



16-Bit, Dual Voltage Output DIGITAL-TO-ANALOG CONVERTER

FEATURES

- **LOW POWER:** 4mW
- **UNIPOLAR OR BIPOLAR OPERATION**
- **SETTLING TIME:** 10 μ s to $\pm 0.003\%$ FSR
- **15-BIT LINEARITY AND MONOTONICITY:** -40°C to $+85^{\circ}\text{C}$
- **PROGRAMMABLE RESET TO MID-SCALE OR ZERO-SCALE**
- **DOUBLE-BUFFERED DATA INPUTS**

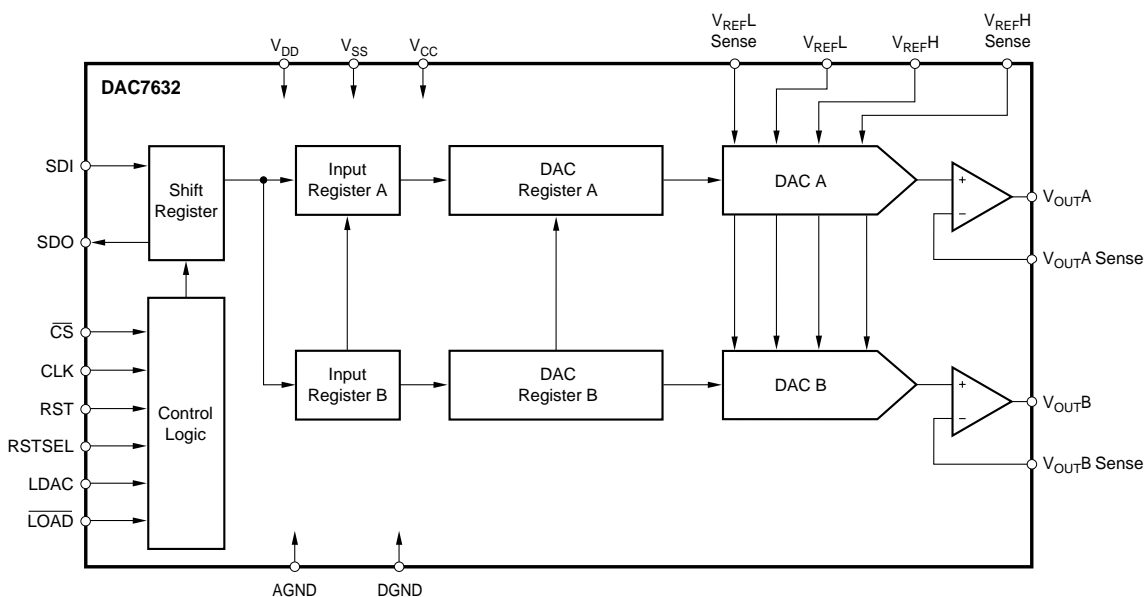
APPLICATIONS

- **PROCESS CONTROL**
- **CLOSED-LOOP SERVO-CONTROL**
- **MOTOR CONTROL**
- **DATA ACQUISITION SYSTEMS**
- **DAC-PER-PIN PROGRAMMERS**

DESCRIPTION

The DAC7632 is a 16-bit, dual channel, voltage output, Digital-to-Analog Converter (DAC) which provides 15-bit monotonic performance over the specified temperature range. The device accepts 24-bit serial input data, has double-buffered DAC input logic (allowing simultaneous update of both DACs), and provides a serial data output for daisy-chaining multiple devices. A programmable asynchronous reset clears all registers to a mid-scale code of 8000_H or to a zero-scale code of 0000_H. The DAC7632 can operate from a single +5V supply or from +5V and -5V supplies, providing an output range of 0V to +2.5V or -2.5V to +2.5V, respectively.

Low power and small size per DAC make the DAC7632 ideal for industrial process control, data acquisition systems, and closed-loop servo-control. The DAC7632 is available in an LQFP-32 package and specified over a -40°C to $+85^{\circ}\text{C}$ temperature range.



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.

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ABSOLUTE MAXIMUM RATINGS⁽¹⁾

| | |
|---|--------------------------------|
| V_{CC} and V_{DD} to V_{SS} | –0.3V to 11V |
| V_{CC} and V_{DD} to GND | –0.3V to 5.5V |
| V_{REFL} to V_{SS} | –0.3V to ($V_{CC} - V_{SS}$) |
| V_{CC} to V_{REFH} | –0.3V to ($V_{CC} - V_{SS}$) |
| V_{REFH} to V_{REFL} | –0.3V to ($V_{CC} - V_{SS}$) |
| Digital Input Voltage to GND | –0.3V to $V_{DD} + 0.3V$ |
| Digital Output Voltage to GND | –0.3V to $V_{DD} + 0.3V$ |
| Maximum Junction Temperature | +150°C |
| Operating Temperature Range | –40°C to +85°C |
| Storage Temperature Range | –65°C to +125°C |
| Lead Temperature (soldering, 10s) | +300°C |

NOTE: (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.



ELECTROSTATIC DISCHARGE SENSITIVITY

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 | MONOTONICITY | PACKAGE-LEAD | PACKAGE DESIGNATOR | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|------------|--------------|--------------|--------------------|-----------------------------|-----------------|-----------------|---------------------------|
| DAC7632VF | 14 Bits | LQFP-32 | VF | –40°C to +85°C | DAC7632 | DAC7632VFT | Tape and Reel, 250 |
| " | " | " | " | " | " | DAC7632VFR | Tape and Reel, 1000 |
| DAC7632VFB | 15 Bits | LQFP-32 | VF | –40°C to +85°C | DAC7632B | DAC7632VFBT | Tape and Reel, 250 |
| " | " | " | " | " | " | DAC7632VFB R | Tape and Reel, 1000 |

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

ELECTRICAL CHARACTERISTICS: Dual Supply

At $T_A = T_{MIN}$ to T_{MAX} , $V_{DD} = V_{CC} = +5V$, $V_{SS} = -5V$, $V_{REFH} = +2.5V$, and $V_{REFL} = -2.5V$, unless otherwise noted.

| PARAMETER | CONDITIONS | DAC7632VF | | | DAC7632VFB | | | UNITS |
|--------------------------------------|--|--------------------|------------|--------------------|------------|---------|---------|-----------------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | |
| ACCURACY | | | | | | | | |
| Linearity Error | | | ± 3 | ± 4 | | ± 2 | ± 3 | LSB |
| Linearity Match | | | ± 4 | | | ± 2 | | LSB |
| Differential Linearity Error | | | ± 2 | ± 3 | | ± 1 | ± 2 | LSB |
| Monotonicity, T_{MIN} to T_{MAX} | | 14 | | | 15 | | | Bits |
| Bipolar Zero Error | | | ± 1 | ± 3 | | * | * | mV |
| Bipolar Zero Error Drift | | | 5 | 10 | | * | * | ppm/°C |
| Full-Scale Error | | | ± 1 | ± 3 | | * | * | mV |
| Full-Scale Error Drift | | | 5 | 10 | | * | * | ppm/°C |
| Bipolar Zero Matching | Channel-to-Channel Matching | | ± 1 | ± 3 | | * | * | mV |
| Full-Scale Matching | Channel-to-Channel Matching | | ± 1 | ± 3 | | * | * | mV |
| Power-Supply Rejection Ratio (PSRR) | At Full Scale | | 10 | 100 | | * | * | ppm/V |
| ANALOG OUTPUT | | | | | | | | |
| Voltage Output | $R_L = 10k\Omega$ | $V_{REFL} - 1.25$ | | $V_{REFH} + 1.25$ | * | | * | V |
| Output Current | | | | | * | | * | mA |
| Maximum Load Capacitance | No Oscillation | | 500 | | | * | | pF |
| Short-Circuit Current | | | -10, +30 | | | * | | mA |
| Short-Circuit Duration | GND or V_{CC} or V_{SS} | | Indefinite | | | * | | |
| REFERENCE INPUT | | | | | | | | |
| Ref High Input Voltage Range | | $V_{REFL} + 1.25$ | | $+2.5$ | * | | * | V |
| Ref Low Input Voltage Range | | -2.5 | | $V_{REFH} - 1.25$ | * | | * | V |
| Ref High Input Current | | | 500 | | | * | | μA |
| Ref Low Input Current | | | -500 | | | * | | μA |
| DYNAMIC PERFORMANCE | | | | | | | | |
| Settling Time | To $\pm 0.003\%$, 5V Output Step | | 8 | 10 | | * | * | μs |
| Channel-to-Channel Crosstalk | | | 0.5 | | | * | | LSB |
| Digital Feedthrough | | | 2 | | | * | | nV-s |
| Output Noise Voltage | $f = 10kHz$ | | 60 | | | * | | nV/ \sqrt{Hz} |
| DAC Glitch | 7FFF _H to 8000 _H or 8000 _H to 7FFF _H | | 40 | | | * | | nV-s |
| DIGITAL INPUT | | | | | | | | |
| V_{IH} | | $0.7 \cdot V_{DD}$ | | | * | | | V |
| V_{IL} | | | | $0.3 \cdot V_{DD}$ | | | * | V |
| I_{IH} | | | | ± 10 | | | * | μA |
| I_{IL} | | | | ± 10 | | | * | μA |
| DIGITAL OUTPUT | | | | | | | | |
| V_{OH} | $I_{OH} = -0.8mA$ | 3.6 | 4.5 | | * | * | | V |
| V_{OL} | $I_{OL} = 1.6mA$ | | 0.3 | 0.4 | | * | * | V |
| POWER SUPPLY | | | | | | | | |
| V_{DD} | | +4.75 | +5.0 | +5.25 | * | * | * | V |
| V_{CC} | | +4.75 | +5.0 | +5.25 | * | * | * | V |
| V_{SS} | | -5.25 | -5.0 | -4.75 | * | * | * | V |
| I_{CC} | | | 0.7 | 1.1 | | * | * | mA |
| I_{DD} | | | 50 | | | * | * | μA |
| I_{SS} | | -1.2 | -0.8 | | * | * | * | mA |
| Power | | | 7.5 | 11.5 | | * | * | mW |
| TEMPERATURE RANGE | | | | | | | | |
| Specified Performance | | -40 | | +85 | * | | * | °C |

* Specifications same as DAC7632VF.

ELECTRICAL CHARACTERISTICS: Single Supply

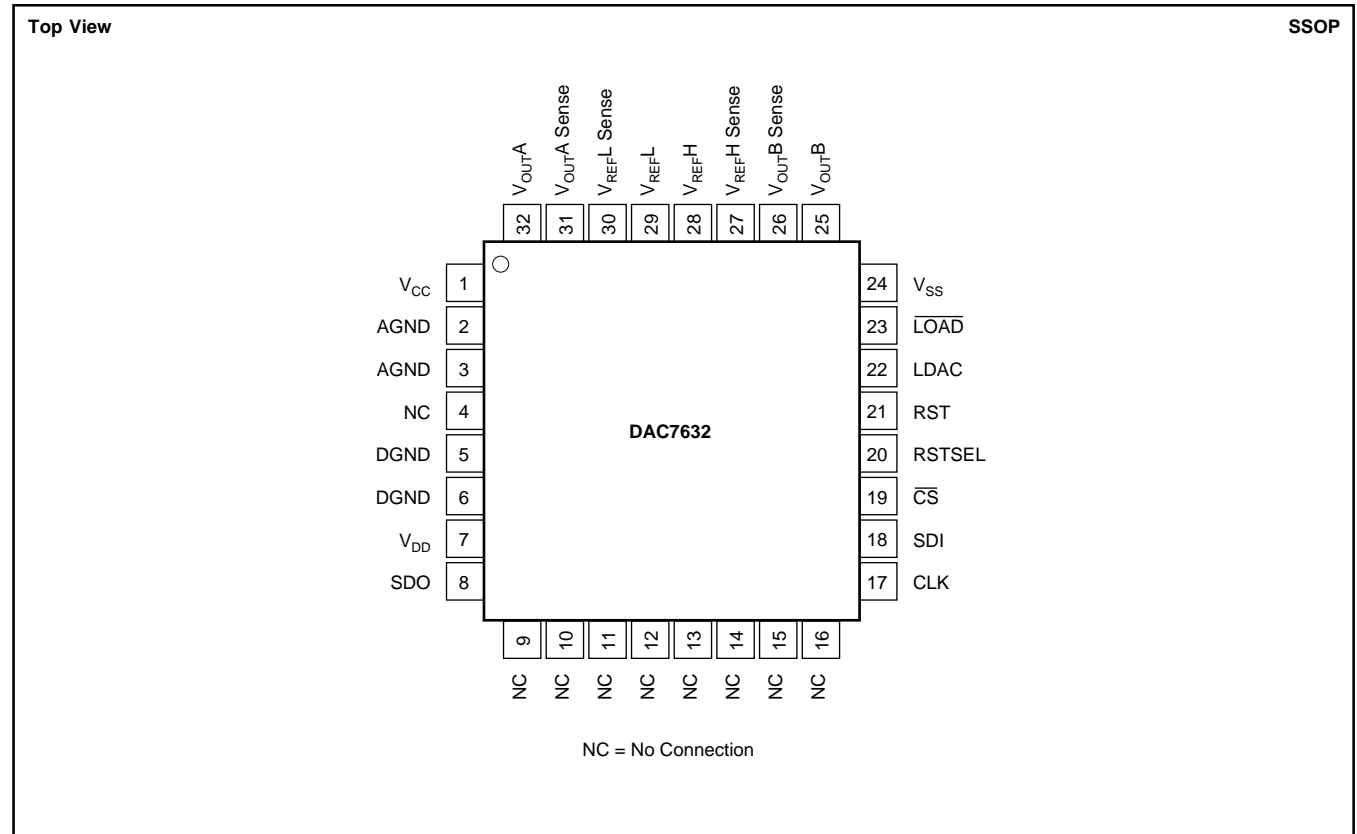
At $T_A = T_{MIN}$ to T_{MAX} , $V_{DD} = V_{CC} = +5V$, $V_{SS} = 0V$, $V_{REFH} = +2.5V$, and $V_{REFL} = 0V$, unless otherwise noted.

