

# AMC3306M25 High-Precision, $\pm 250$ -mV Input, Reinforced Isolated Delta-Sigma Modulator With Integrated DC/DC Converter

## 1 Features

- 3.3-V or 5-V single supply with integrated DC/DC converter
- $\pm 250$ -mV input voltage range optimized for current measurement using shunt resistors
- Low DC errors:
  - Offset error:  $\pm 50$   $\mu$ V (max)
  - Offset drift:  $\pm 1$   $\mu$ V/ $^{\circ}$ C (max)
  - Gain error:  $\pm 0.2\%$  (max)
  - Gain drift:  $\pm 35$  ppm/ $^{\circ}$ C (max)
- High CMTI: 75 kV/ $\mu$ s (min)
- System-level diagnostic features
- Low EMI: Meets CISPR-11 and CISPR-25 standards
- Safety-related certifications:
  - 6000-V<sub>PEAK</sub> reinforced isolation per DIN VDE V 0884-11
  - 4250-V<sub>RMS</sub> isolation for 1 minute per UL1577
- Fully specified over the extended industrial temperature range:  $-40^{\circ}$ C to  $+125^{\circ}$ C

## 2 Applications

- Compact, isolated shunt-based current sensing in:
  - [Protection relays](#)
  - [Motor drives](#)
  - [Power supplies](#)
  - [Photovoltaic inverters](#)

## 3 Description

The AMC3306M25 is a precision, isolated delta-sigma ( $\Delta\Sigma$ ) modulator, optimized for shunt-based current measurements. The fully integrated, isolated DC/DC converter allows single-supply operation from the low-side of the device, which makes the device a unique solution for space-constrained applications. The reinforced capacitive isolation barrier is certified according to VDE V 0884-11 and UL1577 and supports a working voltage of up to 1.2 kV<sub>RMS</sub>.

The isolation barrier separates parts of the system that operate on different common-mode voltage levels and protects the low-voltage side from hazardous voltages and damage.

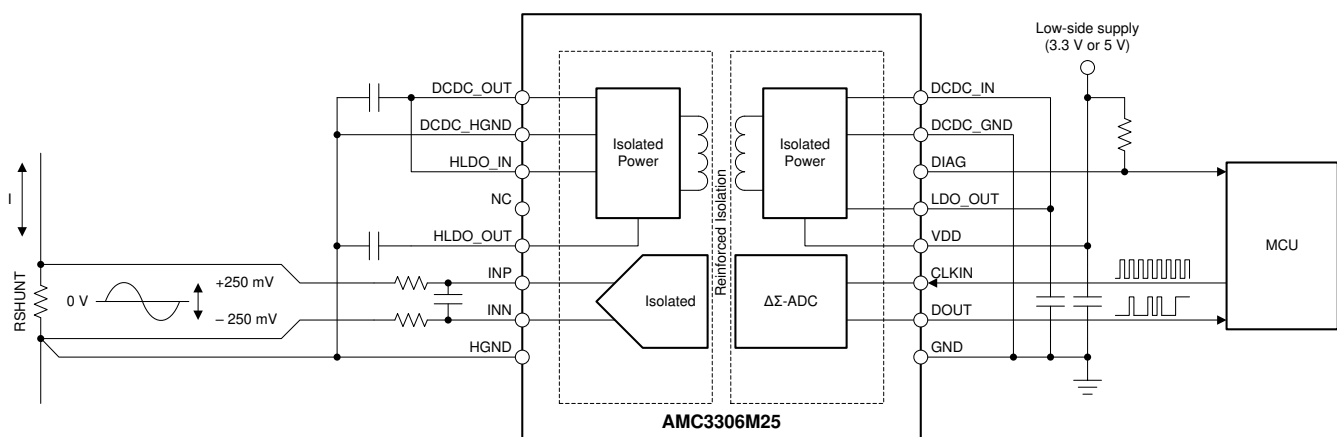
The input of the AMC3306M25 is optimized for direct connection to a low-impedance shunt resistor or other, low-impedance voltage sources with low signal levels. The excellent DC accuracy and low temperature drift support accurate current measurements over the extended industrial temperature range from  $-40^{\circ}$ C to  $+125^{\circ}$ C.

By using a digital filter (such as a sinc<sup>3</sup> filter) to decimate the bitstream, the device can achieve 16 bits of resolution with a dynamic range of 85 dB at a data rate of 78 kSPS.

### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE   | BODY SIZE (NOM)           |
|-------------|-----------|---------------------------|
| AMC3306M25  | SOIC (16) | 10.30 mm $\times$ 7.50 mm |

(1) For all available packages, see the orderable addendum at the end of the datasheet.



Typical Application



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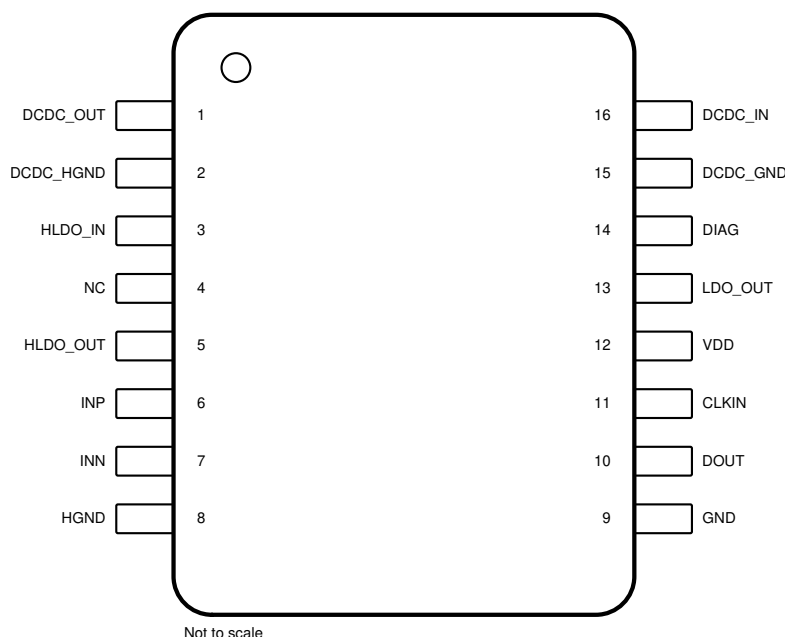
## 4 Revision History

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

| Changes from Revision A (September 2020) to Revision B (April 2021)   | Page |
|---|------|
| • Added <i>Low EMI</i> bullet and changed last bullet of <i>Features</i> section.....   | 1    |
| • Deleted <i>Power delivery systems</i> bullet from <i>Applications</i> section.....  | 1    |
| • Changed <i>Description</i> section.....   | 1    |
| • Changed <i>Absolute Maximum Ratings</i> : changed max for <i>DIAG</i> pin from 5.5 V to 6.5 V.....  | 4    |
| • Changed overvoltage category for rated mains voltage $\leq 600$ V from I-IV to I-III and for rated mains voltage $\leq 1000$ V from I-III to I-II .....   | 6    |
| • Changed <i>Typical Characteristics</i> section. Removed histograms.....   | 12   |
| • Changed <i>Overview</i> section (editorial changes only).....   | 19   |
| • Changed <i>Functional Block Diagram</i> figure.....   | 19   |
| • Changed <i>Analog Input</i> section.....  | 20   |
| • Changed <i>Modulator</i> section.....   | 21   |
| • Changed <i>Isolation Channel Signal Transmission</i> section.....   | 21   |
| • Updated the <i>Isolated DC/DC Converter</i> section. Clarified that the low-side LDO is not intended for driving external loads.....                      | 23   |
| • Added initial paragraph to <i>Application Information</i> section.....  | 25   |
| • Changed <i>Solar Inverter Application</i> section (editorial changes only).....   | 26   |
| • Changed <i>shunt</i> to <i>RSHUNT</i> in <i>Design Requirements</i> table.....  | 26   |
| • Changed <i>Differential Input Filter</i> figure.....  | 27   |
| • Changed referenced family of devices from <i>TMS320F2807x</i> family to <i>C2000</i> or <i>Sitara</i> families in <i>Bitstream Filtering</i> section..... | 27   |
| • Changed <i>What To Do and What Not To Do</i> section.....   | 28   |
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| • Changed <i>Recommended Layout of the AMC3306M25</i> figure.....   | 30   |

| Changes from Revision Original (May 2020) to Revision A (September 2020)    | Page |
|---|------|
| • Changed document status from advanced information to production data..... | 1    |

## 5 Pin Configuration and Functions



**Figure 5-1. DWE Package, 16-Pin SOIC, Top View**

**Table 5-1. Pin Functions**

| PIN<br>NO. | NAME      | TYPE                    | DESCRIPTION   |
|------------|-----------|-------------------------|---|
|            |           |                         |   |
| 1          | DCDC_OUT  | Power                   | High-side output of the DC/DC converter; connect this pin to the HLDO_IN pin. <sup>(1)</sup>  |
| 2          | DCDC_HGND | High-side Power Ground  | High-side ground reference for the DC/DC converter; connect this pin to the HGND pin.   |
| 3          | HLDO_IN   | Power                   | Input of the high-side LDO; connect this pin to the DCDC_OUT pin. <sup>(1)</sup>  |
| 4          | NC        | —                       | No internal connection. Connect this pin to the high-side ground or leave unconnected (floating).   |
| 5          | HLDO_OUT  | Power                   | Output of the high-side LDO. <sup>(1)</sup>   |
| 6          | INP       | Analog Input            | Noninverting analog input. Either INP or INN must have a DC current path to HGND to define the common-mode input voltage. <sup>(2)</sup>                          |
| 7          | INN       | Analog Input            | Inverting analog input. Either INP or INN must have a DC current path to HGND to define the common-mode input voltage. <sup>(2)</sup>                             |
| 8          | HGND      | High-side Signal Ground | High-side analog signal ground; connect this pin to the DCDC_HGND pin.  |
| 9          | GND       | Low-side Signal Ground  | Low-side analog signal ground; connect this pin to the DCDC_GND pin.  |
| 10         | DOUT      | Digital Output          | Modulator data output.  |
| 11         | CLKIN     | Digital Input           | Modulator clock input with internal pulldown resistor (typical value: 1.5 MΩ).  |
| 12         | VDD       | Low-side Power          | Low-side power supply. <sup>(1)</sup>   |
| 13         | LDO_OUT   | Power                   | Output of the low-side LDO; connect this pin to the DCDC_IN pin. The output of the LDO must not be loaded by external circuitry. <sup>(1)</sup>                   |
| 14         | DIAG      | Digital Output          | Active-low, open-drain status indicator output; connect this pin to the pullup supply (for example, VDD) using a resistor or leave this pin floating if not used. |
| 15         | DCDC_GND  | Low-side Power Ground   | Low-side ground reference for the DC/DC converter; connect this pin to the GND pin.   |
| 16         | DCDC_IN   | Power                   | Low-side input of the DC/DC converter; connect this pin to the LDO_OUT pin. <sup>(1)</sup>  |

(1) See the [Power Supply Recommendations](#) section for power-supply decoupling recommendations.

(2) See the [Layout](#) section for details.

## 6 Specifications

### 6.1 Absolute Maximum Ratings

see <sup>(1)</sup>

|                        |  | MIN       | MAX                   | UNIT |
|------------------------|--|-----------|-----------------------|------|
| Power-supply voltage   | VDD to GND                                   | −0.3      | 6.5                   | V    |
| Analog input voltage   | INP, INN                                     | HGND − 6  | $V_{HLDO\_OUT} + 0.5$ | V    |
| Digital input voltage  | CLKIN  | GND − 0.5 | VDD + 0.5             | V    |
| Digital output voltage | DOUT   | GND − 0.5 | VDD + 0.5             | V    |
|                        | DIAG   | GND − 0.5 | 6.5                   |      |
| Input current          | Continuous, any pin except power-supply pins | −10       | 10                    | mA   |
| Temperature            | Junction, $T_J$                              |           | 150                   | °C   |
|                        | Storage, $T_{stg}$                           | −65       | 150                   |      |

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

### 6.2 ESD Ratings

|             |                         |  | VALUE | UNIT |
|-------------|-------------------------|--|-------|------|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±2000 | V    |
|             |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±1000 |      |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.  
 (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

|                          |   |  | MIN   | NOM  | MAX             | UNIT |
|--------------------------|---|--|-------|------|-----------------|------|
| <b>POWER SUPPLY</b>      |   |  |       |      |                 |      |
| VDD                      | Low-side power supply                             | VDD to GND                                       | 3     | 3.3  | 5.5             | V    |
| <b>ANALOG INPUT</b>      |   |  |       |      |                 |      |
| $V_{Clipping}$           | Differential input voltage before clipping output | $V_{IN} = V_{INP} - V_{INN}$                     |       | ±320 |                 | mV   |
| $V_{FSR}$                | Specified linear differential full-scale voltage  | $V_{IN} = V_{INP} - V_{INN}$                     | −250  |      | 250             | mV   |
|                          | Absolute common-mode input voltage <sup>(1)</sup> | $(V_{INP} + V_{INN}) / 2$ to HGND                | −2    |      | $V_{HLDO\_OUT}$ | V    |
| $V_{CM}$                 | Operating common-mode input voltage               | $(V_{INP} + V_{INN}) / 2$ to HGND                | −0.16 |      | 0.9             | V    |
| <b>DIGITAL I/O</b>       |   |  |       |      |                 |      |
| $V_{IO}$                 | Digital input / output voltage                    |  | 0     |      | VDD             | V    |
| $f_{CLKIN}$              | Input clock frequency                             |  | 5     | 20   | 21              | MHz  |
|                          | Input clock duty cycle                            | $5\text{ MHz} \leq f_{CLKIN} \leq 21\text{ MHz}$ | 40%   | 50%  | 60%             |      |
| <b>TEMPERATURE RANGE</b> |   |  |       |      |                 |      |
| $T_A$                    | Specified ambient temperature                     |  | −40   |      | 125             | °C   |

- (1) Steady-state voltage supported by the device in case of a system failure. See specified common-mode input voltage  $V_{CM}$  for normal operation. Observe analog input voltage range as specified in the *Absolute Maximum Ratings* table.

