



Quad, Current Output, Serial Input 14-Bit Multiplying Digital-to-Analog Converter

FEATURES

- Relative Accuracy: 1 LSB Max
- Differential Nonlinearity: 1 LSB Max
- 2-mA Full-Scale Current $\pm 20\%$, With $V_{REF} = \pm 10\text{ V}$
- 0.5- μs Settling Time
- Midscale or Zero-Scale Reset
- Four Separate 4-Quadrant Multiplying Reference Inputs
- Reference Bandwidth: 10 MHz
- Reference Dynamics: -105 dB THD
- 50-MHz SPI™-Compatible 3-Wire Interface
- Double Buffered Registers Enable
- Simultaneous Multichannel Update
- Internal Power On Reset
- Compact SSOP-28 Package
- Industry-Standard Pin Configuration

APPLICATIONS

- Automatic Test Equipment
- Instrumentation
- Digitally Controlled Calibration

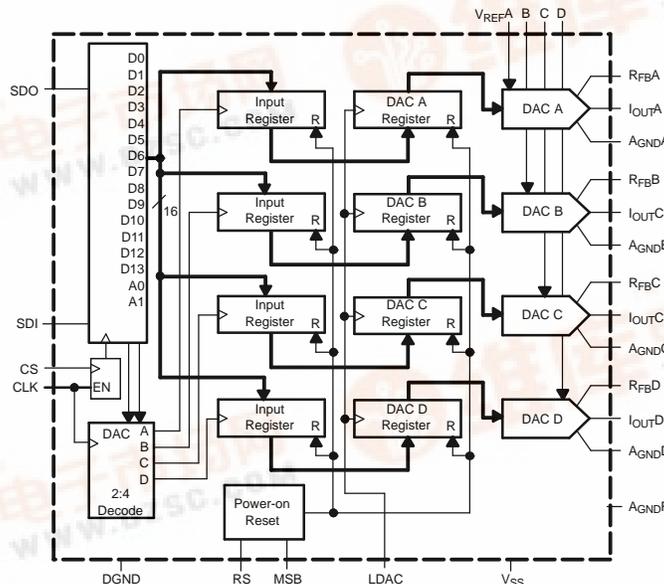
DESCRIPTION

The DAC8803 is a quad, 14-bit, current-output digital-to-analog converter (DAC) designed to operate from a single 2.7 V to 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 doubled buffered serial data interface offers high-speed, 3-wire, SPI and microcontroller compatible inputs using serial data in (SDI), clock (CLK), and a chip select (\overline{CS}). In addition, a serial data out pin (SDO) allows for daisy chaining when multiple packages are used. A common level-sensitive load DAC strobe (LDAC) input allows simultaneous update of all DAC outputs from previously loaded input registers. Additionally, an internal power on reset forces the output voltage to zero at system turn on. An MSB pin allows system reset assertion (\overline{RS}) to force all registers to zero code when MSB = 0, or to half-scale code when MSB = 1.

The DAC8803 is packaged in a SSOP package.



PRODUCT PREVIEW

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.

SPI is a trademark of Motorola, Inc.

All trademarks are the property of their respective owners.



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) | SPECIFIED TEMPERATURE RANGE | PACKAGE-LEAD | PACKAGE DESIGNATOR | ORDERING NUMBER | TRANSPORT MEDIA QUANTITY |
|---------|---------------------------------|---------------------------------|-----------------------------|--------------|--------------------|-----------------|--------------------------|
| DAC8803 | ±1 | ±1 | -40°C to +85°C | SSOP-28 | DB | DAC8803IDBT | Tape and Reel, 250 |
| | | | | | | DAC8803IDBR | Tape and Reel, 2500 |

(1) For the most current specifications and package information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

| | DAC8803 | UNIT |
|---|---|----------|
| V _{DD} to GND | -0.3 to +8 | V |
| V _{SS} to GND | -0.3 to -7 | V |
| V _{REF} to GND | -18 to +18 | V |
| Logic inputs and output to GND | -0.3 to +8 | V |
| V(I _{OUT}) to GND | -0.3 to V _{DD} + 0.3 | V |
| A _{GNDX} to DGND | -0.3 to +0.3 | V |
| Input current to any pin except supplies | ±50 | mA |
| Package power dissipation | (T _{Jmax} - T _A)/θ _{JA} | |
| Thermal resistance, θ _{JA} | 28-Lead shrink surface-mount (RS-28) | 100 °C/W |
| Maximum junction temperature (T _{Jmax}) | 150 | °C |
| Operating temperature range, Model A | -40 to +85 | °C |
| Storage temperature range | -65 to +150 | °C |
| Lead temperature | RS-28 (Vapor phase 60s) | 215 °C |
| Lead temperature | RS-28 (Infrared 15s) | 220 °C |

(1) Stresses above those listed under absolute maximum ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS⁽¹⁾

$V_{DD} = 5\text{ V} \pm 10\%$; $V_{SS} = 0\text{ V}$, $I_{OUTX} = \text{Virtual GND}$, $A_{GNDX} = 0\text{ V}$, $V_{REFA, B, C, D} = 10\text{ V}$, $T_A = \text{full operating temperature range}$, unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | DAC8803 | | | UNIT |
|--|------------------------|--|---------|------------|---------|-----------------------|
| | | | MIN | TYP | MAX | |
| STATIC PERFORMANCE⁽²⁾ | | | | | | |
| Resolution | | | | | 14 | Bits |
| Relative accuracy | | | | | ± 1 | LSB |
| Differential nonlinearity | DNL | | | | ± 1 | LSB |
| Output leakage current | I_{OUTX} | Data = 0000h, $T_A = 25^\circ\text{C}$ | | | 10 | nA |
| | I_{OUTX} | Data = 0000h, $T_A = T_A \text{ max}$ | | | 20 | nA |
| Full-scale gain error | G_{FSE} | Data = FFFFh | | ± 0.75 | ± 3 | mV |
| Full-scale tempco ⁽³⁾ | TCV_{FS} | | | 1 | | ppm/ $^\circ\text{C}$ |
| Feedback resistor | R_{FBX} | $V_{DD} = 5\text{ V}$ | | | | k Ω |
| REFERENCE INPUT | | | | | | |
| V_{REFX} Range | V_{REFX} | | -15 | | 15 | V |
| Input resistance | R_{REFX} | | 4 | 6 | 8 | k Ω |
| Input resistance match | R_{REFX} | Channel-to-channel | | 1 | | % |
| Input capacitance ⁽³⁾ | C_{REFX} | | | 5 | | pF |
| ANALOG OUTPUT | | | | | | |
| Output current | I_{OUTX} | Data = FFFFh | 1.25 | | 2.5 | mA |
| Output capacitance ⁽³⁾ | C_{OUTX} | Code-dependent | | 80 | | pF |
| LOGIC INPUTS AND OUTPUT | | | | | | |
| 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} | | | | 1 | μA |
| Input capacitance ⁽³⁾ | C_{IL} | | | | 10 | pF |
| Logic output low voltage | V_{OL} | $I_{OL} = 1.6\text{ mA}$ | | | 0.4 | V |
| Logic output high voltage | V_{OH} | $I_{OH} = 100\text{ }\mu\text{A}$ | 4 | | | V |
| INTERFACE TIMING^{(3), (4)} | | | | | | |
| Clock width high | t_{CH} | | 25 | | | ns |
| Clock width low | t_{CL} | | 25 | | | ns |
| $\overline{\text{CS}}$ to Clock setup | t_{CSS} | | 0 | | | ns |
| Clock to $\overline{\text{CS}}$ hold | t_{CSH} | | 25 | | | ns |
| Clock to SDO prop delay | t_{PD} | | 2 | | 20 | ns |
| Load DAC pulsewidth | t_{LDAC} | | 25 | | | ns |
| Data setup | t_{DS} | | 20 | | | ns |
| Data hold | t_{DH} | | 20 | | | ns |
| Load setup | t_{LDS} | | 5 | | | ns |
| Load hold | t_{LDH} | | 25 | | | ns |
| SUPPLY CHARACTERISTICS | | | | | | |
| Power supply range | $V_{DD \text{ RANGE}}$ | | 2.7 | | 5.5 | V |
| Positive supply current | I_{DD} | Logic inputs = 0 V | | 2 | 5 | μA |

(1) Specifications subject to change without notice.