| PARAMETER | CONDITIONS | DAC7632VF | | | DAC7632VFB | | | UNITS |
|---|---|---------------------------|---------------------------------------|--|------------|---------|---------|--|
| | | MIN | TYP | MAX | MIN | TYP | MAX | |
| ACCURACY Linearity Error ⁽¹⁾ Linearity Match Differential Linearity Error Monotonicity, T_{MIN} to T_{MAX} Zero Scale Error Zero Scale Error Drift Full-Scale Error Full-Scale Error Drift Zero Scale Matching Full-Scale Matching Power Supply Rejection Ratio (PSRR) | Channel-to-Channel Matching Channel-to-Channel Matching At Full Scale | 14 | ± 3 | ± 4 | 15 | ± 2 | ± 3 | LSB LSB LSB Bits mV ppm/°C mV ppm/°C mV mV ppm/V |
| | | | ± 4 | | | ± 2 | | |
| | | | ± 2 | ± 3 | | ± 1 | ± 2 | |
| | | | ± 1 | ± 3 | | * | * | |
| | | | 5 | 10 | | * | * | |
| | | | ± 1 | ± 3 | | * | * | |
| | | | 5 | 10 | | * | * | |
| | | | ± 1 | ± 3 | | * | * | |
| | | | ± 1 | ± 3 | | * | * | |
| | | | 10 | 100 | | * | * | |
| | | | | | | * | * | |
| ANALOG OUTPUT Voltage Output Output Current Maximum Load Capacitance Short-Circuit Current Short-Circuit Duration | $R_L = 10k\Omega$ No Oscillation GND or V_{CC} | 0 -1.25 | | V_{REFH} +1.25 | * | | * | V mA pF mA |
| | | | 500 -10, +30 Indefinite | | | * | * | |
| REFERENCE INPUT Ref High Input Voltage Range Ref Low Input Voltage Range Ref High Input Current Ref Low Input Current | | $V_{REFL} + 1.25$ -2.5 | | +2.5 $V_{REFH} - 1.25$ | * | | * | V V μA μA |
| | | | 250 -250 | | | * | * | |
| DYNAMIC PERFORMANCE Settling Time Channel-to-Channel Crosstalk Digital Feedthrough Output Noise Voltage, $f = 10kHz$ DAC Glitch | To $\pm 0.003\%$, 5V Output Step 7FFF _H to 8000 _H or 8000 _H to 7FFF _H | | 8 0.5 2 60 40 | 10 | | * | * | μs LSB nV-s nV/ \sqrt{Hz} nV-s |
| DIGITAL INPUT V_{IH} V_{IL} I_{IH} I_{IL} | | $0.7 \cdot V_{DD}$ | | $0.3 \cdot V_{DD}$ ± 10 ± 10 | * | | * | V V μA μA |
| DIGITAL OUTPUT V_{OH} V_{OL} | $I_{OH} = -0.8mA$ $I_{OL} = 1.6mA$ | 3.6 | 4.5 0.3 | 0.4 | * | * | * | V V |
| POWER SUPPLY V_{DD} V_{CC} V_{SS} I_{CC} I_{DD} Power | | +4.75 +4.75 0 | +5.0 +5.0 0 0.5 50 2.5 | +5.25 +5.25 0 0.9 4.5 | * | * | * | V V V mA μA mW |
| TEMPERATURE RANGE Specified Performance | | -40 | | +85 | * | | * | °C |

* Specifications same as DAC7632VF.

NOTE: (1) If $V_{SS} = 0V$, the specification applies to Code 0040_H and above due to possible negative zero-scale error.

PIN CONFIGURATION



PIN DESCRIPTIONS

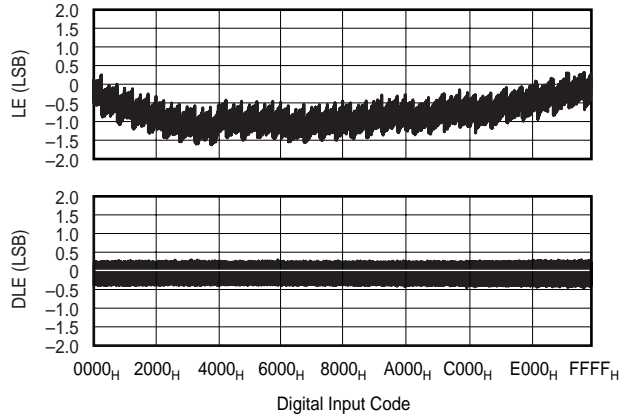
| PIN | NAME | DESCRIPTION | PIN | NAME | DESCRIPTION |
|------|------------------------|--|-----|--------------------------|--|
| 1 | V _{CC} | Analog +5V Power Supply | 22 | LDAC | DAC Register Load Control, Rising Edge Triggered |
| 2, 3 | AGND | Analog Ground | 23 | $\overline{\text{LOAD}}$ | DAC Input Register Load Control, Active LOW |
| 4 | NC | No Connection | 24 | V _{SS} | Analog -5V Power Supply (or 0V for Single Supply) |
| 5, 6 | DGND | Digital Ground | 25 | V _{OUTB} | DAC B Output Voltage |
| 7 | V _{DD} | Digital +5V Power Supply | 26 | V _{OUTB} Sense | DAC B Output Amplifier Inverting Input. Used to close the feedback loop at the load. |
| 8 | SDO | Serial Data Output | 27 | V _{REFH} Sense | DAC A and B Reference High Sense Input |
| 9-16 | NC | No Connection | 28 | V _{REFH} | DAC A and B Reference High Input |
| 17 | CLK | Data Clock Input | 29 | V _{REFL} | DAC A and B Reference Low Input |
| 18 | SDI | Serial Data Input | 30 | V _{REFL} Sense | DAC A and B Reference Low Sense Input |
| 19 | $\overline{\text{CS}}$ | Chip Select, Active LOW | 31 | V _{REFA} Sense | DAC A Output Amplifier Inverting Input. Used to close the feedback loop at the load. |
| 20 | RSTSEL | Reset Select. Determines the action of RST. If HIGH, a RST common will set the DAC registers to mid-scale code (8000 _H). If LOW, a RST command will set the DAC registers to zero-scale code (0000 _H). | 32 | V _{OUTA} | DAC A Output Voltage |
| 21 | RST | Reset, Rising Edge Triggered. Depending on the state of RSTSEL, the DAC registers are set to either mid-scale code or zero-scale code. | | | |

TYPICAL CHARACTERISTICS: $V_{SS} = 0V$

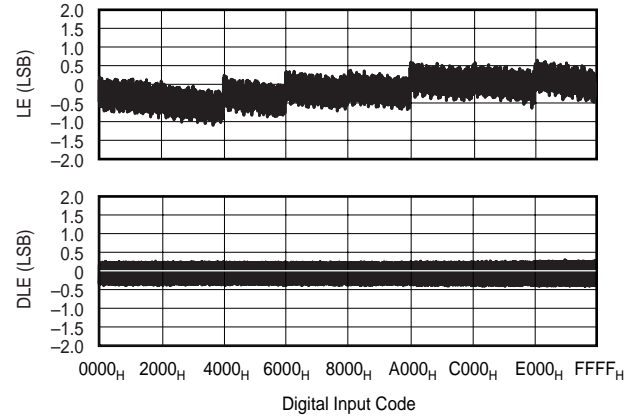
At $T_A = +25^\circ C$, $V_{DD} = V_{CC} = +5V$, $V_{SS} = 0V$, $V_{REFH} = +2.5V$, $V_{REFL} = 0V$, representative unit, unless otherwise specified.

+25°C

LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, +25°C)

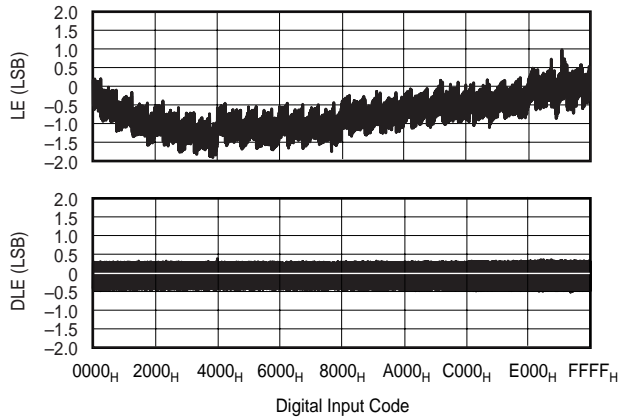


LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, +25°C)

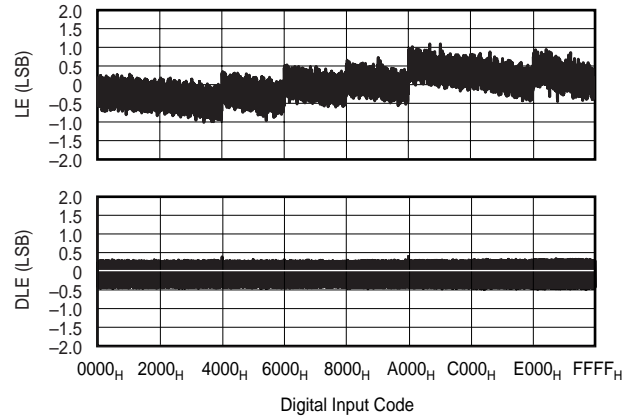


+85°C

LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, +85°C)

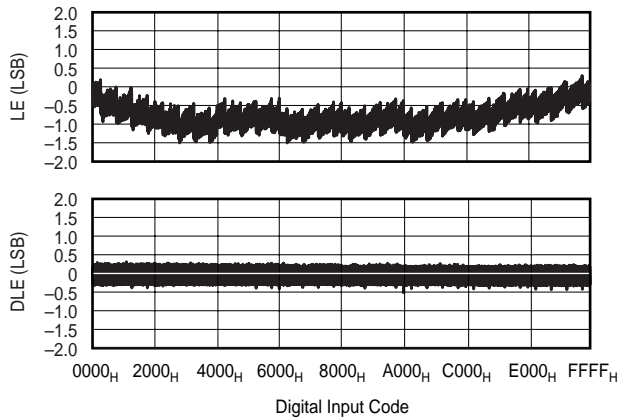


LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, +85°C)

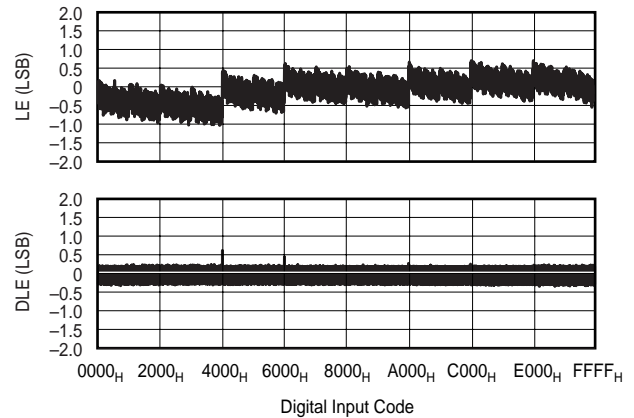


-40°C

LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, -40°C)

