Precision 120kHz Hall-Effect Current Sensor with 3.75kV$_{RMS}$ Isolation Voltage and Zero Current Output Voltage Reference

1. Features

- Differential hall sensing rejects common-mode fields and nearly zero magnetic hysteresis
- Integrated digital temperature compensation circuitry allows for near closed loop accuracy
- High immunity to external magnetic fields
- Precision zero-current reference output
- Primary conductor resistance: 1mΩ
- High current sense range capability
  - CA-IS23025S: ±25A_{PK}
  - CA-IS23030S: ±30A_{PK}
  - CA-IS23050S: ±50A_{PK}
- Fast response
  - Signal bandwidth: 120kHz
  - Propagation delay: 2µs
  - Response time: 3.7µs
- Operating supply voltage: 4.5V to 5.5V
- Bidirectional and unidirectional current sensing
- -40°C to +150°C Operating Junction Temperature Range
- Robust Galvanic Isolation
  - 3750V_{RMS} withstand isolation voltage
  - 297V_{RMS} maximum working isolation voltage
  - 6kV maximum surge isolation withstand voltage
- 8-pin narrow-body SOIC8 (S) Package
- Safety regulatory approvals
  - UL certification according to UL 1577
  - TUV certification

2. Applications

- Solar Energy
- Motor Control
- EC Charging
- Power Supplies
- Industrial AC/DC and DC/DC

3. General Description

The CA-IS23xxxS family is a series of highly accurate and cost-effective current sensor IC suitable for AC/DC current sensing in a variety of industrial, commercial, and communications systems. It features a low-offset, linear Hall sensor circuit and a copper conduction path that generates a magnetic field when current flows through it. The integrated Hall IC senses this magnetic field and converts it into a proportional voltage output, which has a positive slope proportional to the current flowing through the primary copper conduction path. The device senses current differentially, rejecting common-mode fields and improving accuracy in magnetically noisy environments. With its 1mΩ internal resistance, the primary copper conduction path offers low power loss and high inrush current withstand capability.

The CA-IS23xxxS is available in 8-pin narrow-body SOIC packages. The CA-IS23xxxS is rated for operation at junction temperatures of -40°C to +150°C.

Device Information

Part Number	Package	Package Size (NOM)
CA-IS23025S CA-IS23030S CA-IS23050S	SOIC8 (S)	4.9mm x 3.9mm

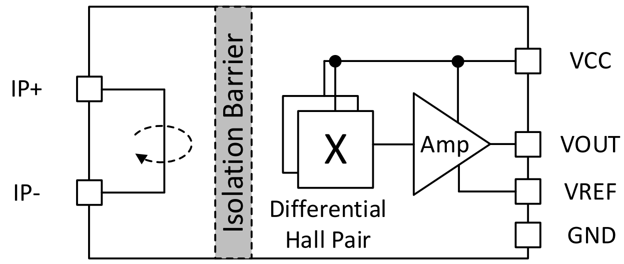

Figure 3-1 Simplified Schematic

4. Ordering Information

Table 4-1 Ordering Information

Part Number	Primary Current (A)	Power Supply (V)	Sensitivity (mV/A)	Zero Current Output Voltage (V)	Package
CA-IS23025S	±25	5	80	2.5	SOIC8 (S)
CA-IS23030S	±30	5	66.67	2.5	SOIC8 (S)
CA-IS23050S	±50	5	40	2.5	SOIC8 (S)

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5. Pin Configuration and Description

5.1. CA-IS23xxxS Pin Configuration and Description

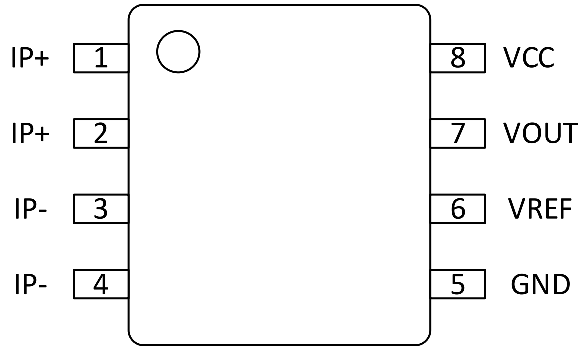


Figure 5-1 The CA-IS23xxxS Pin Configuration

Table 5-1 The CA-IS23xxxS Pin Description

Pin Name	Pin Number	Type	Description
IP+	1, 2	Input	Input current positive pin
IP-	3, 4	Input	Input current negative pin
GND	5	Ground	Ground
VREF	6	Output	Zero current output voltage reference. Leave pin floating if not used
VOUT	7	Output	Output voltage
VCC	8	Power Supply	Power supply