(2) All static performance tests (except I_{OUT}) are performed in a closed-loop system using an external precision OPA277 I-to-V converter amplifier. The DAC8803 R_{FB} terminal is tied to the amplifier output. Typical values represent average readings measured at 25°C .

(3) These parameters are specified by design and not subject to production testing.

(4) All input control signals are specified with $t_R = t_F = 2.5\text{ ns}$ (10% to 90% of 3 V) and timed from a voltage level of 1.5 V.

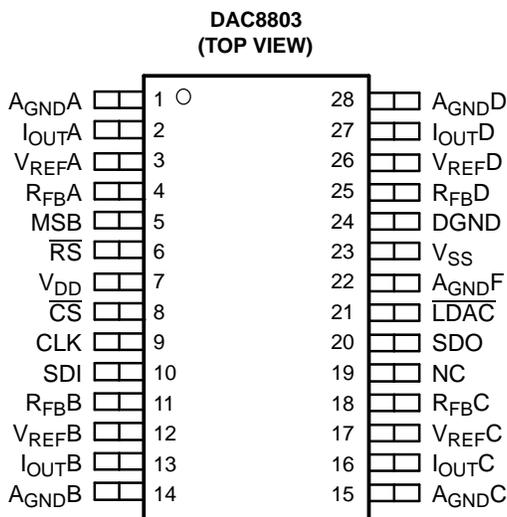
ELECTRICAL CHARACTERISTICS (continued)

$V_{DD} = 5\text{ V} \pm 10\%$; $V_{SS} = 0\text{ V}$, $I_{OUTX} = \text{Virtual GND}$, $A_{GNDX} = 0\text{ V}$, $V_{REFA, B, C, D} = 10\text{ V}$, $T_A = \text{full operating temperature range}$, unless otherwise noted.

| PARAMETER | SYMBOL | CONDITIONS | DAC8803 | | | UNIT |
|---|---------------------|--|---------|-------|-------|------------------------------|
| | | | MIN | TYP | MAX | |
| | I_{DD} | $V_{DD} = +4.5\text{ V to }+5.5\text{ V}$ | | 2 | 5 | μA |
| | I_{DD} | $V_{DD} = +2.7\text{ V to }+3.6\text{ V}$ | | 1 | 2.5 | μA |
| Negative supply current | I_{SS} | Logic inputs = 0 V, $V_{SS} = -5\text{ V}$ | | 0.001 | 1 | μA |
| Power dissipation | P_{DISS} | Logic inputs = 0 V | | | 0.025 | mW |
| Power supply sensitivity | P_{SS} | $\Delta V_{DD} = \pm 5\%$ | | | 0.006 | % |
| AC CHARACTERISTICS⁽⁵⁾ | | | | | | |
| Output voltage settling time | t_s | To $\pm 0.1\%$ of full-scale, Data = 0000h to FFFFh to 0000h | | 0.5 | | μs |
| | t_s | To $\pm 0.006\%$ of full-scale, Data = 0000h to FFFFh to 0000h | | 1 | | μs |
| Reference multiplying BW | BW -3 dB | $V_{REFX} = 100\text{ mV}_{RMS}$, Data = FFFFh, $C_{FB} = 15\text{ pF}$ | | 10 | | MHz |
| DAC glitch impulse | Q | $V_{REFX} = 10\text{ V}$, Data = 0000h to 8000h to 0000h | | 1 | | nV/s |
| Feedthrough error | V_{OUTX}/V_{REFX} | Data = 0000h, $V_{REFX} = 100\text{ mV}_{RMS}$, $f = 100\text{ kHz}$ | | -70 | | dB |
| Crosstalk error | V_{OUTA}/V_{REFB} | Data = 0000h, $V_{REFB} = 100\text{ mV}_{RMS}$, Adjacent channel, $f = 100\text{ kHz}$ | | -90 | | dB |
| Digital feedthrough | Q | $\overline{CS} = 1$ and $f_{CLK} = 1\text{ MHz}$ | | 2 | | nV/s |
| Total harmonic distortion | THD | $V_{REF} = 5\text{ V}_{PP}$, Data = FFFFh, $f = 1\text{ kHz}$ | | -105 | | dB |
| Output spot noise voltage | e_n | $f = 1\text{ kHz}$, BW = 1 Hz | | 12 | | $\text{nV}/\sqrt{\text{Hz}}$ |

(5) All ac characteristic tests are performed in a closed-loop system using an OPA627 I-to-V converter amplifier.

PIN CONFIGURATIONS



NC – No internal connection

PIN DESCRIPTION

| PIN | NAME | DESCRIPTION |
|---------------|-----------------------------|---|
| 1, 14, 15, 28 | AGNDA, AGNDB, AGNDC, AGNDD | DAC A, B, C, D Analog ground |
| 2, 13, 16, 27 | IOUTA, IOUTB, IOUTC, IOUTD | DAC A, B, C, D Current output |
| 3, 12, 17, 26 | VREFA, VREFB, VREFC, VREFD | DAC A, B, C, D Reference voltage input terminal. Establishes DAC A, B, C, D full-scale output voltage. Can be tied to V _{DD} . |
| 4, 11, 18, 25 | RFB A, RFB B, RFB C, RFB D, | Establish voltage output for DAC A, B, C, D by connecting to external amplifier output. |
| 5 | MSB | MSB Bit set during a reset pulse (RS) or at system power on if tied to ground or V _{DD} |
| 6 | RS | Reset pin, active low. Input register and DAC registers are set to all zeros or half scale code (8000h) determined by the voltage on the MSB pin. Register data = 8000h when MSB = 1. |
| 7 | V _{DD} | Positive power-supply input. Specified range of operation 5 V ±10%. |
| 8 | CS | Chip-select; active low input. Disables shift register loading when high. Transfers shift register data to input register when CS/LDAC goes high. Does not affect LDAC operation. |
| 9 | CLK | Clock input; positive edge triggered clocks data into shift register |
| 10 | SDI | Serial data input; data loads directly into the shift register. |
| 19 | NC | Not connected; leave floating |
| 20 | SDO | Serial data output; input data load directly into shift register. Data appears at SDO, 19 clock pulses after input at the SDI pin. |
| 21 | LDAC | Load DAC register strobe; level sensitive active low. Transfers all input register data to the DAC registers. Asynchronous active low input. See Table 1 for operation. |
| 22 | AGNDF | High current analog force ground. |
| 23 | V _{SS} | Negative bias power-supply input. Specified range of operation -0.3 V to -5.5 V. |
| 24 | DGND | Digital ground. |

PRODUCT PREVIEW

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

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

Channel A

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 1.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 2.

LINEARITY ERROR
vs DIGITAL INPUT CODE

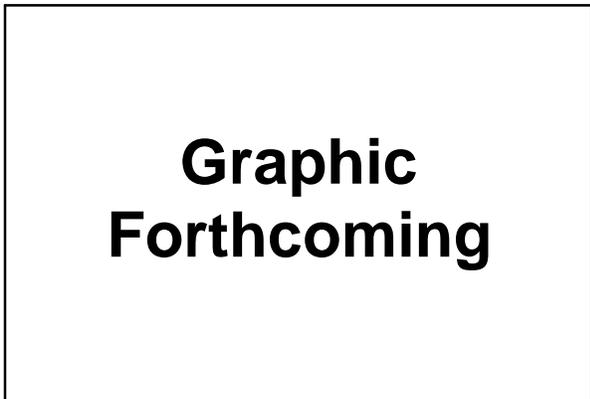


Figure 3.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

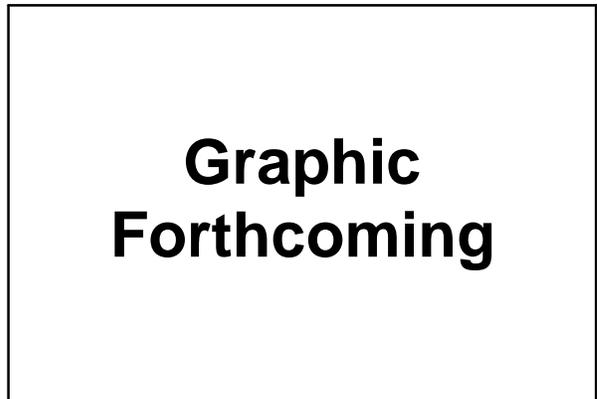


Figure 4.

