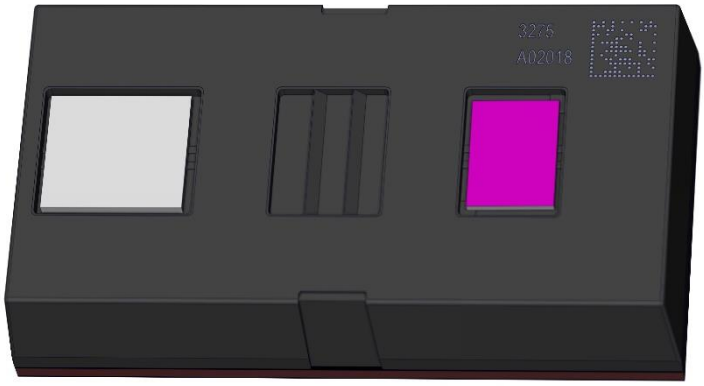
SOT25-001

3D Time-of-Flight Sensor

Datasheet



Restricted

1. Security warning

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2. Publication history

Version	Date	Description	Author	Approved
1.0	2023.08.25	Preliminary datasheet	Klein	Saxon

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1. General description

The SOT25-001 is a highly integrated, compact 3D indirect Time-of-Flight (iToF) sensor module which integrates a VCSEL emitter, a VCSEL driver chip, a ToF sensor and a Flash. SOT25-001 adopts SIP package and built-in depth calculation core. This sensor can achieve an accurate matrix distance measurement up to 4.5 meters without the impact of the reflectivity of the target object in different environments.

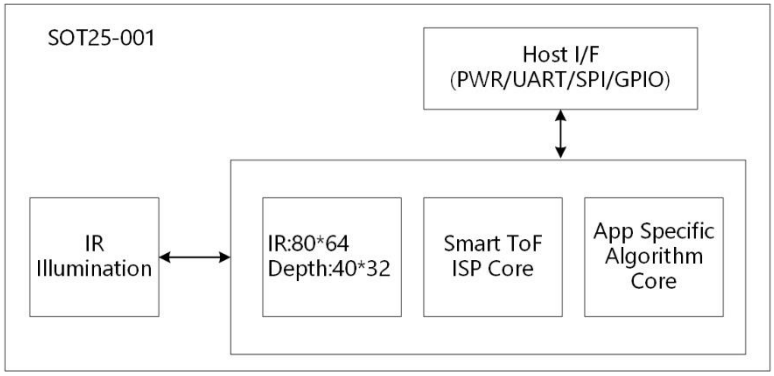


Figure 1: System block diagram

SOT25-001 has a variety of interfaces, support SPI, I2C, UART. SOT25-001 has an open kernel that allows users to develop algorithms. This sensor is designed with eye safety control circuit, which meets the requirements of Class I eye safety standard.

Features

- Fully integrated SIP module
  Transmit and receive integration
  Package：Optical LGA
  Size：17×9×3.72 mm
- Distance measurement
  Range: up to 4.5 m
  Measurement accuracy: ±3%
- Optics
  Class 1 laser device
  850 nm VCSEL emitter
  FOV：54.7° × 38.4°
- Characteristics
  Matrix depth detection, global exposure;
  Built-in depth calculation core, result output;
  The user kernel is open for users to develop their own algorithms;
  Rich and simple interface, support SPI / I2C / UART;
  Compliant with ROHS and REACH regulations