6. Specifications

6.1. Absolute Maximum Ratings[1]

over operating free-air temperature range unless otherwise specified. [1]

Parameters		Minimum	Maximum	Unit
V_{CC}	Supply voltage	0	6	V
V_{RCC}	Reverse supply voltage	-0.5	0	V
V_{OUT}	Output voltage	0	6	V
V_{ROUT}	Reverse output voltage	-0.5	0	V
T_A	Operating ambient temperature	-40	125	°C
T_J[2]	Junction temperature	-55	165	°C
T_{stg}	Storage temperature	-65	170	°C

Notes:

1. The stresses listed under "Absolute Maximum Ratings" are stress ratings only, not for functional operation condition. Exposure to absolute maximum rating conditions for extended periods may cause permanent damage to the device.
2. To maintain the recommended operating junction temperature conditions, see Thermal Information.

6.2. ESD Ratings

			Value	Unit
V_{ESD}	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001.	±2000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101.	±1000	

6.3. Recommended Operating Conditions

Over operating free-air temperature range unless otherwise specified.

Parameters		Minimum	Typical	Maximum	Unit
V_{CC}	Operating supply voltage	4.5	5	5.5	V
T_A	Ambient temperature	-40		125	°C
T_J	Junction temperature	-40		150	°C

6.4. Thermal Information

Thermal Metric		Package	Unit
		SOIC8 (S)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	91	°C/W
$R_{\theta JC(top)}$	Junction to Case (top)	43	°C/W

6.5. Insulation Specifications

Parameters		Test Conditions	Specifications SOIC8 (S)	Unit
Vsurge	Surge voltage	Tested ±5 pulses at 2 minutes in compliance to IEC 61000-4-5 1.2 µs (rise) / 50 µs (width)	6	kV
V_{ISO}	Dielectric Strength Test Voltage	Agency type-tested for 60 seconds per UL standard 60950-1 (edition 2); production- tested at V_{ISO} for 1 second, in accordance with UL 60950-1 (edition 2).	3750	V_{RMS}
V_{WVBI}	Working Voltage for Basic Isolation	Maximum approved working voltage for basic (single) isolation according to UL 60950-1 (edition 2)	420	V_{PK} or V_{DC}
			297	V_{RMS}
D_{cl}	External Clearance	Minimum distance through air from IP leads to signal leads.	4.2	mm
D_{cr}	External Creepage	Minimum distance along package body from IP leads to signal leads.	4.2	mm
DTI	Distance Through Insulation	Minimum internal distance through insulation	90	µm
CTI	Comparative Tracking Index	Material Group II	400 to 599	V

6.6. Safety-Related Certifications

UL (Pending)	TUV (Pending)
Certified according to UL 1577 Component Recognition Program	Certified according to EN 61010-1 and EN 62368-1
Single protection 3750V_{RMS}	EN 61010-1 3750V_{RMS} EN 62368-1 3750V_{RMS}
Certification Number: Pending	Client reference number: 2253313

6.7. Common Electrical Characteristics[1]

All minimum/maximum specs are at T_A = -40°C to +125°C, V_{CC} = 5V, unless otherwise noted.