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**

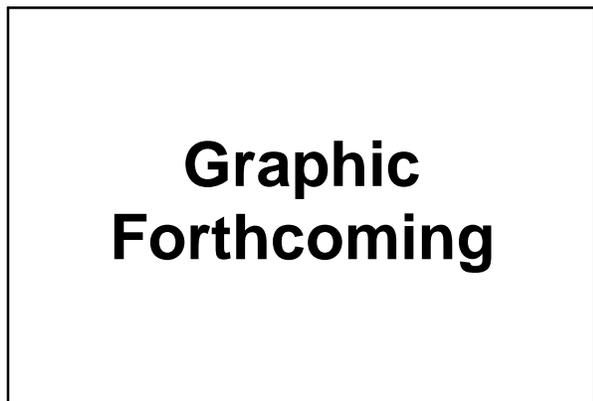


Figure 5.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**



Figure 6.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

Channel B

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 7.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 8.

LINEARITY ERROR
vs DIGITAL INPUT CODE

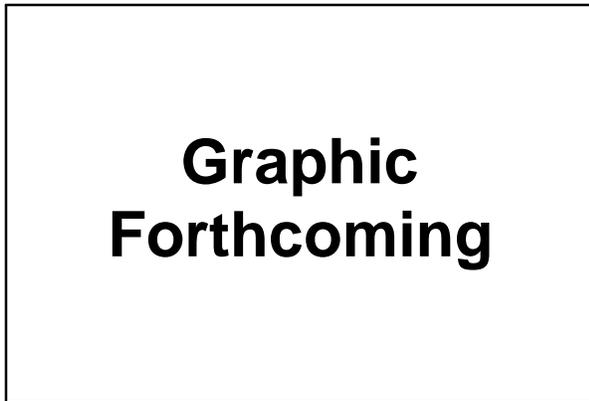


Figure 9.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

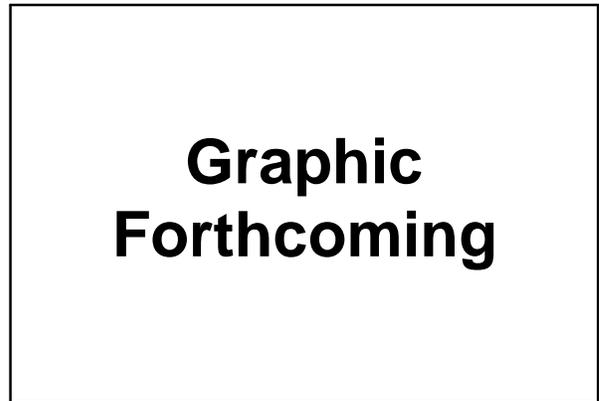


Figure 10.

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

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**

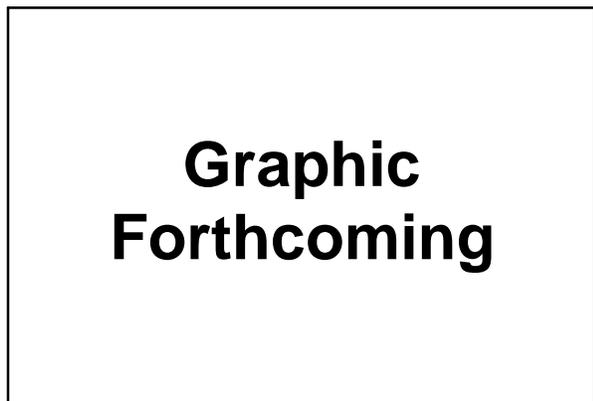


Figure 11.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**

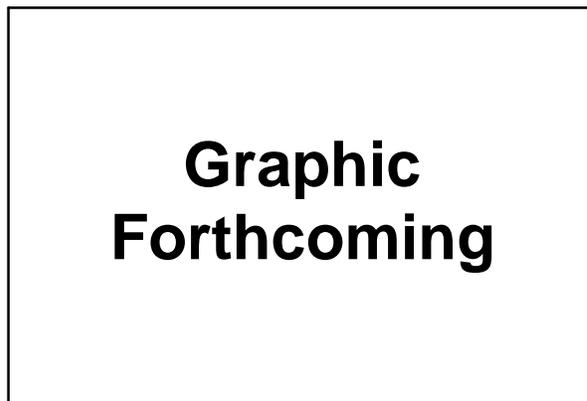


Figure 12.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

Channel C

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 13.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 14.

LINEARITY ERROR
vs DIGITAL INPUT CODE

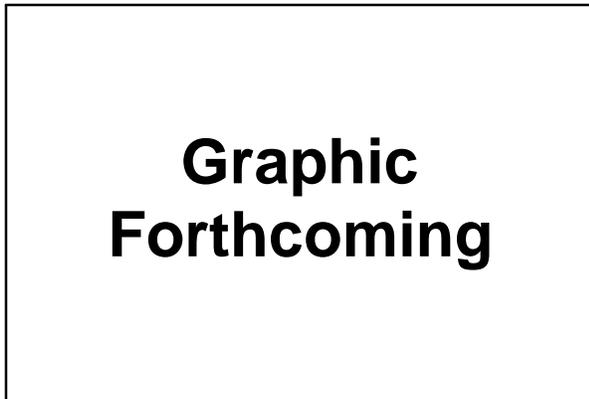


Figure 15.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

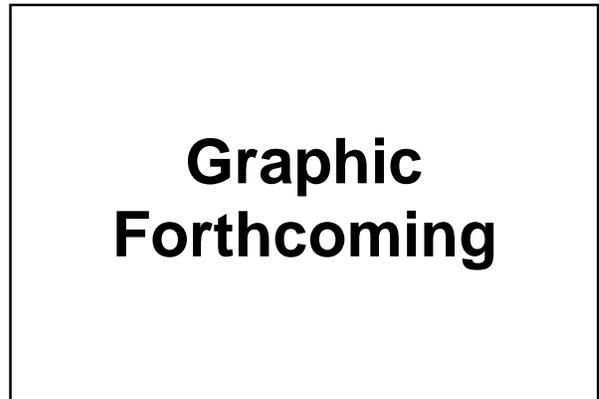


Figure 16.

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

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**

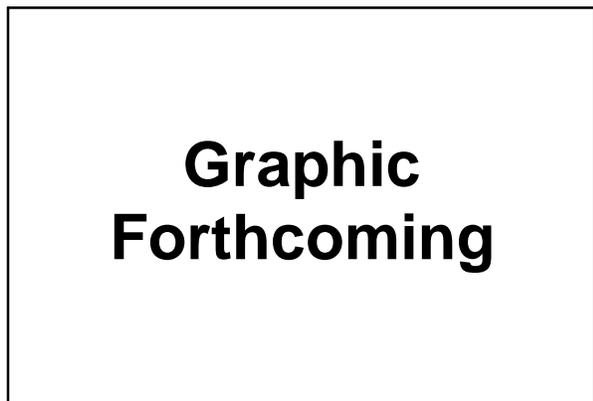


Figure 17.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**

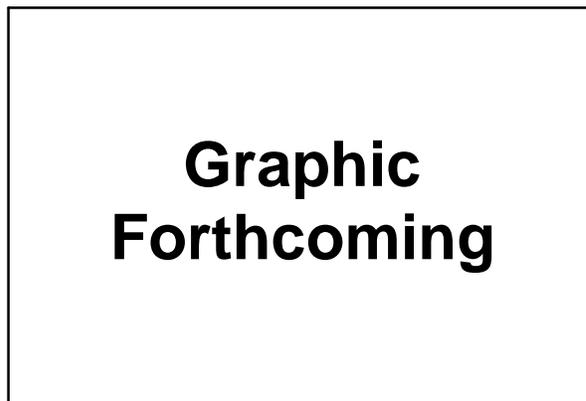


Figure 18.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

Channel D

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 19.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 20.

