MA4424F94BL02 Datasheet

ToF Sensor

4424 Series

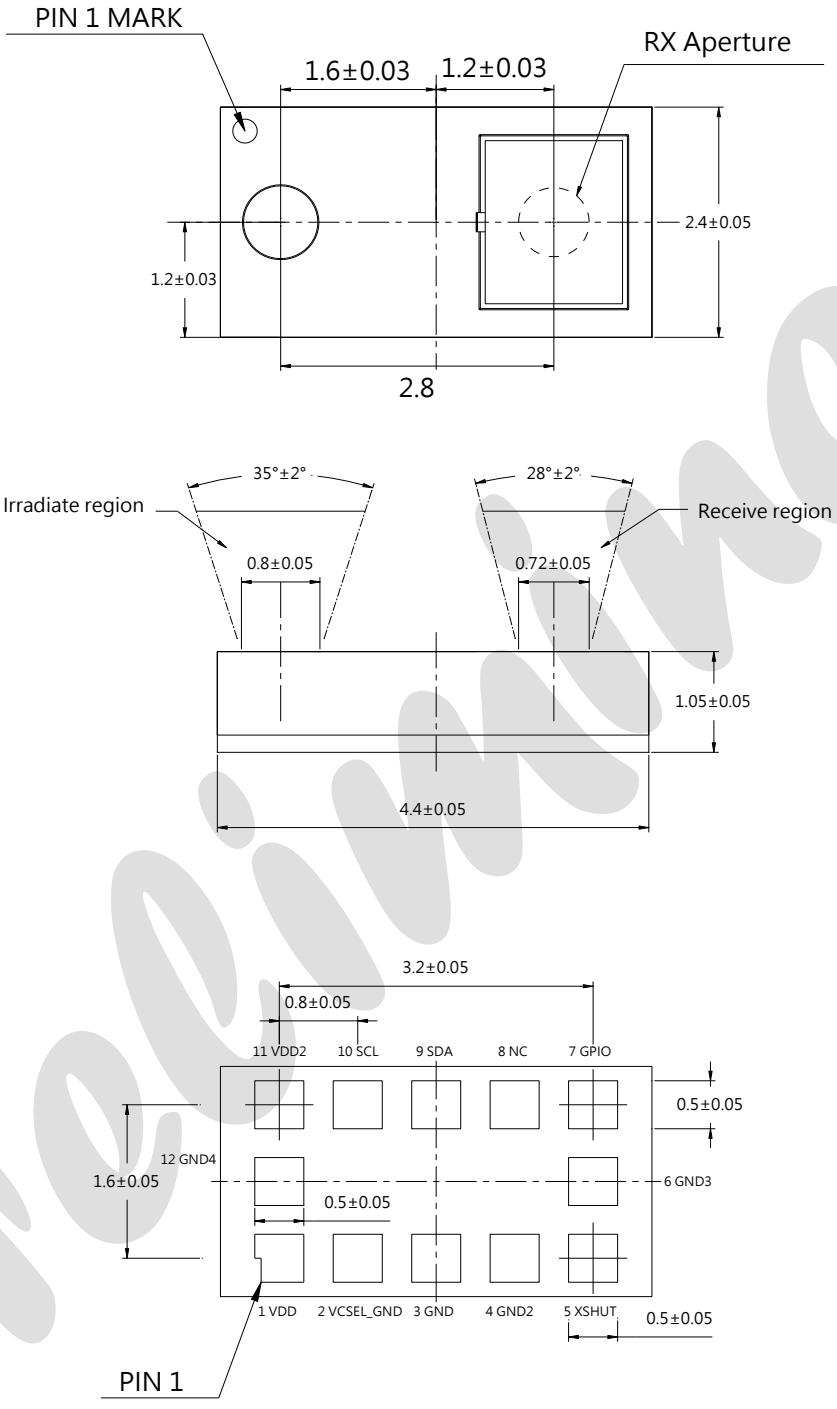
Applications

- Service robots
- Smart lighting
- Laser assisted autofocus (AF)
- Collision avoidance

Features

- Fully integrated miniature module
  - ✓ 940 nm VCSEL
  - ✓ VCSEL driver
  - ✓ Ranging sensor with advanced embedded micro controller
  - ✓ 4.4 x 2.4 x 1.05 mm
- I²C interface (up to 400kHz)
- Class 1 Eye safety
- RoHS 2.0 and REACH compliant
- MSL 3 qualified according to J-STD 020
- Measure absolute distances up to 3m
- Advanced embedded optical cross-talk compensation to simplify cover glass selection

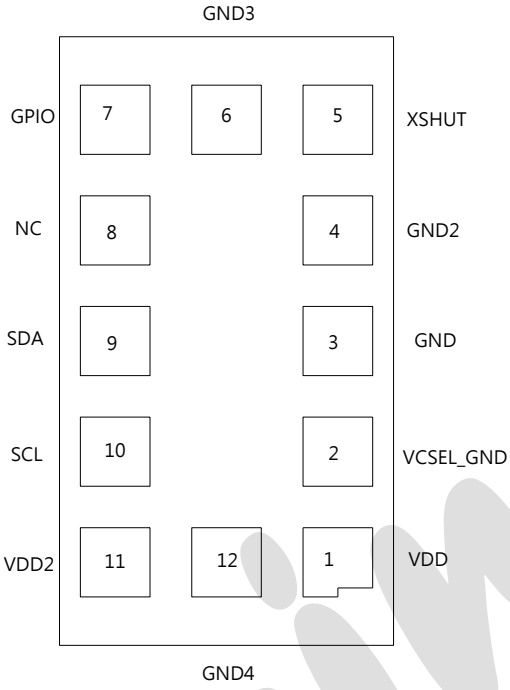
Dimensional Drawing



1. Dimensions are in millimeters.

2. Keep free of mechanical items which interfere with module operation in irradiate and receive area.

Device Pinout



Pin number	Signal name	Signal type	Signal description
1	VDD	Supply	To be connected to main supply,3.0~3.5V
2	VCSEL_GND	Ground	VCSEL ground, to be connected to main ground
3	GND	Ground	To be connected to main ground
4	GND2	Ground	To be connected to main ground
5	XSHUT	Digital input	X shutdown pin ,active low
6	GND3	Ground	To be connected to main ground
7	GPIO	Digital output	Open drain output
8	NC	NC	Do not connect, must be left floating
9	SDA	Digital input/output	I^2C serial data
10	SCL	Digital input	I^2C serial clock input
11	VDD2	Supply	Supply, to be connected to main supply
12	GND4	Ground	To be connected to main ground

Note.1 XSHUT digital input controls whether the device enters reset and low power consumption mode. After the device is powered on, the input level of XSHUT needs to be pulled up, and the sensor enters the working mode.

