SY3016PS32-G00

16-bit Proximity Sensor for TWS Application

General Description

SY3016PS32-G00 integrates a main chip, a vertical cavity surface emitting laser diode (VCSEL) together. With proximity photodiode and high SNR processing circuit integrated on main chip, it can be applied in applications where proximity sensing is necessary, such as slit smart phone and true wireless stereo (TWS).

SY3016PS32-G00 provides an independent pin for two types of interrupt schemes which simplify system design complexity by eliminating the need to poll PXS readings. A SMBus compatible I^2C interface (up to 1MHz) is also integrated for easy connection to a microcontroller or embedded controller.

SY3016PS32-G00 design featuring low power operation, high SNR for proximity sensing, high data uniformity, user friendly interface, wide operating temperature range, is suitable for battery-powered equipment with the requirements of proximity sensing.

Features

- PXS Feature
  - High SNR Circuit Design
  - Programmable VCSEL Drive Current
  - Programmable Integration Time, Gain and Sleep Time Settings
  - Cancellation of Crosstalk
- Wide Operation Range
  - 2.8V~3.6V Operation Voltage
  - -30°C to +85°C Operating Temperature
- Ultra-low Current Consumption with Low-power Mode Integrated During Sleep Time
- Built-in Temperature Compensation for Driving Current
- Good Uniformity for Output Digital Counts
- Package Information
  - Size:2.55mmx1.50mmx0.60mm
  - Type: SMD BT with Transparent Molding Compound

Typical Application Circuit

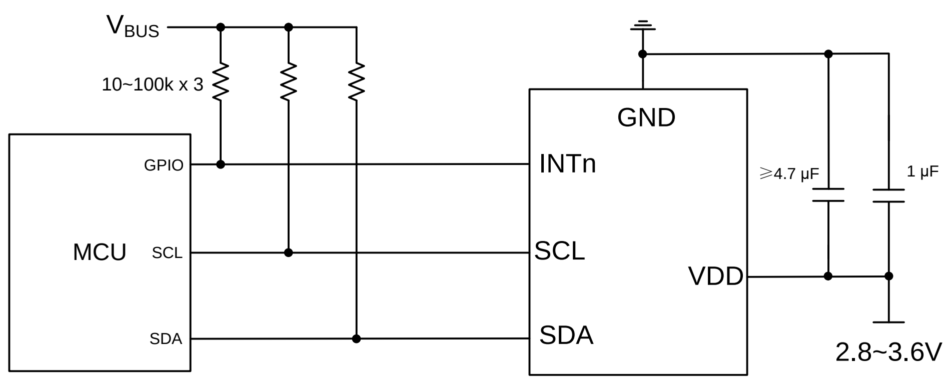


Fig. 1 Typical Application Schematic [1]

Note 1: Bypass capacitors should be placed as close as possible to the device to reject noise.

Pin Assignment

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

Absolute Maximum Ratings [1] (T_A=25°C unless otherwise specified)

Symbol	Parameter	Min	Max	Unit
V_{DD}	Supply voltage	-0.3	4	V
V_{I^2C}	I^2C Bus Voltage	-0.3	4	V
I_{I^2C}	I^2C Bus Current		10	mA
V_{INTn}	INTn Voltage	-0.3	4	V
I_{INTn}	INTn Current		10	mA
ESD	HBM	+/-2000		V
	CDM	+/-500		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: 1.5xVccmax

Recommended Operating Conditions (T_A=25℃ unless otherwise specified)

Symbol	Parameter	Min	Typ	Max	Unit
V_{DD}	Supply voltage	2.8		3.6	V
T_{STG}	Storage temperature	-40		+100	°C
T_{OPR}	Operating temperature	-30		+85	°C

