SY22316PS32-G00

16-bit Proximity Sensor for TWS Application

General Description

SY22316PS32-G00 integrates an IR photodetector, a flexible data acquisition engine and a 940 nm Vertical Cavity Surface Emitting Laser diode (VCSEL) in a single package.

With the proximity photodiode and the high SNR processing circuitry integrated on the main chip, it can be used in low power applications where proximity sensing is required, and where space and low-power power consumption are critical.

The digital interface consists of a 1 MHz SMBus compatible /I²C interface along with a configurable interrupt pin. A flexible interrupt scheme simplifies the system design complexity by eliminating the need to poll the device.

SY22316PS32-G00 design featuring low power operation, high SNR for proximity sensing, high data linearity, user friendly interface and a wide operating temperature range, is suitable for proximity sensing in battery-powered applications.

Applications:

- Smart Phones
- TWS (true wireless stereo) Headphones
- Home Appliances
- Robotics

Features

- Reliable Proximity Detection between 3mm and 15cm
- 16-bit ADC with Programmable Integration Time, Gain and Sleep Time Enables High SNR Measurements and Low Power Operation.
- 940 nm VCSEL Eliminates the “Red Glow”
- Programmable VCSEL Drive Current with Built-in Temperature Compensation.
- Uses Proprietary Design Techniques and Package to Reduce Optical Crosstalk
- Input Voltage Range: 2.8V to 3.6V
- Current Consumption (Max):
  - Inactive -2μA
  - Sleep Mode -13μA
  - ADC Conversion -1.1 mA
- -30°C to +85°C Operating Temperature
- Package Information
  - Size:2.55mm×1.50mm×0.60mm
  - Type: SMD BT with Transparent Molding Compound

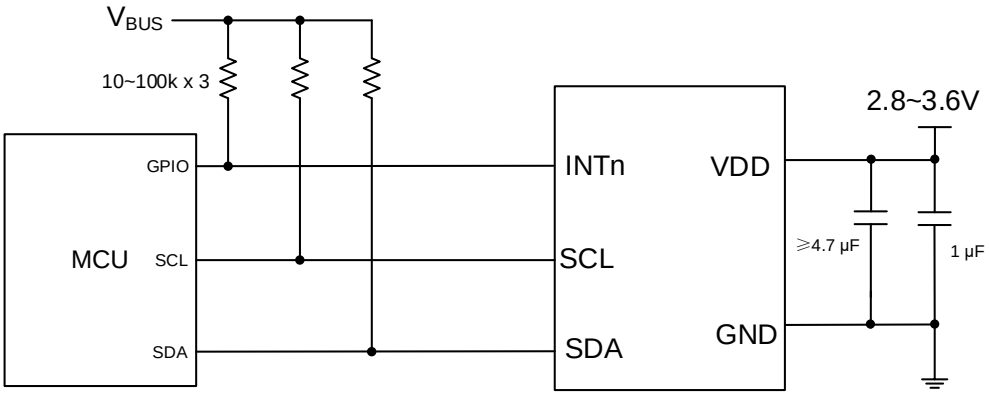


Figure 1. Typical Application Schematic [1]

Note [1]. Bypass capacitors should be placed as close as possible to the device to eliminate noise.

Functional Block Diagram

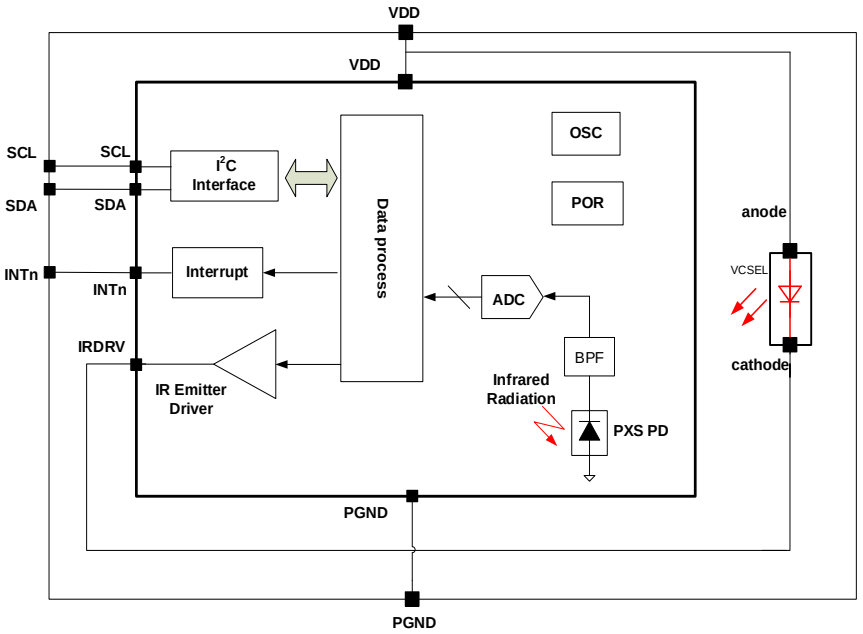


Figure 2. Block Diagram

Pin No	Pin Name	Pin Description
1	VDD	Positive supply: 2.8V to 3.6V.
2	INTn	Interrupt output with open-drain configuration, low level active.
3	SDA	I²C data line. The I²C bus lines can be pulled from 1.7V to above VDD, 3.6V max.
4	SCL	I²C clock line. The I²C bus lines can be pulled from 1.7V to above VDD, 3.6V max.
5	PGND	Power supply ground. All voltages are referenced to PGND.
6	NC	No connection.

Absolute Maximum Ratings [1] T_A=25°C, unless otherwise specified	Min	Max	Unit
Supply Voltage	-0.3	4	V
I²C Bus Voltage	-0.3	4	V
I²C Bus Current		10	mA
INTn Voltage	-0.3	4	V
INTn Current		10	mA
Central Wavelength of VCSEL	940		nm
Human Body Model	±2000		V
Charged Device Model	±500		V

Recommended Operating Conditions	Min	Max	Unit
Supply Voltage	2.8	3.6	V
Storage Temperature	-40	+100	℃
Operating Temperature	-30	+85	

