PAH8002EP: Low Power Optical Heart Rate Detection Sensor

General Description

The PAH8002EP is a low power and high-performance CMOS-process optical sensor with three LEDs: two Green and one Infrared, and integrated DSP, targeted as a Heart Rate Detection (HRD) sensor. It is based on optical sensing technology that captures higher resolution image than the traditional photodiode. The images are then processed through our integrated DSP to attain processed PPG (Photoplethysmogram) data for use in deducing heart rate.

Key Features

- Heart rate detection function (HRD)
- SRAM buffer support
- Integrated ultra-low power mode, while in Sleep mode
- Adjustable sleep rate control
- Communication interface options
  - I^2C
  - Four-Wire SPI
- I^2C interface up to 1 Mbit/s
- SPI interface up to 2 Mbit/s
- Hardware reset support
- Integrated chip-on-board LEDs with wavelength of 525nm and 940nm

Applications

- Heart Rate Monitor Accessories
- Wearables: Smartwatch, Wrist Band

***Disclaimer:**

The PAH8002EP-2P is not designed for usage in medical device. In addition, the data and information of heart rate measurement provided by this sensor may not be completely accurate and may exceed heart rate tolerance as per the specification stated in the document due to different factors, such as interference with signal from external sources, incorrect wearing position and changes in weather conditions or user's body condition.

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Key Parameters

Parameter	Value
Operating Temperature, Tj (°C)	-20 to +60
Array Size	1 pixel
Pixel Size (µm)	780 x 780
Max Frame Rate (fps)	50K
Dynamic Range (dB)	70
Supply Voltage (V)	VDDM: 3.3 – 3.6 VDD_LEDx: 3.3 – 3.6 VDDIO: 1.62 – 3.6 Analog: 2.8 Digital: 1.8
Power Consumption (mW) @3.3V Note: Including LED current, without I/O toggling, package only	Active: ▪ Double Injection Type : 4.95 with one LED 8.25 with two LEDs 0.165 with IR Touch Detection ▪ Printing Cover Type: 2.97 with two LEDs 0.165 with IR Touch Detection Sleep: 0.08
Heart Rate Measurement Range (bpm)	30 - 240
Package Size (mm)	3.6 x 6.36 x 1.0

Ordering Information

Part Number	Package Type
PAH8002EP-2P	22-Pin LGA

Lead (Pb) Free RoHS 6 fully compliant

For any additional inquiries, please contact us at http://www.pixart.com/contact.asp

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1.0 Introduction

1.1 Overview

The PAH8002EP is a low power and high-performance CMOS-process optical sensor, targeted as a Heart Rate Detection (HRD) sensor. It is built-in with 2 Green LEDs, 1 Infrared LED and integrated DSP It comes with two communication interfaces, which are I^2C supporting up to 1 Mbit/s and Four-Wire SPI supporting up to 2 Mbit/s. SRAM buffer of 832 bytes is supported for the power saving at the host.

The Figure 1 shows the architecture block diagram of the device. Refer to the subsequent chapters for detailed information on the functionality of the different interface blocks.

Note: Throughout this document PAH8002EP low power Optical CMOS Heart Rate Sensor is referred to as the sensor.

