



16-Bit, Serial Input Multiplying Digital-to-Analog Converter

FEATURES

- ± 0.5 LSB DNL
- 16-Bit Monotonic
- ± 1 LSB INL
- Low Noise: $12 \text{ nV}/\sqrt{\text{Hz}}$
- Low Power: $I_{\text{DD}} = 2 \mu\text{A}$
- +2.7 V to +5.5 V Analog Power Supply
- 2 mA Full-Scale Current $\pm 20\%$, with $V_{\text{REF}} = 10 \text{ V}$
- 50-MHz Serial Interface
- 0.5 μs Settling Time
- 4-Quadrant Multiplying Reference
- Reference Bandwidth: 10 MHz
- $\pm 10 \text{ V}$ Reference Input
- Reference Dynamics: -105 THD
- Tiny 8-Lead 3 x 3 mm SON and 3 x 5 mm MSOP Packages
- Industry-Standard Pin Configuration

APPLICATIONS

- Automatic Test Equipment
- Instrumentation
- Digitally Controlled Calibration
- Industrial Control PLCs

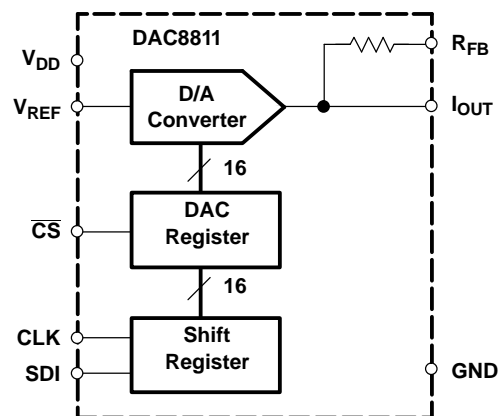
DESCRIPTION

The DAC8811 multiplying digital-to-analog converter (DAC) is designed to operate from a single 2.7-V to 5.5-V supply.

The applied external reference input voltage V_{REF} determines the full-scale output current. An internal feedback resistor (R_{FB}) provides temperature tracking for the full-scale output when combined with an external I-to-V precision amplifier.

A serial data interface offers high-speed, three-wire microcontroller-compatible inputs using data-in (SDI), clock (CLK), and chip-select ($\overline{\text{CS}}$).

The DAC8811 is packaged in space-saving 8-lead SON and MSOP packages.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION⁽¹⁾

| PRODUCT | MINIMUM RELATIVE ACCURACY (LSB) | DIFFERENTIAL NONLINEARITY (LSB) | PACKAGE-LEAD (DESIGNATOR) | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|----------|---------------------------------|---------------------------------|---------------------------|-----------------------------|-----------------|-----------------|---------------------------|
| DAC8811C | ±1 | ±1 | MSOP-8 (DGK) | -40°C to +85°C | D11 | DAC8811ICDGKT | Tape and Reel, 250 |
| DAC8811C | ±1 | ±1 | MSOP-8 (DGK) | -40°C to +85°C | D11 | DAC8811ICDGKR | Tape and Reel, 2500 |
| DAC8811C | ±1 | ±1 | SON-8 (DRB) | -40°C to +85°C | D11 | DAC8811ICDRBT | Tape and Reel, 250 |
| DAC8811C | ±1 | ±1 | SON-8 (DRB) | -40°C to +85°C | D11 | DAC8811ICDRBR | Tape and Reel, 2500 |
| DAC8811B | ±2 | ±1 | MSOP-8 (DGK) | -40°C to +85°C | D11 | DAC8811IBDGKT | Tape and Reel, 250 |
| DAC8811B | ±2 | ±1 | MSOP-8 (DGK) | -40°C to +85°C | D11 | DAC8811IBDGKR | Tape and Reel, 2500 |
| DAC8811B | ±2 | ±1 | SON-8 (DRB) | -40°C to +85°C | D11 | DAC8811IBDRBT | Tape and Reel, 250 |
| DAC8811B | ±2 | ±1 | SON-8 (DRB) | -40°C to +85°C | D11 | DAC8811IBDRBR | Tape and Reel, 2500 |

(1) For the most current specifications and package information, see the Package Option Addendum located at the end of this data sheet or refer to our web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

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

| | DAC8811 | UNIT |
|---|---|------|
| V_{DD} to GND | -0.3 to +7 | V |
| Digital input voltage to GND | -0.3 to $+V_{DD} + 0.3$ | V |
| $V(I_{OUT})$ to GND | -0.3 to $+V_{DD} + 0.3$ | V |
| Operating temperature range | -40 to +105 | °C |
| Storage temperature range | -65 to +150 | °C |
| Junction temperature range (T_J max) | +125 | °C |
| Power dissipation | $(T_J \text{ max} - T_A) / R_{\theta JA}$ | |
| Thermal impedance, $R_{\theta JA}$ | 55 | °C/W |
| Lead temperature, soldering | Vapor phase (60s) | 215 |
| Lead temperature, soldering | Infrared (15s) | 220 |
| ESD rating, HBM | 1500 | V |
| ESD rating, CDM | 1000 | V |

(1) Stresses above those listed under absolute maximum ratings may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

$V_{DD} = +2.7\text{ V to }+5.5\text{ V}$; $I_{OUT} = \text{Virtual GND}$, $\text{GND} = 0\text{ V}$; $V_{REF} = 10\text{ V}$; $T_A = \text{full operating temperature}$. All specifications -40°C to $+85^\circ\text{C}$, unless otherwise noted.