## 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |  | AMC3306M25 | UNIT |
|-------------------------------|--|------------|------|
|                               |  | DWE (SOIC) |      |
|                               |  | 16 PINS    |      |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 73.5       | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 31         | °C/W |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 44         | °C/W |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 16.7       | °C/W |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 42.8       | °C/W |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | n/a        | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.5 Power Ratings

| PARAMETER |                           | TEST CONDITIONS | VALUE | UNIT |
|-----------|---------------------------|-----------------|-------|------|
| $P_D$     | Maximum power dissipation | VDD = 5.5 V     | 231   | mW   |
|           |                           | VDD = 3.6 V     | 151   |      |

## 6.6 Insulation Specifications

over operating ambient temperature range (unless otherwise noted)

| PARAMETER   |   | TEST CONDITIONS  | VALUE              | UNIT             |
|---|---|--|--------------------|------------------|
| GENERAL   |   |  |                    |                  |
| CLR   | External clearance <sup>(1)</sup>                     | Shortest pin-to-pin distance through air   | ≥ 8                | mm               |
| CPG   | External creepage <sup>(1)</sup>                      | Shortest pin-to-pin distance across the package surface  | ≥ 8                | mm               |
| DTI   | Distance through the insulation                       | Minimum internal gap (internal clearance - capacitive signal isolation)  | ≥ 21               | μm               |
|   |   | Minimum internal gap (internal clearance - transformer power isolation)  | ≥ 120              |                  |
| CTI   | Comparative tracking index                            | DIN EN 60112 (VDE 0303-11); IEC 60112  | ≥ 600              | V                |
|   | Material group  | According to IEC 60664-1   | I                  |                  |
|   | Overvoltage category per IEC 60664-1                  | Rated mains voltage ≤ 600 V <sub>RMS</sub>   | I-III              |                  |
|   |   | Rated mains voltage ≤ 1000 V <sub>RMS</sub>  | I-II               |                  |
| DIN VDE V 0884-11 (VDE V 0884-11): 2017-01 <sup>(2)</sup> |   |  |                    |                  |
| V <sub>IORM</sub>   | Maximum repetitive peak isolation voltage             | At AC voltage (bipolar)  | 1700               | V <sub>PK</sub>  |
| V <sub>IOWM</sub>   | Maximum-rated isolation working voltage               | At AC voltage (sine wave)  | 1200               | V <sub>RMS</sub> |
|   |   | At DC voltage  | 1700               | V <sub>DC</sub>  |
| V <sub>IOTM</sub>   | Maximum transient isolation voltage                   | V <sub>TEST</sub> = V <sub>IOTM</sub> , t = 60 s (qualification test)  | 6000               | V <sub>PK</sub>  |
|   |   | V <sub>TEST</sub> = 1.2 × V <sub>IOTM</sub> , t = 1 s (100% production test)   | 7200               | V <sub>PK</sub>  |
| V <sub>IOSM</sub>   | Maximum surge isolation voltage <sup>(3)</sup>        | Test method per IEC 60065, 1.2/50-μs waveform, V <sub>TEST</sub> = 1.6 × V <sub>IOSM</sub> = 10000 V <sub>PK</sub> (qualification)   | 6250               | V <sub>PK</sub>  |
| q <sub>pd</sub>   | Apparent charge <sup>(4)</sup>                        | Method a, after input/output safety test subgroup 2 / 3, V <sub>ini</sub> = V <sub>IOTM</sub> , t <sub>ini</sub> = 60 s, V <sub>pd(m)</sub> = 1.2 × V <sub>IORM</sub> , t <sub>m</sub> = 10 s                      | ≤ 5                | pC               |
|   |   | Method a, after environmental tests subgroup 1, V <sub>ini</sub> = V <sub>IOTM</sub> , t <sub>ini</sub> = 60 s, V <sub>pd(m)</sub> = 1.6 × V <sub>IORM</sub> , t <sub>m</sub> = 10 s                               | ≤ 5                |                  |
|   |   | Method b1, at routine test (100% production) and preconditioning (type test), V <sub>ini</sub> = V <sub>IOTM</sub> , t <sub>ini</sub> = 1 s, V <sub>pd(m)</sub> = 1.875 × V <sub>IORM</sub> , t <sub>m</sub> = 1 s | ≤ 5                |                  |
| C <sub>IO</sub>   | Barrier capacitance, input to output <sup>(5)</sup>   | V <sub>IO</sub> = 0.5 V <sub>PP</sub> at 1 MHz   | ~3.5               | pF               |
| R <sub>IO</sub>   | Insulation resistance, input to output <sup>(5)</sup> | V <sub>IO</sub> = 500 V at T <sub>A</sub> = 25°C   | > 10 <sup>12</sup> | Ω                |
|   |   | V <sub>IO</sub> = 500 V at 100°C ≤ T <sub>A</sub> ≤ 125°C  | > 10 <sup>11</sup> |                  |
|   |   | V <sub>IO</sub> = 500 V at T <sub>S</sub> = 150°C  | > 10 <sup>9</sup>  |                  |
|   | Pollution degree                                      |  | 2                  |                  |
|   | Climatic category                                     |  | 40/125/21          |                  |
| UL1577  |   |  |                    |                  |
| V <sub>ISO</sub>  | Withstand isolation voltage                           | V <sub>TEST</sub> = V <sub>ISO</sub> = 4250 V <sub>RMS</sub> or 6000 V <sub>DC</sub> , t = 60 s (qualification), V <sub>TEST</sub> = 1.2 × V <sub>ISO</sub> , t = 1 s (100% production test)                       | 4250               | V <sub>RMS</sub> |

- (1) Apply creepage and clearance requirements according to the specific equipment isolation standards of an application. Care must be taken to maintain the creepage and clearance distance of a board design to ensure that the mounting pads of the isolator on the printed circuit board (PCB) do not reduce this distance. Creepage and clearance on a PCB become equal in certain cases. Techniques such as inserting grooves, ribs, or both on a PCB are used to help increase these specifications.
- (2) This coupler is suitable for *safe electrical insulation* only within the safety ratings. Compliance with the safety ratings must be ensured by means of suitable protective circuits.
- (3) Testing is carried out in air or oil to determine the intrinsic surge immunity of the isolation barrier.
- (4) Apparent charge is electrical discharge caused by a partial discharge (pd).
- (5) All pins on each side of the barrier are tied together, creating a two-pin device.

## 6.7 Safety-Related Certifications

| VDE  | UL   |
|--|--|
| Certified according to DIN VDE V 0884-11 (VDE V 0884-11): 2017-01, DIN EN 60950-1 (VDE 0805 Teil 1): 2014-08, and DIN EN 60065 (VDE 0860): 2005-11 | Recognized under 1577 component recognition and CSA component acceptance NO 5 programs |
| Reinforced insulation  | Single protection  |
| Certificate number: 40040142   | File number: E181974   |

## 6.8 Safety Limiting Values

Safety limiting<sup>(1)</sup> intends to minimize potential damage to the isolation barrier upon failure of input or output circuitry. A failure of the I/O can allow low resistance to ground or the supply and, without current limiting, dissipate sufficient power to over-heat the die and damage the isolation barrier potentially leading to secondary system failures.

| PARAMETER      |   | TEST CONDITIONS   | MIN | TYP | MAX  | UNIT |
|----------------|---|---|-----|-----|------|------|
| I <sub>S</sub> | Safety input, output, or supply current | R <sub>θJA</sub> = 73.5°C/W, VDD = 5.5 V, T <sub>J</sub> = 150°C, T <sub>A</sub> = 25°C |     |     | 309  | mA   |
|                |   | R <sub>θJA</sub> = 73.5°C/W, VDD = 3.6 V, T <sub>J</sub> = 150°C, T <sub>A</sub> = 25°C |     |     | 472  |      |
| P <sub>S</sub> | Safety input, output, or total power    | R <sub>θJA</sub> = 73.5°C/W, T <sub>J</sub> = 150°C, T <sub>A</sub> = 25°C              |     |     | 1700 | mW   |
| T <sub>S</sub> | Maximum safety temperature              |   |     |     | 150  | °C   |

- (1) The maximum safety temperature, T<sub>S</sub>, has the same value as the maximum junction temperature, T<sub>J</sub>, specified for the device. The I<sub>S</sub> and P<sub>S</sub> parameters represent the safety current and safety power, respectively. Do not exceed the maximum limits of I<sub>S</sub> and P<sub>S</sub>. These limits vary with the ambient temperature, T<sub>A</sub>.

The junction-to-air thermal resistance, R<sub>θJA</sub>, in the [Thermal Information](#) table is that of a device installed on a high-K test board for leaded surface-mount packages. Use these equations to calculate the value for each parameter:

$T_J = T_A + R_{\theta JA} \times P$ , where P is the power dissipated in the device.

$T_{J(max)} = T_S = T_A + R_{\theta JA} \times P_S$ , where T<sub>J(max)</sub> is the maximum junction temperature.

$P_S = I_S \times VDD_{max}$ , where VDD<sub>max</sub> is the maximum low-side voltage.

## 6.9 Electrical Characteristics

all minimum and maximum specifications are at  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ ,  $V_{DD} = 3.0\text{ V}$  to  $5.5\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = 0\text{ V}$ , and sinc<sup>3</sup> filter with  $OSR = 256$  (unless otherwise noted); typical values are at  $T_A = 25^\circ\text{C}$ ,  $CLKIN = 20\text{ MHz}$ ,  $V_{DD} = 3.3\text{ V}$

| PARAMETER         |   | TEST CONDITIONS  | MIN       | TYP     | MAX       | UNIT   |
|-------------------|---|--|-----------|---------|-----------|--------|
| ANALOG INPUT      |   |  |           |         |           |        |
| R <sub>IN</sub>   | Single-ended input resistance             | INN = HGND   | 19        |         |           | kΩ     |
| R <sub>IND</sub>  | Differential input resistance             |  | 22        |         |           | kΩ     |
| I <sub>IB</sub>   | Input bias current                        | INP = INN = HGND;<br>I <sub>IB</sub> = (I <sub>IBP</sub> + I <sub>IBN</sub> ) / 2  | −41       | −30     | −24       | μA     |
| I <sub>IO</sub>   | Input offset current <sup>(1)</sup>       | I <sub>IO</sub> = I <sub>IBP</sub> − I <sub>IBN</sub> ; INP = INN = HGND   | ±10       |         |           | nA     |
| C <sub>IN</sub>   | Single-ended input capacitance            | INN = HGND, f <sub>IN</sub> = 310 kHz  | 2         |         |           | pF     |
| C <sub>IND</sub>  | Differential input capacitance            | f <sub>IN</sub> = 310 kHz  | 1         |         |           | pF     |
| ACCURACY          |   |  |           |         |           |        |
| E <sub>O</sub>    | Offset error <sup>(1)</sup>               | INN = INP = HGND, T <sub>A</sub> = 25°C  | −50       | ±10     | 50        | μV     |
| TCE <sub>O</sub>  | Offset error thermal drift <sup>(4)</sup> | INN = INP = HGND   | −1        |         | 1         | μV/°C  |
| E <sub>G</sub>    | Gain error                                | T <sub>A</sub> = 25°C  | −0.2%     | ±0.005% | 0.2%      | %      |
| TCE <sub>G</sub>  | Gain error drift <sup>(5)</sup>           |  | −35       |         | 35        | ppm/°C |
| DNL               | Differential nonlinearity                 | Resolution: 16 bits  | −0.99     |         | 0.99      | LSB    |
| INL               | Integral nonlinearity                     | Resolution: 16 bits  | −4        | ±1      | 4         | LSB    |
| SNR               | Signal-to-noise ratio                     | f <sub>IN</sub> = 1 kHz  | 81        | 83      |           | dB     |
| SINAD             | Signal-to-noise + distortion              | f <sub>IN</sub> = 1 kHz  | 79        | 82.5    |           | dB     |
| THD               | Total harmonic distortion <sup>(3)</sup>  | 5 MHz ≤ f <sub>CLKIN</sub> ≤ 21 MHz, f <sub>IN</sub> = 1 kHz   |           | −96     | −88       | dB     |
| SFDR              | Spurious-free dynamic range               | f <sub>IN</sub> = 1 kHz  | 88        | 97      |           | dB     |
| CMRR              | Common-mode rejection ratio               | f <sub>IN</sub> = 0 Hz, V <sub>CM min</sub> ≤ V <sub>IN</sub> ≤ V <sub>CM max</sub>  |           | −95     |           | dB     |
|                   |   | f <sub>IN</sub> = 10 kHz, V <sub>CM min</sub> ≤ V <sub>IN</sub> ≤ V <sub>CM max</sub> , V <sub>INP</sub> = V <sub>INN</sub> = 500 mV <sub>PP</sub> |           | −84     |           |        |
| PSRR              | Power-supply rejection ratio              | VDD from 3.0 V to 5.5 V, at DC   |           | −120    |           | dB     |
|                   |   | INP = INN = HGND, VDD from 3.0 V to 5.5 V, 10 kHz, 100 mV ripple   |           | −120    |           |        |
| DIGITAL I/O       |   |  |           |         |           |        |
| I <sub>IN</sub>   | Input leakage current                     | GND ≤ V <sub>IN</sub> ≤ VDD  | 0         |         | 7         | μA     |
| C <sub>IN</sub>   | Input capacitance                         |  |           | 4       |           | pF     |
| V <sub>IH</sub>   | High-level input voltage                  |  | 0.7 × VDD |         | VDD + 0.3 | V      |
| V <sub>IL</sub>   | Low-level input voltage                   |  | −0.3      |         | 0.3 × VDD | V      |
| C <sub>LOAD</sub> | Output load capacitance                   |  |           | 15      | 30        | pF     |
| V <sub>OH</sub>   | High-level output voltage                 | I <sub>OH</sub> = −20 μA   | VDD − 0.1 |         |           | V      |
|                   |   | I <sub>OH</sub> = −4 mA  | VDD − 0.4 |         |           |        |
| V <sub>OL</sub>   | Low-level output voltage                  | I <sub>OL</sub> = 20 μA  |           |         | 0.1       | V      |
|                   |   | I <sub>OL</sub> = 4 mA   |           |         | 0.4       |        |
| CMTI              | Common-mode transient immunity            |  | 75        | 135     |           | kV/μs  |

## 6.9 Electrical Characteristics (continued)

all minimum and maximum specifications are at  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ ,  $V_{DD} = 3.0\text{ V}$  to  $5.5\text{ V}$ ,  $\text{INP} = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $\text{INN} = 0\text{ V}$ , and sinc<sup>3</sup> filter with  $\text{OSR} = 256$  (unless otherwise noted); typical values are at  $T_A = 25^\circ\text{C}$ ,  $\text{CLKIN} = 20\text{ MHz}$ ,  $V_{DD} = 3.3\text{ V}$

| PARAMETER             |   | TEST CONDITIONS  | MIN | TYP  | MAX  | UNIT |
|-----------------------|---|--|-----|------|------|------|
| <b>POWER SUPPLY</b>   |   |  |     |      |      |      |
| IDD                   | Low-side supply current                                       | no external load on HLDO   |     | 26   | 40   | mA   |
|                       |   | 1 mA external load on HLDO   |     | 28   | 42   |      |
| V <sub>DCDC_OUT</sub> | DC/DC output voltage  | DCDC_OUT to HGND   | 3.1 | 3.5  | 4.65 | V    |
| V <sub>DCDCUV</sub>   | DC/DC output undervoltage detection threshold voltage         | V <sub>DCDC_OUT</sub> falling  | 2.1 | 2.25 |      | V    |
| V <sub>HLDO_OUT</sub> | High-side LDO output voltage                                  | HLDO_OUT to HGND, up to 1 mA external load <sup>(2)</sup>  | 3   | 3.2  | 3.4  | V    |
| V <sub>HLDOUV</sub>   | High-side LDO output undervoltage detection threshold voltage | V <sub>HLDO_OUT</sub> falling  | 2.4 | 2.6  |      | V    |
| I <sub>H</sub>        | High-side supply current for auxiliary circuitry              | Load connected from HLDO_OUT to HGND; non-switching; $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ <sup>(2)</sup> |     |      | 1    | mA   |
| t <sub>START</sub>    | Device startup time   | VDD step to 3.0 V to bitstream valid   |     | 0.9  | 1.4  | ms   |