- Low level input voltage: the device resets and enters the low-power standby mode
- High level input voltage: the device wakes up from standby mode

Note.2 GPIO can be used as data interrupt. The high and low levels of GPIO are used to indicate whether the measurement data is ready.

Maximum Ratings

T_A : 25 °C

Parameter	Symbol		Rating
VDD	V_{DD}	min.	-0.3 V
		max.	3.6 V
SCL,SDA,XSHUT,GPIO	$V_{I/O\ terminal\ voltage}$	min.	-0.3 V
		max.	3.6 V
GND,GND2,GND3,GND4,VCSEL_GND	V_g	max.	0.0 V
Storage temperature	T_{stg}	min.	-40 °C
		max.	85 °C
Soldering temperature	T_{sol}	max.	260 °C
Relative Humidity (non-condensing)	RH_{nc}	max.	85 %
ESD withstand voltage (HBM : JEDEC JS-001-2017)	$V_{ESD-HBM}$	max.	2 kV
ESD withstand voltage (CDM : JEDEC EIA/JESD22-C101F)	$V_{ESD-CDM}$	max.	500 V

1. The reflow peak soldering temperature is specified according to IPC/JEDEC J-STD-020.

Recommended operating conditions

Parameter	Symbol		Rating
VDD	V_{DD}	min.	3.0 V
		max.	3.5 V
Operating temperature	T_{op}	min.	-20 °C
		max.	70 °C

Current consumption

T_A : 25°C

Parameter	Symbol		Values
Standby mode consumption	I_{SMC}	max.	12 µA
Active ranging average consumption (including VCSEL)	I_{AAC}	max.	48 mA
Active ranging peak consumption (including VCSEL)	I_{APC}	typ.	134 mA

Digital input and output

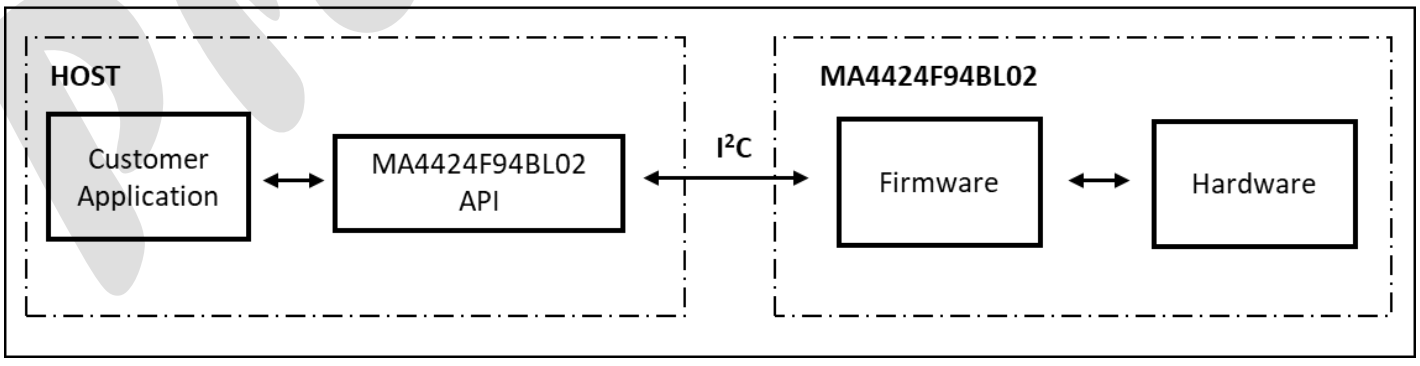
Parameter	Symbol	Min.	Typ.	Max.	Unit
	Interrupt pin(GPIO)				
Low level input voltage	V_{IL}	-	-	0.3VDD	V
High level input voltage	V_{IH}	0.52VDD	-	VDD	V
Low level output voltage (I_{OUT} = 4 mA)	V_{OL}	-	-	0.14	V
High level output voltage (I_{OUT} = 4 mA)	V_{OH}	VDD-0.5	-		V
	I2C interface(SDA/SCL)				
Low level input voltage	V_{IL}	0	-	0.3VDD	V
High level input voltage	V_{IH}	0.52 VDD	-	VDD	V
Low level output voltage (I_{OUT} = 4 mA)	V_{OL}	-	-	0.14	V
Leakage current	$I_{IL/IH}$	-	-	1	μA