Parameters		Test Conditions	Minimum	Typical	Maximum	Unit
POWER						
V_{CC}	Supply Voltage		4.5	5.0	5.5	V
I_{CC}	Supply Current	V_{CC} = 5V, output open	11.5	14.0	16.0	mA
t_{PO}	Power-on Time	T_A = 25°C		78.0		µs
V_{UVLOH}	UVLO voltage threshold	V_{CC} rising		3.8		V
V_{UVLOL}	UVLO voltage threshold	V_{CC} falling		3.2		V
Output Stage						
C_L	Output Capacitance Load	VOUT to GND		1.0	10.0	nF
R_L	Output Resistive Load	VOUT to GND and VOUT to VCC	4.7			kΩ
R_{REF}	VREF Resistive Load	VREF to GND and VREF to VCC	100			kΩ
t_r	Rise Time	T_A = 25°C, C_L = 1nF		3.6		µs
t_{pd}	Propagation Time	T_A = 25°C, C_L = 1nF		2.0		µs
$t_{response}$	Response Time	T_A = 25°C, C_L = 1nF	3.0	3.7		µs
SR	Output Slew Rate	T_A = 25°C, C_L = 1nF		0.4		V/µs
V_{REF_INIT}	Reference Output Voltage		2.48	2.5	2.52	V
$V_{SAT(H)}$	High Output Saturation Soltage[2]	$R_{L(DOWN)}$ = 10kΩ to GND	4.7			V
$V_{SAT(L)}$	Low Output Saturation Voltage[2]	$R_{L(UP)}$ = 10kΩ to VCC			0.3	V
Input Stage						
R_{IP}	Primary Conductor Resistance	T_A = 25°C		1		mΩ
L_{IP}	Primary Conductor Inductance	T_A = 25°C		2		nH
CMFRR	Common Mode Field Rejection Ratio	Uniform external magnetic field		70		dB
Accuracy and Frequency						
BW	Frequency Bandwidth	Small signal -3 dB; C_L = 1nF		120		kHz
I_N	Noise	Input-referenced noise: C_F = 4.7nF, C_L = 1nF, BW = 18kHz, T_A = 25°C		100		mA_{RMS}
E_{LIN}	Nonlinearity	Over full range of I_P		±0.2	±1	%
E_{SYM}	Symmetry	Over full range of I_P		±0.2	±1	%

Notes:
1. Device may be operated at higher primary current levels, I_P, ambient temperatures, T_A, and internal lead-frame temperatures, provided the Maximum Junction Temperature, T_J(max), is not exceeded.
2. The sensor IC will continue to respond to current beyond the range of I_P until the high or low output saturation voltage; however, the nonlinearity in this region will be worse than through the rest of the measurement range.

6.8. Performance Characteristics[1]

All minimum/maximum specs are at T_A = -40°C to +125°C, V_{CC} = 5V, unless otherwise noted.

Parameters		Test Conditions	Minimum	Typical[1]	Maximum	Unit
Nominal Performance (CA-IS23025S)						
I_{PR}	Current-sensing Range		-25		25	A
Sens	Sensitivity	Over full range of I_P, T_A = 25°C		80		mV/A
$V_{OUT(Q)}$	Zero Current Output Voltage	Bidirectional; I_P = 0A, T_A = 25°C	2.49	2.5	2.51	V
Nominal Performance (CA-IS23030S)						
I_{PR}	Current-sensing Range		-30		30	A
Sens	Sensitivity	Over full range of I_P, T_A = 25°C		66.67		mV/A
$V_{OUT(Q)}$	Zero Current Output Voltage	Bidirectional; I_P = 0A, T_A = 25°C	2.49	2.5	2.51	V
Nominal Performance (CA-IS23050S)						
I_{PR}	Current-sensing Range		-50		50	A
Sens	Sensitivity	Over full range of I_P, T_A = 25°C		40		mV/A
$V_{OUT(Q)}$	Zero Current Output Voltage	Bidirectional; I_P = 0A, T_A = 25°C	2.49	2.5	2.51	V

Accuracy Performance						
E_{TOT}	Total Output Error[2]	$I_P = I_{PR(max)}$, T_A = 25°C to 125°C	-3		3	%
		$I_P = I_{PR(max)}$, T_A = -40°C to 25°C	-1		4.5	%
Total Output Error Components[3] $E_{TOT} = E_{SENS} + 100 \times V_{OE}/(Sens \times I_P)$						
E_{SENS}	Sensitivity Error	$I_P = I_{PR(max)}$, T_A = 25°C to 125°C	-2.5		2.5	%
		$I_P = I_{PR(max)}$, T_A = -40°C to 25°C	-0.5		4.0	%
V_{OE}	Voltage Offset Error	I_P = 0A, T_A = 25°C to 125°C	-10		20	mV
		I_P = 0A, T_A = -40°C to 25°C	-10		10	mV
Life Time Drift Characteristics						
E_{SENS_drift}	Sensitivity Error Lifetime Drift			±1		%
E_{TOT_drift}	Total Output Error Lifetime Drift			±1		%

Notes:

1. Typical values with ± are 3 sigma values.
2. Percentage of I_P, with $I_P = I_{PR(max)}$.
3. A single part will not have both the maximum/minimum sensitivity error and maximum/minimum offset voltage, as that would violate the maximum/minimum total output error specification. Also, 3 sigma distribution values are combined by taking the square root of the sum of the squares.