Electrical and Optical Characteristics

(V_{DD} = 3V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Voltage Range	V_{DD}		2.8	3.0	3.6	V
Supply Current when Powered down	I_{DD_SD}	PXS_EN=0			2	µA
Supply Current when in Sleep State	I_{DD_SLP}	LED 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}	LED current excluded, PXS_INT_TIME=0000, WAIT_EN=0		0.9	1.1	mA
Full scale of PXS output	$DATA_{PXS\_FS}$				65535	counts
Driving current	I_{IRDR}	PXS_DRV=0		10		mA
		PXS_DRV=1		15		
Effective PXS reading	$DATA_{PXS\_3cm}$-$DATA_{PXS\_\infty}$	PXS_DRV=0, LED_DUTY=11, PXS_GAIN=01, PXS_INT_TIME=0100, PXS_BG=11, Kodak Grey Card, 18% Refl, Distance is 3cm and ∞	20100	23700	27300	counts
Sleep time between two adjacent PXS ADC	t_{SLP}	PXS_SLP=000		6.25		ms
		PXS_SLP=111		800		ms

I^2C Electrical Specifications

(V_{DD} = 3V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply voltage range for I^2C interface	V_{I^2C}		1.7		V_{DD}+0.3	V
SCL clock frequency	f_{SCL}				750	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 that must be 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 reistor	$R_{pull-up}$	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}		0.1 V_{DD}			V
Noise margin at the HIGH level	V_{nH}		0.2 V_{DD}			V

Note**:** The I^2C bus protocol was developed by Philips (now NXP). For a complete description of the I^2C protocol, please review the NXP I^2C design specification at http://www.i2c−bus.org/references/.

Register Map

There are 15 8-bit registers accessible via I^{2}C. Register 0x02 to 0x05 define the operation mode of device. Register 0x06 to 0x09 store the thresholds which trigger interrupt event. Register 0x0A and 0x0B store the offset cancellation data. Register 0x12 and 0x13 store the proximity reading and register 0x18 stores the status flag of device. Register 0x25 controls the background saturate level when exposed to sunlight.

Table 1. 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)			LED_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

Table 2. 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 PXS interrupt flag 0010:set registers to default value others: reserved

Chip ID Register (0x00)

This read-only register contains a fixed data 0x29. Read this register through I^{2}C interface to identify the IC. It can also help to test whether the communication link is established or not.

Table 3. 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, PXS 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, PXS 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

Table 4. 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	LED_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

Table 5. 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 PXS sleep time is inserted to two adjacent PXS ADC cycle
6:4	RW	0x00	PXS_SLP	For bits 6:4 = (see the following) 000, PXS sleep time is 6.25ms 001, PXS sleep time is 12.5ms 010, PXS sleep time is 25ms 011, PXS sleep time is 50ms 100, PXS sleep time is 100ms 101, PXS sleep time is 200ms 110, PXS sleep time is 400ms 111, PXS sleep time is 800ms
3:0	RW	0x00	Reserved	Reserved. Write as 0

Table 6. 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 PXS ADC cycle generates an interrupt 01: set PXS_FLAG if 1 reading trips the threshold value 10: set PXS_FLAG if 4 reading trip the threshold value 11: set PXS_FLAG if 8 reading trip the threshold value

Table 7. Register 0x06 (PXS_LTL) – Lower byte of PXS low threshold

Bit #	Access	Default	Name	Function / Operation
7:0	RW	0x00	PXS_LTL	Lower 8 bits of PXS low threshold

Table 8. Register 0x07 (PXS_LTH) – Upper byte of PXS low threshold

Bit #	Access	Default	Name	Function / Operation
7:0	RW	0x00	PXS_LTH	Upper 8 bits of PXS low threshold

Table 9. Register 0x08 (PXS_HTL) – Lower byte of PXS high threshold

Bit #	Access	Default	Name	Function / Operation
7:0	RW	0xFF	PXS_HTL	Lower 8 bits of PXS high threshold

Table 10. Register 0x09 (PXS_HTH) – Upper byte of PXS high threshold

Bit #	Access	Default	Name	Function / Operation
7:0	RW	0xFF	PXS_HTH	Upper 8 bits of PXS high threshold

Table 11. Register 0x0A (P_OFFSETL) – Lower byte of PXS offset

Bit #	Access	Default	Name	Function / Operation
7:0	RW	0x00	PXS_OFF_DIGL	Low 8 bits of PXS digital offset. Each count will decrease PXS data by 4 counts

Table 12. Register 0x0B (P_OFFSETH) – Upper byte of PXS 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 PXS analog offset. Setting 1 will decrease PXS data by 17500 counts
4:0	RW	0x00	PXS_OFF_DIGH	Upper 5 bits of PXS digital offset