- (1) The typical value includes one sigma statistical variation at nominal operating conditions.
- (2) High-side LDO supports full external load (I<sub>H</sub>) only up to  $T_A = 85^\circ\text{C}$ . See the *Isolated DC/DC Converter* section for more details.
- (3) THD is the ratio of the rms sum of the amplitudes of first five higher harmonics to the amplitude of the fundamental.
- (4) Offset error temperature drift is calculated using the box method, as described by the following equation:  

$$TCE_O = (Value_{MAX} - Value_{MIN}) / TempRange$$
- (5) Gain error temperature drift is calculated using the box method, as described by the following equation:  

$$TCE_G (ppm) = (Value_{MAX} - Value_{MIN}) / (Value_{(T=25^\circ\text{C})} \times TempRange) \times 10^6$$

## 6.10 Switching Characteristics

| PARAMETER | TEST CONDITIONS                           | MIN   | TYP | MAX | UNIT |
|-----------|---|---|-----|-----|------|
| $t_H$     | DOUT hold time after rising edge of CLKIN | $C_{LOAD} = 15 \text{ pF}$  | 3.5 |     | ns   |
| $t_D$     | Rising edge of CLKIN to DOUT valid delay  | $C_{LOAD} = 15 \text{ pF}$ ; CLKIN 50% to DOUT 10% / 90%                                |     | 15  | ns   |
| $t_r$     | DOUT rise time                            | 10% to 90%, $3.0 \text{ V} \leq V_{DD} \leq 3.6 \text{ V}$ , $C_{LOAD} = 15 \text{ pF}$ | 2.5 | 6   | ns   |
|           |   | 10% to 90%, $4.5 \text{ V} \leq V_{DD} \leq 5.5 \text{ V}$ , $C_{LOAD} = 15 \text{ pF}$ | 3.2 | 6   |      |
| $t_f$     | DOUT fall time                            | 10% to 90%, $3.0 \text{ V} \leq V_{DD} \leq 3.6 \text{ V}$ , $C_{LOAD} = 15 \text{ pF}$ | 2.2 | 6   | ns   |
|           |   | 10% to 90%, $4.5 \text{ V} \leq V_{DD} \leq 5.5 \text{ V}$ , $C_{LOAD} = 15 \text{ pF}$ | 2.9 | 6   |      |

## 6.11 Timing Diagrams

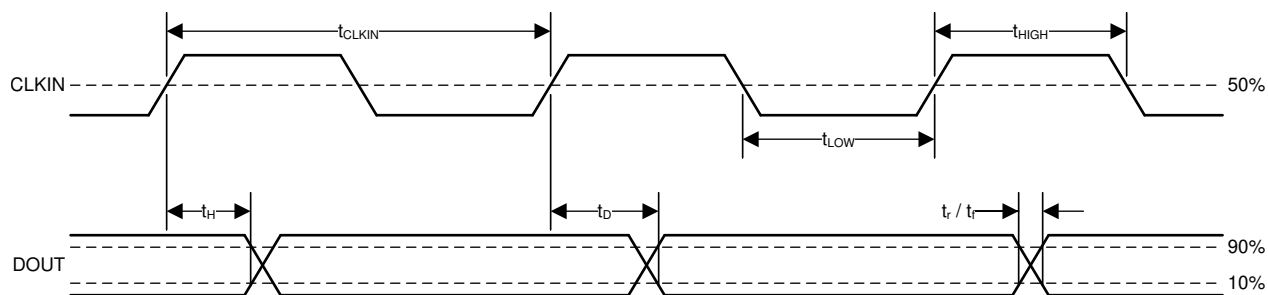


Figure 6-1. Digital Interface Timing

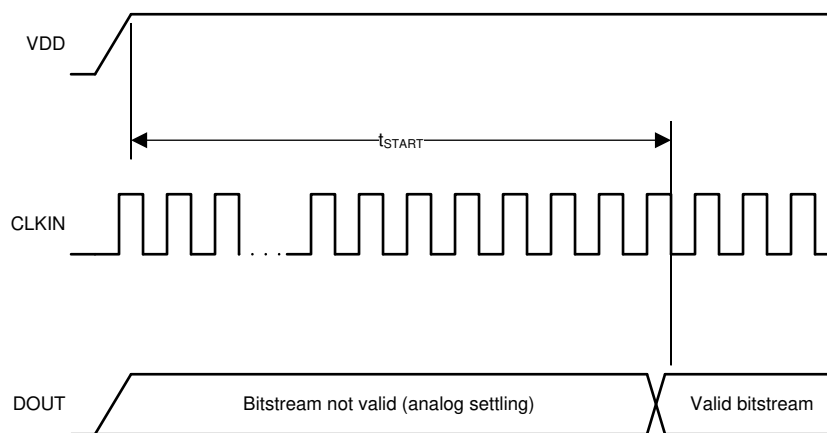
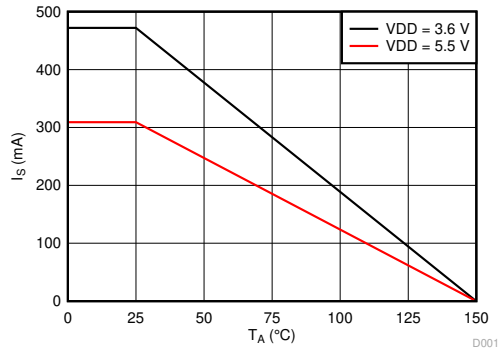
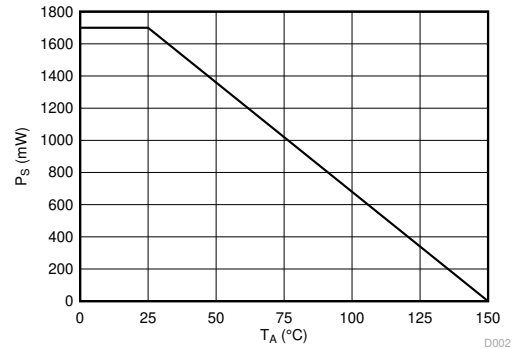


Figure 6-2. Device Startup Timing

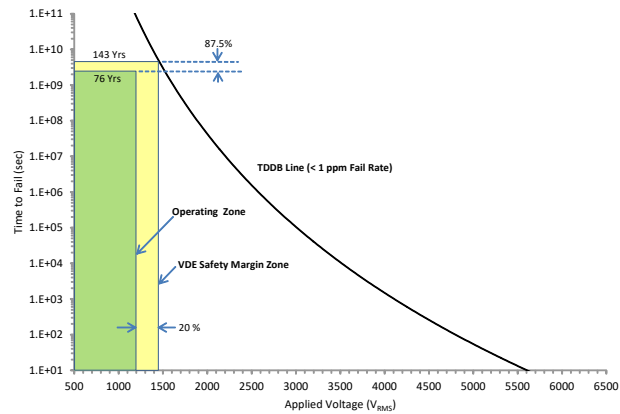
## 6.12 Insulation Characteristics Curves



**Figure 6-3. Thermal Derating Curve for Safety-Limiting Current Per VDE**



**Figure 6-4. Thermal Derating Curve for Safety-Limiting Power Per VDE**



$T_A$  up to 150°C, stress-voltage frequency = 60 Hz, isolation working voltage = 1200  $V_{RMS}$ , operating lifetime = 76 years

**Figure 6-5. Reinforced Isolation Capacitor Lifetime Projection**

## 6.13 Typical Characteristics

at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = HGND$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and sinc<sup>3</sup> filter with OSR = 256, 16-bit resolution (unless otherwise noted)

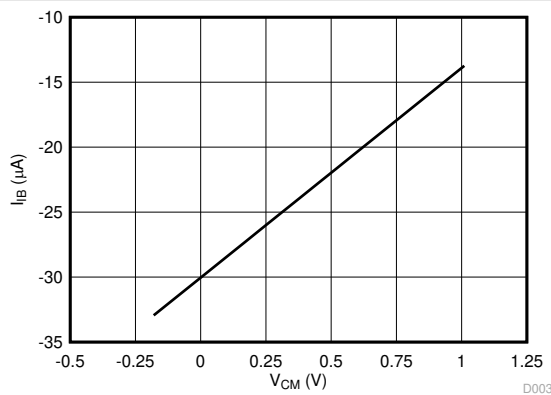


Figure 6-6. Input Bias Current vs Common-Mode Input Voltage

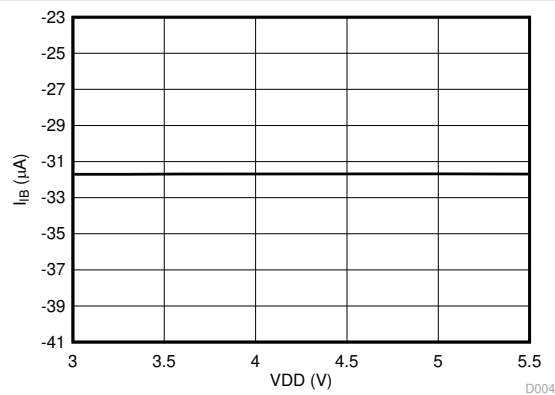


Figure 6-7. Input Bias Current vs Supply Voltage

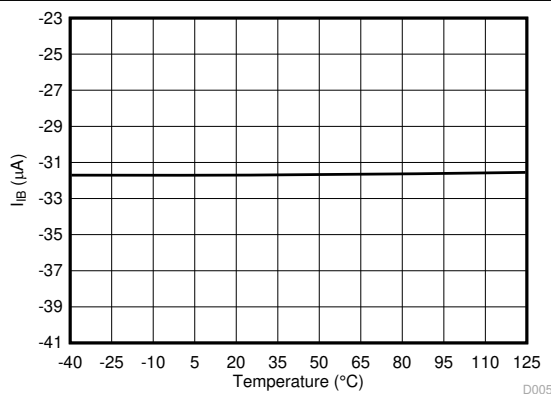


Figure 6-8. Input Bias Current vs Temperature

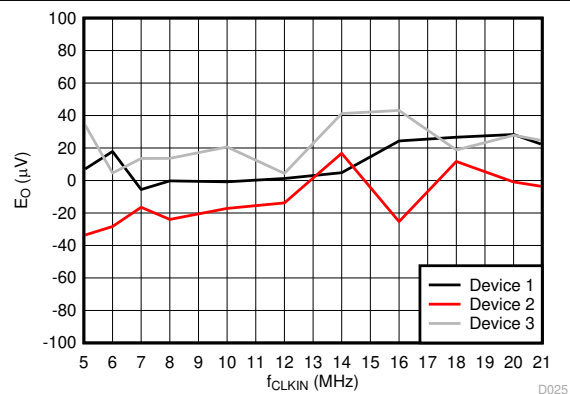


Figure 6-9. Offset Error Histogram

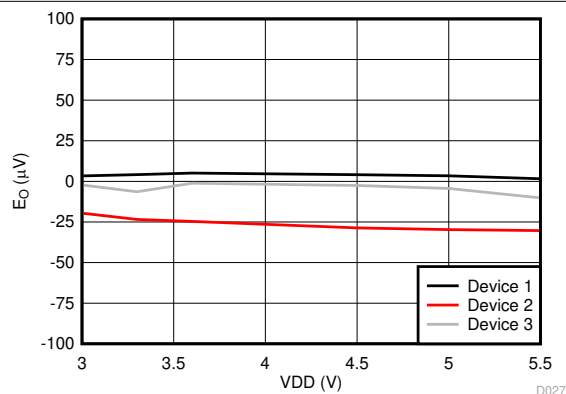


Figure 6-10. Offset Error vs Supply Voltage

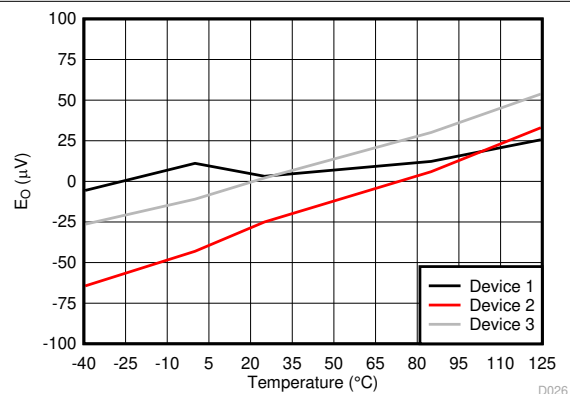
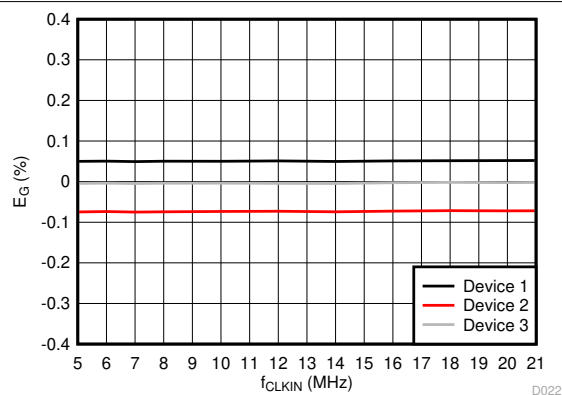


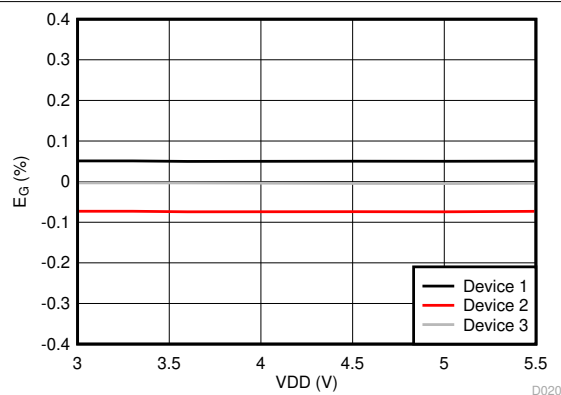
Figure 6-11. Offset Error vs Temperature

## 6.13 Typical Characteristics (continued)

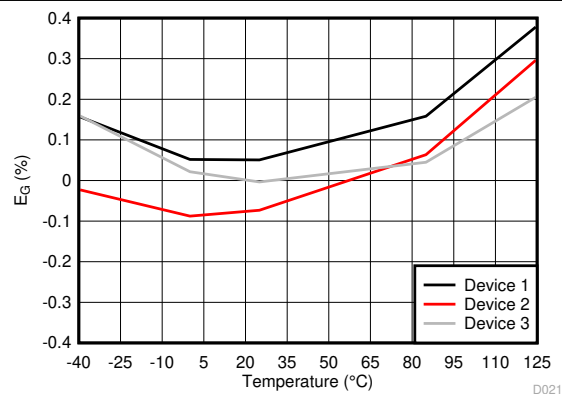
at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = \text{HGND}$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and sinc<sup>3</sup> filter with OSR = 256, 16-bit resolution (unless otherwise noted)



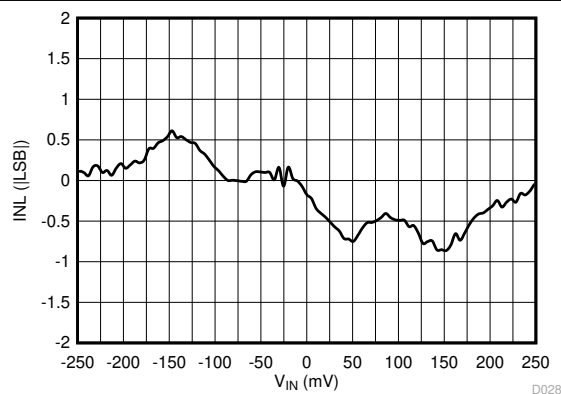
**Figure 6-12. Gain Error vs Input Clock Frequency**



