

## 10-BIT DIGITAL-TO-ANALOG CONVERTERS

### FEATURES

- 10-Bit CMOS Voltage Output DAC in an 8-Terminal Package
- 5V Single Supply Operation
- 3-Wire Serial Interface
- High-Impedance Reference Inputs
- Voltage Output Range: 2 Times the Reference Input Voltage
- Internal Power-On Reset
- Low Power Consumption: 1.75mW Max
- Update Rate of 1.21MHz
- Settling Time to 0.5LSB: 12.5 $\mu$ s Typ
- Monotonic Over Temperature
- Pin-Compatible With the Maxim MAX515

### APPLICATIONS

- Battery-Powered Test Instruments
- Digital Offset and Gain Adjustment
- Battery Operated/Remote Industrial Controls
- Machine and Motion Control Devices
- Cellular Telephones

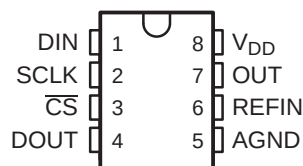
### DESCRIPTION

The TLC5615 is a 10-bit voltage output digital-to-analog converter (DAC) with a buffered reference input (high impedance). The DAC has an output voltage range that is two times the reference voltage, and the DAC is monotonic. The device is simple to use, running from a single supply of 5V. A power-on-reset function is incorporated to ensure repeatable start-up conditions.

Digital control of the TLC5615 is over a three-wire serial bus that is CMOS compatible and easily interfaced to industry standard microprocessor and microcontroller devices. The device receives a 16-bit data word to produce the analog output. The digital inputs feature Schmitt triggers for high noise immunity. Digital communication protocols include the SPI™, QSPI™, and Microwire™ standards.

The 8-terminal small-outline D package allows digital control of analog functions in space-critical applications. The TLC5615C is characterized for operation from 0°C to +70°C. The TLC5615I is characterized for operation from –40°C to +85°C.

**D, P, OR DGK PACKAGE  
(TOP VIEW)**



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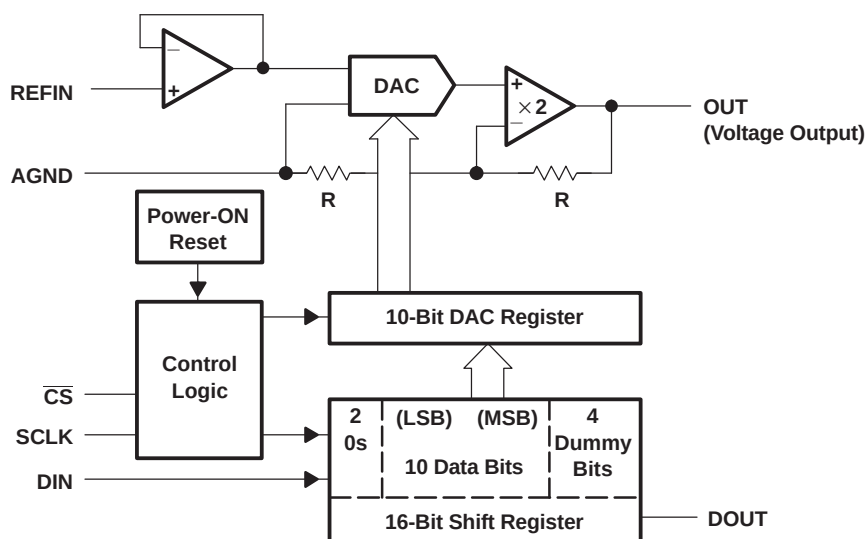
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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

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.

### FUNCTIONAL BLOCK DIAGRAM



### Terminal Functions

| TERMINAL        |     | I/O | DESCRIPTION                           |
|-----------------|-----|-----|---------------------------------------|
| NAME            | NO. |     |                                       |
| DIN             | 1   | I   | Serial data input                     |
| SCLK            | 2   | I   | Serial clock input                    |
| $\overline{CS}$ | 3   | I   | Chip select, active low               |
| DOUT            | 4   | O   | Serial data output for daisy chaining |
| AGND            | 5   |     | Analog ground                         |
| REFIN           | 6   | I   | Reference input                       |
| OUT             | 7   | O   | DAC analog voltage output             |
| $V_{DD}$        | 8   |     | Positive power supply                 |

### PACKAGE/ORDERING INFORMATION

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](http://www.ti.com).

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                                                             |          | UNIT                     |
|-------------------------------------------------------------|----------|--------------------------|
| Supply voltage ( $V_{DD}$ to AGND)                          |          | 7V                       |
| Digital input voltage range to AGND                         |          | -0.3V to $V_{DD} + 0.3V$ |
| Reference input voltage range to AGND                       |          | -0.3V to $V_{DD} + 0.3V$ |
| Output voltage at OUT from external source                  |          | $V_{DD} + 0.3V$          |
| Continuous current at any terminal                          |          | ±20mA                    |
| Operating free-air temperature range, $T_A$                 | TLC5615C | 0°C to +70°C             |
|                                                             | TLC5615I | -40°C to +85°C           |
| Storage temperature range, $T_{stg}$                        |          | -65°C to +150°C          |
| Lead temperature 1.6mm (1/16 inch) from case for 10 seconds |          | +260°C                   |

- (1) Stresses beyond those listed under [Absolute Maximum Ratings](#) may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under [Recommended Operating Conditions](#) is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## RECOMMENDED OPERATING CONDITIONS

|                                                |          | MIN | NOM   | MAX        | UNIT |
|------------------------------------------------|----------|-----|-------|------------|------|
| Supply voltage, $V_{DD}$                       |          | 4.5 | 5     | 5.5        | V    |
| High-level digital input voltage, $V_{IH}$     |          | 2.4 |       |            | V    |
| Low-level digital input voltage, $V_{IL}$      |          |     |       | 0.8        | V    |
| Reference voltage, $V_{ref}$ to REFIN terminal |          | 2   | 2.048 | $V_{DD}-2$ | V    |
| Load resistance, $R_L$                         |          | 2   |       |            | kΩ   |
| Operating free-air temperature, $T_A$          | TLC5615C | 0   |       | 70         | °C   |
|                                                | TLC5615I | 40  |       | 85         | °C   |

## ELECTRICAL CHARACTERISTICS

over recommended operating free-air temperature range,  $V_{DD} = 5V \pm 5\%$ ,  $V_{ref} = 2.048V$  (unless otherwise noted)

| STATIC DAC SPECIFICATIONS                       |                                               |            |                            |                    |                               |      |      |        |
|-------------------------------------------------|-----------------------------------------------|------------|----------------------------|--------------------|-------------------------------|------|------|--------|
| PARAMETER                                       |                                               |            | TEST CONDITIONS            |                    | MIN                           | TYP  | MAX  | UNIT   |
| Resolution                                      |                                               |            |                            |                    | 10                            |      |      | bits   |
| Integral nonlinearity, end point adjusted (INL) |                                               |            | V <sub>ref</sub> = 2.048V, | See <sup>(1)</sup> |                               |      | ±1   | LSB    |
| Differential nonlinearity (DNL)                 |                                               |            | V <sub>ref</sub> = 2.048V, | See <sup>(2)</sup> |                               | ±0.1 | ±0.5 | LSB    |
| E <sub>ZS</sub>                                 | Zero-scale error (offset error at zero scale) |            | V <sub>ref</sub> = 2.048V, | See <sup>(3)</sup> |                               |      | ±3   | LSB    |
| Zero-scale-error temperature coefficient        |                                               |            | V <sub>ref</sub> = 2.048V, | See <sup>(4)</sup> |                               | 3    |      | ppm/°C |
| E <sub>G</sub>                                  | Gain error                                    |            | V <sub>ref</sub> = 2.048V, | See <sup>(5)</sup> |                               |      | ±3   | LSB    |
| Gain-error temperature coefficient              |                                               |            | V <sub>ref</sub> = 2.048V, | See <sup>(6)</sup> |                               | 1    |      | ppm/°C |
| PSRR                                            | Power-supply rejection ratio                  | Zero scale | See <sup>(7)(8)</sup>      |                    | 80                            |      |      | dB     |
|                                                 |                                               | Gain       |                            |                    | 80                            |      |      |        |
| Analog full scale output                        |                                               |            | R <sub>L</sub> = 100kΩ     |                    | 2V <sub>ref</sub> (1023/1024) |      |      | V      |

- (1) The relative accuracy or integral nonlinearity (INL), sometimes referred to as linearity error, is the maximum deviation of the output from the line between zero and full scale excluding the effects of zero code and full-scale errors (see text). Tested from code 3 to code 1024.
- (2) The differential nonlinearity (DNL), sometimes referred to as differential error, is the difference between the measured and ideal 1LSB amplitude change of any two adjacent codes. Monotonic means the output voltage changes in the same direction (or remains constant) as a change in the digital input code. Tested from code 3 to code 1024.
- (3) Zero-scale error is the deviation from zero-voltage output when the digital input code is zero (see text).
- (4) Zero-scale-error temperature coefficient is given by:  $E_{ZS} TC = [E_{ZS}(T_{max}) - E_{ZS}(T_{min})]/V_{ref} \times 10^6/(T_{max} - T_{min})$ .
- (5) Gain error is the deviation from the ideal output ( $V_{ref} - 1LSB$ ) with an output load of 10kΩ excluding the effects of the zero-scale error.
- (6) Gain temperature coefficient is given by:  $E_G TC = [E_G(T_{max}) - E_G(T_{min})]/V_{ref} \times 10^6/(T_{max} - T_{min})$ .
- (7) Zero-scale-error rejection ratio (EZS-RR) is measured by varying the  $V_{DD}$  from 4.5V to 5.5V dc and measuring the proportion of this signal imposed on the zero-code output voltage.
- (8) Gain-error rejection ratio (EG-RR) is measured by varying the  $V_{DD}$  from 4.5V to 5.5V dc and measuring the proportion of this signal imposed on the full-scale output voltage after subtracting the zero-scale change.