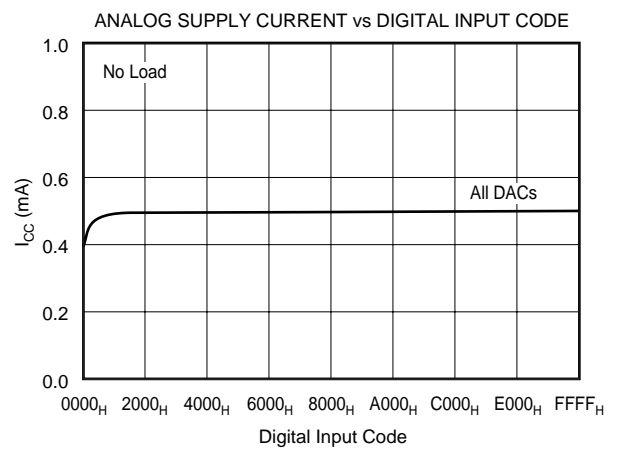
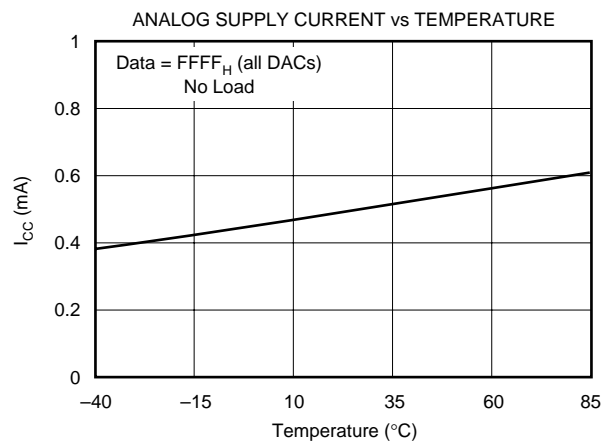
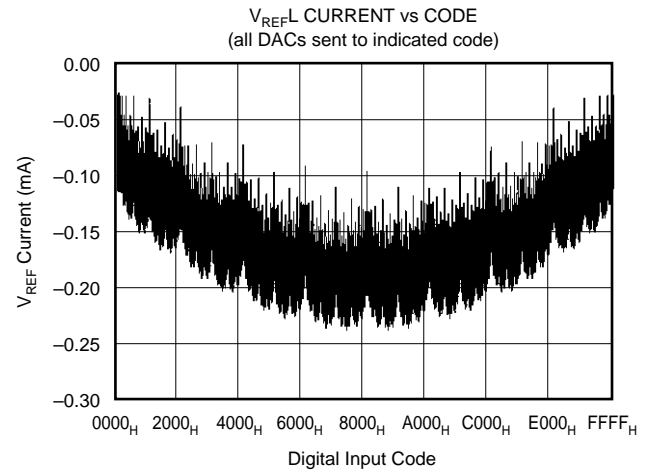
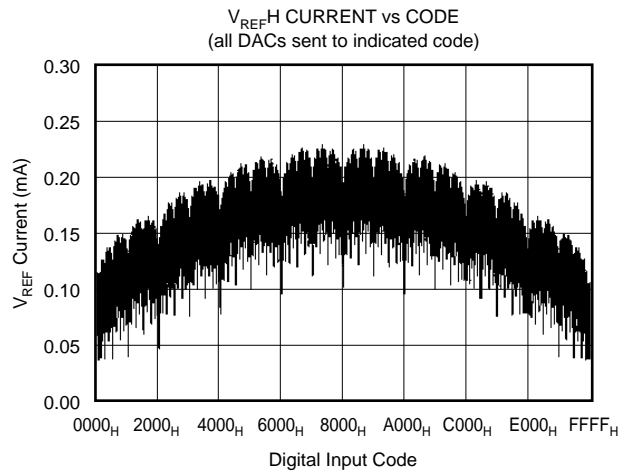
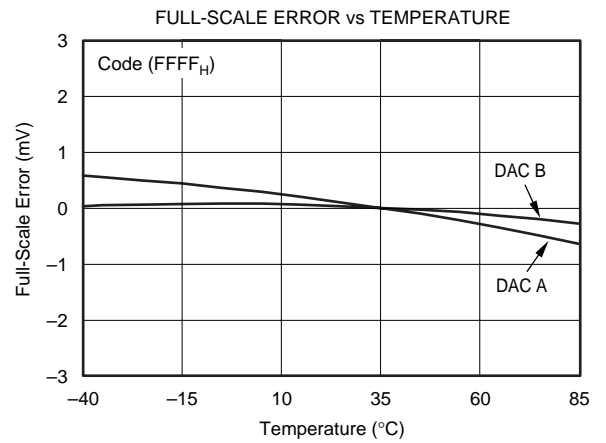
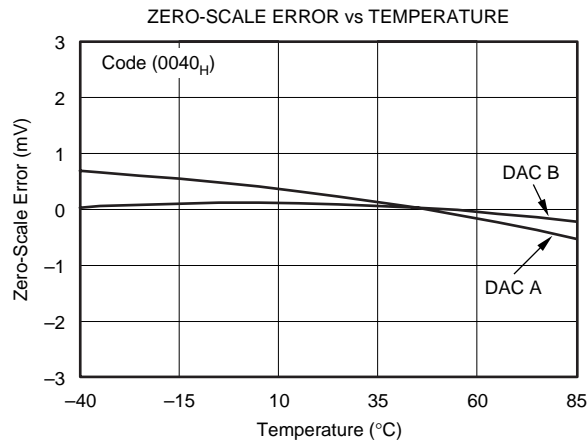


LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, -40°C)



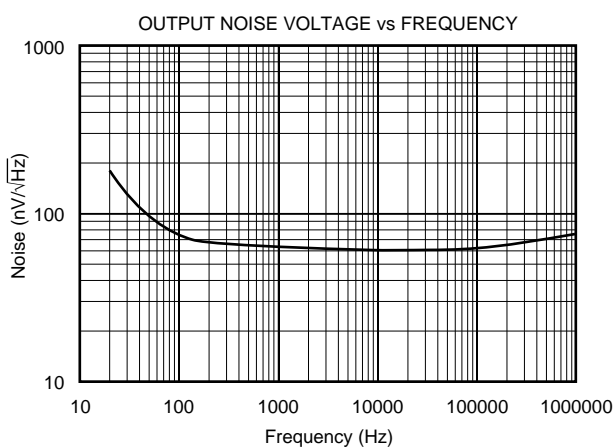
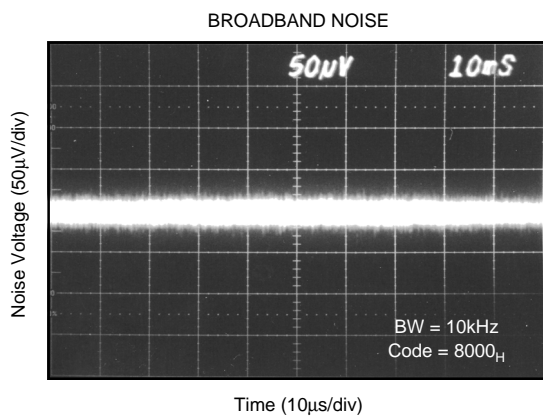
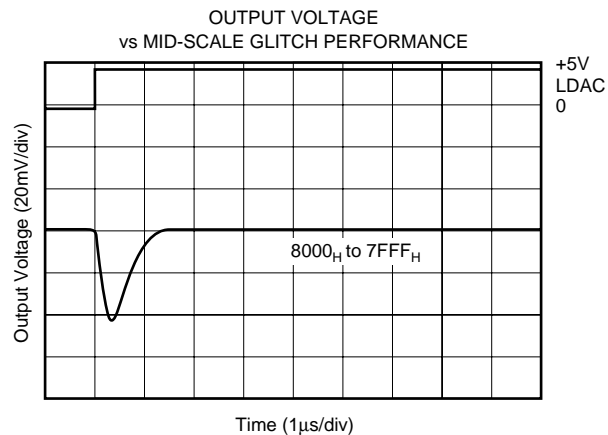
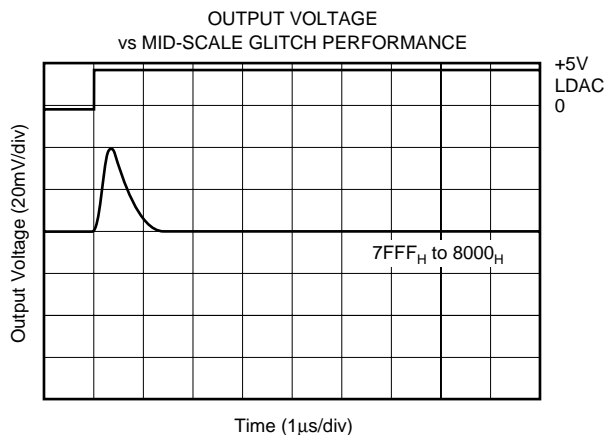
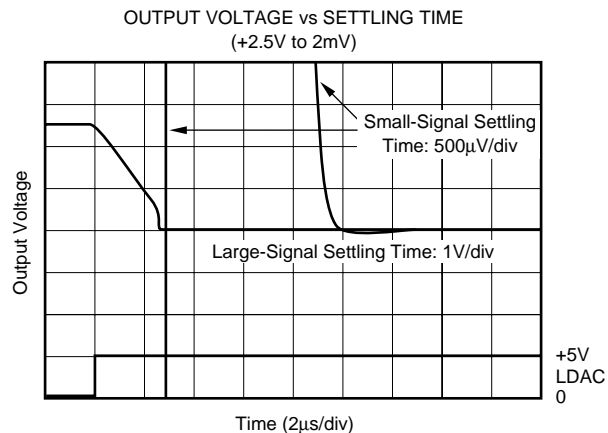
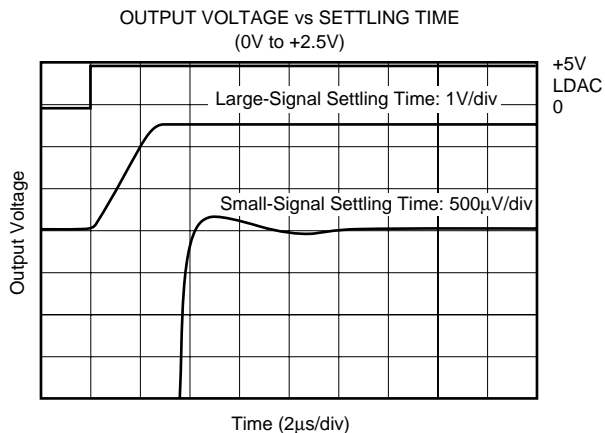
TYPICAL CHARACTERISTICS: $V_{SS} = 0V$ (Cont.)

At $T_A = +25^\circ C$, $V_{DD} = V_{CC} = +5V$, $V_{SS} = 0V$, $V_{REFH} = +2.5V$, $V_{REFL} = 0V$, representative unit, unless otherwise specified.



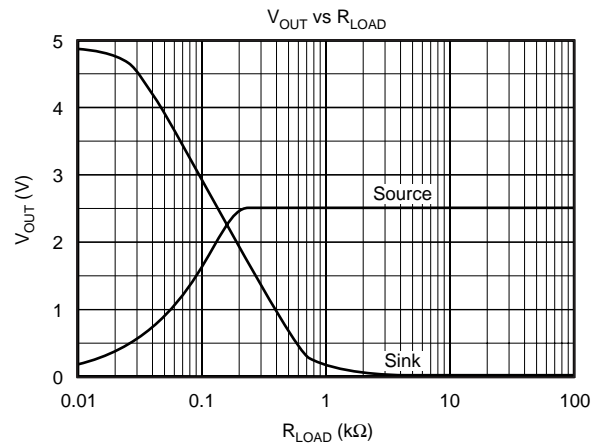
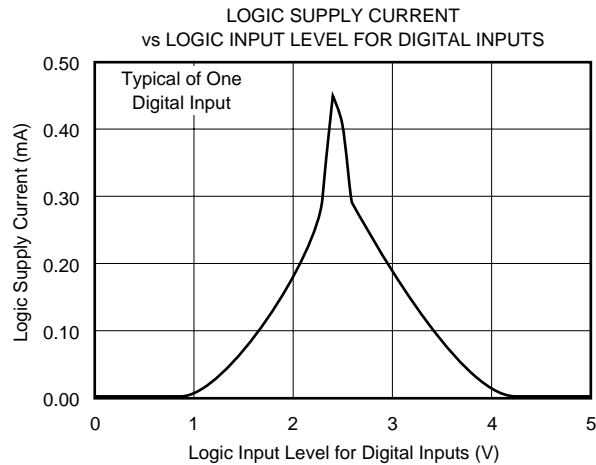
TYPICAL CHARACTERISTICS: $V_{SS} = 0V$ (Cont.)

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TYPICAL CHARACTERISTICS: $V_{SS} = 0V$ (Cont.)

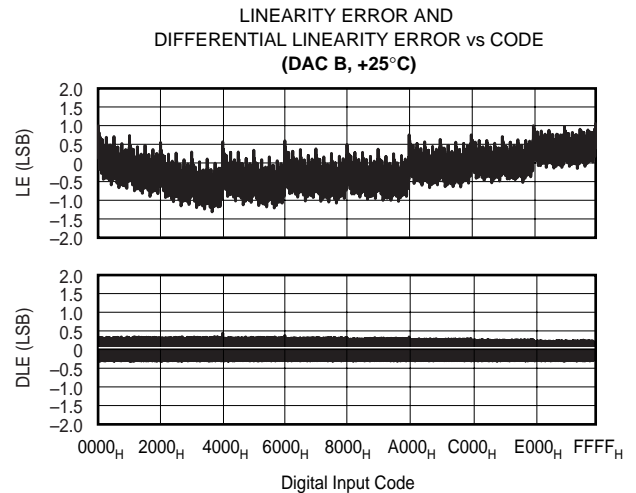
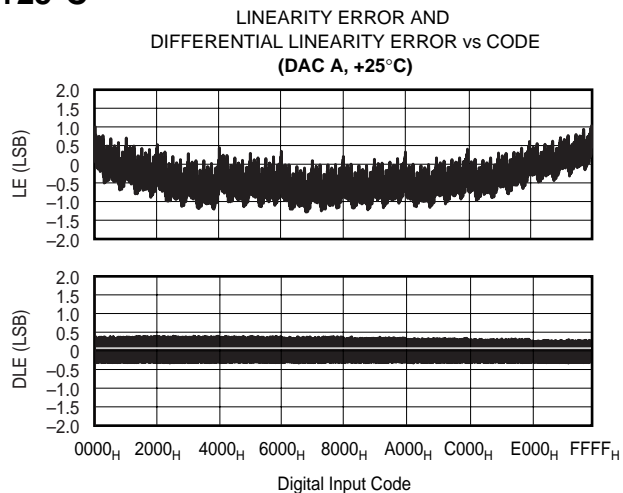
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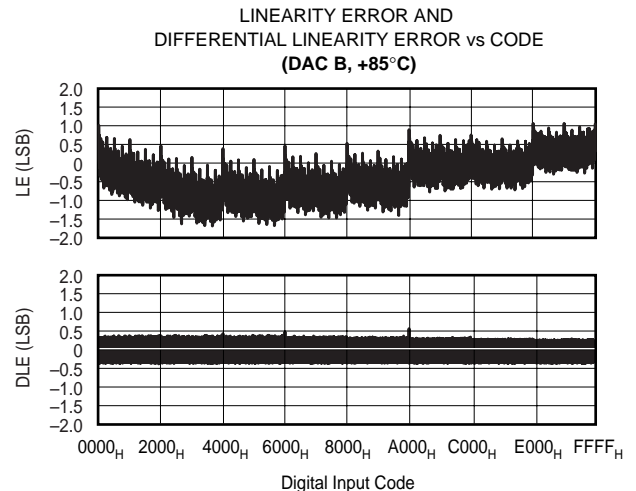
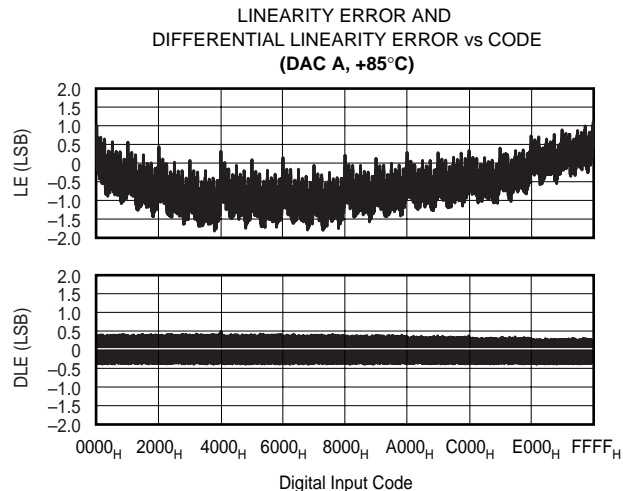
$V_{SS} = -5V$

At $T_A = +25^\circ C$, $V_{DD} = V_{CC} = +5V$, $V_{SS} = -5V$, $V_{REFH} = +2.5V$, $V_{REFL} = -2.5V$, representative unit, unless otherwise specified.