Table 13. Register 0x12 (P_DATAL) – PXS reading

Bit #	Access	Default	Name	Function / Operation
7:0	RO	0x00	PXS_DATA	Lower 8 bits of PXS reading

Table 14. Register 0x13 (P_DATAH) – PXS reading

Bit #	Access	Default	Name	Function / Operation
7:0	RO	0x00	PXS_DATA	Upper 8 bits of PXS reading

Table 15. 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 PXS interrupt has occurred since power-on or last ”clear” When =1, a PXS interrupt event occurred
2	RO	0x00	PXS_INT_LOGIC	When =0, PXS data is below its low threshold(object is far) When =1, PXS 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. PXS_DATA changes to 0
0	RO	0x00	PXS_DATA_VALID	When =0, PXS data is not updated after sensing enabled or last data reading When =1, PXS data is updated after sensing enabled or last data reading

Table 16. 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 3:2 =(see the followings) 00, saturate 50000lux for sunlight (1M) 01, saturate 12500lux for sunlight (4M) 10, saturate 6250lux for sunlight (8M) 11, saturate 2083lux for sunlight (24M)
3:0	RW	0x00	Reserved	Reserved. Write as 0

I²C Read / Write Register Data

The SY3016PS32-G00's I²C slave address is 0x39 (7-bit, 0b' 0111001). Figures 2 and 3 graphically depict the protocol of writing or reading the register data inside the device. The first 8-bit data following the write-operation can be either the register address or special function; referring 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