**VOLTAGE OUTPUT (OUT)**

| PARAMETER                                    |                                       | TEST CONDITIONS                                                                               | MIN                       | TYP | MAX                  | UNIT |
|----------------------------------------------|---------------------------------------|-----------------------------------------------------------------------------------------------|---------------------------|-----|----------------------|------|
| V <sub>O</sub>                               | Voltage output range                  | R <sub>L</sub> = 10kΩ                                                                         | 0                         |     | V <sub>DD</sub> –0.4 | V    |
|                                              | Output load regulation accuracy       | V <sub>O(OUT)</sub> = 2V, R <sub>L</sub> = 2kΩ                                                |                           |     | 0.5                  | LSB  |
| I <sub>OSC</sub>                             | Output short circuit current          | OUT to V <sub>DD</sub> or AGND                                                                |                           | 20  |                      | mA   |
| V <sub>OL(low)</sub>                         | Output voltage, low-level             | I <sub>O(OUT)</sub> ≤ 5mA                                                                     |                           |     | 0.25                 | V    |
| V <sub>OH(high)</sub>                        | Output voltage, high-level            | I <sub>O(OUT)</sub> ≤– 5mA                                                                    | 4.75                      |     |                      | V    |
| REFERENCE INPUT (REFIN)                      |                                       |                                                                                               |                           |     |                      |      |
| V <sub>I</sub>                               | Input voltage                         |                                                                                               | 0                         |     | V <sub>DD</sub> –2   | V    |
| r <sub>i</sub>                               | Input resistance                      |                                                                                               | 10                        |     |                      | MΩ   |
| C <sub>i</sub>                               | Input capacitance                     |                                                                                               |                           | 5   |                      | pF   |
| DIGITAL INPUTS (DIN, SCLK, $\overline{CS}$ ) |                                       |                                                                                               |                           |     |                      |      |
| V <sub>IH</sub>                              | High-level digital input voltage      |                                                                                               | 2.4                       |     |                      | V    |
| V <sub>IL</sub>                              | Low-level digital input voltage       |                                                                                               |                           |     | 0.8                  | V    |
| I <sub>IH</sub>                              | High-level digital input current      | V <sub>I</sub> = V <sub>DD</sub>                                                              |                           |     | ±1                   | μA   |
| I <sub>IL</sub>                              | Low-level digital input current       | V <sub>I</sub> = 0                                                                            |                           |     | ±1                   | μA   |
| C <sub>i</sub>                               | Input capacitance                     |                                                                                               |                           | 8   |                      | pF   |
| DIGITAL OUTPUT (DOUT)                        |                                       |                                                                                               |                           |     |                      |      |
| V <sub>OH</sub>                              | Output voltage, high-level            | I <sub>O</sub> = –2mA                                                                         | V <sub>DD</sub> –1        |     |                      | V    |
| V <sub>OL</sub>                              | Output voltage, low-level             | I <sub>O</sub> = 2mA                                                                          |                           |     | 0.4                  | V    |
| POWER SUPPLY                                 |                                       |                                                                                               |                           |     |                      |      |
| V <sub>DD</sub>                              | Supply voltage                        |                                                                                               | 4.5                       | 5   | 5.5                  | V    |
| I <sub>DD</sub>                              | Power supply current                  | V <sub>DD</sub> = 5.5V, No load,<br>All inputs = 0V or V <sub>DD</sub>                        | V <sub>ref</sub> = 0      | 150 | 250                  | μA   |
|                                              |                                       | V <sub>DD</sub> = 5.5V, No load,<br>All inputs = 0V or V <sub>DD</sub>                        | V <sub>ref</sub> = 2.048V | 230 | 350                  | μA   |
| ANALOG OUTPUT DYNAMIC PERFORMANCE            |                                       |                                                                                               |                           |     |                      |      |
|                                              | Signal-to-noise + distortion, S/(N+D) | V <sub>ref</sub> = 1V <sub>PP</sub> at 1kHz + 2.048Vdc,<br>code = 11 1111 1111 <sup>(1)</sup> | 60                        |     |                      | dB   |

(1) The limiting frequency value at 1V<sub>PP</sub> is determined by the output-amplifier slew rate.

**DIGITAL INPUT TIMING REQUIREMENTS (See Figure 1)**

| PARAMETER            |                                                      | MIN | NOM | MAX | UNIT |
|----------------------|------------------------------------------------------|-----|-----|-----|------|
| t <sub>SU(DS)</sub>  | Setup time, DIN before SCLK high                     | 45  |     |     | ns   |
| t <sub>H(DH)</sub>   | Hold time, DIN valid after SCLK high                 | 0   |     |     | ns   |
| t <sub>SU(CSS)</sub> | Setup time, $\overline{CS}$ low to SCLK high         | 1   |     |     | ns   |
| t <sub>SU(CS1)</sub> | Setup time, $\overline{CS}$ high to SCLK high        | 50  |     |     | ns   |
| t <sub>H(CSH0)</sub> | Hold time, SCLK low to $\overline{CS}$ low           | 1   |     |     | ns   |
| t <sub>H(CSH1)</sub> | Hold time, SCLK low to $\overline{CS}$ high          | 0   |     |     | ns   |
| t <sub>W(CS)</sub>   | Pulse duration, minimum chip select pulse width high | 20  |     |     | ns   |
| t <sub>W(CL)</sub>   | Pulse duration, SCLK low                             | 25  |     |     | ns   |
| t <sub>W(CH)</sub>   | Pulse duration, SCLK high                            | 25  |     |     | ns   |

**OUTPUT SWITCHING CHARACTERISTICS**

| PARAMETER             |                              | TEST CONDITIONS       | MIN | NOM | MAX | UNIT |
|-----------------------|------------------------------|-----------------------|-----|-----|-----|------|
| t <sub>pd(DOUT)</sub> | Propagation delay time, DOUT | C <sub>L</sub> = 50pF |     |     | 50  | ns   |

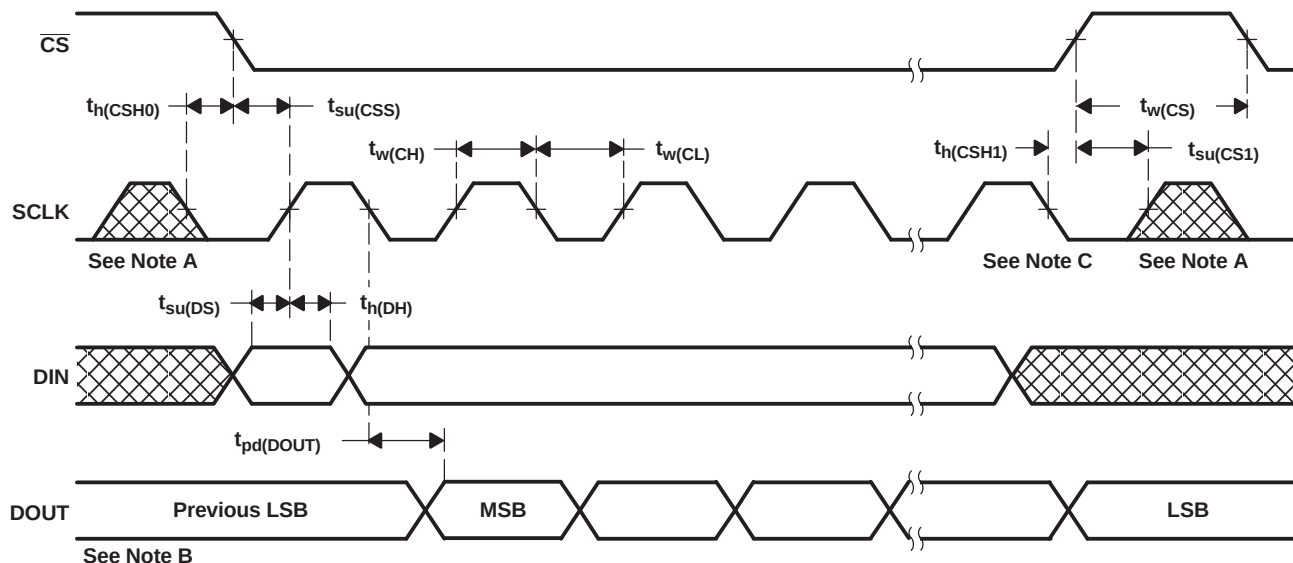
## OPERATING CHARACTERISTICS

over recommended operating free-air temperature range,  $V_{DD} = 5V \pm 5\%$ ,  $V_{ref} = 2.048V$  (unless otherwise noted)

