S4-CSA02

Hall-Effect Current Sensor IC Preliminary Final Data Sheet

1. Introduction

1.1 Major Features

- Operating temperature range: -40°C … +105°C
- Supply voltage range: 4.5V … 5.5V
- Unique backside vertical Hall sensor technology for sensing of lateral magnetic fields
- Factory calibrated sensitivity, zero magnetic field output voltage and temperature drift
- Factory programmable bandwidth 32 … 250 kHz, 3µsec step response (250 kHz BW)
- Optional differential operational mode for enhanced stray field suppression
- Fixed Output Voltage mode
- Supply Under Voltage and Over Voltage detection
- AEC-Q100 qualified

PACKAGE

SOIC-8

1.2 Typical Application

- BLDC Motor Control
- EV and HEV Inverter
- AC/DC and DC/DC Converters
- Smart Fuse

1.3 Description

The S4-CSA02 is a Hall-effect based current sensor employing proprietary backside vertical Hall sensor technology. It is assembled in a small SOIC-8 package and can be mounted on top of a primary current bar or conductor on PCB.

The IC features a fast analog signal path with factory-calibrated gain and offset temperature drift compensation. Parameters like sensitivity, zero output voltage, temperature drift, and signal bandwidth, along with operating modes such as differential and additive, can be configured to create factory preprogrammed versions of the S4-CSA02.

1.4 Functional Block Diagram

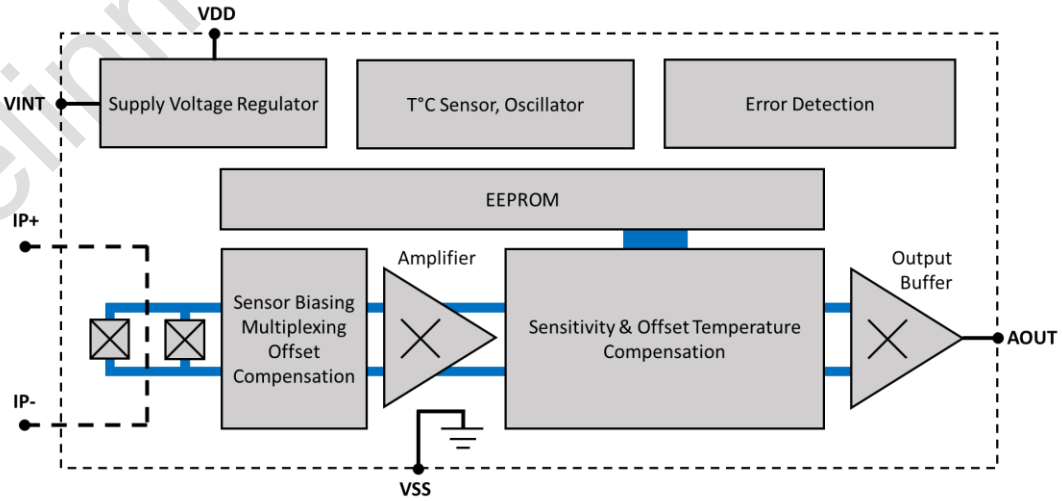


Figure 1: Functional Block Diagram

1.5 Recommended Application Circuit

Recommended component values:

CVDD: 100 nF
COUT: 4.7 … 10 nF
CVINT: 33 nF
ROUT: 4.7 … 100 kOhm

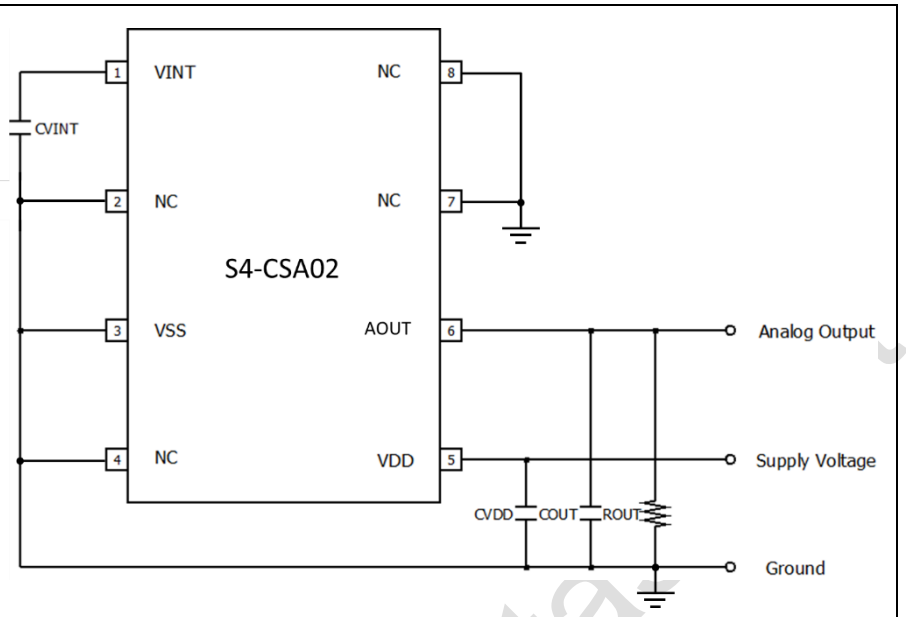


Figure 2: Recommended Application Circuit

1.6 Pin Assignment

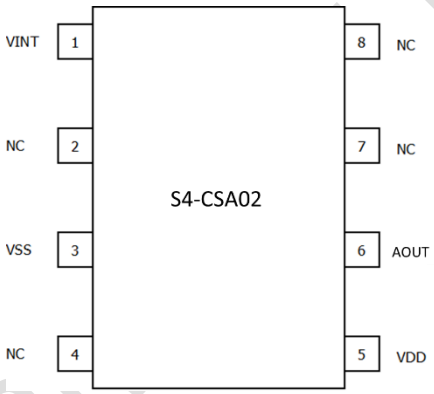


Figure 3: Pin Assignment

1.7 Pin Description

Pin #	Pin Name	Pin Type	Pin Description	Comment
1	VINT	Supply	Internally generated supply for analog and digital circuits	Needs external blocking capacitor (33 nF)
2	NC			Connect to ground
3	VSS	Ground	Ground Supply and Analog Sensor Output Return	Must be supplied from external
4	NC			Connect to ground
5	VDD	Supply	Positive Power Supply	Must be supplied from external
6	AOUT	Analog Output	Analog sensor signal voltage output	Needs external filtering capacitor and load resistor
7	NC			Connect to ground
8	NC			Connect to ground

Table 1: Pin Description

1.8 Sensor Area Location

The S4-CSA02 includes two Hall sensor areas that measure lateral magnetic fields either additively or differentially. Figure 4 shows the location of the sensor areas relative to the package outlines.