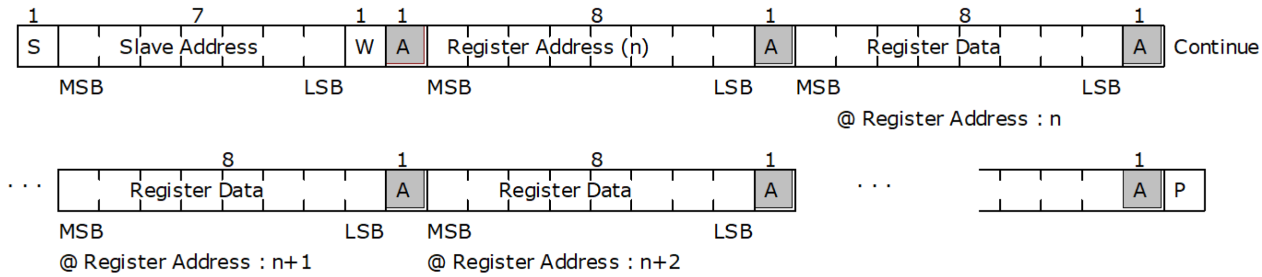


Figure. 2 I²C Write-register-data Protocol

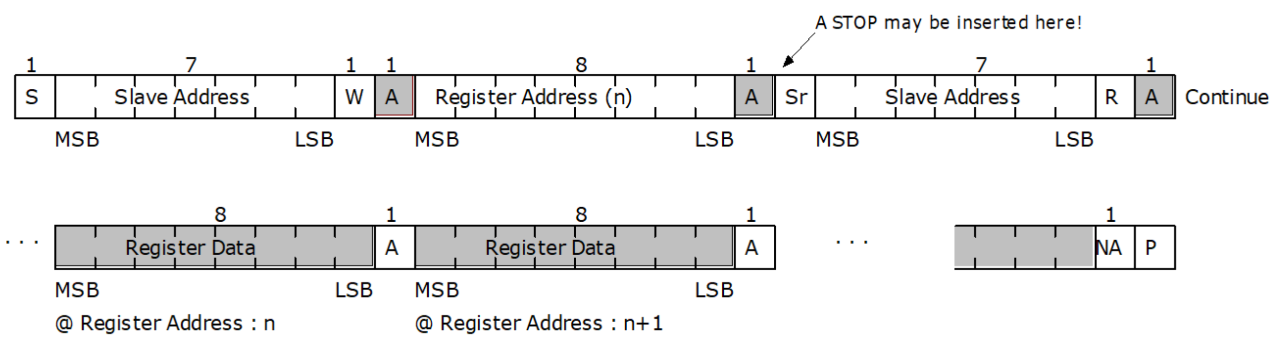


Figure. 3 I²C Read-register-data Procotol

Operation Principles

Block Diagram

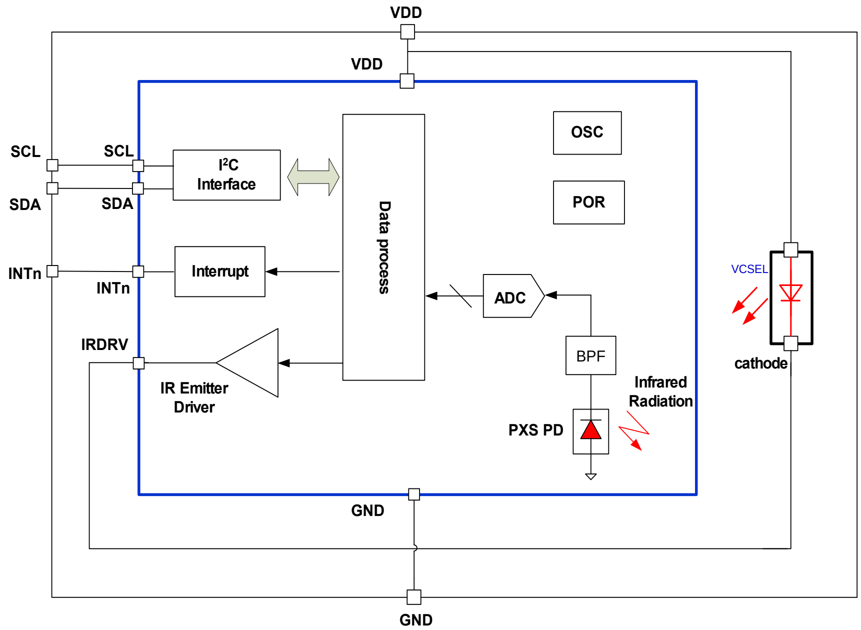


Fig. 4 Functional block diagram

PXS current consumption

IC current consumption can be divided into 3 parts if wait function is enabled. First part is that when analog-digital-conversion is ongoing, second part is that when IC is in sleep state. The last part is that from VCSEL pulsed driving current.

When ADC of IC is ongoing, the current consumption is 0.9mA, and the duration time is just integration time plus 1.72ms of reset time.

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

When wait function is enabled, different sleep time shall be inserted between two adjacent integration, average current consumption of this part is calculated as below.

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

For the time when VCSEL emitting infrared pulse, the average current during is calculated as below.

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

In above formula, t_{SLP} represents sleep time set by PXS_SLP bits, t_{IT} is the integration time of proximity sensing while 1.72ms is the internal circuit reset time of every analog-digital-conversion. I_{DRV} is the driving current of VCSEL and D is duty cycle of 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%, then we can calculated the average current consumption as

$$I_{AVG} = I_{ADC} + I_{SLP} + I_{DRV}$$
$$= \frac{900 \times (1.2 + 1.72)}{100 + 1.2 + 1.72} + \frac{10 \times 100}{100 + 1.2 + 1.72} + \frac{15 \times (1200 + 600) \times 8.3\%}{100 + 1.2 + 1.72}$$
$$\approx 57uA$$

Interrupt Function

Both window type and hysteresis type interrupt are available in SY3016PS32-G00. Interrupt scheme is controlled by PXS_ INT_TYPE bit at register PINT_CON.

PXS interrupt flag (PXS_FLAG) is governed by the low and high threshold stored in register through 0x06 and 0x09. To further control when an interrupt occurs, SY3016PS32-G00 provides a persistence filter which allows the user to specify the number of consecutive readings to meet interrupt conditions before an interrupt is generated. If PI_EN is set, then the INTn pin will also assert. If not, INTn will be in high impedance (HZ) state and irrelevant to PXS_FLAG status. Figure 5 shows the logic connections of different blocks to generate an interrupt. INTn=! (PXS_FLAG && PI_EN)

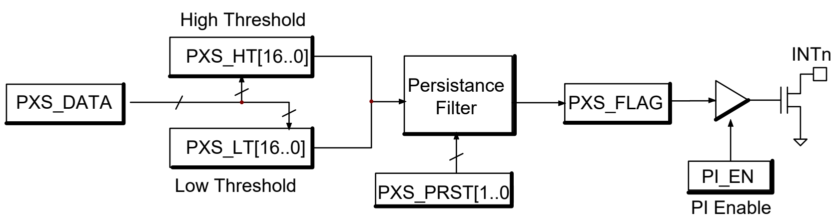


Fig. 5 Interrupt scheme

If set as window type, PXS_FLAG bit will be asserted when PXS reading is above the high threshold or below the low threshold. The interrupt flag is cleared by user via special command code. Refer to Figure 6 for details (PRST is 1).