Applications

Distance measurement

3D modeling

Angle measurement

Intrusion detection

2. Technical parameters

2.1 Typical characteristics

2.1.1 Measuring range

Short range: TBD ~ 2.6m；

Long range: TBD ~ 4.5m。

2.1.2 Energy distribution(IR)

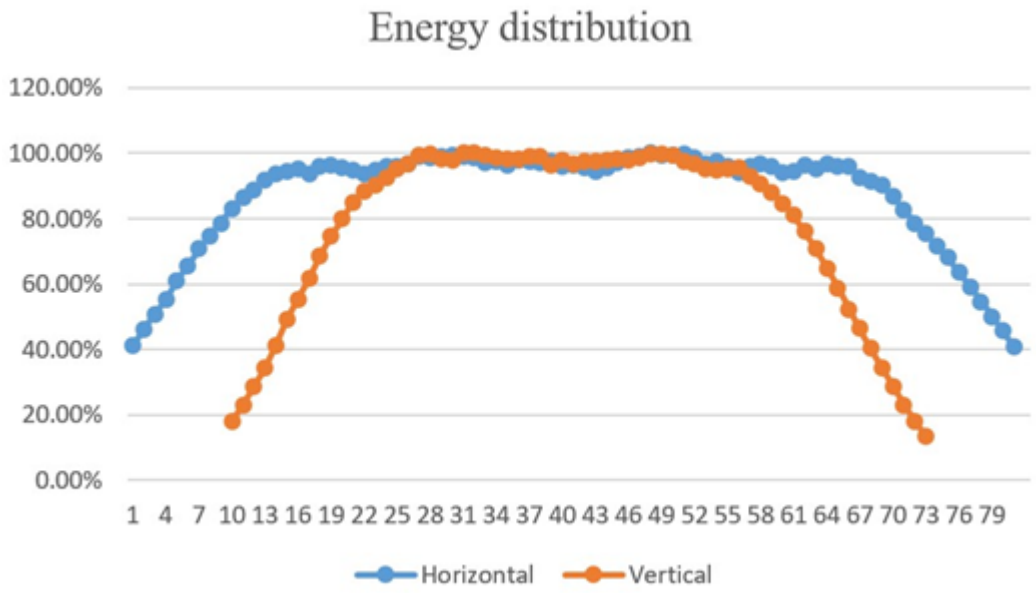


Figure 2 Typical curve of module energy distribution

2.1.3 Typical values region of Interest (ROI) and Field of view (FOV)

Table 1 Depth ROI and FOV

Application	HFOV	VFOV	H（ROI）	V（ROI）
IR	54.7°	38.4°	2：77	6：57
Depth	39.8°	30.2°	7：33	6：25

Note: 1. ROI rows and columns are indexed from 0;

2. FOV≥54.7°（H) * 38.4°（V), refer to Section 5.4 for FOV control;

2.1.4 Field of view (FOV)

The FOV of module is determined by both the FOV of transmit and the FOV of receiv , and tolerance is ±3°.

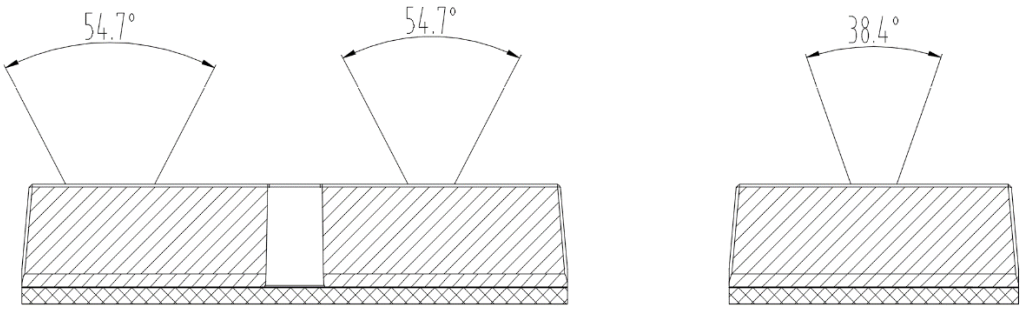
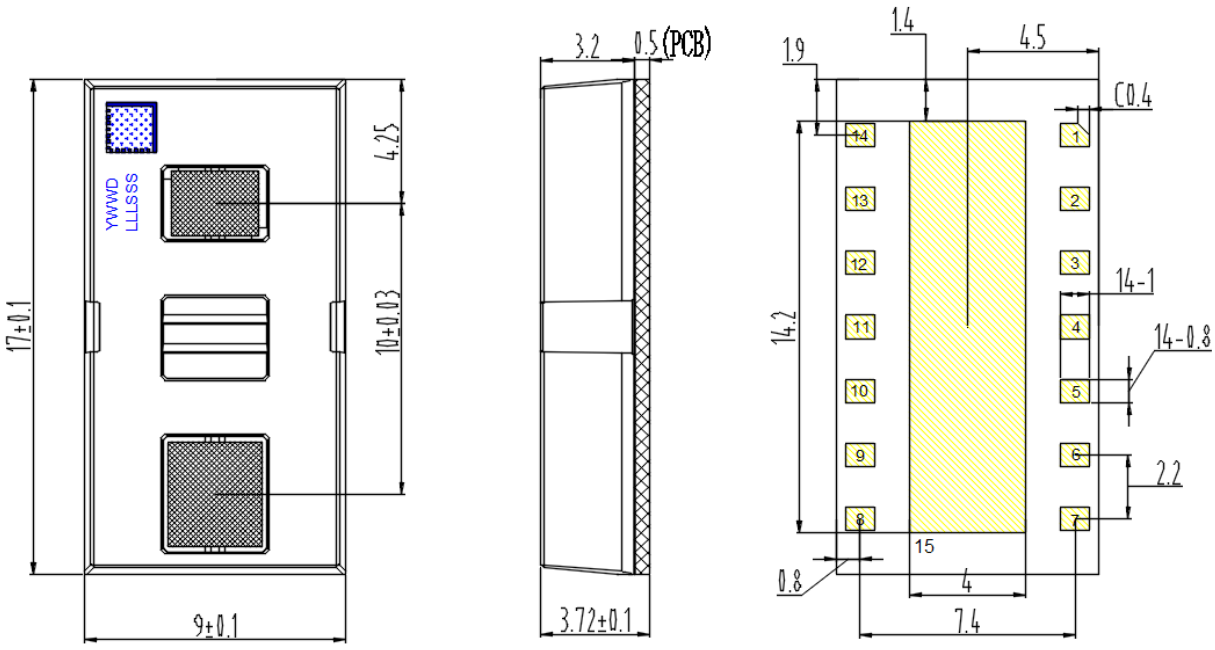


Figure 3 The diagram of light source FOV

2.2 Module dimensions

The SOT25-001 is a 15 Pin LGA package with plastic lid. Its dimensions are 17mm (±0.1 mm) x 9mm (±0.1 mm) x 3.72mm (±0.075mm). Tolerance is ±0.05mm unless otherwise specified.