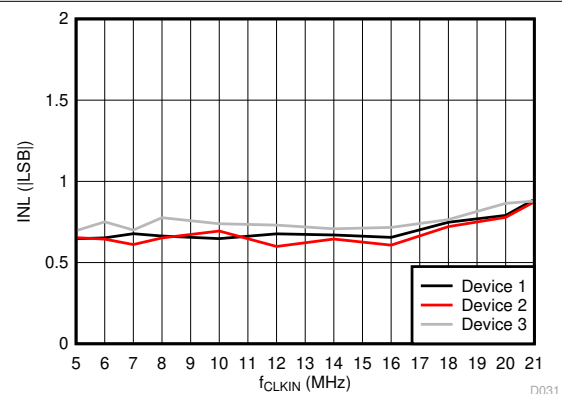
**Figure 6-13. Gain Error vs Supply Voltage**



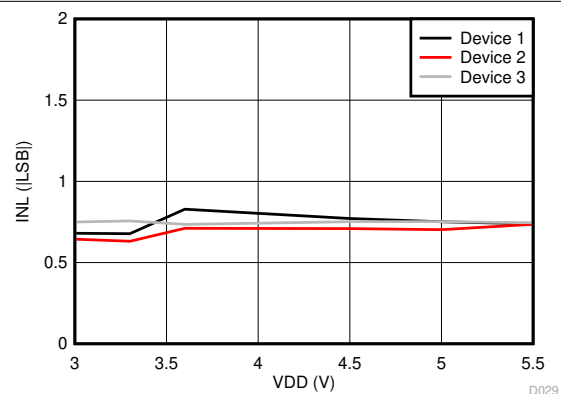
**Figure 6-14. Gain Error vs Temperature**



**Figure 6-15. Integral Nonlinearity vs Input Voltage**



**Figure 6-16. Integral Nonlinearity vs Input Clock Frequency**



**Figure 6-17. Integral Nonlinearity vs Supply Voltage**

## 6.13 Typical Characteristics (continued)

at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = \text{HGND}$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and sinc<sup>3</sup> filter with  $\text{OSR} = 256$ , 16-bit resolution (unless otherwise noted)

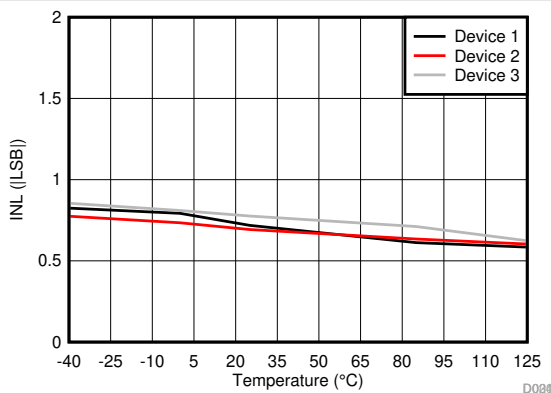


Figure 6-18. Integral Nonlinearity vs Temperature

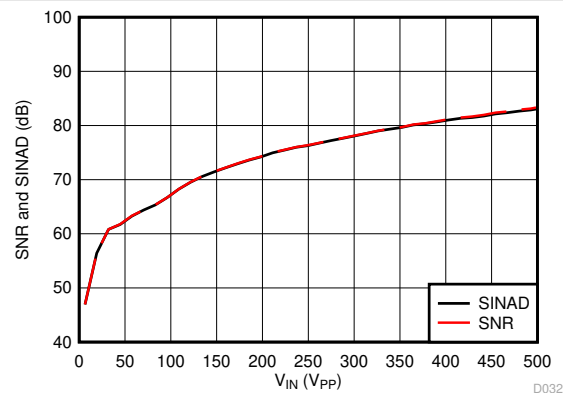


Figure 6-19. Signal-to-Noise Ratio and Signal-to-Noise + Distortion vs Input Signal Amplitude

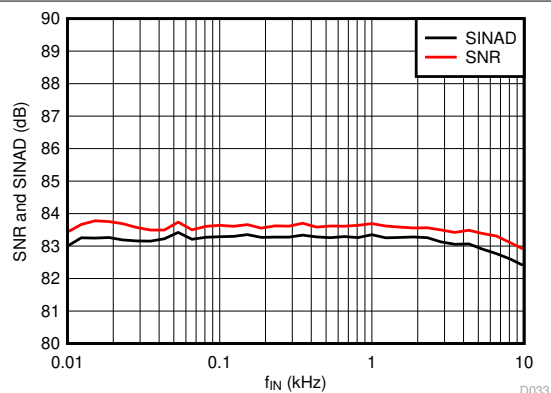


Figure 6-20. Signal-to-Noise Ratio and Signal-to-Noise + Distortion vs Input Signal Frequency

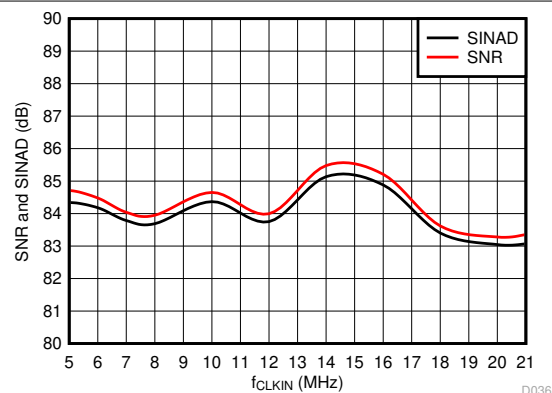


Figure 6-21. Signal-to-Noise Ratio and Signal-to-Noise + Distortion vs Input Clock Frequency

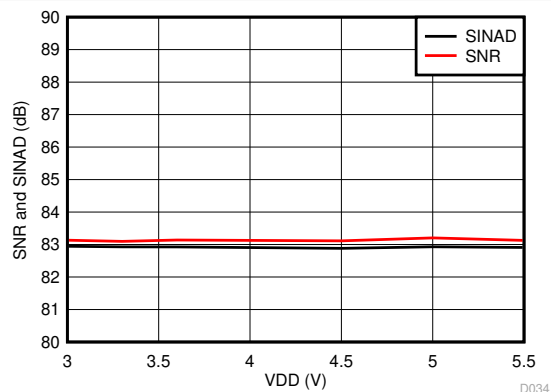


Figure 6-22. Signal-to-Noise Ratio and Signal-to-Noise + Distortion vs Supply Voltage

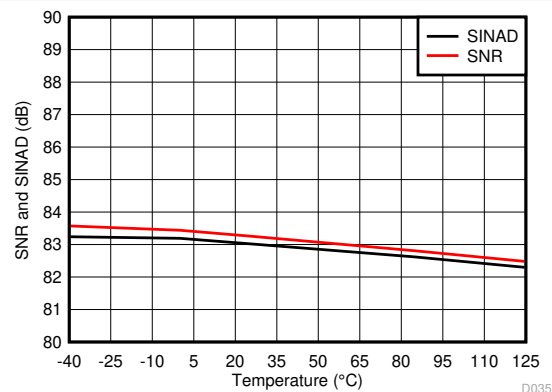
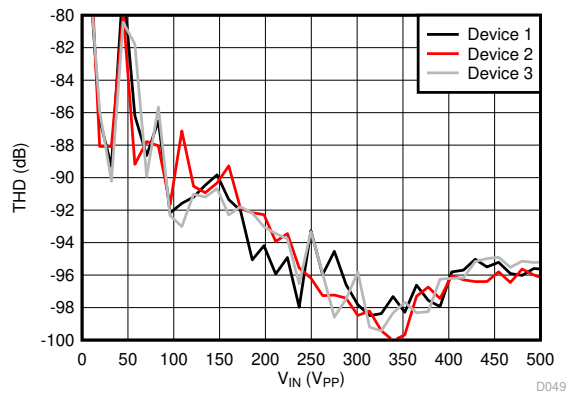


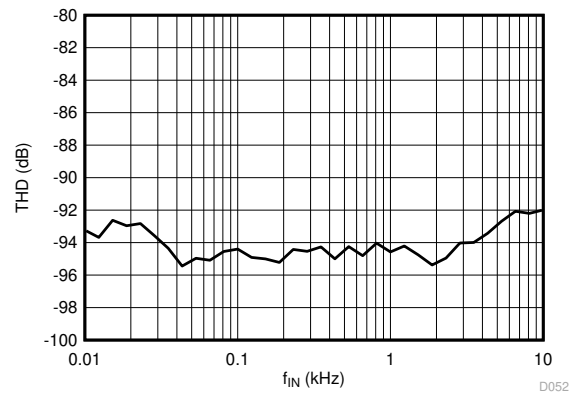
Figure 6-23. Signal-to-Noise Ratio and Signal-to-Noise + Distortion vs Temperature

## 6.13 Typical Characteristics (continued)

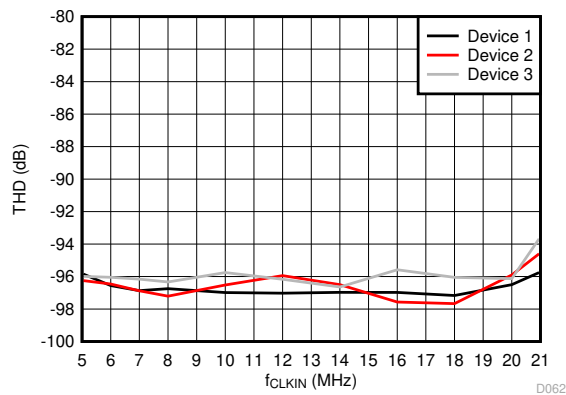
at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = HGND$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and sinc<sup>3</sup> filter with OSR = 256, 16-bit resolution (unless otherwise noted)



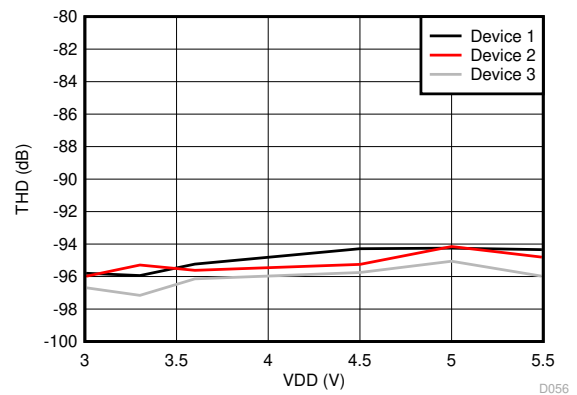
**Figure 6-24. Total Harmonic Distortion vs Input Signal Amplitude**



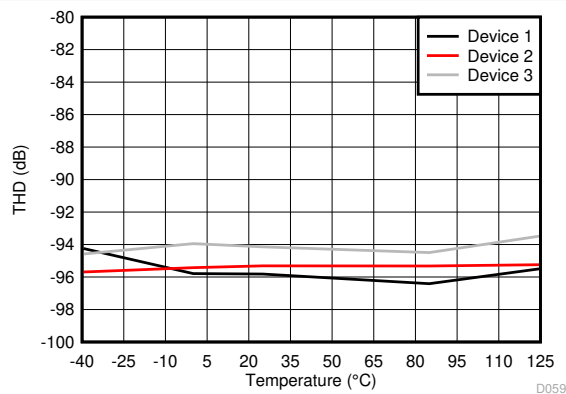
**Figure 6-25. Total Harmonic Distortion vs Input Signal Frequency**



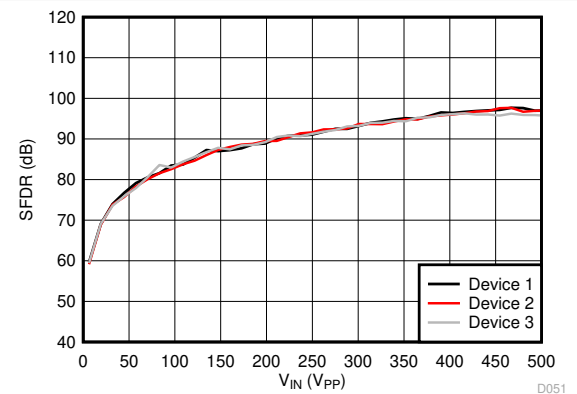
**Figure 6-26. Total Harmonic Distortion vs Input Clock Frequency**



**Figure 6-27. Total Harmonic Distortion vs Supply Voltage**



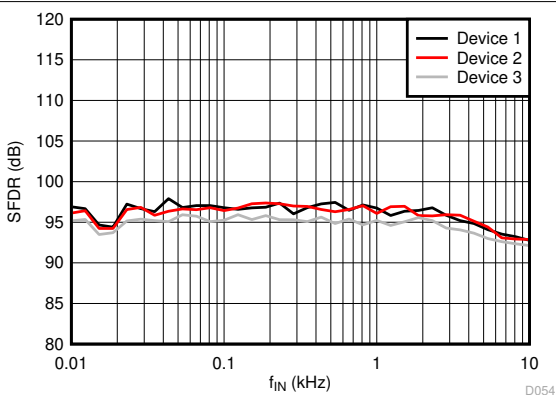
**Figure 6-28. Total Harmonic Distortion vs Temperature**



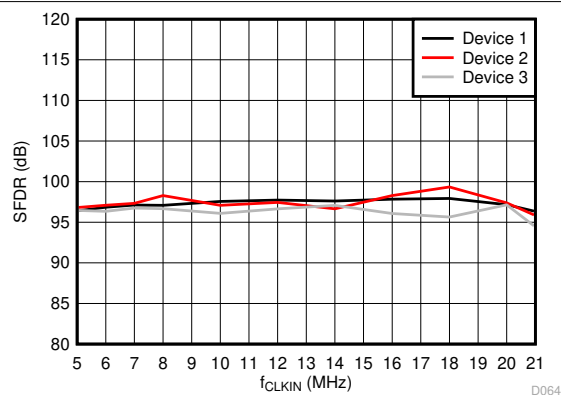
**Figure 6-29. Spurious-Free Dynamic Range vs Input Signal Amplitude**

## 6.13 Typical Characteristics (continued)

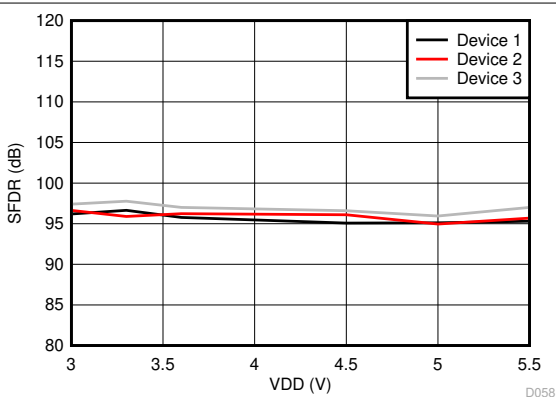
at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = HGND$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and sinc<sup>3</sup> filter with OSR = 256, 16-bit resolution (unless otherwise noted)



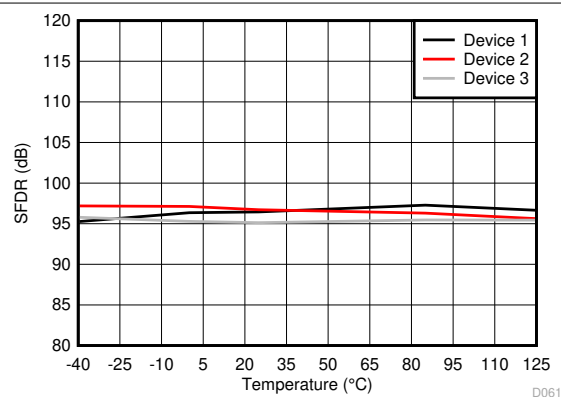
**Figure 6-30. Spurious-Free Dynamic Range vs Input Signal Frequency**