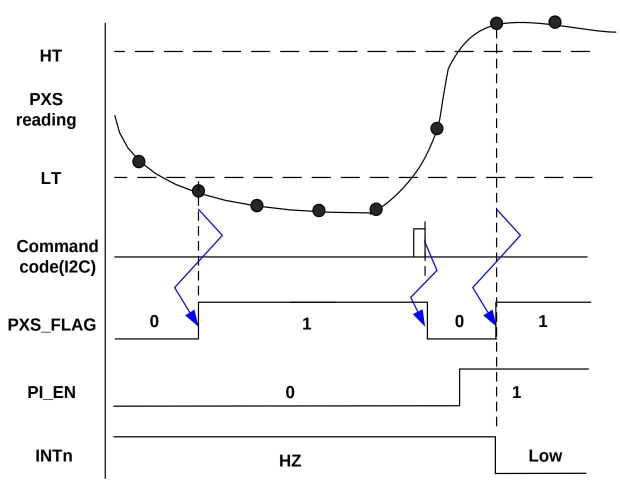


Fig. 6 PXS Window Interrupt

For hysteresis type interrupt, PXS_FLAG will be asserted once PXS reading is above the high threshold. PXS_FLAG bit will be auto-cleared when PXS reading is below low threshold or cleared by user via command code. Refer to Figure 7 for details (PRST is 1).

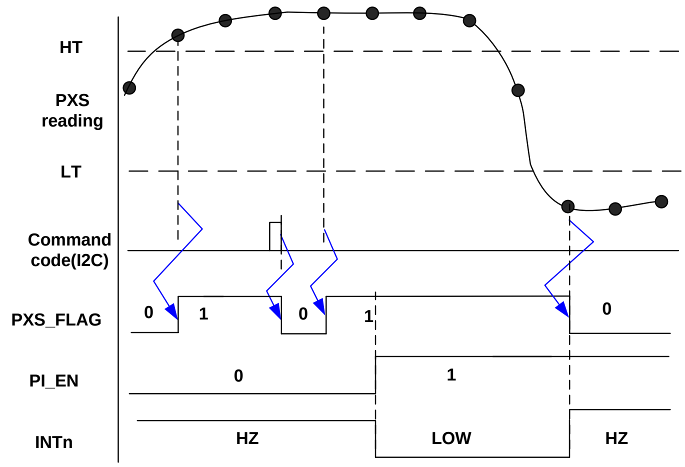


Fig. 7 PXS Hysteresis Interrupt

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

PXS_DATA_VALID flag shall be updated whether an Analog-Digital-Conversion is done or not. Whenever an ADC is finished, new PXS data shall updated to PXS_DATAL and PXS_DATAH registers and PXS_DATA_VALID flag shall be set. This flag will be auto-cleared once PXS_DATA registers are read through I^2C.

Power on Sequence

Please follow the instructions below to properly complete the power on sequence.

(1) To release the power on reset, 2ms is required after the supply voltage goes beyond 2.0V from less than 0.4V;

(2) To re-arm the power on reset, the supply voltage must drop less than 0.4V for more than 1ms;

(3) The slew rate for power on reset must be greater than 0.5V/ms.

