AMC0136 Precision, ±1V Input, Functionally Isolated, Delta-Sigma Modulator With External Clock

1 Features

- Linear input voltage range: ±1V
- High input impedance: 1GΩ (typical)
- Supply voltage range:
  - High-side (AVDD): 3.0V to 5.5V
  - Low-side (DVDD): 2.7V to 5.5V
- Low DC errors:
  - Offset error: ±0.9mV (maximum)
  - Offset drift: 8.5µV/°C (maximum)
  - Gain error: ±0.25% (maximum)
  - Gain drift: ±35ppm/°C (maximum)
- High CMTI: 150V/ns (minimum)
- Missing high-side supply detection
- Low EMI: Meets CISPR-11 and CISPR-25 standards
- Functional Isolation:
  - 200V_{RMS}, 280V_{DC} working voltage
  - 570V_{RMS}, 800V_{DC} transient overvoltage (60s)
- Safety-related certifications:
  - DIN EN IEC 60747-17 (VDE 0884-17)
  - UL1577
- Fully specified over the extended industrial temperature range: –40°C to +125°C

2 Applications

- 48V motor drives
- 48V frequency inverters
- Analog input modules
- Power supplies

3 Description

The AMC0136 is a precision, galvanically isolated delta-sigma (ΔΣ) modulator with a ±1V, high impedance input and external clock. The high-impedance input is optimized for connection to high-impedance resistive dividers or other voltage signal sources with high output resistance.

The isolation barrier separates parts of the system that operate on different common-mode voltage levels. The isolation barrier supports a working voltage up to 200V_{RMS} / 280V_{DC} and transient overvoltages up to 570V_{RMS} / 800V_{DC}.

With a small package size and high input impedance, the AMC0136 is designed for high accuracy, isolated voltage sensing in space-constrained applications.

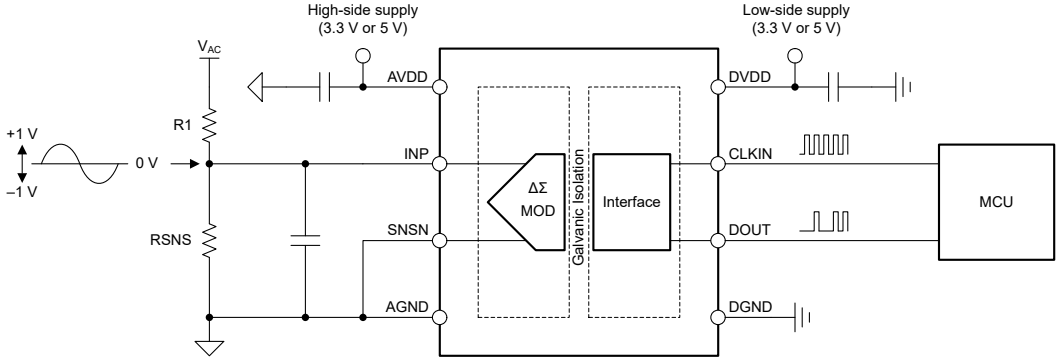
The output bitstream of the AMC0136 is synchronized to an external clock. Combined with a sinc3, OSR 256 filter, the device achieves 14.8 effective bits of resolution or 89dB of dynamic range, at a sample rate of 39kSPS.

The AMC0136 is available in a 8-pin, 0.65mm pitch VSON package and is fully specified over the temperature range from –40°C to +125°C.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
AMC0136	DEN (VSON 8)	3.5mm × 2.7mm

(1) For more information, see the *Mechanical, Packaging, and Orderable Information* section.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Application

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Pin Configuration and Functions

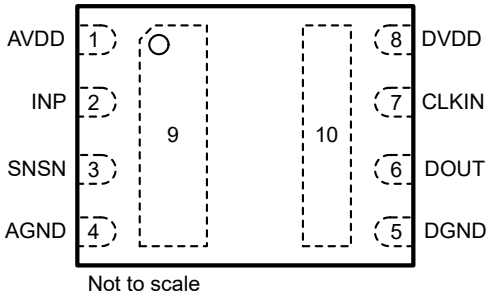

Figure 4-1. DEN Package, 8-pin VSON (Top View)

Table 4-1. Pin Functions

PIN		TYPE	DESCRIPTION
NO.	NAME		
1	AVDD	High-side power	Analog (high-side) power supply(1)
2	INP	Analog input	Noninverting analog input. Connect a 10nF filter capacitor from INP to SNSN.
3	SNSN	Analog input	AGND sense pin and inverting input to the modulator. Connect to AGND.
4	AGND	High-side ground	Analog (high-side) ground
5	DGND	Low-side ground	Digital (low-side) ground
6	DOUT	Digital output	Modulator data output
7	CLKIN	Digital input	Modulator clock input with internal pulldown resistor (typical value: 1.5MΩ)
8	DVDD	Low-side power	Digital (low-side) power supply(1)

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

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5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Power-supply voltage	High-side AVDD to AGND	–0.3	6.5	V
	Low-side DVDD to DGND	–0.3	6.5	
Analog input voltage	INP to AGND	AGND – 3	AVDD + 0.5	V
Digital input voltage	CLKIN to DGND	DGND – 0.5	DVDD+ 0.5	V
Digital output voltage	DOUT to DGND	DGND – 0.5	DVDD + 0.5	V
Transient isolation voltage(2)	AC voltage, t = 60s(3)		570	V_{RMS}
	DC voltage, t = 60s(3)		800	V_{DC}
Input current	Continuous, any pin except power-supply pins	–10	10	mA
Temperature	Junction, T_J		150	°C
	Storage, T_{stg}	–65	150	

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) Common-mode from left-side (pins1-4) to right-side (pins5-8) of the package.
(3) Cumulative.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged-device model (CDM), per per ANSI/ESDA/JEDEC JS-002(2)	±1000	

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

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5.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

			MIN	NOM	MAX	UNIT
POWER SUPPLY						
AVDD	Hgh-side power supply	AVDD to AGND	3	5.0	5.5	V
DVDD	Low-side power supply	DVDD to DGND	2.7	3.3	5.5	V
ANALOG INPUT						
$V_{Clipping}$	Input voltage before clipping output	$V_{IN} = V_{INP} – V_{SNSN}$		±1.25		V
V_{FSR}	Specified linear differential input voltage	$V_{IN} = V_{INP} – V_{SNSN}$	–1		1	V
DIGITAL I/O						
V_{IO}	Digital input/output voltage		0		DVDD	V
f_{CLKIN}	Input clock frequency		5	10	11	MHz
t_{HIGH}	Input clock high time		40	50	110	ns
t_{LOW}	Input clock low time		40	50	110	ns
ISOLATION BARRIER						
V_{IOWM}	Functional isolation working voltage(1)	AC voltage (sine wave)			200	V_{RMS}
		DC voltage			280	V_{DC}
TEMPERATURE RANGE						
T_A	Specified ambient temperature		–40		125	°C

(1) Common-mode from left-side (pins1-4) to right-side (pins5-8) of the package.

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5.4 Thermal Information (DEN Package)

THERMAL METRIC[1]		DEN (VSON)	UNIT
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	64.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	53.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	29.6	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	10.1	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	29.4	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	23.4	°C/W

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

5.5 Package Characteristics

PARAMETER		TEST CONDITIONS	VALUE	UNIT
DEN PACKAGE				
CLR	External clearance	Shortest pin-to-pin distance through air	≥ 1	mm
CPG	External creepage	Shortest pin-to-pin distance across the package surface	≥ 1	mm
CTI	Comparative tracking index	DIN EN 60112 (VDE 0303-11); IEC 60112	≥ 600	V
	Material group	According to IEC 60664-1	I	
C_{IO}	Capacitance, input to output[1]	V_{IO} = 0.5 V_{PP} at 1MHz	~1.5	pF
R_{IO}	Resistance, input to output[1]	T_A = 25°C	> 10^{12}	Ω

(1) All pins on each side of the barrier are tied together, creating a two-pin device.

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5.6 Electrical Characteristics

minimum and maximum specifications apply from T_A = –40°C to +125°C, AVDD = 3.0V to 5.5V, DVDD = 2.7V to 5.5V, V_{INP} = –1V to +1V, and SNSN = AGND; typical specifications are at T_A = 25°C, AVDD = 5V, DVDD = 3.3V, and f_{CLKIN} = 10MHz (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
ANALOG INPUT						
C_{IN}	Input capacitance	f_{CLKIN} = 10MHz		2		pF
R_{IN}	Input resistance	INP pin to AGND, SNSN = AGND	0.1	1		GΩ
I_{IB}	Input bias current(1)	INP = AGND	–10	±3	10	nA
CMTI	Common-mode transient immunity		150			V/ns
DC ACCURACY						
E_O	Offset error	T_A = 25°C, INP = AGND	–0.9	±0.08	0.9	mV
TCE_O	Offset error temperature drift(3)			3.5	8.5	µV/°C
E_G	Gain error(1)	Initial, at T_A = 25°C, V_{INP} = 1V or V_{INP} = –1V	–0.25	±0.02	0.25	%
TCE_G	Gain error temperature drift(4)		–35	±10	35	ppm/°C
INL	Integral nonlinearity(2)	Resolution: 16 bits	–6	±1	6	LSB
DNL	Differential nonlinearity	Resolution: 16 bits	–0.99		0.99	LSB
PSRR	Power-supply rejection ratio	AVDD DC PSRR, IN = AGND, AVDD from 3.0V to 5.5V		–83		dB
		AVDD AC PSRR, IN = AGND, AVDD with10kHz / 100mV ripple		–63		
AC ACCURACY						
SNR	Signal-to-noise ratio	V_{IN} = $2V_{PP}$, f_{IN} = 1kHz	86	89		dB
SINAD	Signal-to-noise + distortion	V_{IN} = $2V_{PP}$, f_{IN} = 1kHz	77	88		dB
THD	Total harmonic distortion(5)	V_{IN} = $2V_{PP}$, f_{IN} = 1kHz		–91	–80	dB
DIGITAL INPUT (CMOS Logic With Schmitt-Trigger)						
I_{IN}	Input current	DGND ≤ V_{IN} ≤ DVDD			7	µA
C_{IN}	Input capacitance			4		pF
V_{IH}	High-level input voltage		0.7 x DVDD		DVDD + 0.3	V
V_{IL}	Low-level input voltage		–0.3		0.3 x DVDD	V
DIGITAL OUTPUT (CMOS)						
C_{LOAD}	Output load capacitance	f_{CLKIN} = 10MHz		15	30	pF
V_{OH}	High-level output voltage	I_{OH} = –4mA	DVDD – 0.4			V
V_{OL}	Low-level output voltage	I_{OL} = 4mA			0.4	V
POWER SUPPLY						
I_{AVDD}	High-side supply current			5.3	7	mA
I_{DVDD}	Low-side supply current	C_{LOAD} = 15pF		3.6	5	mA
$AVDD_{UV}$	High-side undervoltage detection threshold	AVDD rising	2.4	2.6	2.7	V
		AVDD falling	1.9	2.0	2.1	
$DVDD_{UV}$	Low-side undervoltage detection threshold	DVDD rising	2.3	2.5	2.7	V
		DVDD falling	1.9	2.0	2.1	