Electrical Characteristics V_{DD} = 3.0V, T_A = +25°C, unless otherwise specified						
Parmeter	**Symbol**	**Test Condition**	**Min**	**Typ**	**Max**	**Unit**
Supply Voltage Range	V_{DD}		2.8	3.0	3.6	V
Supply Current when Disabled	I_{DD_SD}	PXS_EN=0			2	μA
Supply Current when in Sleep State	I_{DD_SLP}	VCSEL current excluded, PXS_INT_TIME=0000,WAIT_EN=1, PXS_SLP=111		10	13	μA
Supply Current when A-D Conversion is Ongoing	I_{DD_ADC}	VCSEL current excluded, PXS_INT_TIME=0000, WAIT_EN=0		0.9	1.1	mA
Full Scale of Proximity ADC Output	$DATA_{PXS\_FS}$				65535	counts
Driving Current	I_{IRDR}	PXS_DRV=0		10		mA
		PXS_DRV=1		15		
Effective Proximity Reading	$DATA_{PXS\_3cm}$-$DATA_{PXS\_\infty}$	PXS_DRV=0, VCSEL_DUTY=11, PXS_GAIN=01, PXS_INT_TIME=0100, PXS_BG=11, Kodak Grey Card, 18% Reflectivity, Distance is 3cm and ∞	20100	23700	27300	counts
Sleep Time between Two Adjacent Proximity ADC Conversions	t_{SLP}	PXS_SLP=000		6.25		ms
		PXS_SLP=111		800		ms

I²C Electrical Specifications [2] V_{DD} = 3.0V, T_A = +25°C, unless otherwise specified						
Parameter	**Symbol**	**Test Condition**	**Min**	**Typ**	**Max**	**Unit**
Supply Voltage Range for I²C Interface	V_{I^2C}		1.7		V_{DD}+0.3	V
SCL Clock Frequency	f_{SCL}				400	kHz
Low Level Input Voltage of SCL and SDA	V_{IL}				0.55	V
High Level Input Voltage of SCL and SDA	V_{IH}		1.25			V
SDA Current Sinking Capability	I_{SDA}	V_{OL} = 0.4V	2.7	5		mA
Hysteresis of Schmitt Trigger Input	V_{hys}		0.05V_{DD}			V
Low-level Output Voltage of SDA	V_{OL}	I_{OL}=4mA			0.4	V
Input Leakage for SDA, SCL	I_i		-10		10	μA
Pulse Width of Spikes Suppressed by the Input Filter	t_{SP}				50	ns
Capacitance for Each SDA and SCL Pin	C_i				10	pF
Hold Time (repeated) START Condition	$t_{HD:STA}$		0.6			μs
Low Period of the SCL Clock	t_{LOW}		1.3			μs
High Period of the SCL Clock	t_{HIGH}		0.6			μs
Set-up Time for a Repeated START Condition	$t_{SU:STA}$		0.6			μs
Data Hold Time	$t_{HD:DAT}$		30			ns
Data Set-up Time	$t_{SU:DAT}$		100			ns
Set-up Time for STOP Condition	$t_{SU:STO}$		0.6			μs
Bus Free Time between a STOP and START Condition	t_{BUF}		1.3			μs
Rise Time of both SDA and SCL	t_R	$R_{pull-up}$ = 10kΩ, C_b = 10pF		95		ns
Fall Time of SDA and SCL	t_F	$R_{pull-up}$ = 10kΩ, C_b = 10pF		25		ns
Capacitive Load for each Bus Line	C_b				0.4	nF
SDA and SCL System Bus Pull-up Resistor	$R_{pull-up}$	Maximum is determined by t_R and t_F		10		kΩ
Data Valid Time	$t_{VD:DAT}$				0.9	μs
Data Valid to Acknowledge Time	$t_{VD:ACK}$				0.9	μs
Noise Margin at the LOW Level	V_{nL}		0.1V_{DD}			V
Noise Margin at the HIGH Level	V_{nH}		0.2V_{DD}			V

Note [1]. Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note [2]. The I²C bus protocol was developed by Philips (now NXP). For a complete description of the I²C protocol, please review the NXP I²C design specification at http://www.I²C−bus.org/references/.

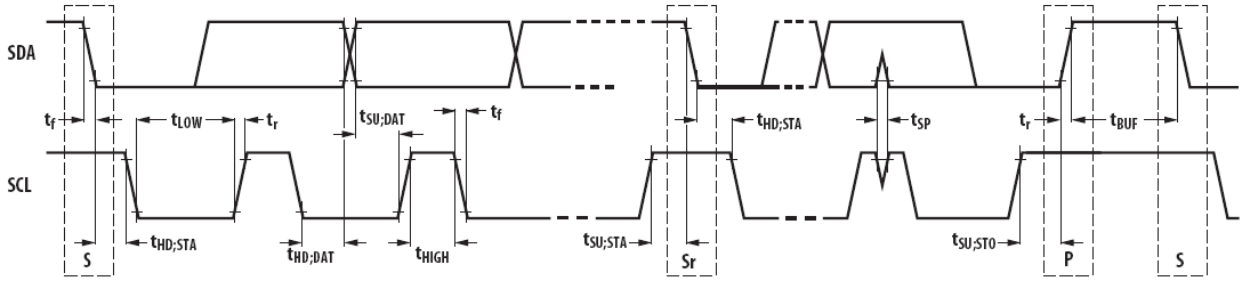
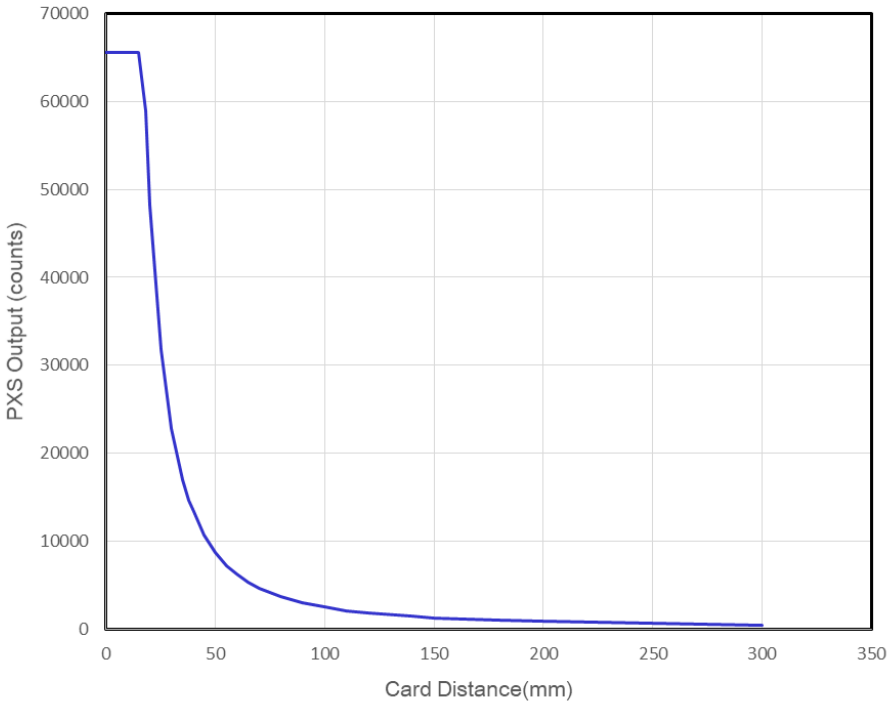


