SBAS157A – OCTOBER 2000 – REVISED MARCH 2003

Low-Power, Rail-to-Rail Output, 12-Bit Serial Input DIGITAL-TO-ANALOG CONVERTER

FEATURES

- ***micro*POWER OPERATION: 115μA at 5V**
- **POWER-ON RESET TO ZERO**
- **POWER SUPPLY: +2.7V to +5.5V**
- **ENSURED MONOTONIC BY DESIGN**
- **SETTLING TIME: 10μs to 1LSB**
- **LOW-POWER SERIAL INTERFACE WITH SCHMITT-TRIGGERED INPUTS**
- **ON-CHIP OUTPUT BUFFER AMPLIFIER, RAIL-TO-RAIL OPERATION**
- **$\overline{\text{SYNC}}$ INTERRUPT FACILITY**
- **SOT23-8 AND MSOP-8 PACKAGES**

APPLICATIONS

- **PROCESS CONTROL**
- **DATA ACQUISITION SYSTEMS**
- **CLOSED-LOOP SERVO-CONTROL**
- **PC PERIPHERALS**
- **PORTABLE INSTRUMENTATION**
- **PROGRAMMABLE ATTENUATION**

DESCRIPTION

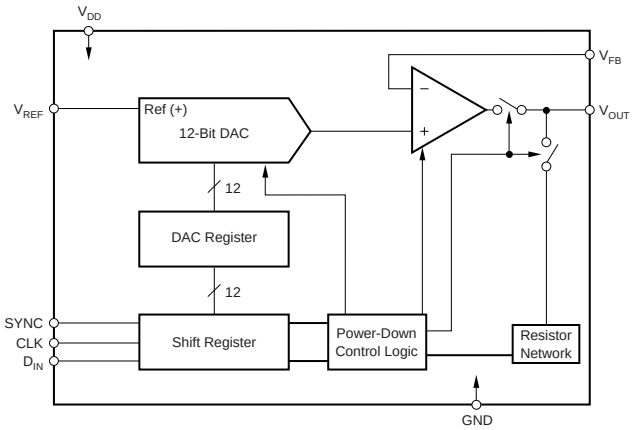
The DAC7513 is a low-power, single, 12-bit buffered voltage output Digital-to-Analog Connector (DAC). The on-chip precision output amplifier allows rail-to-rail output swing to be achieved. The DAC7513 uses a versatile 3-wire serial interface that operates at clock rates up to 30MHz and is compatible with standard SPI™, QSPI™, Microwire™, and DSP interfaces.

The DAC7513 requires an external reference voltage to set the output range of the DAC, this allows the DAC7513 to be used in a multiplying mode. The DAC7513 incorporates a power-on reset circuit which ensures that the DAC output powers up at 0V and remains there until a valid write takes place to the device. The DAC7513 contains a power-down feature, accessed over the serial interface, that reduces the current consumption of the device to 200nA at 5V.

The low-power consumption of this part in normal operation makes it ideally suited to portable battery-operated equipment. The power consumption is 0.5mW at 5V reducing to 1μW in power-down mode.

The DAC7513 is available in an SOT23-8 package and an MSOP-8 package.

SPI and QSPI are registered trademarks of Motorola.
Microwire is a registered trademark of National Semiconductor.



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ABSOLUTE MAXIMUM RATINGS[1]

V_{DD} to GND	–0.3V to +6V
Digital Input Voltage to GND	–0.3V to $+V_{DD}$ + 0.3V
V_{OUT} to GND	–0.3V to $+V_{DD}$ + 0.3V
Operating Temperature Range	–40°C to +105°C
Storage Temperature Range	–65°C to +150°C
Junction Temperature Range (T_J max)	+150°C
SOT23 Package:	
Power Dissipation	$(T_J$ max – $T_A)/\theta_{JA}$
θ_{JA} Thermal Impedance	240°C/W
Lead Temperature, Soldering:	
Vapor Phase (60s)	+215°C
Infrared (15s)	+220°C
MSOP Package:	
Power Dissipation	$(T_J$ max – $T_A)/\theta_{JA}$
θ_{JA} Thermal Impedance	206°C/W
θ_{JC} Thermal Impedance	44°C/W
Lead Temperature, Soldering:	
Vapor Phase (60s)	+215°C
Infrared (15s)	+220°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.

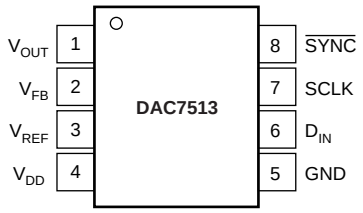
PACKAGE/ORDERING INFORMATION

PRODUCT	MINIMUM RELATIVE ACCURACY (LSB)	DIFFERENTIAL NONLINEARITY (LSB)	PACKAGE-LEAD	PACKAGE DESIGNATOR[1]	SPECIFICATION TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
DAC7513E	±8	±1	MSOP-8	DGK	–40°C to +105°C	D13E	DAC7513E/250	Tape and Reel, 250
"	"	"	"	"	"	"	DAC7513E/2K5	Tape and Reel, 2500
DAC7513N	±8	±1	SOT23-8	DCN	–40°C to +105°C	D13N	DAC7513N/250	Tape and Reel, 250
"	"	"	"	"	"	"	DAC7513N/3K	Tape and Reel, 3000

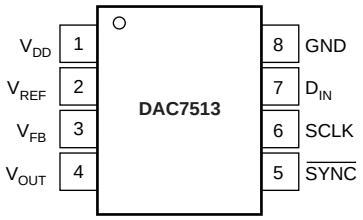
NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

PIN CONFIGURATIONS

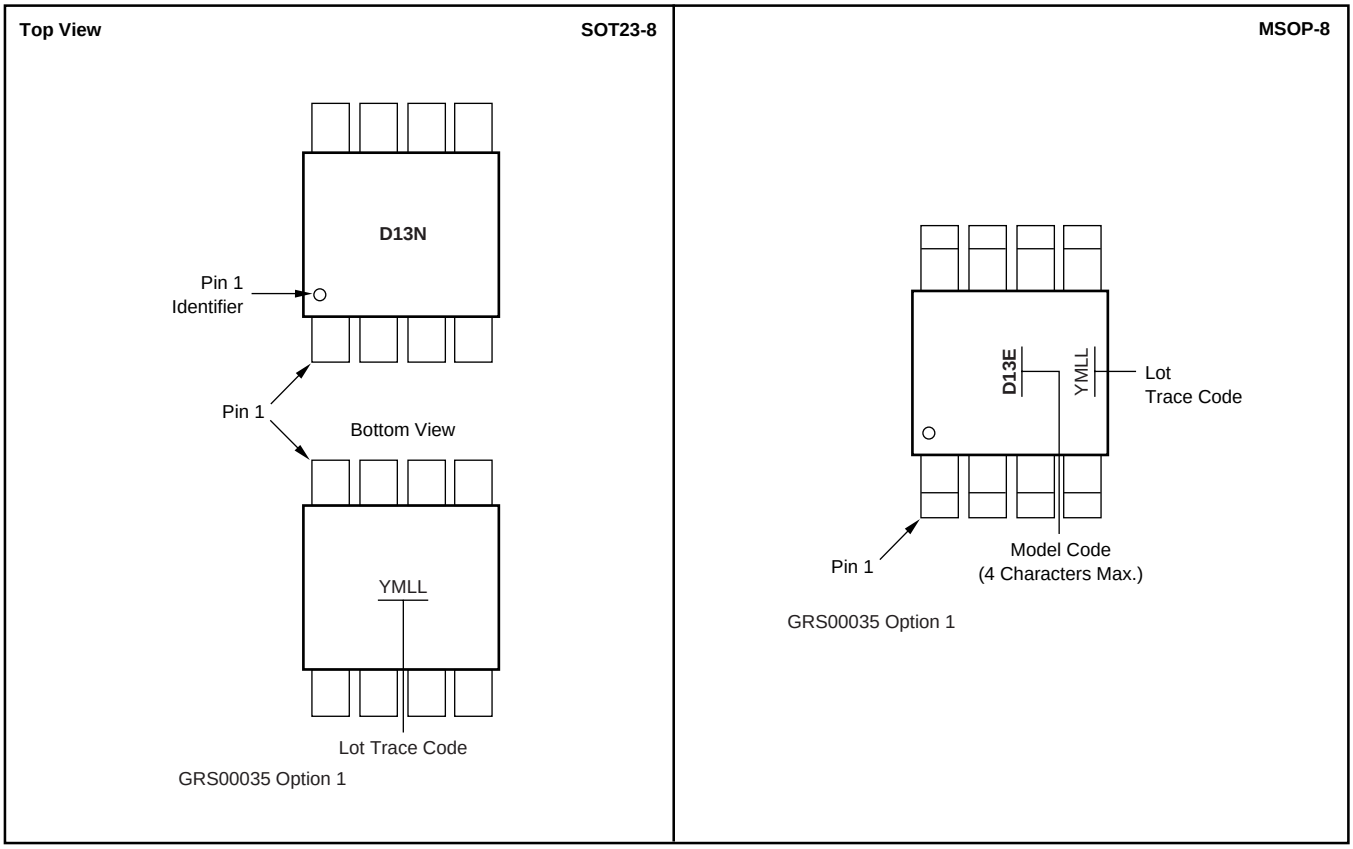
Top View **SOT23-8**



MSOP-8



MARKING ARTWORK



PIN DESCRIPTIONS

MSOP-8	SOT23-8	NAME	DESCRIPTION
1	4	V_{DD}	Power Supply Input, +2.7V to +5.5V
2	3	V_{REF}	Reference Voltage Input
3	2	V_{FB}	Feedback connection for the output amplifier.
4	1	V_{OUT}	Analog output voltage from DAC. The output amplifier has rail-to-rail operation.
5	8	$\overline{SYNC}$	Level triggered control input (active LOW), this is the frame sychronization signal for the input data. When $\overline{SYNC}$ goes LOW, it enables the input shift register and data is transferred in on the falling edges of the following clocks. The DAC is updated following the 16th clock cycle unless $\overline{SYNC}$ is taken HIGH before this edge in which case the rising edge of $\overline{SYNC}$ acts as an interrupt and the write sequence is ignored by the DAC7513.
6	7	SCLK	Serial Clock Input. Data can be transferred at rates up to 30MHz.
7	6	D_{IN}	Serial Data Input. Data is clocked into the 16-bit input shift register on the falling edge of the serial clock input.
8	5	GND	Ground reference point for all circuitry on the part.

ELECTRICAL CHARACTERISTICS

V_{DD} = +2.7V to +5.5V, R_L = 2kΩ to GND, and C_L = 200pF to GND, unless otherwise noted.

PARAMETER	CONDITIONS	DAC7513E, N			UNITS
		MIN	TYP	MAX	
STATIC PERFORMANCE (1)					
Resolution		12			Bits
Relative Accuracy				±8	LSB
Differential Nonlinearity	Tested Monotonic by Design			±1	LSB
Zero Code Error	All Zeroes Loaded to DAC Register		+5	+20	mV
Full-Scale Error	All Ones Loaded to DAC Register		–0.15	–1.25	% of FSR
Gain Error				±1.25	% of FSR
Zero Code Error Drift			–20		µV/°C
Gain Temperature Coefficient			–5		ppm of FSR/°C
OUTPUT CHARACTERISTICS (2)					
Output Voltage Range		0		V_{REF}	V
Output Voltage Settling Time	1/4 Scale to 3/4 Scale Change (400_H to $C00_H$)		8	10	µs
	R_L = 2kΩ; 0pF < C_L < 200pF				
	R_L = 2kΩ; C_L = 500pF		12		µs
Slew Rate			1		V/µs
Capacitive Load Stability	R_L = ∞		470		pF
	R_L = 2kΩ		1000		pF
Code Change Glitch Impulse	1LSB Change Around Major Carry		20		nV-s
Digital Feedthrough			0.5		nV-s
DC Output Impedance			1		Ω
Short-Circuit Current	V_{DD} = +5V		50		mA
	V_{DD} = +3V		20		mA
Power-Up Time	Coming Out of Power-Down Mode				
	V_{DD} = +5V		2.5		µs
	Coming Out of Power-Down Mode				
	V_{DD} = +3V		5		µs
REFERENCE INPUT					
Reference Current	V_{REF} = V_{DD} = +5V		17	25	µA
	V_{REF} = V_{DD} = +3.6V		12	18	µA
Reference Input Range		0		V_{DD}	V
Reference Input Impedance			300		kΩ
LOGIC INPUTS (2)					
Input Current				±1	µA
V_{IN}L, Input Low Voltage	V_{DD} = +5V			0.8	V
V_{IN}L, Input Low Voltage	V_{DD} = +3V			0.6	V
V_{IN}H, Input High Voltage	V_{DD} = +5V	2.4			V
V_{IN}H, Input High Voltage	V_{DD} = +3V	2.1			V
Pin Capacitance				3	pF
POWER REQUIREMENTS					
V_{DD}		2.7		5.5	V
I_{DD} (normal mode)	DAC Active and Excluding Load Current				
V_{DD} = +3.6V to +5.5V	V_{IH} = V_{DD} and V_{IL} = GND		115	170	µA
V_{DD} = +2.7V to +3.6V	V_{IH} = V_{DD} and V_{IL} = GND		100	145	µA
I_{DD} (all power-down modes)					
V_{DD} = +3.6V to +5.5V	V_{IH} = V_{DD} and V_{IL} = GND		0.2	1	µA
V_{DD} = +2.7V to +3.6V	V_{IH} = V_{DD} and V_{IL} = GND		0.05	1	µA
POWER EFFICIENCY					
I_{OUT}/I_{DD}	I_{LOAD} = 2mA, V_{DD} = +5V		93		%
TEMPERATURE RANGE					
Specified Performance		–40		+105	°C

NOTES: (1) Linearity calculated using a reduced code range of 48 to 4047; output unloaded. (2) Ensured by design and characterization, not production tested.