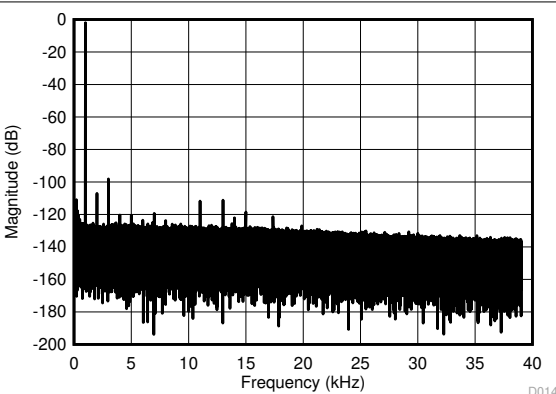
**Figure 6-31. Spurious-Free Dynamic Range vs Input Clock Frequency**



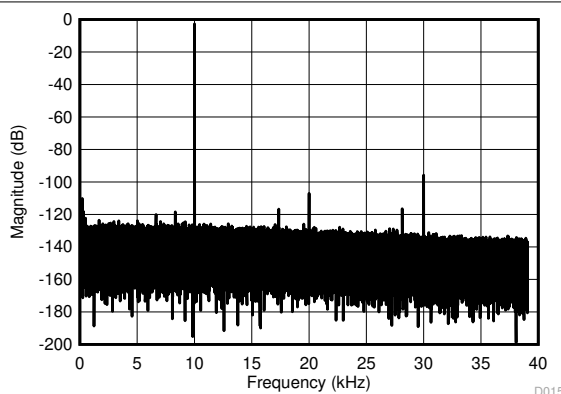
**Figure 6-32. Spurious-Free Dynamic Range vs Supply Voltage**



**Figure 6-33. Spurious-Free Dynamic Range vs Temperature**



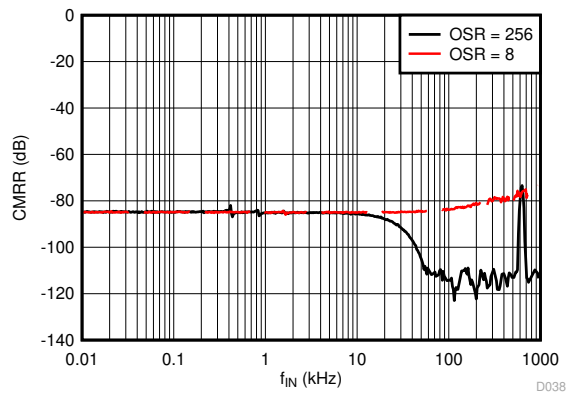
**Figure 6-34. Output Frequency Spectrum With 1-kHz Input Signal**



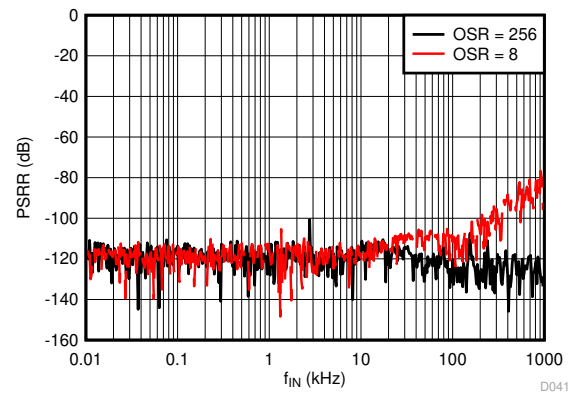
**Figure 6-35. Output Frequency Spectrum With 10-kHz Input Signal**

## 6.13 Typical Characteristics (continued)

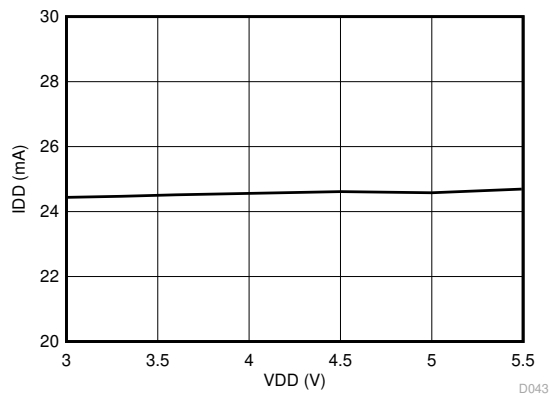
at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = HGND$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and sinc<sup>3</sup> filter with  $OSR = 256$ , 16-bit resolution (unless otherwise noted)



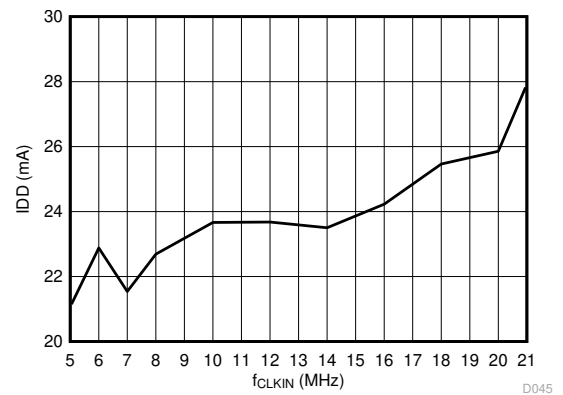
**Figure 6-36. Common-Mode Rejection Ratio vs Input Signal Frequency**



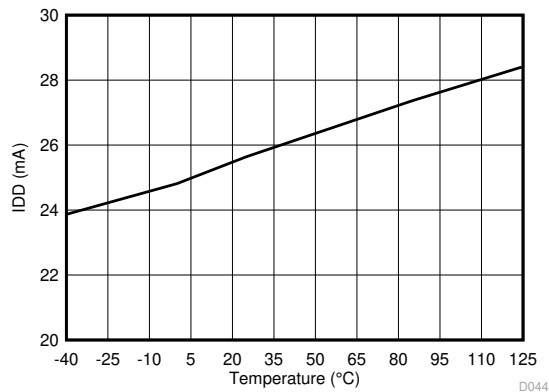
**Figure 6-37. Power-Supply Rejection Ratio vs Ripple Frequency**



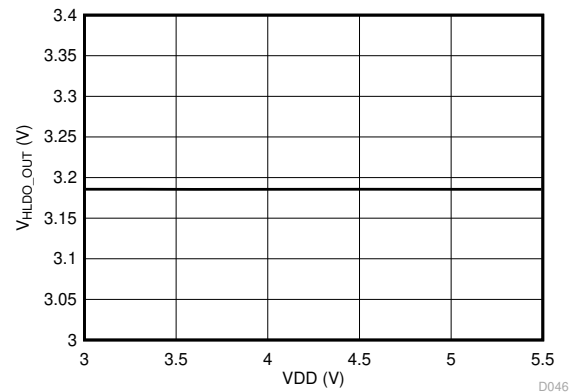
**Figure 6-38. Supply Current vs Supply Voltage**



**Figure 6-39. Supply Current vs Input Clock Frequency**



**Figure 6-40. Supply Current vs Temperature**



**Figure 6-41. High-Side LDO Output Voltage vs Supply Voltage**

## 6.13 Typical Characteristics (continued)

at  $V_{DD} = 3.3\text{ V}$ ,  $INP = -250\text{ mV}$  to  $+250\text{ mV}$ ,  $INN = HGND$ ,  $f_{CLKIN} = 20\text{ MHz}$ , and  $\text{sinc}^3$  filter with  $OSR = 256$ , 16-bit resolution (unless otherwise noted)

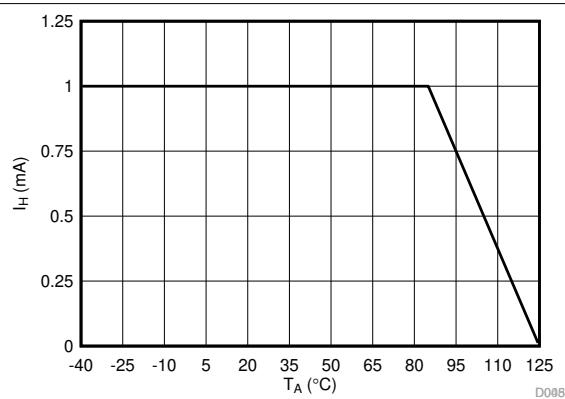


Figure 6-42.  $I_H$  Derating vs Temperature

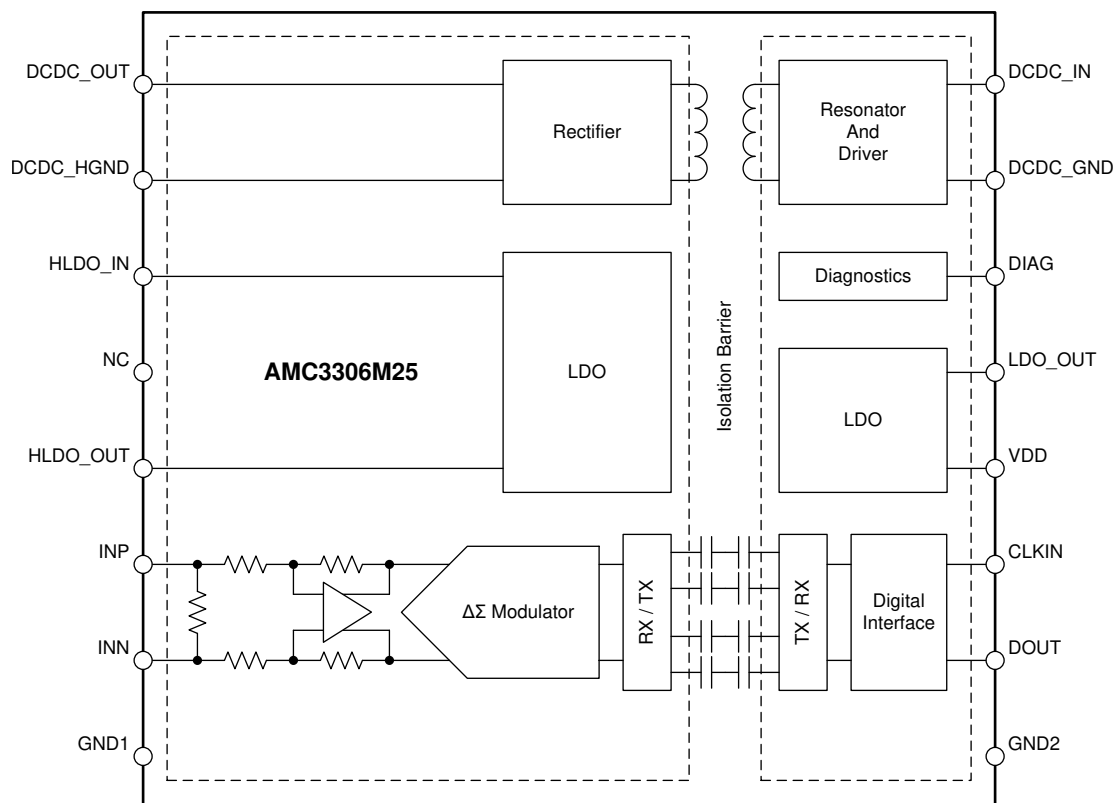
## 7 Detailed Description

### 7.1 Overview

The AMC3306M25 is a fully differential, precision, isolated modulator with an integrated DC/DC converter that can supply the high-side of the device from a single 3.3-V or 5-V voltage supply on the low side. The analog input pins INP and INN are connected to a fully differential amplifier that feeds the switched-capacitor input of a second-order, delta-sigma ( $\Delta\Sigma$ ) modulator. The modulator converts the analog input signal into a digital bitstream that is transferred across the isolation barrier and separates the high-side from the low-side. The isolated data output DOUT of the converter provides a stream of digital ones and zeros that is synchronous to the externally-provided clock source at the CLKIN pin. The time average of this serial bitstream output is proportional to the analog input voltage. The external clock input simplifies the synchronization of multiple current-sensing channels on the system level.

The signal path is isolated by a double capacitive silicon dioxide ( $\text{SiO}_2$ ) insulation barrier, whereas power isolation uses an on-chip transformer separated by a thin-film polymer as the insulating material.

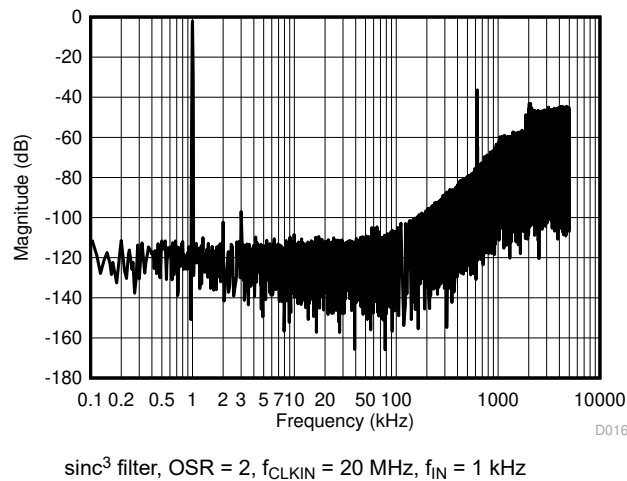
### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Analog Input

The differential amplifier input stage of the AMC3306M25 feeds a second-order, switched-capacitor, feed-forward  $\Delta\Sigma$  modulator. The gain of the differential amplifier is set by internal precision resistors with a differential input impedance of  $R_{IND}$ . The modulator converts the analog input signal into a bitstream that is transferred across the isolation barrier, as described in the [Isolation Channel Signal Transmission](#) section.

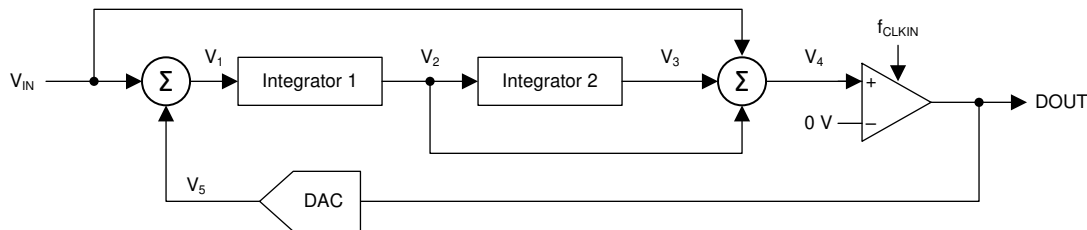


**Figure 7-1. Quantization Noise Shaping**

There are two restrictions on the analog input signals INP and INN. First, if the input voltages  $V_{INP}$  or  $V_{INN}$  exceed the range specified in the [Absolute Maximum Ratings](#) table, the input currents must be limited to the absolute maximum value because the electrostatic discharge (ESD) protection turns on. In addition, the linearity and parametric performance of the device are ensured only when the analog input voltage remains within the linear full-scale range ( $V_{FSR}$ ) and within the common-mode input voltage range ( $V_{CM}$ ) as specified in the [Recommended Operating Conditions](#) table.