| PARAMETER                                |                                   | TEST CONDITIONS                                                  | MIN | TYP  | MAX | UNIT       |
|------------------------------------------|-----------------------------------|------------------------------------------------------------------|-----|------|-----|------------|
| <b>ANALOG OUTPUT DYNAMIC PERFORMANCE</b> |                                   |                                                                  |     |      |     |            |
| SR                                       | Output slew rate                  | $C_L = 100pF$ ,<br>$T_A = +25^\circ C$ $R_L = 10k\Omega$ ,       | 0.3 | 0.5  |     | V/ $\mu s$ |
| $t_s$                                    | Output settling time              | To 0.5LSB,<br>$R_L = 10k\Omega$ , $C_L = 100pF$ , <sup>(1)</sup> |     | 12.5 |     | $\mu s$    |
|                                          | Glitch energy                     | DIN = All 0s to all 1s                                           |     | 5    |     | nV-s       |
| <b>REFERENCE INPUT (REFIN)</b>           |                                   |                                                                  |     |      |     |            |
|                                          | Reference feedthrough             | REFIN = $1V_{PP}$ at 1kHz + 2.048Vdc <sup>(2)</sup>              | -80 |      |     | dB         |
|                                          | Reference input bandwidth (f-3dB) | REFIN = $0.2V_{PP} + 2.048Vdc$                                   | 30  |      |     | kHz        |

- (1) Settling time is the time for the output signal to remain within  $\pm 0.5LSB$  of the final measured value for a digital input code change of 000 hex to 3FF hex or 3FF hex to 000 hex.  
(2) Reference feedthrough is measured at the DAC output with an input code = 000 hex and a  $V_{ref}$  input =  $2.048Vdc + 1V_{PP}$  at 1kHz.

## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The input clock, applied at the SCLK terminal, should be inhibited low when  $\overline{CS}$  is high to minimize clock feedthrough.  
B. Data input from preceeding conversion cycle.  
C. Sixteenth SCLK falling edge

**Figure 1. Timing Diagram**

## TYPICAL CHARACTERISTICS

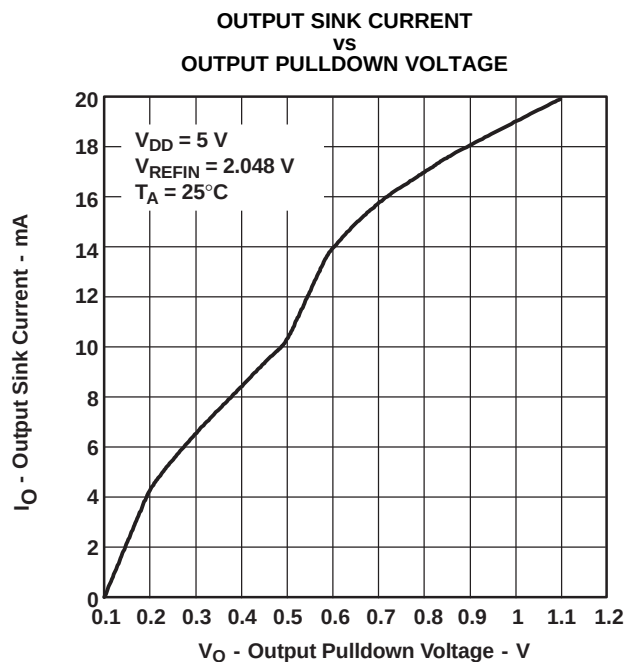


Figure 2.

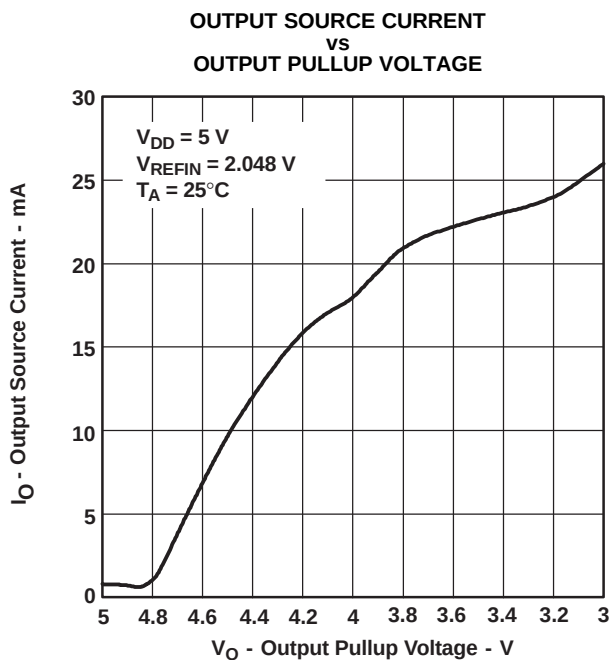


Figure 3.

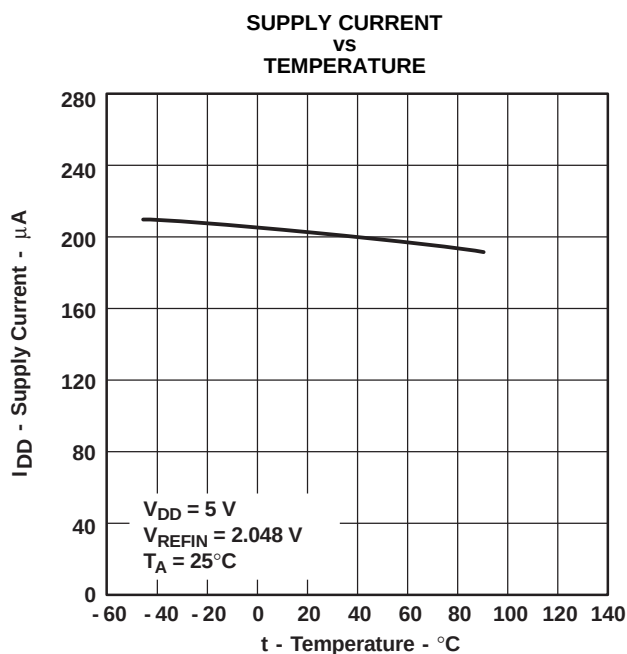


Figure 4.

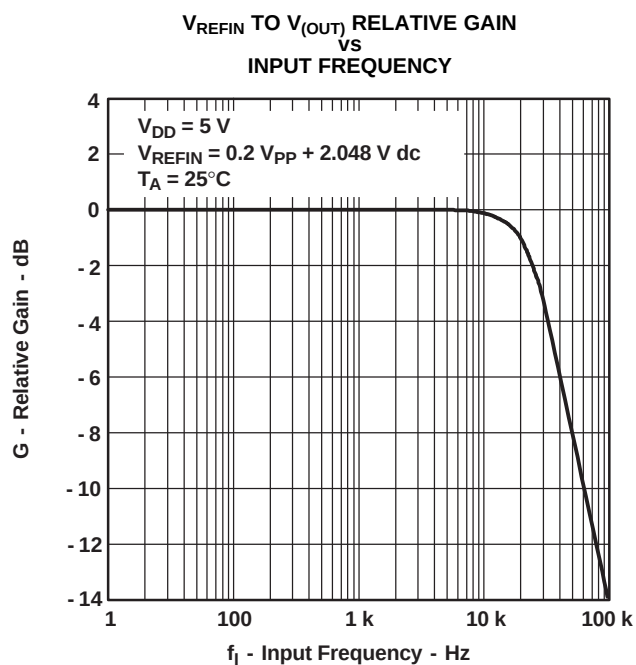


Figure 5.

## TYPICAL CHARACTERISTICS (continued)

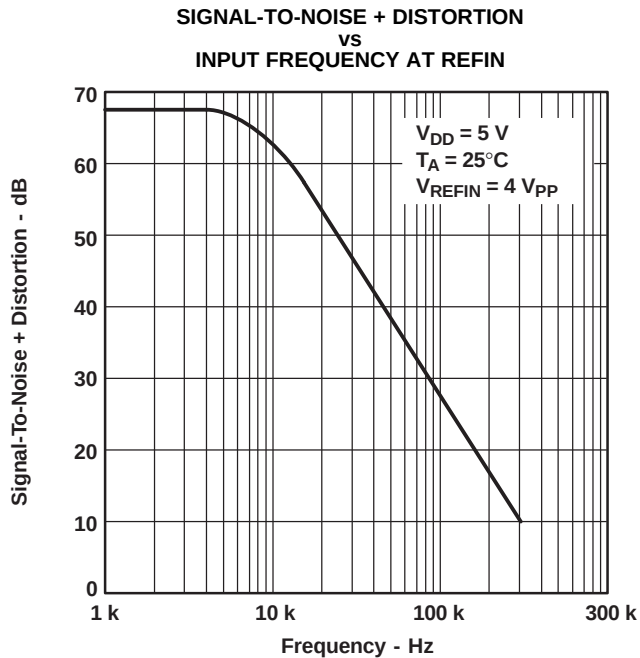


Figure 6.