+25°C



+85°C

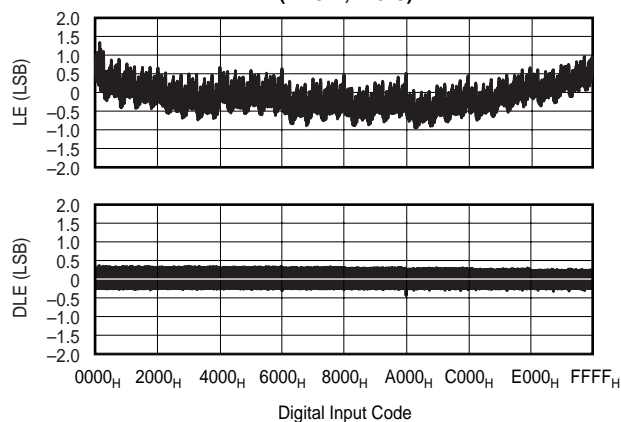


TYPICAL CHARACTERISTICS: $V_{SS} = -5V$ (Cont.)

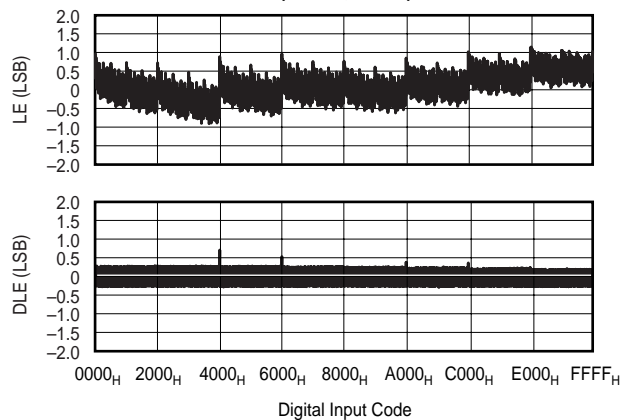
At $T_A = +25^\circ C$, $V_{DD} = V_{CC} = +5V$, $V_{SS} = -5V$, $V_{REFH} = +2.5V$, $V_{REFL} = -2.5V$, representative unit, unless otherwise specified.

$-40^\circ C$

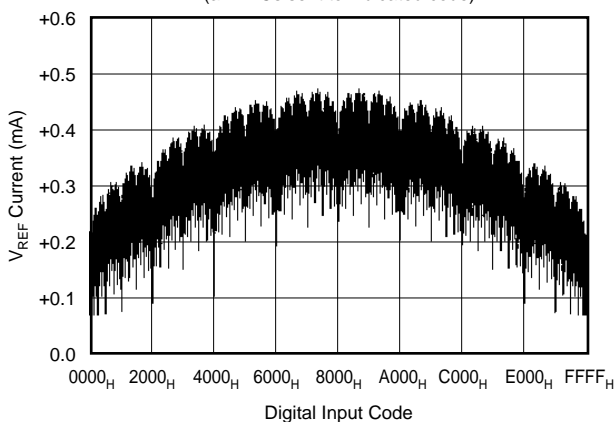
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, $-40^\circ C$)



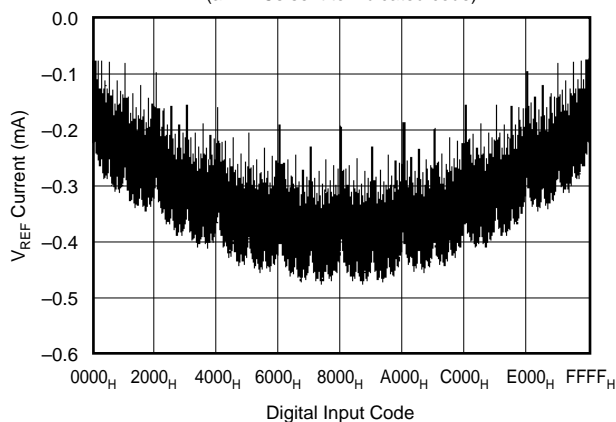
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, $-40^\circ C$)



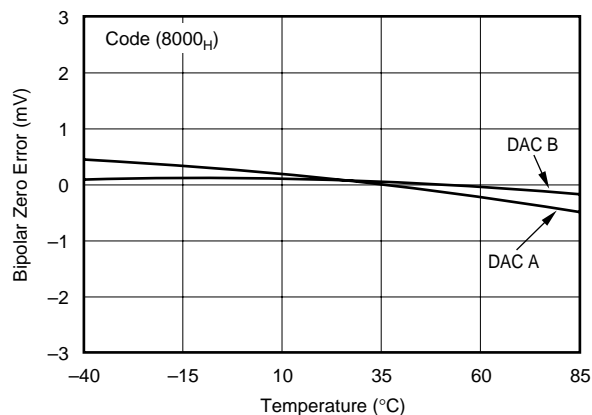
V_{REFH} CURRENT vs CODE
(all DACs sent to indicated code)



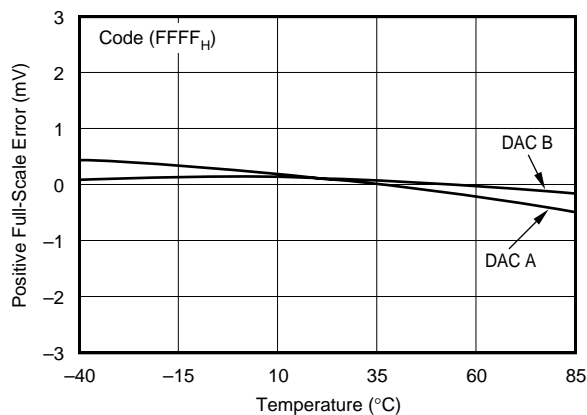
V_{REFL} CURRENT vs CODE
(all DACs sent to indicated code)



BIPOLAR ZERO ERROR vs TEMPERATURE

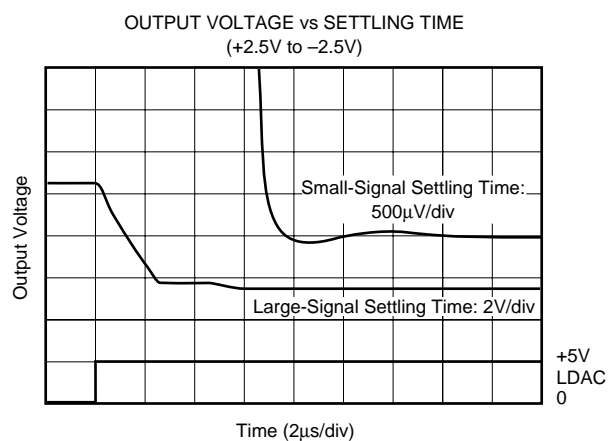
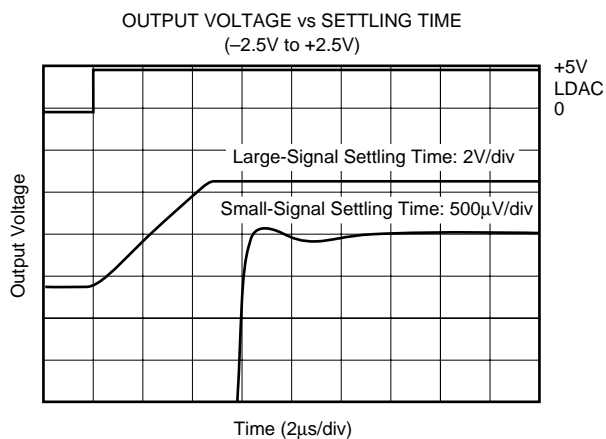
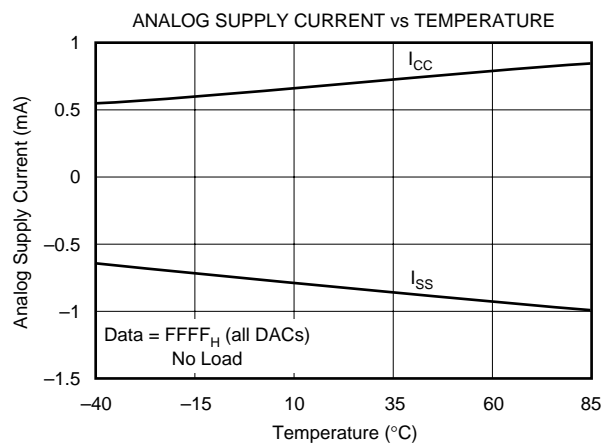
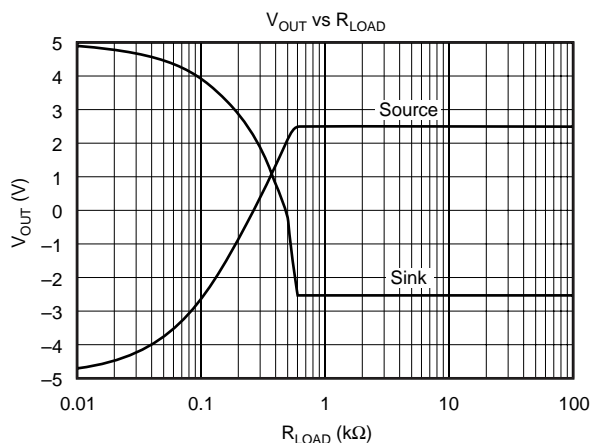
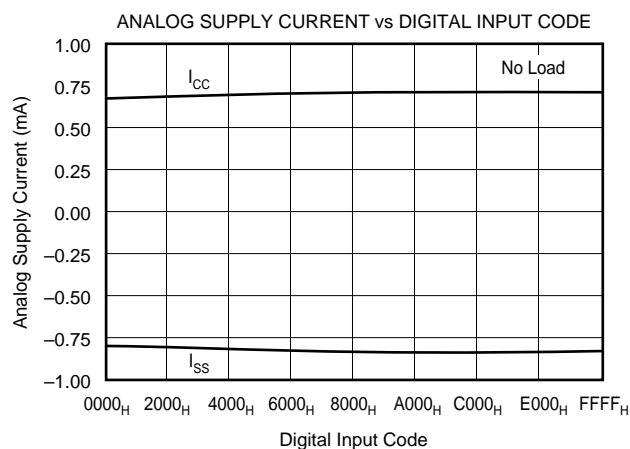
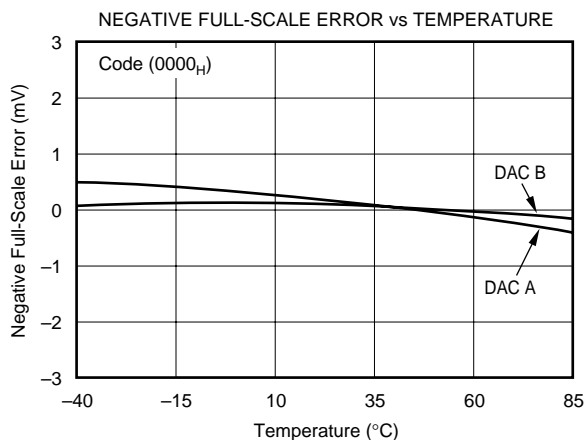


POSITIVE FULL-SCALE ERROR vs TEMPERATURE



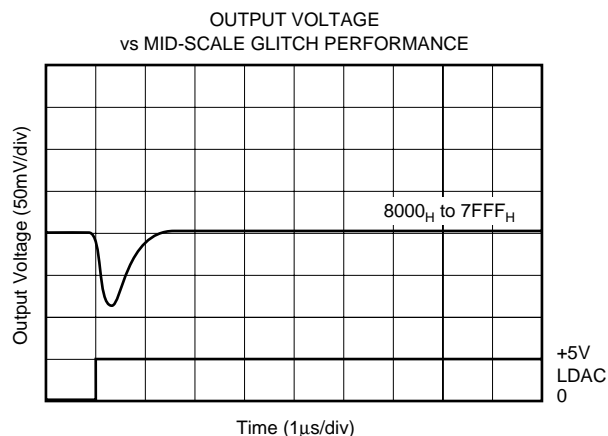
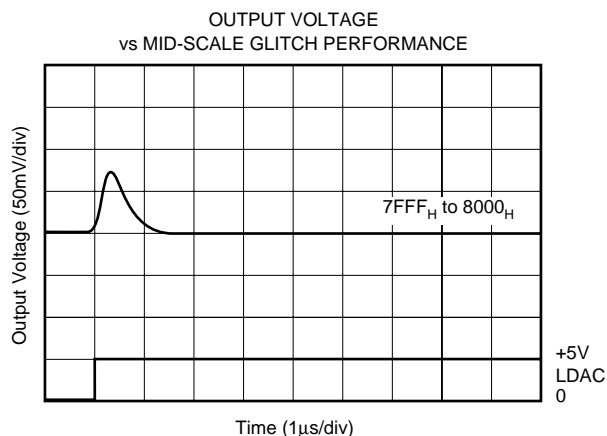
TYPICAL CHARACTERISTICS: $V_{SS} = -5V$ (Cont.)

At $T_A = +25^\circ C$, $V_{DD} = V_{CC} = +5V$, $V_{SS} = -5V$, $V_{REFH} = +2.5V$, $V_{REFL} = -2.5V$, representative unit, unless otherwise specified.