LINEARITY ERROR
vs DIGITAL INPUT CODE

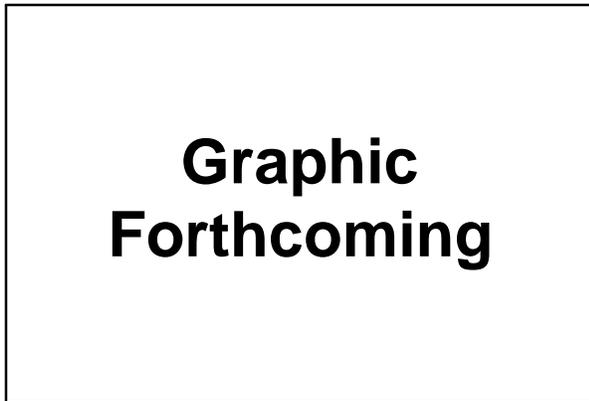


Figure 21.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

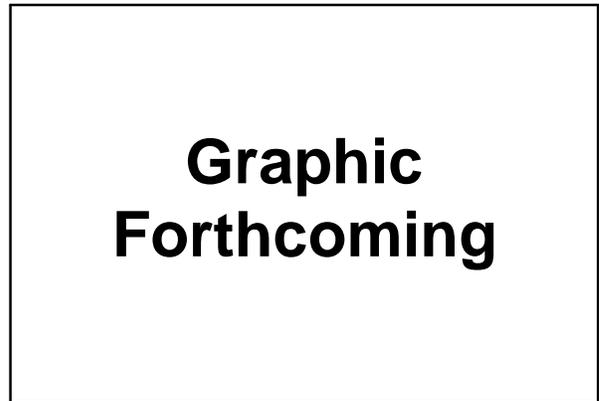


Figure 22.

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**

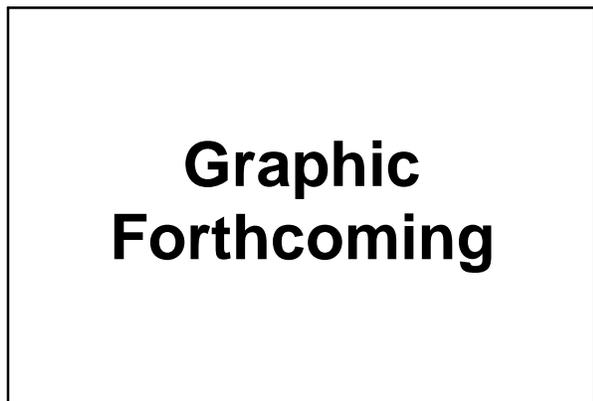


Figure 23.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**

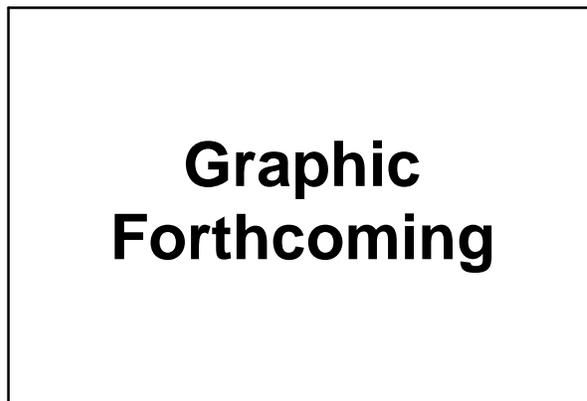


Figure 24.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

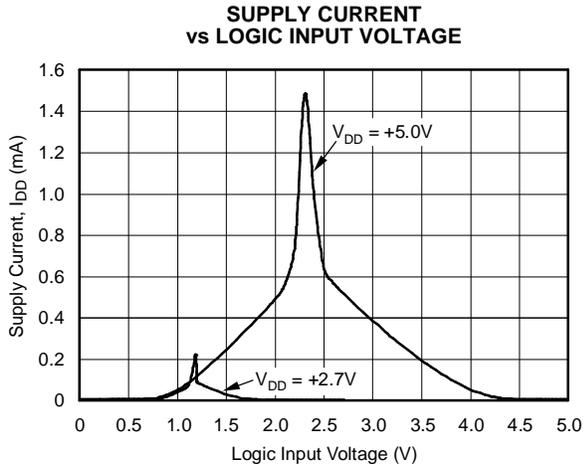


Figure 25.

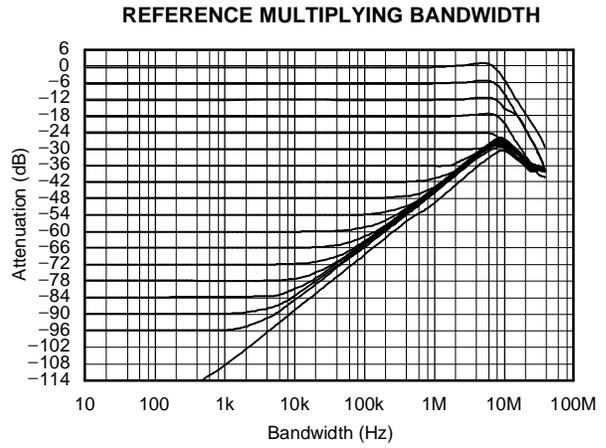


Figure 26.

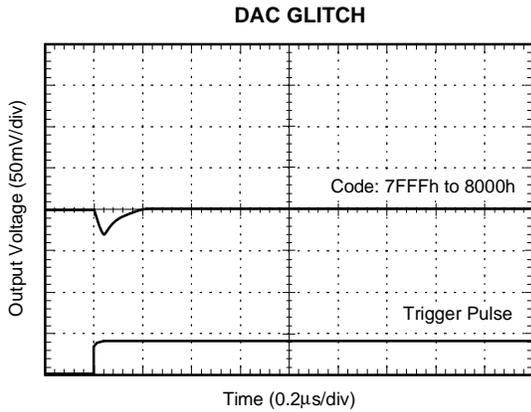


Figure 27.

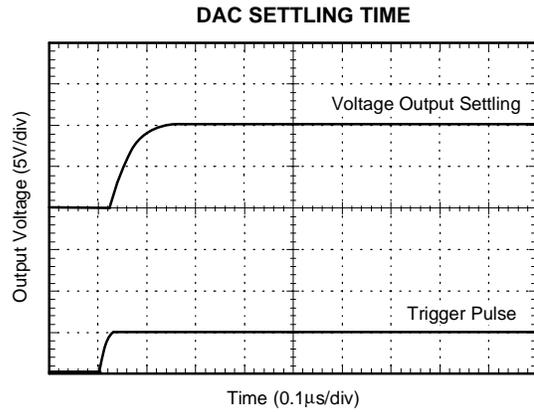


Figure 28.

Channel A

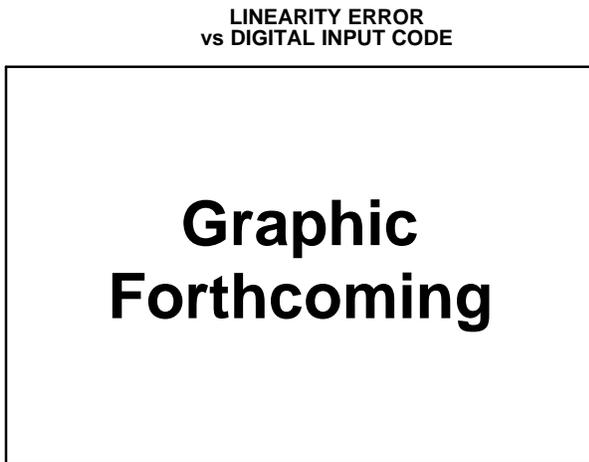


Figure 29.

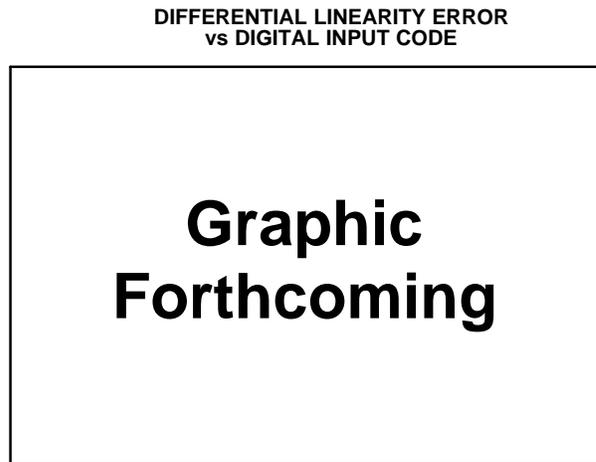


Figure 30.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**



Figure 31.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**



Figure 32.