Functional description

1.1 System function description

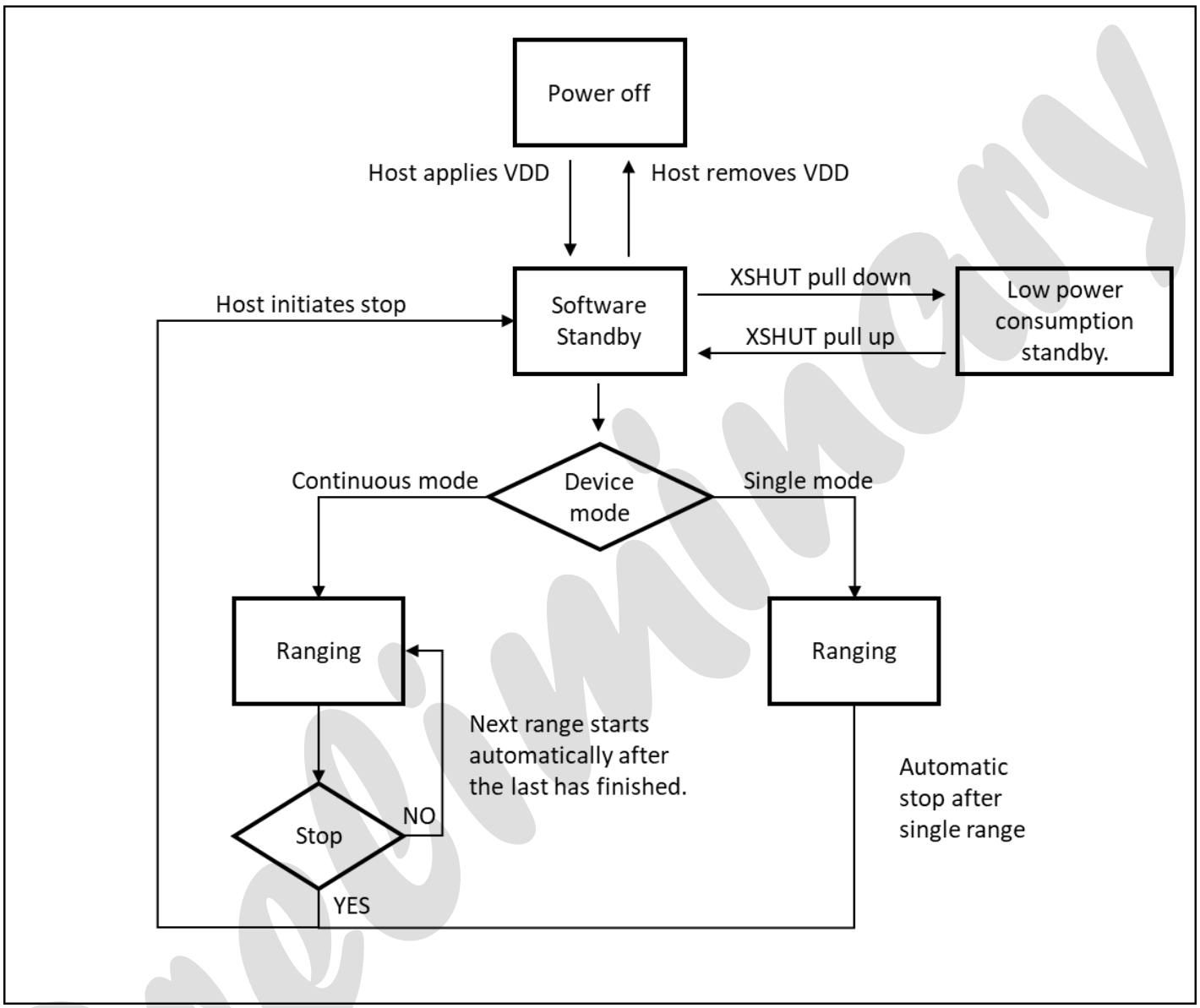
The MA4424F94BL02 system function description is shown in figure 1. The host application program is controlling the MA4424F94BL02 sensor device via API in the MA4424 ToF SDK. The SDK is applied for the functions of device initialization, ranging and measurement Functional APIs such as distance mode configuration and calibration that are available for users to take full advantage of the device capabilities.

Figure 1. MA4424F94BL02 system function description



1.2 Firmware state machine description

Figure 2 Firmware state machine.



1.3 Working mode

1.3.1 Device mode

- Single measure mode

  After the call is completed once, the MA4424F94BL02 system will automatically return to the software standby state

- Continuous measure mode

  After one measurement is completed, MA4424F94BL02 will automatically carry out the next measurement.

  Until the host initiates MA4424F94BL02 stop, it returns to software ready status after finished last measure.

1.3.2 Measurement mode

Measurement mode is a configurable option in working mode, and the default is normal mode. Customers can configure this mode according to their own needs.

1.4 Typical ranging flow

A typical complete measurement process consists of the following three stages:

- Waiting for the device to start
- Initialize sensor device
- Ranging

1.4.1 Wait for the device to start

The device check by itself and initial to standby mode in this step. Please check these items If the error happens.

- Peripheral circuit error.
- The sensor is damaged due to SMT issue or excessive temperature.
- There is a problem with the I^2C reading and writing program. Please check the waveform for analysis.

1.4.2 Ranging

A Ranging operation is including working mode and starting ranging configuration. The working mode is applied on what the users configure in different conditions. Since the ranging mode enabled, the user need to filter the invalid ranges of depth data as 65500 or 65300.

Note: If the target is not too far away and the measure data of the sensor is keeping the outliner value as 65300, please check whether the welding or peripheral circuit layout meets the standard.

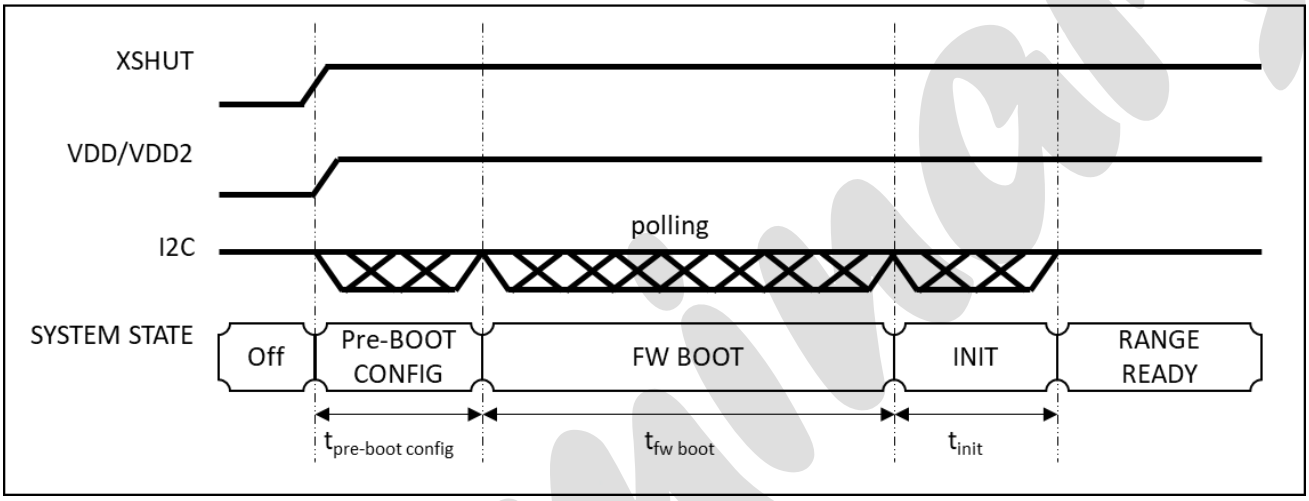
1.5 GPIO function

The GPIO pin will be raises when initiates MA4424F94BL02 start measurement by SDK and completes, until initiates SDK “GetRangingData” reads out the data and the GPIO will be pulled low. The user can use this pin as the trigger operations to interrupt reading data.