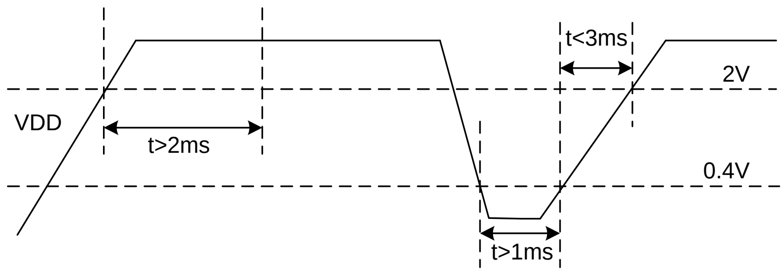
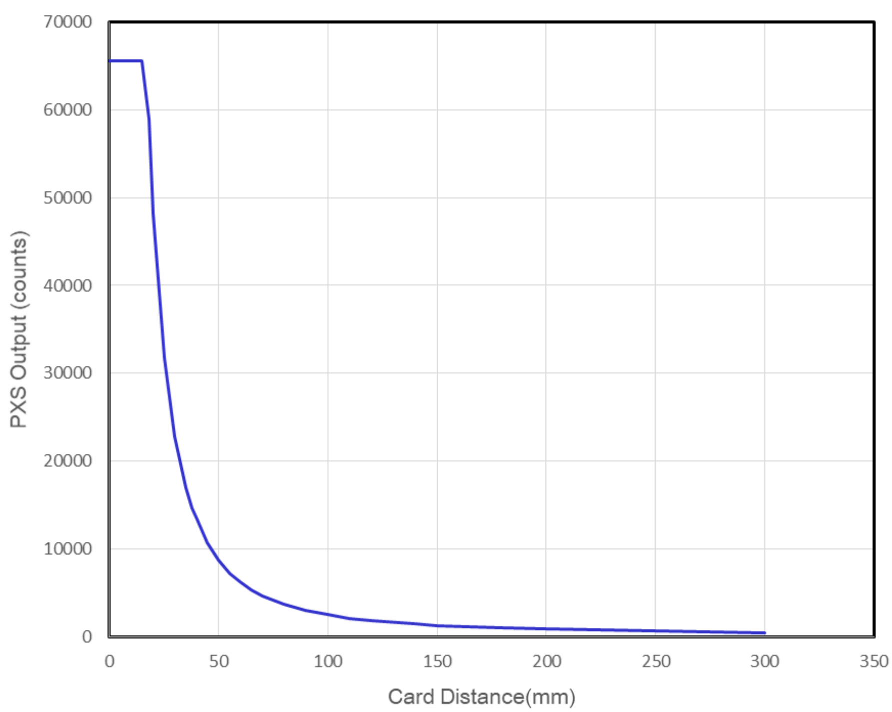


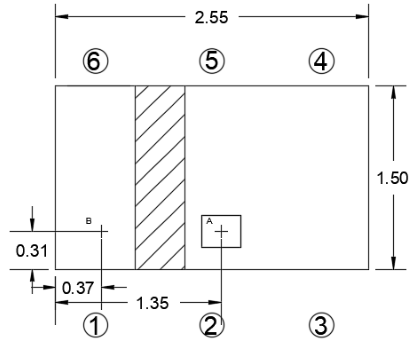
Fig. 8 Power on sequence

Typical Characteristic

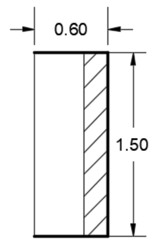
PXS Output Data vs. Card Distance
(IT=0100, Duty=11, DRV=0, Gain=01, BG=11)