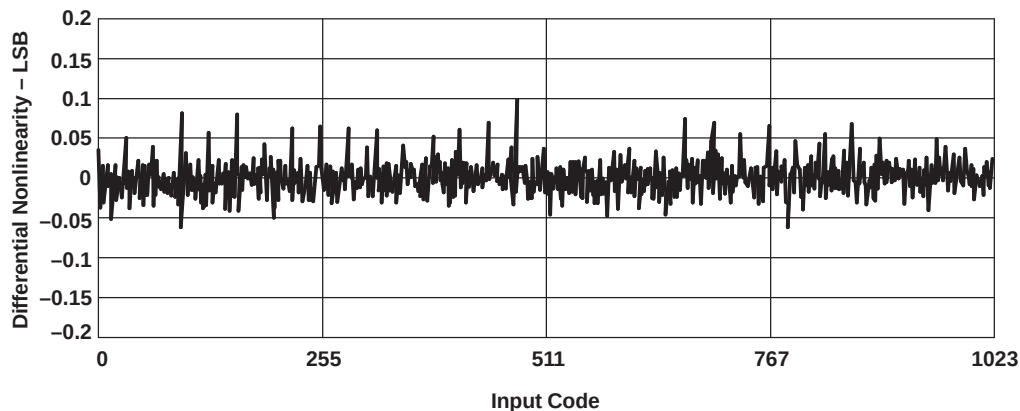


Figure 7. Differential Nonlinearity With Input Code

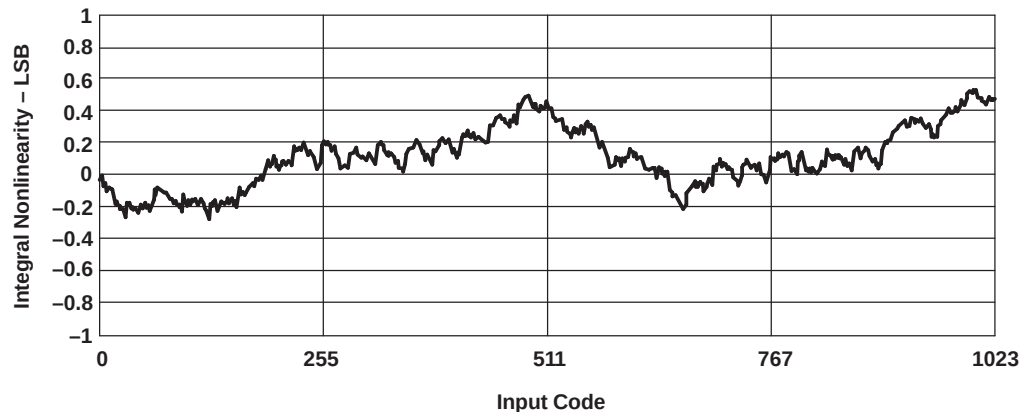


Figure 8. Integral Nonlinearity With Input Code

APPLICATION INFORMATION

GENERAL FUNCTION

The TLC5615 uses a resistor string network buffered with an op amp in a fixed gain of 2 to convert 10-bit digital data to analog voltage levels (see functional block diagram and Figure 9). The output of the TLC5615 is the same polarity as the reference input (see Table 1).

An internal circuit resets the DAC register to all zeros on power up.

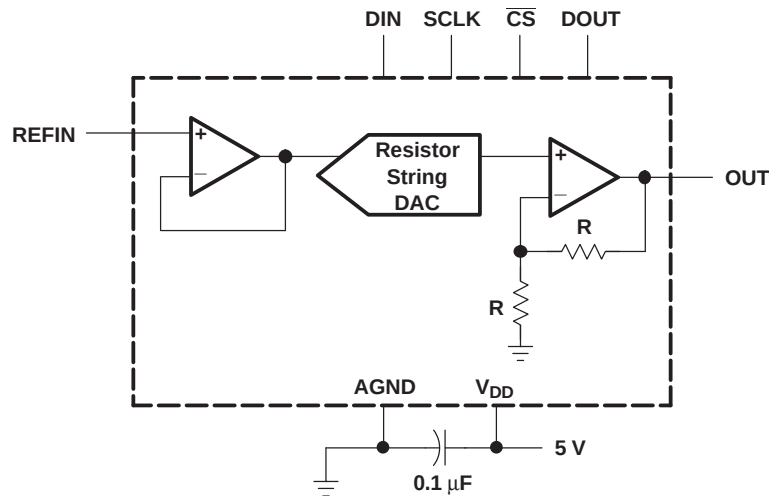


Figure 9. TLC5615 Typical Operating Circuit

Table 1. Binary Code Table (0V to 2V<sub>REFIN</sub> Output), Gain = 2

| INPUT <sup>(1)</sup> |      |        | OUTPUT                                      |
|----------------------|------|--------|---------------------------------------------|
| 1111                 | 1111 | 11(00) | $2(V_{REFIN}) \frac{1023}{1024}$            |
|                      | :    |        | :                                           |
| 1000                 | 0000 | 01(00) | $2(V_{REFIN}) \frac{513}{1024}$             |
| 1000                 | 0000 | 00(00) | $2(V_{REFIN}) \frac{512}{1024} = V_{REFIN}$ |
| 0111                 | 1111 | 11(00) | $2(V_{REFIN}) \frac{511}{1024}$             |
|                      | :    |        | :                                           |
| 0000                 | 0000 | 01(00) | $2(V_{REFIN}) \frac{1}{1024}$               |
| 0000                 | 0000 | 00(00) | 0 V                                         |

(1) A 10-bit data word with two bits below the LSB bit (sub-LSB) with 0 values must be written since the DAC input latch is 12 bits wide.



## BUFFER AMPLIFIER

The output buffer has a rail-to-rail output with short circuit protection and can drive a 2kΩ load with a 100pF load capacitance. Settling time is 12.5μs typical to within 0.5LSB of final value.

## EXTERNAL REFERENCE

The reference voltage input is buffered, which makes the DAC input resistance not code dependent. Therefore, the REFIN input resistance is 10MΩ and the REFIN input capacitance is typically 5pF independent of input code. The reference voltage determines the DAC full-scale output.

## LOGIC INTERFACE

The logic inputs function with either TTL or CMOS logic levels. However, using rail-to-rail CMOS logic achieves the lowest power dissipation. The power requirement increases by approximately 2 times when using TTL logic levels.

## SERIAL CLOCK AND UPDATE RATE

Figure 1 shows the TLC5615 timing. The maximum serial clock rate is:

$$f_{(\text{SCLK})\text{max}} = \frac{1}{t_{w(\text{CH})} + t_{w(\text{CL})}}$$

or approximately 14MHz. The digital update rate is limited by the chip-select period, which is:

$$t_{p(\text{CS})} = 16 \times (t_{w(\text{CH})} + t_{w(\text{CL})}) + t_{w(\text{CS})}$$

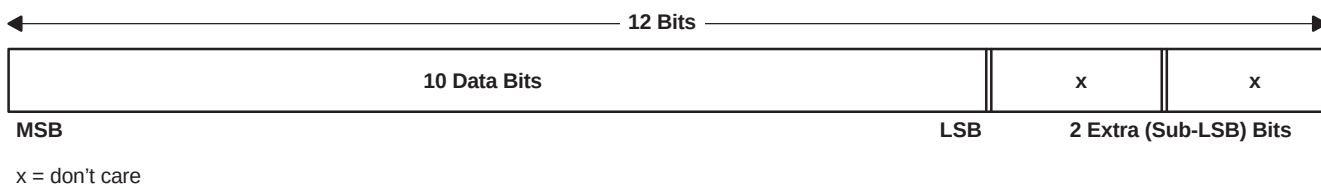
and is equal to 820ns which is a 1.21MHz update rate. However, the DAC settling time to 10 bits of 12.5μs limits the update rate to 80kHz for full-scale input step transitions.

## SERIAL INTERFACE

When chip select ( $\overline{\text{CS}}$ ) is low, the input data is read into a 16-bit shift register with the input data clocked in most significant bit first. The rising edge of the SCLK input shifts the data into the input register.

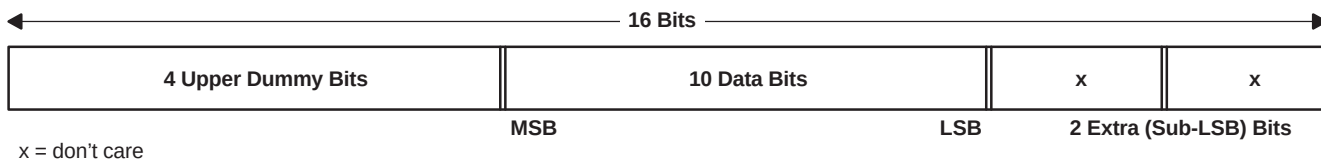
The rising edge of  $\overline{\text{CS}}$  then transfers the data to the DAC register. When  $\overline{\text{CS}}$  is high, input data cannot be clocked into the input register. All  $\overline{\text{CS}}$  transitions should occur when the SCLK input is low.