1.6 Power sequence

Since the power is supplying to VDD/VDD2, it is necessary to ensure that the XSHUT pin is in a high state to enable I2C for the communicate normally. While the device enters the pre-boot configuration stage, and the initialization will be start automatically after the firmware is streaming in. After the initialization is completed, the system is ready for the range measurement. I2C is only involved from the pre-boot configuration phase to the initialization phase. During the firmware startup phase, the device polls through I2C, and if the startup is successful, the polling ends.

Figure 3 The power-on sequence



Note:

- $t_{pre\text{-}boot\ config}$: The time from sensor power-up to pre-boot configuration, maximum up to 1.2ms.
- $t_{fw\ boot}$: The time for the sensor firmware to start, maximum up to 9ms
- t_{init} : The time of sensor initialization, maximum is 0.8ms

1.7 Standby mode

MA4424F94BL02 has standby mode, which can greatly reduce the power consumption of sensor

1.7.1 Entering standby mode

- Hardware mode: Pull-down the MA4424F94BL02 XSHUT before entry to standby mode.
- Software mode: Send I^2C command the sensor will enter standby mode (refer to SDKs for details).

1.7.2 Wake up device

- If the hardware is used to enter the standby mode, that raise the XSHUT level high to wake up device.
- If the software is used to enter the standby mode, that send I^2C command to make the sensor exit the standby mode to wake up device (refer to SDKS for details).

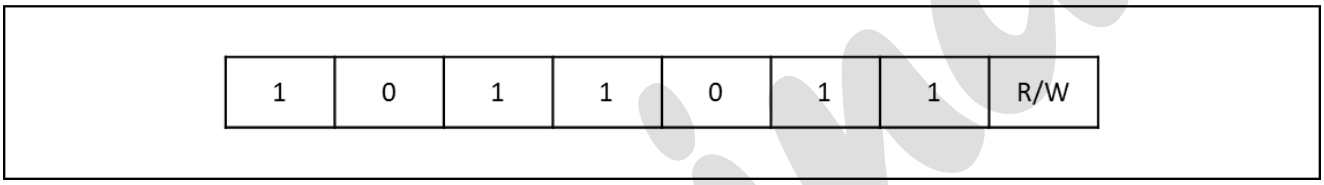
Control interface

2.1 I²C timing

I²C bus is composed of serial data line (SDA) and serial clock line (SCL), which is used to send and receive data. All controlled devices are connected in parallel on the bus. The I²C bus speed is 400kHz and the MA4424F94BL02 address is 0x5b.

During data transmission, the host sends a start signal, and then sends 7-bit device address and 1-bit read-write control bit R / W in order from high to low; When the read-write control bit is 0, it indicates that the master writes to the slave, and 1 indicates that the master reads to the slave, and then receives the slave response, as shown in Figure 4.

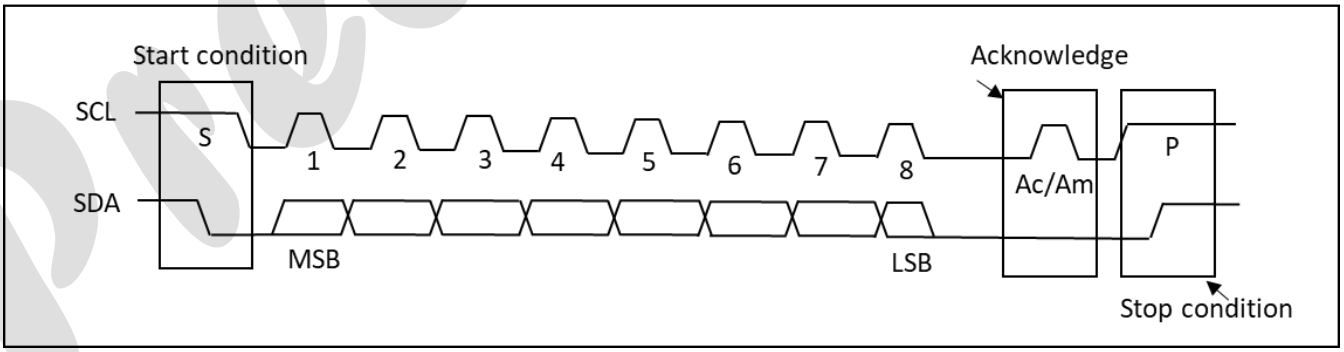
Figure 4 MA4424F94BL02 Address :0x5b



As shown in Figure 5 Data Transmission Protocol, the slave is connected to the bus with open drain structure, and both SCL and SDA need to be connected to pull-up resistance, so when the bus is idle, both lines are at high level. When any device outputs low level, it will pull the bus low.

- Start bit: when SCL is at high level, pull SDA down to generate start signal. After the slave detects the start signal, it shall be accurate ready to receive data. The data transmission state is from the start signal to the stop signal, which is completed by the bidirectional data line SDA.
- Stop bit: when SCL is high level, pull SDA high to generate end signal. After the slave detects the end signal, stop receiving data.

Figure 5 Data transfer protocol

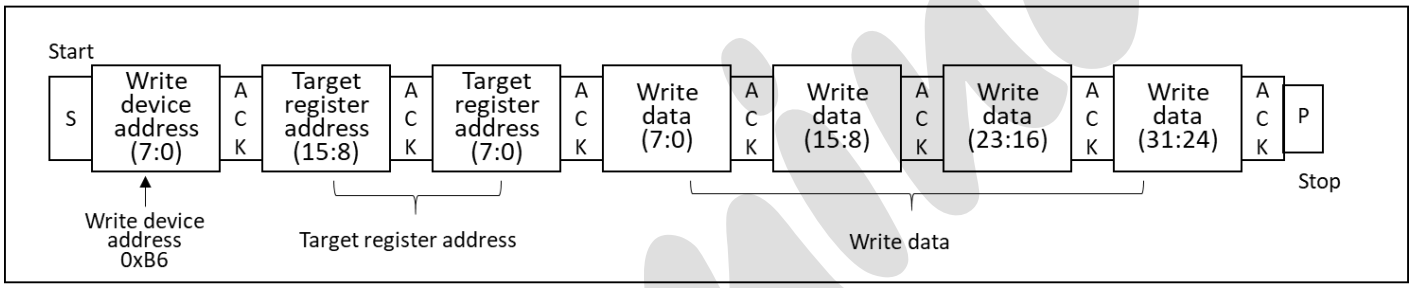


During data transmission, when the clock line SCL is at low level, SDA allows to change the transmitted data bits. When the SCL is at high level, SDA is required to remain stable, which is equivalent to transmitting 1 bit of data in one clock cycle.