Top view Side view Bottom view

Figure 4: SOT25-001 outline dimension

2.3 Pin definition

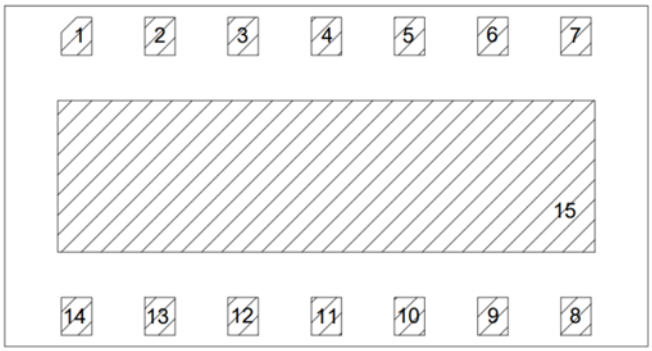


Figure 5: Pin out diagram (bottom view)

As shown in Figure 5, position of module Pin1 is marked. Module pin definitions are shown in the following table.

Table 2: Pin definition

Number	Pin name	Note
1	SPI_MISO/I2C_SDA	SPI data and I2C data multiplexed ports
2	CLKI	clock input, 24MHz
3	SPI_CLK/I2C_SCL	SPI clock and I2C clock multiplexed ports
4	HOST_IRQ	Interrupt
5	BOOT_MODE	select boot mode
6	SPI_MOSI/I2C_ADDR	SPI data and I2C device address selection
7	SPI_CSN	SPI enable, active low, Internal pull-up
8	PVDD	Transmission power supply,, 3.6V, ripple≤150mV, current≥1.2A
9	PVDD	Transmission power supply,, 3.6V, ripple≤150mV, current≥1.2A
10	PDN	Power down reset
11	UART0_RX	UART input
12	UART0_TX	UART output
13	VDD	Power supply, 3.3V, ripple≤50mV, current≥300mA
14	GND	To be connected to ground
15	GND	To be connected to ground

3. Electrical characteristics

3.1 Absolute maximum ratings

Table 3: Absolute maximum ratings (Ta=25℃)

Parameter	Symbol	Min.	Max.	Unit
Light source voltage	PVDD	-0.3	5	V
Sensor power supply	VDD	-0.3	3.6	V
Digital input/output	GPIO	-0.3	3.8	V
Storage Temperature	$T_{Storage}$	-40	85	℃
ESD (HBM)	ESD	-2k	2k	V

3.2 Recommended operating conditions

Table 4: Recommended operating conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit
Voltage	PVDD	3.4	3.6	3.8	V
	VDD	3.2	3.3	3.4	V
Temperature	T	-20	25	70	℃

3.3 DC characteristic parameters

The following table defaults on test condition: room temperature, PVDD=3.6V, VDD=3.3V, frame rate = 10FPS。

Table 5 DC characteristic

Parameter	Symbol	Min.	Typ.	Max.	Unit
Power	PVDD	3.4	3.6	3.9	V
	VDD	3.2	3.3	3.4	V
	Ishort		0.133 @10fps		A
	Ilong		0.187 @10fps		A
Digital input/output	VIH	2.1		-	V
	VIL	-		0.9	V
	VOH	2.3		/	V
	VOL	-		0.6	V
UART	VIH	2.1			V
	VIL			0.6	V
	VOH	2.3		-	V
	VOL	/		0.6	V

SPI	VIH	2.1		-	V
	VIL	-		0.9	V
	VOH	2.3		-	V
	VOL	-		0.6	V
	Phase(CPHA)		1		
	Polarity(CPOL)		1		

3.4 AC characteristic parameters

The following table defaults on test condition: room temperature, VDD=3.3V。

Table 6 AC characteristic

Parameter	Symbol	Min.	Typ.	Max.	Unit
UART	Baud rate		115200		bps
	Parity bit		NONE		bits
	Data bit		8		bits
	Stop bit		1		bits
	Flow control		NONE		
SPI	SPI_CLK Clock Frequency(f_{SPI_CLK})			25	MHz
	SPI_CLK pulse width Low（t_{CCPL}）	15			ns
	SPI_CLK pulse width high（t_{CCPH}）	15			ns
	SPI_CSN setup Time to SPI_CLK rising（t_{CLS}）	5			ns
	SPI_CSN hold.Timing from SPI_CLK rising（t_{CLH}）	15			ns
	SPI_CSN pulse width high（t_{CLPH}）	20			ns
	SPI_MOSI setup.Timing to SPI_CLK rising（t_{CDS}）	8			ns
	SPI_MOSI hold.Timing from SPI_CLK rising（t_{CDH}）	12			ns
	SPI_MISO three-stated.Timing from SPI_CLK falling（t_{COD}）			18	ns