(1) The typical value includes one sigma statistical variation.
(2) Integral nonlinearity is defined as the maximum deviation from a straight line passing through the end-points of the ideal ADC transfer function expressed as number of LSBs or as a percent of the specified linear full-scale range FSR.
(3) Offset error drift is calculated using the box method, as described by the following equation:
TCE_O = ($value_{MAX}$ - $value_{MIN}$) / TempRange
(4) Gain error drift is calculated using the box method, as described by the following equation:
TCE_G (ppm) = (($value_{MAX}$ - $value_{MIN}$) / (value x TempRange)) X 10^6
(5) THD is the ratio of the rms sum of the amplitudes of first five higher harmonics to the amplitude of the fundamental.

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5.7 Switching Characteristics

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_H	DOUT hold time after rising edge of CLKIN	C_{LOAD} = 15pF	10			ns
t_D	Rising edge of CLKIN to DOUT valid delay	C_{LOAD} = 15pF			35	ns
t_r	DOUT rise time	10% to 90%, 2.7V ≤ DVDD ≤ 3.6V, C_{LOAD} = 15pF		2.5	6	ns
		10% to 90%, 4.5V ≤ DVDD ≤ 5.5V, C_{LOAD} = 15pF		3.2	6	
t_f	DOUT fall time	10% to 90%, 2.7V ≤ DVDD ≤ 3.6V, C_{LOAD} = 15pF		2.2	6	ns
		10% to 90%, 4.5V ≤ DVDD ≤ 5.5V, C_{LOAD} = 15pF		2.9	6	
t_{START}	Device start-up time	AVDD step from 0 to 3.0V with AVDD ≥ 2.7V to bitstream valid, 0.1% settling		30		µs

5.8 Timing Diagram

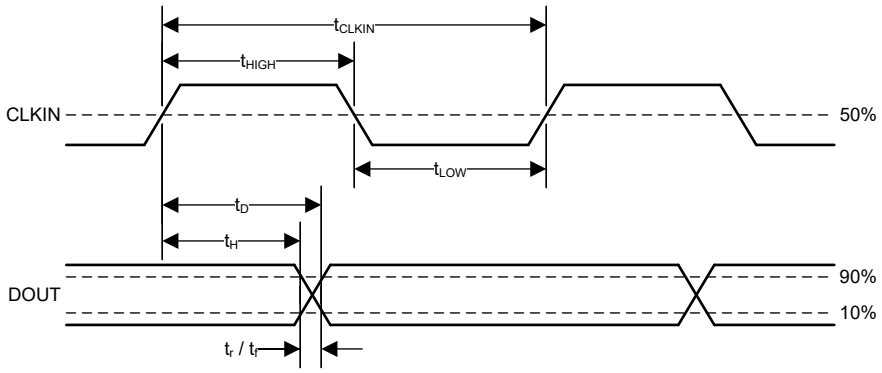

Figure 5-1. Digital Interface Timing

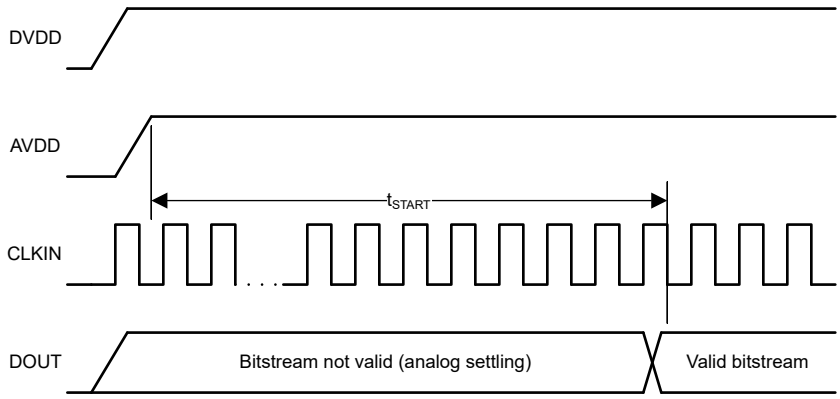

Figure 5-2. Device Start-Up Timing

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5.9 Typical Characteristics

at AVDD = 5 V, DVDD = 3.3 V, V_{INP} = –1 V to 1 V, SNSN = AGND, and sinc^3 filter with OSR = 256 (unless otherwise noted)