At the end of the 8th clock cycle, the master releases the SDA to make the slave respond. In the 9th clock cycle, the slave pulls the SDA down to respond; In the 9th clock cycle, if SCL is high level and SDA is not detected as low level, it is regarded as non-response, indicating that the data transmission fails. At the end of the 9th clock cycle or the end of the current transmission, the slave releases SDA to enable the host to continue transmitting data. If the host sends a stop signal, the transmission ends.

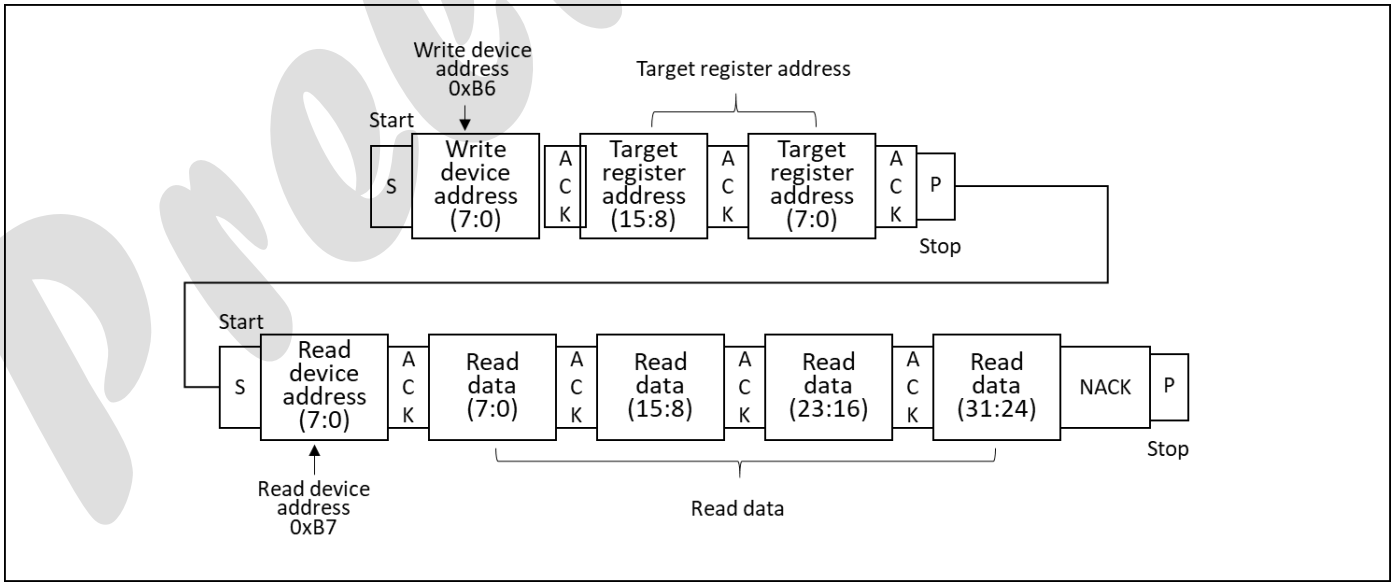
After the start bit starts, the first byte (7-Bit device address and 1-bit read-write control bit) is sent and received from the slave Start sending the word address after the response of. Inside MA4424F94BL02 is a series of sequentially addressed storage units. When we analyze the memory in the device, When the storage unit reads and writes, first specify the address of the storage unit, that is, the word address, and then write the content to the address for data transmission, the format is shown in below figure 6.

Figure 6 MA4424F94BL02 data format (write)



For the read timing, after sending the device address (write command) and word address, send the start signal and device address (read command) again. First do the virtual write operation to make the storage unit address pointer of the slave point to the storage unit address we want to read, and then read the data normally. The format is shown in below figure 7.

Figure 7 MA4424F94BL02 data format (read)

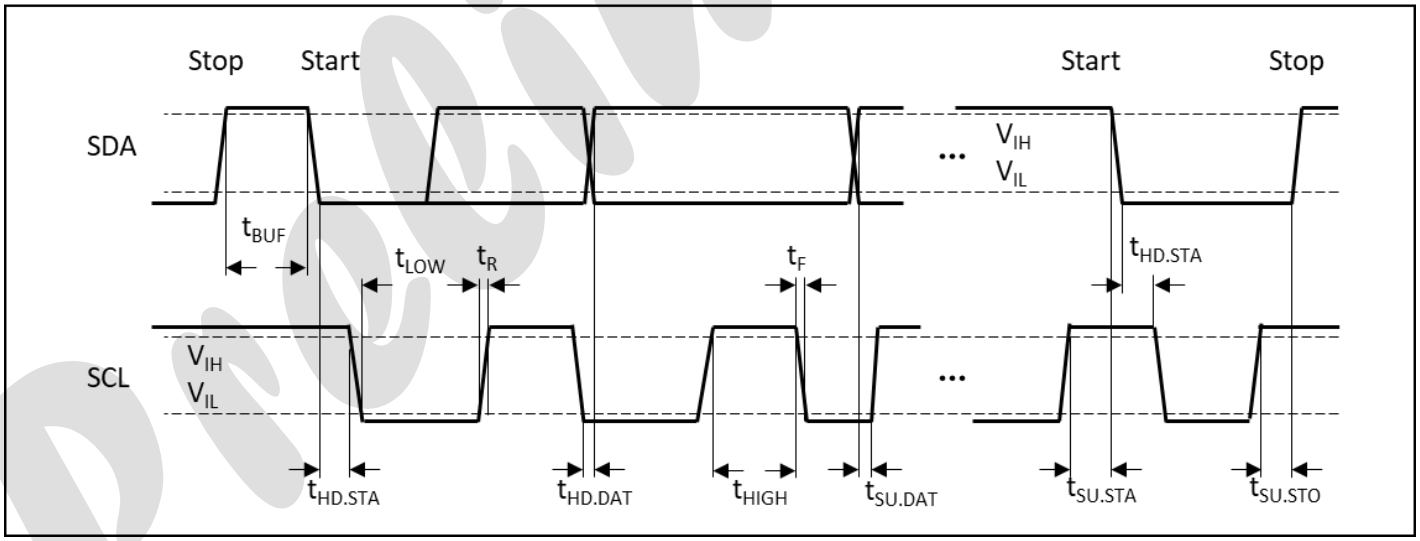


2.2 I²C interface - timing characteristics

Timings are given for all PVT conditions.