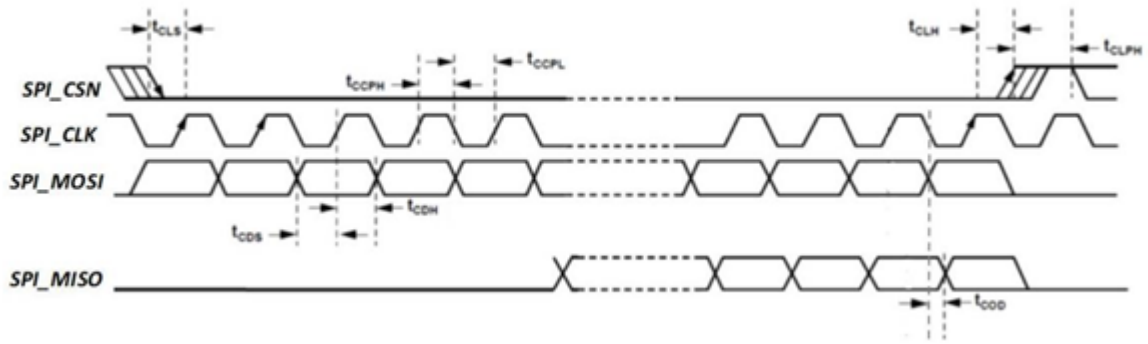


Figure 6 SPI timing

4. Functional description

4.1 Operating modes

The module has two working modes: Standby and Normal.

1. The chip powers on to enter Standby mode, at which time the module is in low-power mode, waiting for the user processor to issue commands.

2. After the module enters Normal mode, the user processor can send a command to make the module enter Standby mode again, the system will not interrupt the current frame data processing, and the system will enter Standby mode after the current frame is processed.

4.2 Range switching

The module has two ranges, short range and long distance, which can be realized by processing and sending commands, and the switching time is less than 75ms.

4.3 Frame rate setting

The frame rate of the module can be set according to the actual algorithm needs, but the influence of exposure time, overall power consumption and heat generation of the module needs to be comprehensively considered. The module frame rate is determined by the ROI, SPI rate, and output mode, as detailed in the table below.

Table 7 Frame rate table

SPI rate	output mode	Frame rate range
24 MHz	Depth (32*40)	5-30 FPS
24 MHz	IR (32*40) + Depth (32*40)	5-20 FPS
24 MHz	IR (64*80)	5-20 FPS
12.5 MHz	Depth (32*40)	5-30 FPS
12.5 MHz	IR (32*40) + Depth (32*40)	5-20 FPS
12.5 MHz	IR (64*80)	5-20 FPS

4.4 Power-on timing

The module is powered first, and then the module is started through the SPI command, t_{wait} > 100ms。

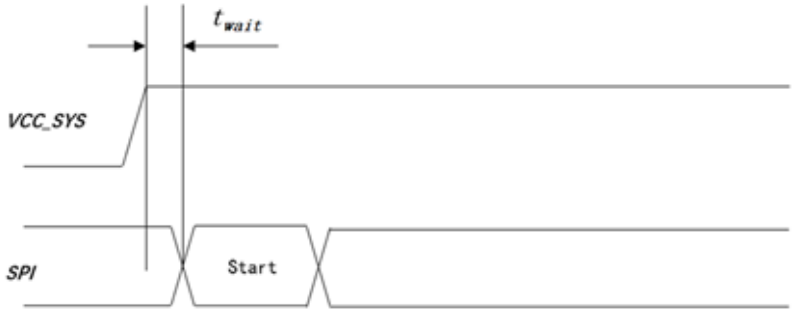


Figure 7 Power-on timing

4.5 Power-off timing

When the module is powered off, stop the module first, and then power off the module, t_{stop} ≥ 20ms

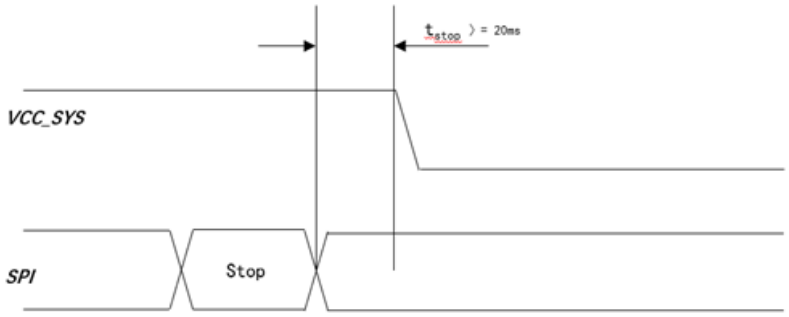


Figure 8 Power-off timing

4.6 OTA

The user processor can update the firmware of the module online, please refer to the module SDK and its instructions for details.

5. Module performance evaluation method

5.1 Module evaluation conditions

TOF module is a hand active light source sensor, and its performance has a certain correlation with the test scene. Based on this feature, the module evaluation needs to have a standard scenario. All test results in this article were measured using the following conditions.