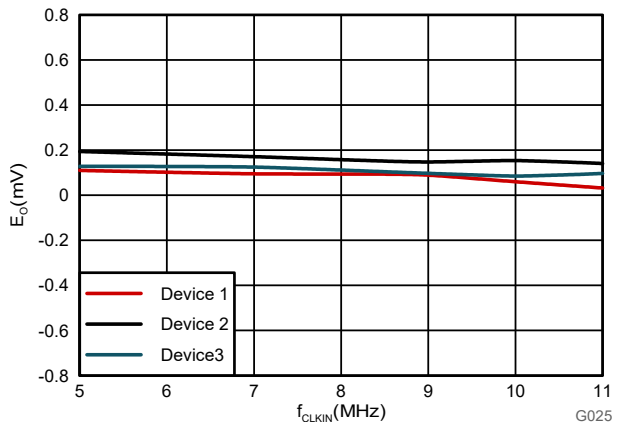

Figure 5-3. Offset Error vs Clock Frequency

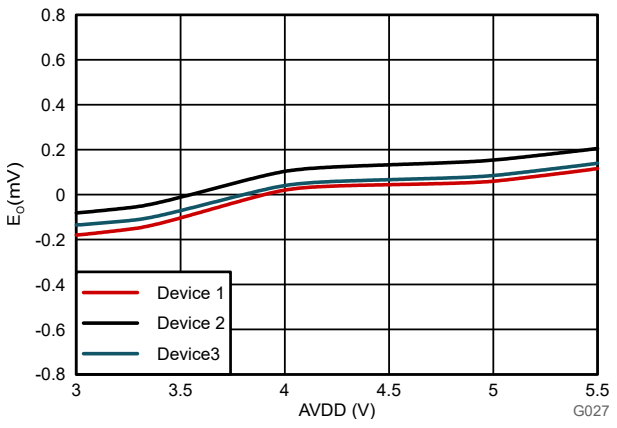

Figure 5-4. Offset Error vs High-Side Supply Voltage

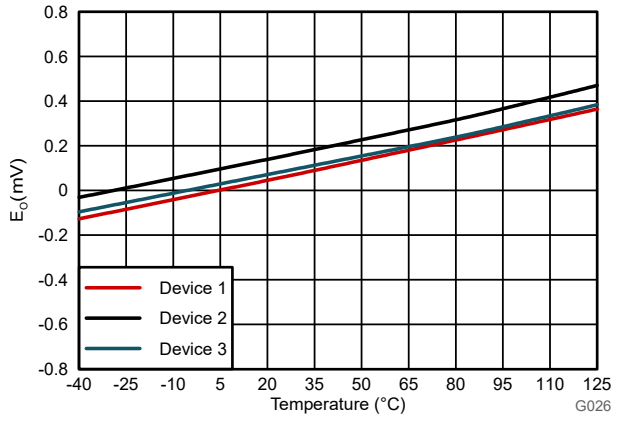

Figure 5-5. Offset Error vs Temperature

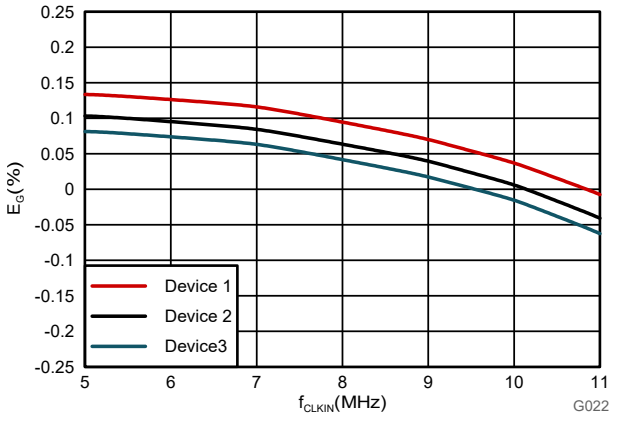

Figure 5-6. Gain Error vs Clock Frequency

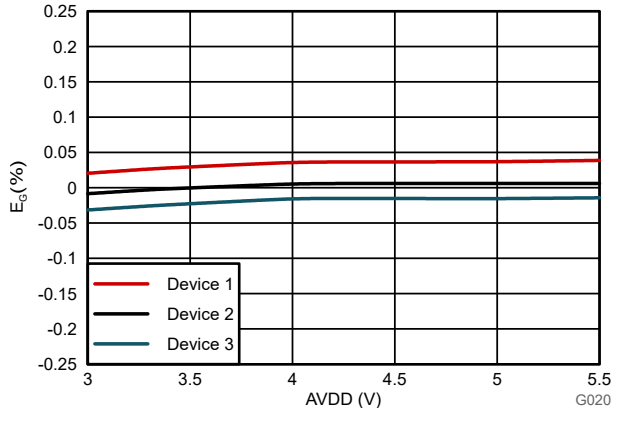

Figure 5-7. Gain Error vs High-Side Supply Voltage

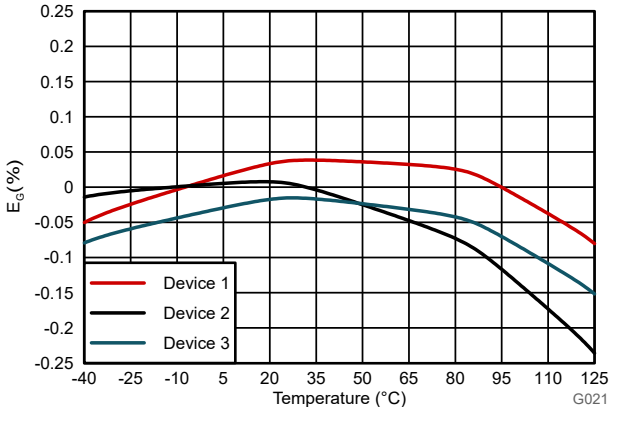

Figure 5-8. Gain Error vs Temperature

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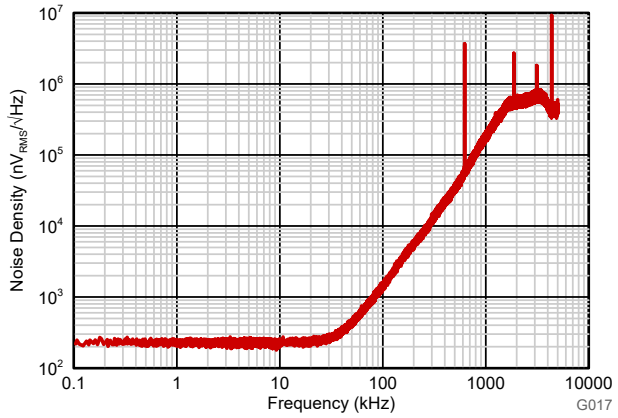
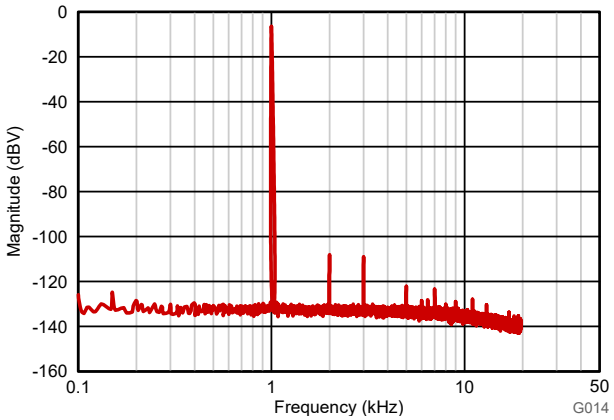
5.9 Typical Characteristics (continued)

at AVDD = 5 V, DVDD = 3.3 V, V_{INP} = –1 V to 1 V, SNSN = AGND, and sinc^3 filter with OSR = 256 (unless otherwise noted)



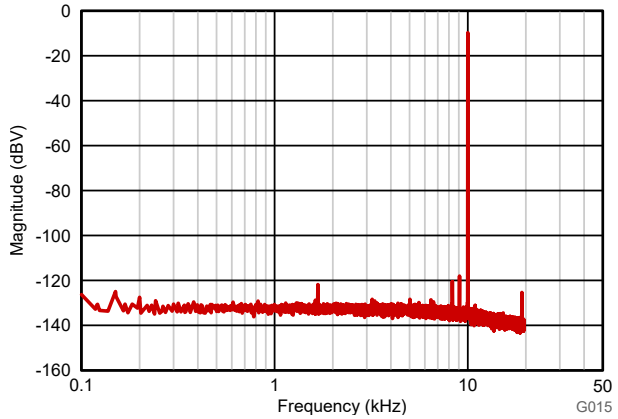
sinc^3, OSR = 1; Frequency bin-width equals 1Hz

Figure 5-9. Noise Density With Both Inputs Shorted to AGND



sinc^3, OSR = 256, V_{INP} = 2V_{PP}

Figure 5-10. Frequency Spectrum With 1-kHz Input Signal



sinc^3, OSR = 256, V_{INP} = 2V_{PP}

Figure 5-11. Frequency Spectrum With 10-kHz Input Signal

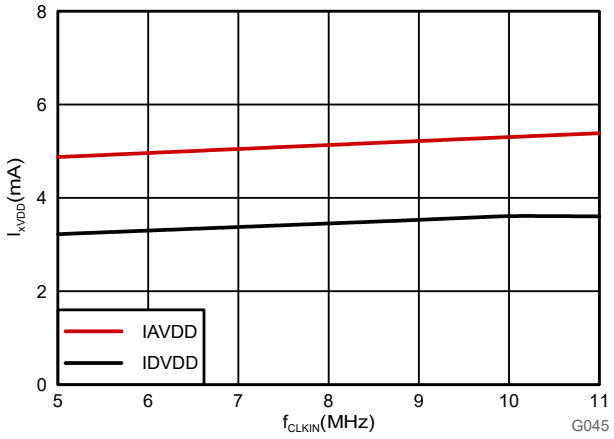


Figure 5-12. Supply Current vs Clock Frequency

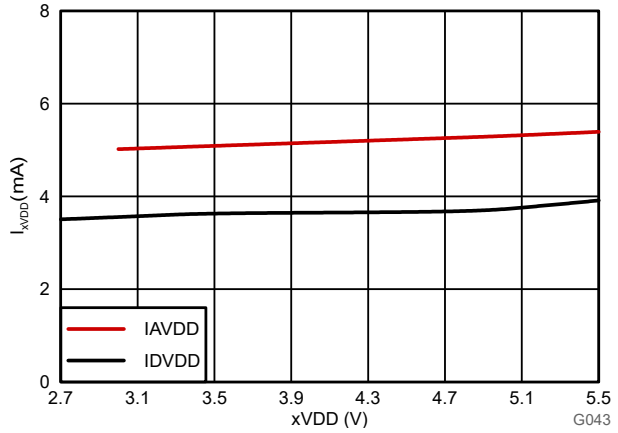


Figure 5-13. Supply Current vs Supply Voltage

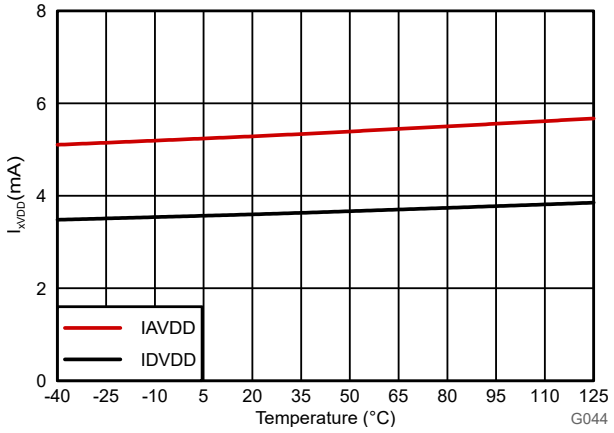


Figure 5-14. Supply Current vs Temperature

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6 Detailed Description

6.1 Overview

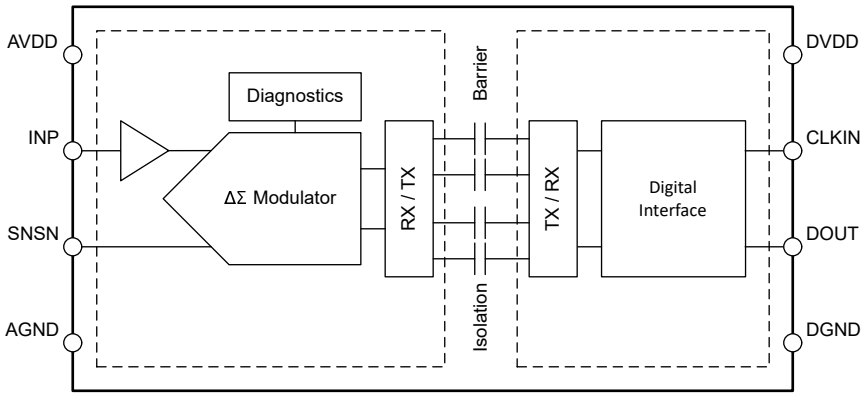
The AMC0136 is a single-channel, second-order, CMOS, delta-sigma (ΔΣ) modulator with a high impedance input, designed for high resolution voltage measurements. The isolated output of the converter (DOUT) provides a stream of digital ones and zeros synchronous to the external clock applied to the CLKIN pin. The time average of this serial output is proportional to the analog input voltage.

The modulator shifts the quantization noise to high frequencies; therefore, use a digital low-pass digital filter, such as a Sinc filter at the device output to increase overall performance. This filter also converts the 1-bit data stream at a high sampling rate into a higher-bit data word at a lower rate (decimation). Use a microcontroller (μC) or field-programmable gate array (FPGA) to implement the filter.