TYPICAL CHARACTERISTICS: $V_{SS} = -5V$ (Cont.)

At $T_A = +25^\circ C$, $V_{DD} = V_{CC} = +5V$, $V_{SS} = -5V$, $V_{REFH} = +2.5V$, $V_{REFL} = -2.5V$, representative unit, unless otherwise specified.



THEORY OF OPERATION

The DAC7632 is a dual channel, voltage output, 16-bit DAC. The architecture is an R-2R ladder configuration with the three MSB's segmented, followed by an operational amplifier that serves as a buffer. Each DAC has its own R-2R ladder network, segmented MSBs, and output op amp, as shown in Figure 1. The minimum voltage output (zero-scale) and maximum voltage output (full-scale) are set by the external voltage references V_{REFL} and V_{REFH} , respectively.

The digital input is a 24-bit serial word that contains an address bit for selecting one of two DACs, a quick load bit, six unused bits, and the 16-bit DAC code (MSB first). The converters can be powered from either a single +5V supply or a dual $\pm 5V$ supply. The device offers a reset function which immediately sets all DAC output voltages, DAC registers and input registers to mid-scale (code 8000_H) or to zero-scale (code 0000_H), depending on the state of RSTSEL. See Figures 2 and 3 for the basic configurations of the DAC7632.

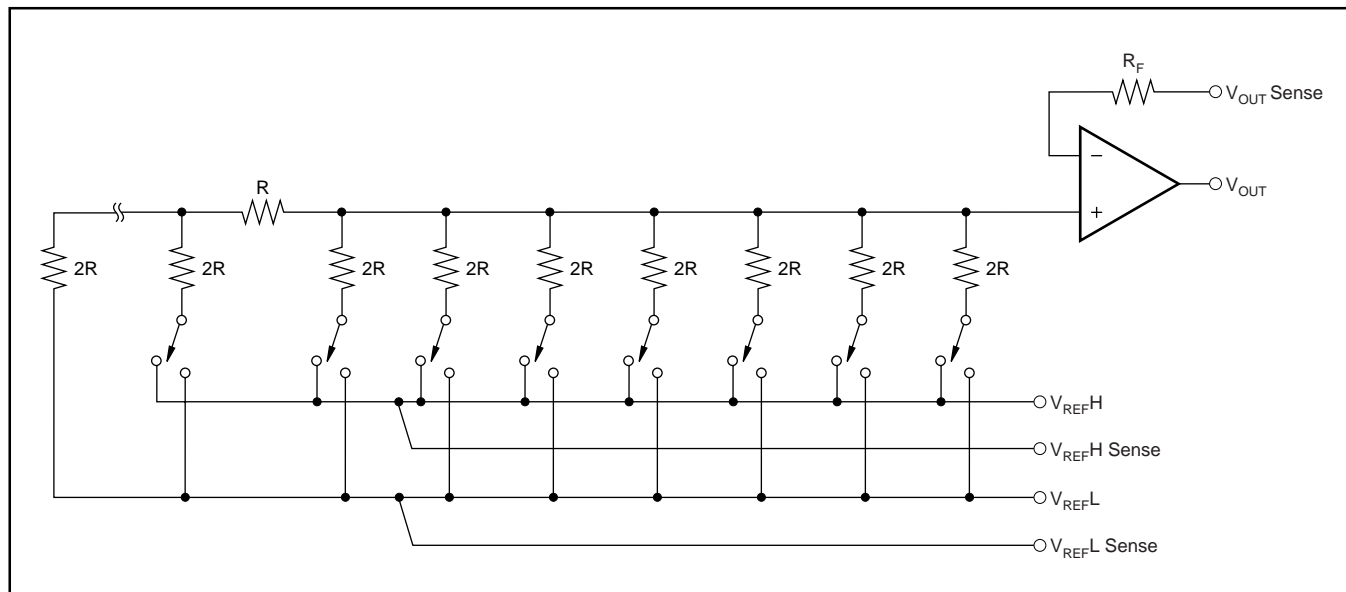


FIGURE 1. DAC7632 Architecture.

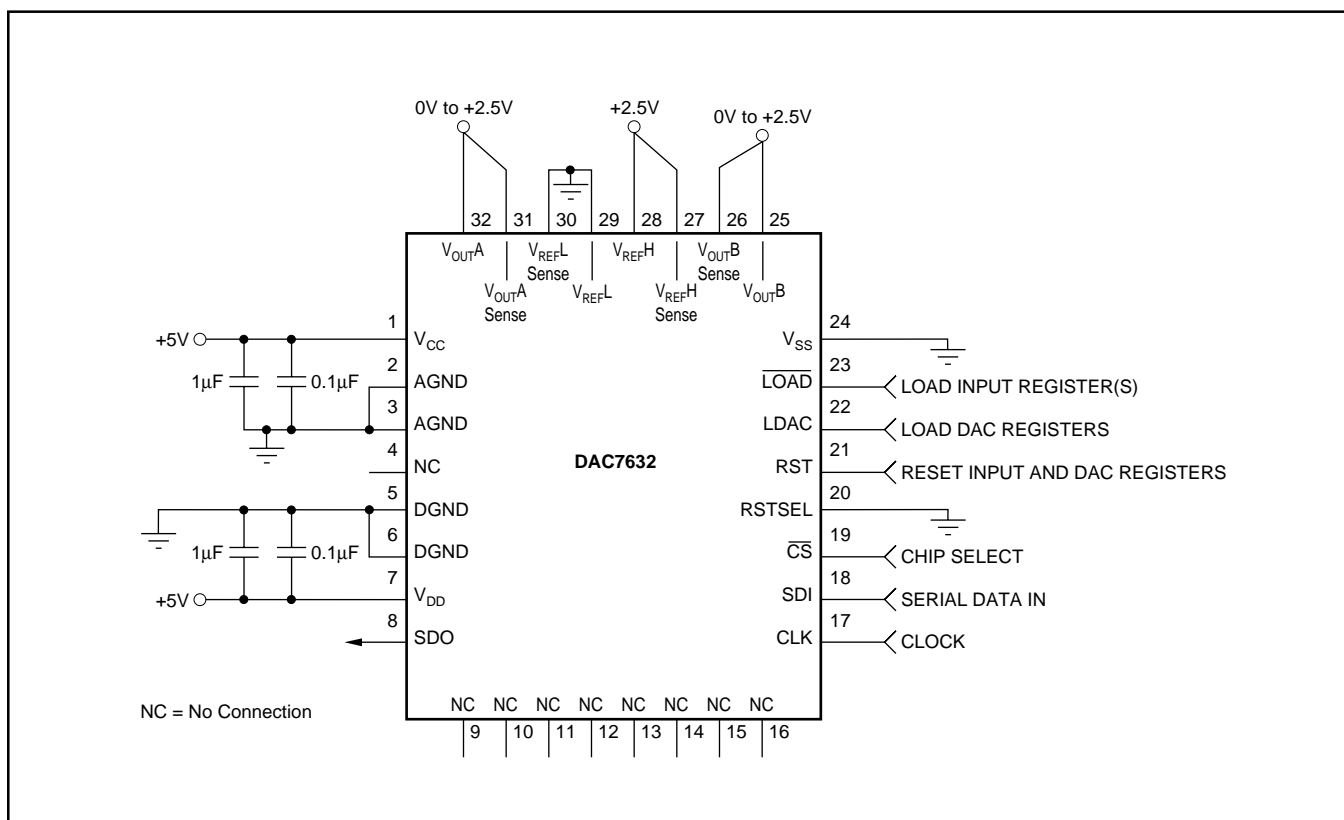


FIGURE 2. Basic Single-Supply Operation of the DAC7632.

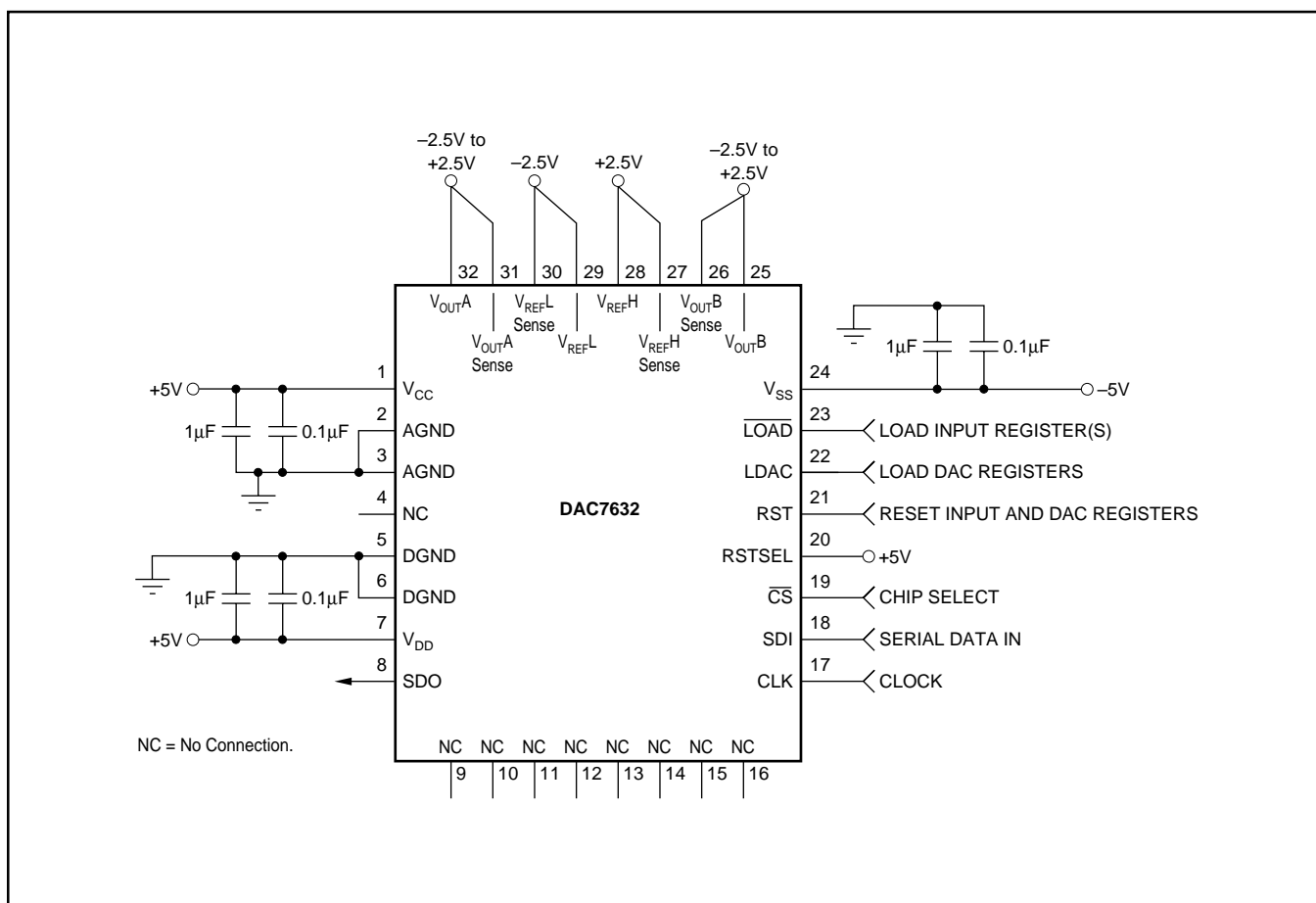


FIGURE 3. Basic Dual-Supply Operation of the DAC7632.

ANALOG OUTPUTS

When $V_{SS} = -5V$ (dual-supply operation), the output amplifier can swing to within 2.25V of the supply rails over the $-40^{\circ}C$ to $+85^{\circ}C$ temperature range. When $V_{SS} = 0V$ (single-supply operation), and with R_{LOAD} also connected to ground, the output can swing to ground. Care must also be taken when measuring the zero-scale error when $V_{SS} = 0V$. Since the output cannot swing below ground, the output voltage may not change for the first few digital input codes (0000_H, 0001_H, 0002_H, etc.) if the output amplifier has a negative offset. At the negative limit of $-2mV$, the first specified output starts at code 0040_H.

Due to the high accuracy of these DACs, system design problems such as grounding and contact resistance become very important. A 16-bit converter with a 2.5V full-scale range has a 1LSB value of $38\mu V$. With a load current of 1mA, series wiring and connector resistance of only $40m\Omega$ (R_{W2}) will cause a voltage drop of $40\mu V$, as shown in Figure 4. To understand what this means in terms of a system layout, the resistivity of a typical 1 ounce copper-clad printed circuit board is $1/2m\Omega$ per square. For a 1mA load, a 10 milli-inch wide printed circuit conductor 600 milli-inches long will result in a voltage drop of $30\mu V$.

The DAC7632 offers a force and sense output configuration for the high open-loop gain output amplifier. This feature allows the loop around the output amplifier to be closed at the load, as shown in Figure 4, thus ensuring an accurate output voltage.