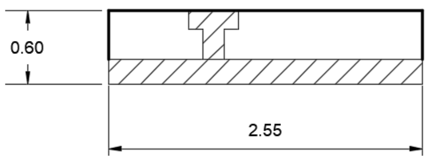
Package Outline Drawings



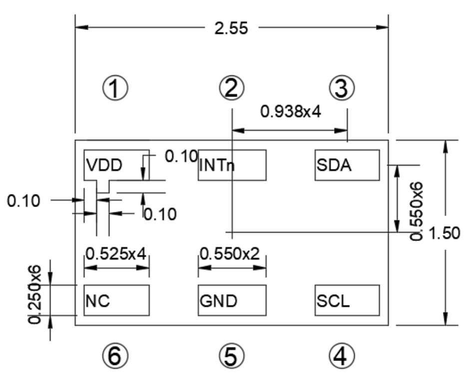
Top View



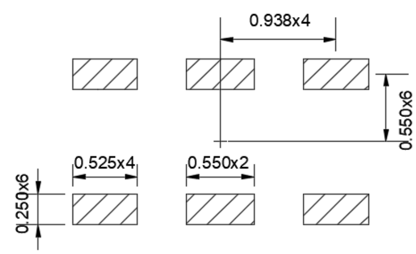
Edge View



Side View



Bottom View



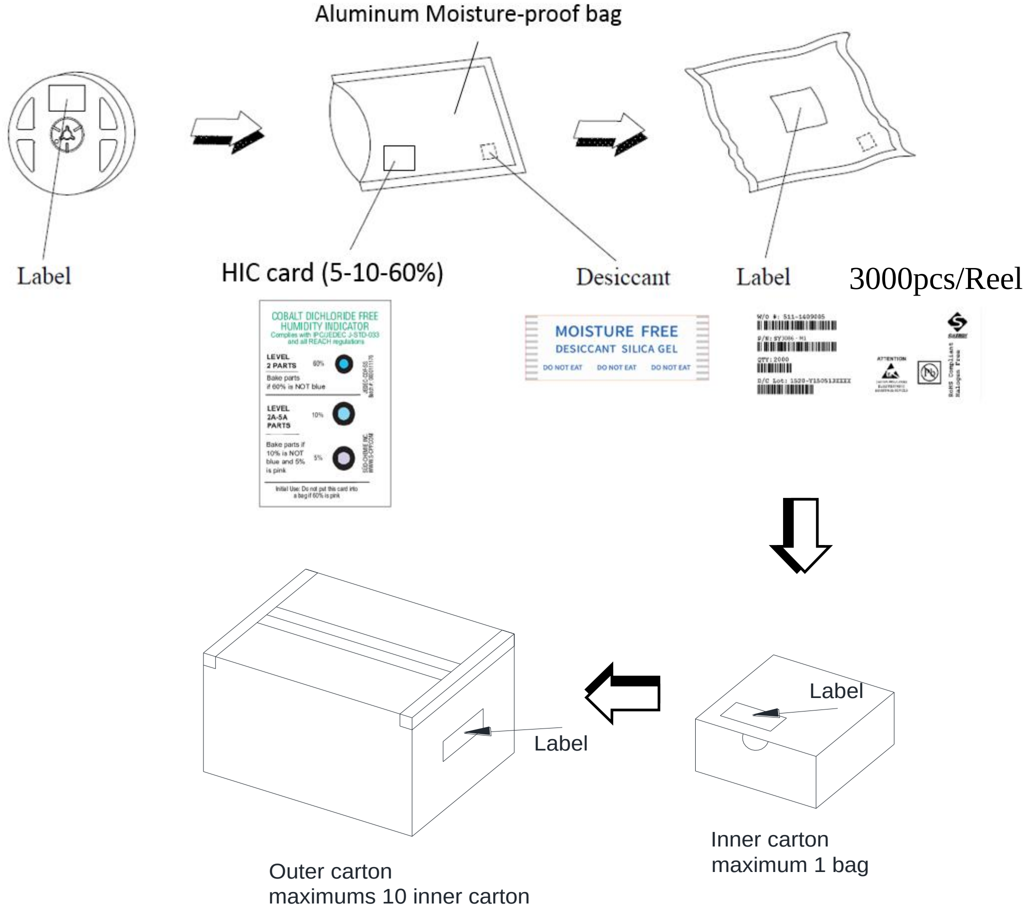
Recommended Land Pattern

Notes:

1. All tolerances are ± 0.1mm, unless otherwise noted.
2. Proximity sensing center is at point A (x,y) = (1.35, 0.31).
3. Proximity sensing area: 318um x 265um.
4. Emitting center is at point B (x,y) = (0.37, 0.31).

Unit is in mm.