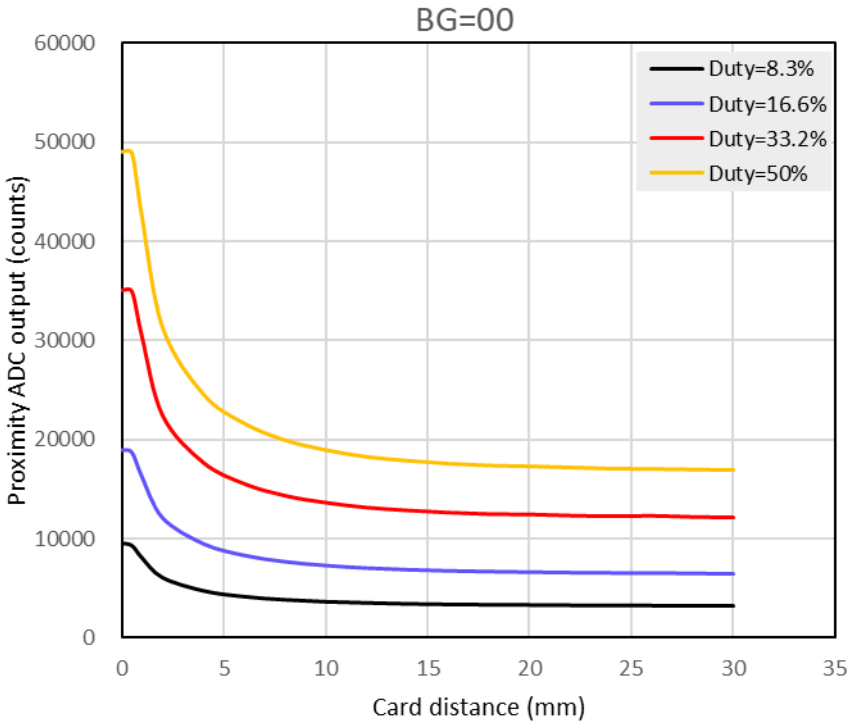
Figure 3. I²C Timing Diagram

Typical Performance Curves

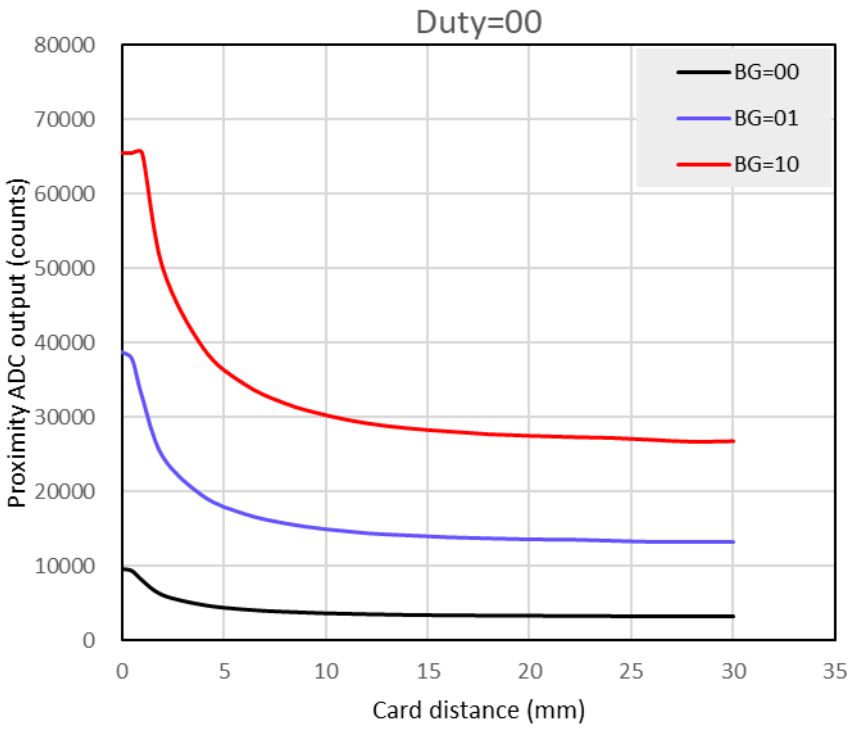
Proximity ADC Output Data vs. Card Distance
(IT=0100, Duty=11, DRV=0, Gain=01, BG=11)



Proximity ADC Output Data vs. Card Distance for Different Duty Cycle
(IT=0100, DRV=0, Gain=01)



Proximity ADC Output Data vs. Card Distance for Different Background Settings (BG)
(IT=0100, DRV=0, Gain= 01, Duty=00)



Detailed Description

Current Consumption Estimation

The device average current consumption can be calculated by adding the following 3 parts if the wait function is enabled: ADC conversion, Sleep, pulsed VCSEL drive.

When the ADC performs a conversion, the current consumption is 0.9mA, for a duration consisting of the sum of the configured integration time and reset time (1.72ms).

$$I_{ADC} = \frac{900 \times (t_{IT} + 1.72)}{(t_{SLP} + t_{IT} + 1.72)} \mu A$$

When the wait time is enabled, the average current consumption can be calculated using the following formula:

$$I_{SLP} = \frac{10 \times t_{SLP}}{(t_{SLP} + t_{IT} + 1.72)} \mu A$$

Calculating the average current consumption to include the VCSEL current can be done using the following equation:

$$I_{DRV} = \frac{I_{DRV} \times (t_{IT} \times 1000 + 600) \times D}{(t_{SLP} + t_{IT} + 1.72)} \mu A$$

Where t_{SLP} represents the sleep time set by PXS_SLP bits, t_{IT} is the integration time for the ADC and 1.72ms represents the reset time for the internal circuitry, I_{DRV} is the VCSEL driving current, and D is duty cycle of the pulsed driving current.

$$I_{AVG} = I_{ADC} + I_{SLP} + I_{DRV}$$

For example, if t_{SLP} is set 100ms and t_{IT} is 1.2ms, driving current I_{DRV} is 15mA and duty cycle is 8.3%, the average current consumption can be calculated as:

$$\begin{aligned} I_{AVG} &= I_{ADC} + I_{SLP} + I_{DRV} \\ &= \frac{900 \times (1.2 + 1.72)}{100 + 1.2 + 1.72} + \frac{10 \times 100}{100 + 1.2 + 1.72} + \frac{15 \times (1200 + 600) \times 8.3\%}{100 + 1.2 + 1.72} \\ &\approx 57 \mu A \end{aligned}$$

Interrupt Configuration

Both window type and hysteresis type interrupts are available in SY22316PS32-G00. The Interrupt scheme is controlled by PXS_INT_TYPE bit in the register PINT_CON.