| PARAMETER | CONDITIONS | DAC8811 | | | UNITS |
|--|---|-------------------------|---------|---------|-----------------------|
| | | MIN | TYP | MAX | |
| STATIC PERFORMANCE⁽¹⁾ | | | | | |
| Resolution | | 16 | | | Bits |
| Relative accuracy | DAC8811C | | | ± 1 | LSB |
| Relative accuracy | DAC8811B | | | ± 2 | LSB |
| Differential nonlinearity | | | | ± 1 | LSB |
| Output leakage current | Data = 0000h, $T_A = +25^\circ\text{C}$ | | | 10 | nA |
| Output leakage current | Data = 0000h, $T_A = T_{MAX}$ | | | 10 | nA |
| Full-scale gain error | All ones loaded to DAC register | | ± 1 | ± 4 | mV |
| Full-scale tempco | | | ± 3 | | ppm/ $^\circ\text{C}$ |
| OUTPUT CHARACTERISTICS⁽²⁾ | | | | | |
| Output current | | | 2 | | mA |
| Output capacitance | Code dependent | | 50 | | pF |
| REFERENCE INPUT | | | | | |
| VREF Range | | -15 | | 15 | V |
| Input resistance | | | 5 | | k Ω |
| Input capacitance | | | 5 | | pF |
| LOGIC INPUTS AND OUTPUT⁽²⁾ | | | | | |
| Input low voltage | V_{IL} | $V_{DD} = +2.7\text{V}$ | | 0.6 | V |
| | V_{IL} | $V_{DD} = +5\text{V}$ | | 0.8 | V |
| Input high voltage | V_{IH} | $V_{DD} = +2.7\text{V}$ | 2.1 | | V |
| | V_{IH} | $V_{DD} = +5\text{V}$ | 2.4 | | V |
| Input leakage current | I_{IL} | | | 10 | μA |
| Input capacitance | C_{IL} | | | 10 | pF |
| INTERFACE TIMING | | | | | |
| Clock input frequency | f_{CLK} | | | 50 | MHz |
| Clock pulse width high | | 10 | | | ns |
| Clock pulse width low | | 10 | | | ns |
| $\overline{\text{CS}}$ to Clock setup time | | 0 | | | ns |
| Clock to $\overline{\text{CS}}$ hold time | | 10 | | | ns |
| Data setup time | | 5 | | | ns |
| Data hold time | | 10 | | | ns |
| POWER REQUIREMENTS | | | | | |
| V_{DD} | | 2.7 | | 5.5 | V |
| I_{DD} (normal operation) | Logic inputs = 0 V | | | 5 | μA |
| $V_{DD} = +4.5\text{V to }+5.5\text{V}$ | $V_{IH} = V_{DD}$ and $V_{IL} = \text{GND}$ | | 3 | 5 | μA |
| $V_{DD} = +2.7\text{V to }+3.6\text{V}$ | $V_{IH} = V_{DD}$ and $V_{IL} = \text{GND}$ | | 1 | 2.5 | μA |
| AC CHARACTERISTICS | | | | | |
| Output voltage settling time | | | 0.5 | | μs |
| Reference multiplying BW | $V_{REF} = 5\text{ V}_{PP}$, Data = FFFFh | | 10 | | MHz |
| DAC glitch impulse | $V_{REF} = 0\text{ V to }10\text{ V}$, Data = 7FFFh to 8000h to 7FFFh | | 2 | | nV/s |
| Feedthrough error V_{OUT}/V_{REF} | Data = 0000h, $V_{REF} = 100\text{kHz}$ | | -70 | | dB |
| Digital feedthrough | | | 2 | | nV/s |

(1) Linearity calculated using a reduced code range of 48 to 4047; output unloaded.

(2) Specified by design and characterization; not production tested.

ELECTRICAL CHARACTERISTICS (continued)

$V_{DD} = +2.7\text{ V to }+5.5\text{ V}$; $I_{OUT} = \text{Virtual GND}$, $GND = 0\text{ V}$; $V_{REF} = 10\text{ V}$; $T_A = \text{full operating temperature}$. All specifications -40°C to $+85^\circ\text{C}$, unless otherwise noted.

| PARAMETER | CONDITIONS | DAC8811 | | | UNITS |
|---------------------------|------------|---------|------|-----|------------------------------|
| | | MIN | TYP | MAX | |
| Total harmonic distortion | | | -105 | | dB |
| Output spot noise voltage | | | 12 | | $\text{nV}/\sqrt{\text{Hz}}$ |

PIN ASSIGNMENTS

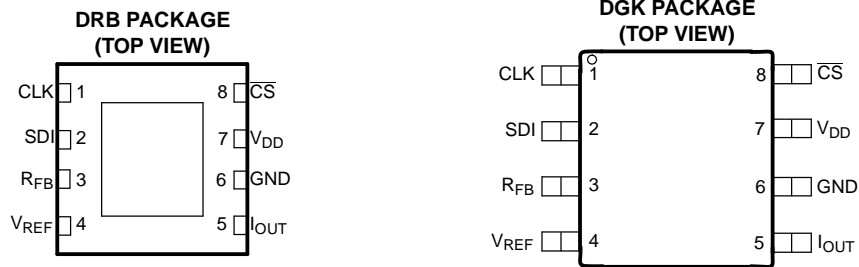


Table 1. TERMINAL FUNCTIONS

| PIN | NAME | DESCRIPTION |
|-----|-----------------|---|
| 1 | CLK | Clock input; positive edge triggered clocks data into shift register |
| 2 | SDI | Serial register input; data loads directly into the shift register MSB first. Extra leading bits are ignored. |
| 3 | R_{FB} | Internal matching feedback resistor. Connect to external op amp output. |
| 4 | V_{REF} | DAC reference input pin. Establishes DAC full-scale voltage. Constant input resistance versus code. |
| 5 | I_{OUT} | DAC current output. Connects to inverting terminal of external precision I/V op amp. |
| 6 | GND | Analog and digital ground. |
| 7 | V_{DD} | Positive power supply input. Specified operating range of 2.7 V to 5.5 V. |
| 8 | \overline{CS} | Chip-select; active low digital input. Transfers shift register data to DAC register on rising edge. See Table 2 for operation. |

TYPICAL CHARACTERISTICS: $V_{DD} = +5\text{ V}$

At $T_A = +25^\circ\text{C}$, $+V_{DD} = +5\text{ V}$, unless otherwise noted.

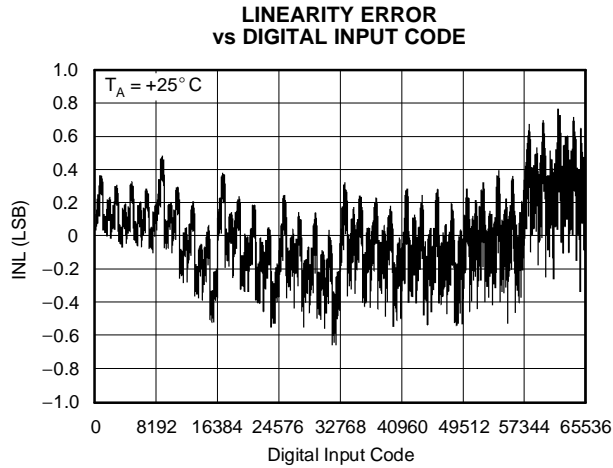


Figure 1.