If the daisy chain (cascading) function (see daisy-chaining devices section) is not used, a 12-bit input data sequence with the MSB first can be used as shown in [Figure 10](#):



**Figure 10. 12-Bit Input Data Sequence**

or 16 bits of data can be transferred as shown in [Figure 11](#) with the 4 upper dummy bits first.



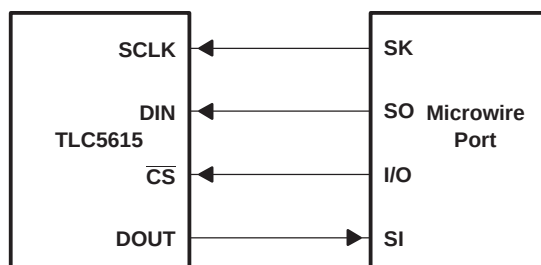
**Figure 11. 16-Bit Input Data Sequence**

The data from DOUT requires 16 falling edges of the input clock and, therefore, requires an extra clock width. When daisy chaining multiple TLC5615 devices, the data requires 4 upper dummy bits because the data transfer requires 16 input-clock cycles plus one additional input-clock falling edge to clock out the data at the DOUT terminal (see Figure 1).

The two extra (sub-LSB) bits are always required to provide hardware and software compatibility with 12-bit data converter transfers.

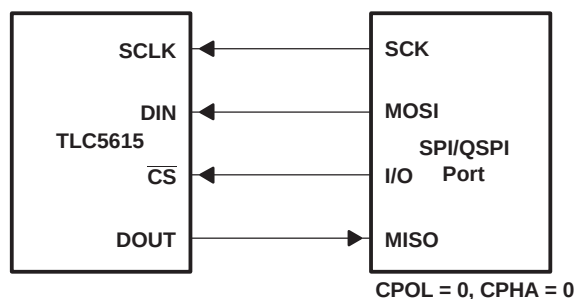
The TLC5615 three-wire interface is compatible with the SPI, QSPI, and Microwire serial standards. The hardware connections are shown in Figure 12 and Figure 13.

The SPI and Microwire interfaces transfer data in 8-bit bytes; therefore, two write cycles are required to input data to the DAC. The QSPI interface, which has a variable input data length from 8 to 16 bits, can load the DAC input register in one write cycle.



NOTE A: The DOUT-SI connection is not required for writing to the TLC5615 but may be used for verifying data transfer if desired.

**Figure 12. Microwire Connection**



NOTE A: The DOUT-MISO connection is not required for writing to the TLC5615 but may be used for verifying data transfer.

**Figure 13. SPI/QSPI Connection**

## DAISY-CHAINING DEVICES

DACs can be daisy-chained by connecting the DOUT terminal of one device to the DIN of the next device in the chain, providing that the setup time,  $t_{su(CSS)}$  ( $\overline{CS}$  low to SCLK high), is greater than the sum of the setup time,  $t_{su(DS)}$ , plus the propagation delay time,  $t_{pd(DOUT)}$ , for proper timing (see digital input timing requirements section). The data at DIN appears at DOUT, delayed by 16 clock cycles plus one clock width. DOUT is a totem-poled output for low power. DOUT changes on the SCLK falling edge when  $\overline{CS}$  is low. When  $\overline{CS}$  is high, DOUT remains at the value of the last data bit and does not go into a high-impedance state.

## LINEARITY, OFFSET, AND GAIN ERROR USING SINGLE-ENDED SUPPLIES

When an amplifier is operated from a single supply, the voltage offset can still be either positive or negative. With a positive offset, the output voltage changes on the first code change. With a negative offset the output voltage may not change with the first code depending on the magnitude of the offset voltage.

The output amplifier attempts to drive the output to a negative voltage. However, because the most negative supply rail is ground, the output cannot drive below ground and clamps the output at 0V.

The output voltage then remains at zero until the input code value produces a sufficient positive output voltage to overcome the negative offset voltage, resulting in the transfer function shown in Figure 14.

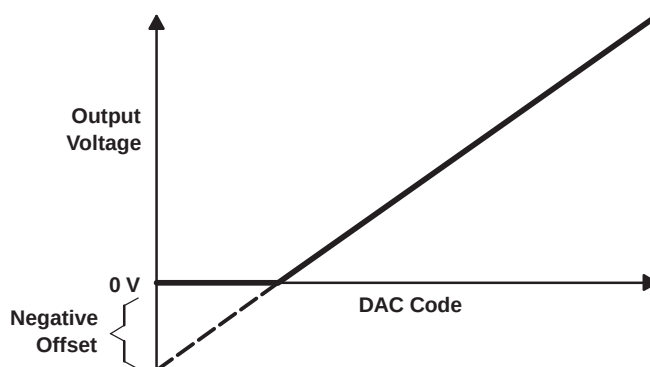


Figure 14. Effect of Negative Offset (Single Supply)

This offset error, not the linearity error, produces this breakpoint. The transfer function would have followed the dotted line if the output buffer could drive below the ground rail.

For a DAC, linearity is measured between zero-input code (all inputs '0') and full-scale code (all inputs '1') after offset and full scale are adjusted out or accounted for in some way. However, single supply operation does not allow for adjustment when the offset is negative due to the breakpoint in the transfer function. So the linearity is measured between full-scale code and the lowest code that produces a positive output voltage. For the TLC5615, the zero-scale (offset) error is  $\pm 3\text{LSB}$  maximum. The code is calculated from the maximum specification for the negative offset.

## POWER-SUPPLY BYPASSING AND GROUND MANAGEMENT

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

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

Figure 15 shows the ground plane layout and bypassing technique.

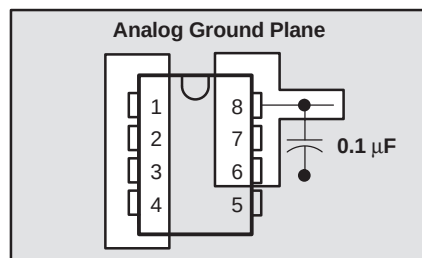


Figure 15. Power-Supply Bypassing

## SAVING POWER

Setting the DAC register to all 0s minimizes power consumption by the reference resistor array and the output load when the system is not using the DAC.

## AC CONSIDERATIONS

### Digital Feedthrough

Even with  $\overline{CS}$  high, high-speed serial data at any of the digital input or output terminals may couple through the DAC package internal stray capacitance and appear at the DAC analog output as digital feedthrough. Digital feedthrough is tested by holding  $\overline{CS}$  high and transmitting 0101010101 from DIN to DOUT.

### Analog Feedthrough

Higher frequency analog input signals may couple to the output through internal stray capacitance. Analog feedthrough is tested by holding  $\overline{CS}$  high, setting the DAC code to all 0s, sweeping the frequency applied to REFIN, and monitoring the DAC output.

## Revision History

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

| Changes from D Revision (August 2003) to E Revision         | Page |
|-------------------------------------------------------------|------|
| • Added ESD statement. ....                                 | 2    |
| • Changed —moved package option table from front page. .... | 2    |

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TLC5615CD        | ACTIVE        | SOIC         | D                  | 8    | 75             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 5615C                   | <a href="#">Samples</a> |
| TLC5615CDG4      | ACTIVE        | SOIC         | D                  | 8    | 75             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 5615C                   | <a href="#">Samples</a> |
| TLC5615CDGK      | ACTIVE        | VSSOP        | DGK                | 8    | 80             | RoHS & Green    | NIPDAUAG                             | Level-1-260C-UNLIM   | 0 to 70      | AEM                     | <a href="#">Samples</a> |
| TLC5615CDGKR     | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | RoHS & Green    | NIPDAUAG                             | Level-1-260C-UNLIM   | 0 to 70      | AEM                     | <a href="#">Samples</a> |
| TLC5615CDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 5615C                   | <a href="#">Samples</a> |
| TLC5615CP        | ACTIVE        | PDIP         | P                  | 8    | 50             | RoHS & Green    | NIPDAU                               | N / A for Pkg Type   | 0 to 70      | TLC5615CP               | <a href="#">Samples</a> |
| TLC5615ID        | ACTIVE        | SOIC         | D                  | 8    | 75             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 5615I                   | <a href="#">Samples</a> |
| TLC5615IDGK      | ACTIVE        | VSSOP        | DGK                | 8    | 80             | RoHS & Green    | NIPDAUAG                             | Level-1-260C-UNLIM   | -40 to 85    | AEN                     | <a href="#">Samples</a> |
| TLC5615IDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 5615I                   | <a href="#">Samples</a> |
| TLC5615IP        | ACTIVE        | PDIP         | P                  | 8    | 50             | RoHS & Green    | NIPDAU                               | N / A for Pkg Type   | -40 to 85    | TLC5615IP               | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