The proximity interrupt flag (PXS_FLAG) is governed by the low and high thresholds stored in registers PXS_LTx and PXS_HTx at addresses 0x06 through 0x09. The SY22316PS32-G00 also provides a persistence filter which allows the user to specify the number of consecutive readings to meet the interrupt conditions before an interrupt is generated.

If PI_EN is set the INTn pin will also assert. If not, INTn will be in high impedance (HZ) state, independent of the status of the PXS_FLAG signal. Figure 4 shows the logic connections for the different blocks used to generate an interrupt.

INTn=! (PXS_FLAG && PI_EN)

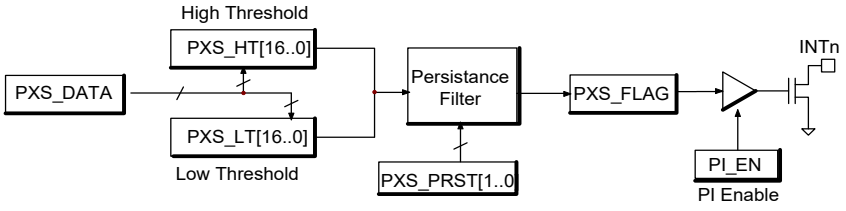


Figure 4. Interrupt Scheme

If the interrupt is configured for window detection, the PXS_FLAG bit will be asserted when the PXS reading is above the high threshold or below the low threshold. The interrupt flag can be cleared by the user via the special command code. Refer to Figure 5 for details (PRST is 1).

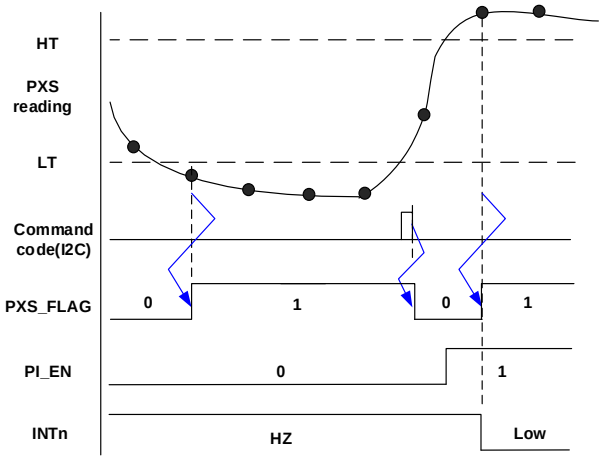


Figure 5. Proximity Window Interrupt

For the hysteresis type interrupt, the PXS_FLAG will be asserted once the PXS reading is above the high threshold. The PXS_FLAG bit will be auto-cleared when a PXS reading is below the low threshold, or cleared by the user via command code. Refer to Figure 6 for details (PRST is 1).

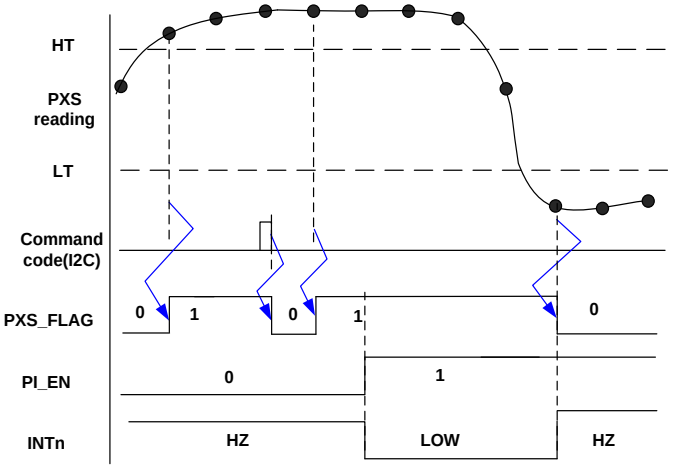


Figure 6. Proximity Hysteresis Interrupt

The PXS_INT_LOGIC flag in the register INT_FLAG is only valid for window type interrupt. The status of this bit can show whether proximity reading is above the high threshold or below the low threshold, indicating that the target is near or far from sensor.

The PXS_DATA_VALID flag is set when an ADC conversion is completed, and data is available in the PXS_DATAL and PXS_DATAH registers. Reading these registers through the I²C interface will reset the bit.

Power on Sequence

(1) To release the Power on Reset (POR), a duration of at least 2ms is required after the supply voltage goes above 2.0V from less than 0.4V;

(2) The POR is triggered when the supply voltage drops to less than 0.4V for longer than 1ms.

(3) For proper operation, the slew rate for the power supply rail must be greater than 0.5V/ms.

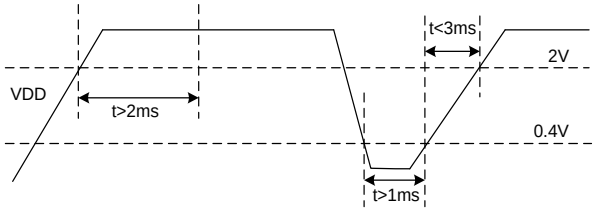


Figure 7. Power on Sequence

Register Map

There are 15 8-bit registers accessible via I²C. Each of the registers and configuration bits are described in more detail below. Registers 0x02 to 0x05 define the operation mode of the device. Registers 0x06 to 0x09 store the thresholds which trigger interrupt events. Registers 0x0A and 0x0B store the offset cancellation data. Registers 0x12 and 0x13 store the proximity reading and register 0x18 stores the status bits. Register 0x25 controls the background saturation (maximum level when the photodetectors are exposed to direct sunlight).