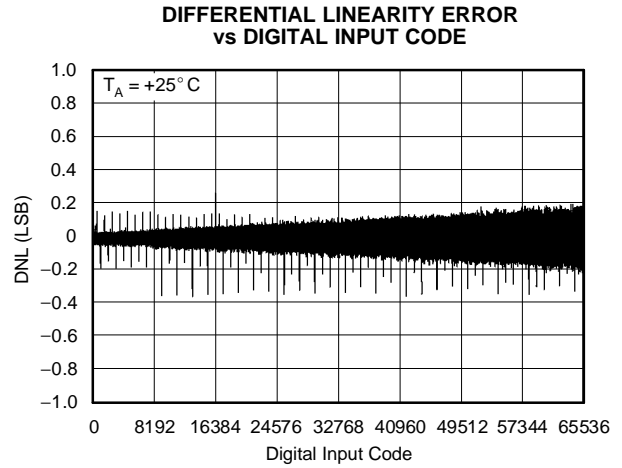


Figure 2.

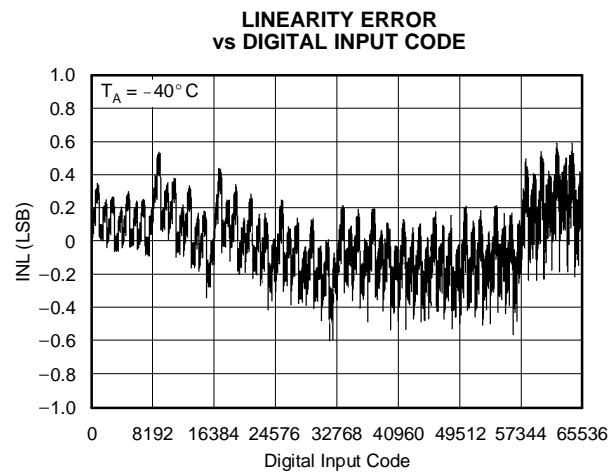


Figure 3.

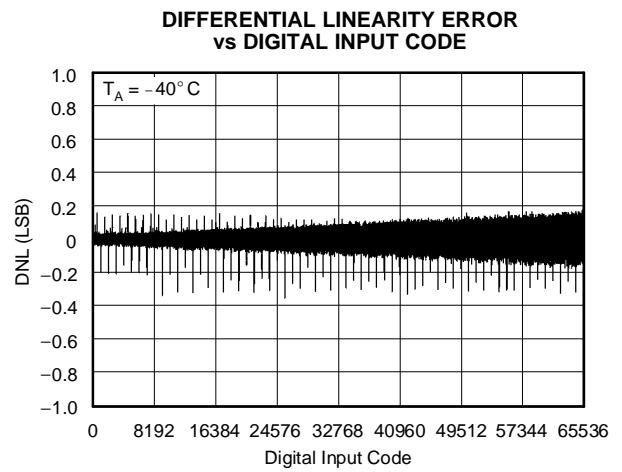


Figure 4.

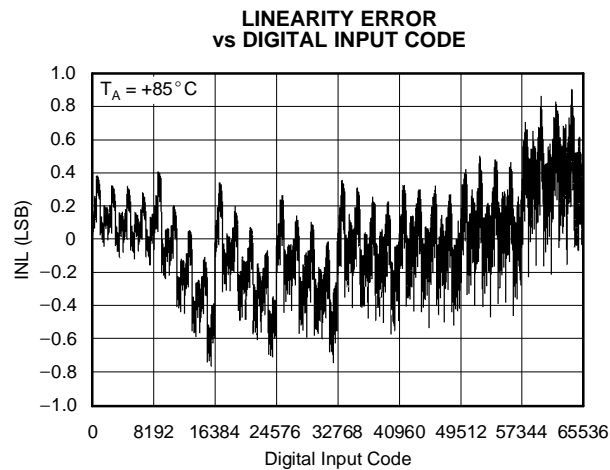


Figure 5.

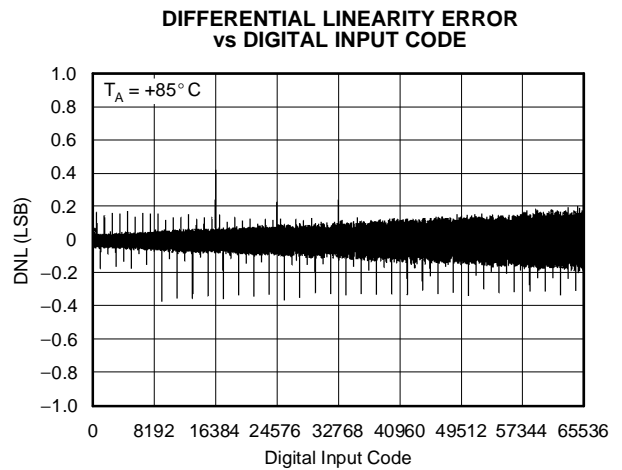


Figure 6.

TYPICAL CHARACTERISTICS: $V_{DD} = +5\text{ V}$ (continued)

At $T_A = +25^\circ\text{C}$, $+V_{DD} = +5\text{ V}$, unless otherwise noted.

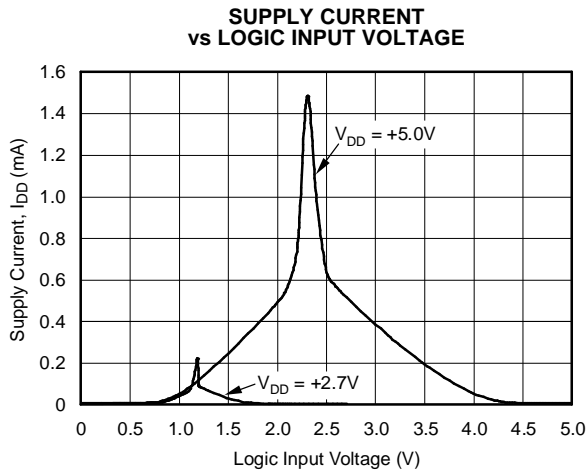


Figure 7.