The overall performance (speed and resolution) depends on the selection of an appropriate oversampling ratio (OSR) and filter type. A higher OSR results in higher resolution while operating at a lower refresh rate. A lower OSR results in lower resolution, but provides data at a higher refresh rate. This system allows flexibility with the digital filter design and is capable of analog-to-digital conversion results with a dynamic range exceeding 89dB with OSR = 256.

The silicon-dioxide (SiO_2) based capacitive isolation barrier supports a high level of magnetic field immunity; see the *ISO72x Digital Isolator Magnetic-Field Immunity* application note. The AMC0136 uses an on-off keying (OOK) modulation scheme to transmit data across the isolation barrier. This modulation and the isolation barrier characteristics, result in high reliability in noisy environments and high common-mode transient immunity.

6.2 Functional Block Diagram

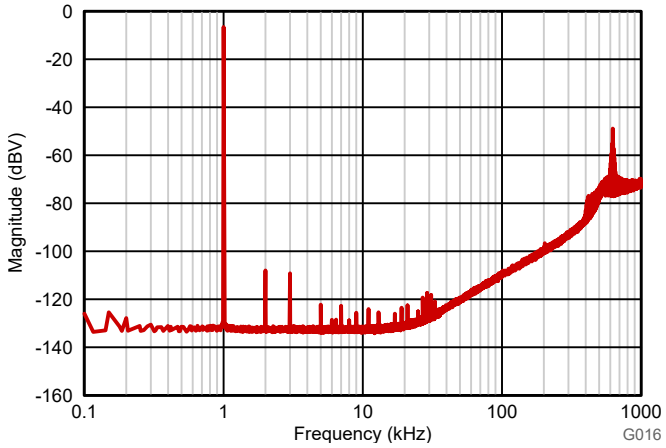


6.3 Feature Description

6.3.1 Analog Input

The high-impedance input buffer on the INP pin feeds a second-order, switched-capacitor, feed-forward ΔΣ modulator. The modulator converts the analog signal into a bitstream that is transferred across the isolation barrier, as described in the *Isolation Channel Signal Transmission* section.

For reduced offset and offset drift, the input buffer is chopper-stabilized with the chopping frequency set at $f_{CLKIN}/16$. Figure 6-1 shows the spur at 625kHz that is generated by the chopping frequency for a modulator clock of 10MHz.



sinc^3 filter, OSR = 1, f_{CLKIN} = 10 MHz, f_{IN} = 1 kHz

Figure 6-1. Quantization Noise Shaping

There are two restrictions on the analog input signal. First, if the input voltage exceeds the value specified in the *Absolute Maximum Ratings* table, the input current must be limited to 10mA. This limitation is caused by the device input electrostatic discharge (ESD) diodes turning on. Second, linearity and noise performance are specified only when the input voltage is within the linear fullscale range (V_{FSR}). V_{FSR} is specified in the *Recommended Operating Conditions* table.

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6.3.2 Modulator

Figure 6-2 conceptualizes the second-order, switched-capacitor, feed-forward ΔΣ modulator implemented in the AMC0136. The output V_5 of the 1-bit, digital-to-analog converter (DAC) is subtracted from the input voltage V_{IN} = (V_{INP} – V_{SNSN}). This subtraction provides 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. The result or the second integration is an output voltage V_3 that is summed with the input signal V_{IN} and the output of the first integrator V_2. Depending on the value 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. Thus, causing the integrators to progress in the opposite direction and forcing the integrator output value to track the average value of the input.

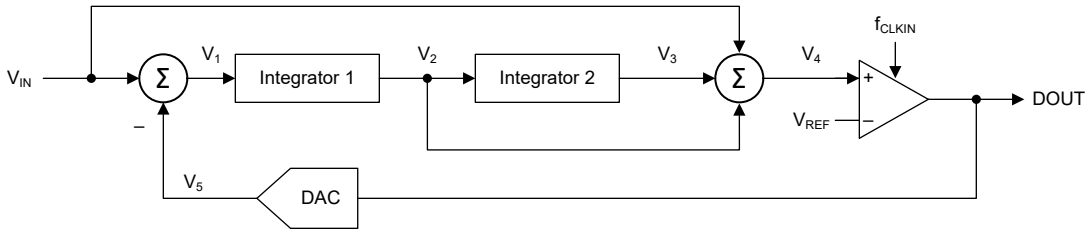

Figure 6-2. Block Diagram of the Second-Order Modulator

6.3.3 Isolation Channel Signal Transmission

The AMC0136 uses an on-off keying (OOK) modulation scheme, as shown in Figure 6-3, to transmit the modulator output bitstream across the SiO_2-based isolation barrier. The transmit driver (TX) as illustrated in the *Functional Block Diagram* transmits an internally generated, high-frequency carrier across the isolation barrier to represent a digital *one*. However, TX does not send a signal to represent a digital *zero*. The nominal frequency of the carrier used inside the AMC0136 is 480MHz.

The AMC0136 transmission channel is optimized to achieve the highest level of common-mode transient immunity (CMTI) and the lowest level of radiated emissions. The high-frequency carrier and RX/TX buffer switching cause these emissions.

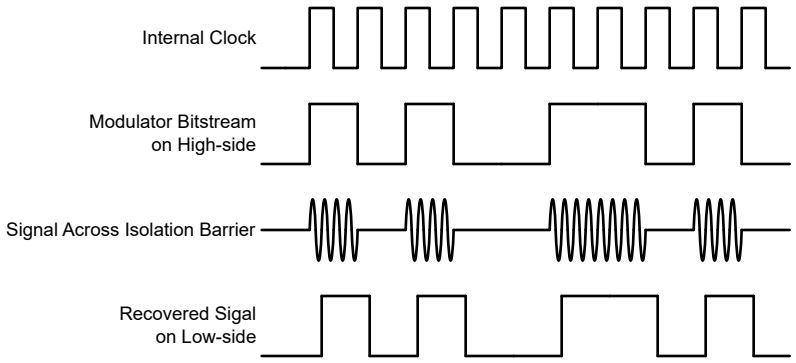

Figure 6-3. OOK-Based Modulation Scheme

6.3.4 Digital Output

An input signal of 0V ideally produces a stream of ones and zeros that are high 50% of the time. An input of 1V produces a stream of ones and zeros that are high 90.0% of the time. With 16 bits of resolution, that percentage ideally corresponds to code 58982. An input of –1V produces a stream of ones and zeros that are high 10.0% of the time. With 16 bits of resolution, that percentage ideally corresponds to code 6554. These input voltages are also the specified linear range of the AMC0136. If the input voltage value exceeds this range, the output of the modulator shows increasing nonlinear behavior as the quantization noise increases. The modulator output clips with a constant stream of zeros at an input ≤–1.25V or with a constant stream of ones at an input ≥1.25V. In this case, however, the AMC0136 generates a single 1 or 0 every 128 clock cycles to indicate proper device function. A single 1 is generated if the input is at negative fullscale and a 0 is generated if the input is at positive fullscale. See the *Output Behavior in Case of a Full-Scale Input* section for more details. Figure 6-4 shows the input voltage versus the output modulator signal.

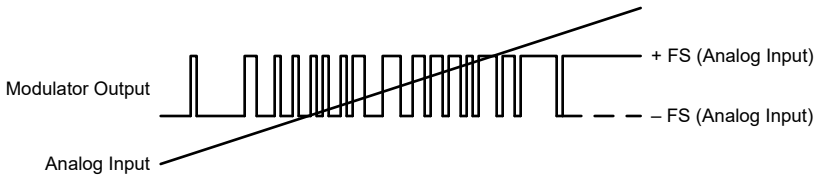

Figure 6-4. Modulator Output vs Analog Input

Calculate the density of ones in the output bitstream with Equation 1 for any input voltage $V_{IN} = (V_{INP} – V_{SNSN})$ value. The only exception is a fullscale input signal. See the *Output Behavior in Case of a Full-Scale Input* section.

$$\rho = (|V_{Clipping}| + V_{IN}) / (2 \times V_{Clipping}) \quad (1)$$

6.3.4.1 Output Behavior in Case of a Full-Scale Input

If a fullscale input signal is applied to the AMC0136, the device generates a single one or zero every 128 bits at DOUT. Figure 6-5 shows a timing diagram of this process. A single 1 or 0 is generated depending on the actual polarity of the signal being sensed. A fullscale signal is defined as $|V_{INP} – V_{SNSN}| \geq |V_{Clipping}|$. In this way, differentiating between a missing AVDD and a fullscale input signal is possible on the system level. See the *Diagnosing Delta-Sigma Modulator Bitstream Using C2000™ Configurable Logic Block (CLB)* application note for code examples of diagnosing the digital bitstream.

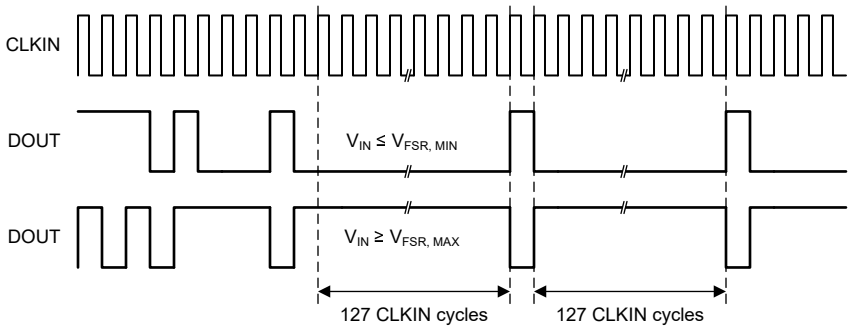

Figure 6-5. Fullscale Output of the AMC0136

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6.3.4.2 Output Behavior in Case of a Missing High-Side Supply

If the high-side supply (AVDD) is missing, the device provides a constant bitstream of logic 0's at the output, and DOUT is permanently low. Figure 6-6 shows a timing diagram of this process. A one is not generated every 128 clock pulses, which differentiates this condition from a valid negative fullscale input. This feature helps identify high-side power-supply problems on the board. See the *Diagnosing Delta-Sigma Modulator Bitstream Using C2000™ Configurable Logic Block (CLB)* application note for code examples of diagnosing the digital bitstream.