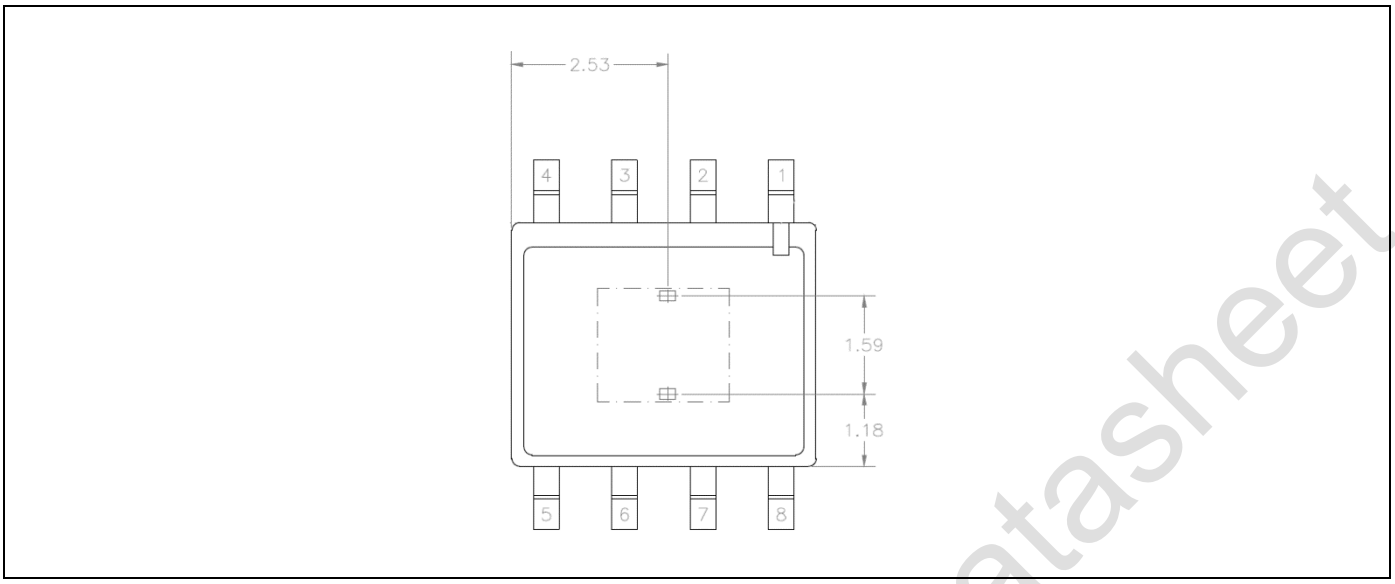


Figure 4: Sensor Area Location (size of die and sensors not in scale)

2. Electrical Characteristics

2.1 Absolute Maximum Ratings

Symbol	Parameter	Unit	Min	Max	Comment
TAmax	Max/min ambient temperature range	°C	-40	+105	
TSmax*	Max/min storage temperature range	°C	-55	+105	
VDDmax*	Max/min supply voltage range	V	-0.3	+15	Referred to VSS
VINTmax*	Max/min output voltage at pin VINT	V	-0.3	+4.0	Referred to VSS
IVINTmax*	Max/min output current at pin VINT	mA	-10	+10	Positive current flowing into pin
VOUTmax*	Max/min output voltage at pin VINT	V	-0.3	+7.0	Referred to VSS, max. VDD+0.3V
IOUTmax*	Max/min output current at pin AOUT	mA	-15	+15	Positive current flowing into pin
VESDHBM	Electrostatic discharge Human-Body Model	kV	-2	+2	HBM according to AEC-Q100
VESDCDM	Electrostatic discharge Charged-Device Model	kV	-1	+1	CDM according to AEC-Q100
BMAX*	Maximum magnetic field range	T			unlimited

* Guaranteed by design

Table 2: Absolute Maximum Ratings

2.2 Operating Conditions and Characteristics

If not otherwise stated, the following conditions are valid:
TA = -40 … +105 °C, VDD = 4.5V … 5.5V, COUT = 4.7 nF, CVINT = 33 nF, IOUT = -2 … +2 mA, recommended application circuit as described in Figure 2

Symbol	Parameter	Condition	Unit	Min	Typ	Max	Comment
VDD	Supply Voltage Range	Operating Mode	V	4.5		5.5	Referred to VSS
ISUP	Supply Current	ROUT = 100 kOhm	mA		12	15	
IOUT	Output Sink/Source Current Range	ROUT = 4.7…100 kOhm	mA	-2		+2	Operating load current range
IOLIMH	Output Source Current Limit	ROUT = 4.7…100 kOhm	mA	-30		-5	Built-in output short circuit current limit
IOLIML	Output Sink Current Limit	ROUT = 4.7…100 kOhm	mA	5		30	Built-in output short circuit current limit