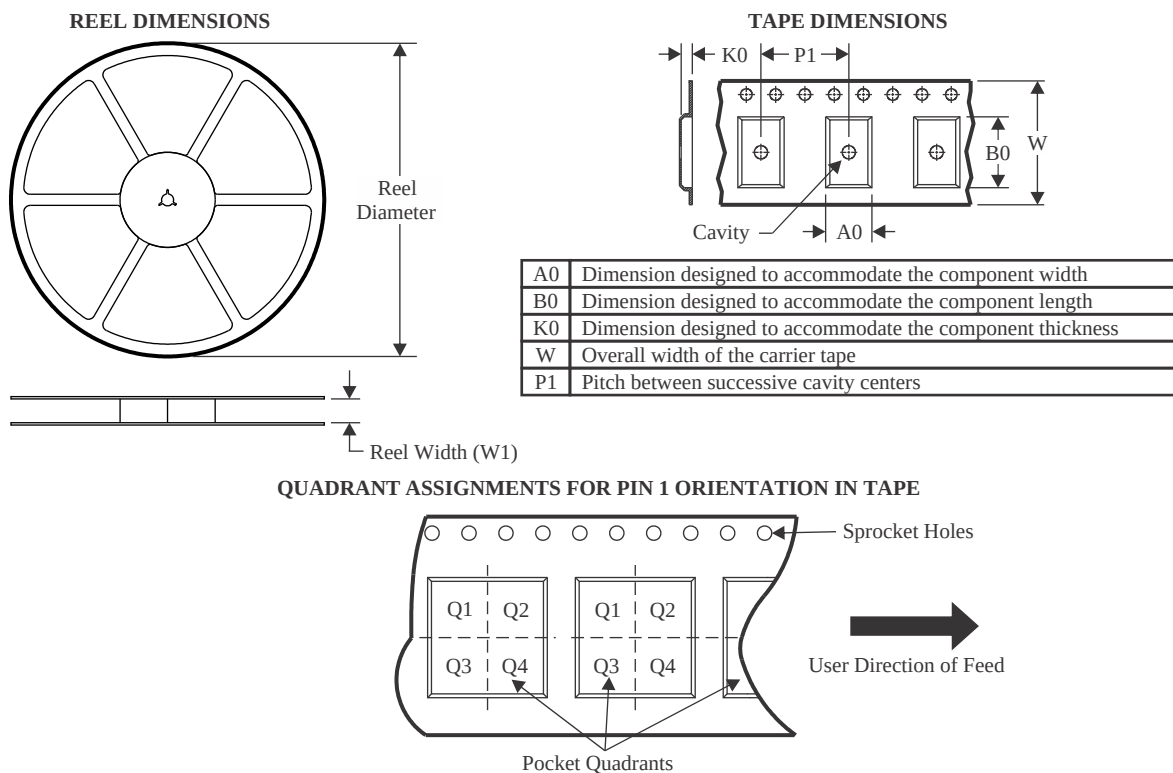
<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead finish/Ball material - Orderable Devices 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.

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## TAPE AND REEL INFORMATION

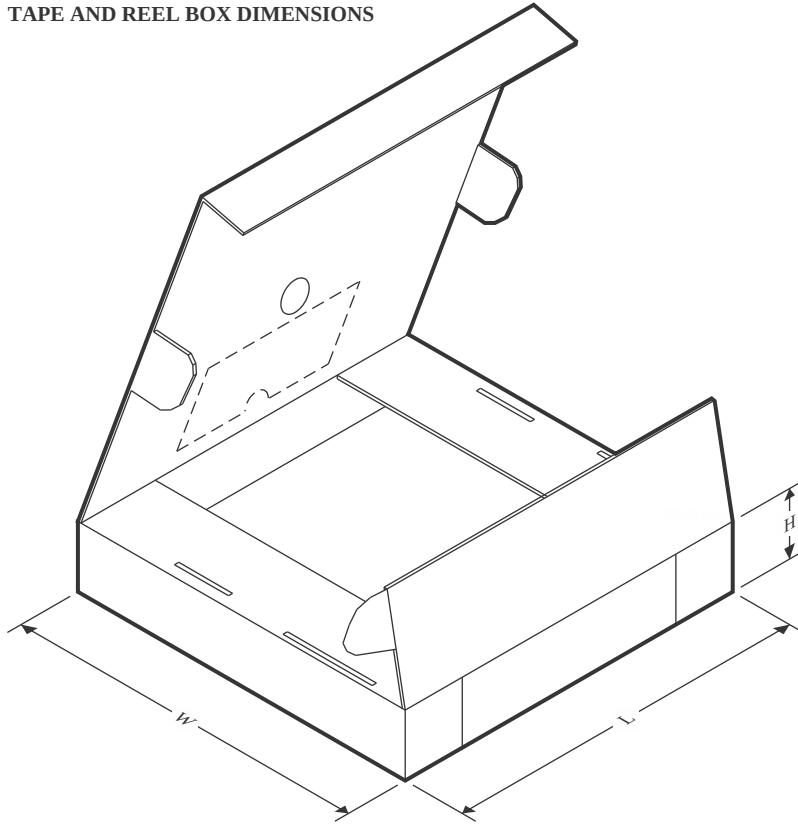


\*All dimensions are nominal

| 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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLC5615CDGKR | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| TLC5615CDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLC5615IDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |



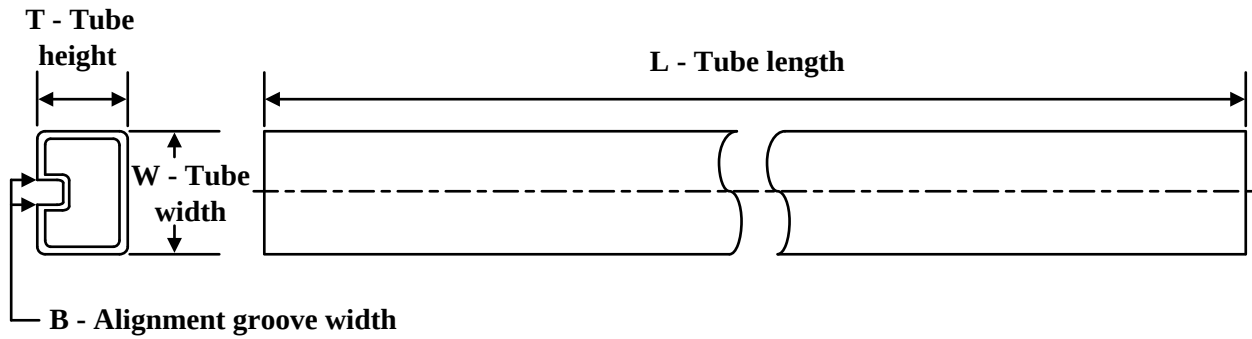
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

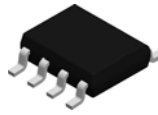
| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLC5615CDGKR | VSSOP        | DGK             | 8    | 2500 | 350.0       | 350.0      | 43.0        |
| TLC5615CDR   | SOIC         | D               | 8    | 2500 | 340.5       | 336.1      | 25.0        |
| TLC5615IDR   | SOIC         | D               | 8    | 2500 | 340.5       | 336.1      | 25.0        |