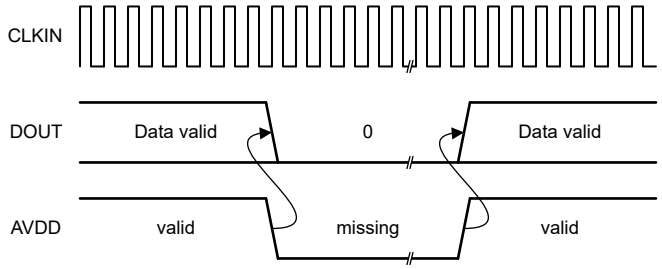

Figure 6-6. Output of the AMC0136 in Case of a Missing High-Side Supply

6.4 Device Functional Modes

The AMC0136 operates in one of the following states:

- OFF-state: The low-side of the device (DVDD) is below the $DVDD_{UV}$ threshold. The device is not responsive. DOUT is Hi-Z state. Internally, DOUT and CLKIN are clamped to DVDD and DGND by ESD protection diodes.
- Missing high-side supply: The low-side of the device (DVDD) is supplied and within *Recommended Operating Conditions* . The high-side supply (AVDD) is below the $AVDD_{UV}$ threshold. The device outputs a constant bitstream of logic 0's, as described in the section.
- Analog input overrange (positive fullscale input): AVDD and DVDD are within recommended operating conditions but the analog input voltage $V_{IN} = (V_{INP} – V_{SNSN})$ is above the maximum clipping voltage ($V_{Clipping, MAX}$). The device outputs a logic 0 every 128 clock cycles, as described in the *Output Behavior in Case of a Full-Scale Input* section.
- Analog input underrange (negative fullscale input): AVDD and DVDD are within recommended operating conditions but the analog input voltage $V_{IN} = (V_{INP} – V_{SNSN})$ is below the minimum clipping voltage ($V_{Clipping, MIN}$). The device outputs a logic 1 every 128 clock cycles, as described in the *Output Behavior in Case of a Full-Scale Input* section.
- Normal operation: AVDD, DVDD, and V_{IN} are within the recommended operating conditions. The device outputs a digital bitstream, as explained in the *Digital Output* section.

Table 6-1 lists the operational modes.

Table 6-1. Device Operational Modes

OPERATINAL MODE	AVDD	DVDD	V_{IN}	DEVICE RESPONSE
OFF	Don't care	$V_{DVDD} < DVDD_{UV}$	Don't care	DOUT is Hi-Z state. Internally, DOUT and CLKIN are clamped to DVDD and DGND by ESD protection diodes.
Missing high-side supply	$V_{AVDD} < AVDD_{UV}$	Valid(1)	Don't care	The device outputs a constant bitstream of logic 0's, as described in the section.
Input overrange	Valid(1)	Valid(1)	$V_{IN} > V_{Clipping, MAX}$	The device outputs a logic 0 every 128 clock cycles, as described in the *Output Behavior in Case of a Full-Scale Input* section.
Input underrange	Valid(1)	Valid(1)	$V_{IN} < V_{Clipping, MIN}$	The device outputs a logic 1 every 128 clock cycles, as described in the *Output Behavior in Case of a Full-Scale Input* section.
Normal operation	Valid(1)	Valid(1)	Valid(1)	Normal operation

(1) "Valid" denotes within the recommended operating conditions.

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7 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.

7.1 Application Information

Isolated modulators are widely used in applications where a noisy power domain is galvanically isolated from a quiet signal domain for safety or functional reasons. A typical application is the sensing of the DC link voltage in a frequency inverter.

7.2 Typical Application

Figure 7-1 shows a simplified schematic of a full-bridge motor drive that uses an AMC0136 to sense the 48V DC link voltage. The DC link voltage is divided down to a 1V level by the resistive divider consisting of R1 and RSNS. The AMC0136 digitizes the analog input signal on the high-side and transfers the data across the isolation barrier to the low-side. The device then outputs the digital bitstream on the DOUT pin that is synchronized to the clock applied to the CLKIN pin. The digital bitstream is processed by a low-pass digital filter in a micro control unit (MCU) or FPGA.

The motor current in this application is sensed by an AMC0106M05 isolated modulator.

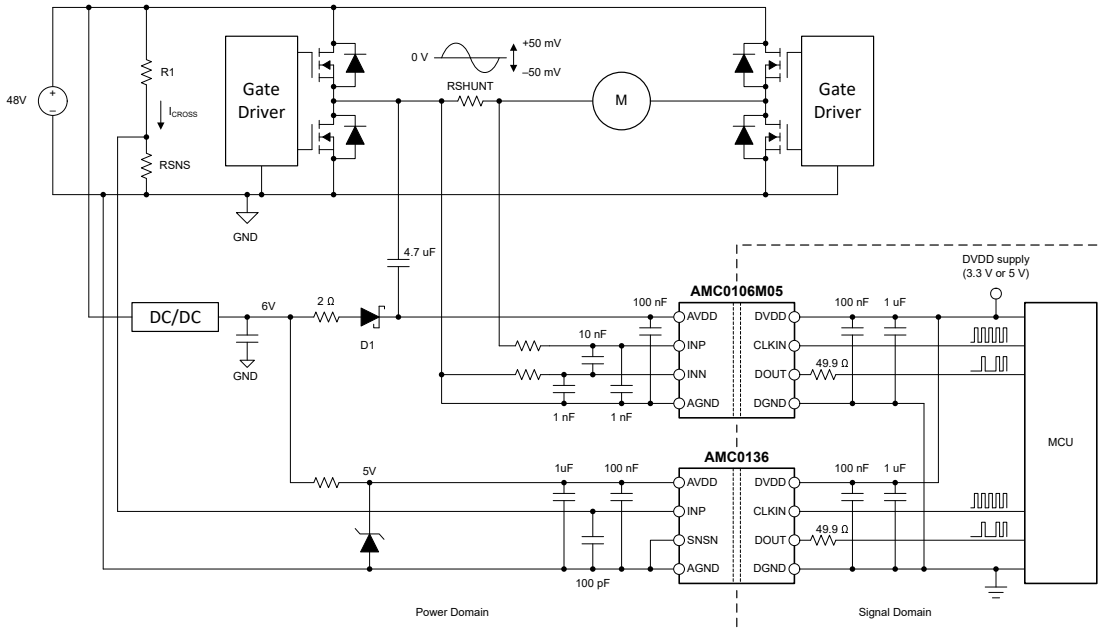

Figure 7-1. Using the AMC0136 in a Typical Application

The AMC0136 requires a 3.3V or 5V supply to power the high-side (AVDD) of the isolated modulator. In this example, AVDD is derived from the 48V rail by a DC/DC converter and a shunt regulator. The low-side supply (DVDD) is shared with circuitry in the signal domain. Use the optional 49.9Ω resistor on the DOUT pin for line-termination to improve signal integrity on the receiving end.

The galvanic isolation barrier and high common-mode transient immunity (CMTI) of the AMC0136 provide reliable and accurate operation even in high-noise environments.

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7.2.1 Design Requirements

Table 7-1 lists the parameters for this typical application.

Table 7-1. Design Requirements

PARAMETER	VALUE
Nominal DC link voltage	48V
Linear voltage sensing range (V_{FSR})	60V
Voltage drop across the sensing resistor (RSNS) for a linear response	1V
Maximum current through the resistive divider, I_{CROSS}, at linear full-scale voltage	100µA

7.2.2 Detailed Design Procedure

The 100µA cross-current requirement at the maximum system voltage (60V) determines that the total impedance of the resistive divider is 600kΩ. The impedance of the resistive divider is dominated by R1, thus neglecting the voltage drop across RSNS for a moment is acceptable. The closest value to 600kΩ from the E96 series is 604kΩ. This value is for R1.

The linear full-scale input voltage (V_{FSR}) of the AMC0136 is 1V. RSNS is sized to produce a 1V drop at the maximum system voltage of 60V. RSNS is calculated as RSNS = V_{FSR} / ($V_{DC\text{-}link,\ max}$ – V_{FSR}) × R_1. The resulting value is 10.24kΩ and the closest value from the E96 series is 10.2kΩ.

Table 7-2 summarizes the design parameters for this application.

Table 7-2. Design Summary

PARAMETER	VALUE
R1 resistor value	604kΩ
Sense resistor value (RSNS)	10.2kΩ
Resulting current through resistive divider (I_{CROSS} at 60V)	97.7µA
Resulting full-scale voltage drop across sense resistor (RSNS)	996mV
Total power dissipated in resistive divider	5.9mW

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7.2.2.1 Input Filter Design

Place a RC filter in front of the device to improve signal-to-noise performance of the signal path. Input noise with a frequency close to the ΔΣ modulator sampling frequency (typically 10MHz) is folded back into the low-frequency range by the modulator. The purpose of the RC filter is to attenuate high-frequency noise below the desired noise level of the measurement. In practice, a cutoff frequency that is two orders of magnitude lower than the modulator frequency yields good results.

Most voltage-sensing applications use high-impedance resistive dividers in front of the isolated modulator to scale down the input voltage. In this case, a single capacitor, as shown in Figure 7-2, is sufficient to filter the input signal. For R1 >> RSNS, the cut-off frequency of the input filter is 1 / (2 x π x RSNS x C5). For example, RSNS =10kΩ and C5 = 100pF results in a cutoff frequency of 160kHz.