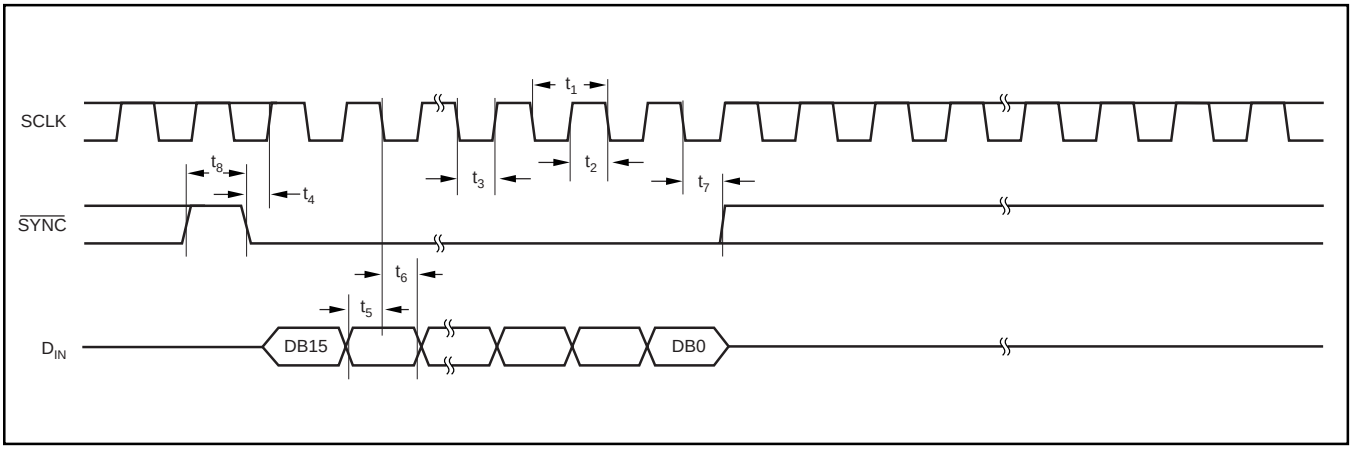
TIMING CHARACTERISTICS[1, 2]

V_{DD} = +2.7V to +5.5V, all specifications –40°C to +105°C, unless otherwise noted.

PARAMETER	DESCRIPTION	CONDITIONS	DAC7513E, N			UNITS
			MIN	TYP	MAX	
t_1[3]	SCLK Cycle Time					
		V_{DD} = 2.7V to 3.6V	50			ns
		V_{DD} = 3.6V to 5.5V	33			ns
t_2	SCLK HIGH Time					
		V_{DD} = 2.7V to 3.6V	13			ns
		V_{DD} = 3.6V to 5.5V	13			ns
t_3	SCLK LOW Time					
		V_{DD} = 2.7V to 3.6V	22.5			ns
		V_{DD} = 3.6V to 5.5V	13			ns
t_4	$\overline{SYNC}$ to SCLK Rising Edge Setup Time					
		V_{DD} = 2.7V to 3.6V	0			ns
		V_{DD} = 3.6V to 5.5V	0			ns
t_5	Data Setup Time					
		V_{DD} = 2.7V to 3.6V	5			ns
		V_{DD} = 3.6V to 5.5V	5			ns
t_6	Data Hold Time					
		V_{DD} = 2.7V to 3.6V	4.5			ns
		V_{DD} = 3.6V to 5.5V	4.5			ns
t_7	SCLK Falling Edge to $\overline{SYNC}$ Rising Edge					
		V_{DD} = 2.7V to 3.6V	0			ns
		V_{DD} = 3.6V to 5.5V	0			ns
t_8	Minimum $\overline{SYNC}$ HIGH Time					
		V_{DD} = 2.7V to 3.6V	50			ns
		V_{DD} = 3.6V to 5.5V	33			ns

NOTES: (1) All input signals are specified with $t_R = t_F$ = 5ns (10% to 90% of V_{DD}) and timed from a voltage level of $(V_{IL} + V_{IH})/2$. (2) See Serial Write Operation timing diagram, below. (3) Maximum SCLK frequency is 30MHz at V_{DD} = +3.6V to +5.5V and 20MHz at V_{DD} = +2.7V to +3.6V.

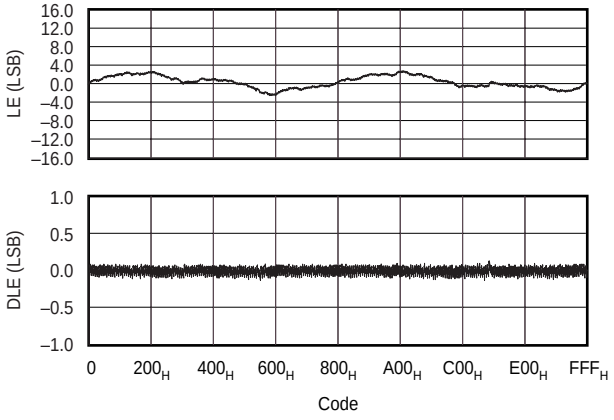
SERIAL WRITE OPERATION



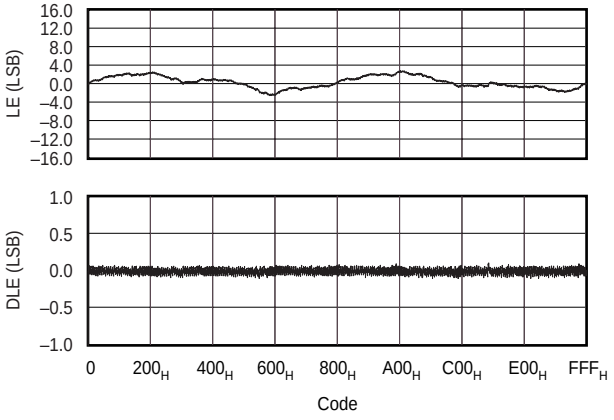
TYPICAL CHARACTERISTICS: V_{DD} = +5V

At T_A = +25°C and $+V_{DD}$ = +5V, unless otherwise noted.

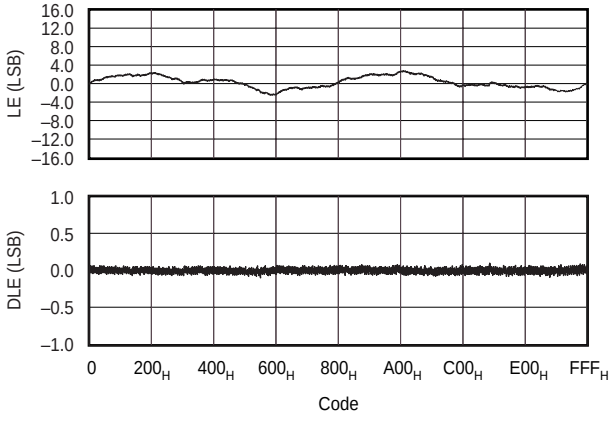
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(–40°C)



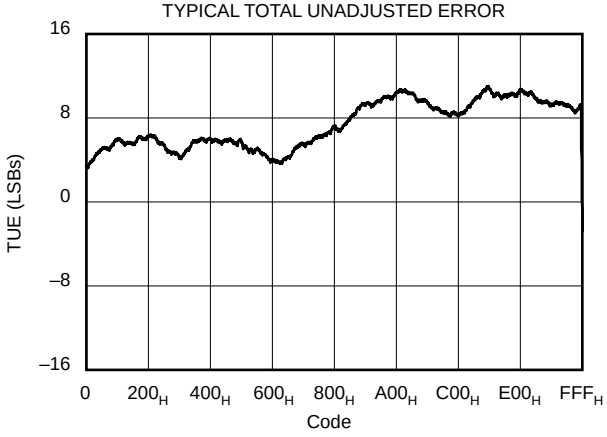
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(+25°C)



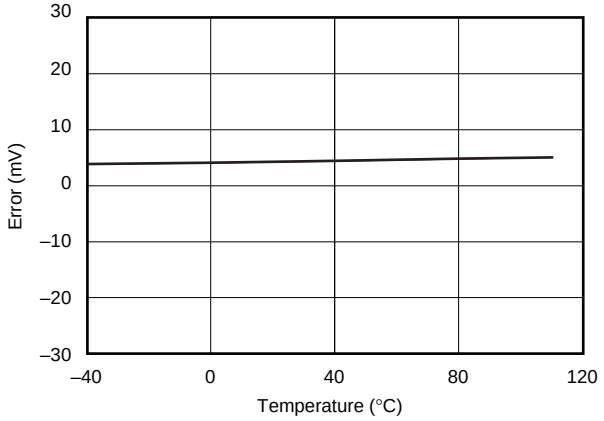
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(+105°C)



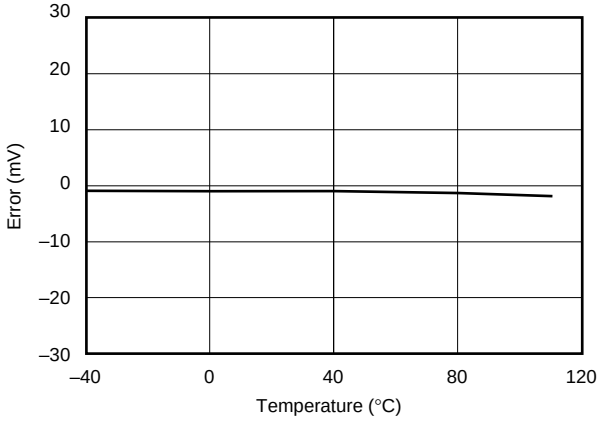
TYPICAL TOTAL UNADJUSTED ERROR



ZERO-SCALE ERROR vs TEMPERATURE



FULL-SCALE ERROR vs TEMPERATURE

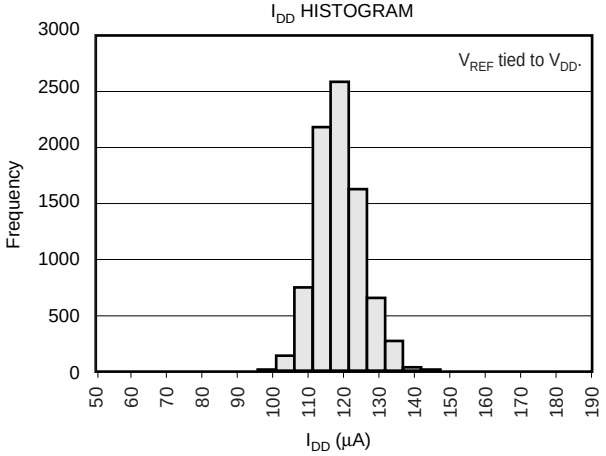


TYPICAL CHARACTERISTICS: V_{DD} = +5V (Cont.)

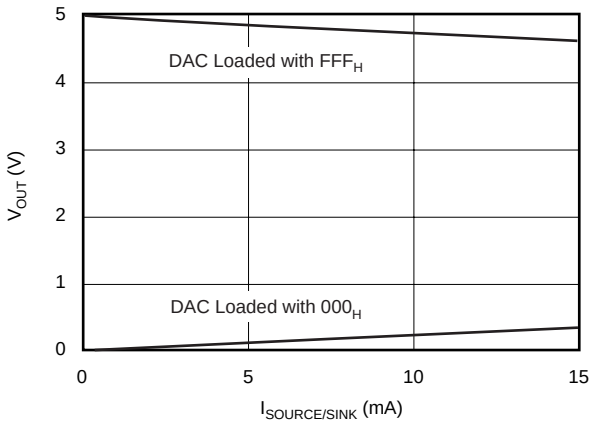
At T_A = +25°C and $+V_{DD}$ = +5V, unless otherwise noted.