Registers and Register Bits										
REG Address	REG Name	Bit								Default
		7	6	5	4	3	2	1	0	
0x00	COM_TEST	Chip ID								0x29
0x02	PXS_CON1	PXS_EN	PXS_GAIN[1:0]		(Write 0)	PXS_INT_TIME[3:0]				0x00
0x03	PXS_CON2	(Write 0)			VCSEL_DUTY[1:0]		(Write 0)		PXS_DRV	0x00
0x04	WAIT_CON	WAIT_EN	PXS_SLP [2:0]			(Write 0)				0x00
0x05	PINT_CON	PI_EN	PXS_INT_TYPE	(Write 0)				PXS_PRST[1:0]		0x00
0x06	PXS_LTL	PXS_LT[7:0]								0x00
0x07	PXS_LTH	PXS_LT[15:8]								0x00
0x08	PXS_HTL	PXS_HT[7:0]								0xFF
0x09	PXS_HTH	PXS_HT[15:8]								0xFF
0x0A	P_OFFSETL	PXS_OFF_DIG[7:0]								0x00
0x0B	P_OFFSETH	(Write 0)		PXS_OFF_ANA	PXS_OFF_DIG[12:8]					0x00
0x12	P_DATAL	PXS_DATA[7:0]								0x00
0x13	P_DATAH	PXS_DATA[15:8]								0x00
0x18	INT_FLAG	(unused)				PXS_FLAG	PXS_INT_LOGIC	BOF	PXS_DATA_Valid	0x00
0x25	BG_CON	(Write 0)		PXS_BG[1:0]		(Write 0)				0x00

Register Description

Command Code				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:6				Unused register bits - write 0
5:4				11, special function others, register address
3:0			Register Address /Special Function Register	Special function: 0000: clears proximity interrupt flag 0010: set registers to default value others: reserved

Register 0x00 (COM_TEST) – Communication Test Register				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RO	0x29	Chip ID	Read this register through I²C interface to identify the device with chip ID is 0x29. It can also help to test whether the communication link is established or not.

Register 0x02 (PXS_CON1) – Proximity Sensing Configuration				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7	RW	0x00	PXS_EN	When =0, proximity sensing is disabled When =1, proximity sensing is enabled
6:5	RW	0x00	PXS_GAIN	For bits 6:5 = (see the following) 00, proximity ADC gain is 1x 01, gain is 2x 10, gain is 4x 11, gain is 8x
4	RW	0x00	Reserved	Reserved. Write as 0
3:0	RW	0x00	PXS_INT_TIME	For bits 3:0 = (see the following) 0000, proximity ADC integration time is 0.6ms 0001, integration time is 1.2ms 0010, integration time is 4.8ms 0011, integration time is 9.6ms 0100, integration time is 19ms 0101, integration time is 38ms 0110, integration time is 77ms 0111, integration time is 154ms 1000, integration time is 308ms others, reserved

Register 0x03 (PXS_CON2) – Proximity Sensing Configuration 2				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:5	RW	0x00	Reserved	Reserved. Write as 0
4:3	RW	0x00	VCSEL_DUTY	For bits 4:3 = (see the following) 00, duty cycle of pulsed driving current is 8.3% 01, duty cycle of pulsed driving current is 16.6% 10, duty cycle of pulsed driving current is 33.2% 11, duty cycle of pulsed driving current is 50%
2:1	RW	0x00	Reserved	Reserved. Write as 0
0	RW	0x00	PXS_DRV	When=0, driving current for VCSEL is 10mA When=1, driving current is 15mA

Register 0x04 (WAIT_CON) – Wait Configuration				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7	RW	0x00	WAIT_EN	When =0, wait function is disabled When =1, wait function is enabled and proximity sleep time is inserted to two adjacent proximity ADC cycle
6:4	RW	0x00	PXS_SLP	For bits 6:4 = (see the following) 000, proximity sleep time is 6.25ms 001, sleep time is 12.5ms 010, sleep time is 25ms 011, sleep time is 50ms 100, sleep time is 100ms 101, sleep time is 200ms 110, sleep time is 400ms 111, sleep time is 800ms
3:0	RW	0x00	Reserved	Reserved. Write as 0

Register 0x05 (PINT_CON) – Proximity Interrupt Configuration				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7	RW	0x00	PI_EN	When =0, interrupt pin is HZ and irrelevant to internal logic When =1, interrupt pin shall react according to PXS_FLAG bit
6	RW	0x00	PXS_INT_TYPE	When =0, interrupt is of Window type When =1, interrupt is of Hysteresis type
5:2	RW	0x00	Reserved	Reserved. Write as 0
1:0	RW	0x00	PXS_PRST	For bits 1:0 = (see the followings) 00, every proximity ADC cycle generates an interrupt 01, set PXS_FLAG if 1 proximity reading trips the threshold value 10, set PXS_FLAG if 4 proximity reading trip the threshold value 11, set PXS_FLAG if 8 proximity reading trip the threshold value

Register 0x06 (PXS_LTL) – Lower Byte of Proximity Low Threshold				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RW	0x00	PXS_LTL	Lower 8 bits of proximity low threshold

Register 0x07 (PXS_LTH) – Upper Byte of Proximity Low Threshold				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RW	0x00	PXS_LTH	Upper 8 bits of proximity low threshold

Register 0x08 (PXS_HTL) – Lower Byte of Proximity High Threshold				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RW	0xFF	PXS_HTL	Lower 8 bits of proximity high threshold

Register 0x09 (PXS_HTH) – Upper Byte of Proximity High Threshold				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RW	0xFF	PXS_HTH	Upper 8 bits of proximity high threshold

Register 0x0A (P_OFFSETL) – Lower Byte of Proximity Offset				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RW	0x00	PXS_OFF_DIGL	Low 8 bits of proximity digital offset. Each count will decrease proximity data by 4 counts

Register 0x0B (P_OFFSETH) – Upper Byte of Proximity Offset				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:6	RW	0x00	Reserved	Reserved. Write as 0
5	RW	0x00	PXS_OFF_ANA	1 bit of proximity analog offset. Setting 1 will decrease proximity data by 17500 counts
4:0	RW	0x00	PXS_OFF_DIGH	Upper 5 bits of proximity digital offset. Refer to Table 11 for details

Register 0x12 (P_DATAL) –Proximity Reading				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RO	0x00	PXS_DATA	Lower 8 bits of proximity reading

Register 0x13 (P_DATAH) –Proximity Reading				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:0	RO	0x00	PXS_DATA	Upper 8 bits of proximity reading

Register 0x18 (INT_FLAG) – Interrupt Flag				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:4	RO	0x00	Unused	Unused
3	RO	0x00	PXS_FLAG	When =0, no proximity interrupt has occurred since power-on or last "clear" When =1, a proximity interrupt event occurred
2	RO	0x00	PXS_INT_LOGIC	When =0, proximity data is below its low threshold (object is far) When =1, proximity data is above its high threshold (object is close)
1	RO	0x00	BOF	When =0, background light does not overflow When =1, background light overflows (refer to PXS_BG at register 0x25) and PXS_DATA shall change to 0
0	RO	0x00	PXS_DATA_VALID	When =0, proximity data is not updated after sensing enabled or last data reading When =1, proximity data is updated after sensing enabled or last data reading