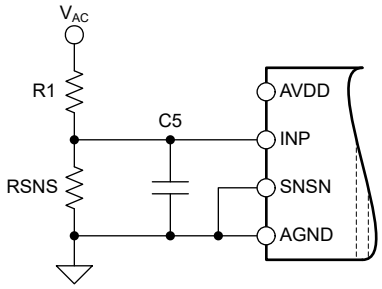

Figure 7-2. Input Filter

7.2.2.2 Bitstream Filtering

The modulator generates a bitstream that is processed by a digital filter to obtain a digital word similar to a conversion result of a conventional analog-to-digital converter (ADC). Equation 2 represents a $sinc^3$-type filter, which is a very simple filter that is built with minimal effort and hardware.

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

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 also done with a $sinc^3$ filter with an oversampling ratio (OSR) of 256 and an output word width of 16 bits.

An example code for implementing a $sinc^3$ 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.

For modulator output bitstream filtering, a device from TI's C2000 or Sitara microcontroller families is recommended. These families support multichannel dedicated hardwired filter structures that significantly simplify system level design by offering two filtering paths per channel: one path provides high-accuracy results for the control loop and the other provides a fast-response path for overcurrent detection.

A *delta sigma modulator filter calculator* is available for download at 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.

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7.2.2.3 Application Curves

The effective number of bits (ENOB) is often used to compare the performance of ADCs and ΔΣ modulators. Figure 7-3 shows the ENOB of the AMC0136 with different oversampling ratios.

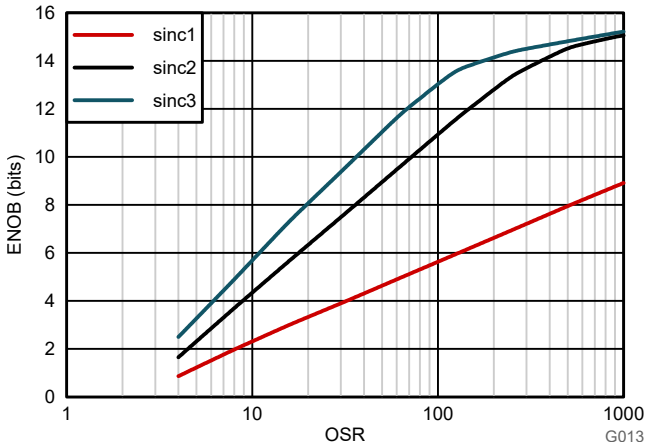

Figure 7-3. Measured Effective Number of Bits vs Oversampling Ratio

7.3 Best Design Practices

Do not leave the analog input (INP pin) of the AMC0136 unconnected when the device is powered up. If the device input is left floating, the output of the device is not valid.

Do not connect protection diodes to the input (INP pin) of the AMC0136. Diode leakage current potentially introduces significant measurement error especially at high temperatures. The input pin is protected against high voltages by the ESD protection circuit and the high impedance of the external resistive divider.

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7.4 Power Supply Recommendations

In a typical application, the high-side power supply (AVDD) for the AMC0136 is generated from the low-side supply (DVDD) by an isolated DC/DC converter. A low-cost option is based on the push-pull driver SN6501 and a transformer that supports the desired isolation voltage ratings.

The AMC0136 does not require any specific power-up sequencing. The high-side power supply (AVDD) is decoupled with a low-ESR, 100nF capacitor (C1) parallel to a low-ESR, 1µF capacitor (C2). The low-side power supply (DVDD) is equally decoupled with a low-ESR, 100nF capacitor (C3) parallel to a low-ESR, 1µF capacitor (C4). Place all four capacitors (C1, C2, C3, and C4) as close to the device as possible. Figure 7-4 shows a decoupling diagram for the AMC0136.

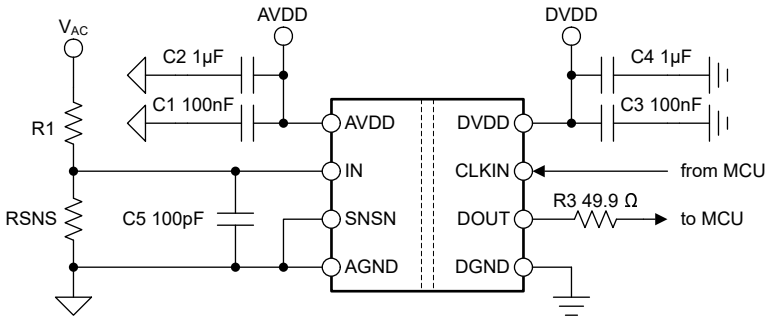

Figure 7-4. Decoupling of the AMC0136

Capacitors provide adequate effective capacitance under the applicable DC bias conditions experienced in the application. Multilayer ceramic capacitors (MLCC) typically exhibit only a fraction of the nominal capacitance under real-world conditions. Consider this factor when selecting these capacitors. This issue 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.

7.5 Layout

7.5.1 Layout Guidelines

The *Layout Example* section provides a layout recommendation showing the critical placement of the decoupling and filter capacitors. Decoupling and filter capacitors are placed as close as possible to the AMC0136 input pins.

7.5.2 Layout Example

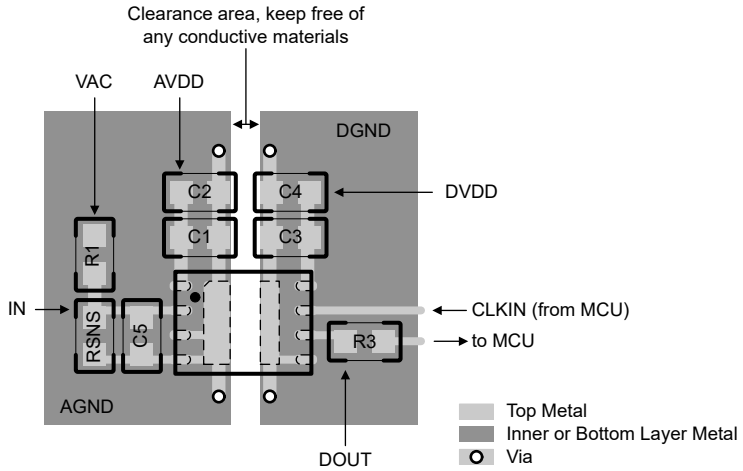

Figure 7-5. Recommended Layout of the AMC0136

8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

8.1 Documentation Support

8.1.1 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, *ISO72x Digital Isolator Magnetic-Field Immunity* application report
- Texas Instruments, *Diagnosing Delta-Sigma Modulator Bitstream Using C2000™ Configurable Logic Block (CLB)* application report
- Texas Instruments, *Combining the ADS1202 with an FPGA Digital Filter for Current Measurement in Motor Control Applications* application report
- Texas Instruments, *Delta Sigma Modulator Filter Calculator* design tool

8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* 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.

8.3 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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8.4 Trademarks

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All trademarks are the property of their respective owners.

8.5 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.

8.6 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

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

Changes from Revision * (August 2024) to Revision A (December 2024)	Page
• Updated the numbering format for tables, figures, and cross-refrerences throughout the document	1
• Changed the device status from Advanced to Production	1

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10 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.

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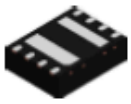
10.1 Mechanical Data