## TUBE

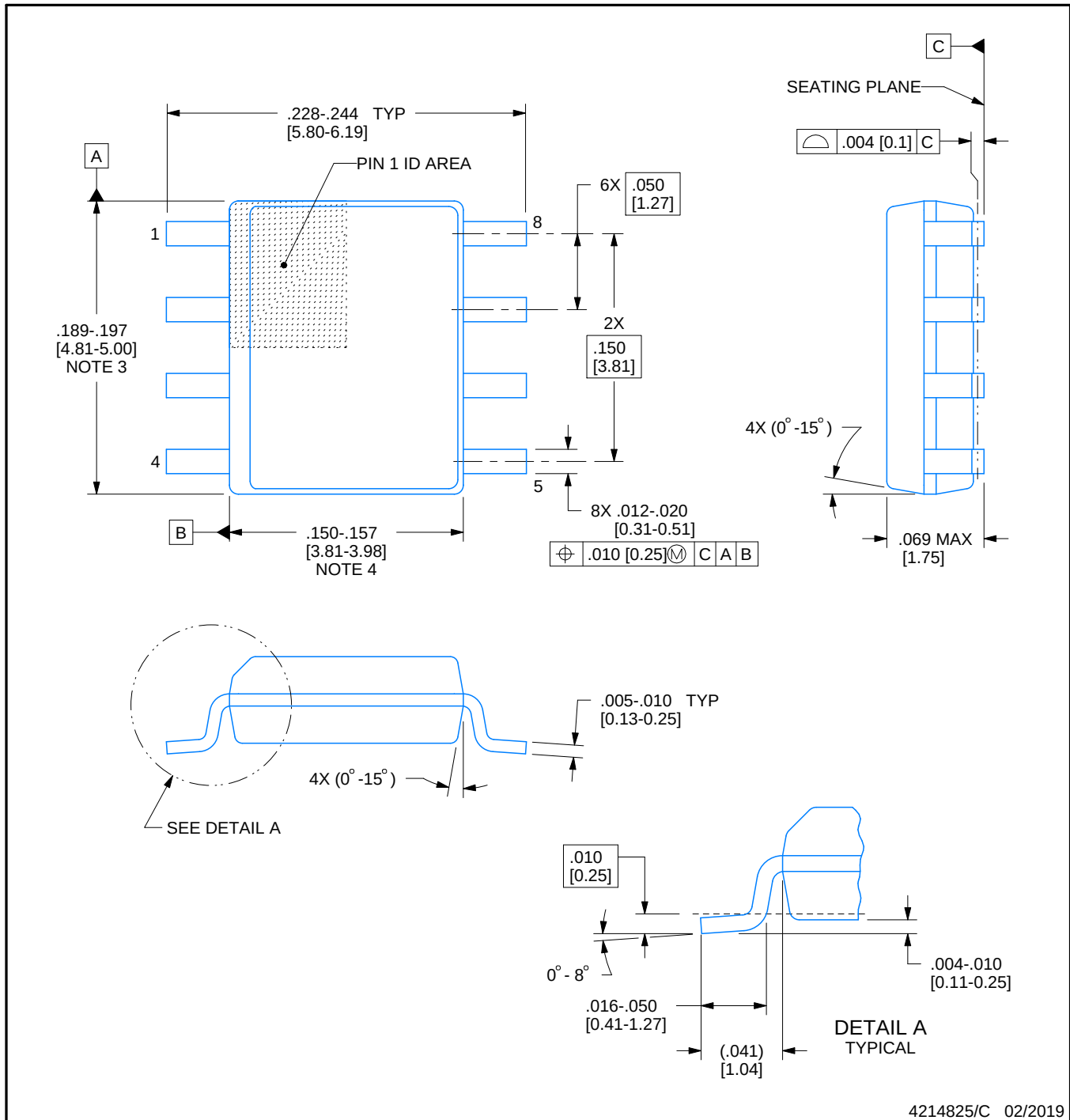


\*All dimensions are nominal

| Device      | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| TLC5615CD   | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLC5615CD   | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLC5615CDG4 | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLC5615CDG4 | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLC5615CDGK | DGK          | VSSOP        | 8    | 80  | 331.47 | 6.55   | 3000   | 2.88   |
| TLC5615CP   | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLC5615ID   | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLC5615ID   | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLC5615IDGK | DGK          | VSSOP        | 8    | 80  | 331.47 | 6.55   | 3000   | 2.88   |
| TLC5615IP   | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |

**D0008A****PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

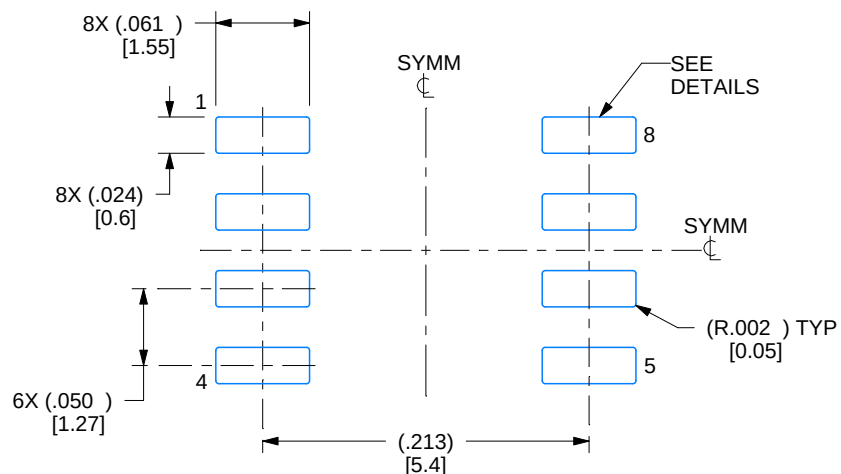
**NOTES:**

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. 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  $.006$  [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

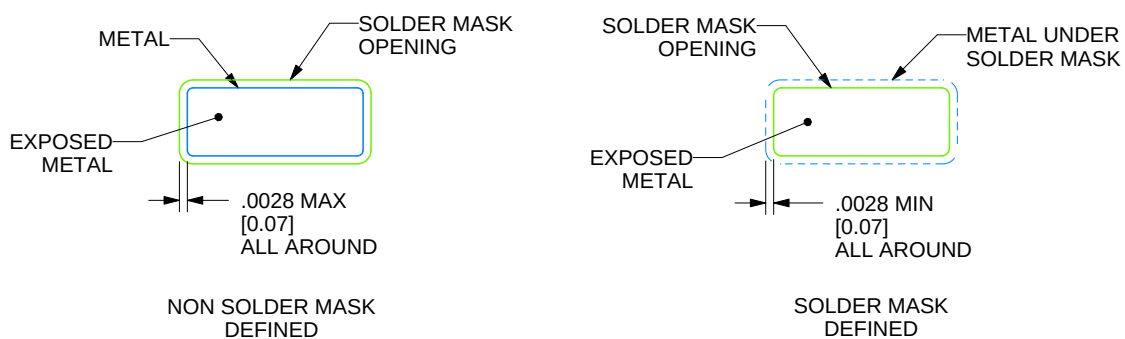
**D0008A**

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



## SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

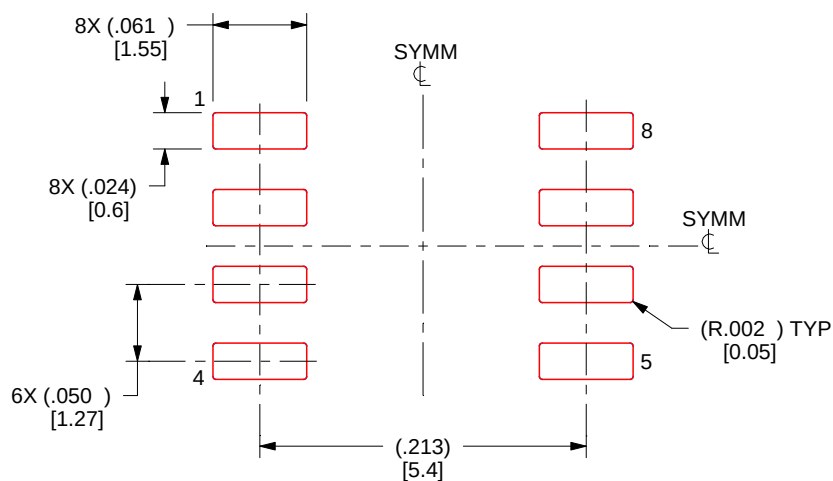
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

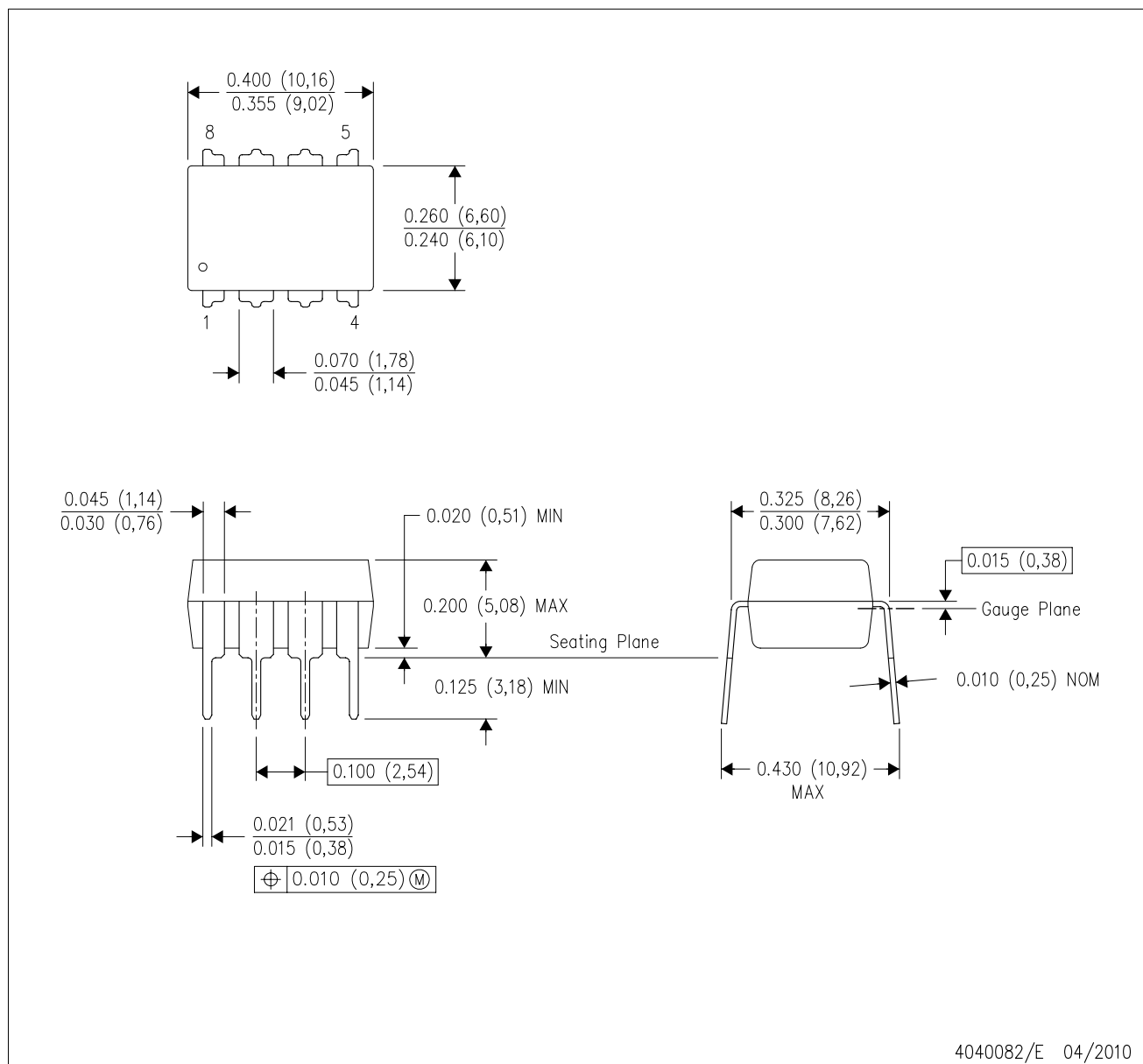
4214825/C 02/2019

NOTES: (continued)