Symbol	Parameter	Condition	Unit	Min	Typ	Max	Comment
ROUT	Output Resistive Load	VOUT = 10%...90% VDD	kOhm	4.7		100	Refer to Figure 2
COUT	Output Capacitive Load	VOUT = 10%...90% VDD	nF	4.7		10	Refer to Figure 2
ILOUT	Output Leakage Current	High Impedance Mode	µA	-20		+20	VOUT ≤ 3 V
CVINT	VINT Capacitive Load		nF	25		50	Blocking capacitance for internal 3.3 V voltage regulator, refer to Figure 2
VOUTF	Output Voltage Range in Fixed Output Voltage Mode	VDD = 5 V, ROUT ≥ 10 kOhm	V	0.5		4.5	Bipolar Output Mode, refer to Figure 5
VOUTHZ	Output Voltage in High Impedance Mode	VDD = 5V, ROUT ≤ 10 kOhm to VSS	V			0.25	Refer to Figure 6
VOVLH	Over Voltage Detection Threshold Low→High	Increasing supply voltage	V	6.5	7	7.5	Signal output transitions to a High-Z state, refer to Figure 6
VOVHL	Over Voltage Detection Threshold High→Low	Decreasing supply voltage	V	6	6.5	7	Signal output returns to normal, refer to Figure 6
VOVHYS	Over Voltage Detection Threshold Hysteresis		V		0.5		refer to Figure 6
VUVHL	Under Voltage Detection Threshold High→Low	Decreasing supply voltage	V	3.3	3.6	3.9	Signal output transitions to a High-Z state, refer to Figure 6
VUVLH	Under Voltage Detection Threshold Low→High	Increasing supply voltage	V		3.9	4.2	Signal output returns to normal, refer to Figure 6
VPORHL**	Voltage Power On Reset Threshold High→Low	Decreasing supply voltage	V		2.8		Refer to Figure 6
VUVHYS	Under Voltage Detection Threshold Hysteresis		V		0.3		Refer to Figure 6
TPON**	Power On Time	VDD rise time 1 µsec from 0 V to 5 V	msec			1	Up to 95% of the final output value, refer to Figure 6
SENS	Sensitivity Programming Range		mV/mT	25		100	Other sensitivities (5 mV/mT … 500 mV/mT) on request
ELIN*	Linearity Error	VDD = 5 V, Sensitivity 100 mV/mT, B = -16…+16 mT	%	-0.5		+0.5	Refer to Figure 7
ESENS*	Sensitivity Error	VDD = 5 V, Sensitivity 100 mV/mT, B = -16…+16 mT	%	-1		+1	Excluding lifetime drift, refer to Figure 8
ESENSLT*	Sensitivity Error over Lifetime	VDD = 5 V, Sensitivity 100 mV/mT, B = -16…+16 mT	%	-2		+2	Lifetime drift, refer to Figure 8
VOUTB0*	Zero Magnetic Field Bipolar Output Voltage	Fixed Output Voltage Mode, VDD = 5 V, Sensitivity 100 mV/mT, B = 0 mT	V	2.49	2.5	2.51	For details refer to Figure 9
VOUTB0LT*	Zero Magnetic Field Bipolar Output Voltage Includes Lifetime Error	Fixed Output Voltage Mode, VDD = 5 V, Sensitivity 100 mV/mT, B = 0 mT	V	2.48	2.5	2.52	
BW	Small Signal 3dB Signal Bandwidth Setting Range		kHz	32		250	For details refer to Table 5

Symbol	Parameter	Condition	Unit	Min	Typ	Max	Comment
TSTEP**	Step Response Time	VDD = 5 V, Sensitivity 100 mV/mT, BW = 250 kHz, COUT = 4.7 nF	µsec		3		For details refer to Figure 10
TPROP**	Propagation Delay Time	VDD = 5 V, BW = 250 kHz	µsec		1.25		For details refer to Figure 10
NRMS**	RMS Noise at AOUT	Sensitivity 50 mV/mT, BW = 32 kHz	mV		7		VDD = 5 V, B = 0 mT, COUT = 4.7 nF, 1σ value
		Sensitivity 50 mV/mT, BW = 250 kHz			16		
		Sensitivity 100 mV/mT, BW = 32 kHz			14		
		Sensitivity 100 mV/mT, BW = 250 kHz			31		

* Limits may be adjusted following the mass production ramp-up
** Tested at the room temperature on small number of samples

Table 3: Operating Conditions and Characteristics

2.3 Characteristic and Definitions of Electrical Parameters

2.3.1 Output Voltage Characteristic versus Output Voltage Mode and Output Polarity

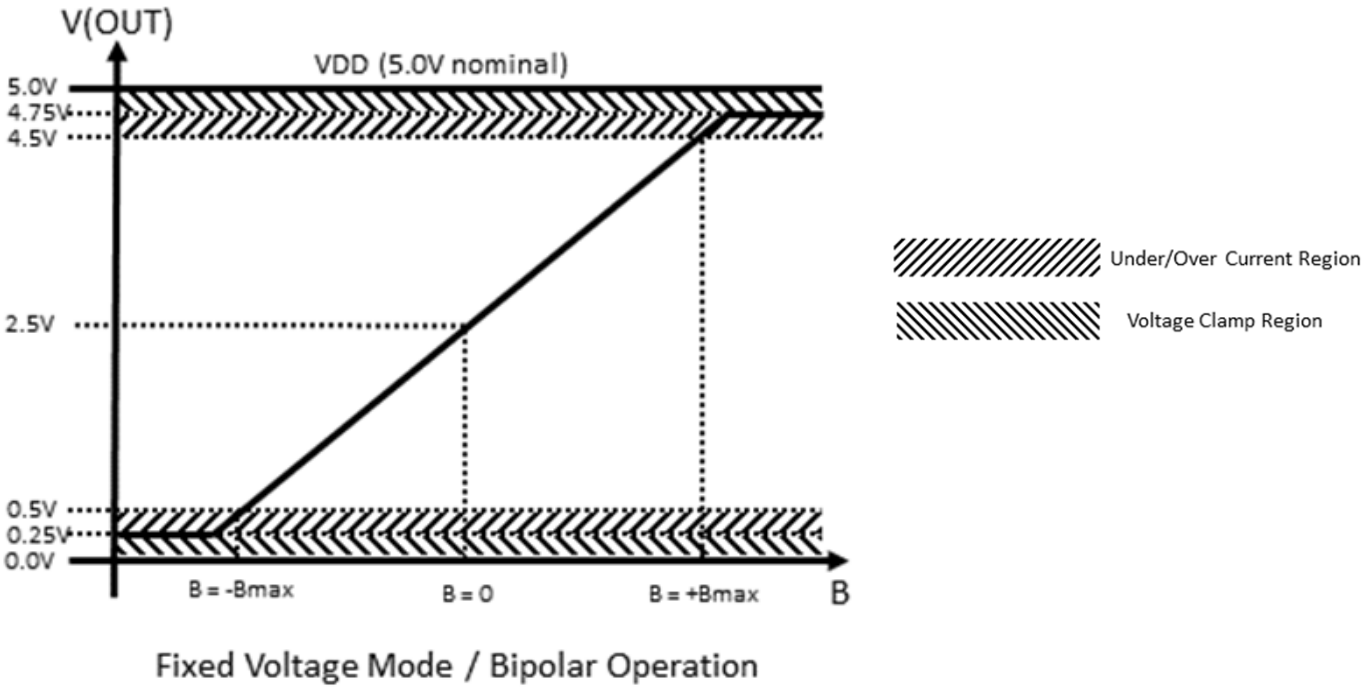


Figure 5: Output Voltage Characteristic versus Output Voltage Mode and Output Polarity