NOTE: All references to I_{DD} include I_{REF} current.

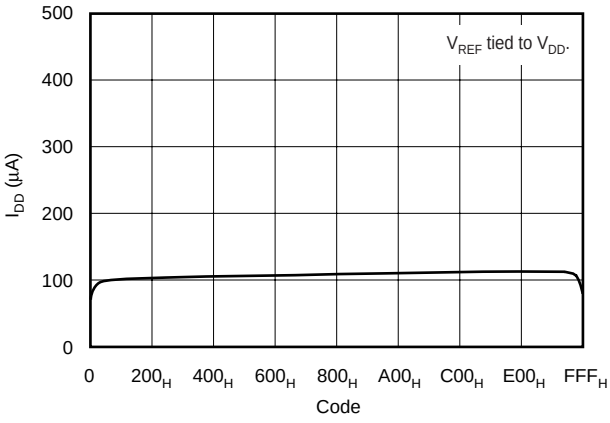
I_{DD} HISTOGRAM



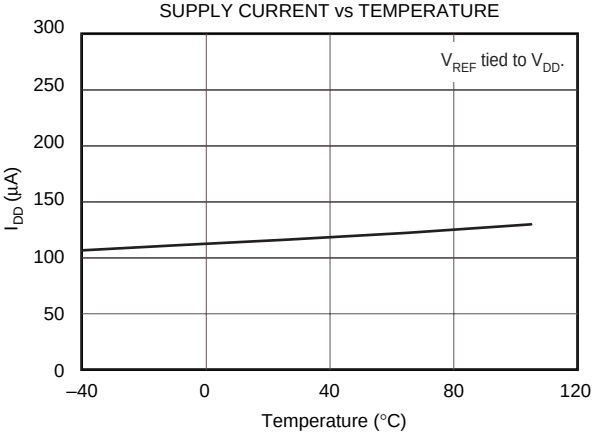
SOURCE AND SINK CURRENT CAPABILITY



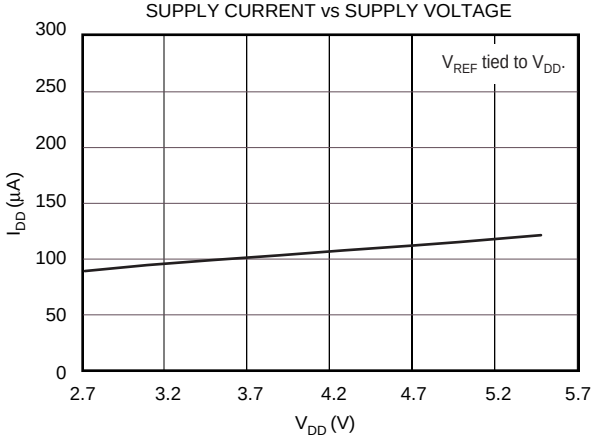
SUPPLY CURRENT vs CODE



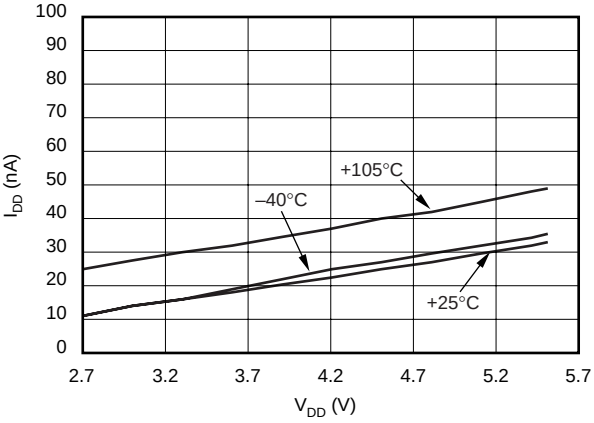
SUPPLY CURRENT vs TEMPERATURE



SUPPLY CURRENT vs SUPPLY VOLTAGE



POWER-DOWN CURRENT vs SUPPLY VOLTAGE

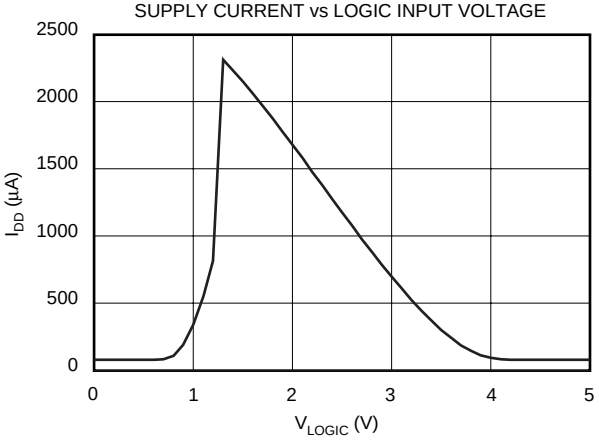


TYPICAL CHARACTERISTICS: V_{DD} = +5V (Cont.)

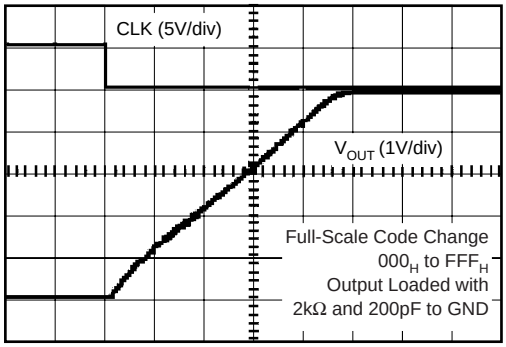
At T_A = +25°C and $+V_{DD}$ = +5V, unless otherwise noted.

NOTE: All references to I_{DD} include I_{REF} current.

SUPPLY CURRENT vs LOGIC INPUT VOLTAGE

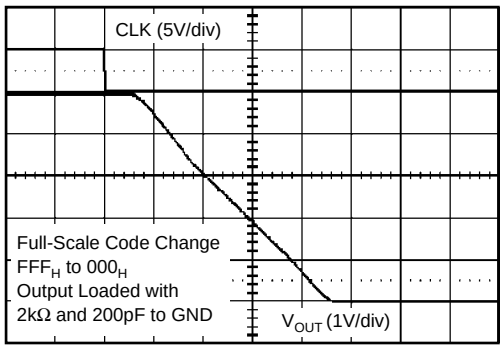


FULL-SCALE SETTLING TIME



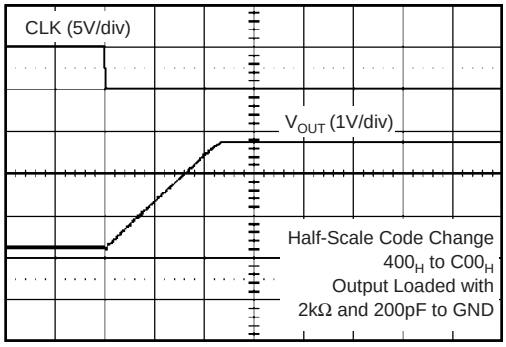
Time (1µs/div)

FULL-SCALE SETTLING TIME



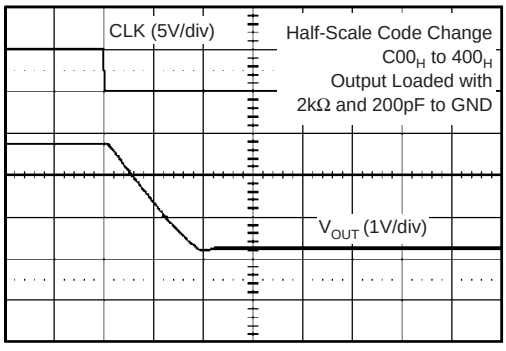
Time (1µs/div)

HALF-SCALE SETTLING TIME



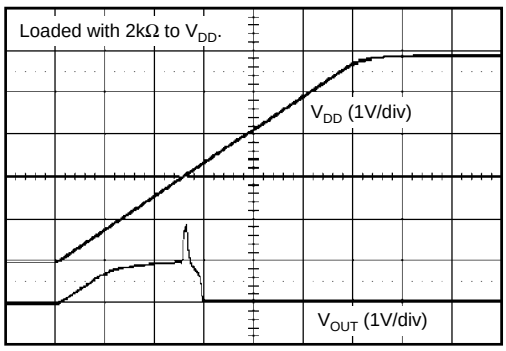
Time (1µs/div)

HALF-SCALE SETTLING TIME



Time (1µs/div)

POWER-ON RESET TO 0V

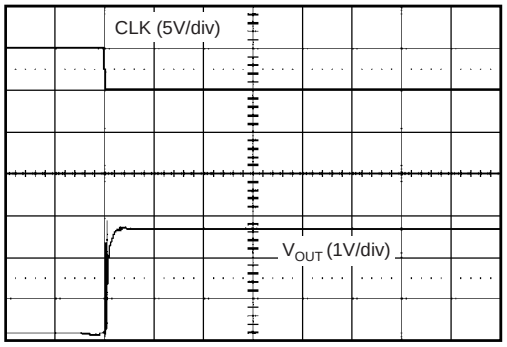


Time (20µs/div)

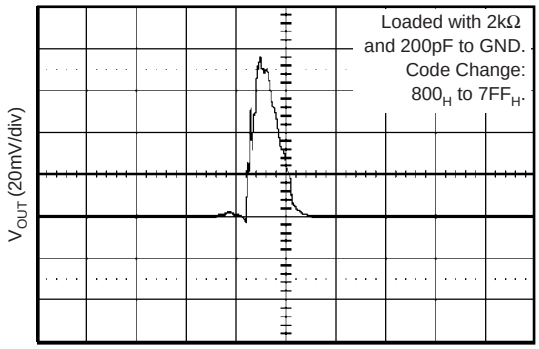
TYPICAL CHARACTERISTICS: V_{DD} = +5V (Cont.)

At T_A = +25°C and $+V_{DD}$ = +5V, unless otherwise noted.

EXITING POWER-DOWN
(800_H Loaded)



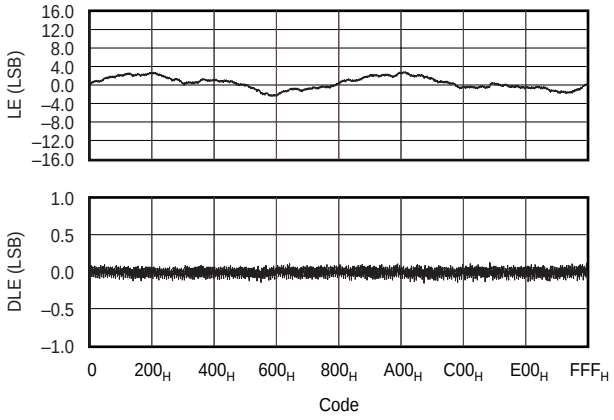
CODE CHANGE GLITCH



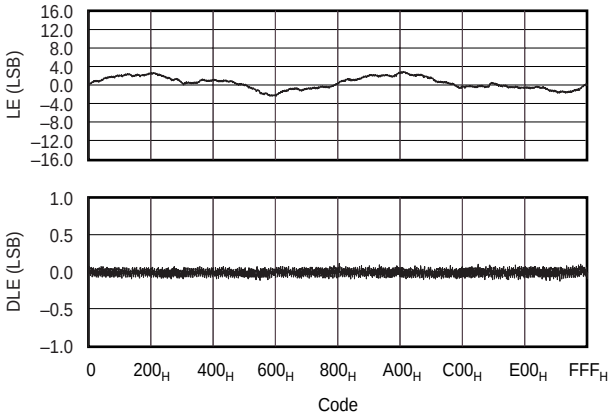
TYPICAL CHARACTERISTICS: V_{DD} = +2.7V

At T_A = +25°C and $+V_{DD}$ = +2.7V, unless otherwise noted.