**LINEARITY ERROR
vs DIGITAL INPUT CODE**



Figure 33.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**



Figure 34.

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

Channel B

LINEARITY ERROR
vs DIGITAL INPUT CODE

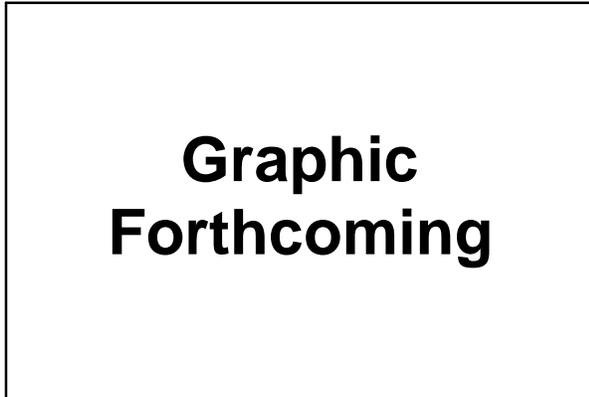


Figure 35.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 36.

LINEARITY ERROR
vs DIGITAL INPUT CODE

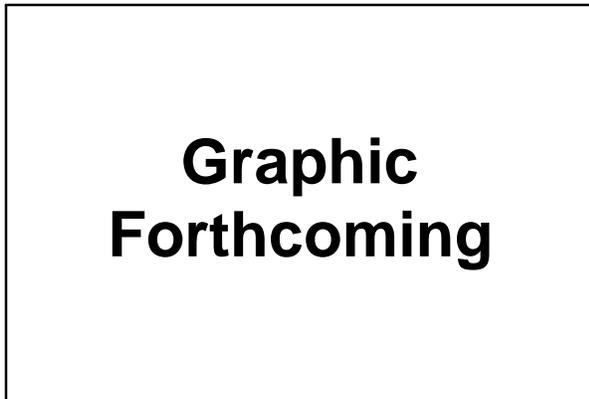


Figure 37.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

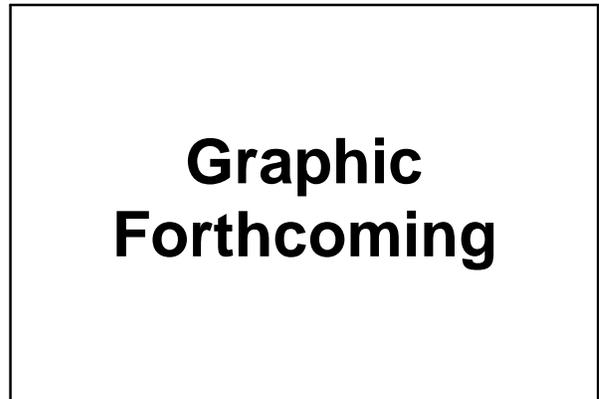


Figure 38.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**



Figure 39.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**

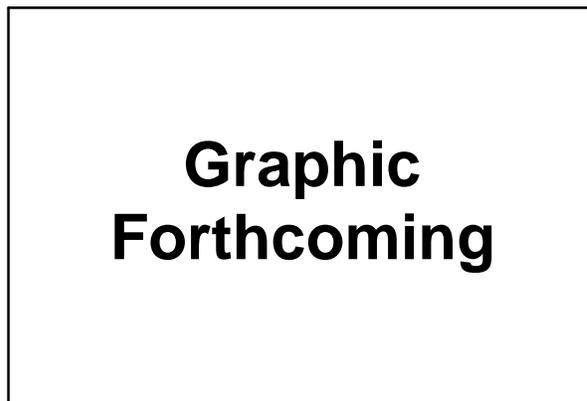


Figure 40.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

Channel C

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 41.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 42.

LINEARITY ERROR
vs DIGITAL INPUT CODE

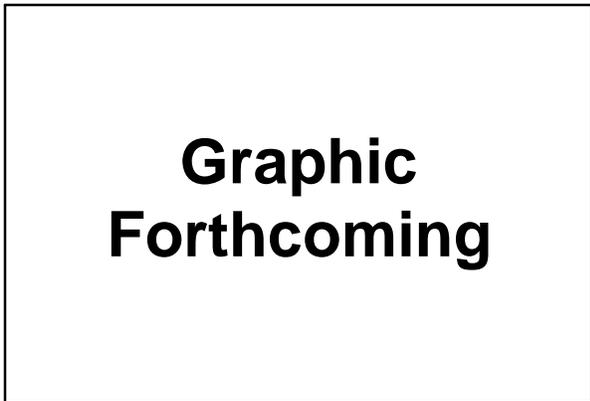


Figure 43.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

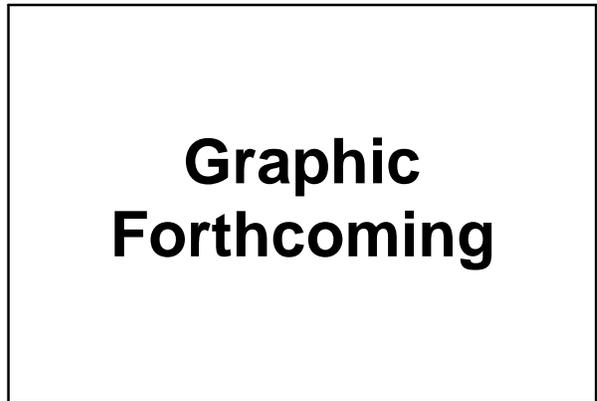


Figure 44.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

**LINEARITY ERROR
vs DIGITAL INPUT CODE**

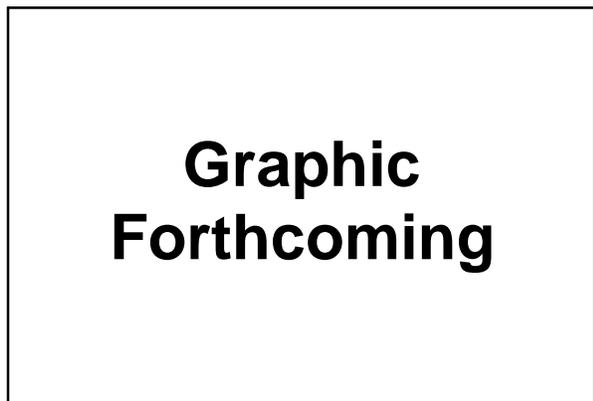


Figure 45.

**DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE**

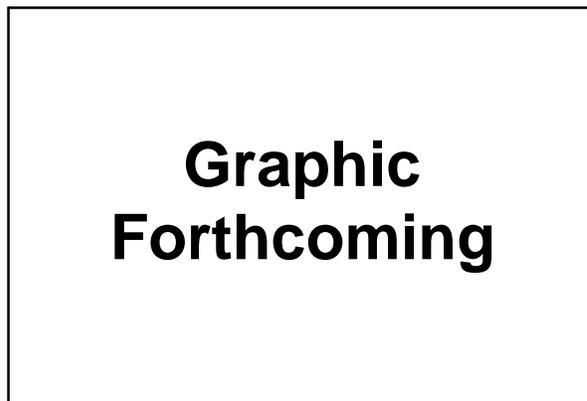


Figure 46.

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

Channel D

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 47.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 48.