2.3.2 Power-up, Under- and Over-Voltage Characteristics

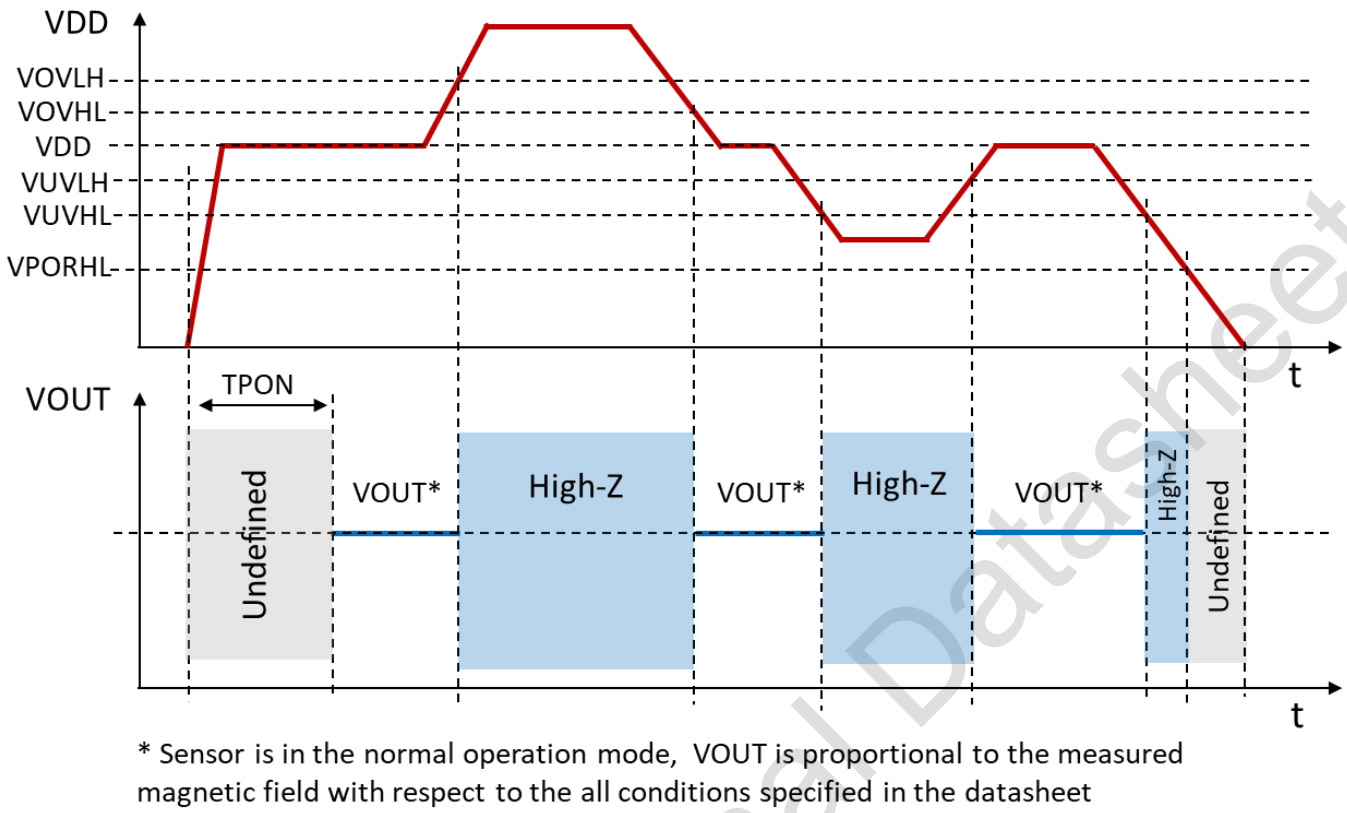


Figure 6: Power-up, Under- and Over-Voltage Characteristics (at B=0)