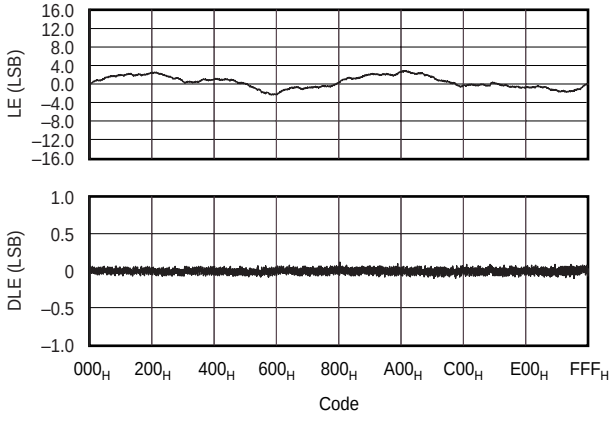
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(–40°C)



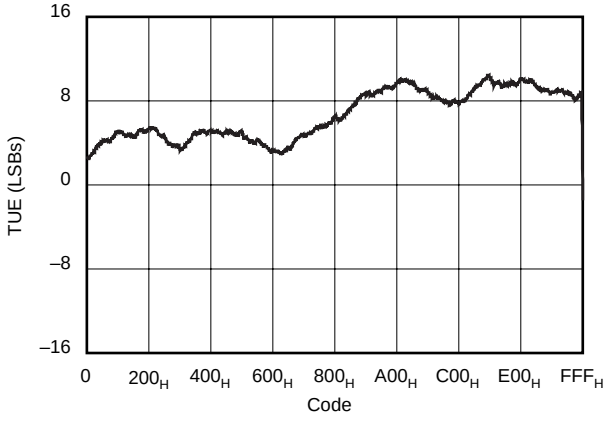
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(+25°C)



LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(+105°C)



TYPICAL TOTAL UNADJUSTED ERROR

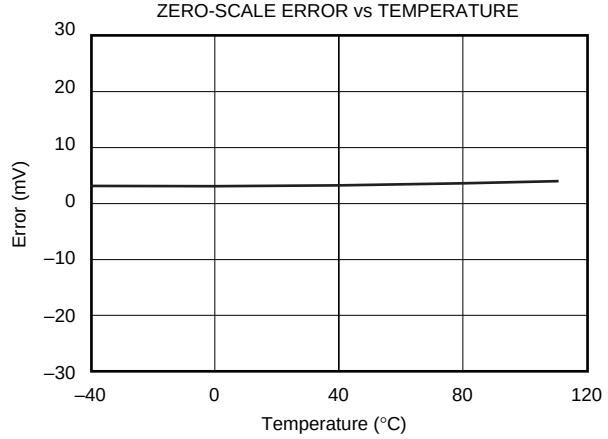


TYPICAL CHARACTERISTICS: V_{DD} = +2.7V (Cont.)

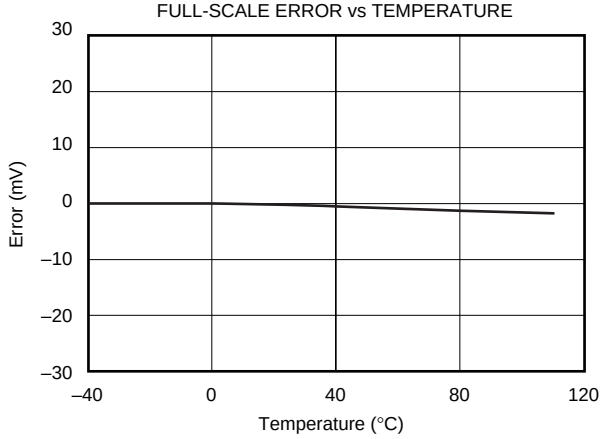
At T_A = +25°C and $+V_{DD}$ = +2.7V, unless otherwise noted.

NOTE: All references to I_{DD} include I_{REF} current.

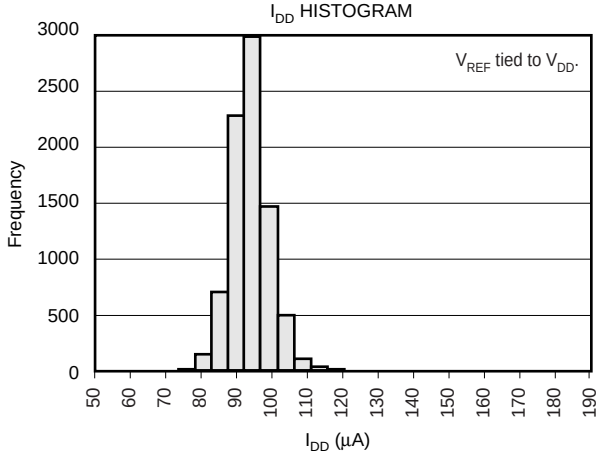
ZERO-SCALE ERROR vs TEMPERATURE



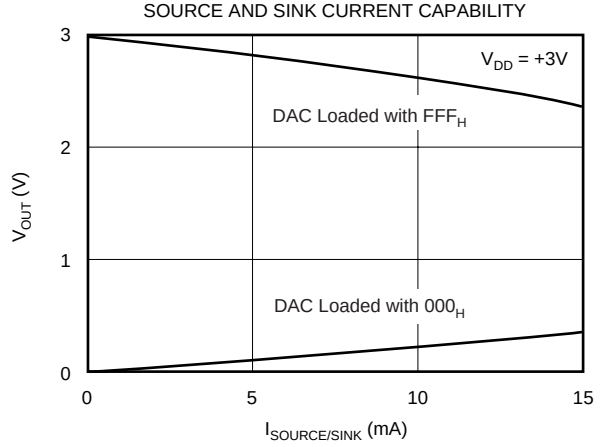
FULL-SCALE ERROR vs TEMPERATURE



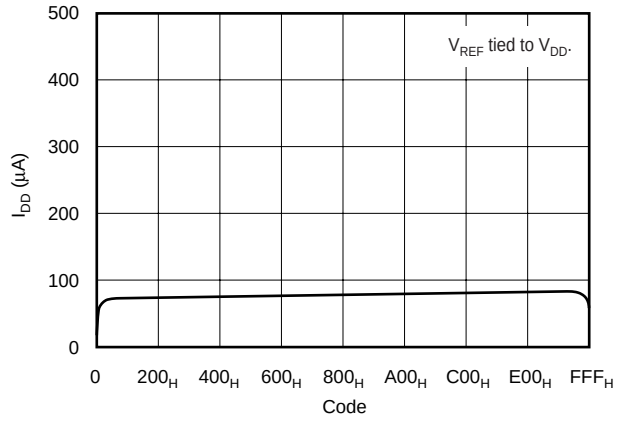
I_{DD} HISTOGRAM



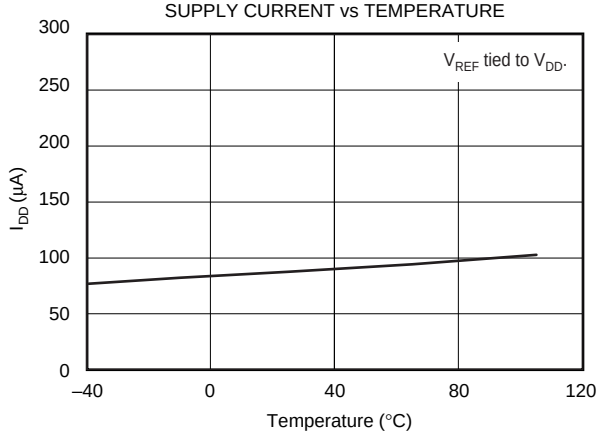
SOURCE AND SINK CURRENT CAPABILITY



SUPPLY CURRENT vs CODE



SUPPLY CURRENT vs TEMPERATURE

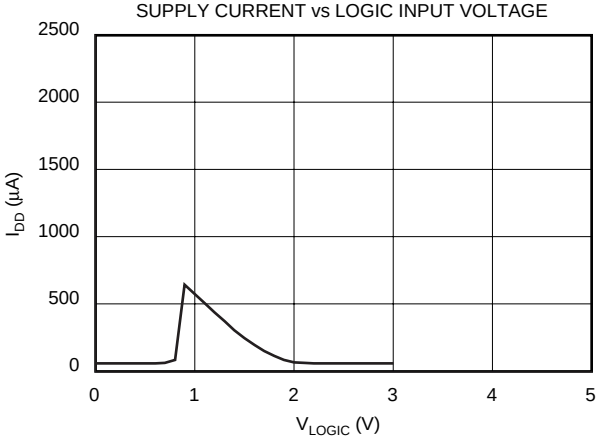


TYPICAL CHARACTERISTICS: V_{DD} = +2.7V (Cont.)

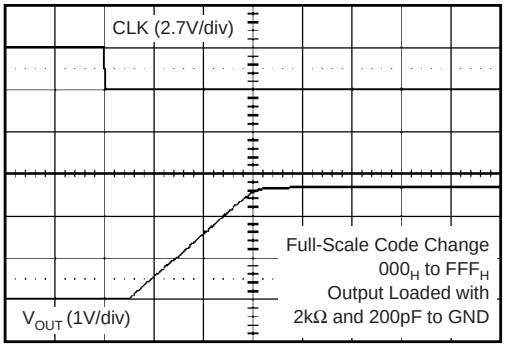
At T_A = +25°C and $+V_{DD}$ = +2.7V, unless otherwise noted.

NOTE: All references to I_{DD} include I_{REF} current.

SUPPLY CURRENT vs LOGIC INPUT VOLTAGE

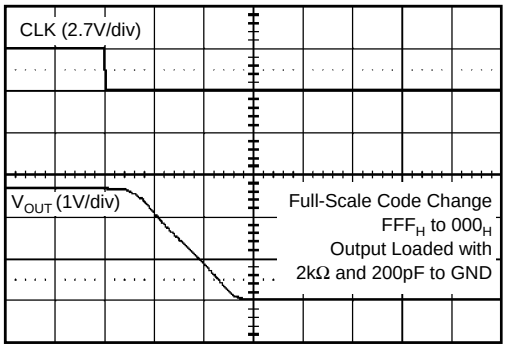


FULL-SCALE SETTLING TIME



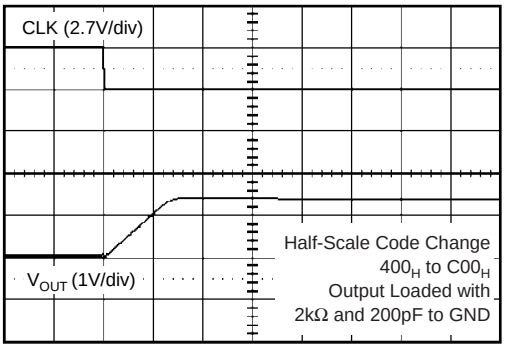
Time (1µs/div)

FULL-SCALE SETTLING TIME



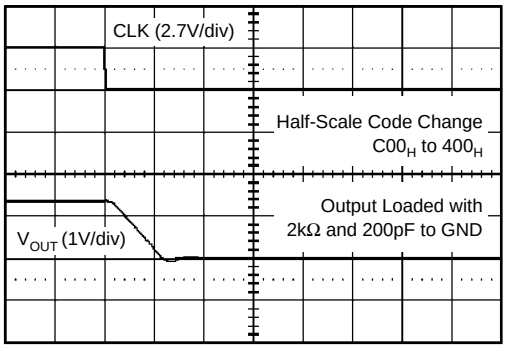
Time (1µs/div)

HALF-SCALE SETTLING TIME



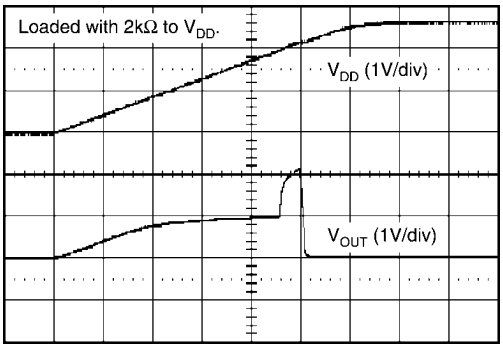
Time (1µs/div)

HALF-SCALE SETTLING TIME



Time (1µs/div)

POWER-ON RESET to 0V

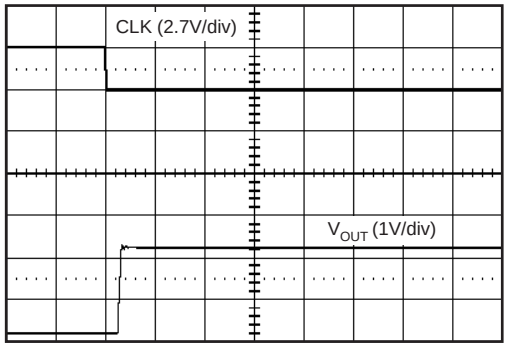


Time (20µs/div)

TYPICAL CHARACTERISTICS: V_{DD} = +2.7V (Cont.)

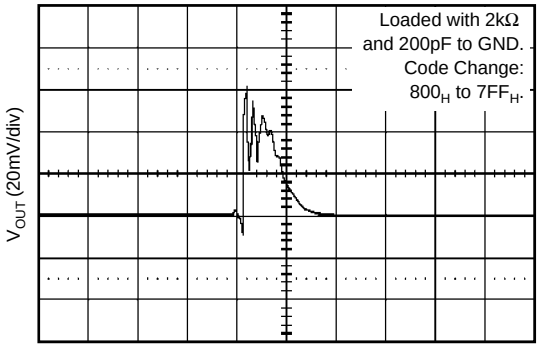
At T_A = +25°C and $+V_{DD}$ = +2.7V, unless otherwise noted.