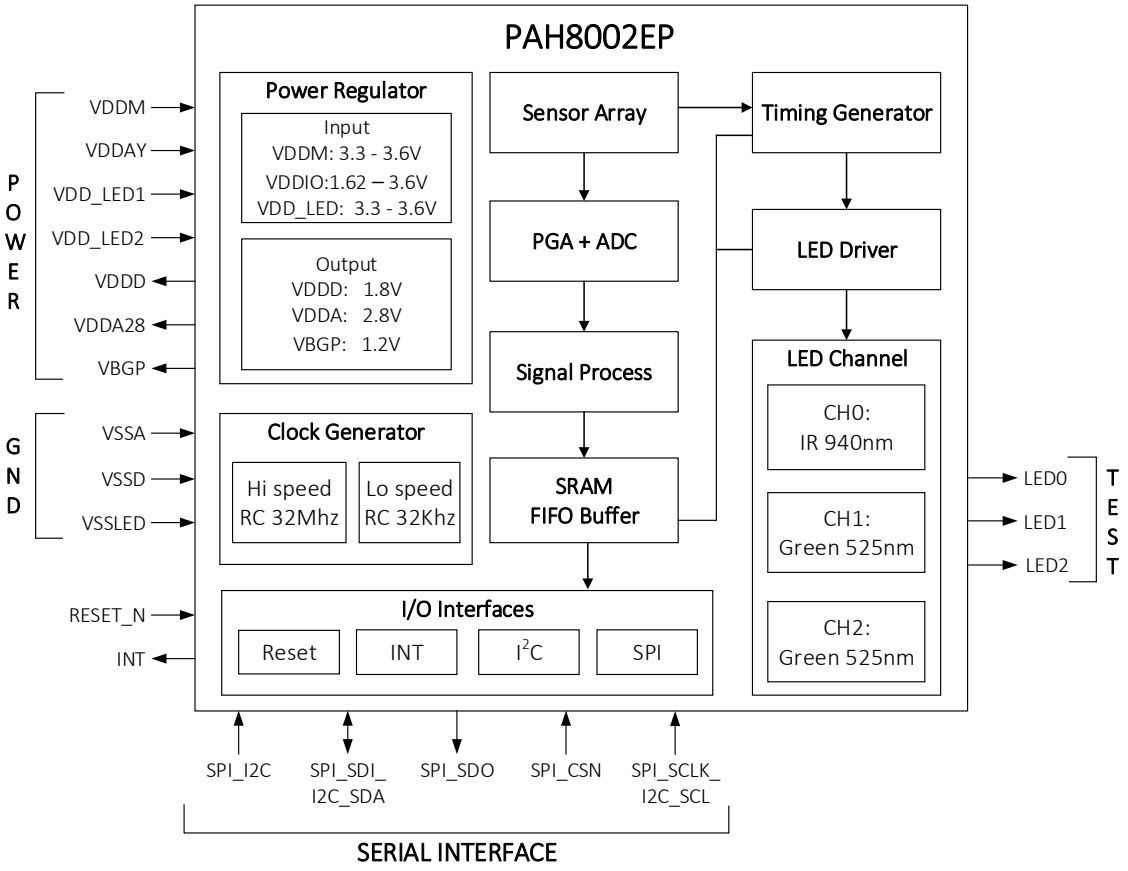

Figure 1. Functional Block Diagram

1.2 Terminology

Term	Description
GND	Ground
BiDir	Bi-Directional
PPG	Photoplethysmogram
Touch	Touch detection for wear on or wear off
SW reset	Software reset by register