2.3.3 Sensitivity and Linearity Definition

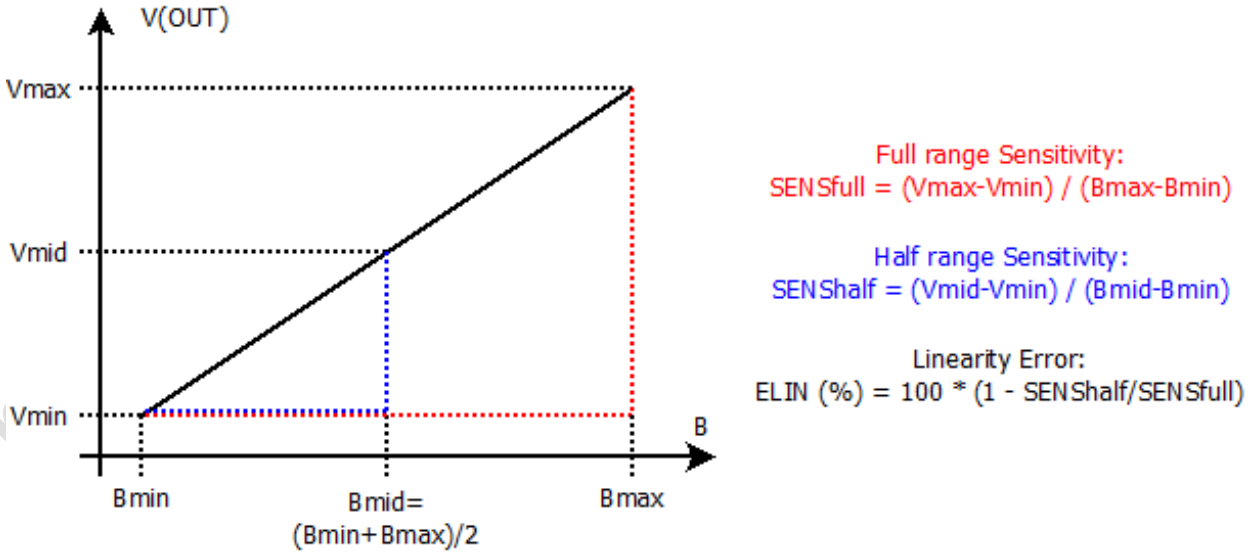


Figure 7: Sensitivity and Linearity Definition

2.3.4 Sensitivity Error

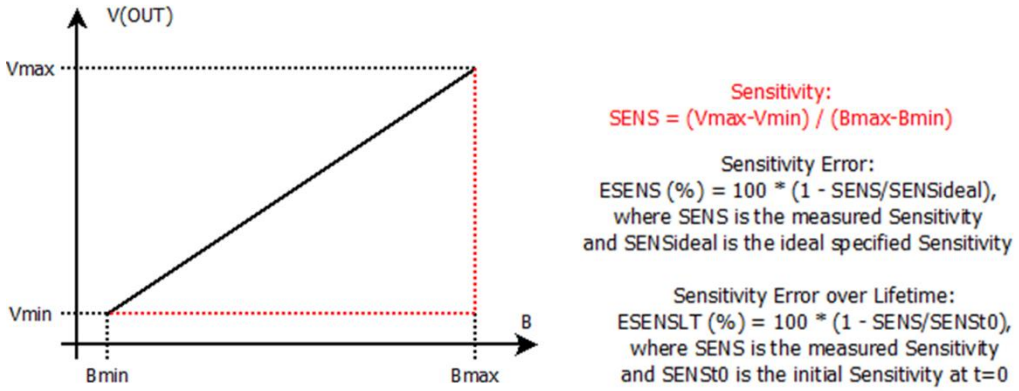


Figure 8: Sensitivity Error

2.3.5 Zero Field Output Voltage

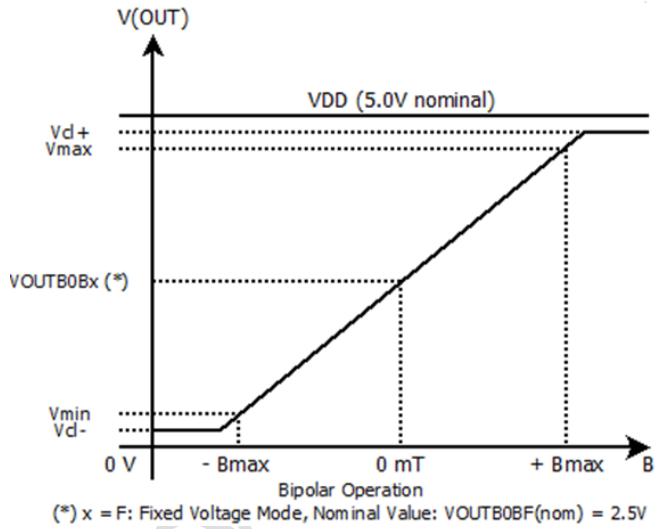


Figure 9: Zero Field Output Voltage

2.3.6 Step Response Time TSTEP and Propagation Delay Time TPRO

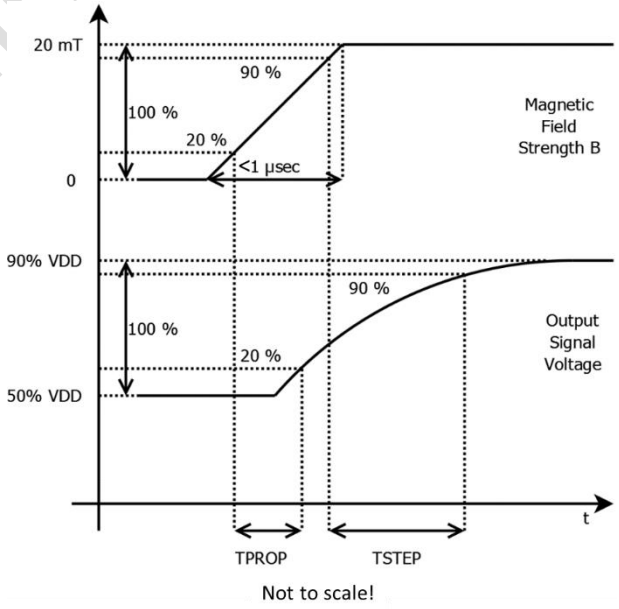


Figure 10: Definition of Step Response Time and Propagation Delay Time

2.4 Self Diagnostics

Symbol	Error Condition Description	IC Condition	Output AOUT Condition	Comments
MEMERR	NVM Memory Error (SEC Check)	Initialization Procedure	High Impedance	Detect by VOUT < 0.25 V with ROUT ≤ 10 kOhm
OVERR	Supply Over Voltage Error	Normal Operation	High Impedance	Detect by VOUT < 0.25 V with ROUT ≤ 10 kOhm
UVERR	Supply Under Voltage Error	Normal Operation	High Impedance	Detect by VOUT < 0.25 V with ROUT ≤ 10 kOhm
TOORERR	Temperature Sensor Value Out of Range Error	Normal Operation	High Impedance	Detect by VOUT < 0.25 V with ROUT ≤ 10 kOhm

Table 4: Self Diagnostics

3. Application Description

3.1 Sensing and Output Modes

The S4-CSA02 has the following selectable combinations of sensing and output modes.

Sensing Modes:

The S4-CSA02 has two geometrically separated Hall sensor areas, located approximately 1.6 mm apart from each other (refer to Figure 4). Depending on the programmed mode, the chip adds (in Additive Mode) or subtracts (in Differential Mode) the two Hall sensor signals.

By choosing Differential Mode, the application benefits from high stray field suppression when the IC is located symmetrically over a U-shaped bus bar or wire on PCB as shown on the Figure .

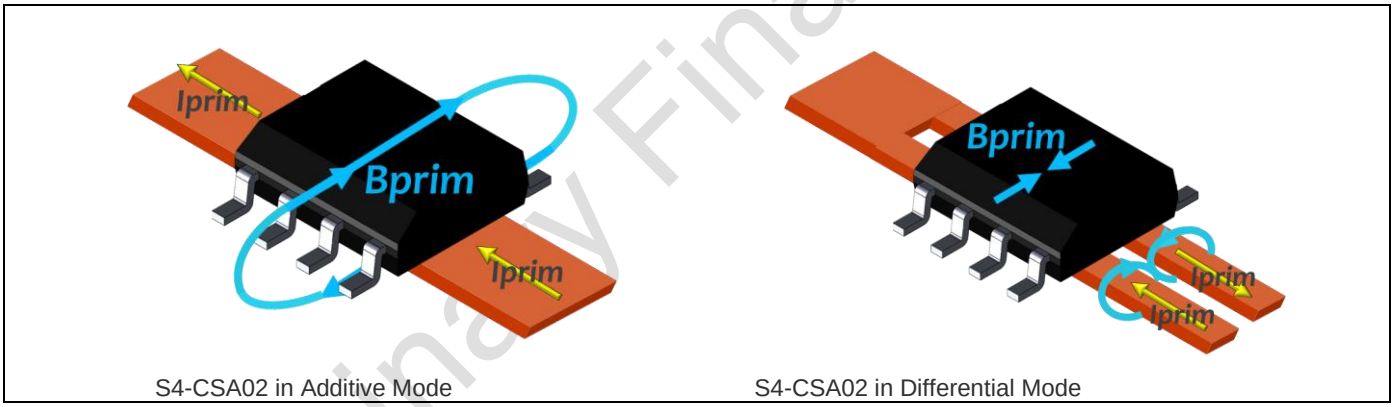


Figure 11: Additive and Differential Sensing Mode

Output Modes:

The S4-CSA02 can operate in Fixed Output Voltage Mode.