- Module working environment: room temperature, about 25°C
- Chart reflectivity: 90%@850nm, 940nm
- Chart Size: 7m*2.5m

- Chart Surface flatness: less than 5mm
- Light conditions: dark room
- Orbit and Chart plane perpendicularity: error less than 0.5°

5.2 Center 10*10 Time domain accuracy percentage

Control specification: ≤0.2%

Calculation method:

1. Accuracy definition: accuracy is a parameter that reflects fluctuations, which is the root mean square error (STD), the smaller the number, the higher the stability of the measurement accuracy;

2. Statistical calculation: 30 frames of data are averaged for 3 frames, and after averaging into 10 frames, the average value of the center 10*10 data in RO1 of each frame is taken to calculate STD for a total of 10 data;

- Accuracy percentage = STD/1500mm*100%, STD calculation method is as follows.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(x_{obs,i} - x_{model,i})^2}{n}}$$

5.3 Center 10*10 accuracy percentage

Control specification: ≤ 15%

Calculation method:

1. Accuracy definition: accuracy is the error between the TOF test output distance and the real distance;

2. Statistical calculation: 30 frames of data average, take the average of 10*10 data in the center of ROI as the measured value;

- Accuracy percentage = (measured value -1500mm) /1500mm*100%

5.4 Module Energy (IR) Distribution

Control specification: >800

Calculation method:

1. IR Definition: The energy received by the module Sensor is fed back to the test range of the module;

2. Statistical calculation:

1) Take the center 10*10 pixel IR data output average at a distance of 1500mm;

2) The intrusion detection ROI corresponds to R at FOV, and the actual value of 1R on the four

sides is counted;

3. Reference test conditions: (do not meet the following test conditions need to be data benchmarking)

1) Distance: 1500mm, use equipment laser tester (rangefinder reference accuracy is 1.5mm);

2) The test chart is parallel to the camera using laser collimator correction, and at least 3pcs Golden sample is checked and confirmed every day to ensure test stability;

3) Chart reflectivity: ≥95% reflectivity, no convex four points on the target surface, deformation affects the product test results;

4) The overall environment is a dark room, the illuminance is less than 0.11ux, and there is no high specular reflection scene in the dark room;

5) The module fixed fixture should not be shaken, and the basic heat dissipation effect needs to be ensured (both parties use the same fixture),

6) Number of points: 60000;

5.5 Spatial depth STD percentage

Control specification: ≤1.5%

Calculation method:

1 Spatial depth STD definition: spatial depth STD reflects the spatial accuracy of TOF;

2. Statistical calculation: Calculate the spatial depth of all pixels within the ROI STD;

- spatial depth STD percentage = spatial depth STD/1500mm *100%;

5.6 Time Domain Depth STD Percentage

Control Specification: ≥ 98%

Calculation method:

1 Time Domain Depth STD Definition: Time Domain Depth STD reflects the time domain accuracy of TOF;

2. Statistical calculation: all pixels within ROI 30 frames time domain depth STD;

- time domain depth STD percentage = time domain depth STD/1500mm*100%;
- Statistics ≤1% STD pixels in Gurpy = (Number of ≤ 1% pixels within ROI) / Total number of pixels in ROI * 100%:

5.7 Percentage of time domain depth range

Control specification: ≥95%

Calculation method:

1. Time domain depth range definition: Time domain depth range is a parameter that reflects time

domain depth;

2. Statistical calculation: 30 frames time domain depth range of all pixels within the ROI;

- Range = Depth Max - Depth Minimum;
- Time domain depth range percentage = time domain depth range / 1500mm * 100%;
- Statistics≤3% Extreme Pixel Gubby = (Number of ≤3% Pixels in ROI) / Total Number of Pixels in ROI * 100%;

5.8 Number of consecutive dead pixels

Control specifications: less than or equal to 5

Calculation method:

1. Definition of continuous dead pixels: pixels with invalid depth in the output depth data are defined as dead pixels, and the number of consecutive dead pixels adjacent to each other is called continuous dead pixels;

2. Calculation statistics: count the depth abnormality with the real distance exceeding 10% accuracy, and then count the number of continuous dead pixels, if the continuous dead pixels exceed the set network value, it is judged as continuous dead pixels. The description of continuous dead pixels is as follows:

Note:

- For details, please refer to the TOF module detection scheme;
- Sampling level: According to GB/T2828.1-2003 single normal sampling level 1 sampling test, AQL=0.65.