REFERENCE INPUTS

The reference inputs, V_{REFL} and V_{REFH} , can be any voltage between $V_{SS} + 2.5V$ and $V_{CC} - 2.5V$, provided that V_{REFH} is at least 1.25V greater than V_{REFL} . The minimum output of each DAC is equal to V_{REFL} plus a small offset voltage (essentially, the offset of the output op amp). The maximum output is equal to V_{REFH} plus a similar offset voltage. Note

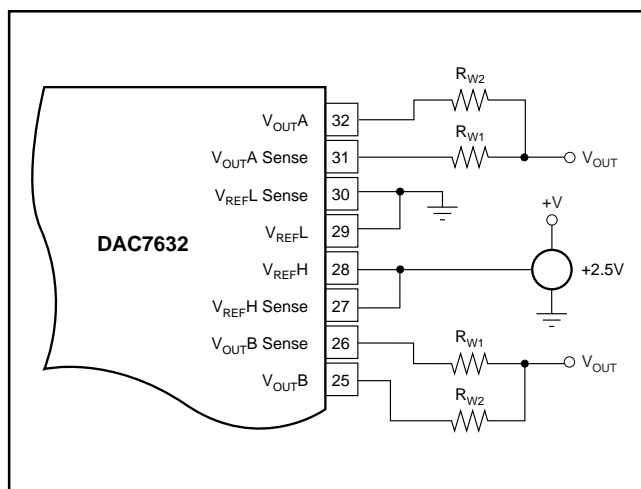


FIGURE 4. Analog Output Closed-Loop Configuration
 R_W represents wiring resistances.

that V_{SS} (the negative power supply) must either be connected to ground or must be in the range of $-4.75V$ to $-5.25V$. The voltage on V_{SS} sets several bias points within the converter. If V_{SS} is not in one of these two configurations, the bias values may be in error and proper operation of the device may be affected.

The current into the V_{REFH} input and out of V_{REFL} depends on the DAC output voltages, and can vary from a few microamps to approximately 0.5mA. The reference input appears as a varying load to the reference supply. If the reference applied can sink or source the required current, a reference buffer is not required. The DAC7632 features reference drive and sense connections such that the internal errors caused by the changing reference current and the circuit impedances can be minimized. Figures 5 through 13 show different reference configurations and the effect on the integral linearity and differential linearity, for each case.

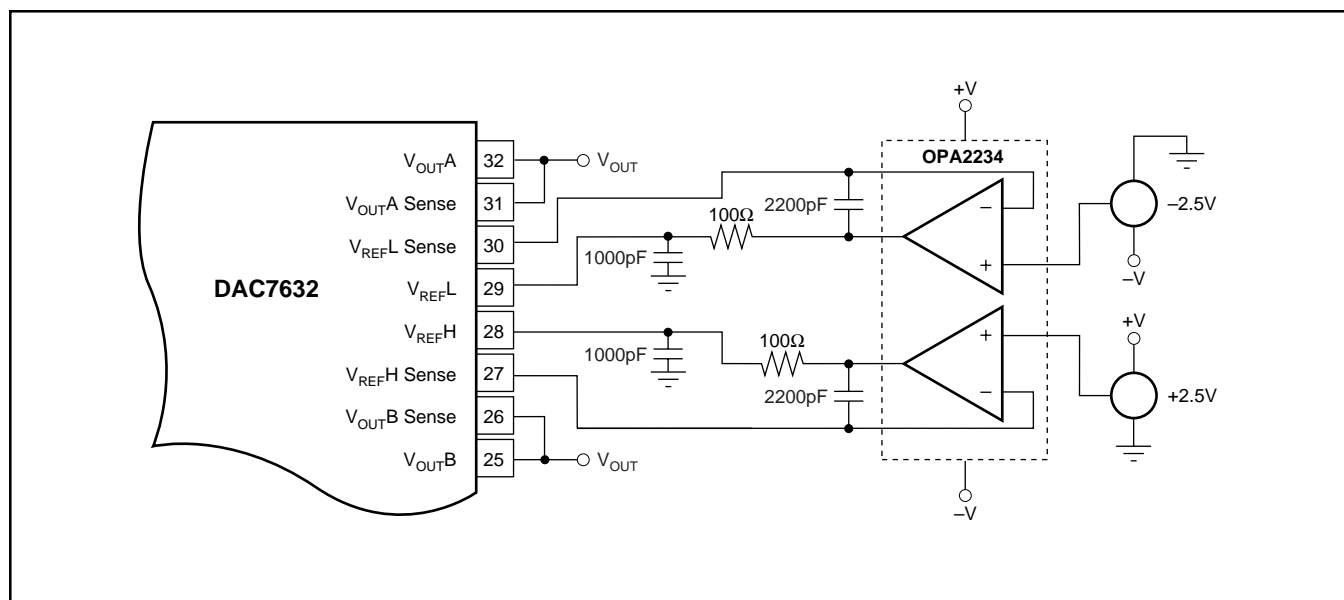


FIGURE 5. Dual Supply Configuration-Buffered References, used for Dual-Supply Performance.

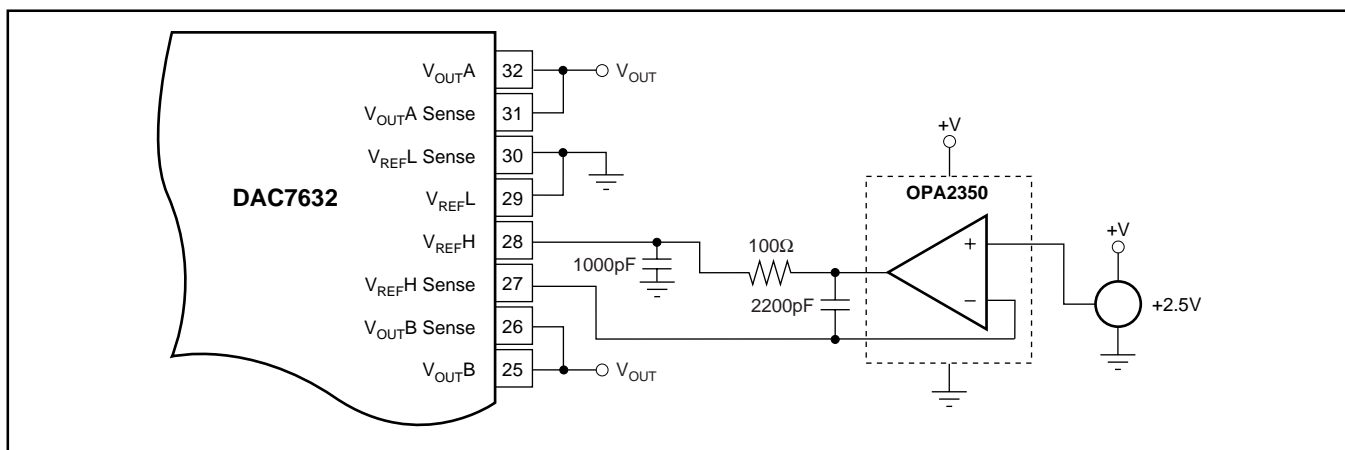


FIGURE 10. Single-Supply Buffered V_{REFH} .

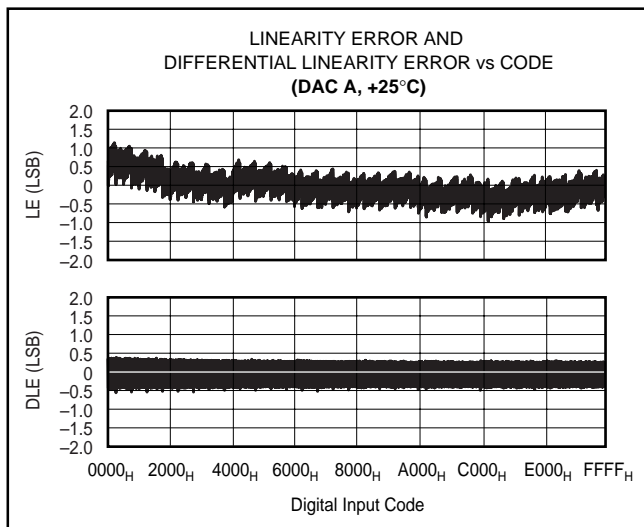


FIGURE 11. Linearity and Differential Linearity Error Characteristic Curves for Figure 10.

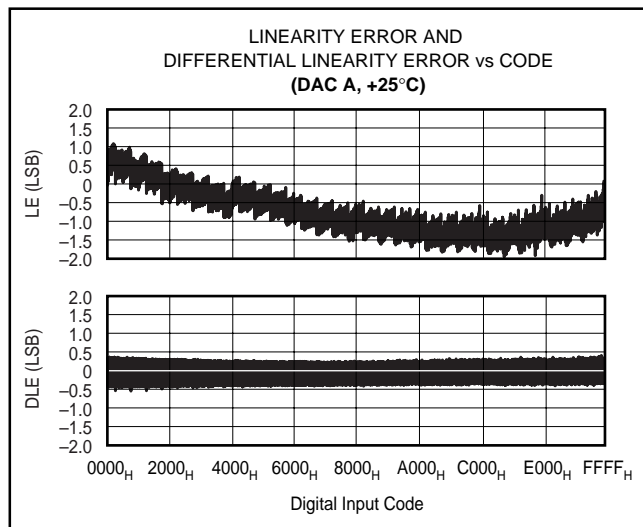


FIGURE 13. Linearity and Differential Linearity Error Characteristic Curves for Figure 12.

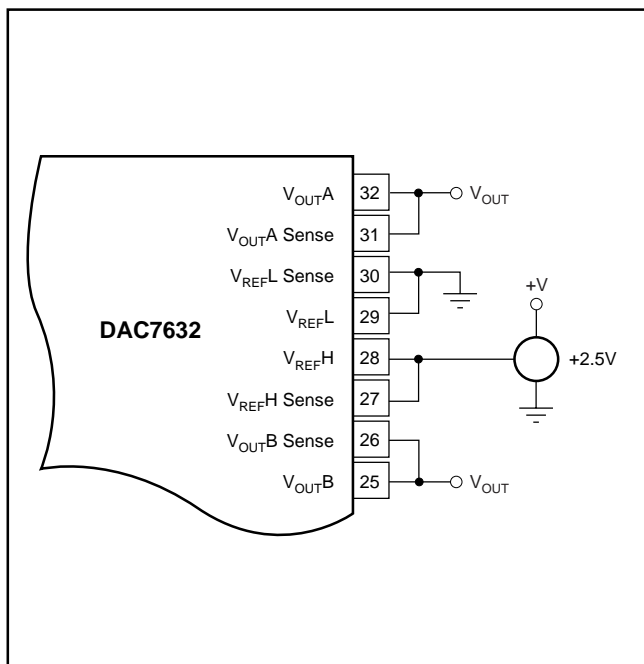


FIGURE 12. Low-Cost Single-Supply Configuration.

DIGITAL INTERFACE

See Table I for the basic control logic for the DAC7632. The interface consists of a Serial Data Clock (CLK) input, Serial Data Input (SDI), Input Register Load Control Signal (\overline{LOAD}), and DAC Register Load Control Signal (LDAC). In addition, a Chip Select (\overline{CS}) input is available to enable serial communication when there are multiple serial devices attached to a single serial bus. An asynchronous Reset (RST) input (rising edge triggered) is provided to simplify start-up conditions, periodic resets, or emergency resets to a known state, depending on the status of the Reset Select (RSTSEL) signal.

The DAC code, quick load control, and address are provided via a 24-bit serial interface (see Figure 15). The first bit (DACSEL) selects the input register that will be updated when \overline{LOAD} goes LOW. The third bit is a "Quick Load" bit such that if HIGH, the code in the shift register is loaded into both input registers when the \overline{LOAD} signal goes LOW. If the "Quick Load" bit is LOW when an active \overline{LOAD} signal is issued, the content of the shift register is loaded only to the input register that is addressed by DACSEL. The "Quick Load" bit is followed by five unused bits. The last 16 bits (MSB first) make up the DAC code.

SERIAL DATA INPUT

| B23 | B22 | B21 | B20 | B19 | B18 | B17 | B16 | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 |
|--------|-----|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| DACSEL | X | QUICK LOAD | X | X | X | X | X | D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

| DACSEL | $\overline{\text{CS}}$ | RST | RSTSEL | LDAC | $\overline{\text{LOAD}}$ | INPUT REGISTER | DAC REGISTER | MODE | DAC |
|--------|------------------------|------------|--------|------------|--------------------------|----------------------------|----------------------------|---------------------|-----|
| 0 | L | H | X | X | L | Write | Hold | Write Input | A |
| 1 | L | H | X | X | L | Write | Hold | Write Input | B |
| X | H | H | X | \uparrow | H | Hold | Write | Update | All |
| X | H | H | X | H | H | Hold | Hold | Hold | All |
| X | X | \uparrow | L | X | X | Reset to 0000 _H | Reset to 0000 _H | Reset to Zero-Scale | All |
| X | X | \uparrow | H | X | X | Reset to 8000 _H | Reset to 8000 _H | Reset to Mid-scale | All |

TABLE I. DAC7632 Logic Truth Table.

Data presented to SDI is clocked into the shift register on each rising CLK edge. This data is latched into the input register(s) via a logic-low level on $\overline{\text{LOAD}}$. The data is directed from the shift register to the desired input register(s) specified by data bits 21 and 23. The internal DAC registers are edge triggered and not level triggered. When the LDAC signal is transitioned from LOW to HIGH, the digital word currently in the input registers are latched. This double-buffered architecture has been designed so that new data can be entered for each DAC without disturbing the analog outputs. When the new data has been entered into the device, both DAC outputs can be updated simultaneously by the rising edge of LDAC. Additionally, it allows the input registers to be written to at any point, then the DAC output voltages can be synchronously changed via a trigger signal (LDAC).