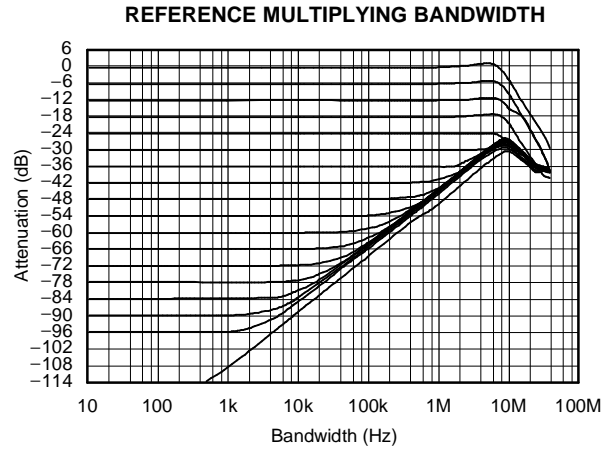


Figure 8.

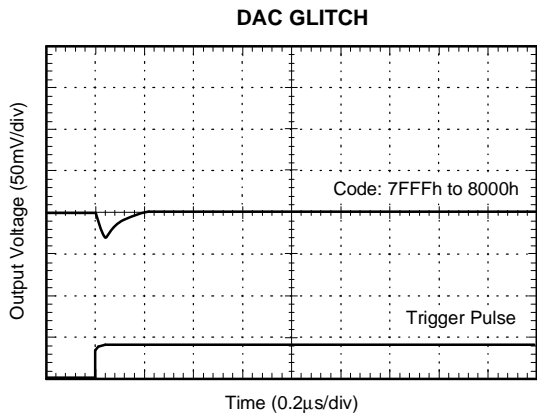


Figure 9.

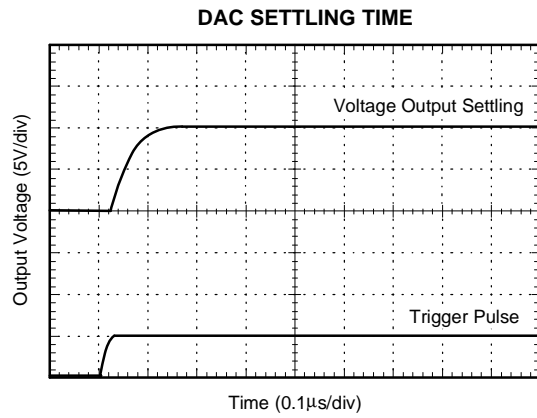


Figure 10.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7V$

At $T_A = +25^\circ C$, $+V_{DD} = +2.7V$, unless otherwise noted.

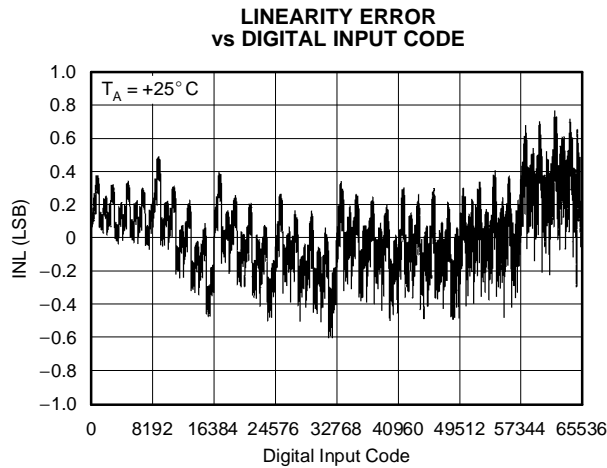


Figure 11.

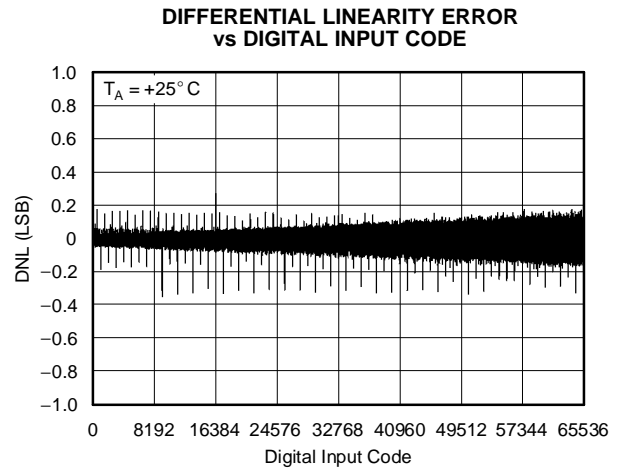


Figure 12.

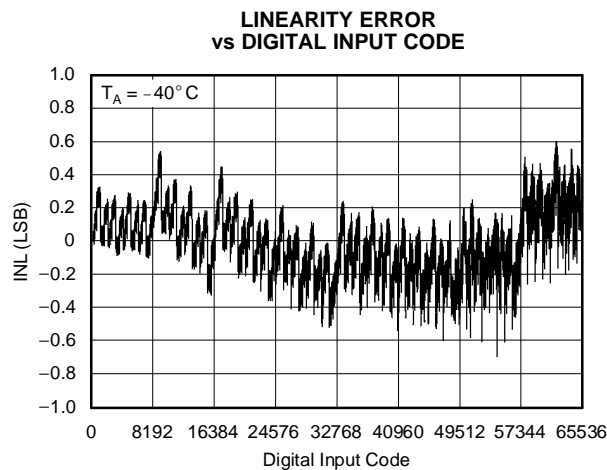


Figure 13.

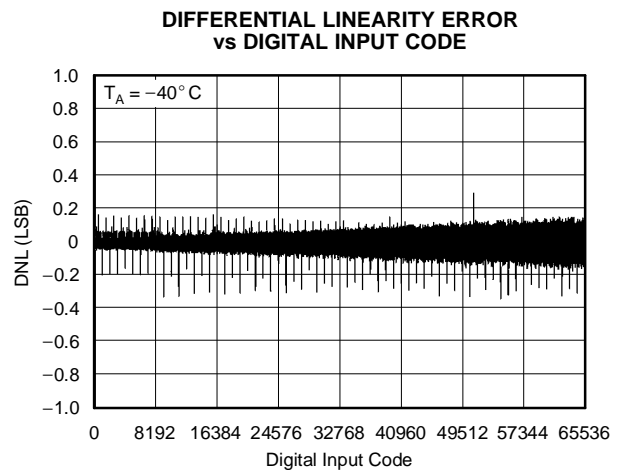


Figure 14.