EXITING POWER-DOWN
(800_H Loaded)



Time (5µs/div)

CODE CHANGE GLITCH



Time (0.5µs/div)

THEORY OF OPERATION

DAC SECTION

The architecture consists of a string DAC followed by an output buffer amplifier. Figure 1 shows a block diagram of the DAC architecture.

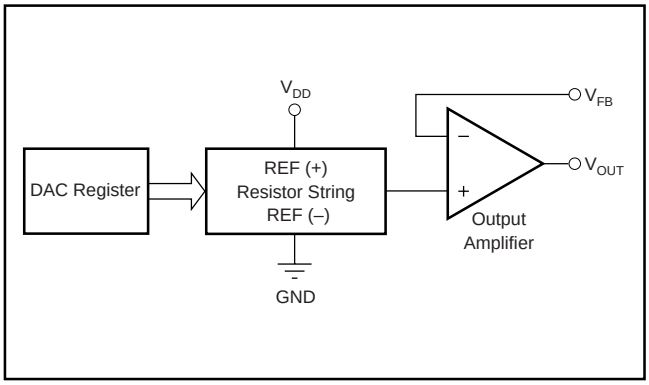


FIGURE 1. DAC7513 Architecture.

The input coding to the DAC7513 is straight binary, so the ideal output voltage is given by:

$$V_{OUT} = V_{REF} \bullet \frac{D}{4096} \quad (1)$$

where D = decimal equivalent of the binary code that is loaded to the DAC register; it can range from 0 to 4095.

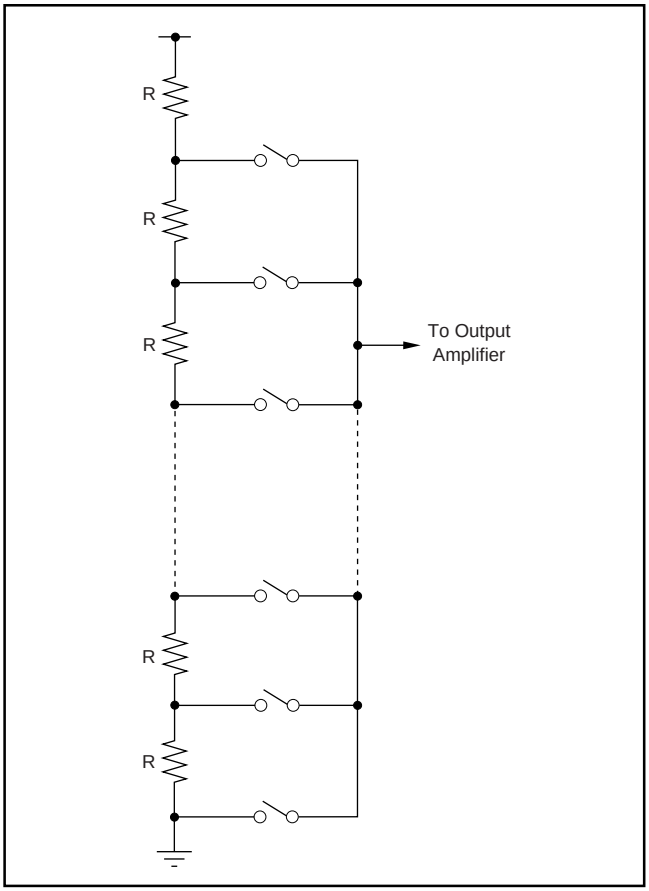


FIGURE 2. Resistor String.

RESISTOR STRING

The resistor string shown in Figure 2 is simply a string of resistors, each of value R. The code loaded into the DAC register determines at which node on the string the voltage is tapped off to be fed into the output amplifier by closing one of the switches connecting the string to the amplifier. It is ensured monotonic because it is a string of resistors.

OUTPUT AMPLIFIER

The output buffer amplifier is capable of generating rail-to-rail voltages on its output which gives an output range of 0V to V_{DD}, it is capable of driving a load of 2kΩ in parallel with 1000pF to GND. The source and sink capabilities of the output amplifier can be seen in the typical characteristics. The slew rate is 1V/µs with a half-scale settling time of 8µs with the output unloaded.

The inverting input of the output amplifier is brought out to the V_{FB} pin. This allows for better accuracy in critical applications by tying the V_{FB} point and the amplifier output together directly at the load. Other signal conditioning circuitry can also be connected between these points for specific applications.

SERIAL INTERFACE

The DAC7513 has a 3-wire serial interface $\overline{SYNC}$, SCLK, and D_{IN}, which is compatible with SPI, QSPI, and Microwire interface standards as well as most Digital Signal Processors (DSPs). See the Serial Write Operation timing diagram for an example of a typical write sequence.

The write sequence begins by bringing the $\overline{SYNC}$ line LOW, data from the D_{IN} line is clocked into the 16-bit shift register on the falling edge of SCLK. The serial clock frequency can be as high as 30MHz, making the DAC7513 compatible with high-speed DSPs. On the 16th falling edge of the serial clock, the last data bit is clocked in and the programmed function is executed (i.e., a change in the DAC register contents and/or a change in the mode of operation).

At this point, the $\overline{SYNC}$ line may be kept LOW or brought HIGH. In either case, it must be brought HIGH for a minimum of 33ns before the next write sequence so that a falling edge of $\overline{SYNC}$ can initiate the next write sequence. As the $\overline{SYNC}$ buffer draws more current when the $\overline{SYNC}$ signal is HIGH than it does when it is LOW, $\overline{SYNC}$ must be idled LOW between write sequences for lowest power operation of the part. As mentioned above, however, it must be brought HIGH again just before the next write sequence.

INPUT SHIFT REGISTER

The input shift register is 16 bits wide, as shown in Figure 3. The first two bits are *don't cares*. The next two bits (PD1 and PD0) are control bits that control which mode of operation the part is in (normal mode or any one of three power-down modes). There is a more complete description of the various modes in the Power-Down Modes section. The next 12 bits are the data bits. These are transferred to the DAC register on the 16th falling edge of SCLK.

$\overline{SYNC}$ INTERRUPT

In a normal write sequence, the $\overline{SYNC}$ line is kept LOW for at least 16 falling edges of SCLK and the DAC is updated on the 16th falling edge. However, if $\overline{SYNC}$ is brought HIGH before the 16th falling edge, this acts as an interrupt to the write sequence. The shift register is reset and the write sequence is seen as invalid. Neither an update of the DAC register contents or a change in the operating mode occurs, as shown in Figure 4.

POWER-ON RESET

The DAC7513 contains a power-on reset circuit that controls the output voltage during power-up. Upon power up, the DAC register is filled with zeros and the output voltage is 0V; it remains there until a valid write sequence is made to the DAC. This is useful in applications where it is important to know the state of the output of the DAC while it is in the process of powering up.

POWER-DOWN MODES

The DAC7513 contains four separate modes of operation, which are programmable by setting two bits (PD1 and PD0) in the control register. Table I shows how the state of the bits corresponds to the mode of operation of the device.

DB13	DB12	OPERATING MODE
0	0	Normal Operation
		Power-Down Modes
0	1	Output 1kΩ to GND
1	0	Output 100kΩ to GND
1	1	High-Z

TABLE I. Modes of Operation for the DAC7513.

When both bits are set to 0, the part works normally with its normal power consumption of 115µA at 5V. However, for the three power-down modes, the supply current falls to 200nA at 5V (50nA at 3V). Not only does the supply current fall, but the output stage is also internally switched from the output of the amplifier to a resistor network of known values. This has

DB15															DB0
X	X	PD1	PD0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

FIGURE 3. Data Input Register.

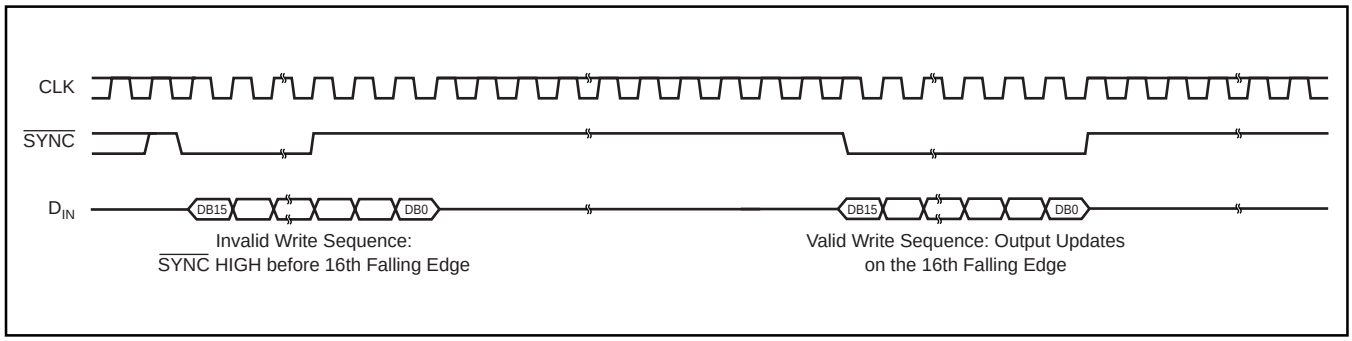


FIGURE 4. $\overline{SYNC}$ Interrupt Facility.

the advantage that the output impedance of the part is known while the part is in power-down mode. There are three different options: the output is connected internally to GND through a 1kΩ resistor; a 100kΩ resistor; or it is left open-circuited (High-Z). The output stage is illustrated in Figure 5.

All linear circuitry is shut down when the power-down mode is activated, however, the contents of the DAC register are unaffected when in power-down. The time to exit power-down is typically 2.5µs for V_{DD} = 5V, and 5µs for V_{DD} = 3V, (see the Typical Chacteristics for more information).

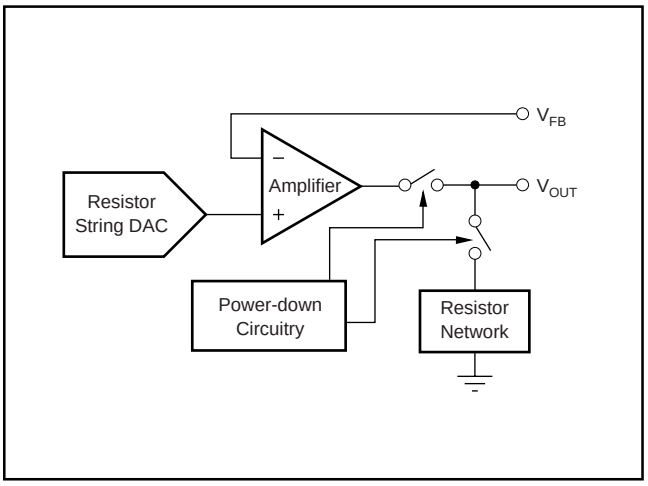


FIGURE 5. Output Stage During Power-Down.

MICROPROCESSOR INTERFACING

DAC7513 TO 8051 INTERFACE

Figure 6 shows a serial interface between the DAC7513 and a typical 8051-type microcontroller. The setup for the interface is as follows: TXD of the 8051 drives SCLK of the DAC7513, while RXD drives the serial data line of the part; the $\overline{\text{SYNC}}$ signal is derived from a bit programmable pin on the port. In this case, port line P3.3 is used. When data is to be transmitted to the DAC7513, P3.3 is taken LOW. The 8051 transmits data only in 8-bit bytes; thus only eight falling clock edges occur in the transmit cycle. To load data to the DAC, P3.3 is left LOW after the first eight bits are transmitted, a second write cycle is initiated to transmit the second byte of data, and P3.3 is taken HIGH following the completion of this cycle. The 8051 outputs the serial data in a format which has the LSB first. The DAC7513 requires its data with the MSB as the first bit received, thus, the 8051 transmit routine must therefore take this into account and mirror the data as needed.

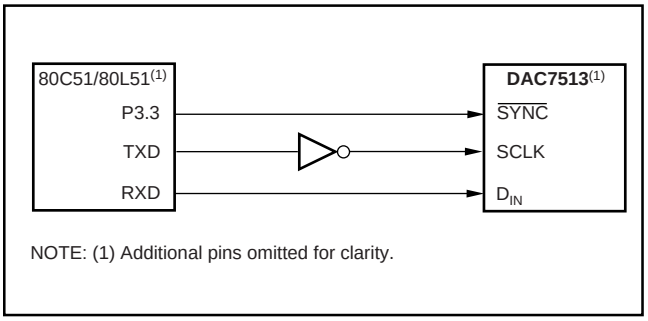


FIGURE 6. DAC7513 to 80C51/80L51 Interface.

DAC7513 TO Microwire INTERFACE

Figure 7 shows an interface between the DAC7513 and any Microwire compatible device. Serial data is shifted out on the falling edge of the serial clock and is clocked into the DAC7513 on the rising edge of the SK signal.