7. Detailed Description

7.1. Overview

The CA-IS23xxxS current sensor are based on the Hall principle and can accurately measure AC/DC current while minimizing measurement costs. This sensor finds extensive use in various current monitoring applications, including consumer, industrial, and automotive scenarios. Compared to current transformers, the CA-IS23xxxS offers a compact size, which can significantly reduce PCB size. In comparison to shunt resistor + isolated amplifier solutions, the CA-IS23xxxS only requires low-side power supply, eliminating the complexity of high-side power supply design.

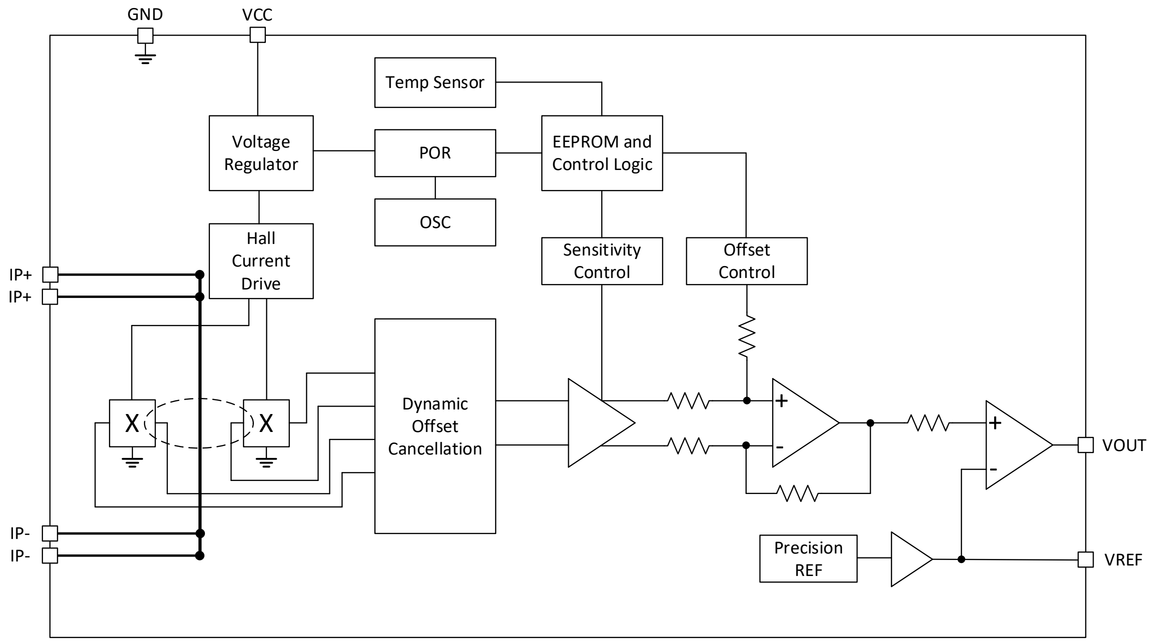


Figure 7-1 Functional Block Diagram

The internal conductor of the CA-IS23xxxS generates a magnetic field proportional to the current value, according to Maxwell's equations. The sensor converts this magnetic field value into a voltage output, ensuring a high level of accuracy. Moreover, the sensor has an ultra-small resistor value, ensuring little influence on thermal power consumption.

7.2. Quiescent Output Voltage ($V_{OUT(Q)}$)

The quiescent output voltage $V_{OUT(Q)}$ of the CA-IS23xxxS indicates the output voltage of the IC when there is no magnetic field. Although the theoretical output voltage of the CA-IS23xxxS is 2.5V, factors such as offset voltage, sensitivity, packaging stress, and temperature coefficient may cause the actual quiescent output voltage to deviate from the theoretical figure. During factory testing, the actual quiescent voltage is modified to be within ±20mV of the theoretical value. The quiescent output voltage is also influenced by the temperature coefficient, which means that as the temperature changes, the quiescent output voltage will also change (this effect is more noticeable when sensitivity is higher). The CA-IS23xxxS is equipped with temperature sensors that can modify the temperature coefficient of the quiescent output voltage.

7.3. Response Time ($t_{RESPONSE}$)

Response Time is a term used to define the time difference between the moment when the magnetic field reaches 80% of its target value and the moment when the output voltage of the IC reaches 80% of its target value. This difference is measured and expressed in micro seconds. The Response Time is related to the sensitivity of the IC and the size of the output load capacitance. It is an important parameter to consider when using magnetic sensors, especially in applications where a quick response is required. The accuracy of the Response Time measurement is crucial to ensure reliable and precise operation of the sensor in various conditions.