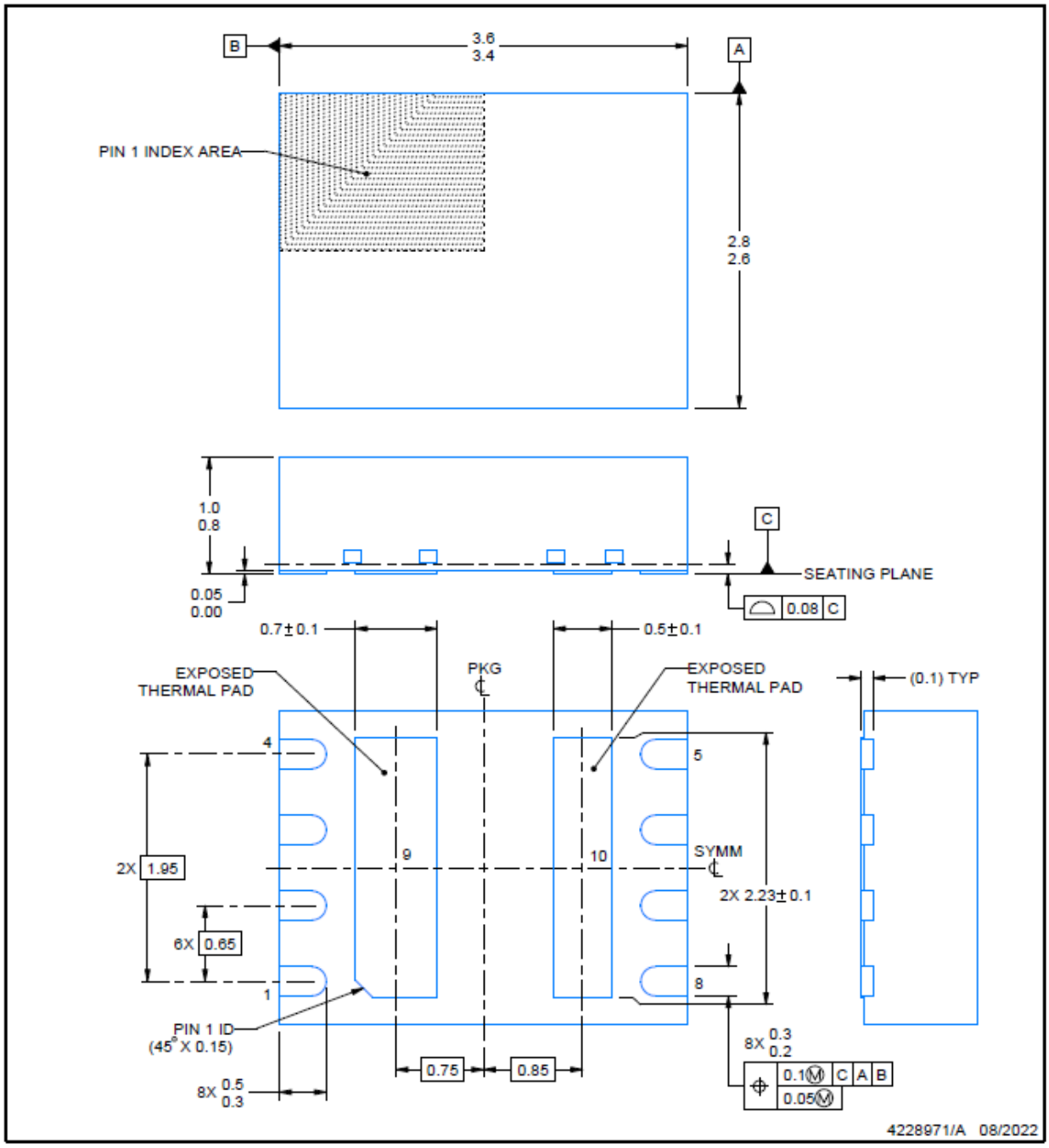
DEN0008A



PACKAGE OUTLINE

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



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. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

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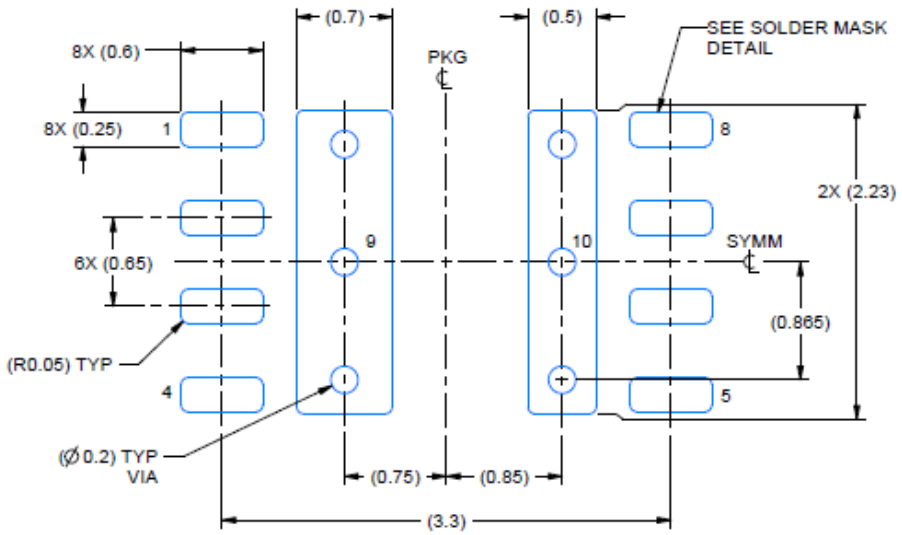
EXAMPLE BOARD LAYOUT

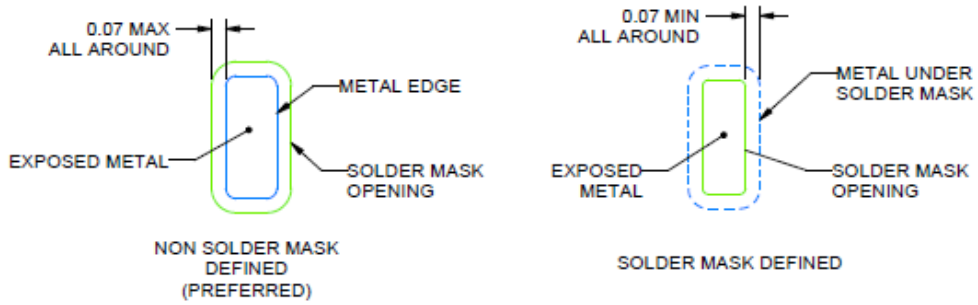
DEN0008A

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X



SOLDER MASK DETAILS

4228971/A 08/2022

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

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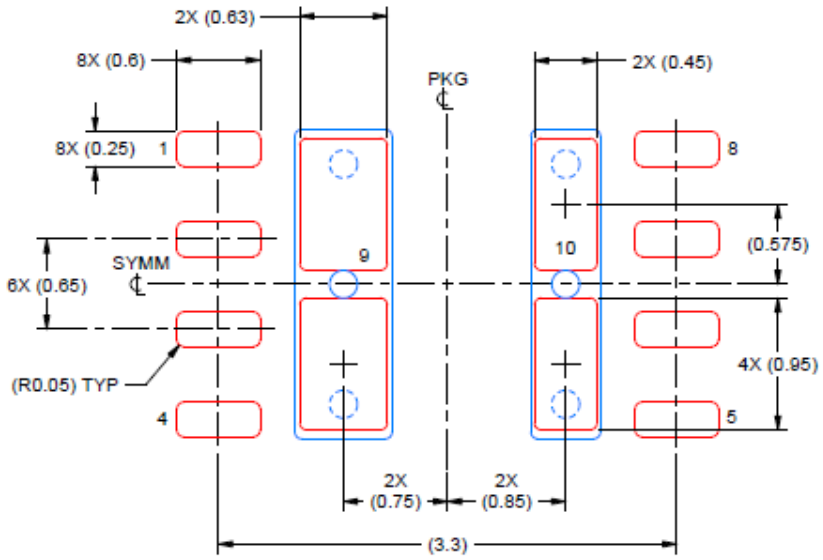
EXAMPLE STENCIL DESIGN

DEN0008A

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 20X

PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
PADS 9 & 10: 77%

4228971/A 08/2022

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
AMC0136DENR	Active	Production	VSON (DEN) | 8	5000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	0136
AMC0136DENR.A	Active	Production	VSON (DEN) | 8	5000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	0136
AMC0136DENR.B	Active	Production	VSON (DEN) | 8	5000 | LARGE T&R	-	Call TI	Call TI	-40 to 125	
PAMC0136DENR.B	Active	Preproduction	VSON (DEN) | 8	5000 | LARGE T&R	-	Call TI	Call TI	-40 to 125	

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

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

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

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

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

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

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

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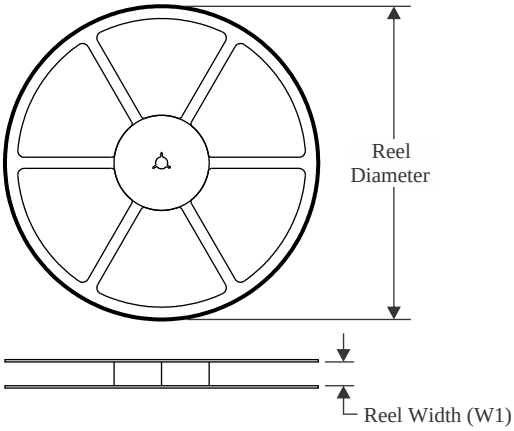
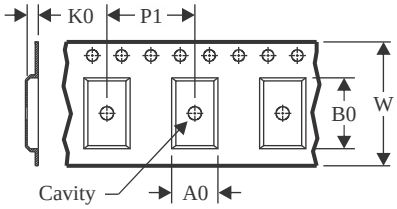
TAPE AND REEL INFORMATION

REEL DIMENSIONS

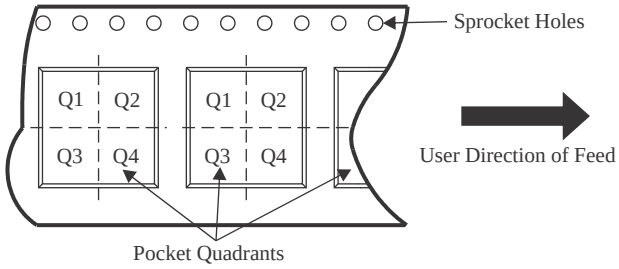


TAPE DIMENSIONS



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

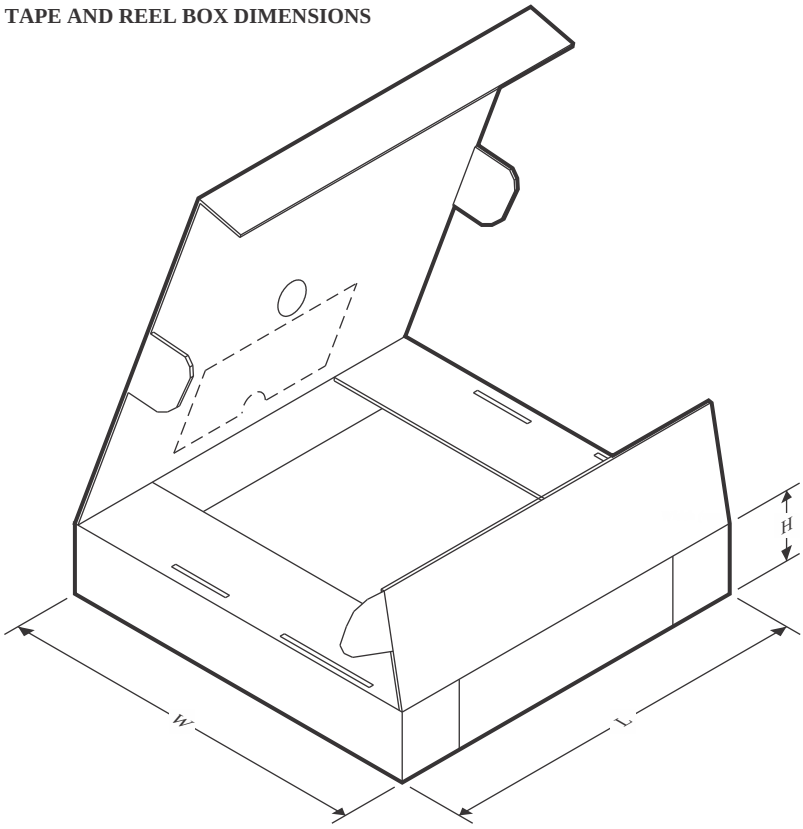
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
AMC0136DENR	VSON	DEN	8	5000	330.0	12.4	3.0	3.8	1.2	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