Register 0x25 (BG_CON) – Interrupt Flag				
Bit	**Access**	**Default**	**Name**	**Function / Operation**
7:6	RW	0x00	Reserved	Reserved. Write as 0
5:4	RW	0x00	PXS_BG	For bits 5:4 = (see the followings) When the PXS senses the BG (background) light overflow, PXS_data will be 0 for "object is far" judgement 00, BG overflow occurs when exposed to 50000lux sunlight 01, BG overflow occurs when exposed to 12500lux sunlight 10, BG overflow occurs when exposed to 6250lux sunlight 11, BG overflow occurs when exposed to 2083lux sunlight
3:0	RW	0x00	Reserved	Reserved. Write as 0

I²C Read / Write Register Data

The SY22316PS32-G00's I²C slave address is 0x39 (7-bit, 0b' 0111001). Figures 8 and 9 graphically depict the protocol used for writing or reading the device register data. The first 8-bit of data following the write-operation can be either the register address or special function. Refer to Table 2 for details.

A : Acknowledge (0)
NA : Not Acknowledged (1)
P : Stop Condition
R : Read (1)
W : Write (0)
S : Start Condition
Sr : Repeat Start
... : Continuation of Protocol
: Mater to Slave
: Slave to Mater

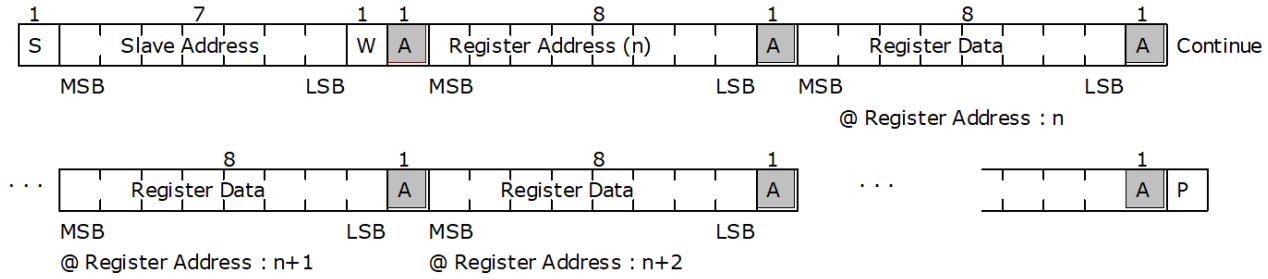


Figure 8. I²C Write-register-data Protocol

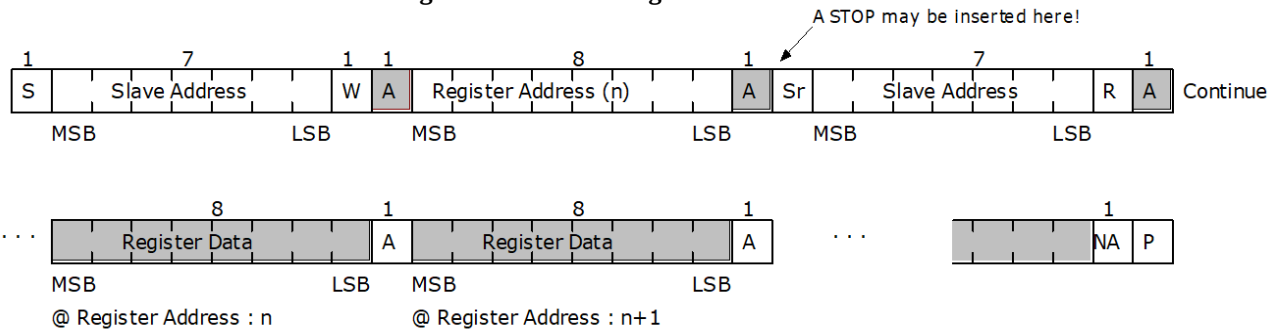
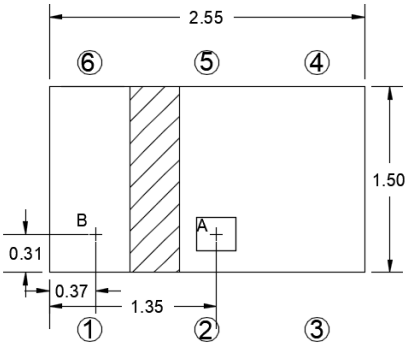
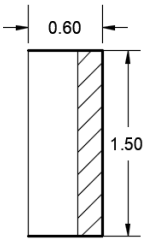