6. Soldering and storage

6.1 Manufacturing and soldering

It is suggested that the peak reflow temperature is 240ºC ~ 260ºC and the absolute maximum reflow temperature is 260ºC. The recommended reflow soldering thermal profile (lead-free reflow soldering) and related parameters are shown below:

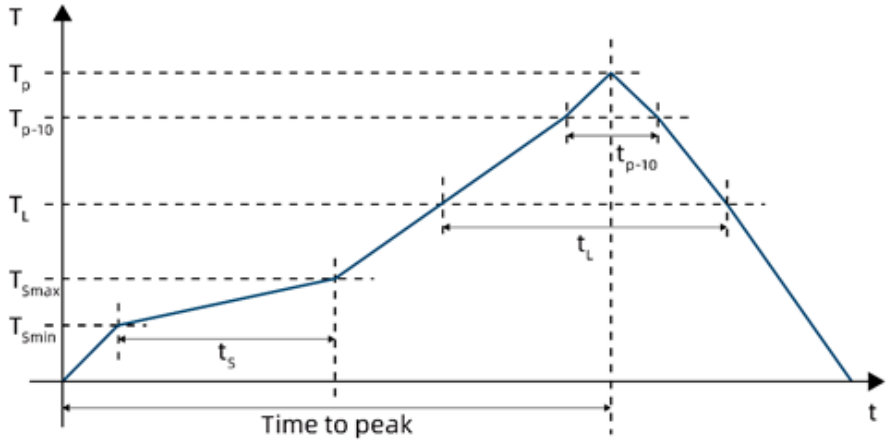


Figure 9: Recommended reflow soldering thermal profile

Table 8: Recommended thermal profile parameters

Parameter	Recomm. value	Max. value	Unit
Minimum temperature (T_{Smin})	130	150	°C
Maximum temperature (T_{Smax})	200	200	°C
Time t_S (T_{Smin} to T_{Smax})	90-110	60 - 120	s
Temperature (T_L)	217	217	°C
Time (t_L)	55-65	55 - 65	s
Ramp up	+2	+3	°C/s
Temperature (T_{p-10})	-	250	°C
Time (t_{p-10})	-	10	s
Ramp up	-	+3	°C/s
Peak temperature (T_p)	240	260 max.	°C
Time to peak	300	300	s
Ramp down (peak to T_L)	-4	-6	°C/s

Note:

- Temperature mentioned in the table above is measured at the top of the device package.
- The component should be limited to a maximum of 3 passes through this solder profile.

6.2 Storage information

The SOT25-001 is delivered in sealed moisture-barrier bags. It has been assigned a moisture sensitivity level of MSL 3. The following storage conditions must be noted:

Moisture Sensitivity

Optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package.

To ensure the package contains the smallest amount of absorbed moisture possible, each device is baked prior to being dry packed for shipping. Devices are dry packed in a sealed aluminized envelope called a moisture-barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

Shelf Life

The calculated shelf life of the device in an unopened moisture barrier bag is 12 months from the date code on the bag when stored under the following conditions:

- Shelf Life: 12 months
- Ambient temperature: ≤ 40℃
- Relative humidity: ≤ 90%

Re-baking of the devices will be required if the devices exceed the 12 months shelf life or the Humidity Indicator Card shows that the devices were exposed to conditions beyond the allowable moisture region.

Floor Life

The SOT25-001 is rated at MSL 3. As a result, the floor life of devices removed from the moisture barrier bag is 168 hours from the time the bag was opened, provided that the devices are stored under the following conditions:

- Floor Life: 168 hours
- Ambient temperature: ≤ 30℃
- Relative humidity: ≤ 60%

If the floor life or the temperature/humidity conditions have been exceeded, the devices must be re-baked prior to solder reflow or dry packing.

Re-baking Instructions

The re-baking conditions are as follows:

- 125±5 degrees Celsius for 8 hours;
- The product cannot be baked directly in the carrier tape;
- Avoid excessive vibration or impact to prevent serious deformation or damage of packaging material.

7. Package Specifications

7.1 Tape Specifications

Quantity per reel: 1100 pcs.