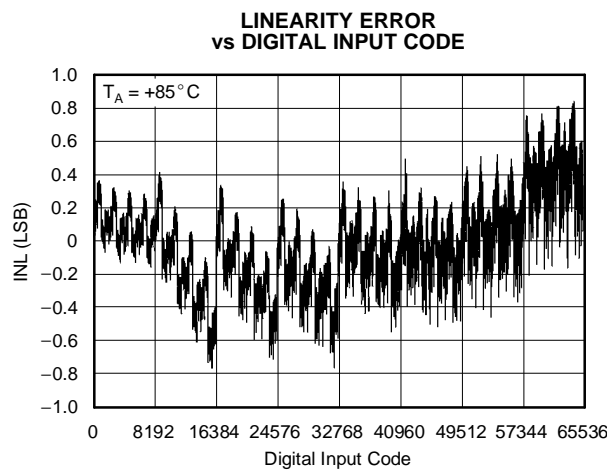


Figure 15.

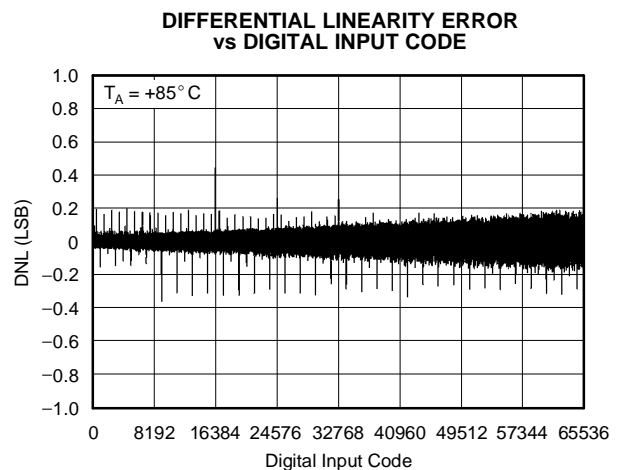


Figure 16.

THEORY OF OPERATION

The DAC8811 is a single channel current output, 16-bit digital-to-analog converter (DAC). The architecture, illustrated in Figure 17, is an R-2R ladder configuration with the three MSBs segmented. Each 2R leg of the ladder is either switched to GND or the I_{OUT} terminal. The I_{OUT} terminal of the DAC is held at a virtual GND potential by the use of an external I/V converter op amp. The R-2R ladder is connected to an external reference input V_{REF} that determines the DAC full-scale current. The R-2R ladder presents a code independent load impedance to the external reference of 5 kΩ ± 25%. The external reference voltage can vary in a range of -15 V to 15 V, thus providing bipolar I_{OUT} current operation. By using an external I/V converter and the DAC8811 R_{FB} resistor, output voltage ranges of -V_{REF} to V_{REF} can be generated.

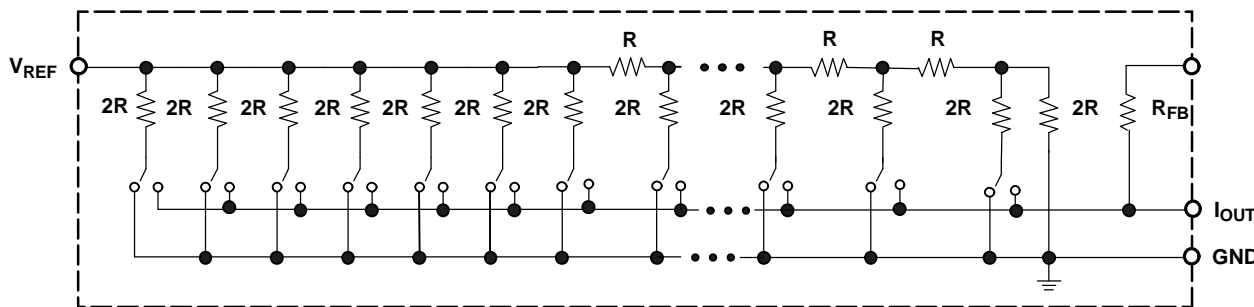


Figure 17. Equivalent R-2R DAC Circuit

When using an external I/V converter and the DAC8811 R_{FB} resistor, the DAC output voltage is given by Equation 1:

$$V_{OUT} = -V_{REF} \times \frac{CODE}{65536} \tag{1}$$

Each DAC code determines the 2R leg switch position to either GND or I_{OUT}. Because the DAC output impedance as seen looking into the I_{OUT} terminal changes versus code, the external I/V converter noise gain will also change. Because of this, the external I/V converter op amp must have a sufficiently low offset voltage such that the amplifier offset is not modulated by the DAC I_{OUT} terminal impedance change. External op amps with large offset voltages can produce INL errors in the transfer function of the DAC8811 due to offset modulation versus DAC code. For best linearity performance of the DAC8811, an op amp (OPA277) is recommended (Figure 18). This circuit allows V_{REF} swinging from -10 V to +10 V.

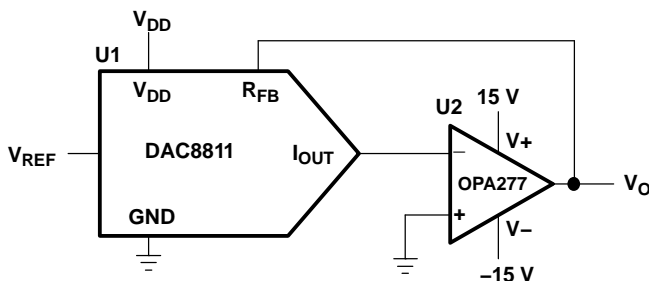


Figure 18. Voltage Output Configuration

THEORY OF OPERATION (continued)