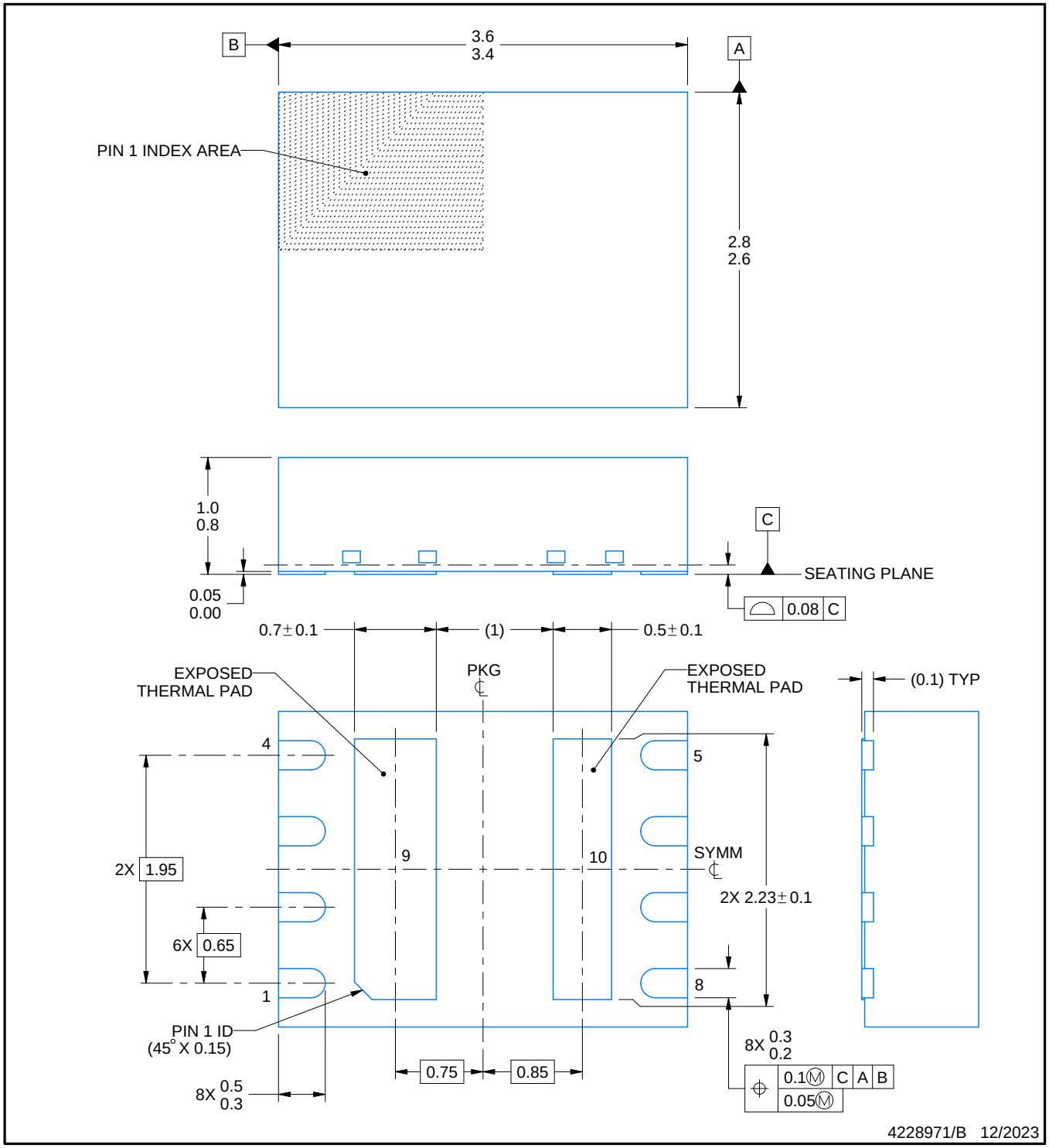
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
AMC0136DENR	VSON	DEN	8	5000	346.0	346.0	33.0

PACKAGE OUTLINE

DEN0008A

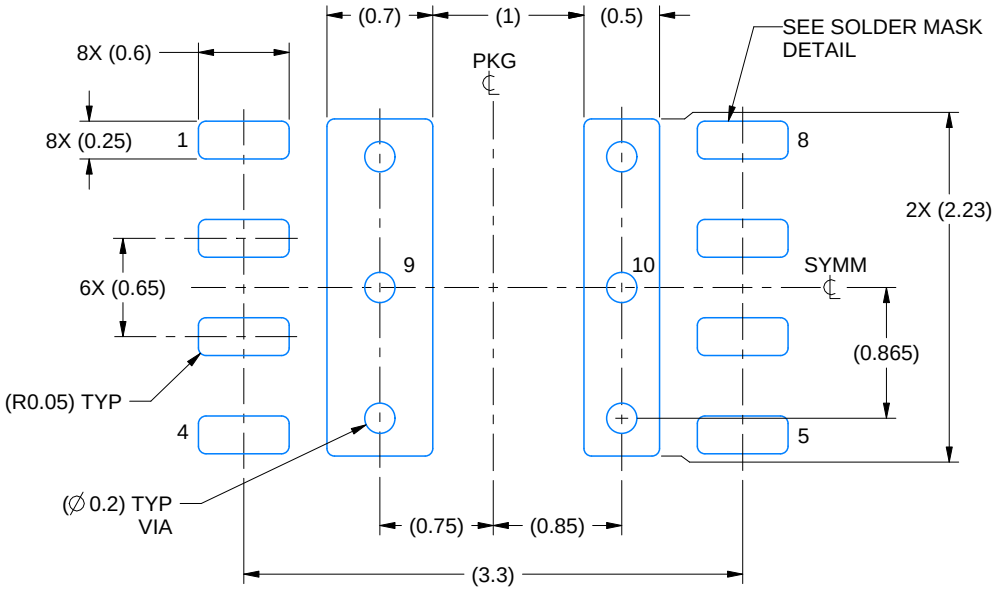
VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

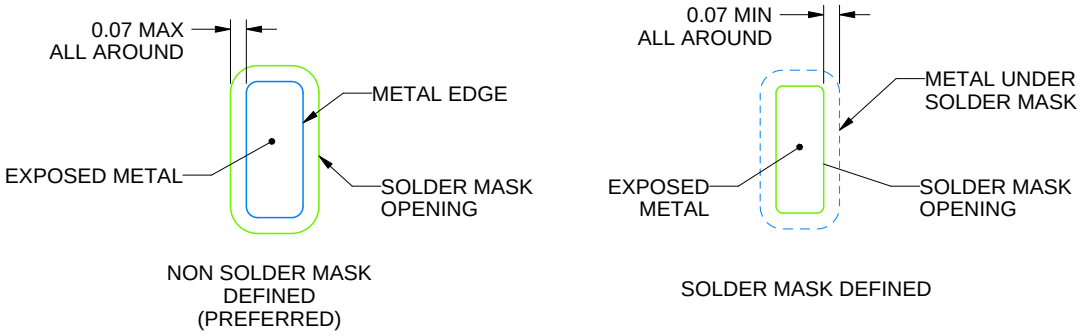


NOTES:

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. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X



SOLDER MASK DETAILS

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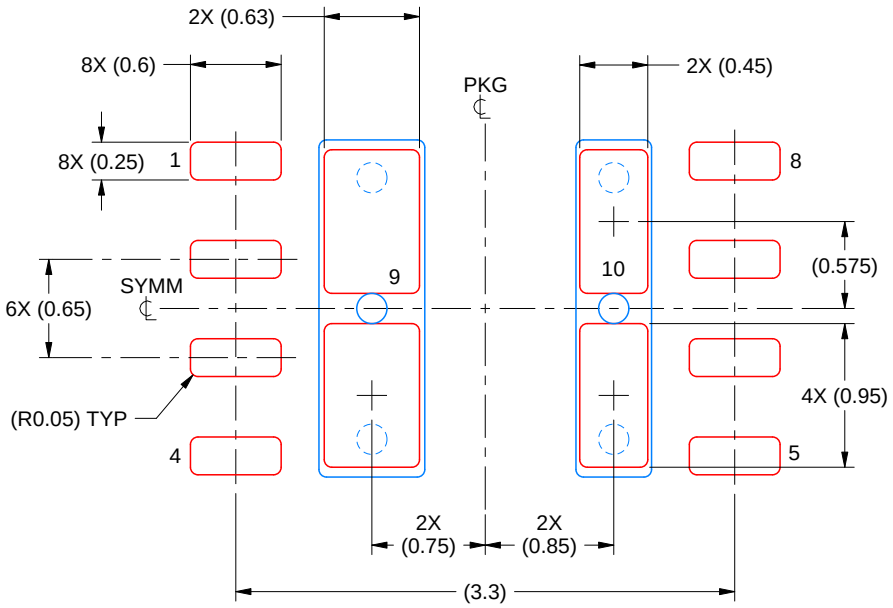
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 20X

PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
PADS 9 & 10: 77%

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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