### 7.3.2 Modulator

The second-order, switched-capacitor, feed-forward  $\Delta\Sigma$  modulator conceptualized in Figure 7-2 is implemented in the AMC3306M25. The analog input voltage  $V_{IN}$  and the output  $V_5$  of the 1-bit digital-to-analog converter (DAC) are differentiated, providing an analog voltage  $V_1$  at the input of the first integrator stage. The output of the first integrator feeds the input of the second integrator stage, resulting in an output voltage  $V_3$  that is differentiated with the input signal  $V_{IN}$  and the output of the first integrator  $V_2$ . Depending on the polarity of the resulting voltage  $V_4$ , the output of the comparator is changed. In this case, the 1-bit DAC responds on the next clock pulse by changing the associated analog output voltage  $V_5$ , causing the integrators to progress in the opposite direction, and forcing the value of the integrator output to track the average value of the input.



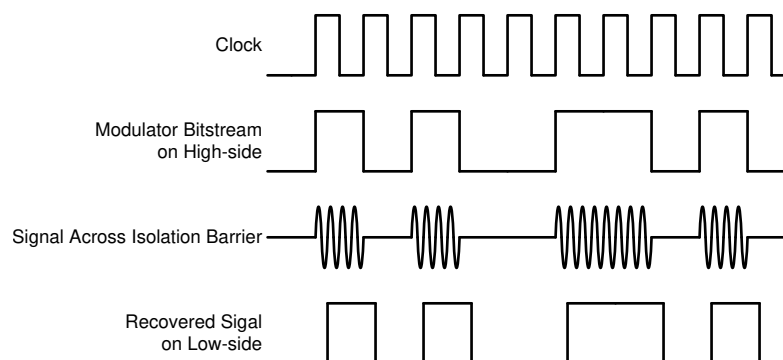
**Figure 7-2. Block Diagram of a Second-Order Modulator**

The modulator shifts the quantization noise to high frequencies, as depicted in Figure 7-1. Therefore, use a low-pass digital filter at the output of the device to increase the overall performance. This filter is also used to convert the 1-bit data stream at a high sampling rate into a higher-bit data word at a lower rate (decimation). TI's C2000™ and Sitara™ microcontroller families offer a suitable programmable, hardwired filter structure termed a *sigma-delta filter module* (SDFM) optimized for usage with the AMC3306M25. Alternatively, a field-programmable gate array (FPGA) or complex programmable logic device (CPLD) can be used to implement the filter.

### 7.3.3 Isolation Channel Signal Transmission

The AMC3306M25 uses an on-off keying (OOK) modulation scheme, as shown in Figure 7-3, to transmit the modulator output bitstream across the SiO<sub>2</sub>-based isolation barrier. The transmit driver (TX) illustrated in the [Functional Block Diagram](#) transmits an internally generated, high-frequency carrier across the isolation barrier to represent a digital *one* and does not send a signal to represent a digital *zero*. The nominal frequency of the carrier used inside the AMC3306M25 is 480 MHz.

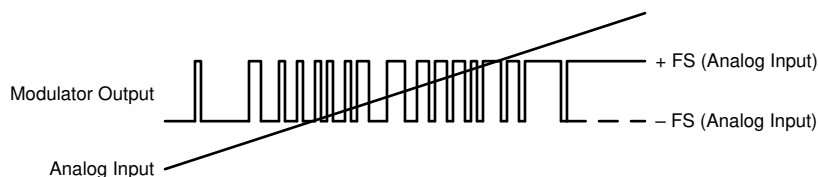
Figure 7-3 shows the concept of the on-off keying scheme.



**Figure 7-3. OOK-Based Modulation Scheme**

### 7.3.4 Digital Output

A differential input signal of 0 V ideally produces a stream of ones and zeros that are high 50% of the time. A differential input of 250 mV produces a stream of ones and zeros that are high 89.06% of the time. With 16 bits of resolution, that percentage ideally corresponds to code 58368. A differential input of –250 mV produces a stream of ones and zeros that are high 10.94% of the time and ideally results in code 7168 with 16-bit resolution. These input voltages are also the specified linear range of the AMC3306M25. If the input voltage value exceeds this range, the output of the modulator shows nonlinear behavior as the quantization noise increases. The output of the modulator clips with a stream of only zeros with an input less than or equal to –320 mV or with a stream of only ones with an input greater than or equal to 320 mV. In this case, however, the AMC3306M25 generates a single 1 (if the input is at negative full-scale) or 0 (if the input is at positive full-scale) every 128 clock cycles to indicate proper device function (see the [Output Behavior in Case of a Full-Scale Input](#) section for more details). [Figure 7-4](#) shows the input voltage versus the output modulator signal.



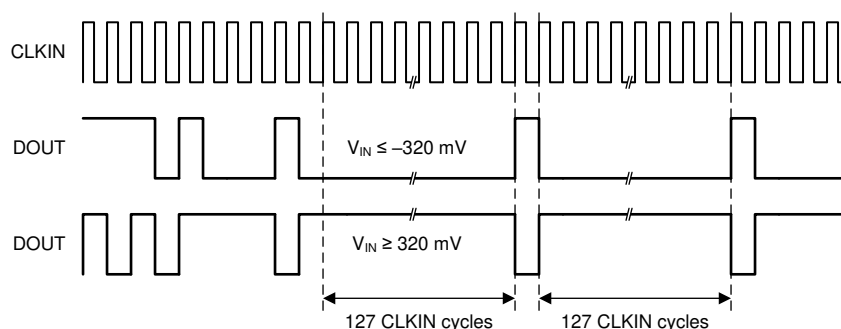
**Figure 7-4. Analog Input vs Modulator Output**

The density of ones in the output bitstream for any input voltage value can be calculated using [Equation 1](#) (with the exception of a full-scale input signal, as described in the [Output Behavior in Case of a Full-Scale Input](#) section):

$$\frac{V_{IN} + V_{Clipping}}{2 \times V_{Clipping}} \quad (1)$$

#### 7.3.4.1 Output Behavior in Case of a Full-Scale Input

If a full-scale input signal is applied to the AMC3306M25 (that is,  $|V_{IN}| \geq V_{Clipping}$ ), as shown in [Figure 7-5](#), the device generates a single one or zero every 128 bits at DOUT, depending on the actual polarity of the signal being sensed. In this way, detecting a valid full-scale input signal and differentiating it from a missing high-side supply is possible on the system level.



**Figure 7-5. Full-Scale Output of the AMC3306M25**

#### 7.3.4.2 Output Behavior in Case of a High-Side Supply Failure

The AMC3306M25 provides a failsafe output that ensures that the output DOUT of the device is a constant bitstream of logic 0's in case the integrated DC/DC converter output voltage is below the undervoltage detection threshold. See the [Diagnostic Output](#) section for more information.

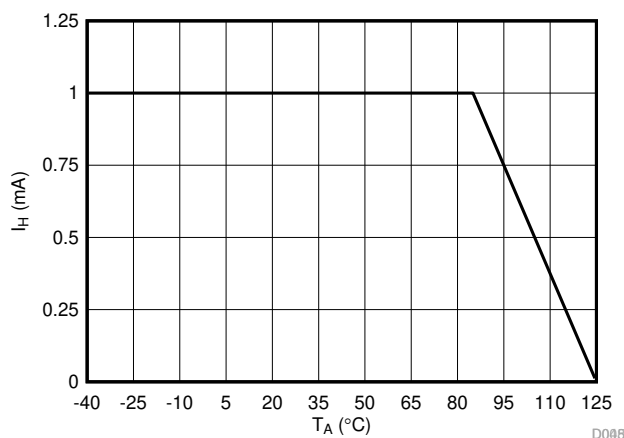
### 7.3.5 Isolated DC/DC Converter

The AMC3306M25 offers a fully integrated isolated DC/DC converter stage that includes the following components illustrated in the [Functional Block Diagram](#) section:

- Low-dropout regulator (LDO) on the low-side to stabilize the supply voltage VDD that drives the low-side of the DC/DC converter. This circuit does not output a constant voltage and is not intended for driving any external load.
- Low-side full-bridge inverter and drivers
- Laminate-based, air-core transformer for high immunity to magnetic fields
- High-side full-bridge rectifier
- High-side LDO to stabilize the output voltage of the DC/DC converter for high analog performance of the signal path. The high-side LDO outputs a constant voltage and can provide a limited amount of current to power external circuitry.

The DC/DC converter uses a spread-spectrum clock generation technique to reduce the spectral density of the electromagnetic radiation. The resonator frequency is synchronized to the operation of the  $\Delta\Sigma$  modulator to minimize interference with data transmission and support the high analog performance of the device.

The architecture of the DC/DC converter is optimized to drive the high-side circuitry of the AMC3306M25 and can source up to  $I_H$  of additional DC current for an optional auxiliary circuit such as an active filter, pre-amplifier, or comparator. As shown in [Figure 7-6](#),  $I_H$  is specified up to an ambient temperature of 85°C and derates linearly at higher temperatures.

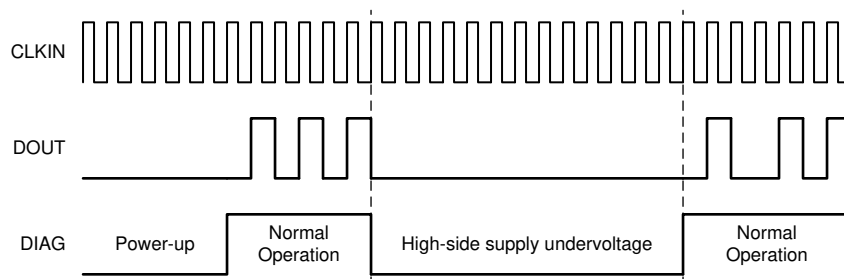


**Figure 7-6. Derating of  $I_H$  at Ambient Temperatures >85°C**

### 7.3.6 Diagnostic Output

As shown in [Figure 7-7](#), the open-drain DIAG pin can be monitored to confirm the device is operational, and the output data are valid. During power-up, the DIAG pin is actively held low until the high-side supply is in regulation and the modulator starts outputting data. The DIAG pin is actively pulled low if:

- The low-side does not receive data from the high-side (for example, because of a loss of power on the high-side). The modulator itself outputs a constant bitstream of logic 0's in this case, that is, the DOUT pin is permanently low.
- The high-side DC/DC output voltage (DCDC\_OUT) or the high-side LDO output voltage (HLDO\_OUT) drop below their respective undervoltage detection thresholds (brown-out). In this case, the low-side may still receive data from the high-side but the data may not be valid. However, the modulator itself outputs a constant bitstream of logic 0's in this case, meaning that the DOUT pin is permanently low.



**Figure 7-7. DIAG and Output under Different Operating Conditions**

## 7.4 Device Functional Modes

The AMC3306M25 is operational when VDD is applied, as specified in the [Recommended Operating Conditions](#) table.

## 8 Application and Implementation

### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 8.1 Application Information

The low analog input voltage range, excellent accuracy, and low temperature drift make the AMC3306M25 a high performance solution for industrial applications where shunt-based current sensing in the presence of high common-mode voltage levels is required.

#### 8.1.1 Digital Filter Usage

The modulator generates a bitstream that has to be processed by a digital filter to obtain a digital word similar to a conversion result of a conventional analog-to-digital converter (ADC). A very simple filter, as shown in [Equation 2](#), built with minimal effort and hardware, is a sinc<sup>3</sup>-type filter:

$$H(z) = \left( \frac{1 - z^{-\text{OSR}}}{1 - z^{-1}} \right)^3 \quad (2)$$

This filter provides the best output performance at the lowest hardware size (count of digital gates) for a second-order modulator. All characterization in this document is done with a sinc<sup>3</sup> filter with an oversampling ratio (OSR) of 256 and an output word width of 16 bits, unless specified otherwise. The measured effective number of bits (ENOB) as a function of the OSR is illustrated in [Figure 8-3](#) of the [Typical Application](#) section.

A [delta sigma modulator filter calculator](#) is available for download at [www.ti.com](http://www.ti.com) that aids in the filter design and selecting the right OSR and filter-order to achieve the desired output resolution and filter response time.

An example code for implementing a sinc<sup>3</sup> filter in an FPGA is discussed in the [Combining the ADS1202 with an FPGA Digital Filter for Current Measurement in Motor Control Applications](#) application note, available for download at [www.ti.com](http://www.ti.com).

## 8.2 Typical Application

### 8.2.1 Solar Inverter Application

The AMC3306M25 is ideally suited for shunt-based current sensing applications where accurate current monitoring is required in the presence of high common-mode voltages. The AMC3306M25 integrates an isolated power supply for the high-voltage side and therefore makes the device particularly easy to use in applications that do not have a high-side supply readily available or where a high-side supply is referenced to a different ground potential than the signal to be measured.

Figure 8-1 shows a simplified schematic of the AMC3306M25 in a solar inverter where the phase current is measured on the grid-side of an LCL filter. Although the system offers a supply for the high-side gate driver, there is a large common-mode voltage between the gate driver supply ground reference and the shunt resistor on the other side of the LCL filter. Therefore, the gate driver supply is not suitable for powering the high-side of an isolated modulator that measures the voltage across the shunt. The integrated isolated power-supply of the AMC3306M25 solves that problem and enables current sensing at locations that is optimal for the system.

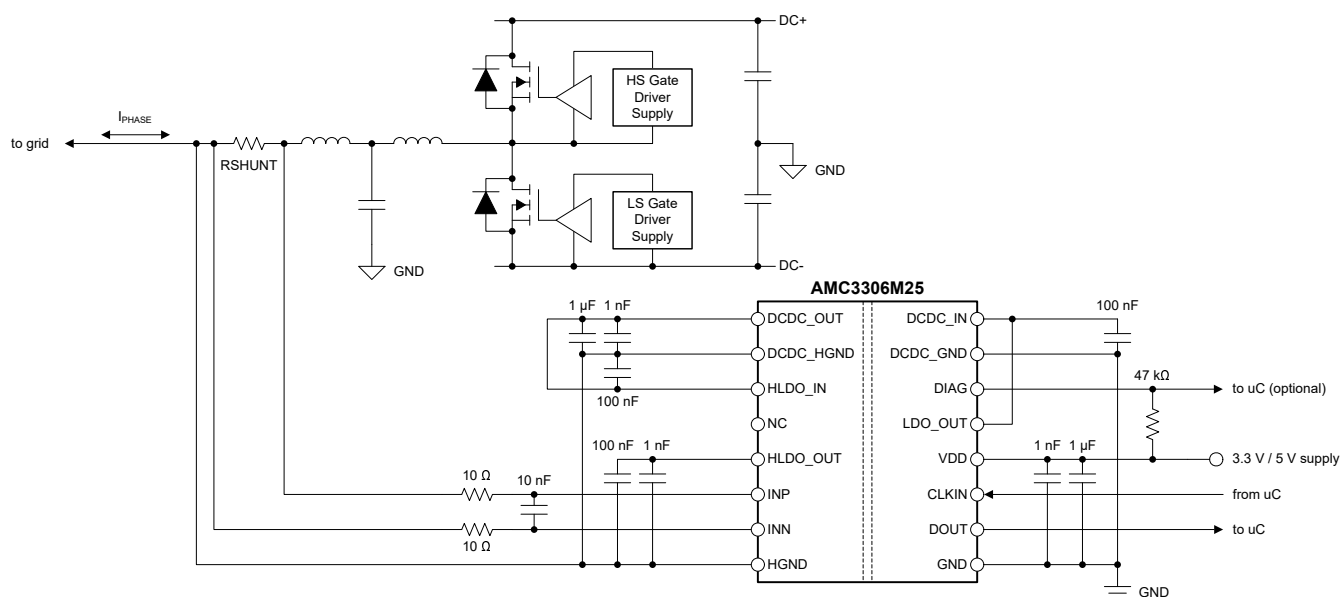


Figure 8-1. The AMC3306M25 in a Solar Inverter Application

#### 8.2.1.1 Design Requirements

Table 8-1 lists the parameters for this typical application.

