   TR0                 ; start timer 0

always:
   SJMP   always              ; while(1) !
   RET
;-----------------------------------------------------------------------------
; Table of 32 sine wave samples used as DAC data
;-----------------------------------------------------------------------------
   RSEG   SINTBL
sinevals:
   DW     01000H
   DW     0903EH
   DW     05097H
   DW     0305CH
   DW     0B086H
   DW     070CAH
   DW     0F0E0H
   DW     0F06EH
   DW     0F039H
   DW     0F06EH
   DW     0F0E0H
   DW     070CAH
   DW     0B086H
   DW     0305CH
   DW     05097H
   DW     0903EH
   DW     01000H
   DW     06021H
   DW     0A0E8H
   DW     0C063H
   DW     040F9H
   DW     080B5H
   DW     0009FH
   DW     00051H
   DW     00026H
   DW     00051H
   DW     0009FH
   DW     080B5H
   DW     040F9H
   DW     0C063H
   DW     0A0E8H
   DW     06021H
END
```

APPLICATION INFORMATION

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 19.

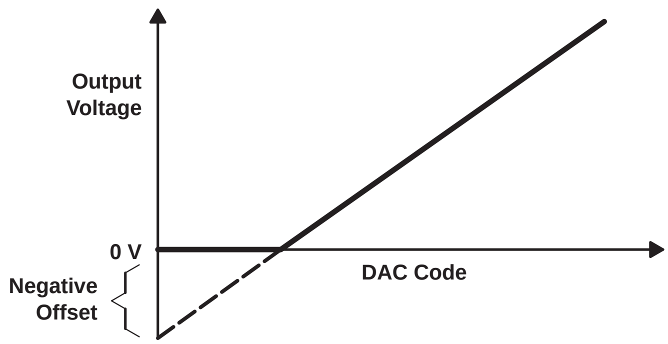

Figure 19. Effect of Negative Offset (Single Supply)

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.

power-supply bypassing and ground management