Note that $\overline{\text{CS}}$ and CLK are combined with an OR gate, which controls the serial-to-parallel shift register. These two inputs are completely interchangeable. In addition, care must be taken with the state of CLK when $\overline{\text{CS}}$ rises at the end of a serial transfer. If CLK is LOW when $\overline{\text{CS}}$ rises, the OR gate will provide a rising edge to the shift register, shifting the internal data one additional bit. The result will be incorrect data and possible selection of the wrong input register(s). If both $\overline{\text{CS}}$ and CLK are used, $\overline{\text{CS}}$ should rise only when CLK is HIGH. If not, then either $\overline{\text{CS}}$ or CLK can be used to operate the shift register (the remaining pin should be tied to DGND). Please refer to Table II for more information.

| $\overline{\text{CS}}^{(1)}$ | CLK ⁽¹⁾ | $\overline{\text{LOAD}}$ | RST | SERIAL SHIFT REGISTER |
|------------------------------|--------------------|--------------------------|------------------|-----------------------|
| H ⁽²⁾ | X ⁽³⁾ | H | H | No Change |
| L ⁽⁴⁾ | L | H | H | No Change |
| L | $\uparrow^{(5)}$ | H | H | Advanced One Bit |
| \uparrow | L | H | H | Advanced One Bit |
| H ⁽⁶⁾ | X | L ⁽⁷⁾ | H | No Change |
| H ⁽⁶⁾ | X | H | $\uparrow^{(8)}$ | No Change |

NOTES: (1) $\overline{\text{CS}}$ and CLK are interchangeable. (2) H = Logic HIGH. (3) X = Don't Care. (4) L = Logic LOW. (5) = Positive Logic Transition. (6) A HIGH value is suggested in order to avoid a "false clock" from advancing the shift register and changing the shift register. (7) If data is clocked into the serial register while $\overline{\text{LOAD}}$ is LOW, the input registers will change as data flows through the shift register. This will corrupt the data in each DAC register that has been erroneously selected. (8) Rising edge of RST causes no change in the contents of the serial shift register.

TABLE II. Serial Shift Register Truth Table.

SERIAL-DATA OUTPUT

The Serial-Data Output pin (SDO) is the internal shift register's output. For the DAC7632, SDO is a driven output and does not require an external pull-up. Any number of DAC7632s can be daisy-chained by connecting the SDO pin of one device to the SDI pin of the following device in the chain, as shown in Figure 14.

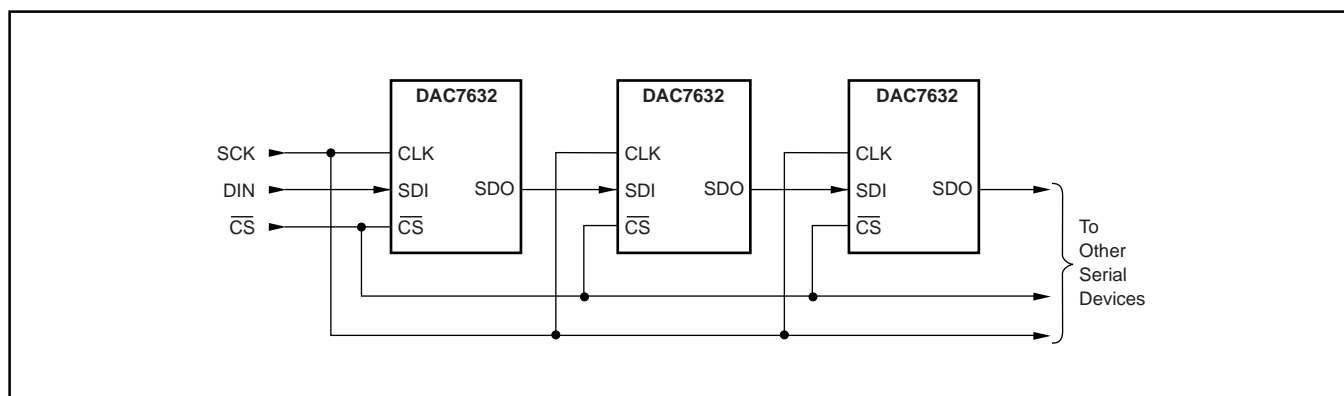


FIGURE 14. Daisy-Chaining Multiple DAC7632s.

DIGITAL TIMING

Figure 15 and Table III provide detailed timing for the digital interface of the DAC7632.

DIGITAL INPUT CODING

The DAC7632 input data is in Straight Binary format. The output voltage is given by Equation 1.

$$V_{OUT} = V_{REFL} + \frac{(V_{REFH} - V_{REFL}) \cdot N}{65,536}$$

where N is the digital input code. This equation does not include the effects of offset (zero-scale) or gain (full-scale) errors.

DIGITALLY-PROGRAMMABLE CURRENT SOURCE

The DAC7632 offers a unique set of features that allows a wide range of flexibility in designing application circuits such as programmable current sources. The DAC7632 offers both a differential reference input, as well as an open-loop configuration around the output amplifier. The open-loop configuration around the output amplifier allows a transistor to be placed within the loop to implement a digitally-programmable, unidirectional current source. The availability of a differential reference allows programmability for both the full-scale and zero-scale currents. The output current is calculated as:

$$I_{OUT} = \left(\left(\frac{V_{REFH} - V_{REFL}}{R_{SENSE}} \right) \cdot \left(\frac{N}{65,536} \right) \right) + (V_{REFL} / R_{SENSE})$$

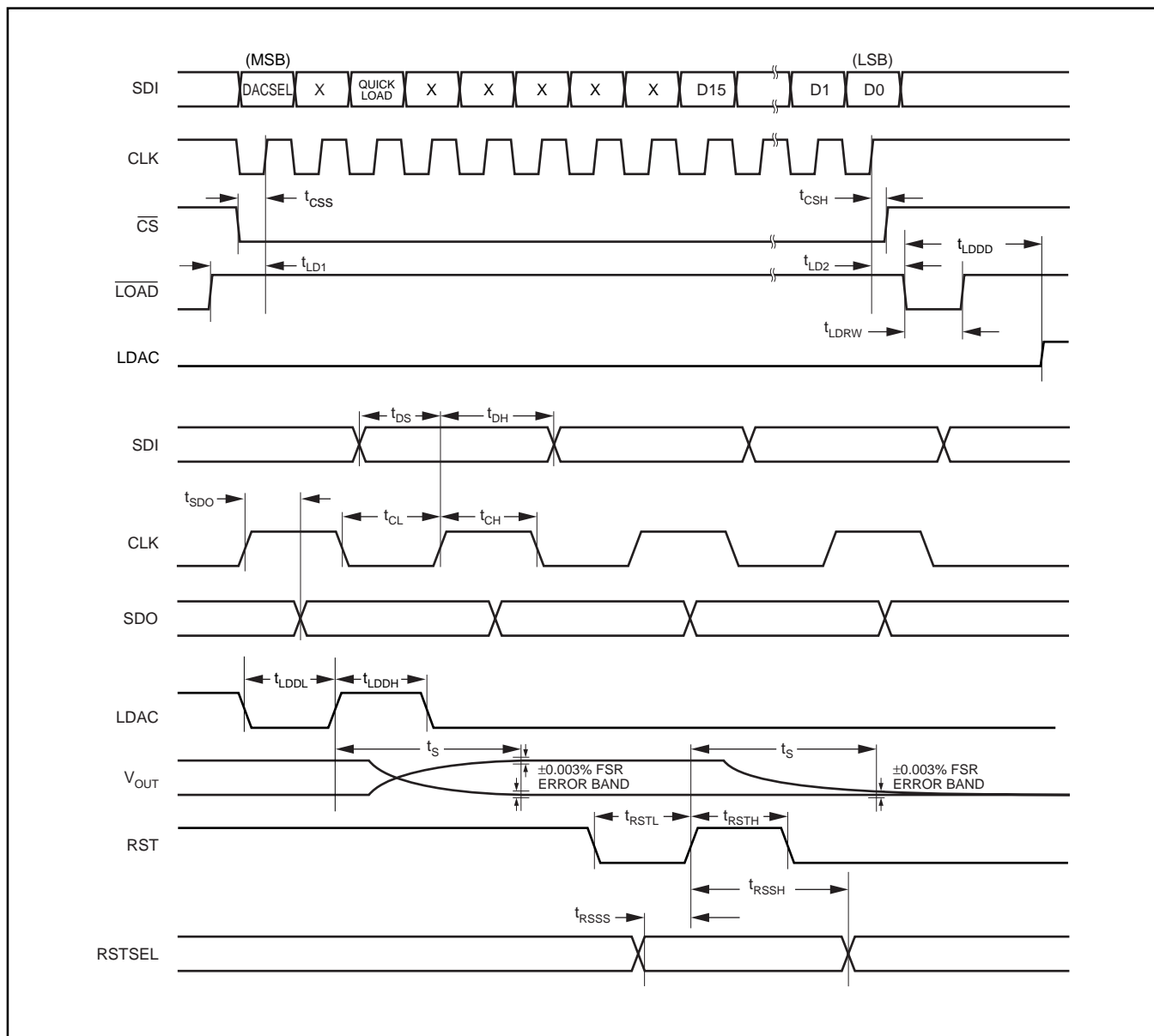


FIGURE 15. Digital Input and Output Timing.

| SYMBOL | DESCRIPTION | MIN | MAX | UNITS |
|------------|--------------------------------------|-----|-----|---------|
| t_{DS} | Data Valid to CLK Rising | 10 | | ns |
| t_{DH} | Data Held Valid after CLK Rises | 20 | | ns |
| t_{CH} | CLK HIGH | 25 | | ns |
| t_{CL} | CLK LOW | 25 | | ns |
| t_{CSS} | \overline{CS} LOW to CLK Rising | 15 | | ns |
| t_{CSH} | CLK HIGH to \overline{CS} Rising | 0 | | ns |
| t_{LD1} | \overline{LOAD} HIGH to CLK Rising | 10 | | ns |
| t_{LD2} | CLK Rising to \overline{LOAD} LOW | 30 | | ns |
| t_{LDRW} | \overline{LOAD} LOW Time | 30 | | ns |
| t_{LDDL} | LDAC LOW Time | 100 | | ns |
| t_{LDDH} | LDAC HIGH Time | 100 | | ns |
| t_{LDD} | \overline{LOAD} LOW to LDAC Rising | 40 | | ns |
| t_{RSS} | RESETSEL Valid to RESET HIGH | 0 | | ns |
| t_{RSSH} | RESET HIGH to RESETSEL Not Valid | 100 | | ns |
| t_{RSTL} | RESET LOW Time | 10 | | ns |
| t_{RSTH} | RESET HIGH Time | 10 | | ns |
| t_{SDO} | SDO Propagation Delay | 10 | 30 | ns |
| t_S | Settling Time | | 10 | μ s |

TABLE III. Timing Specifications ($T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$).

Figure 16 shows a DAC7632 in a 4-20mA current output configuration. The output current can be determined by Equation 3:

$$I_{OUT} = \left(\left(\frac{2.5V - 0.5V}{125\Omega} \right) \cdot \left(\frac{N}{65,536} \right) \right) + \left(\frac{0.5V}{125\Omega} \right)$$

At full-scale, the output current is 16mA, plus the 4mA, for the zero current. At zero scale the output current is the offset current of 4mA ($0.5V/125\Omega$).

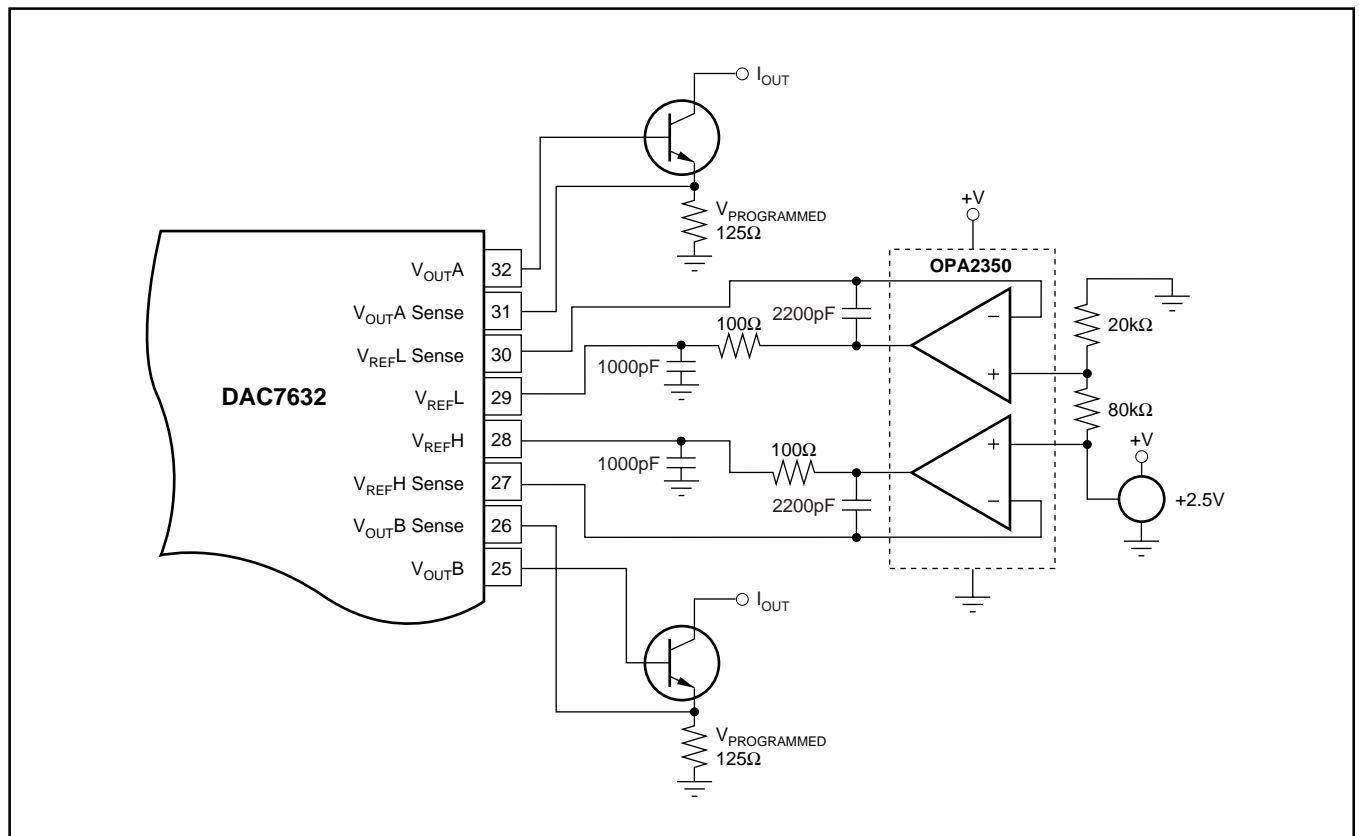


FIGURE 16. 4-20mA Digitally-Controlled Current Source.