7.4. Power-On Time (t_{PO})

Power-On Time is a term used to define the time required for the output voltage of a sensor to reach 90% of its target value after the supply voltage reaches 4.5V, at a specific magnetic field strength. This time difference is measured and expressed in micro seconds. The Power-On Time is an important parameter to consider when using magnetic sensors, especially in applications where a quick response is required. The accuracy of the Power-On Time measurement is crucial to ensure reliable and precise operation of the sensor in various conditions.

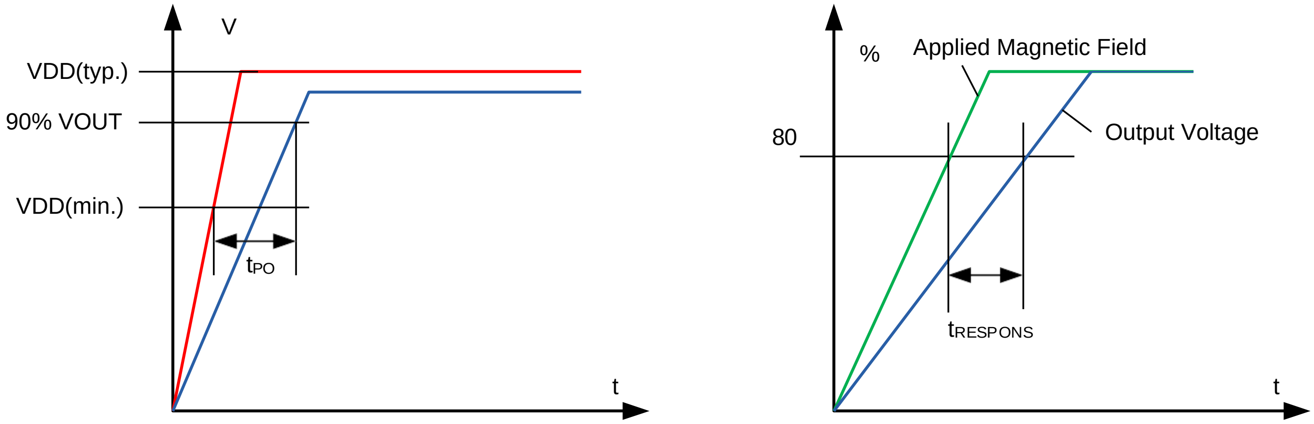


Figure 7-2 Power-On Time and Response Time

7.5. Transfer Function

The ideal first-order transfer function of the CA-IS23xxxS is given by Equation 1, where the output voltage V_{OUT} is a linear function of input current I_P. The accuracy of the device is quantified both by the error terms in the transfer function parameters, as well as by nonidealities that introduce additional error terms not in the simplified linear model.

$$V_{OUT} = (I_P \times Sens) + V_{REF}$$

Where:

- V_{OUT} is the output voltage.
- I_P is the isolated input current.
- Sens is the sensitivity of the CA-IS23xxxS.
- V_{REF} is the zero current reference output voltage.