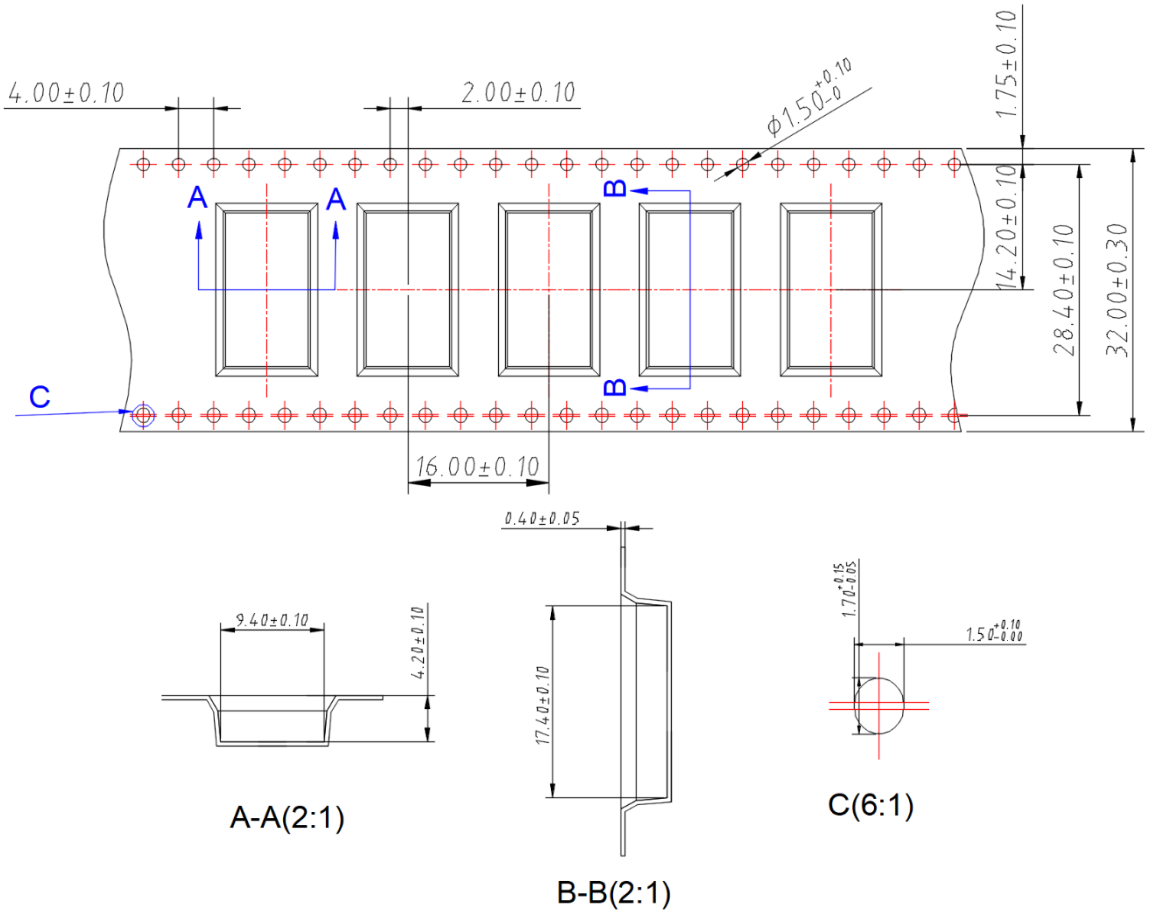


Figure 10: Tape Information (Unit: mm)

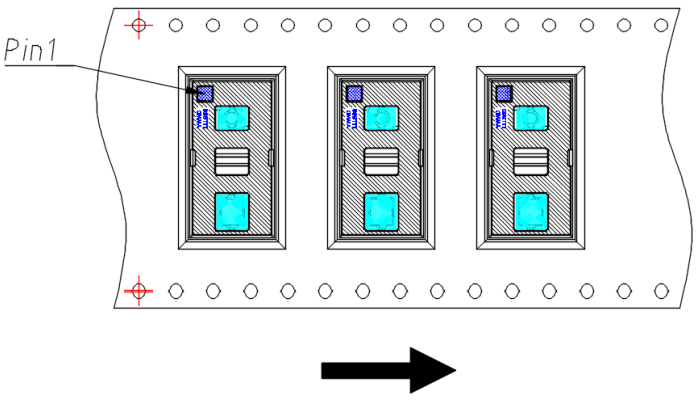
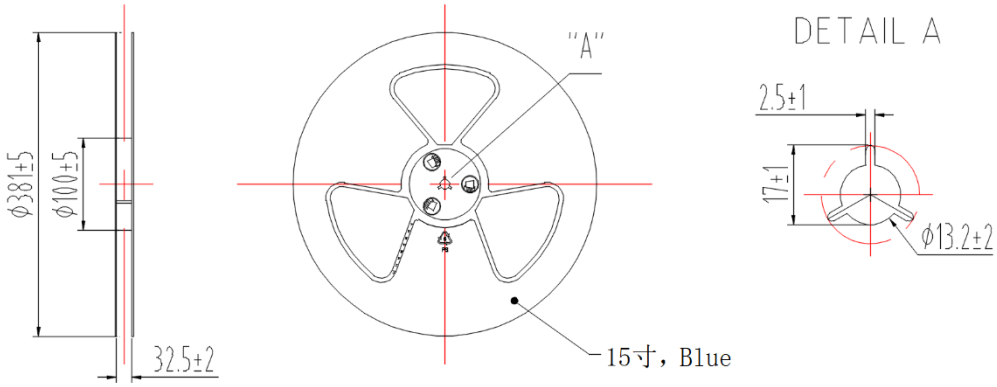