LINEARITY ERROR
vs DIGITAL INPUT CODE

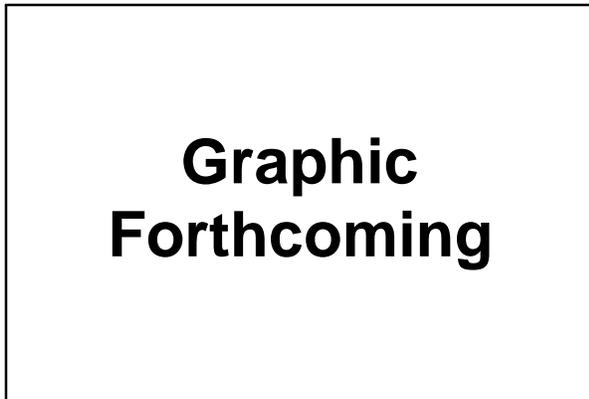


Figure 49.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE

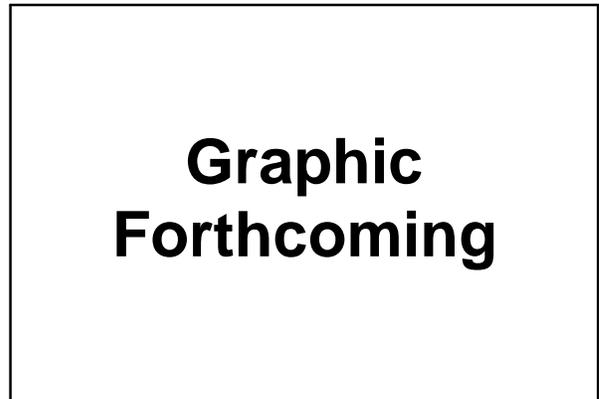


Figure 50.

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS: $V_{DD} = +2.7\text{ V}$ (continued)

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

LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 51.

DIFFERENTIAL LINEARITY ERROR
vs DIGITAL INPUT CODE



Figure 52.

PARAMETER MEASUREMENT INFORMATION

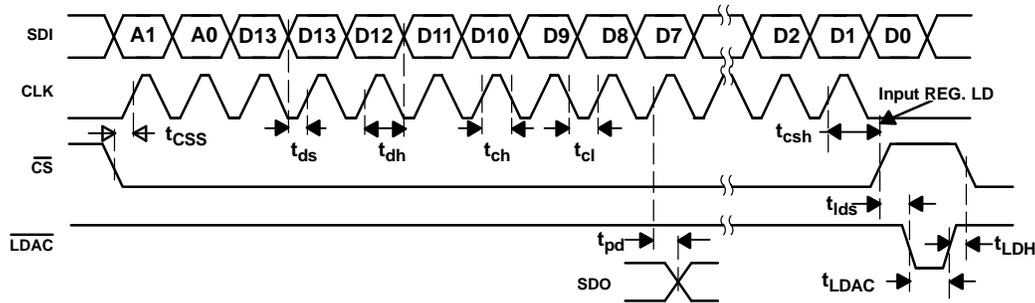


Figure 53. DAC8803 Timing Diagram

CIRCUIT OPERATION

The DAC8803 contains four 14-bit, current-output, digital-to-analog converters respectively. Each DAC has its own independent multiplying reference input. The DAC8803 uses a 3-wire SPI compatible serial data interface, with a configurable asynchronous \overline{RS} pin for half-scale (MSB = 1) or zero-scale (MSB = 0) preset. In addition, an \overline{LDAC} strobe enables four channel simultaneous updates for hardware synchronized output voltage changes.

D/A Converter

The DAC8803 contains four current-steering R-2R ladder DACs. [Figure 54](#) shows a typical equivalent DAC. Each DAC contains a matching feedback resistor for use with an external I-to-V converter amplifier. The R_{FBX} pin is connected to the output of the external amplifier. The I_{OUTX} terminal is connected to the inverting input of the external amplifier. The A_{GNDX} pin should be Kelvin-connected to the load point in the circuit requiring the full 14-bit accuracy.

The DAC is designed to operate with both negative or positive reference voltages. The V_{DD} power pin is only used by the logic to drive the DAC switches on and off. Note that a matching switch is used in series with the internal $5\text{ k}\Omega$ feedback resistor. If users are attempting to measure the value of R_{FB} , power must be applied to V_{DD} in order to achieve continuity. An additional V_{SS} bias pin is used to guard the substrate during high temperature applications to minimize zero-scale leakage currents that double every 10°C . The DAC output voltage is determined by V_{REF} and the digital data (D) according to Equation 1:

$$V_{OUT} = -V_{REF} \times \frac{D}{16384} \tag{1}$$

Note that the output polarity is opposite to the V_{REF} polarity for dc reference voltages.

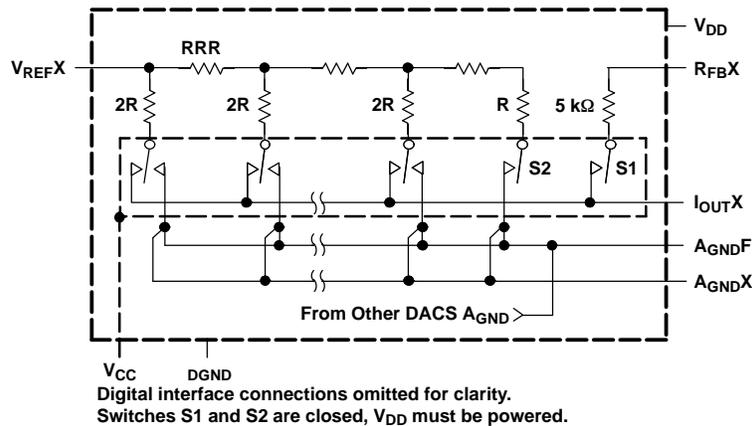


Figure 54. Typical Equivalent DAC Channel

The DAC is also designed to accommodate ac reference input signals. The DAC8803 accommodates input reference voltages in the range of -12 V to $+12\text{ V}$. The reference voltage inputs exhibit a constant nominal input resistance of $5\text{ k}\Omega$, $\pm 20\%$. On the other hand, the DAC outputs I_{OUTA} , B, C, D are code-dependent and produce various output resistances and capacitances.

The choice of external amplifier should take into account the variation in impedance generated by the DAC8803 on the amplifiers' inverting input node. The feedback resistance, in parallel with the DAC ladder resistance, dominates output voltage noise. For multiplying mode applications, an external feedback compensation capacitor (C_{FB}) may be needed to provide a critically damped output response for step changes in reference input voltages.

Figure 5 and Figure 6 show the gain vs frequency performance at various attenuation settings using a 23 pF external feedback capacitor connected across the I_{OUTX} and R_{FBX} terminals. In order to maintain good analog performance, power supply bypassing of $0.01\text{ }\mu\text{F}$, in parallel with $1\text{ }\mu\text{F}$, is recommended. Under these conditions, clean power supply with low ripple voltage capability should be used. Switching power supplies is usually not suitable for this application due to the higher ripple voltage and PSS frequency-dependent characteristics. It is best to derive the DAC8803 5-V supply from the system analog supply voltages. (Do not use the digital 5-V supply.) See Figure 55.