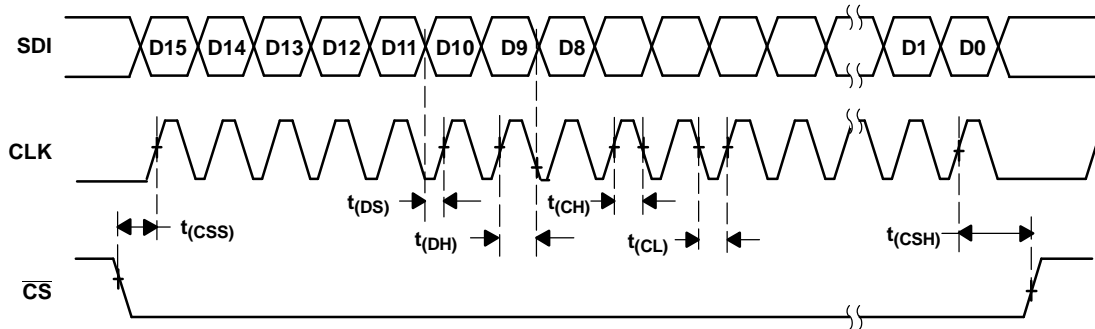


Figure 19. DAC8811 Timing Diagram

Table 2. Control Logic Truth Table⁽¹⁾

| CLK | \overline{CS} | Serial Shift Register | DAC Register |
|-------------|-----------------|---|--------------------------------------|
| X | H | No effect | Latched |
| $\uparrow+$ | L | Shift register data advanced one bit | Latched |
| X | H | No effect | Latched |
| X | $\uparrow+$ | Shift register data transferred to DAC register | New data loaded from serial register |

(1) $\uparrow+$ Positive logic transition; X = Don't care

Table 3. Serial Input Register Data Format, Data Loaded MSB First

| Bit | B15 (MSB) | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 (LSB) |
|------|-----------|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----------|
| Data | D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

APPLICATION INFORMATION

Stability Circuit

For a current-to-voltage design (see Figure 20), the DAC8811 current output (I_{OUT}) and the connection with the inverting node of the op amp should be as short as possible and according to correct PCB layout design. For each code change there is a step function. If the GBP of the op amp is limited and parasitic capacitance is excessive at the inverting node then gain peaking is possible. Therefore, for circuit stability, a compensation capacitor C1 (4 pF to 20 pF typ) can be added to the design, as shown in Figure 20.

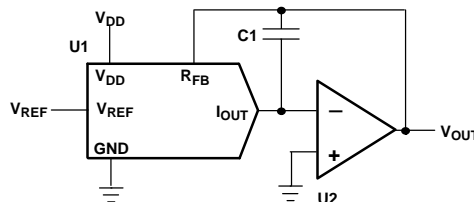


Figure 20. Gain Peaking Prevention Circuit With Compensation Capacitor

Positive Voltage Output Circuit

As Figure 21 illustrates, in order to generate a positive voltage output, a negative reference is input to the DAC8811. This design is suggested instead of using an inverting amp to invert the output due to tolerance errors of the resistor. For a negative reference, V_{OUT} and GND of the reference are level-shifted to a virtual ground and a -2.5 V input to the DAC8811 with an op amp.

APPLICATION INFORMATION (continued)

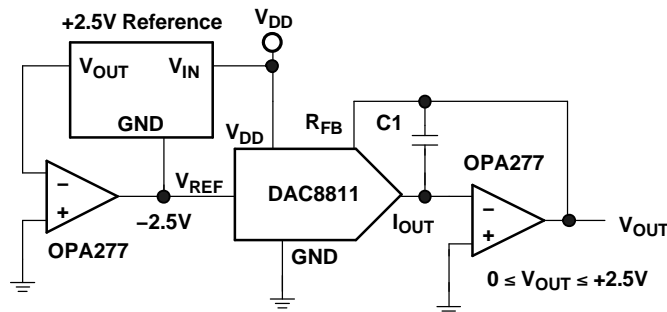


Figure 21. Positive Voltage Output Circuit

Bipolar Output Circuit

The DAC8811, as a 2-quadrant multiplying DAC, can be used to generate a unipolar output. The polarity of the full-scale output I_{OUT} is the inverse of the input reference voltage at V_{REF} .

Some applications require full 4-quadrant multiplying capabilities or bipolar output swing. As shown in Figure 22, external op amp U4 is added as a summing amp and has a gain of 2X that widens the output span to 5 V. A 4-quadrant multiplying circuit is implemented by using a 2.5-V offset of the reference voltage to bias U4. According to the circuit transfer equation given in Equation 2, input data (D) from code 0 to full scale produces output voltages of $V_{OUT} = -2.5\text{ V}$ to $V_{OUT} = +2.5\text{ V}$.

$$V_{OUT} = \left(\frac{D}{32,768} - 1 \right) \times V_{REF} \tag{2}$$

External resistance mismatching is the significant error in Figure 22.

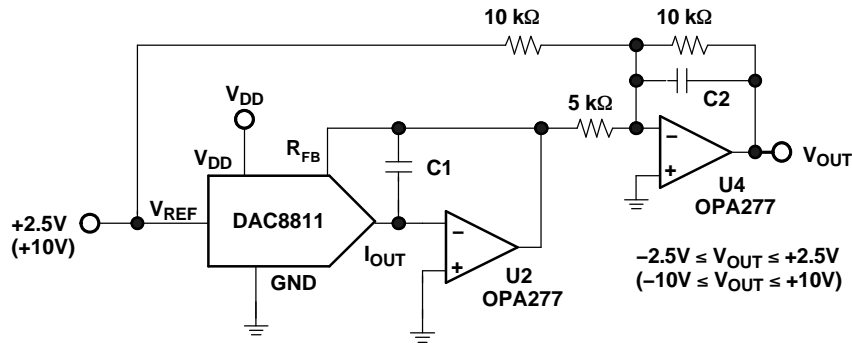


Figure 22. Bipolar Output Circuit

Programmable Current Source Circuit

A DAC8811 can be integrated into the circuit in Figure 23 to implement an improved Howland current pump for precise voltage to current conversions. Bidirectional current flow and high voltage compliance are two features of the circuit. With a matched resistor network, the load current of the circuit is shown by Equation 3:

$$I_L = \frac{(R2 + R3) / R1}{R3} \times V_{REF} \times D \tag{3}$$

The value of R_3 in the previous equation can be reduced to increase the output current drive of U_3 . U_3 can drive ± 20 mA in both directions with voltage compliance limited up to 15 V by the U_3 voltage supply. Elimination of the circuit compensation capacitor C_1 in the circuit is not suggested as a result of the change in the output impedance Z_o , according to Equation 4:

$$Z_o = \frac{R_1' R_3 (R_1 + R_2)}{R_1 (R_2' + R_3') - R_1' (R_2 + R_3)} \quad (4)$$

As shown in Equation 4, with matched resistors, Z_o is infinite and the circuit is optimum for use as a current source. However, if unmatched resistors are used, Z_o is positive or negative with negative output impedance being a potential cause of oscillation. Therefore, by incorporating C_1 into the circuit, possible oscillation problems are eliminated. The value of C_1 can be determined for critical applications; for most applications, however, a value of several pF is suggested.