Figure 9. I²C Read-register-data Procotol

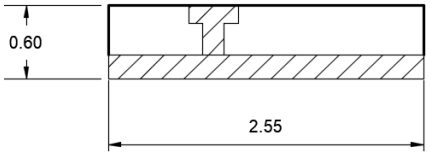
Package Outline Drawing



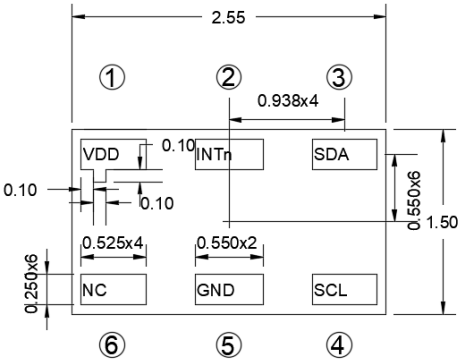
Top View



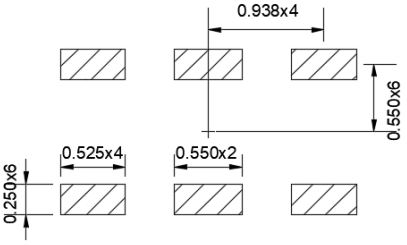
Edge View



Side View



Bottom View

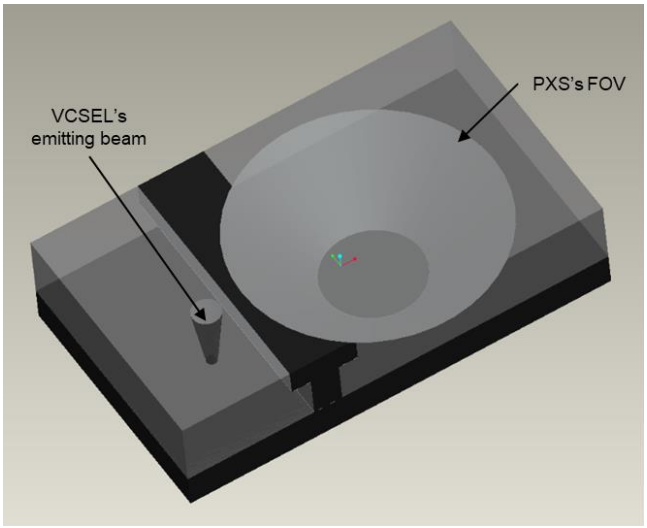


Recommended Land Pattern

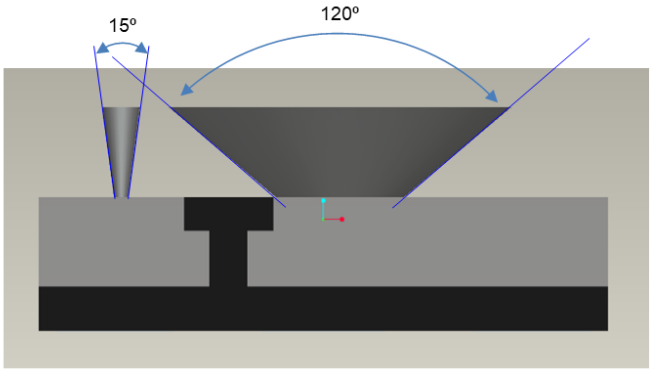
Notes 1: All tolerances are ±0.1mm, unless otherwise specified.
Notes 2: Proximity sensing center is at point A (x, y) = (1.35, 0.31).
Notes 3: Proximity sensing area: 318μm×265μm.
Notes 4: VCSEL emitting center is at point B (x, y) = (0.37, 0.31).
Notes 5: Unit is mm.

3D Drawing of Product

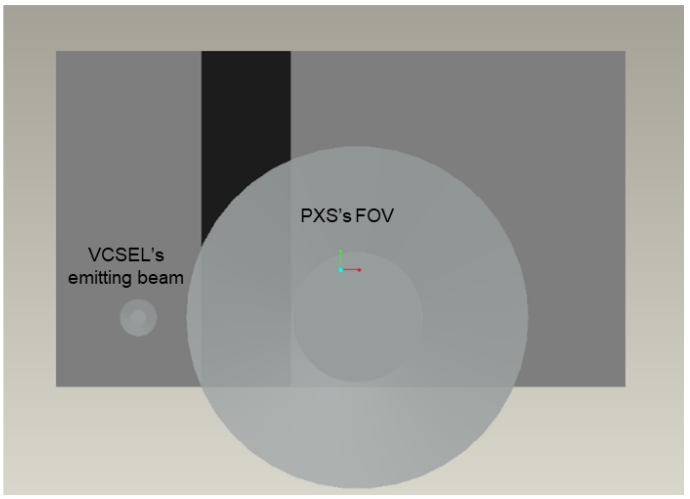
Refer to below 3D drawing of SY22316PS32-G00 with the VCSEL's emitting beam and proximity's FOV (field of view).