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

P (R-PDIP-T8)

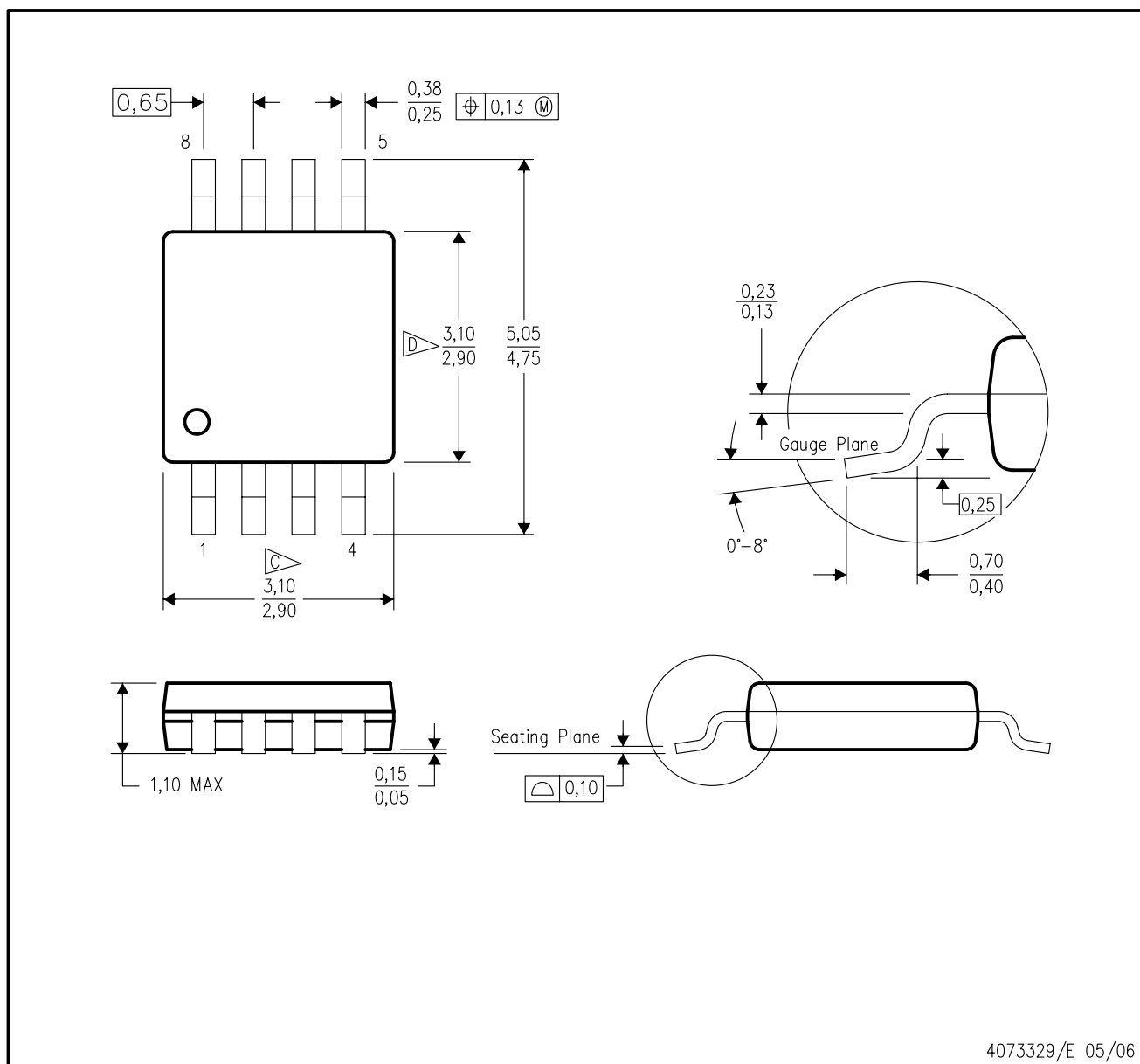
PLASTIC DUAL-IN-LINE PACKAGE



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

DGK (S-PDSO-G8)

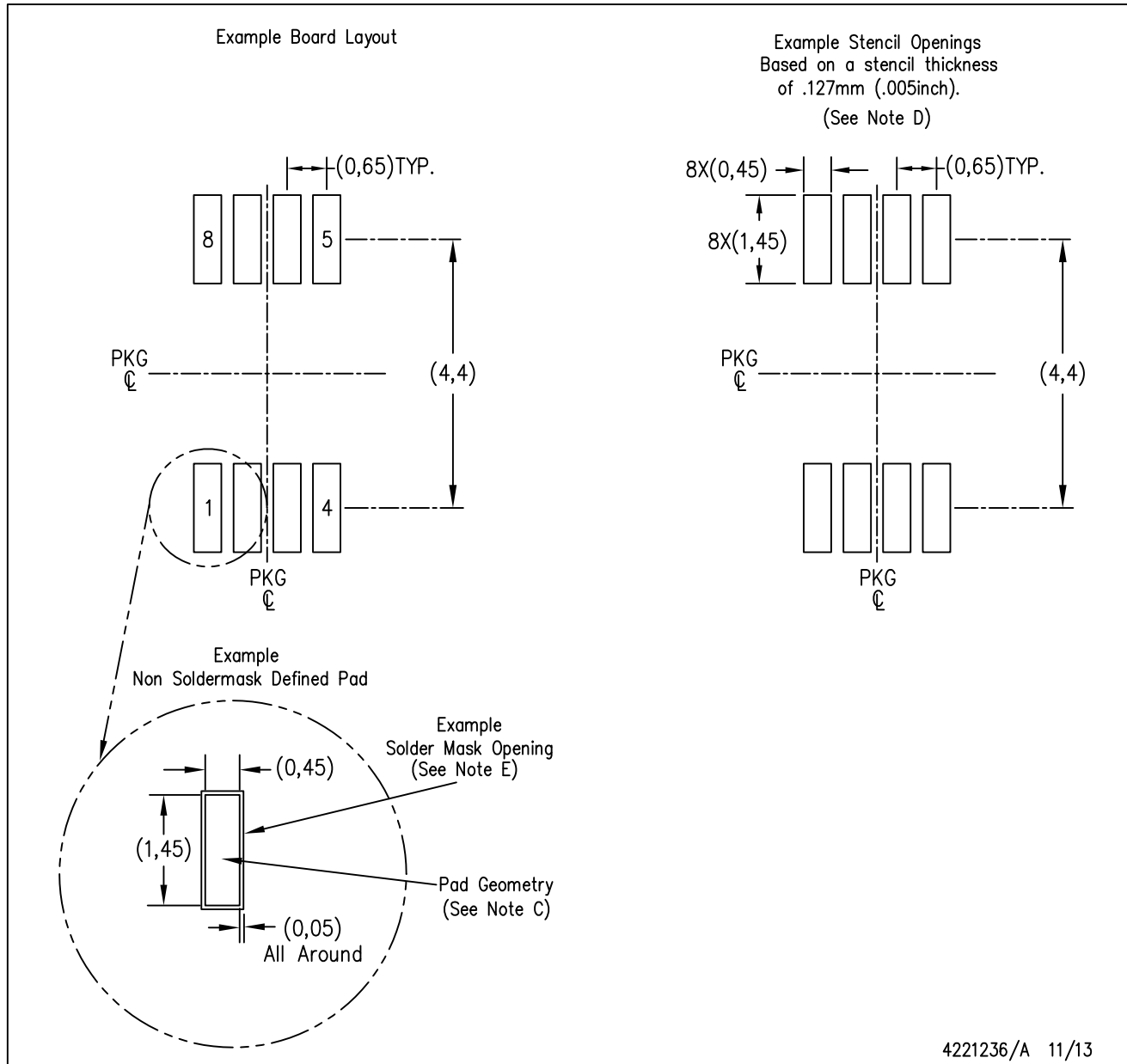
PLASTIC SMALL-OUTLINE PACKAGE



4073329/E 05/06

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - 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 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



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