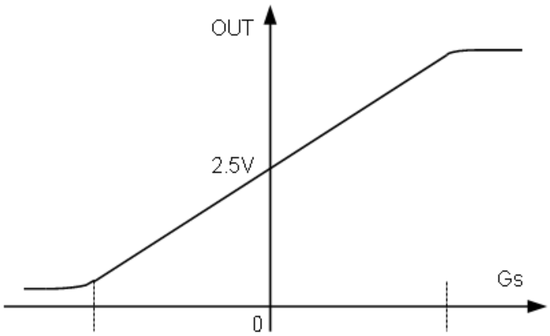


Figure 7-3 Transfer Function

8. Application and Implementation

8.1. Typical Application Circuit

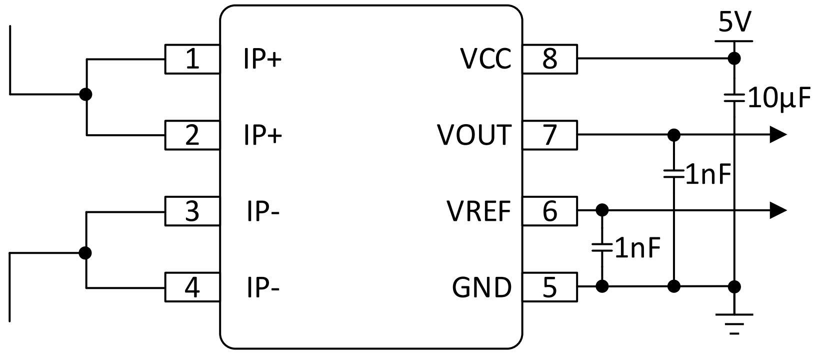


Figure 8-1 Single-Ended Output Application

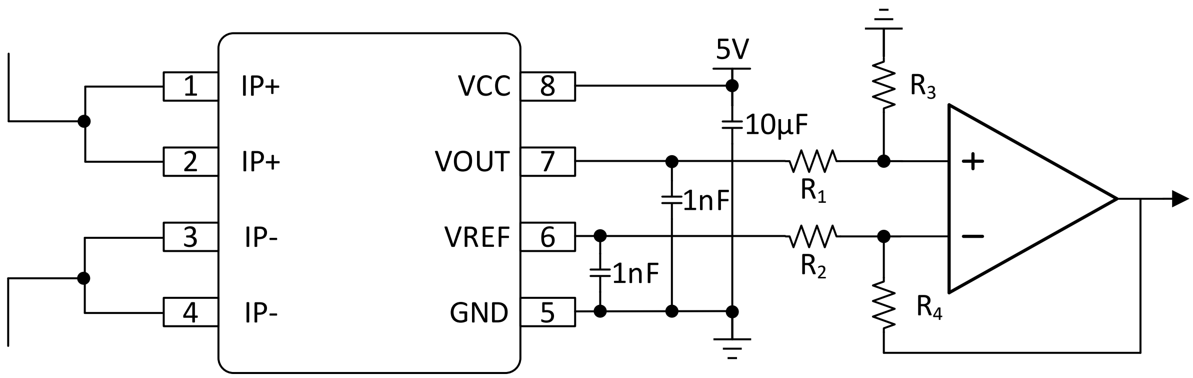


Figure 8-2 Differential Output Application

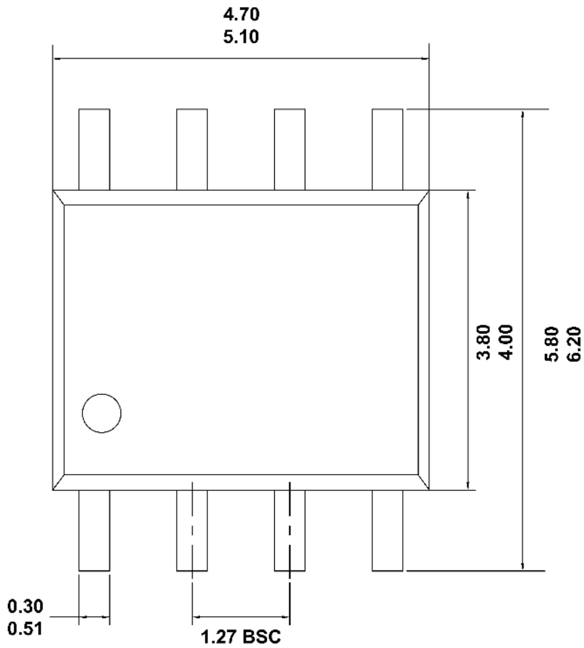
8.2. PCB Layout Guidelines

The CA-IS23xxxS is specified for a continuous current handling capability on the EVM which uses 4oz copper planes. This current capability is fundamentally limited by the maximum device junction temperature and the thermal environment, primarily the PCB layout and design. To maximize current-handling capability and thermal stability of the device, take care with PCB layout and construction to optimize the thermal capability. Efforts to improve the thermal performance beyond the design and construction of the EVM can result in increased continuous-current capability due to higher heat transfer to the ambient environment. Keys to improve thermal performance of the PCB include:

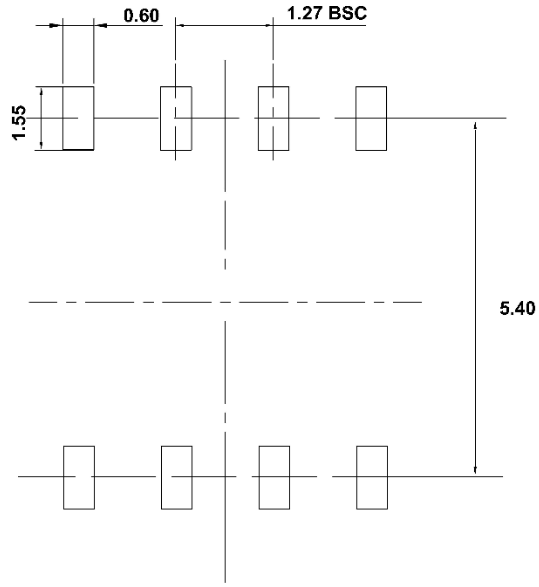
- Use large copper planes for both input current path and isolated power planes and signals.
- Use heavier copper PCB construction.
- Place thermal via farms around the isolated current input.
- Provide airflow across the surface of the PCB.