Fixed Output Voltage Mode: The output voltage and the zero magnetic field voltage are referred to a fix integrated voltage reference. Default zero magnetic field voltage is 2.5V.

3.2 Factory Programmable Parameters

The S4-CSA02 is delivered as versions with the below described factory preprogrammed parameters stored in EEPROM.

Sensitivity:

The S4-CSA02 sensitivity can be programmed from 5 mV/mT up to 500 mV/mT. The sensitivity is referred to the sum / difference of the magnetic field at sensor area 1 and 2 in Additive or Differential Mode, respectively.

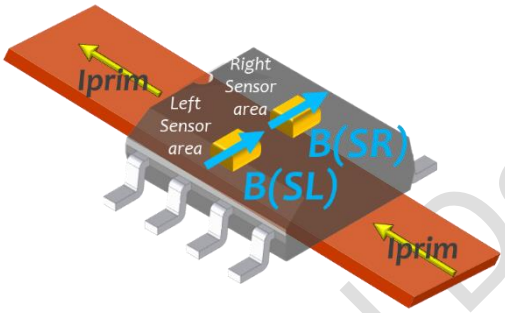
The S4-CSA02 comes with factory calibrated sensitivity and zero field output voltage.

Sensitivity in Additive Mode:

In Additive Mode, the output voltage VOUT of the S4-CSA02 can be calculated from the magnetic field strength B(SL) at the center of the left sensor area and the field strength B(SR) at the center of the right sensor area using the formula:

VOUT = VOUTB0 + [(-1) * (SENS / 2) * B(SL) + (-1) * (SENS / 2) * B(SR)]
= VOUTB0 - SENS/2 * [B(SL) + B(SR)]
= VOUTB0 - SENS * B, if B(SL) = B(SR) = B, where:

- VOUT is the output voltage at pin AOUT in Fixed Output Voltage Mode (VOUTF, see Table 3)
- VOUTB0 is the Zero Field Output Voltage in Fixed Output Voltage Bipolar Mode, respectively (see Table 3)
- SENS is the factory calibrated Sensitivity (see Table 3).

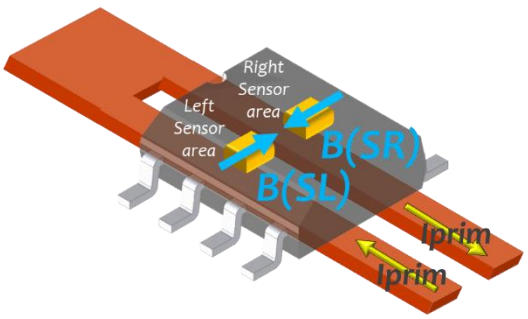


Sensitivity in Differential Mode:

In Differential Mode, the output voltage VOUT of the S4-CSA02 can be calculated from the magnetic field strength B(SL) at the center of the left sensor area and the field strength B(SR) at the center of the right sensor area using the formula:

VOUT = VOUTB0 + [(-1) * (SENS / 2) * B(SL) + (+1) * (SENS / 2) * B(SR)]
= VOUTB0 - SENS/2 * [B(SL) – B(SR)]
= VOUTB0 - SENS * B, if B(SL) = - B(SR) = B, where:

- VOUT is the output voltage at pin AOUT in in Fixed Output Voltage Mode (VOUTF, see Table 3)
- VOUTB0 is the Zero Field Output Voltage in Fixed Output Voltage Bipolar Mode, respectively (see Table 3)
- SENS is the factory calibrated Sensitivity (see Table 3).



For proper calculation of the additive or differential total sensitivity, it is important to keep in mind that both, B(SL) and B(SR), will be composed of field contributions from both left and right current bar arms.

Sensitivity Temperature Drift:

The S4-CSA02 includes piecewise linear temperature drift setting in 3 temperature segments. The IC comes with factory trimming for constant sensitivity over the whole temperature range.

Zero Magnetic Field Output Voltage:
The S4-CSA02 zero magnetic field output voltage is 2.5V for Fixed Output Voltage Mode.

Fine setting can be achieved by using the Zero Magnetic Field Output Voltage Temperature Compensation.

Signal Bandwidth:
The 3 dB signal bandwidth of the analog signal processing chain is factory programmable from 32 kHz to 250 kHz. For details refer to Table 5.

Symbol	Parameter	Bits	Range / Values
BW[1:0]	Filter 3 dB Bandwidth setting	2	BW[1:0] = [0,0]: 250 kHz, BW[1:0] = [0,1]: 150 kHz, BW[1:0] = [1,0]: 70 kHz, BW[1:0] = [1,1]: 32 kHz,

Table 5: Factory Programmable Parameters Table

4. Package Information

4.1 Package Dimensions

The S4-CSA02 is packaged in a 3.9 mm x 4.9 mm SOIC-8 package.