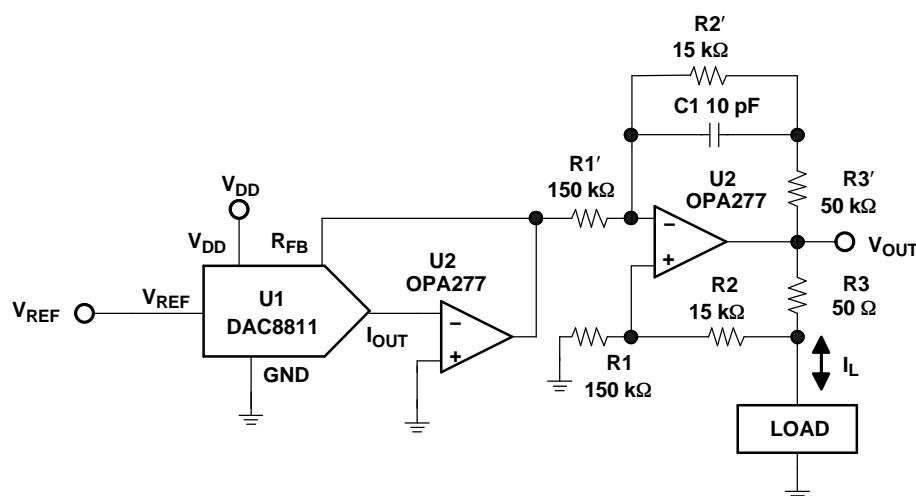


Figure 23. Programmable Bidirectional Current Source Circuit

Cross-Reference

The DAC8811 has an industry-standard pinout. Table 4 provides the cross-reference information.

Table 4. Cross-Reference

| PRODUCT | INL (LSB) | DNL (LSB) | SPECIFIED TEMPERATURE RANGE | PACKAGE DESCRIPTION | PACKAGE OPTION | CROSS-REFERENCE PART |
|--------------|-----------|-----------|-----------------------------|----------------------|----------------|----------------------|
| DAC8811ICDGK | ± 1 | ± 1 | -40°C to +85°C | 8-Lead MicroSOIC | MSOP-8 | N/A |
| DAC8811IBDGK | ± 2 | ± 1 | -40°C to +85°C | 8-Lead MicroSOIC | MSOP-8 | AD5543BRM |
| DAC8811ICDRB | ± 1 | ± 1 | -40°C to +85°C | 8-Lead Small Outline | SON-8 | N/A |
| DAC8811IBDRD | ± 2 | ± 1 | -40°C to +85°C | 8-Lead Small Outline | SON-8 | N/A |
| N/A | ± 2 | ± 1 | -40°C to +85°C | 8-Lead SOIC | SOIC-8 | AD5543BR |

PACKAGING INFORMATION

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| DAC8811BDGKR | ACTIVE | MSOP | DGK | 8 | 2500 | None | Call TI | Call TI |
| DAC8811BDGKT | ACTIVE | MSOP | DGK | 8 | 250 | None | Call TI | Call TI |
| DAC8811BDRBR | ACTIVE | SON | DRB | 8 | 3000 | None | Call TI | Call TI |
| DAC8811BDRBT | ACTIVE | SON | DRB | 8 | 250 | None | Call TI | Call TI |
| DAC8811ICDGKR | ACTIVE | MSOP | DGK | 8 | 2500 | None | Call TI | Call TI |
| DAC8811ICDGKT | ACTIVE | MSOP | DGK | 8 | 250 | None | Call TI | Call TI |
| DAC8811ICDRBR | ACTIVE | SON | DRB | 8 | 3000 | None | Call TI | Call TI |
| DAC8811ICDRBT | ACTIVE | SON | DRB | 8 | 250 | None | Call TI | Call TI |

⁽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 - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

None: Not yet available Lead (Pb-Free).

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.

Green (RoHS & no Sb/Br): TI defines "Green" to mean "Pb-Free" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