Revision History

| DATE | REVISION | PAGE | SECTION | DESCRIPTION |
|------|----------|------|----------------------------|---|
| 4/08 | A | — | Entire Data Sheet | Updated document format. |
| | | 4 | Electrical Characteristics | Changed section title from "Dual Supply" to "Single Supply" (typo). |
| | | 13 | Figures 2, 3 | Updated text in figures to correct names (typo). |

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|-----------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| DAC7632VFBT | Active | Production | LQFP (VF) 32 | 250 SMALL T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 B |
| DAC7632VFBT.A | Active | Production | LQFP (VF) 32 | 250 SMALL T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 B |
| DAC7632VFBTG4 | Active | Production | LQFP (VF) 32 | 250 SMALL T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 B |
| DAC7632VFR | Active | Production | LQFP (VF) 32 | 1000 LARGE T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 |
| DAC7632VFR.A | Active | Production | LQFP (VF) 32 | 1000 LARGE T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 |
| DAC7632VFT | Active | Production | LQFP (VF) 32 | 250 SMALL T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 |
| DAC7632VFT.A | Active | Production | LQFP (VF) 32 | 250 SMALL T&R | Yes | Call TI | Level-3-260C-168 HR | -40 to 85 | DAC7632 |

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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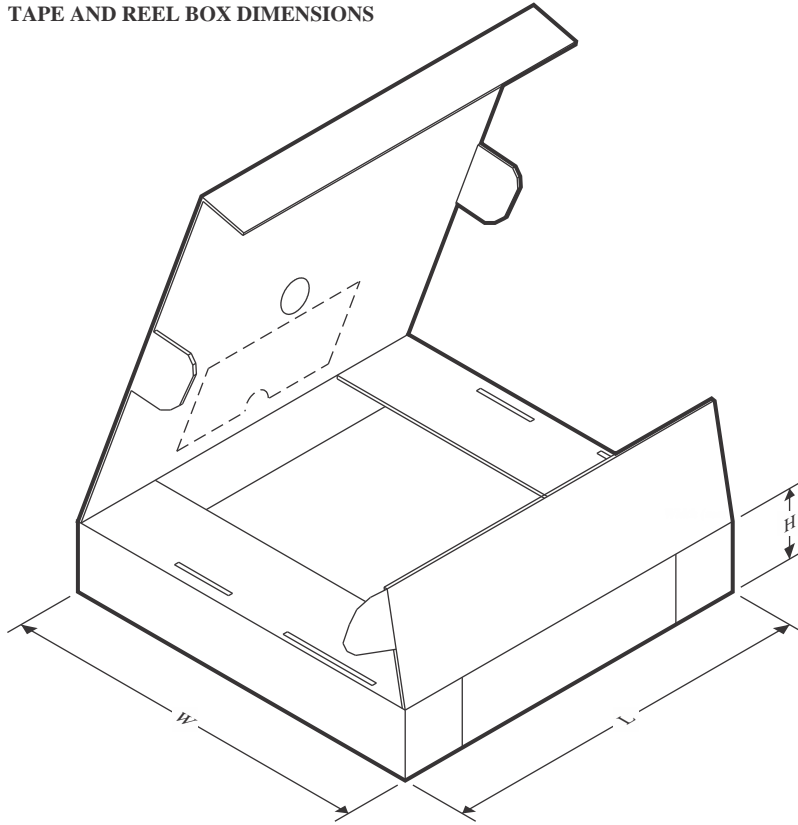
TAPE AND REEL INFORMATION



*All dimensions are nominal

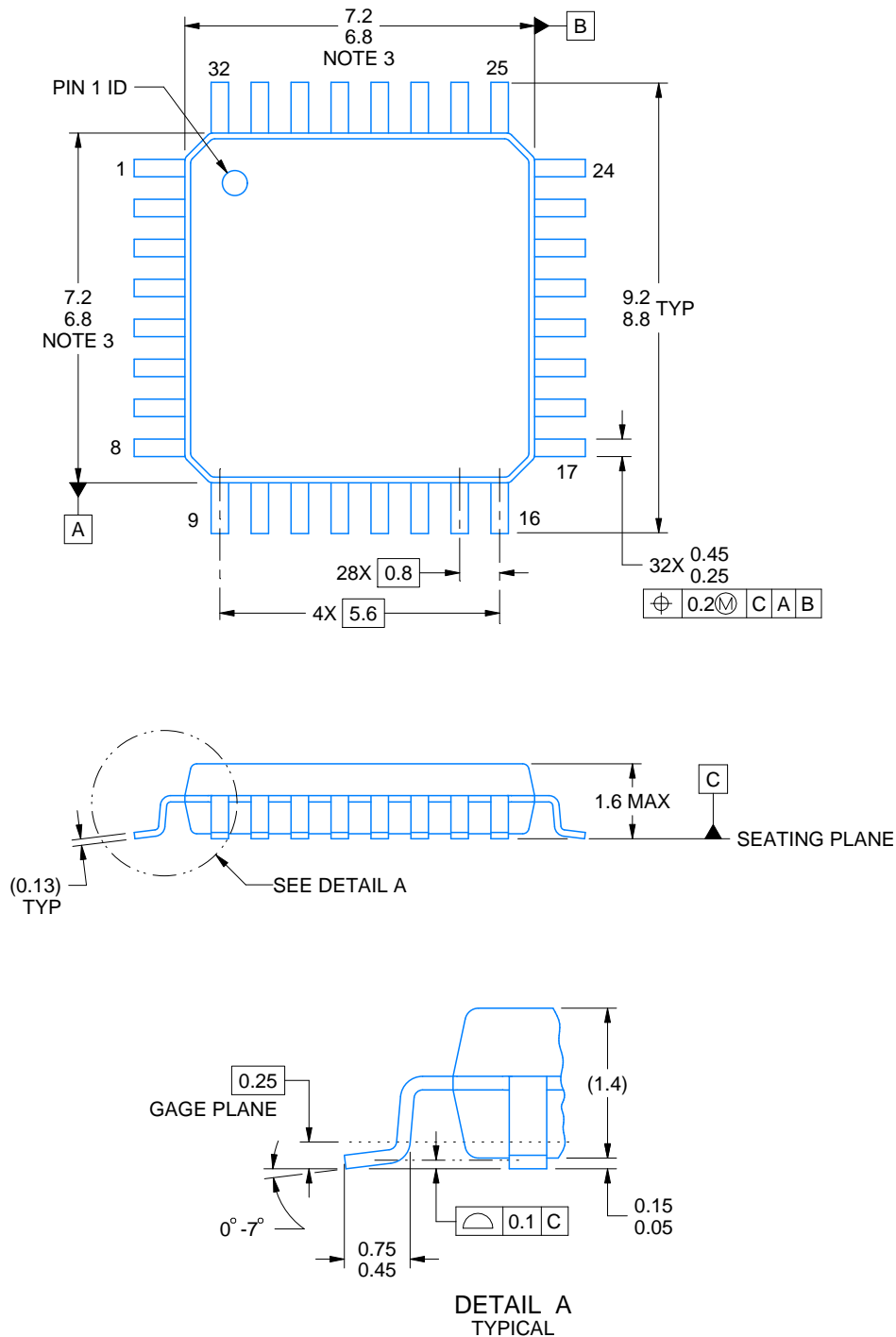
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| DAC7632VFR | LQFP | VF | 32 | 1000 | 330.0 | 16.4 | 9.6 | 9.6 | 1.9 | 12.0 | 16.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|------------|--------------|-----------------|------|------|-------------|------------|-------------|
| DAC7632VFR | LQFP | VF | 32 | 1000 | 350.0 | 350.0 | 43.0 |



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NOTES:

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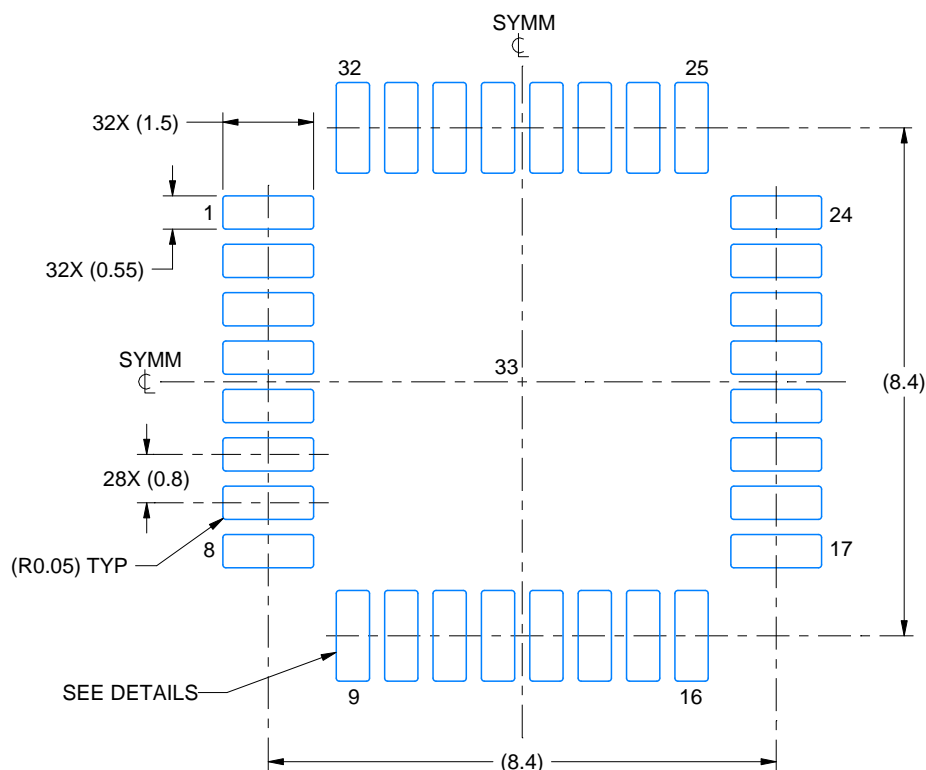
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs.
4. Reference JEDEC registration MS-026.

EXAMPLE BOARD LAYOUT

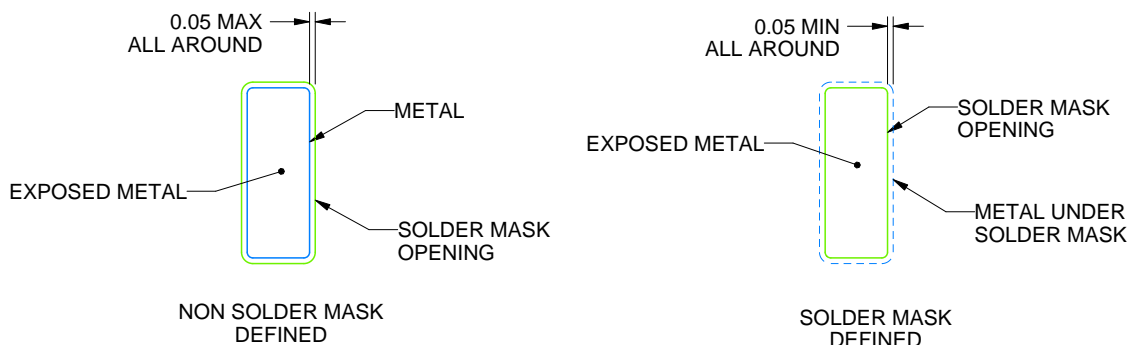
VF0032A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

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NOTES: (continued)

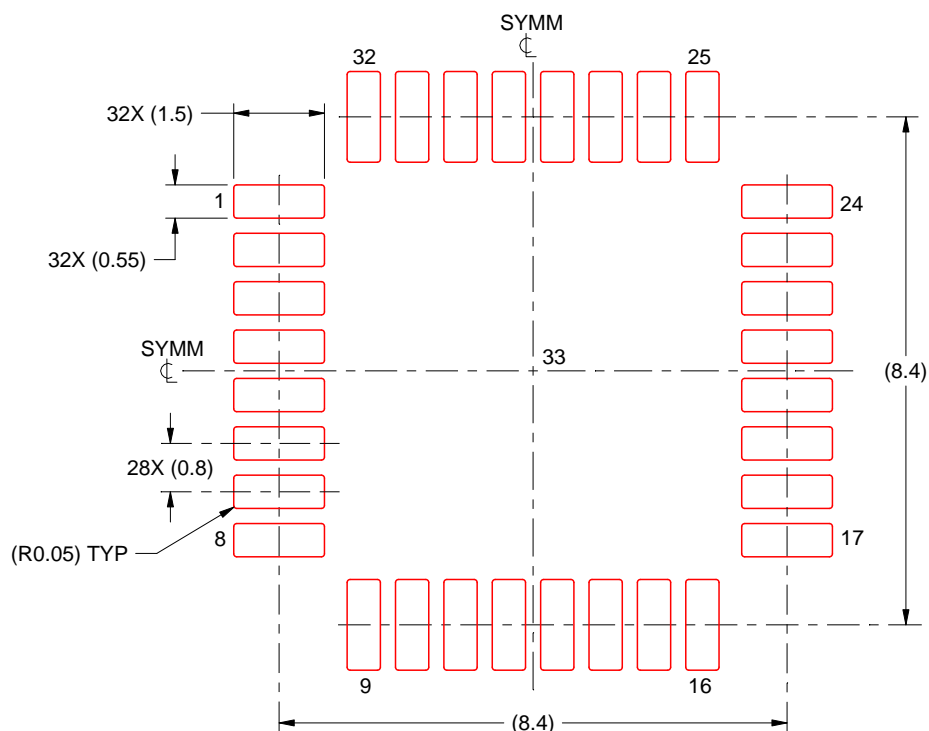
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

VF0032A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE
SCALE:8X

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NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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