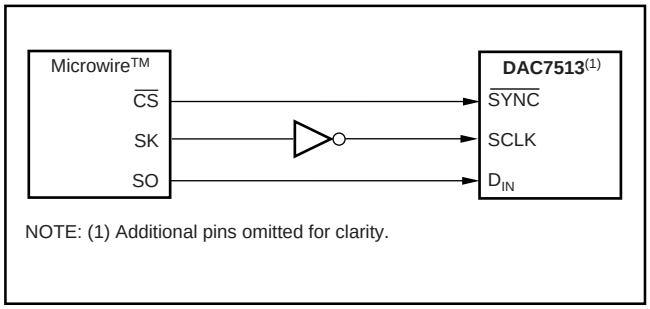


FIGURE 7. DAC7513 to Microwire Interface.

DAC7513 TO 68HC11 INTERFACE

Figure 8 shows a serial interface between the DAC7513 and the 68HC11 microcontroller. SCK of the 68HC11 drives the SCLK of the DAC7513, while the MOSI output drives the serial data line of the DAC. The $\overline{\text{SYNC}}$ signal is derived from a port line (PC7), similar to what was done for the 8051.

The 68HC11 must be configured so that its CPOL bit is a 0 and its CPHA bit is a 1, this configuration causes data appearing on the MOSI output as valid on the falling edge of SCK. When data is being transmitted to the DAC, the $\overline{\text{SYNC}}$ line is taken LOW (PC7). Serial data from the 68HC11 is transmitted in 8-bit bytes with only eight falling clock edges occurring in the transmit cycle. Data is transmitted MSB first. In order to load data to the DAC7513, PC7 is left LOW after the first eight bits are transferred, and a second serial write operation is performed to the DAC and PC7 is taken HIGH at the end of this procedure.

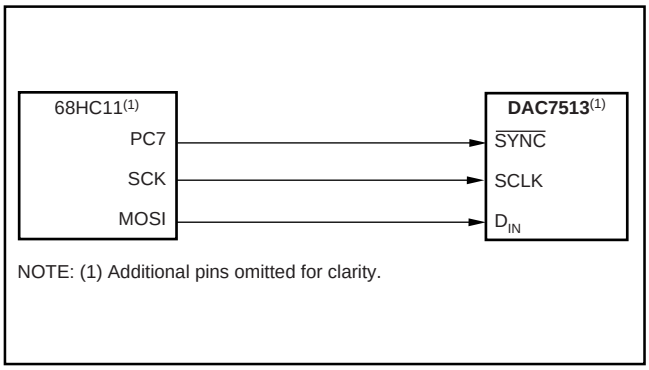


FIGURE 8. DAC7513 to 68HC11 Interface.

APPLICATIONS

USING REF02 AS A POWER SUPPLY FOR THE DAC7513

Due to the extremely low supply current required by the DAC7513, an alternative option is to use a REF02 +5V precision voltage reference to supply the required voltage to the part, as shown in Figure 9. This is especially useful if the power supply is quite noisy or if the system supply voltages are at some value other than 5V. The REF02 will output a steady supply voltage for the DAC7513; if the REF02 is used, the current it needs to supply to the DAC7513 is 132µA. This is with no load on the output of the DAC, so when the DAC output is loaded, the REF02 also needs to supply the current to the load. The total current required (with a 5kΩ load on the DAC output) is:

$$132\mu A + (5V/5k\Omega) = 1.13mA \quad (2)$$

The load regulation of the REF02 is typically 0.005%/mA, which results in an error of 285µV for the 1.13mA current drawn from it; this corresponds to a 0.2LSB error.

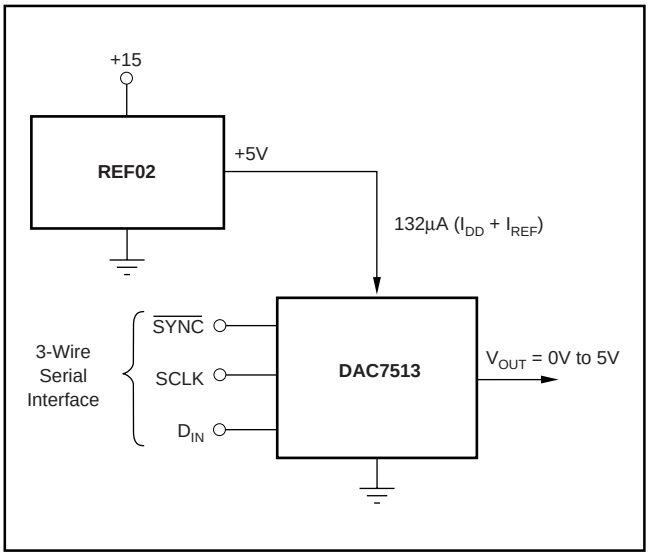


FIGURE 9. REF02 as Power Supply to the DAC7513.

BIPOLAR OPERATION USING THE DAC7513

The DAC7513 has been designed for single-supply operation, but a bipolar output range is also possible using the circuit in Figure 10 which will give an output voltage range of $\pm V_{REF}$. Rail-to-rail operation at the amplifier output is achievable using an OPA703 as the output amplifier.

The output voltage for any input code can be calculated as follows:

$$V_O = \left[V_{REF} \bullet \left(\frac{D}{4096} \right) \bullet \left(\frac{R_1 + R_2}{R_1} \right) - V_{REF} \bullet \left(\frac{R_2}{R_1} \right) \right] \quad (3)$$

where D represents the input code in decimal (0 to 4095).

With V_{REF} = 5V, $R_1 = R_2$ = 10kΩ:

$$V_O = \left(\frac{10 \bullet D}{4096} \right) - 5V \quad (4)$$

This is an output voltage range of ±5V with 000_H corresponding to a –5V output and FFF_H corresponding to a +5V output. Similarly, using V_{REF} = 2.5V, ±2.5V output voltage raw can be achieved.

LAYOUT

A precision analog component requires careful layout, adequate bypassing, and clean, well-regulated power supplies.

As the DAC7513 offers single-supply operation, it will often be used in close proximity with digital logic, microcontrollers, microprocessors, and digital signal processors. The more digital logic present in the design and the higher the switching speed, the more difficult it will be to achieve good performance from the converter.

Due to the single ground pin of the DAC7513, all return currents, including digital and analog return currents, must flow through the GND pin, which would, ideally, be connected directly to an analog ground plane. This plane would be separate from the ground connection for the digital components until they were connected at the power-entry point of the system.

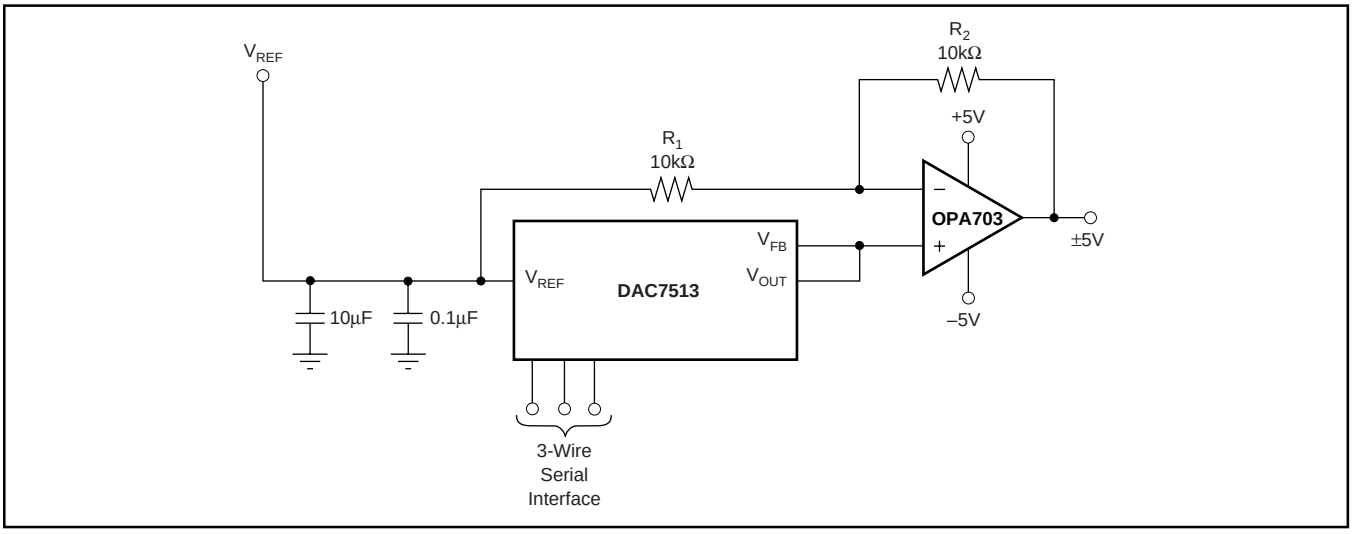
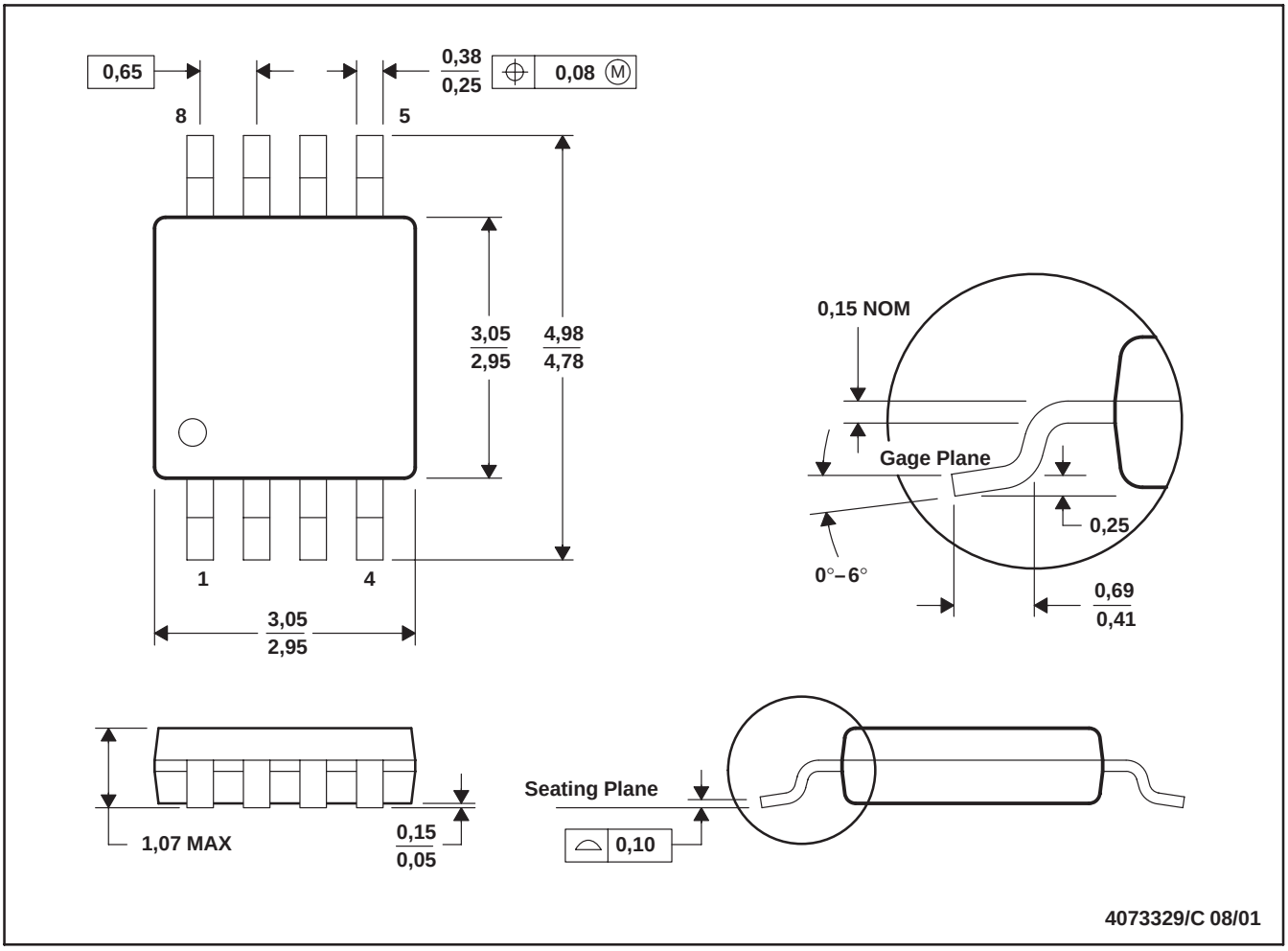


FIGURE 10. Bipolar Operation with the DAC7513.