The package is fully compliant with JEDEC Standard MS-012

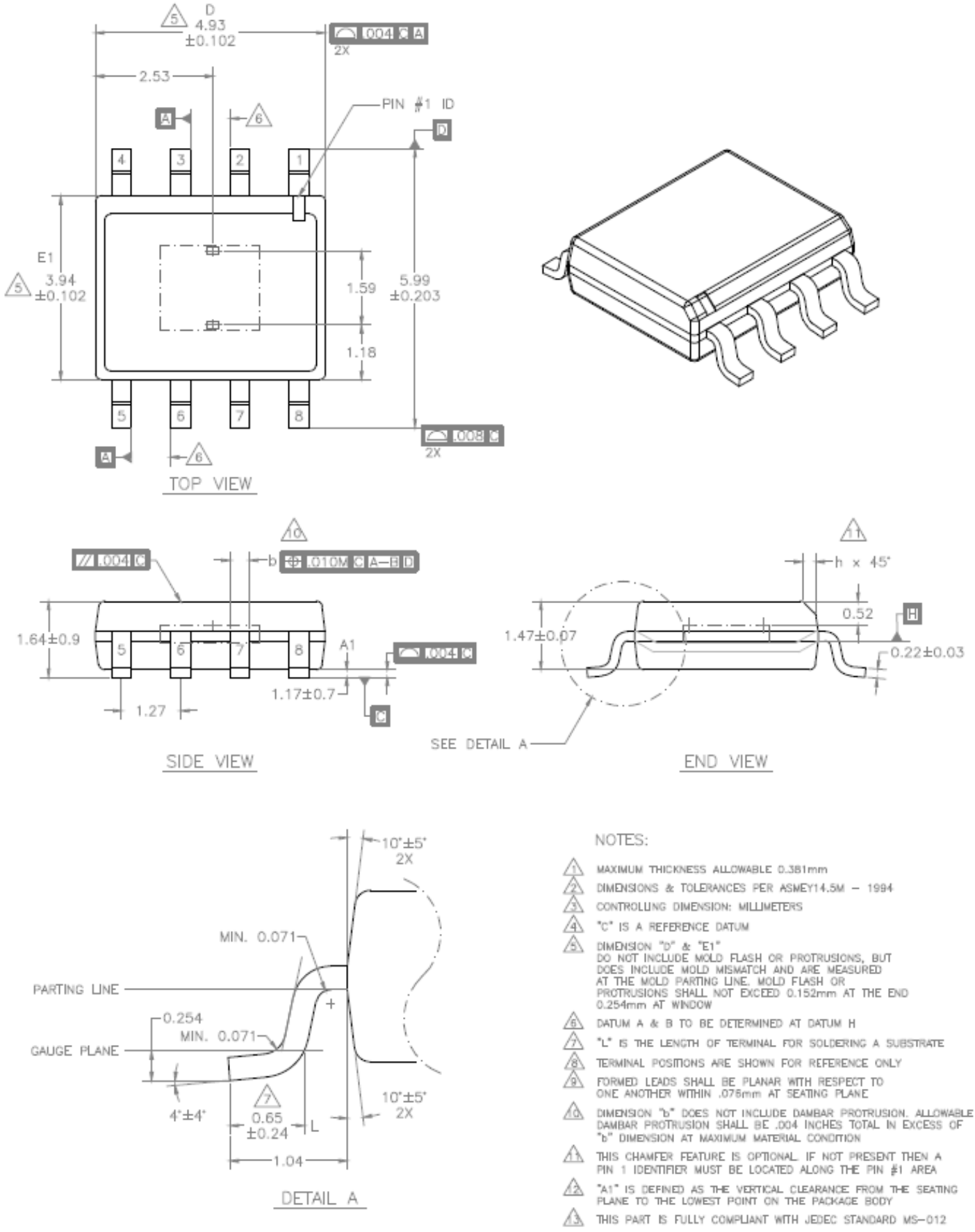


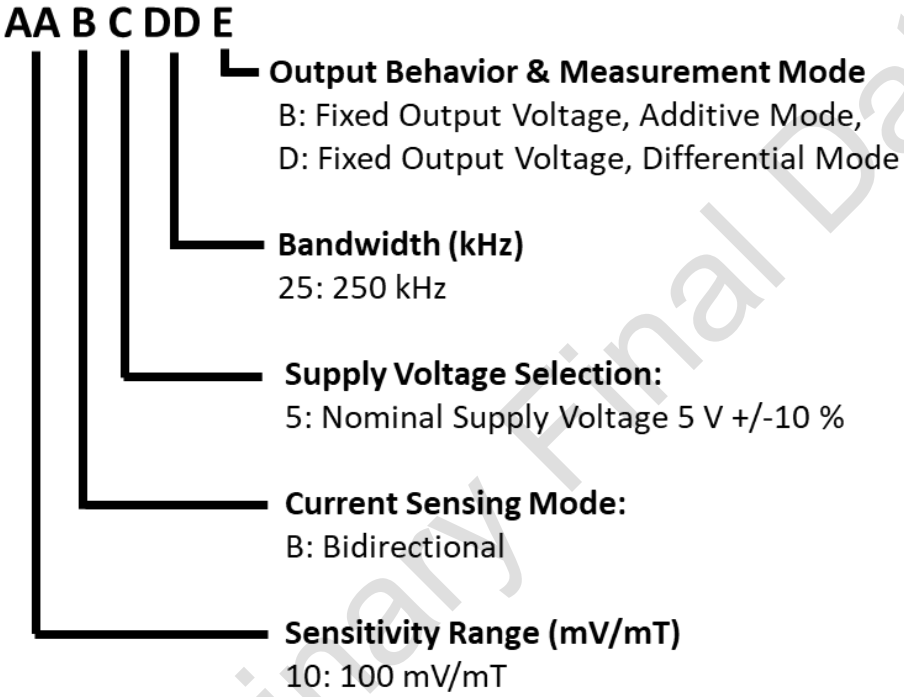
Figure 12: Package Outlines

All dimensions are in millimeter (angles in degree)

4.2 Package Marking

Figure 13: Package Marking

AA: Sensitivity Range B: Current Sensing Mode C: Supply Voltage DD: Bandwidth E: Output Behavior & Measurement Mode



XXXX: Assembly Lot Code, YYWW: date Code

Figure 14: Device Variants Code (Example)

4.3 Package Thermal Characteristics and soldering conditions

Symbol	Parameter	Unit	Typ	Comment
RΘJA	Thermal Resistance	°C/W	150	Soldered on 4-layer PCB

Table 6: Package Thermal Characteristics

Reflow soldering process for SMD's are recommended for the S4-CSA02. The soldering conditions shall follow the instruction IPC/JEDEC J-STD-020 or EIA/JEDEC22-A113.

4.4 Storage Precautions

The S4-CSA02 is packaged in a package with Moisture Sensitivity Level MSL3.