9. Package Information

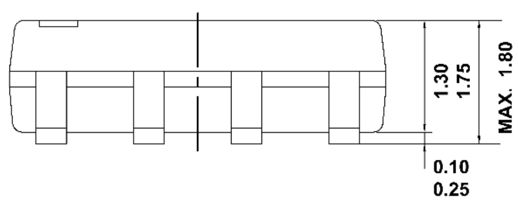
9.1. 8-Pin Narrow Body SOIC Package Outline



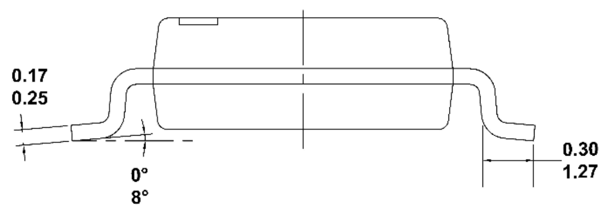
TOP VIEW



RECOMMENDED LAND PATTERN



FRONT VIEW



LEFT SIDE VIEW

Note:

1. All dimensions are in millimeters, angles are in degrees.

10. Soldering Information

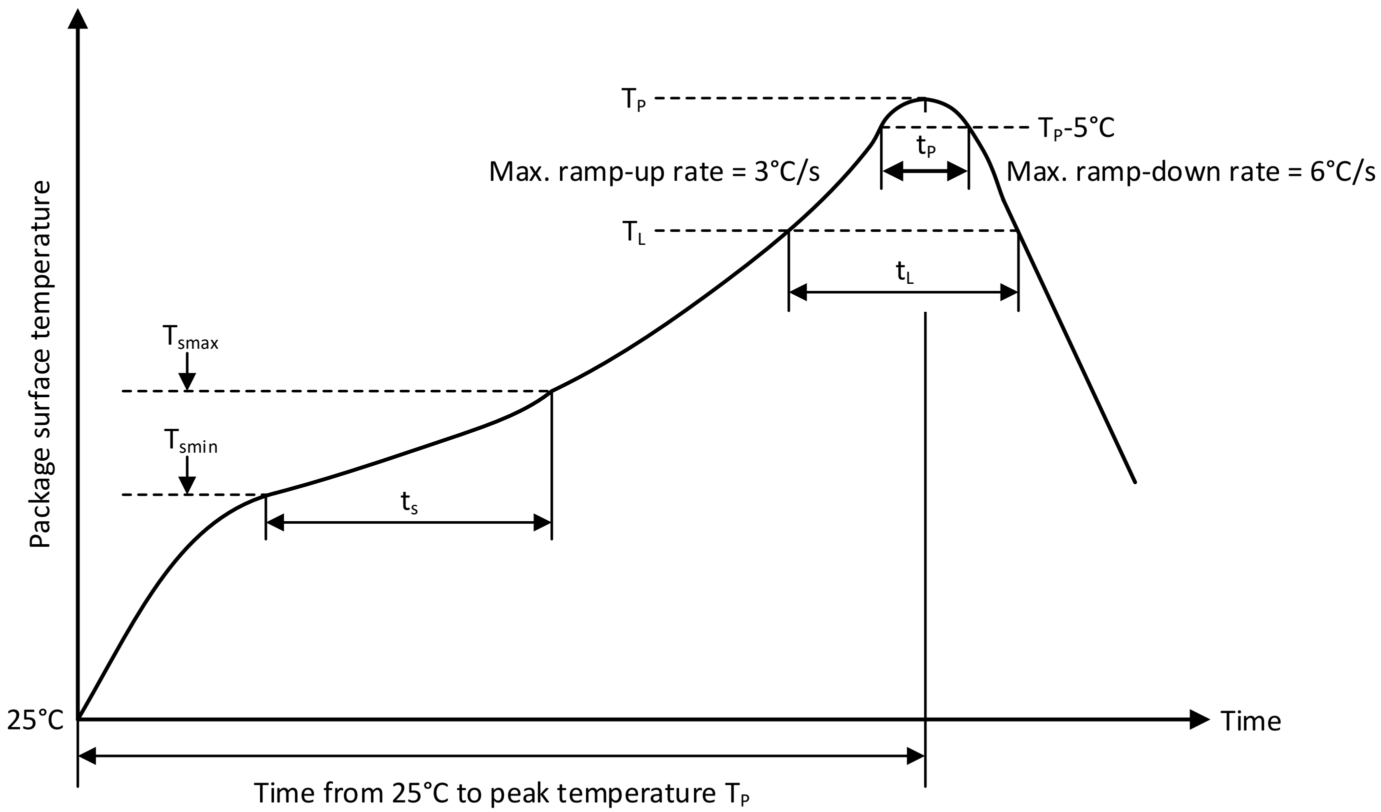


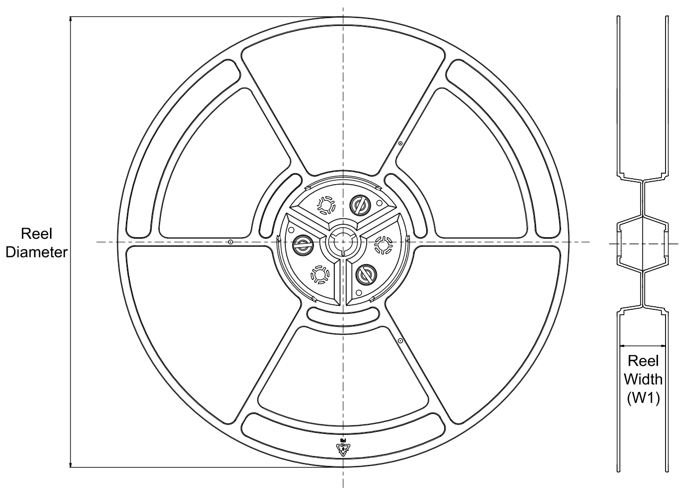
Figure 10-1 Soldering Temperature (reflow) Profile

Table 10-1 Soldering Temperature Parameter

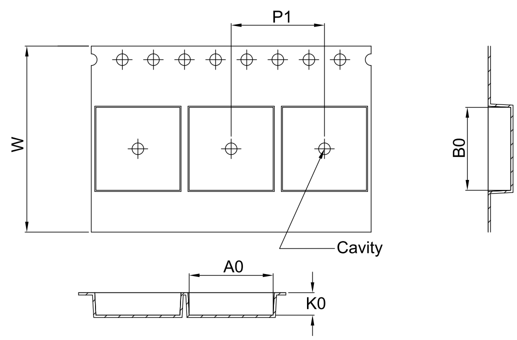
Profile Feature	Pb-Free Soldering
Ramp-up rate (T_L = 217°C to peak T_P)	3°C/s max
Time t_s of preheat temp (T_{smin} = 150°C to T_{smax} = 200°C)	60~120 seconds
Time t_L to be maintained above 217°C	60~150 seconds