The power applied to V_{DD} should be well regulated and low noise. Switching power supplies and DC/DC converters will often have high-frequency glitches or spikes riding on the output voltage. In addition, digital components can create similar high-frequency spikes as their internal logic switches states; this noise can easily couple into the DAC output voltage through various paths between the power connections and analog output. This is only true for the DAC7513 if the power supply is also opted to be used as the source of reference voltage for the DAC.

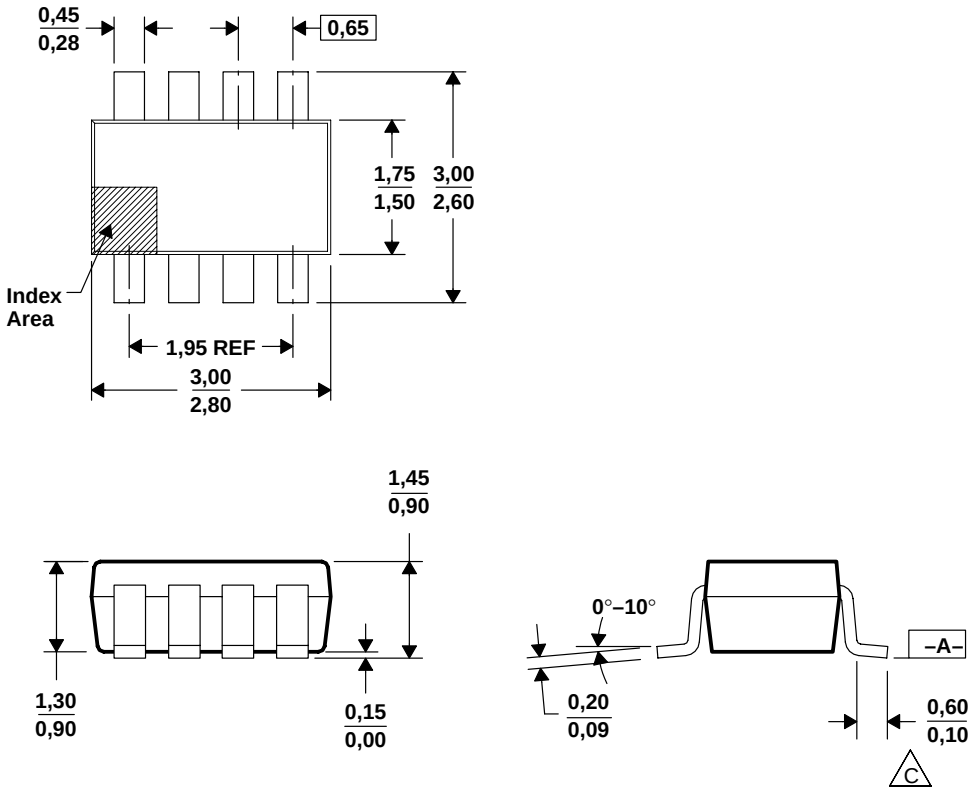
As with the GND connection, V_{DD} should be connected to a +5V power-supply plane or trace that is separate from the connection for digital logic until they are connected at the power-entry point. In addition, the 1µF to 10µF and 0.1µF bypass capacitors are strongly recommended. In some situations, additional bypassing may be required, such as a 100µF electrolytic capacitor or even a *Pi* filter made up of inductors and capacitors—all designed to essentially low-pass filter the +5V supply, removing the high-frequency noise.

DGK (R-PDSO-G8) **PLASTIC SMALL-OUTLINE PACKAGE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO-187

DCN (R-PDSO-G8) **PLASTIC SMALL-OUTLINE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Foot length measured reference to flat foot surface parallel to Datum A.
D. Package outline exclusive of mold flash, metal burr and dambar protrusion/intrusion.
E. Package outline inclusive of solder plating.
F. A visual index feature must be located within the cross-hatched area.

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)
DAC7513E/250	Active	Production	VSSOP (DGK) | 8	250 | SMALL T&R	Yes	Call TI | Nipdauag | Nipdau	Level-2-260C-1 YEAR	-40 to 105	D13E
DAC7513E/250.B	Active	Production	VSSOP (DGK) | 8	250 | SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 105	D13E
DAC7513E/250G4	Active	Production	VSSOP (DGK) | 8	250 | SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 105	D13E
DAC7513E/2K5	Active	Production	VSSOP (DGK) | 8	2500 | LARGE T&R	Yes	Call TI | Nipdauag | Nipdau	Level-2-260C-1 YEAR	-40 to 105	D13E
DAC7513E/2K5.B	Active	Production	VSSOP (DGK) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 105	D13E
DAC7513N/250	Active	Production	SOT-23 (DCN) | 8	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	D13N
DAC7513N/250.B	Active	Production	SOT-23 (DCN) | 8	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	D13N
DAC7513N/250G4	Active	Production	SOT-23 (DCN) | 8	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	D13N
DAC7513N/3K	Active	Production	SOT-23 (DCN) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	D13N
DAC7513N/3K.B	Active	Production	SOT-23 (DCN) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 105	D13N

(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.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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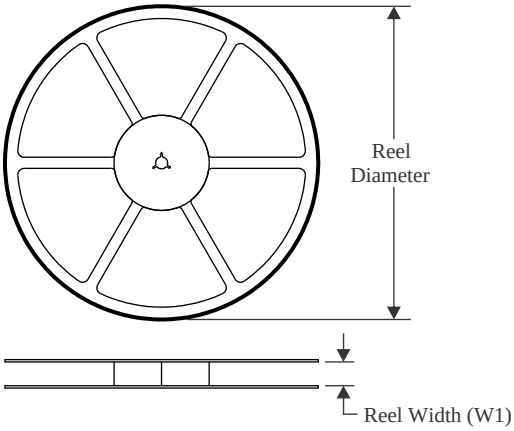
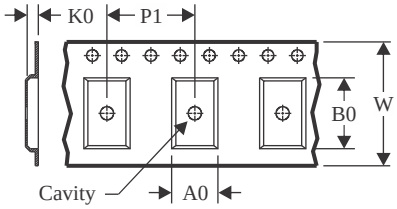
TAPE AND REEL INFORMATION

REEL DIMENSIONS

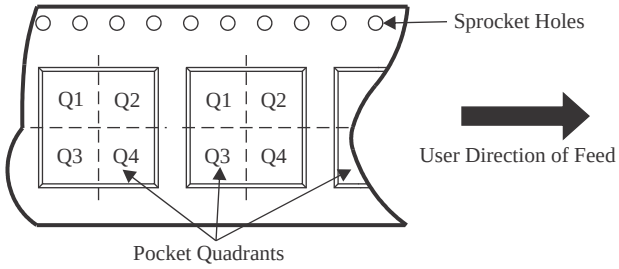


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

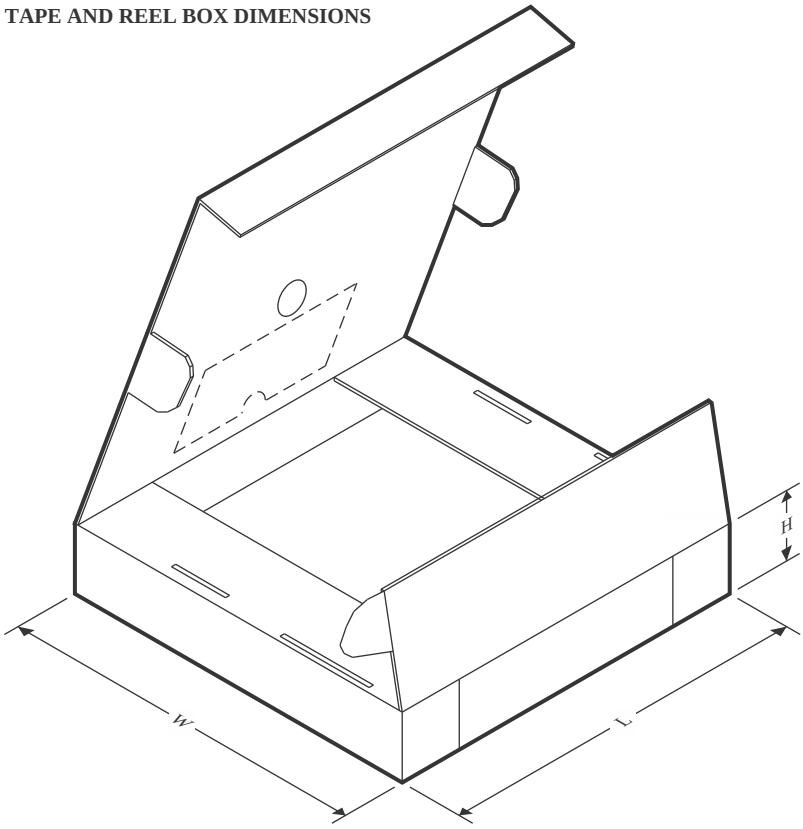
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
DAC7513N/250	SOT-23	DCN	8	250	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
DAC7513N/3K	SOT-23	DCN	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

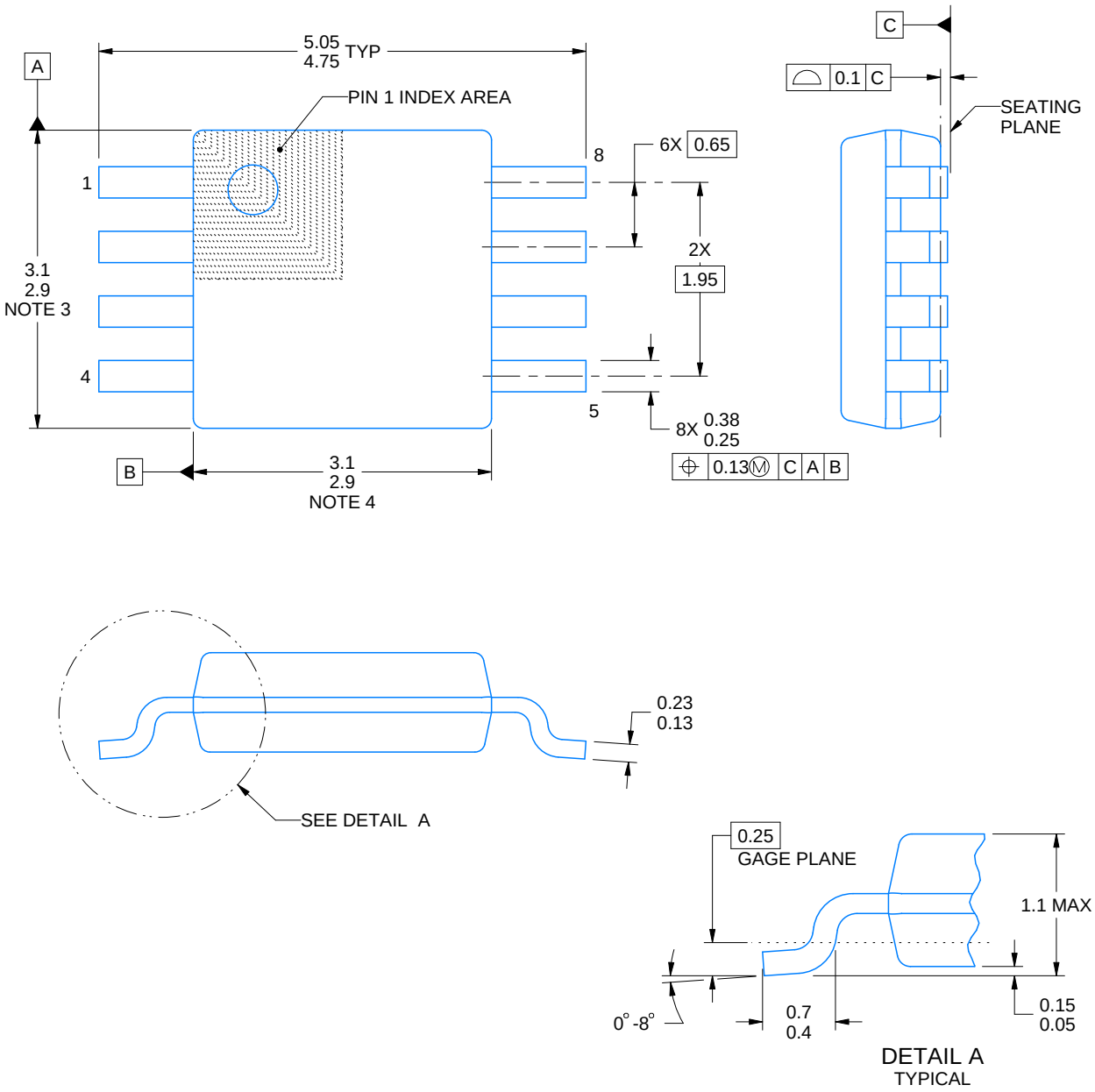
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DAC7513N/250	SOT-23	DCN	8	250	213.0	191.0	35.0
DAC7513N/3K	SOT-23	DCN	8	3000	213.0	191.0	35.0