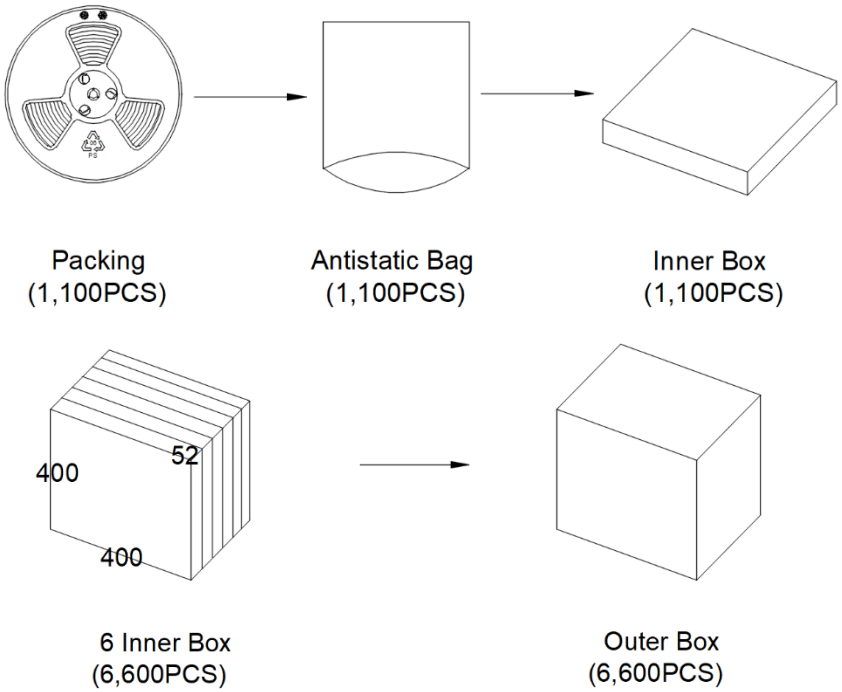
Figure 11: Pin Information

7.2 Reel Specification

15" Reel Specification (Unit: mm)

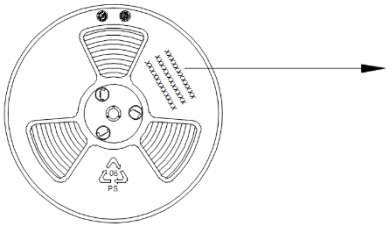


7.3 The content of Box



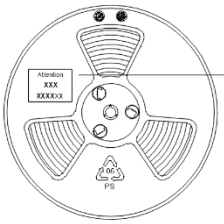
7.4 Packing Explain

The Label Content of the Reel



The Content Includes:
RoHS+HF, MSL:3;
Product type, Lot, Customer P/N;
and other essential information such as
Quality, Date etc.

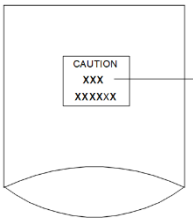
The Label Content of ESD Caution



ESD Caution Label

The Label Content of Moisture Caution

Moisture Caution: MSL 3



MSL 3 Caution Label

8. Module reliability test

8.1 Test item and condition

Table 9 Reliability test item and condition

Number	Test item	Test condition
1	High Temperature Storage	85℃，120H，test after stay in room temperature 2H
2	Steady State Temperature Humidity Storage	60℃，95%RH，120H，test after stay in room temperature 2H
3	Steady State Temperature Humidity Life	Power-on state，85℃，85%RH，96H；test after stay in room temperature 2H
4	Low Temperature Life	Power-on state，-30℃，96H；test after stay in room temperature 2H
5	Low Temperature Storage	-30℃，120H，test after stay in room temperature 2H
6	Thermal shock	1. Put the module into the anti-static box and keep it at +60℃ for 30min. 2. Reduce to -10℃ within 5min and maintain for 30min. 3. Rise to +60℃ within 5min and hold for 30min. 4. Then change its temperature to -10℃, according to the above cycle test 6cycles; 5. Samples are taken out at +60℃，test after stay in room temperature 2H
7	ESD	1. Air discharge, ±10kV plus or minus 5 times each, collect plus or minus 10 times each total 20 times limit test results; 2. Contact discharge: ±2KV plus or minus 10 times; 3. Connector: each Pin pin plus or minus 10 times, ±2KV; 4. Reference standards: IEC 61000−4−2, shell Level 3, signal cable level1
8	Drop test	Place the module in jig (jig weight 190g); Six facess, 1m, two times each, 12 times in total
9	Repetitive drop	Place the module in jig (jig weight 190g); Work face down, 15cm height drop, 300 times
10	Vibration	Frequency: 5-500Hz; PSD: 0.04G2/Hz,; The X,Y, and Z axes are 1H each
11	Package drop	Drop surface: 6 faces, 4 angles and 8 edges; Drop floor: cement floor; 2 rounds, height: 0.76m

8.2 Test Standard

- After the reliability test experiment, the functional test results shall be the criterion. Broken & falling parts not allowed.
- Module meet specifications before routine reliability test.

9. Laser eye safety

The SOT25-001 is designed to meet the Class 1 laser safety limits including single faults in compliance with IEC / EN 60825-1:2014. This applies to the stand-alone device and the included software supplied by Goermicro. In an end application system environment, the system may need to be tested to ensure it remains compliant. The system must not include any additional lens to concentrate the laser light or parameters set outside of the recommended operating conditions. Use outside of the recommended condition or any physical modification to the module during development could result in hazardous levels of radiation exposure.

10. Acronyms and abbreviations

Table 10: Acronyms and abbreviations

Abbr.	Definition
ESD	Electrostatic discharge
TOF	Time of flight
FOV	Field of view
FOI	Field of illumination
IIC	Inter-integrated circuit(serial bus)
VCSEL	Vertical cavity surface emitting laser