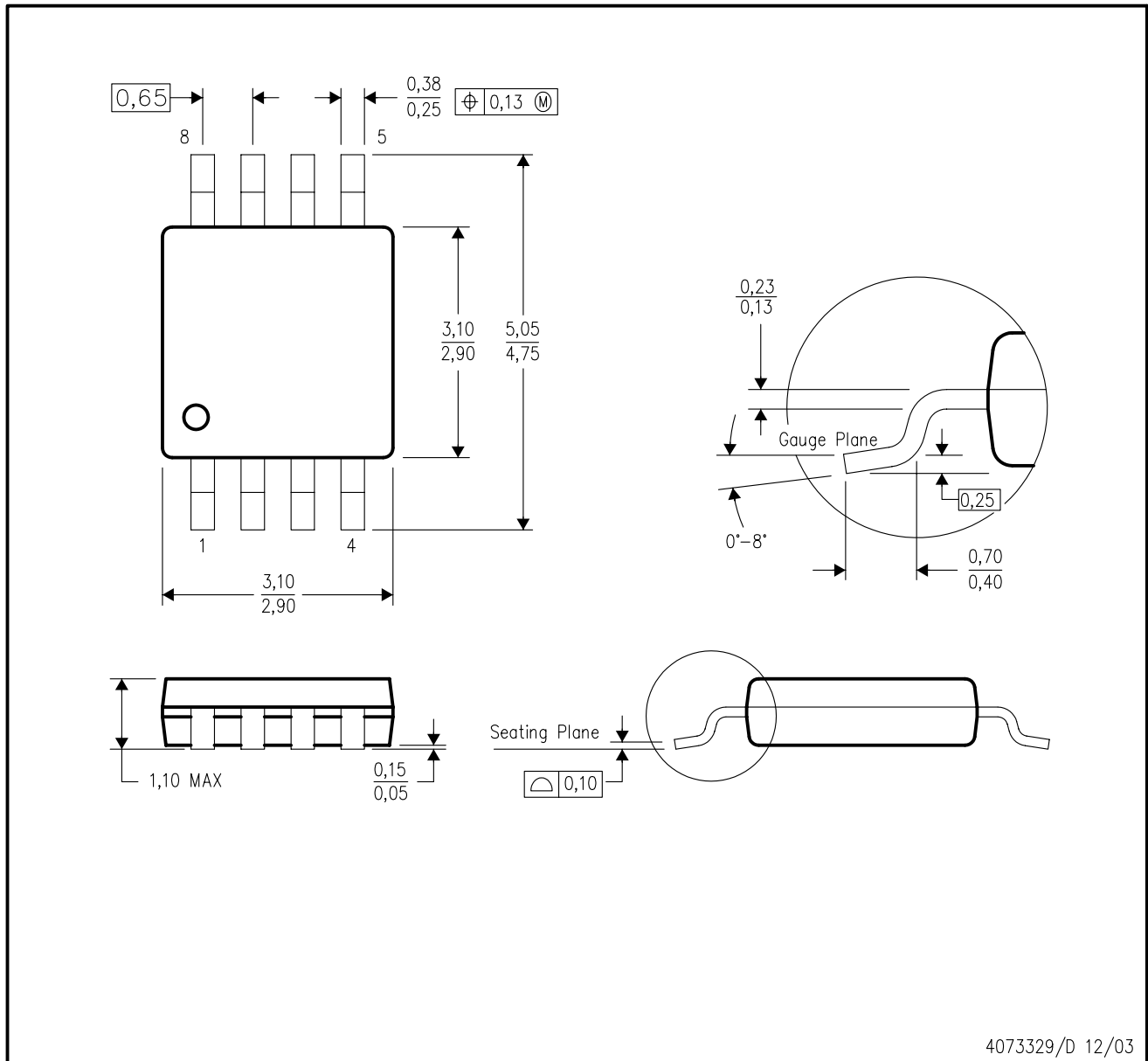
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

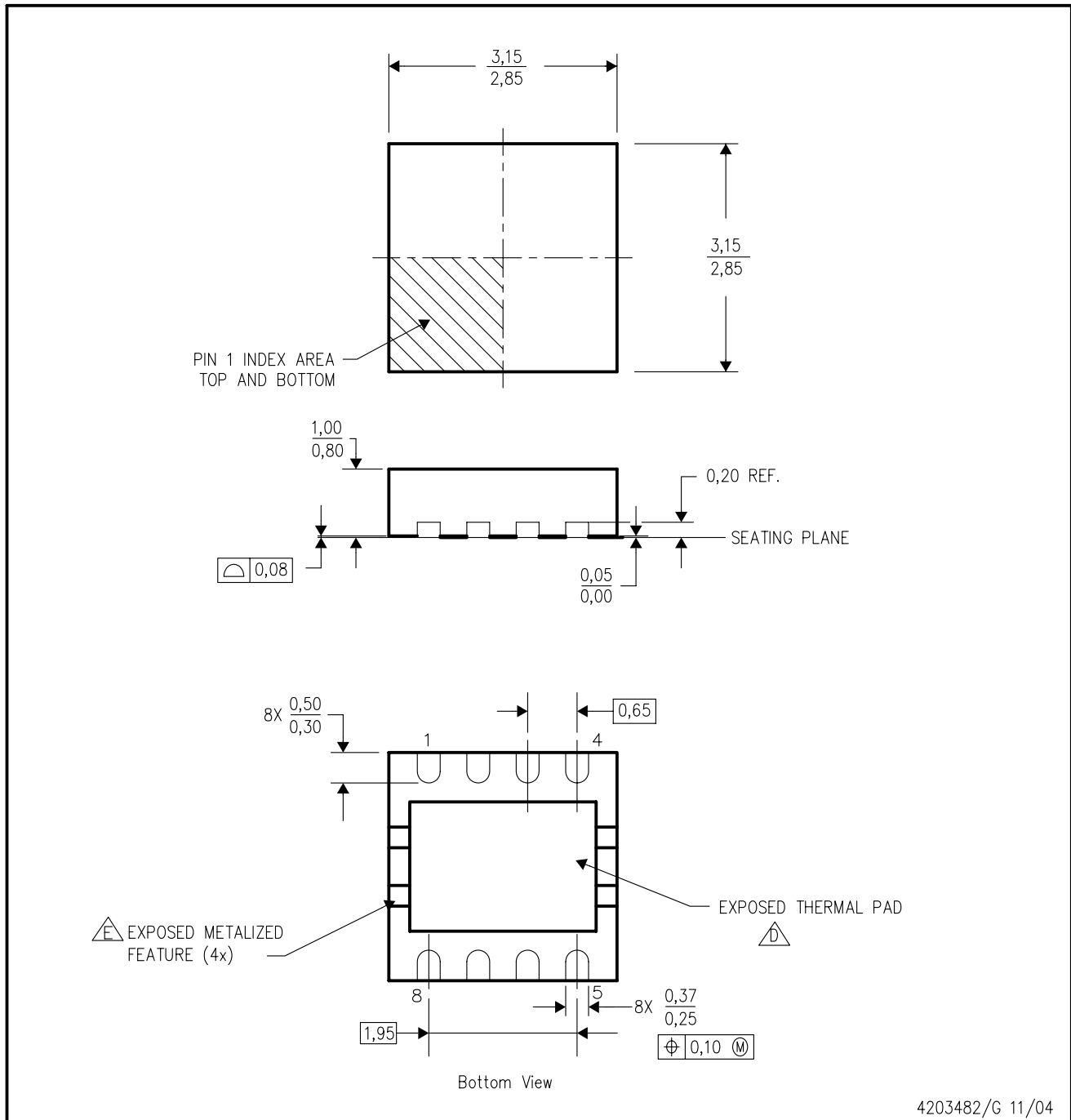




4073329/D 12/03

- 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.

DRB (S-PDSO-N8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Small Outline No-Lead (SON) package configuration.
 -  The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
 -  Metalized features are supplier options and may not be on the package.

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

Copyright © 2004, Texas Instruments Incorporated