Table 8-1. Design Requirements

| PARAMETER  | VALUE             |
|--|-------------------|
| Low-side supply voltage                          | 3.3 V or 5 V      |
| Voltage drop across RSHUNT for a linear response | ±250 mV (maximum) |

### 8.2.1.2 Detailed Design Procedure

The AMC3306M25 requires a single 3.3-V or 5-V supply on its low-side. The high-side supply is internally generated by an integrated DC/DC converter as explained in the [Isolated DC/DC Converter](#) section.

The ground reference (HGND) is derived from the terminal of the shunt resistor that is connected to the negative input of the AMC3306M25 (INN). If a four-pin shunt is used, the inputs of the device are connected to the inner leads and HGND is connected to one of the outer leads. To minimize offset and improve accuracy, set the ground connection to a separate trace that connects directly to the shunt resistor rather than shorting HGND to INN directly at the input to the device. See the [Layout](#) section for more details.

#### 8.2.1.2.1 Shunt Resistor Sizing

Use Ohm's Law to calculate the voltage drop across the shunt resistor ( $V_{SHUNT}$ ) for the desired measured current:  $V_{SHUNT} = I \times R_{SHUNT}$ .

Consider the following two restrictions to choose the proper value of the shunt resistor,  $R_{SHUNT}$ :

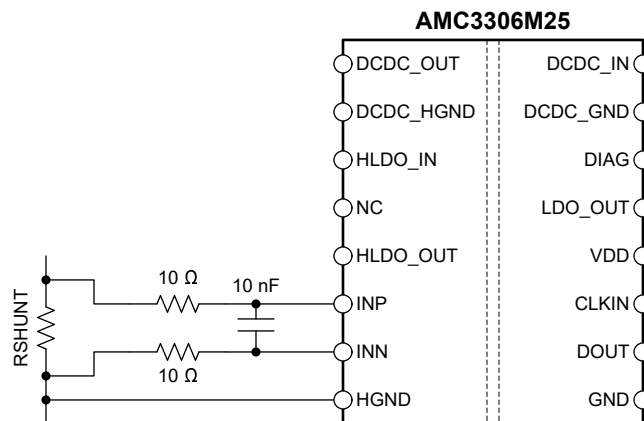
- The voltage drop caused by the nominal current range must not exceed the recommended differential input voltage range for linear response:  $|V_{SHUNT}| \leq V_{FSR}$
- The voltage drop caused by the maximum allowed overcurrent must not exceed the input voltage that causes a clipping output:  $|V_{SHUNT}| \leq |V_{Clipping}|$

#### 8.2.1.2.2 Input Filter Design

TI recommends placing a RC filter in front of a  $\Delta\Sigma$  modulator to improve signal-to-noise performance of the signal path. Design the input filter such that:

- The cutoff frequency of the filter is at least one order of magnitude lower than the sampling frequency of the  $\Delta\Sigma$  modulator ( $f_{CLKIN}$ )
- The input bias current does not generate significant voltage drop across the DC impedance of the input filter
- The impedances measured from the analog inputs are equal

For most applications the structure shown in [Figure 8-2](#) achieves excellent performance.



**Figure 8-2. Differential Input Filter**

#### 8.2.1.2.3 Bitstream Filtering

For modulator output bitstream filtering, a device from TI's [C2000™](#) or [Sitara™](#) microcontroller families is recommended. These families support up to eight channels of dedicated hardwired filter structures that significantly simplify system level design by offering two filtering paths per channel: one providing high-accuracy results for the control loop and one fast-response path for overcurrent detection.

A [delta sigma modulator filter calculator](#) is available for download at [www.ti.com](http://www.ti.com) that aids in the filter design and selecting the right OSR and filter-order to achieve the desired output resolution and filter response time.

### 8.2.1.3 Application Curve

The effective number of bits (ENOB) is often used to compare the performance of ADCs and  $\Delta\Sigma$  modulators. Figure 8-3 shows the ENOB of the AMC3306M25 with different oversampling ratios. By using Equation 3, this number can also be calculated from the SINAD:

$$\text{SINAD} = 1.76 \text{ dB} + 6.02 \text{ dB} \times \text{ENOB} \quad (3)$$

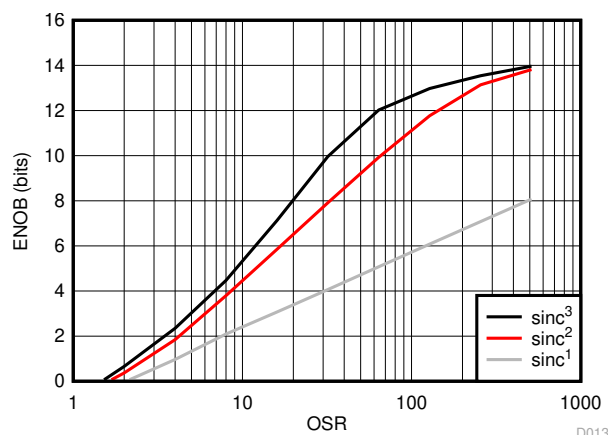


Figure 8-3. Measured Effective Number of Bits vs Oversampling Ratio

### 8.2.2 What To Do and What Not To Do

Do not leave the inputs of the AMC3306M25 unconnected (floating) when the device is powered up. If the device inputs are left floating, the input bias current may drive the inputs to a positive value that exceeds the operating common-mode input voltage and the output of the device is undetermined.

Connect the negative input (INN) to the high-side ground (HGND), either by a hard short or through a resistive path. A DC current path between INN and HGND is required to define the input common-mode voltage. Take care not to exceed the input common-mode range as specified in the [Recommended Operating Conditions](#) table. For best accuracy, route the ground connection as a separate trace that connects directly to the shunt resistor rather than shorting AGND to INN directly at the input to the device. See the [Layout](#) section for more details.

The high-side LDO can source a limited amount of current ( $I_H$ ) to power external circuitry. Take care not to over-load the high-side LDO and be aware of the derating of  $I_H$  at high temperatures as explained in the [Isolated DC/DC Converter](#) section.

The low-side LDO does not output a constant voltage and is not intended for powering any external circuitry. Do not connect any external load to the HLDO\_OUT pin.

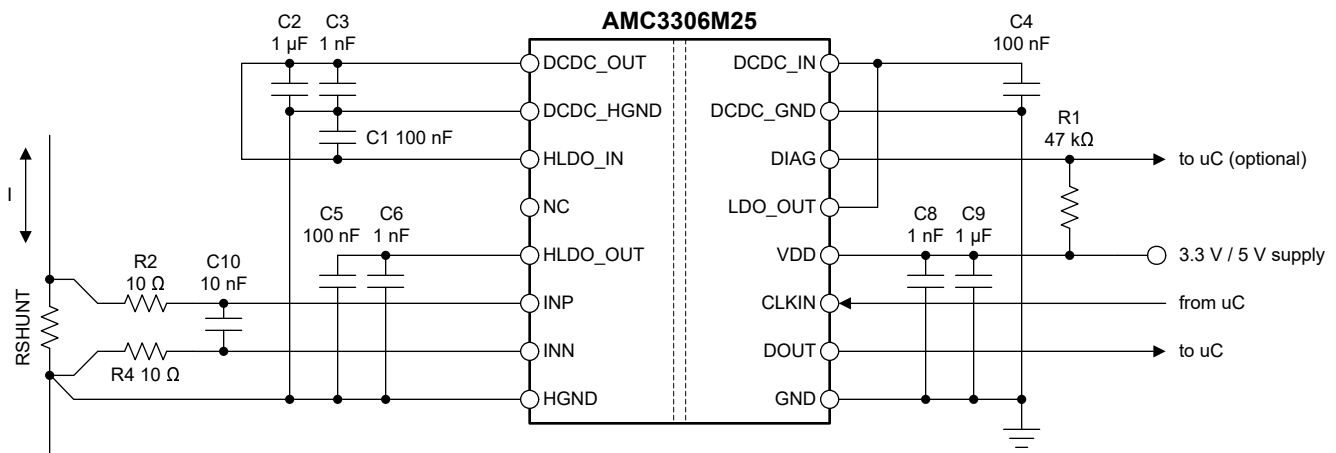
## 9 Power Supply Recommendations

The AMC3306M25 is powered from the low-side power supply (VDD) with a nominal value of 3.3 V (or 5 V). TI recommends a low-ESR decoupling capacitor of 1 nF (C8 in [Figure 9-1](#)) placed as close as possible to the VDD pin, followed by a 1-μF capacitor (C9) to filter this power-supply path.

The low-side of the DC/DC converter is decoupled with a low-ESR 100-nF capacitor (C4) positioned close to the device between the DCDC\_IN and DCDC\_GND pins. Use a 1- $\mu$ F capacitor (C2) to decouple the high-side in addition to a low-ESR, 1-nF capacitor (C3) placed as close as possible to the device and connected to the DCDC\_OUT and DCDC\_HGND pins.

For the high-side LDO, use low-ESR capacitors of 1-nF (C6), placed as close as possible to the AMC3306M25, followed by a 100-nF decoupling capacitor (C5).

The ground reference for the high-side (HGND) is derived from the terminal of the shunt resistor which is connected to the negative input (INN) of the device. For best DC accuracy, use a separate trace to make this connection instead of shorting HGND to INN directly at the device input. The high-side DC/DC ground terminal (DCDC\_HGND) is shorted to HGND directly at the device pins.



### Figure 9-1. Decoupling the AMC3306M25

Capacitors must provide adequate *effective* capacitance under the applicable DC bias conditions they experience in the application. MLCC capacitors typically exhibit only a fraction of their nominal capacitance under real-world conditions and this factor must be taken into consideration when selecting these capacitors. This problem is especially acute in low-profile capacitors, in which the dielectric field strength is higher than in taller components. Reputable capacitor manufacturers provide capacitance versus DC bias curves that greatly simplify component selection.

Table 9-1 lists components suitable for use with the AMC3306M25. This list is not exhaustive. Other components may exist that are equally suitable (or better), however these listed components have been validated during the development of the AMC3306M25.

**Table 9-1. Recommended External Components**

| DESCRIPTION     |                         | PART NUMBER          | MANUFACTURER | SIZE (EIA, L x W)     |
|-----------------|-------------------------|----------------------|--------------|-----------------------|
| VDD             |                         |                      |              |                       |
| C8              | 1 nF ± 10%, X7R, 50 V   | 12065C102KAT2A       | AVX          | 1206, 3.2 mm x 1.6 mm |
| C9              | 1 μF ± 10%, X7R, 25 V   | 12063C105KAT2A       | AVX          | 1206, 3.2 mm x 1.6 mm |
| DC/DC CONVERTER |                         |                      |              |                       |
| C4              | 100 nF ± 10%, X7R, 50 V | C0603C104K5RACAUTO   | Kemet        | 0603, 1.6 mm x 0.8 mm |
| C3              | 1 nF ± 10%, X7R, 50 V   | C0603C102K5RACTU     | Kemet        | 0603, 1.6 mm x 0.8 mm |
| C2              | 1 μF ± 10%, X7R, 25 V   | CGA3E1X7R1E105K080AC | TDK          | 0603, 1.6 mm x 0.8 mm |
| HLDO            |                         |                      |              |                       |
| C1              | 100 nF ± 10%, X7R, 50 V | C0603C104K5RACAUTO   | Kemet        | 0603, 1.6 mm x 0.8 mm |
| C5              | 100 nF ± 5%, NP0, 50 V  | C3216NP01H104J160AA  | TDK          | 1206, 3.2 mm x 1.6 mm |
| C6              | 1 nF ± 10%, X7R, 50 V   | 12065C102KAT2A       | AVX          | 1206, 3.2 mm x 1.6 mm |

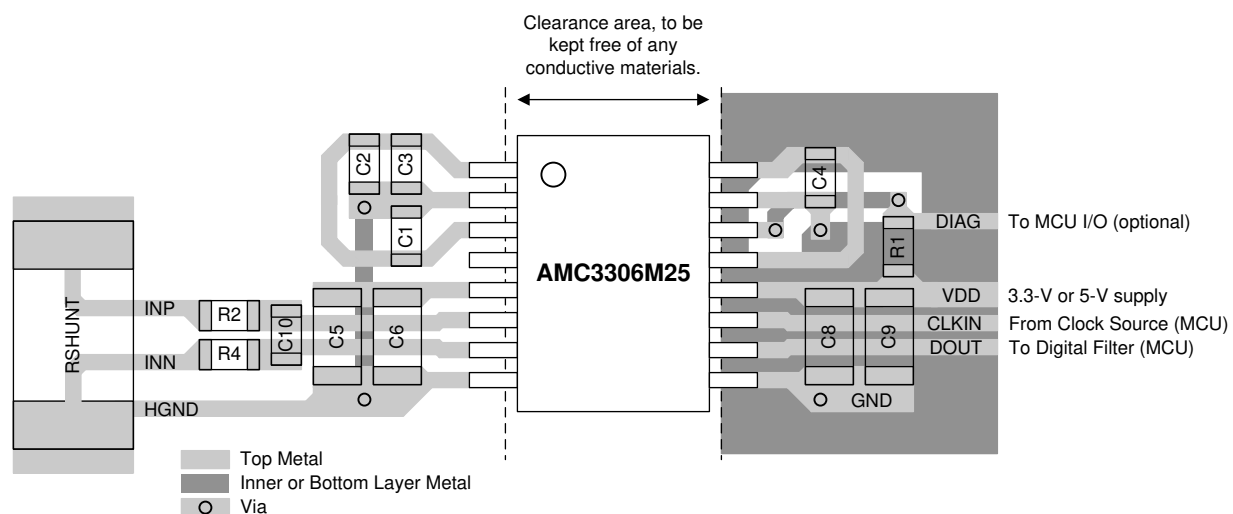
## 10 Layout

### 10.1 Layout Guidelines

Figure 10-1 shows a layout recommendation with the critical placement of the decoupling capacitors. The same component reference designators are used as in the [Power Supply Recommendations](#) section. Decoupling capacitors are placed as close as possible to the AMC3306M25 supply pins. For best performance, place the shunt resistor close to the INP and INN inputs of the AMC3306M25 and keep the layout of both connections symmetrical.

This layout is used on the AMC3306M25 EVM and supports CISPR-11 compliant electromagnetic radiation levels.

### 10.2 Layout Example



**Figure 10-1. Recommended Layout of the AMC3306M25**

## 11 Device and Documentation Support

### 11.1 Device Support

#### 11.1.1 Device Nomenclature

##### 11.1.1.1 Isolation Glossary

See the [Isolation Glossary](#)

### 11.2 Documentation Support

#### 11.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, [Isolation Glossary](#) application report
- Texas Instruments, [Semiconductor and IC Package Thermal Metrics](#) application report
- Texas Instruments, [ISO72x Digital Isolator Magnetic-Field Immunity](#) application report
- Texas Instruments, [Delta Sigma Modulator Filter Calculator](#) design tool

### 11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](#). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 11.4 Support Resources

TI E2E™ [support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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### 11.5 Trademarks

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### 11.6 Electrostatic Discharge Caution



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.