Printed-circuit boards that use separate analog and digital ground planes offer the best system performance. Wire-wrap boards do not perform well and should not be used. The two ground planes should be connected together at the low-impedance power-supply source. The best ground connection may be achieved by connecting the DAC AGND terminal to the system analog ground plane, making sure that analog ground currents are well managed and there are negligible voltage drops across the ground plane.

A 0.1-µF ceramic-capacitor bypass should be connected between V_{DD} and AGND and mounted with short leads as close as possible to the device. Use of ferrite beads may further isolate the system analog supply from the digital power supply.

Figure 20 shows the ground plane layout and bypassing technique.

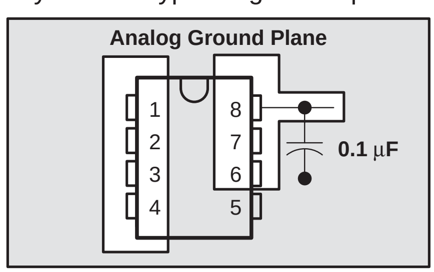

Figure 20. Power-Supply Bypassing

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.

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)

SFDR 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.

total harmonic distortion (THD)

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TLV5616CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDGK	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDGKG4	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616CP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV5616CPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV5616ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IDGK	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IDGKG4	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV5616IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV5616IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type

(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.

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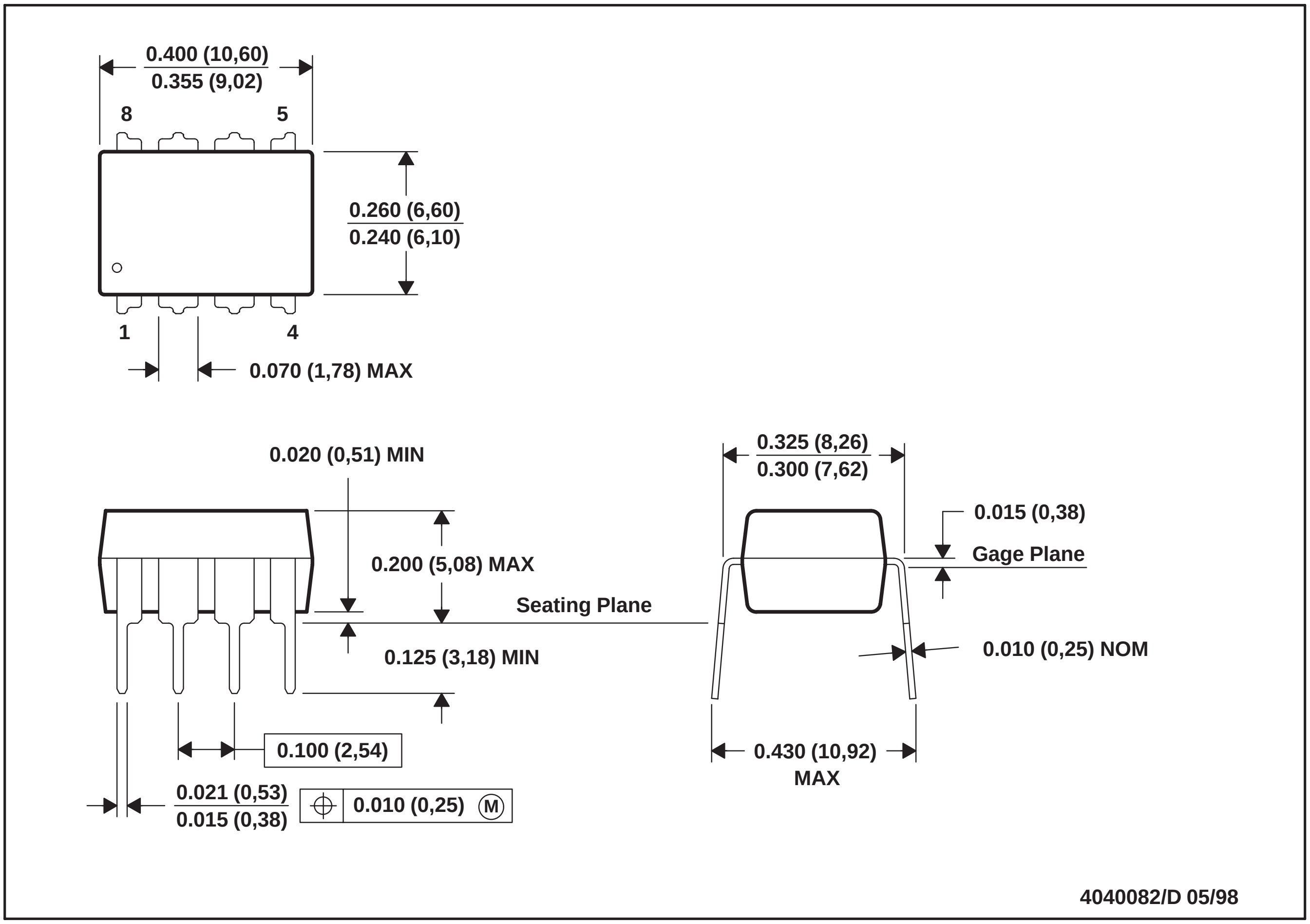
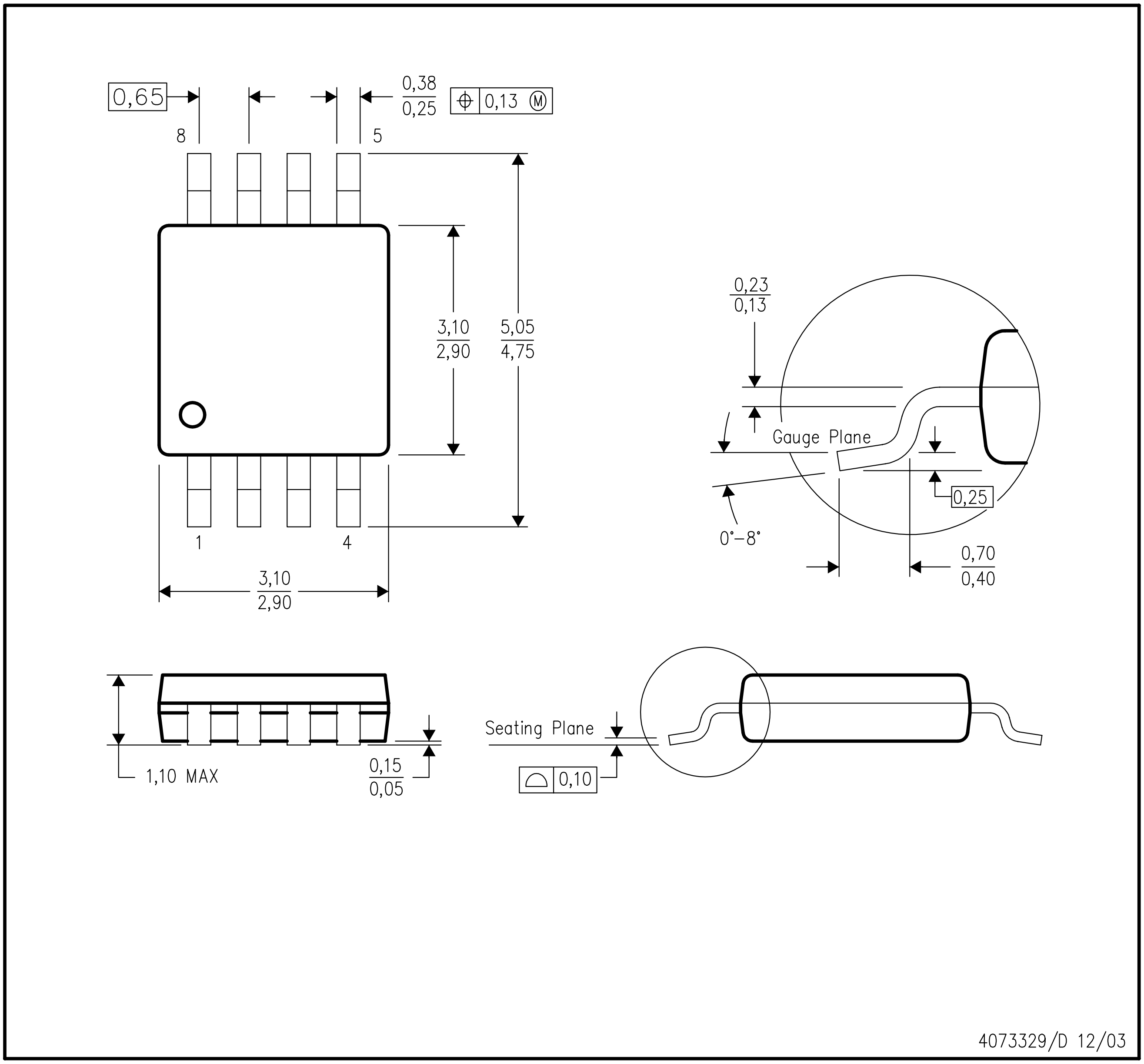
P (R-PDIP-T8) **PLASTIC DUAL-IN-LINE**



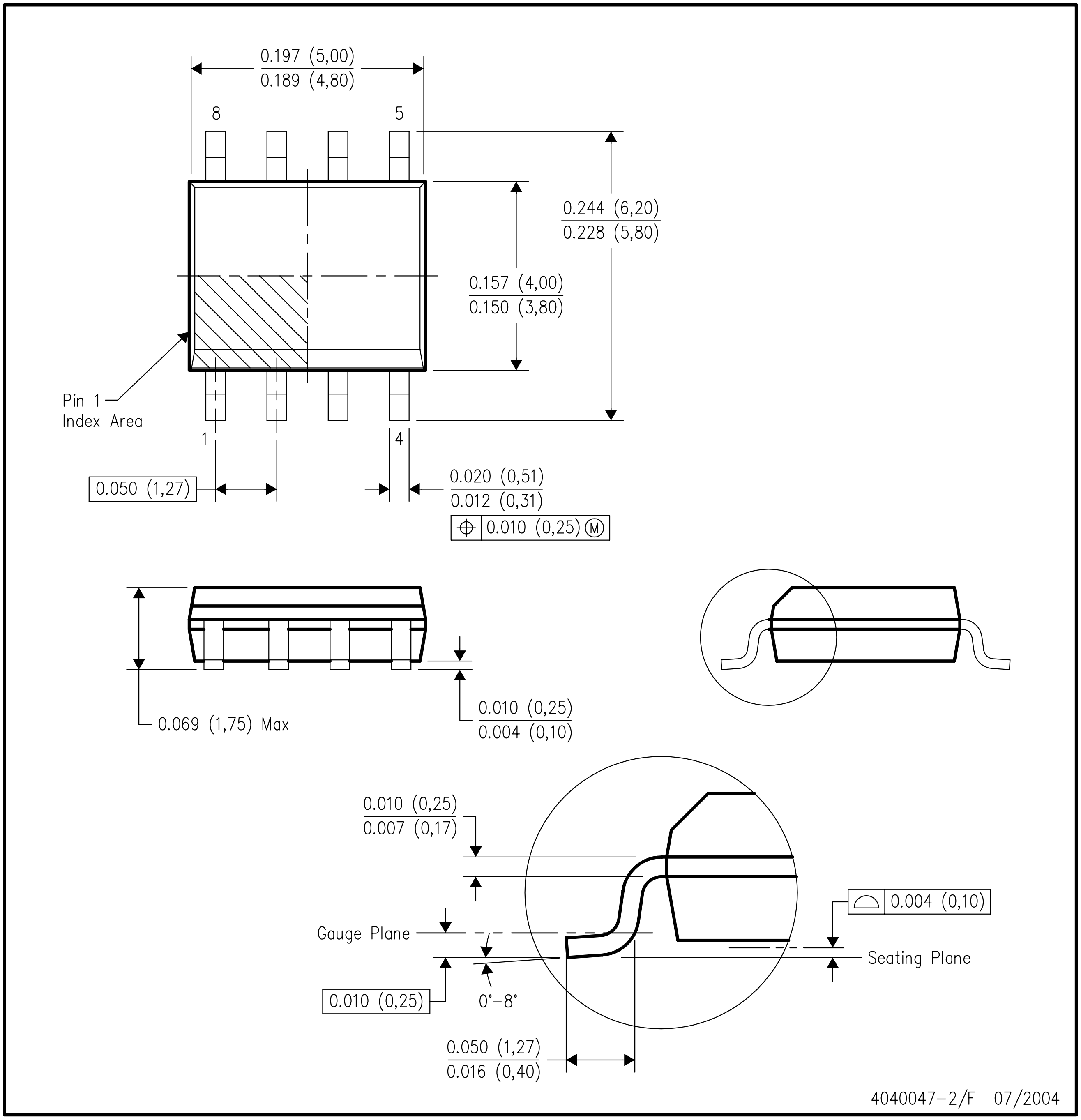
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

DGK (S-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE



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.
D. Falls within JEDEC MO-187 variation AA.

D (R–PDSO–G8) 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–012 variation AA.

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