Peak temperature T_P	260°C
Time t_P within 5°C of actual peak temp	30 seconds max
Ramp-down rate (peak T_P to T_L = 217°C)	6°C/s max
Time from 25°C to peak temperature T_P	8 minutes max

11. Tape and Reel Information

REEL DIMENSIONS

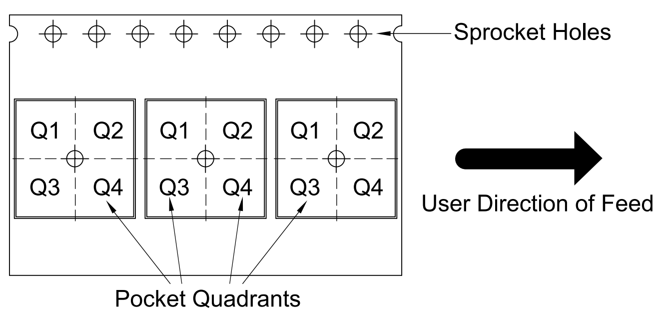


TAPE DIMENSIONS



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
CA-IS23025S	SOIC	S	8	2500	330	12.40	6.40	5.40	2.10	8.00	12.00	Q1
CA-IS23030S	SOIC	S	8	2500	330	12.40	6.40	5.40	2.10	8.00	12.00	Q1
CA-IS23050S	SOIC	S	8	2500	330	12.40	6.40	5.40	2.10	8.00	12.00	Q1

12. Revision History

Revision Number	Description	Date	Page Changed
Version 1.00	Initial Version	2024/11/21	NA

13. Important Statement

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