PRODUCT PREVIEW

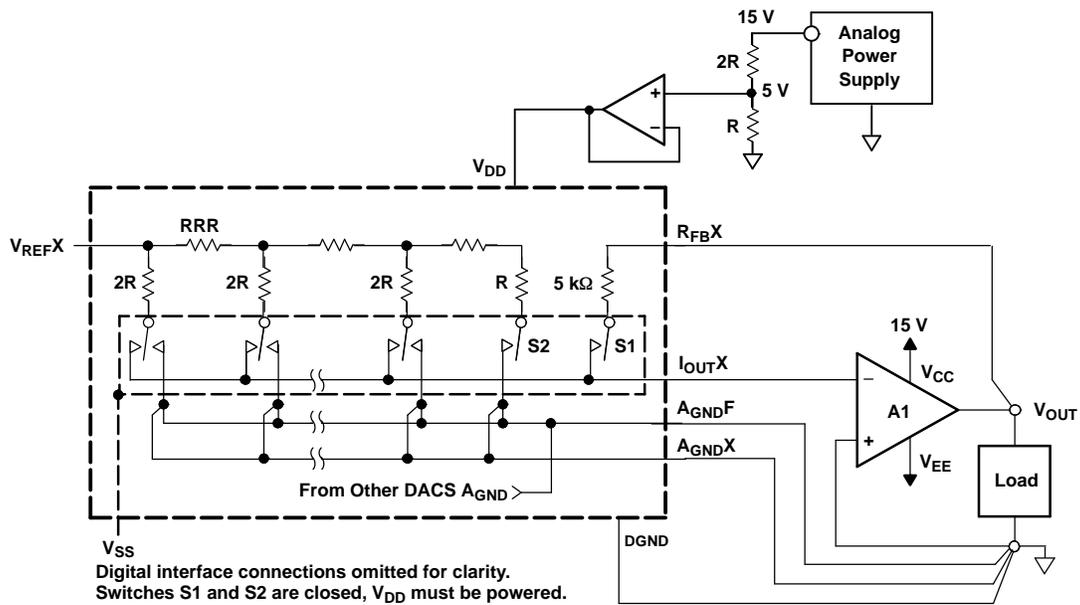


Figure 55. Recommended Kelvin-Sensed Hookup

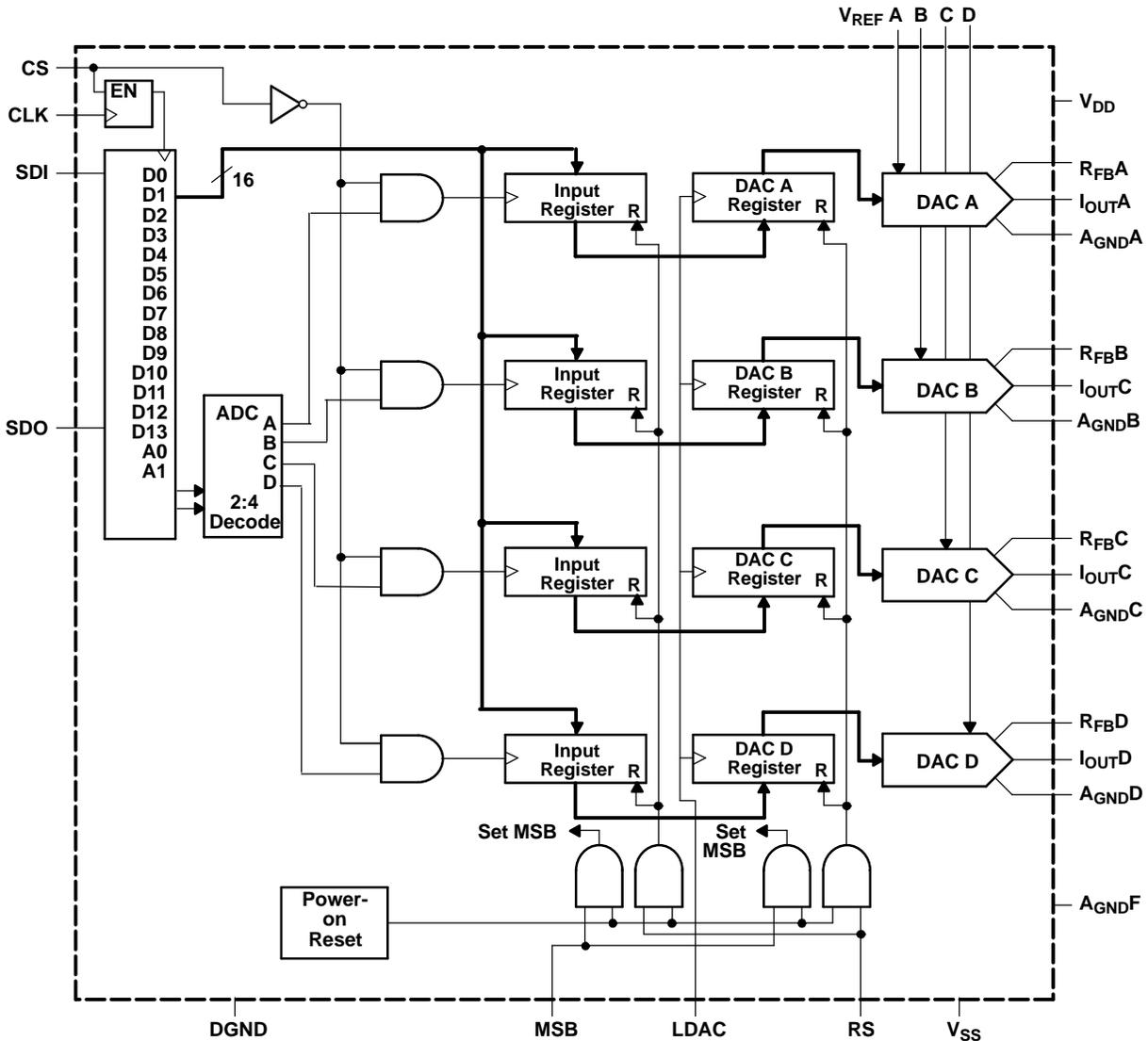


Figure 56. System Level Digital Interfacing

SERIAL DATA INTERFACE

The DAC8803 uses a 3-wire (\overline{CS} , SDI, CLK) SPI compatible serial data interface. Serial data of the DAC8803 is clocked into the serial input register in an 14-bit data-word format. MSB bits are loaded first. Table 3 defines the 16 data-word bits for the DAC8803.

Data is placed on the SDI pin, and clocked into the register on the positive clock edge of CLK subject to the data setup and data hold time requirements specified in the Interface Timing Specifications. Data can only be clocked in while the \overline{CS} chip select pin is active low. For the DAC8803, only the last 16 bits clocked into the serial register are interrogated when the \overline{CS} pin returns to the logic high state.

Since most microcontrollers output serial data in 8-bit bytes, three right-justified data bytes can be written to the DAC8803. Keeping the \overline{CS} line low between the first, second, and third byte transfers results in a successful serial register update. Similarly, two right-justified data bytes can be written to the DAC8803. Keeping the \overline{CS} line low between the first and second byte transfer will result in a successful serial register update.

PRODUCT PREVIEW

Once the data is properly aligned in the shift register, the positive edge of the \overline{CS} initiates the transfer of new data to the target DAC register, determined by the decoding of address bits A1 and A0. For DAC8803, Table 1, Table 3 and Figure 57 define the characteristics of the software serial interface. Figures 8 and 9 show the equivalent logic interface for the key digital control pins for DAC8803.

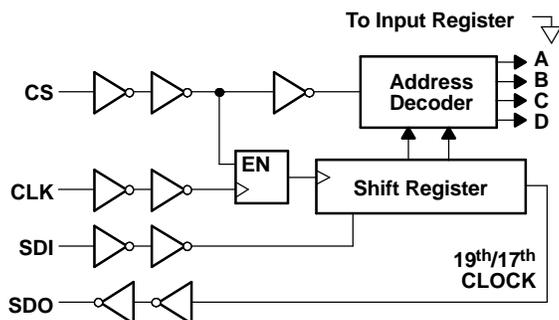


Figure 57. DAC8803 Equivalent Logic Interface

Two additional pins \overline{RS} and MSB provide hardware control over the preset function and DAC register loading. If these functions are not needed, the \overline{RS} pin can be tied to logic high. The asynchronous input \overline{RS} pin forces all input and DAC registers to either the zero-code state (MSB = 0), or the half-scale state (MSB = 1).

POWER ON RESET

When the V_{DD} power supply is turned on, an internal reset strobe forces all the Input and DAC registers to the zero-code state or half-scale, depending on the MSB pin voltage. The V_{DD} power supply should have a smooth positive ramp without drooping in order to have consistent results, especially in the region of $V_{DD} = 1.5$ V to 2.3 V. The V_{SS} supply has no effect on the power-on reset performance. The DAC register data stays at zero or half-scale setting until a valid serial register data load takes place.

ESD Protection Circuits

All logic-input pins contain back-biased ESD protection Zener diodes connected to ground (DGND) and V_{DD} as shown in Figure 58.