4.5 Packing Information

Number of parts per reel: 3000 Pieces

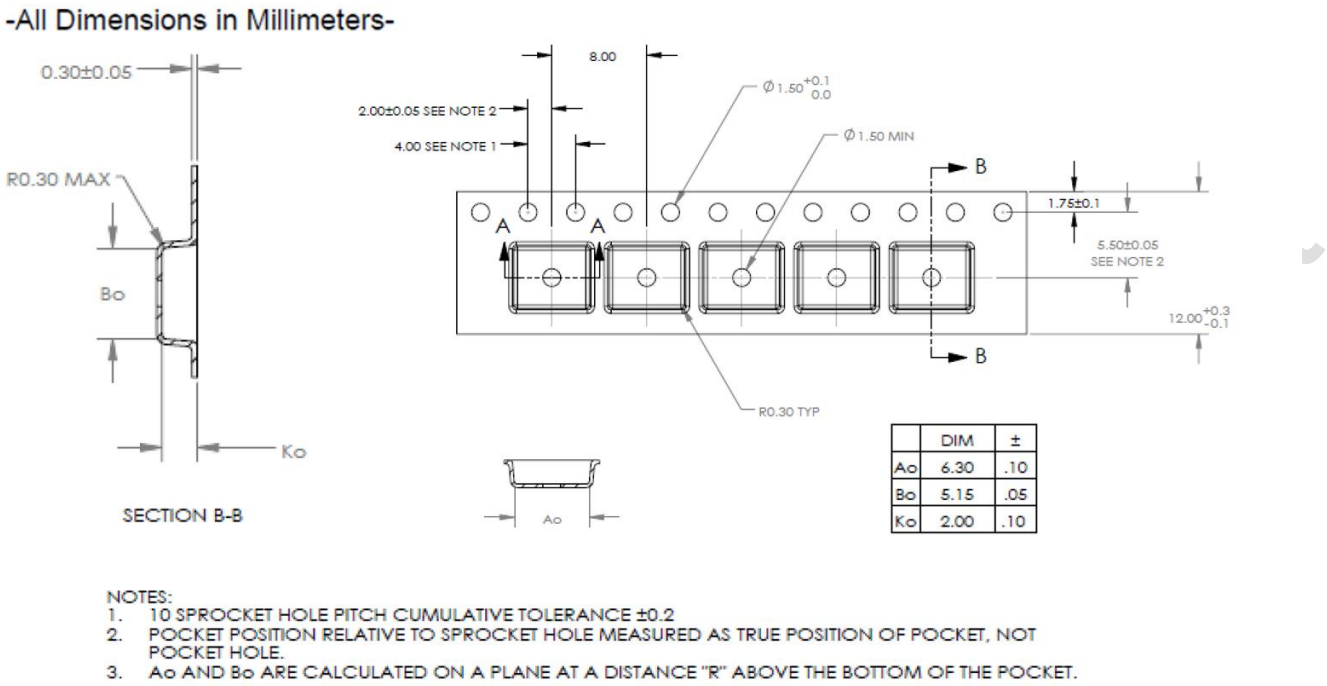


Figure 10: Carrier Tape Specifications

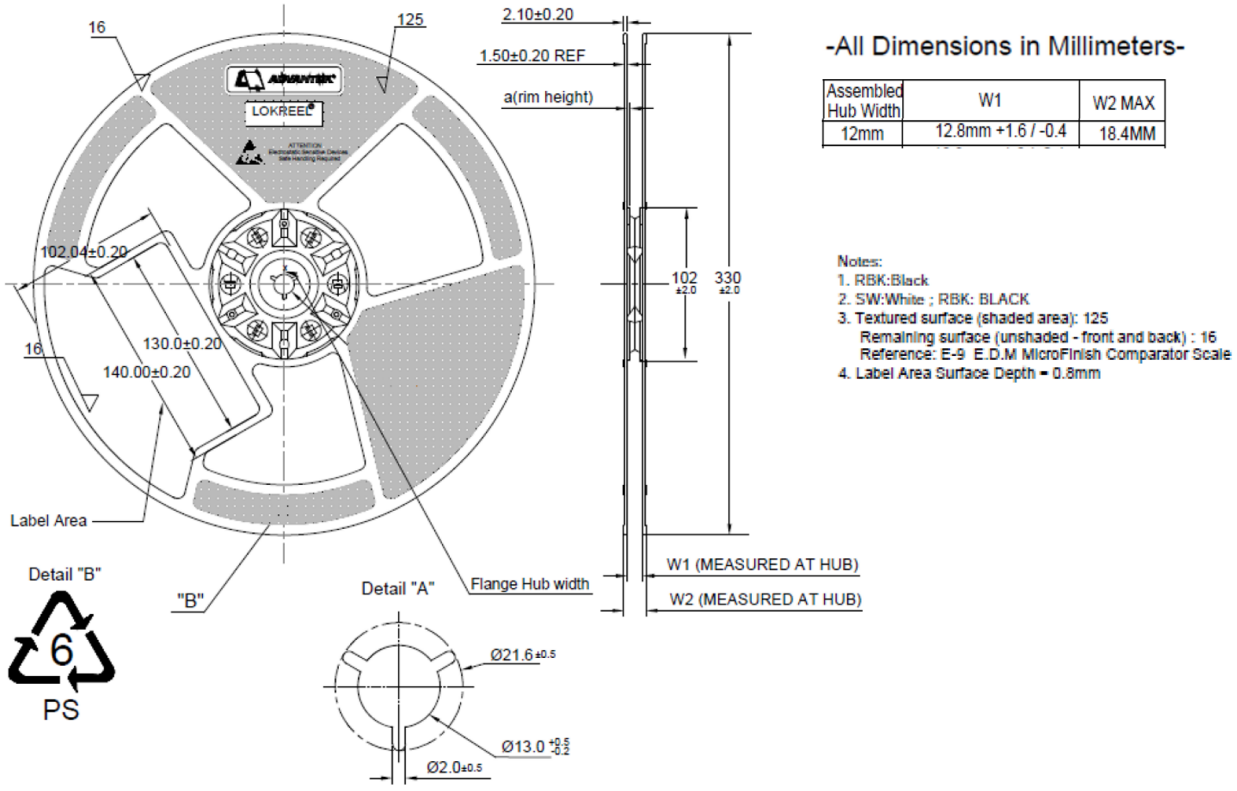


Figure 11: Plastic Reel Specifications

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6. Revision History

Revision	Date	Comments
V 1.0	31-JAN-2025	First Release of the Preliminary Final Data Sheet
V 1.1	06-FEB-2025	Figures 2, 3, 4, 6, 12 & 14, Tables 1, 2, 3, 4 & 5 and Chapters 1.3 & 3.1 updated, Figure 10 deleted