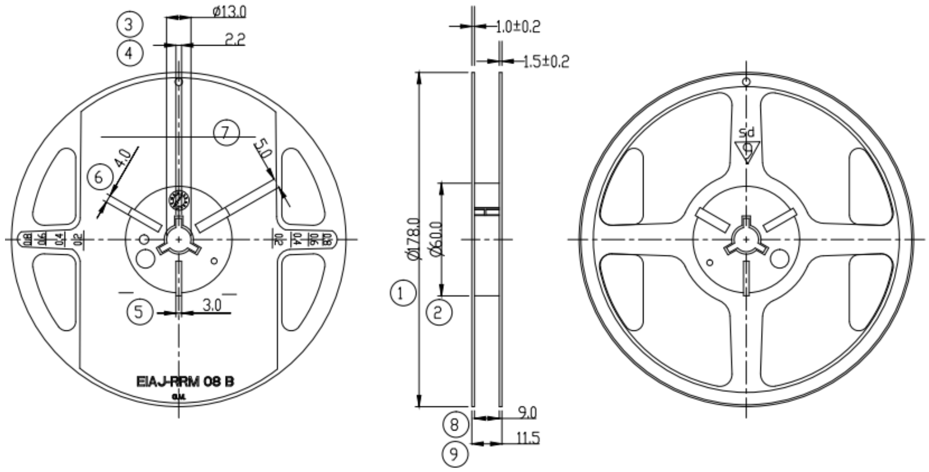
Packaging Quantity Specifications



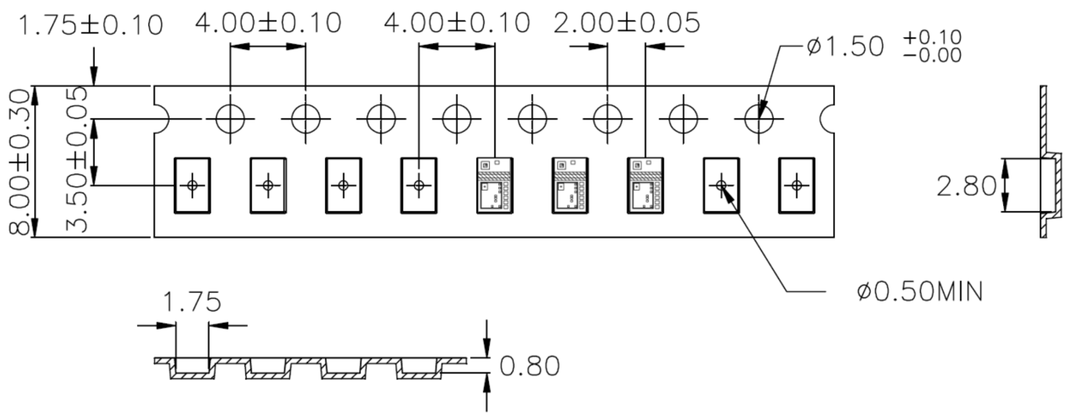
Packaging specifications

● 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℃ to 30℃
- Storage humidity: ≤60% RH max
- Storage time: ≤168hrs 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 store unopened for more than six months.

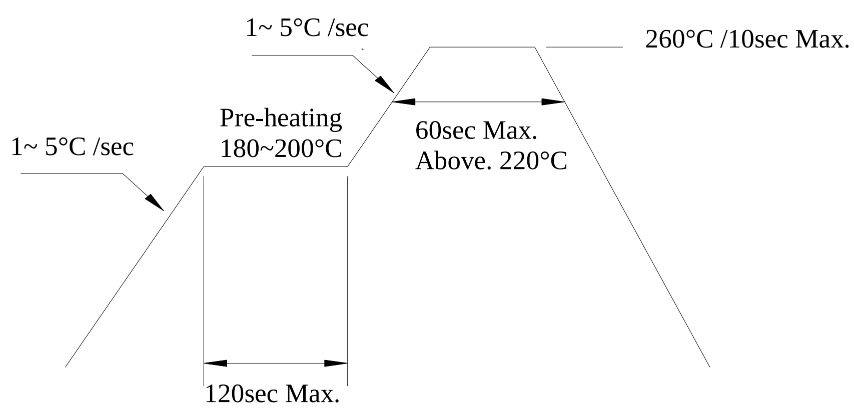
ESD Precaution

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

Recommended Solder Profile



Note:

[1]. Reflow soldering should not be done more than twice.

[2]. Do not put stress on the ALS devices during heating stage while soldering.

[3]. Do not warp the circuit board after soldering.

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
Jan.18, 2022	Revision 1.0	Production release
Jan.18, 2021	Revision 0.9	Initial Release

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