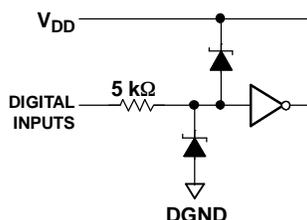


Figure 58. Equivalent ESD Protection Circuits

PCB LAYOUT

In printed circuit board (PCB) layout, all analog ground, A_{GND}X, should be tied together. Amplifiers suitable for:

Table 1. Control Logic Truth Table⁽¹⁾

| \overline{CS} | CLK | \overline{LDAC} | \overline{RS} | MSB | SERIAL SHIFT REGISTER | INPUT REGISTER | DAC REGISTER |
|-----------------|-------------|-------------------|-----------------|-----|--------------------------------------|---|----------------------|
| H | X | H | H | X | No effect | Latched | Latched |
| L | L | H | H | X | No effect | Latched | Latched |
| L | $\uparrow+$ | H | H | X | Shift register data advanced one bit | Latched | Latched |
| L | H | H | H | X | No effect | Latched | Latched |
| $\uparrow+$ | L | H | H | X | No effect | Selected DAC updated with current SR contents | Latched |
| H | X | L | H | X | No effect | Latched | Transparent |
| H | X | H | H | X | No effect | Latched | Latched |
| H | X | $\uparrow+$ | H | X | No effect | Latched | Latched |
| H | X | H | L | 0 | No effect | Latched data = 0000h | Latched data = 0000h |
| X | $\uparrow+$ | H | L | H | No effect | Latched data = 8000h | Latched data = 8000h |

(1) $\uparrow+$ Positive logic transition; X = Do not care

Table 2. Serial Input Register Data Format, Data Loaded MSB First⁽¹⁾

| Bit | B17 (MSB) | B16 | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 (LSB) |
|------|-----------|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----------|
| Data | A1 | A0 | X | X | D13 | D12 | D11 | D10 | D9 | D8 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

(1) Only the last 18 bits of data clocked into the serial register (address + data) are inspected when the \overline{CS} line's positive edge returns to logic high. At this point an internally generated load strobe transfers the serial register data contents (bits D13-D0) to the decoded DAC-input-register address determined by bits A1 and A0. Any extra bits clocked into the DAC8803 shift register are ignored, only the last 18 bits clocked in are used. If double-buffered data is not needed, the \overline{LDAC} pin can be tied logic low to disable the DAC registers.

Table 3. Address Decode

| A1 | A0 | DAC DECODE |
|----|----|------------|
| 0 | 0 | DAC A |
| 0 | 1 | DAC B |
| 1 | 0 | DAC C |
| 1 | 1 | DAC D |

APPLICATION INFORMATION

The DAC8803, 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. An additional external op amp A2 is added as a summing amp. In this circuit the first and second amps (A1 and A2) provide a gain of 2X that widens the output span to 20 V. A 4-quadrant multiplying circuit is implemented by using a 10-V offset of the reference voltage to bias A2. According to the following circuit transfer equation (Equation 2), input data (D) from code 0 to full scale produces output voltages of $V_{OUT} = -10\text{ V}$ to $V_{OUT} = 10\text{ V}$.

$$V_{OUT} = (D/32,768 - 1) \times V_{REF} \quad (2)$$

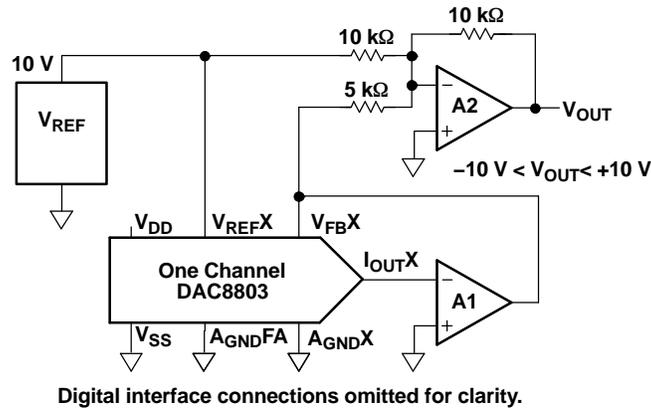


Figure 59. Four-Quadrant Multiplying Application Circuit

Cross-Reference

The DAC8803 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 |
|------------|-----------|-----------|-----------------------------|---------------------|----------------|----------------------|
| DAC8803IDB | ±1 | ±1 | -40°C to +85°C | 28-Lead MicroSOIC | SSOP-28 | AD5554BRS |

PACKAGING INFORMATION

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| DAC8803IDBR | PREVIEW | SSOP | DB | 28 | 2500 | TBD | Call TI | Call TI |
| DAC8803IDBT | PREVIEW | SSOP | DB | 28 | 250 | TBD | 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 - The planned eco-friendly classification: Pb-Free (RoHS) 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.

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

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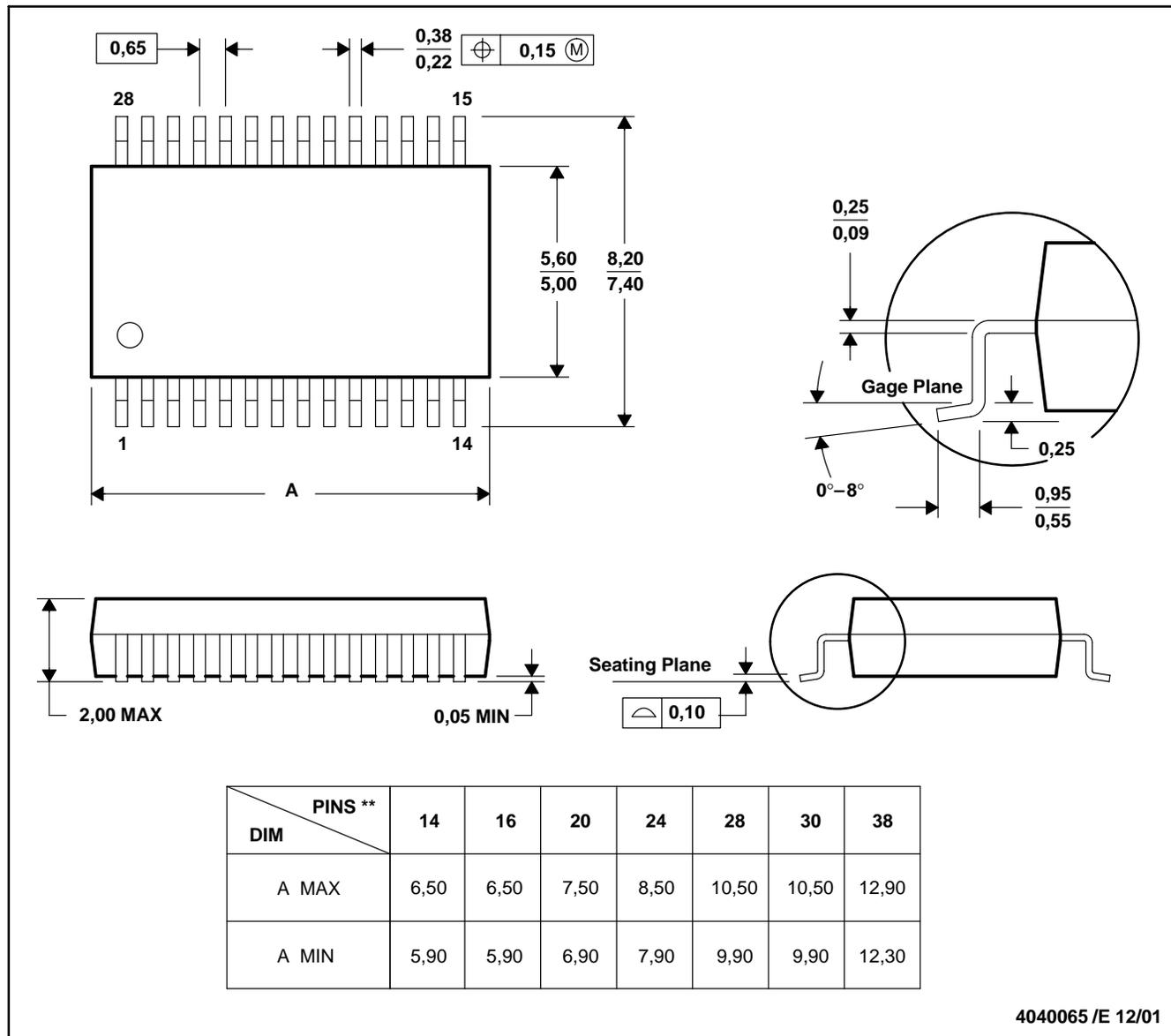
MECHANICAL DATA

MSS0002E – JANUARY 1995 – REVISED DECEMBER 2001

DB (R-PDSO-G**)

PLASTIC SMALL-OUTLINE

28 PINS SHOWN



- 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-150

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