Symbol	Parameter	Minimum	Typical	Maximum	Unit
F_{I2C}	Operating frequency	0		400	kHz
t_{LOW}	Clock pulse width low	1.71		1.74	µs
t_{HIGH}	Clock pulse width high	0.81		0.904	µs
t_{SP}	Pulse width of spikes which are suppressed by the input filter		330		ns
t_{BUF}	Bus free time between transmissions	2.6		29	µs
$t_{HD.STA}$	Start hold time		0.825		µs
$t_{SU.STA}$	Start setup time	0.63		2.83	µs
$t_{HD.DAT}$	Data in hold time	0.057		0.87	µs
$t_{SU.DAT}$	Data in setup time	0.82		2.1	µs
t_R	SCL/SDA rise time	216		334	ns
t_F	SCL/SDA fall time	4		6	ns
$t_{SU.STO}$	Stop setup time	0.70	0.76		µs
$C_{i/o}$	Input/output capacitance (SDA)		5.5		pF
C_{in}	Input capacitance (SCL)		4.5		pF
C_L	Load capacitance		125	400	pF

Figure 8 I²C timing characteristics



Performance

Measurement conditions of maximum ranging distance and ranging accuracy scene:

- Target reflectance used: gray (18%), Light grey (55%), white (90%)
- The sensor is corrected at a distance of 15 cm
- Indoor: without strong light, in white light 300 lux environment
- Outdoor: Use a halogen lamp to simulate a 5K lux outdoor lighting environment, and the ambient light is applied to the target reflector, not directly illuminating the module.
- Operating voltage: 3.3V
- All distances are for the full field of view covered (FOV = 25 °)

3.1 Maximum ranging distance

Target reflectivity	Condition	Indoor	Outdoor(5K lux)
White card (90%)	typical	4000 mm	3500 mm
	Minimum	3000 mm	3000 mm
Light grey (55%)	typical	3500 mm	3500 mm
	Minimum	3000 mm	3000 mm
Gray card (18%)	typical	2500 mm	2500 mm
	Minimum	2000 mm	2000 mm

3.2 Ranging accuracy

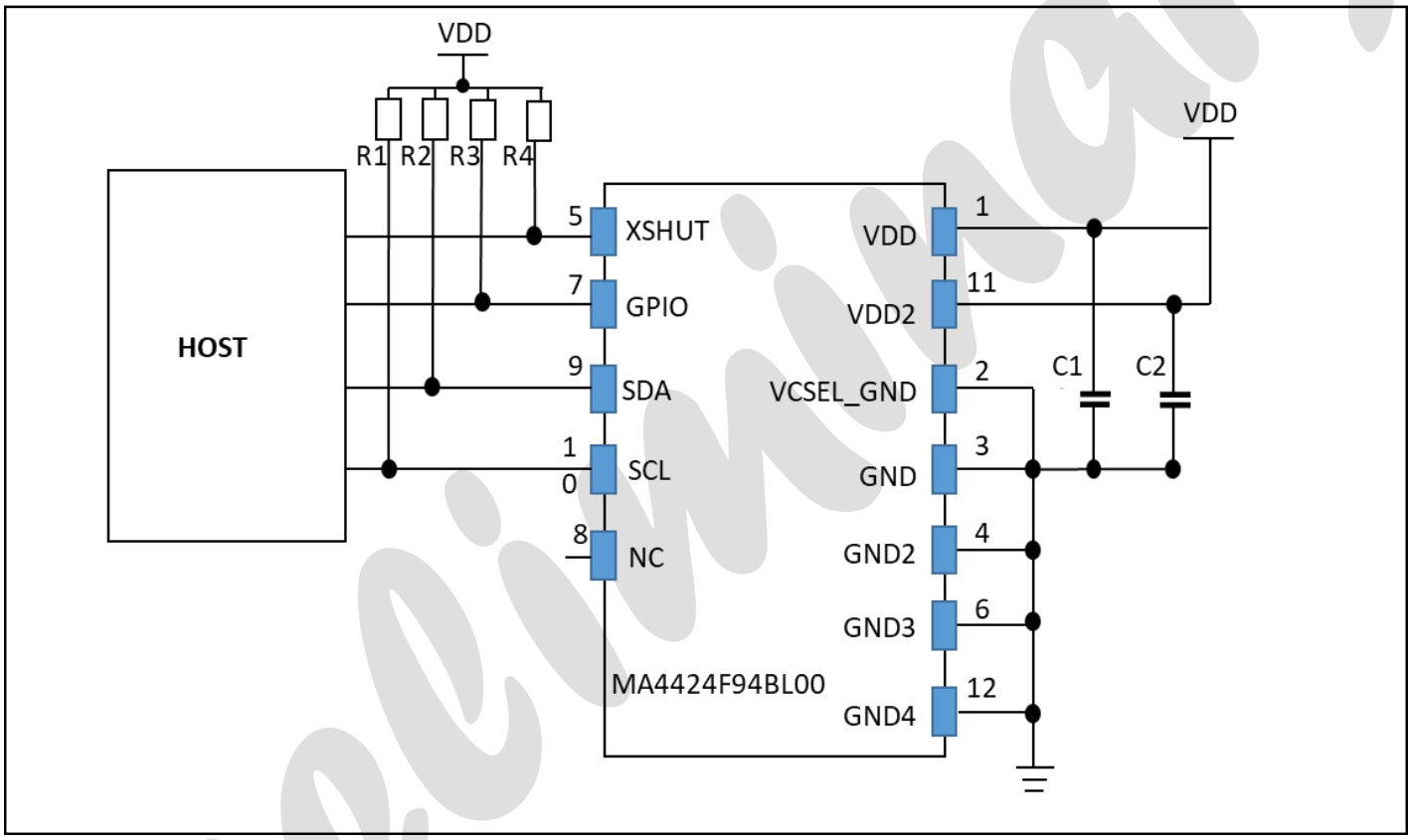
Parameter	Indoor		Outdoor(5K lux)	
	20-300 mm	>300 mm	20-300 mm	>300 mm
White card (90%)	±10 mm	±4%	±10 mm	±7%
Light grey (55%)	±10 mm	±4%	±20 mm	±7%
Gray card (18%)	±10 mm	±4%	±40 mm	±9%

Application schematic

- The capacitance on the external power supply VDD should be closed to the sensor pin1 and pin11 as possible, and its routing distance should be controlled within 3 mm.
- Xshut pin needs to be connected to the host terminal. If the status of the host terminal pin is uncertain, it needs to be connected with a pull-up resistance value of 10 kΩ.