PACKAGE OUTLINE

DGK0008A

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



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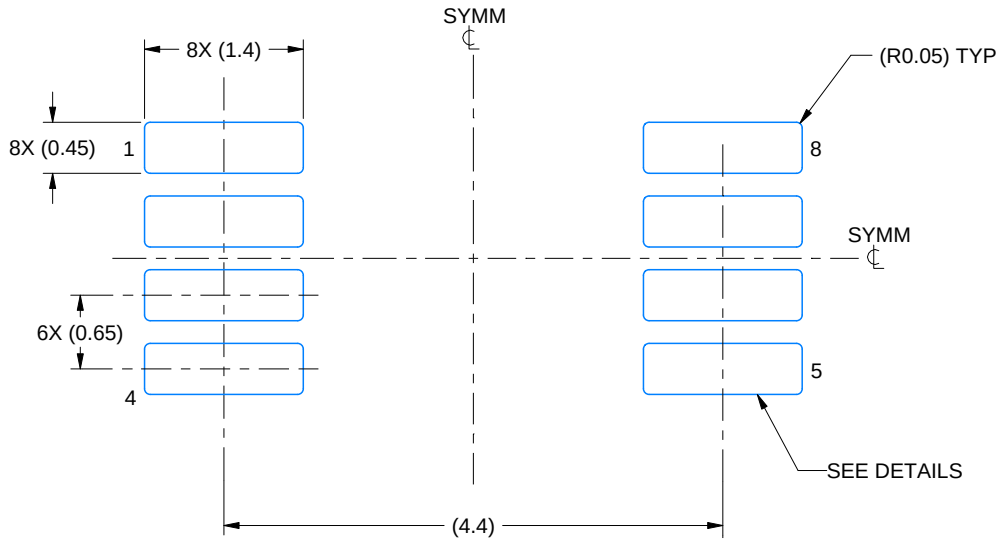
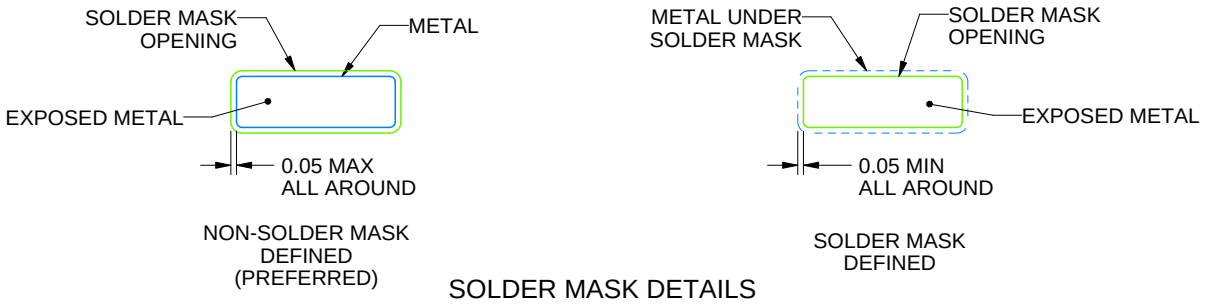
NOTES:

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. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X



SOLDER MASK DETAILS

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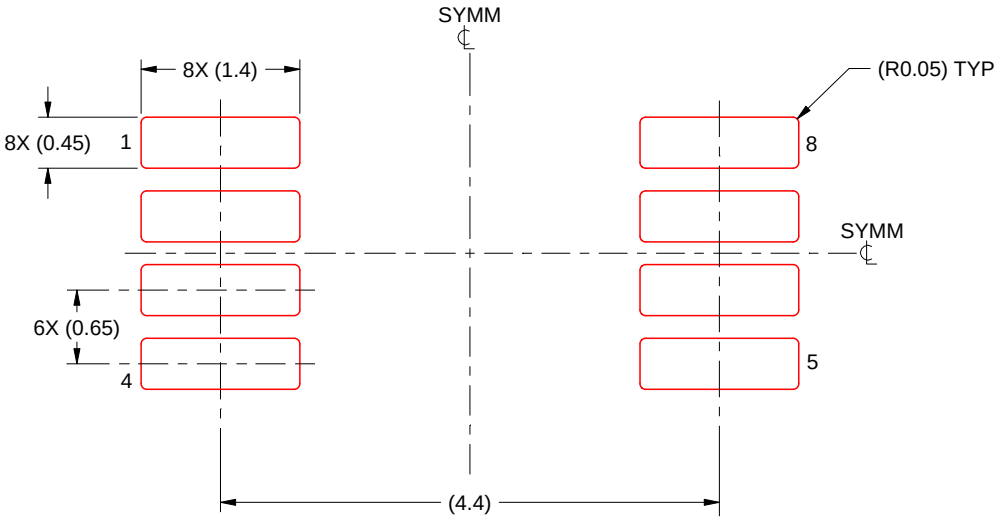
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.



SOLDER PASTE EXAMPLE
SCALE: 15X

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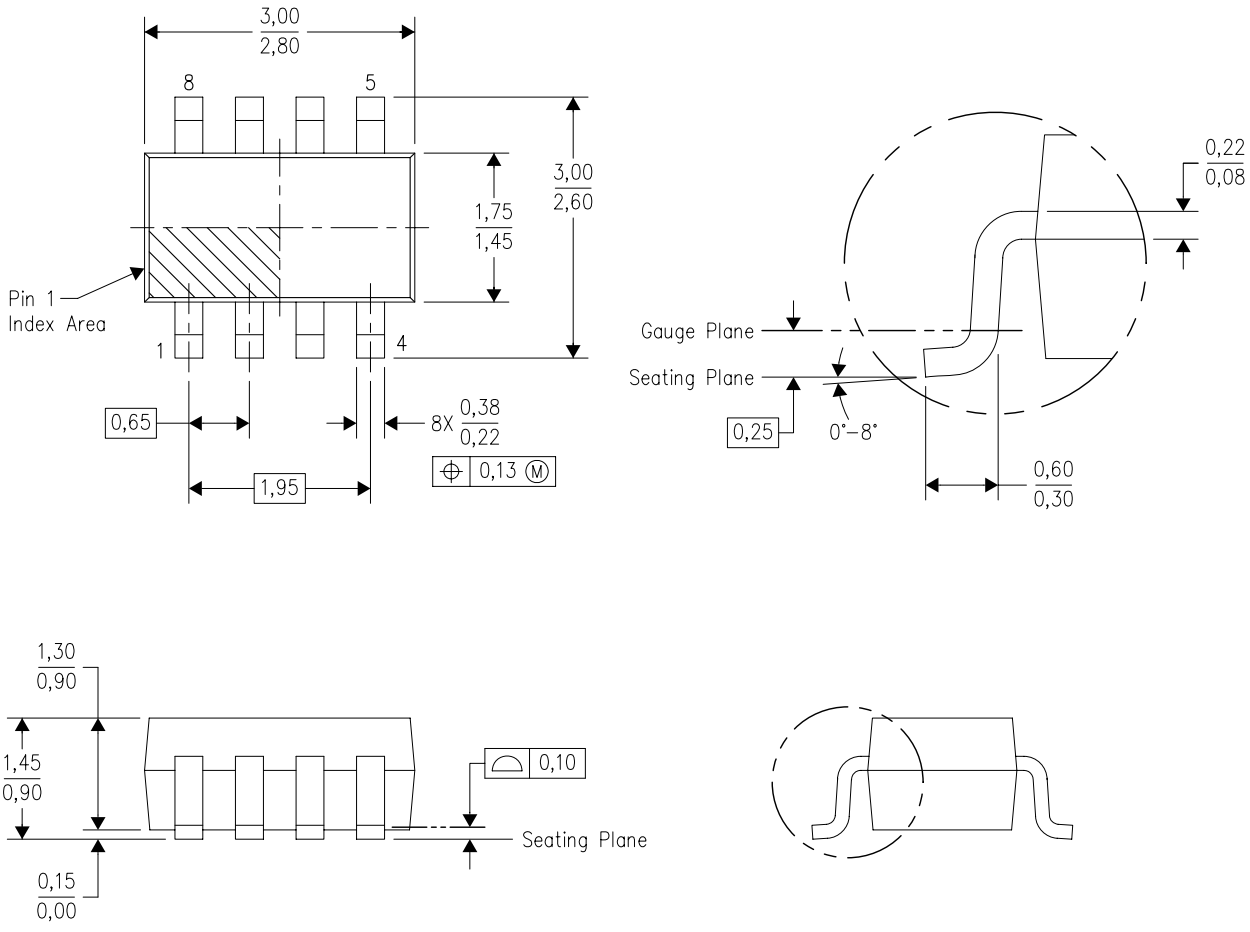
NOTES: (continued)

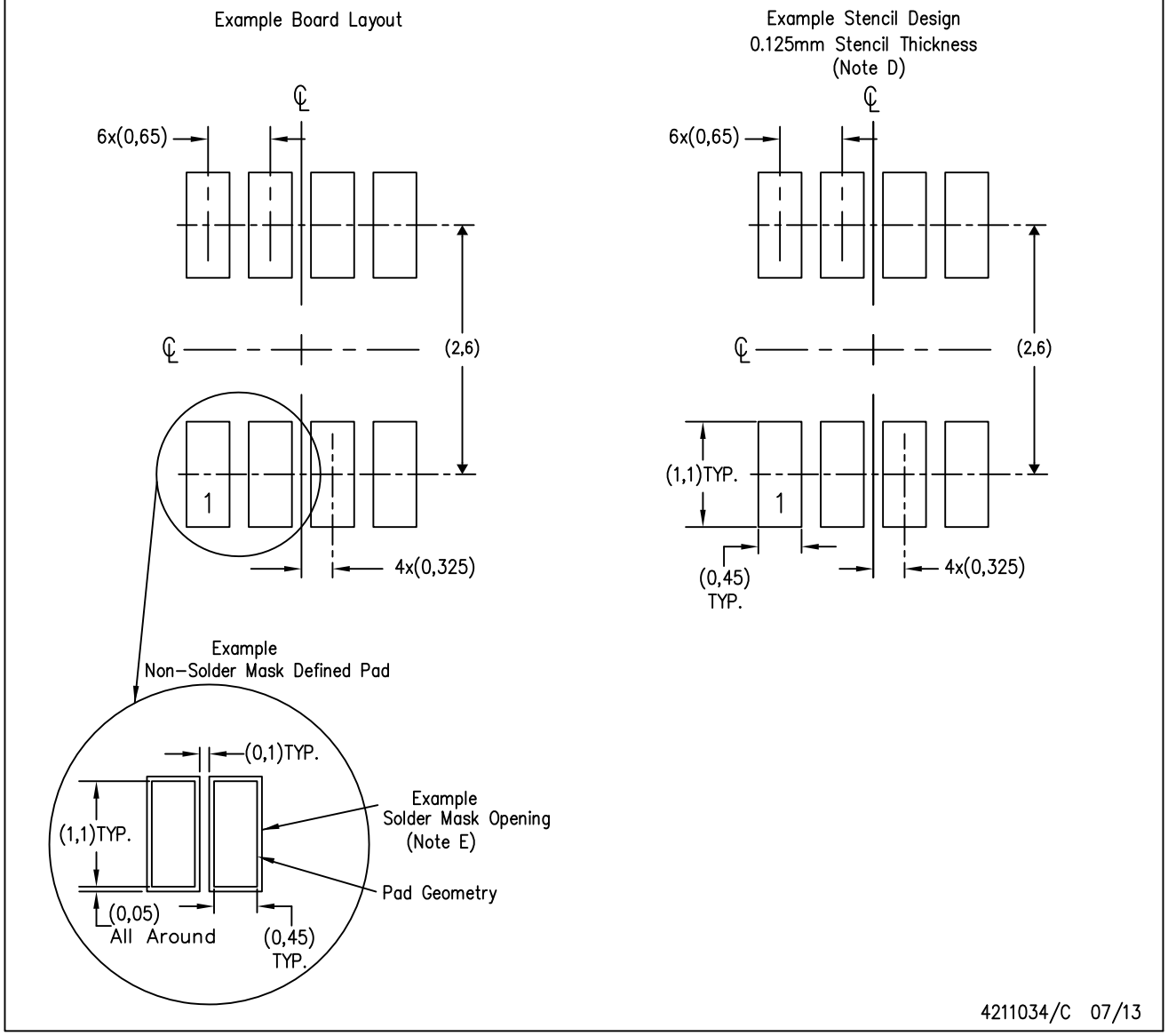
11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

DCN (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE (DIE DOWN)



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Package outline exclusive of metal burr & dambar protrusion/intrusion.
D. Package outline inclusive of solder plating.
E. A visual index feature must be located within the Pin 1 index area.
F. Falls within JEDEC MO–178 Variation BA.
G. Body dimensions do not include flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.

DCN (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE (DIE DOWN)



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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