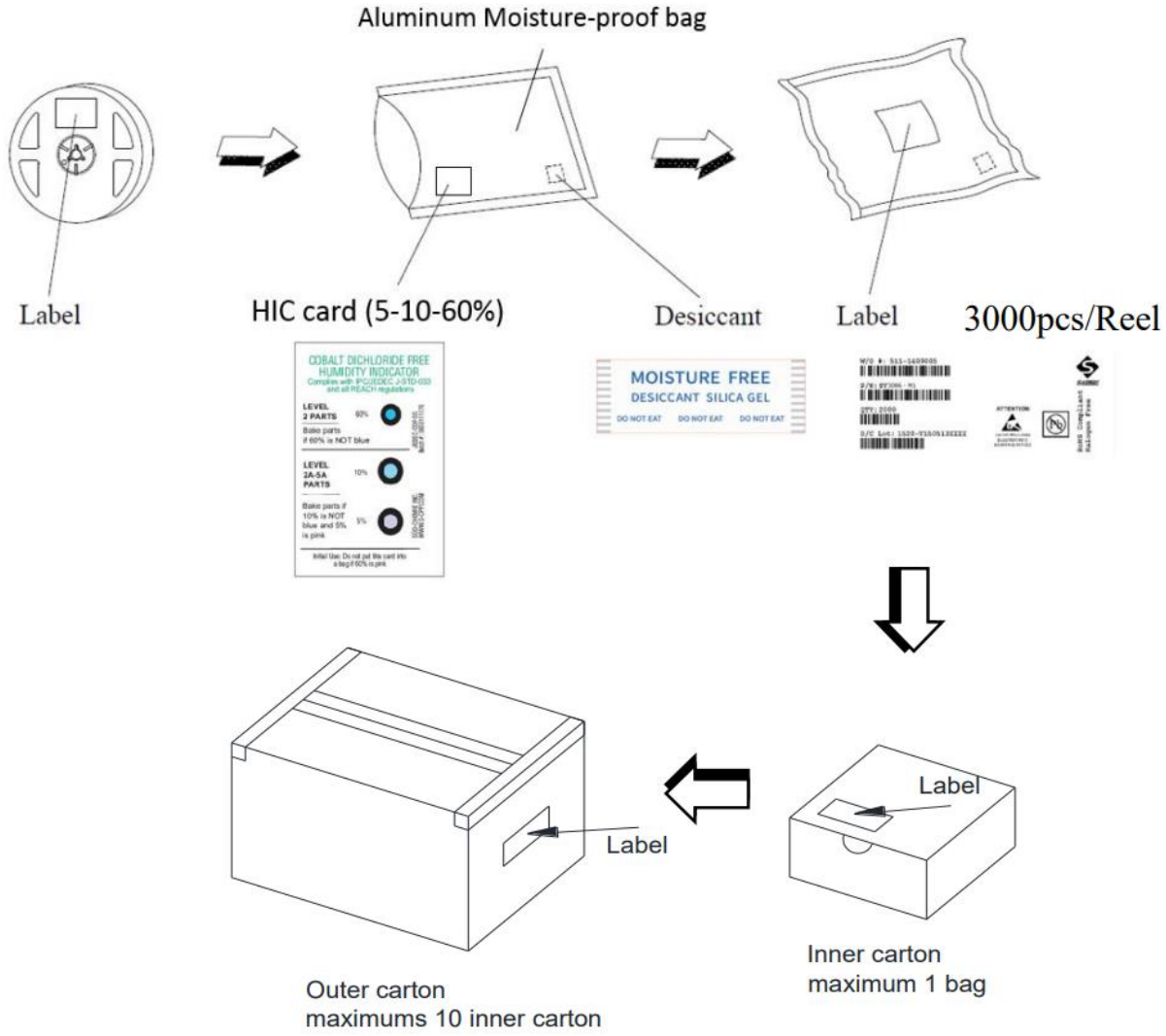
Side-view



Top-view

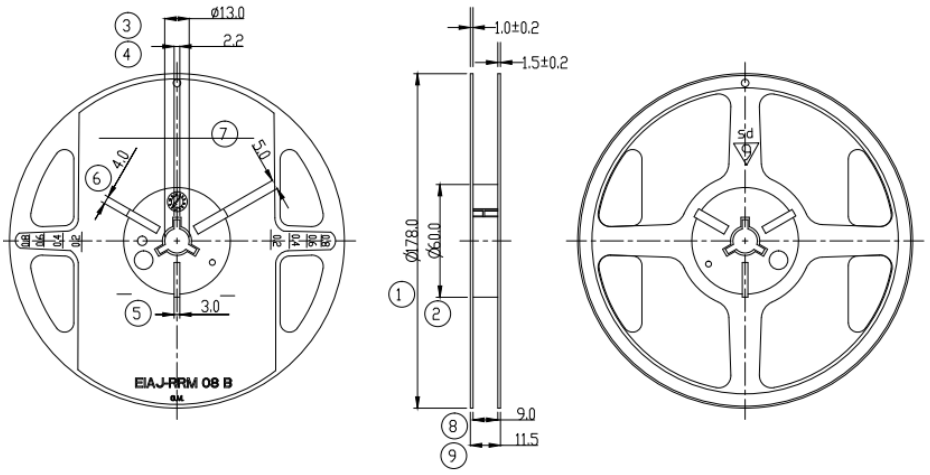


Packaging Quantity Specifications

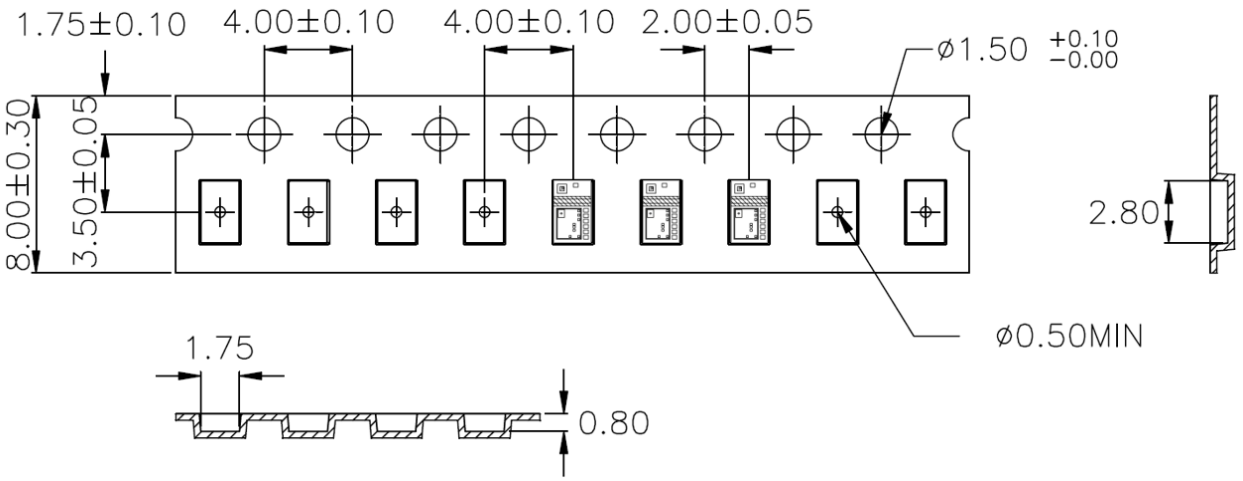


Dimensions of Reel (Unit: mm)

Width	1	2	3	4	5	6	7	8	9
7"	178±1	60±0.5	13±0.5	2.2±0.5	$3^{+0.5}_{-0}$	$4^{+0.5}_{-0}$	$5.0^{+0.5}_{-0}$	9±0.5	11.5±0.5



Dimensions of Tape (Unit: mm)



Recommended Method of Storage

Storage is recommended as soon as the bag has been opened to prevent moisture absorption. The following conditions should be observed, if bags are not available:

- Storage temperature: 10°C to 30°C
- Storage humidity: ≦60%RH max
- Storage Time: ≦168hr max

Moisture-Proof Package

To avoid moisture absorption by the resin, the product should be stored under the following conditions:

- Temperature: 23 ± 5°C
- Relative humidity: 60% (max)
- Baking is required if the devices have been stored unopen for more than six months.

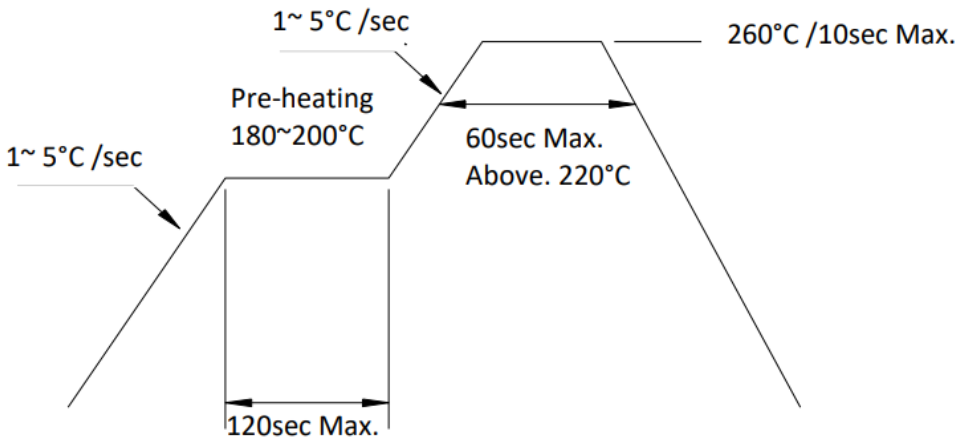
ESD Precaution

Proper storage and handling procedures should be followed to prevent ESD damage to the devices especially when they are removed from the Anti-static bag. Electro-Static Sensitive Devices warning labels are on the packing.

Make any necessary soldering correction manually

Temperature shall be no more than 350°C (25W for soldering iron) within 3 sec. Make sure do not do this more than one time for any given pin.

Recommended Solder Profile



Notes 1: Reflow soldering should not be done more than twice.
Notes 2: Do not put stress on the devices during heating stage while soldering.
Notes 3: Do not warp the circuit board after soldering.

Revision History

Revision Number	Revision Date	Description	Pages changed
0.9	01/18/2021	Initial Release	
1.0	01/18/2022	Production Release	

Revision history is for reference only and may not be comprehensive or complete.

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