4.1 Application schematic

Figure 9 Application schematic



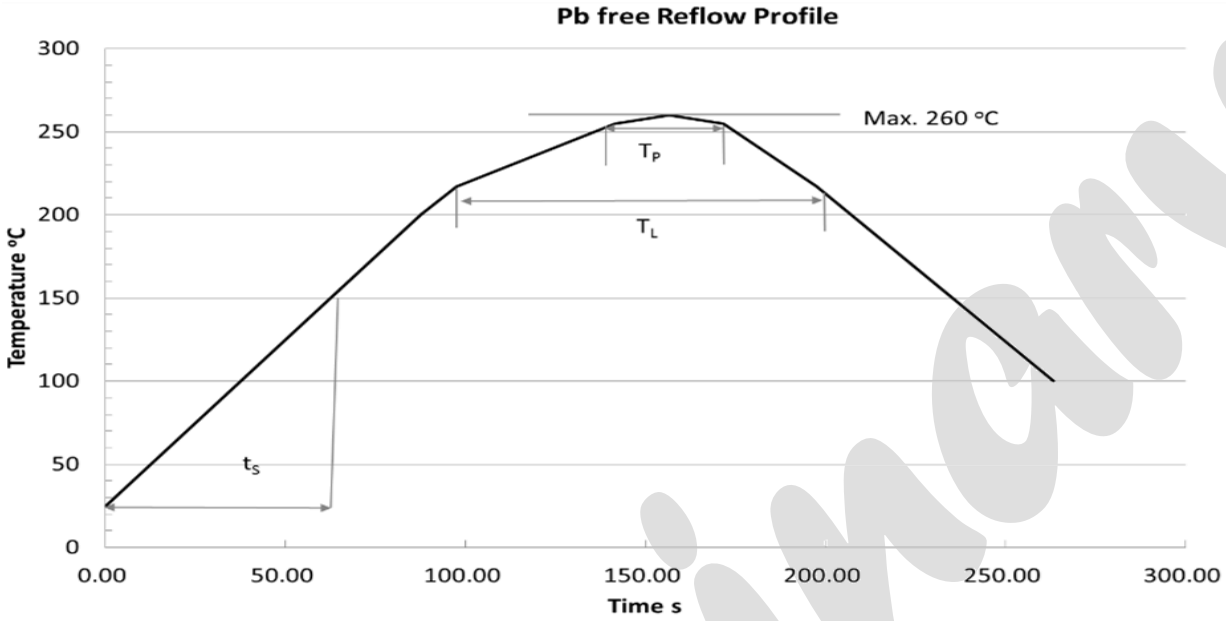
Lib ref.	Quantity	Position	Parameter	Tolerance
Capacitor	1	C1	4.7μF	±20%
Capacitor	1	C2	100nF	±20%
Resistor	2	R1、R2	1.5k-2.0k	5%
Resistor	2	R3、R4	10k	5%

Note:

If the parasitic capacitance of the user's equipment is relatively large, the pull-up resistors of I2C can be appropriately reduced and the rise time of I2C waveform can be reduced.

Reflow Soldering Profile

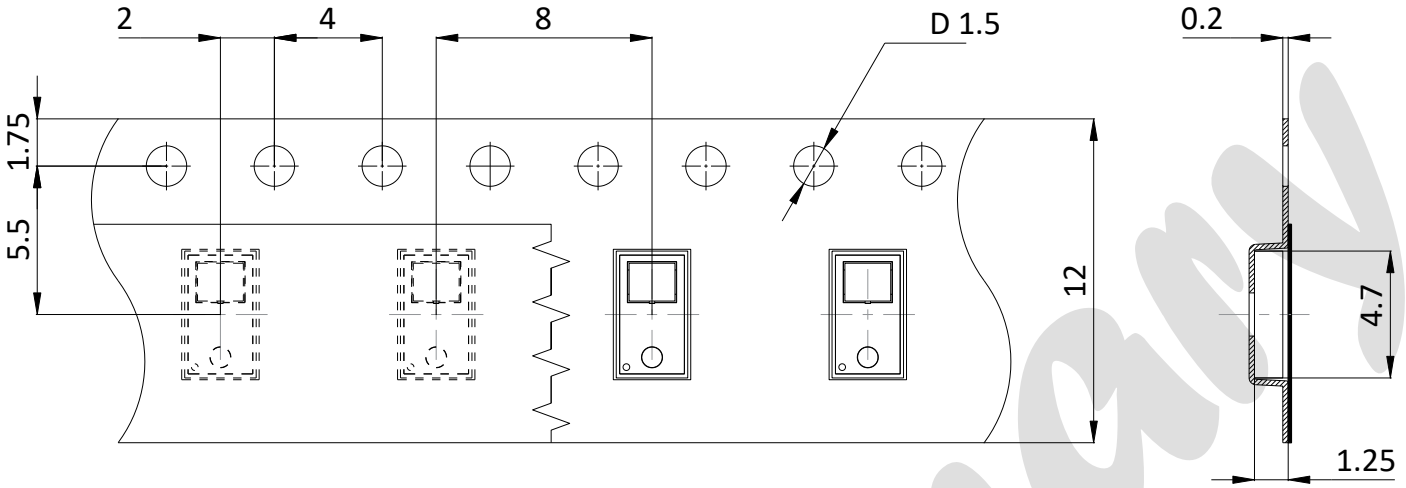
Product complies to MSL Level 3 acc. to JEDEC J-STD-020E



Profile Feature	Symbol	Pb-Free (SnAgCu) Assembly			Unit
		Minimum	Recommendation	Maximum	
Ramp-up rate to preheat 25 °C to 150 °C			2	3	K/s
Time t_S T_{Smin} to T_{Smax}	t_S	60	100	120	s
Ramp-up rate to peak T_{Smax} to T_P			2	3	K/s
Liquidus temperature	T_L		217		°C
Time above liquidus temperature	t_L		80	100	s
Peak temperature	T_P		245	260	°C
Time within 5 °C of the specified peak temperature TP - 5 K	T_P	10	20	30	s
Ramp-down Rate T_P to 100 °C			3	4	K/s
Time 25 °C to T_P				480	s