### 11.7 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number          | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|--------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">AMC3306M25DWE</a>  | Active        | Production           | SOIC (DWE)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 125   | AMC3306M25          |
| AMC3306M25DWE.A                | Active        | Production           | SOIC (DWE)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 125   | AMC3306M25          |
| AMC3306M25DWE.B                | Active        | Production           | SOIC (DWE)   16 | 40   TUBE             | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 125   | AMC3306M25          |
| <a href="#">AMC3306M25DWER</a> | Active        | Production           | SOIC (DWE)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 125   | AMC3306M25          |
| AMC3306M25DWER.A               | Active        | Production           | SOIC (DWE)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 125   | AMC3306M25          |
| AMC3306M25DWER.B               | Active        | Production           | SOIC (DWE)   16 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 125   | AMC3306M25          |

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

<sup>(2)</sup> **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.

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

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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.

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

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

**OTHER QUALIFIED VERSIONS OF AMC3306M25 :**

- Automotive : [AMC3306M25-Q1](#)

## NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

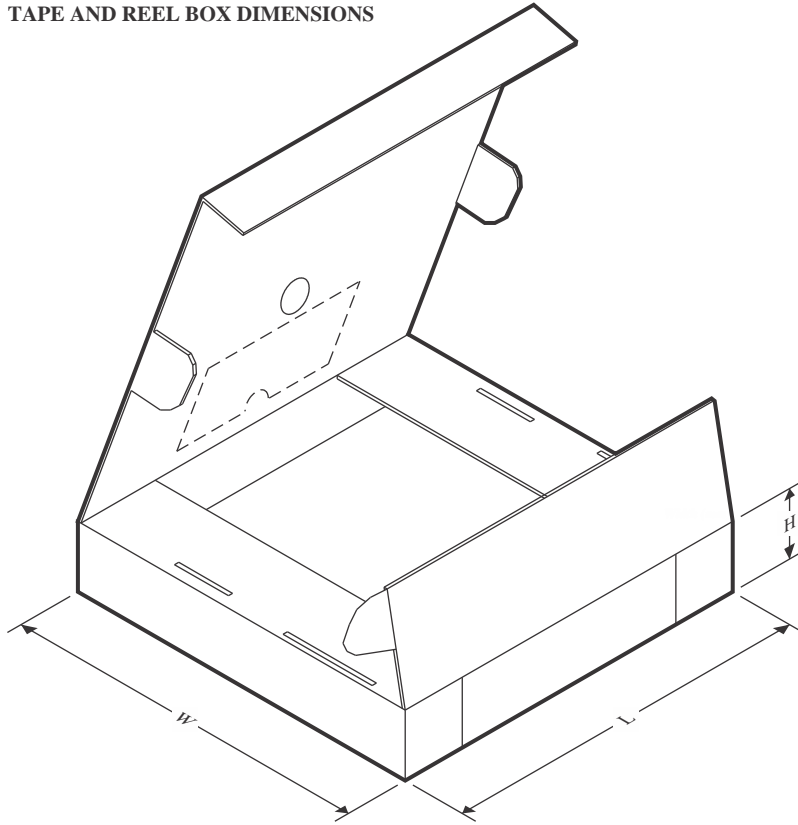
## TAPE AND REEL INFORMATION



\*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| AMC3306M25DWER | SOIC         | DWE             | 16   | 2000 | 330.0              | 16.4               | 10.75   | 10.7    | 2.7     | 12.0    | 16.0   | Q1            |

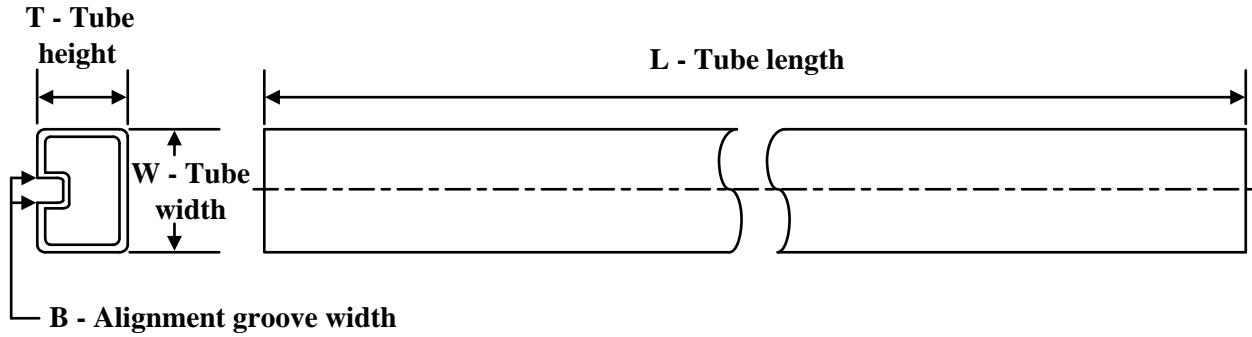
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

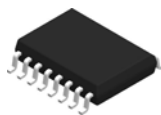
| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| AMC3306M25DWER | SOIC         | DWE             | 16   | 2000 | 350.0       | 350.0      | 43.0        |

## TUBE



\*All dimensions are nominal

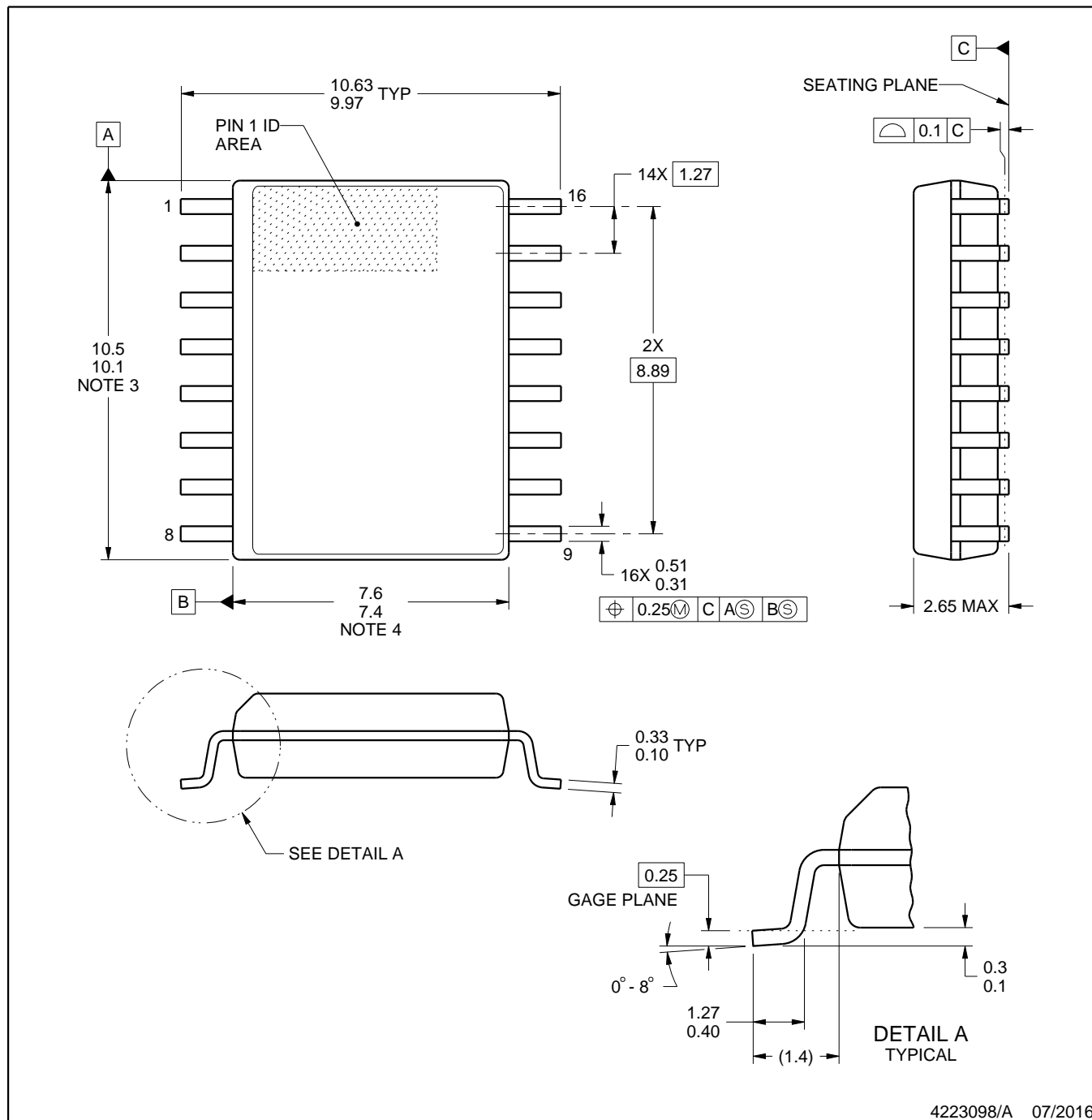
| Device          | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| AMC3306M25DWE   | DWE          | SO-MOD       | 16   | 40  | 506.98 | 12.7   | 4826   | 6.6    |
| AMC3306M25DWE.A | DWE          | SO-MOD       | 16   | 40  | 506.98 | 12.7   | 4826   | 6.6    |
| AMC3306M25DWE.B | DWE          | SO-MOD       | 16   | 40  | 506.98 | 12.7   | 4826   | 6.6    |



**DWE0016A**

# **PACKAGE OUTLINE** **SOIC - 2.65 mm max height**

SOIC



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## **NOTES:**

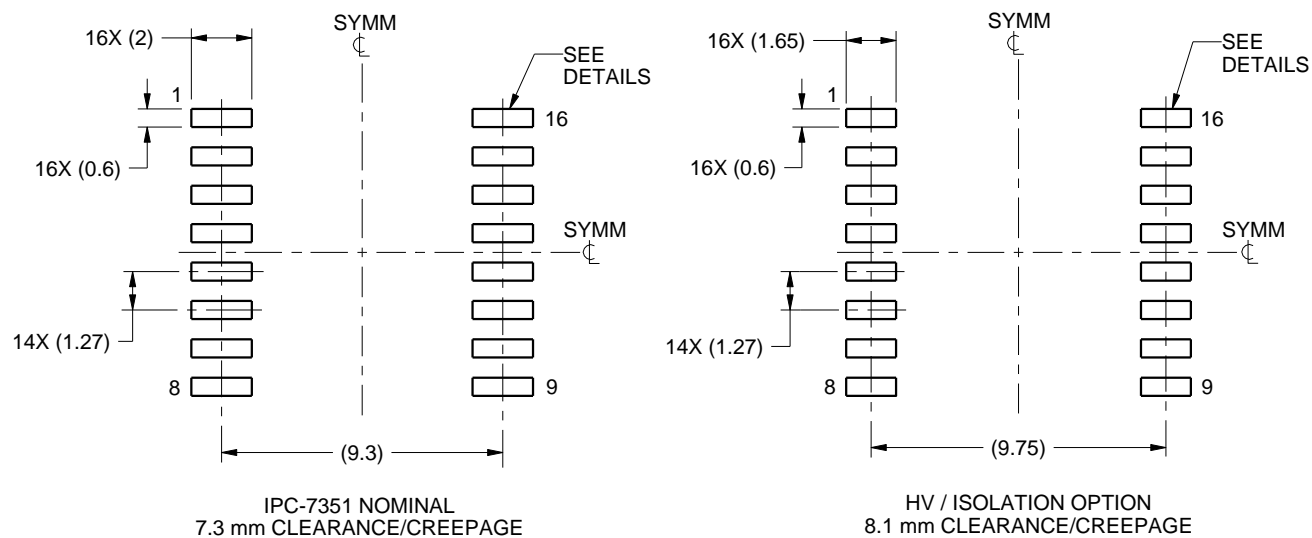
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or 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 MS-013.

# EXAMPLE BOARD LAYOUT

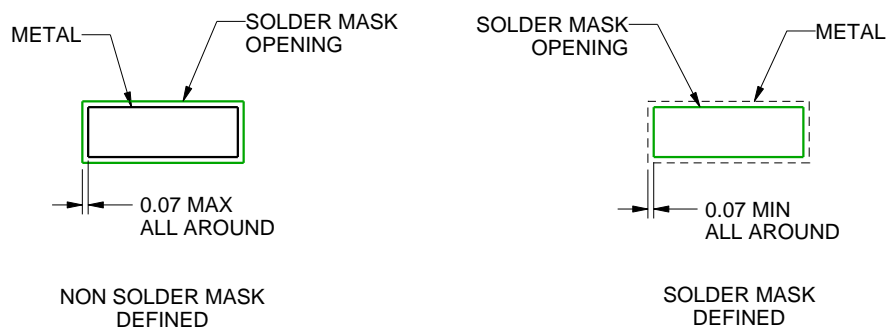
DWE0016A

SOIC - 2.65 mm max height

SOIC



LAND PATTERN EXAMPLE  
SCALE:4X



SOLDER MASK DETAILS

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

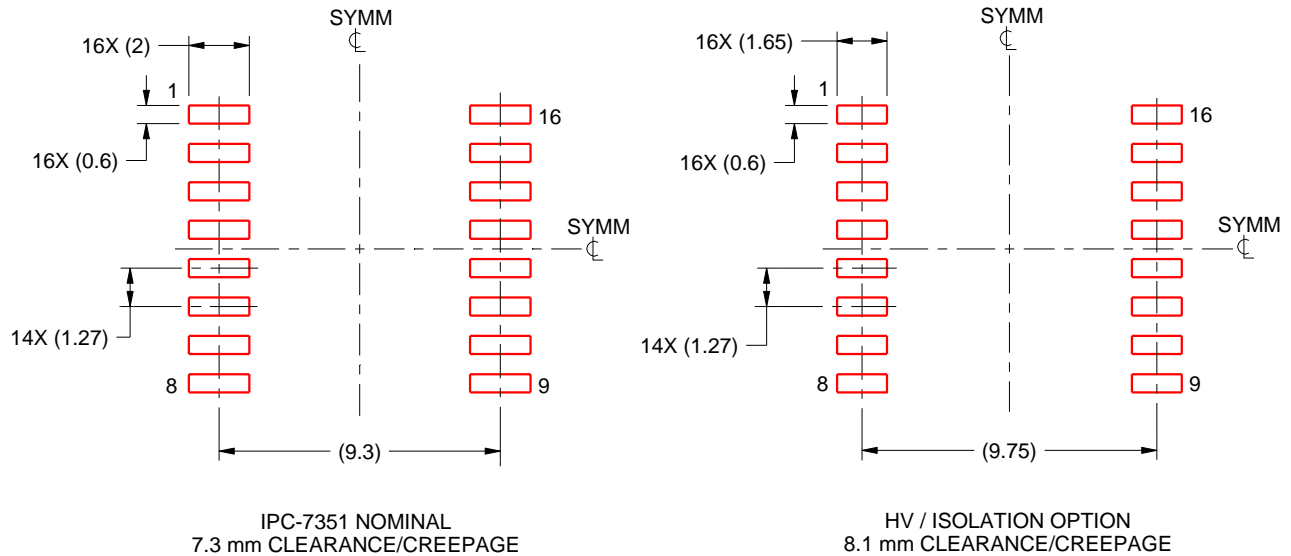
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

DWE0016A

SOIC - 2.65 mm max height

SOIC



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:4X

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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.

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