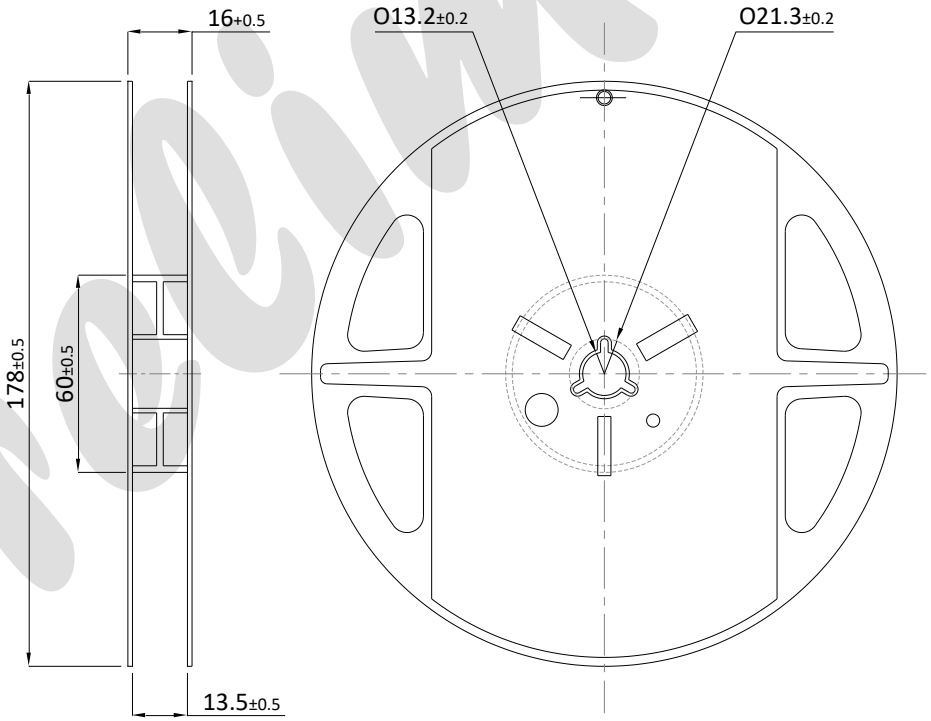
1. Do not stress the silicone resin while it is exposed to high temperature.
2. The reflow process should not exceed 3 times.

Dimensions of Tape



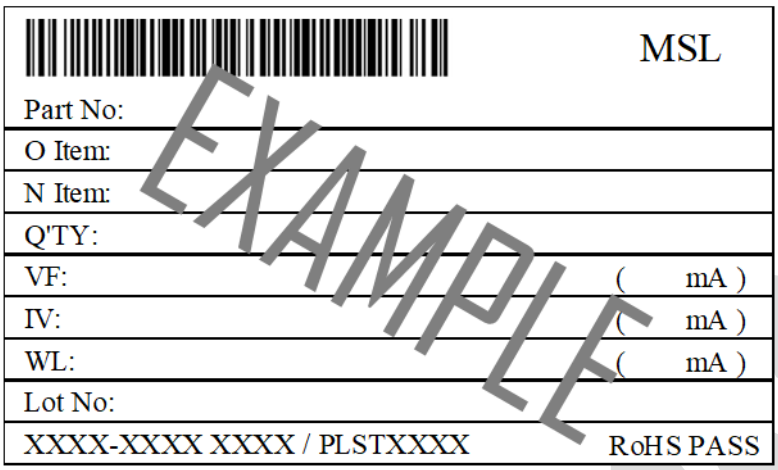
1. Dimensions are in millimeters.
2. General tolerance is ± 0.1mm.

Dimensions of Reel

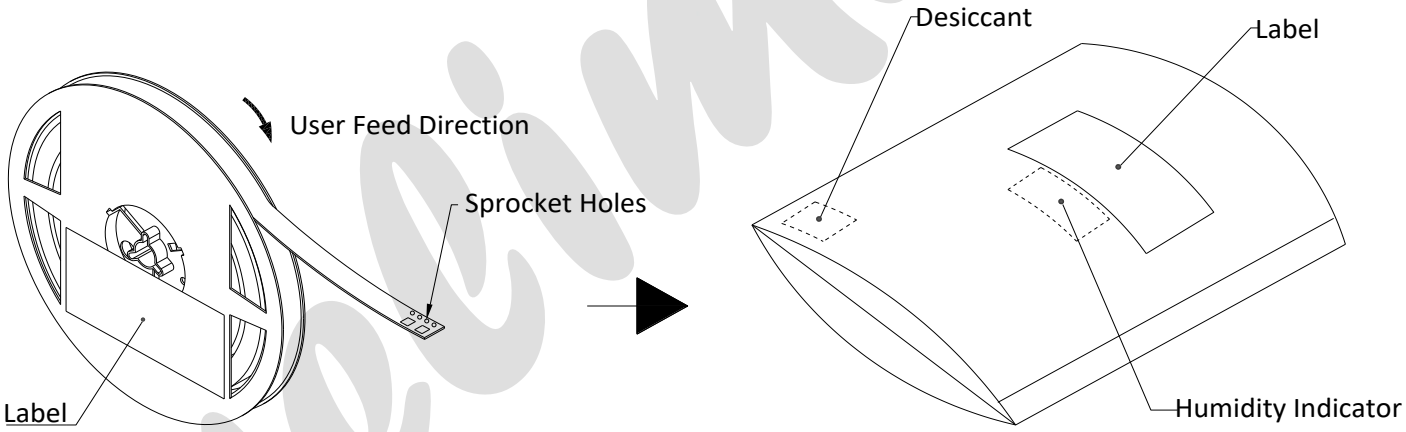


1. Dimensions are in millimeters.
2. 1000 pieces per reel.
3. Dimensions acc. to EIA 481-E.

Barcode-Product-Label (BPL)



Dry Packing Process and Materials



1. Moisture-sensitive product is packed in a dry bag containing desiccant and a humidity card according JEDEC-STD-033.

Disclaimer

1. BRIGHTEK reserves the right(s) on the adjustment of product material mix for the specification.
2. The product meets BRIGHTEK published specification for a period of one year from date of shipment.
3. The graphs shown in this datasheet are representing typical data only and do not show guaranteed values.
4. When using this product, please observe the absolute maximum ratings and the instructions for using outlined in these specification sheets. BRIGHTEK assumes no responsibility for any damage resulting from the use of the product which does not comply with the absolute maximum ratings and the instructions included in these specification sheets.
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