1.3 Signal Description

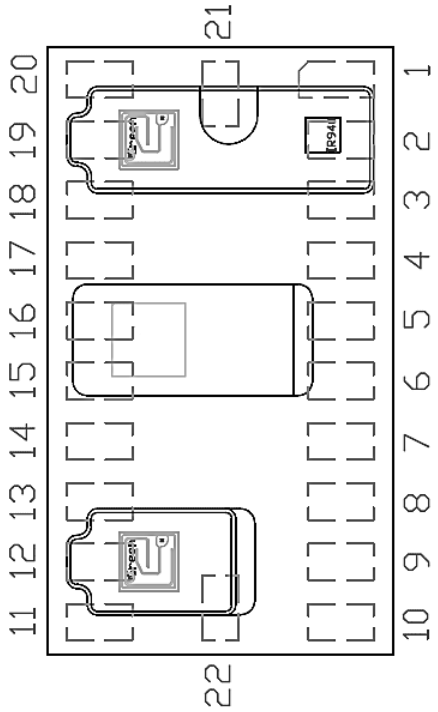

Figure 2. Pin Configuration

Table 1. Signal Pins Description

Pin No.	Signal Name	Type	Description
Functional Group:		Power Supplies	
1	VDD_LED01	Input	IR/Green LED Anode. Provide VDDM supply voltage
2	VDDAY	Input	Analog circuit power regulator input. Connect to VDDA28 or provide 2.8V voltage
3	VDDA28	Output	Analog circuit power regulator output. Must connect 1µF capacitor to GND
4	VDDD	Output	Digital circuit power regulator output. Must connect 1µF capacitor to GND
5	VBGP	Output	Reference regulator output. Must connect 0.1µF capacitor to GND
7	VDDM	Input	Power supply (3.3 - 3.6V) for internal power regulator
8	VSSLED	GND	LED Ground
15	VSSD	GND	Digital Ground
19	VDDIO	Input	I/O Power Supply (1.62 - 3.6V)
20	VSSA	GND	Analog Ground
s22	VDD_LED2	Input	Green LED Anode. Provide VDDM supply voltage
Functional Group:		Interface	
11	SPI_SDI_I2C_SDA	BiDir	4-wire SPI: Data input I^2C: Data input-output
12	SPI_SDO	Output	4-wire SPI: Data output
13	SPI_CSN	Input	4-wire SPI: Chip Select. Active Low
14	SPI_SCLK_I2C_SCL	Input	4-wire SPI/ I^2C: Clock

Pin No.	Signal Name	Type	Description
Functional Group:		Functional I/O	
16	INT	Output	Data ready interrupt. Default is edge sensitive interrupt, can be changed to level sensitive interrupt (high active) in INT Type register
17	SPI_I2C	Input	Interface Selection I^2C: Pull down (Tie to GND) 4-wire SPI: Pull high (Tie to VDDIO)
18	RESET_N	Input	Hardware control to enter Reset Mode. Connect to VDDIO when not used Level High: Leave Reset Mode Level Low: Enter Reset Mode
Functional Group:		Reserved	
9	LED0	RSV	Reserved for LED0 test pin
6	LED1	RSV	Reserved for LED1 test pin
10	LED2	RSV	Reserved for LED2 test pin
21	NC	RSV	Reserved. No Connection

2.0 Operating Specifications

2.1 Absolute Maximum Ratings

Table 2. Absolute Maximum Ratings

Parameters	Symbol	Min.	Max.	Unit	Notes
Analog Voltage	V_{DDM_MAX}	-0.4	V_{DDM} + 0.3	V	
I/O Voltage	V_{DDIO_MAX}	-0.4	V_{DDIO} + 0.3	V	
I/O Pin Input High Voltage	V_{DDIO_IN}	-0.4	V_{DDIO} + 0.3	V	All I/O pins
Relative Humidity	RH	0	50	%	Non-condensing, Non-biased
ESD	ESD_{HBM}		2	kV	Class 2 on all pins, as per human body model. JESD22-A114E with 15 sec zap interval.

Notes:
1. At room temperature.
2. Maximum Ratings are those values beyond which damage to the device may occur.
3. Exposure to these conditions or conditions beyond those indicated may adversely affect device reliability.
4. Functional operation under absolute maximum-rated conditions is not implied and should be restricted to the Recommended Operating Conditions.

2.2 Recommended Operating Conditions

Table 3. Recommended Operating Conditions

Description	Symbol	Min.	Typ.	Max.	Unit	Notes
Ambient Temperature	T_A	-20	25	60	°C	
Operating Junction Temperature	T_J	-20	-	60	°C	
Power Supply Voltage	V_{DDM}	3.25	3.3	3.6	V	Power regulator input supply. Includes ripples
Analog Supply Voltage	V_{DDAY}	2.66	2.8	2.94	V	If supply from external power regulator. Includes ripples
I/O Supply Voltage	V_{DDIO}	1.62	1.8	3.6	V	Includes ripples
Power Regulator Output Voltage	V_{DDD}	1.62	1.8	1.98	V	For digital circuit. Includes ripples
	V_{DDA28}	2.52	2.8	3.08	V	For analog circuit to be connected to V_{DDAY}. Includes ripples
	V_{BGP}	1.08	1.2	1.32	V	For power regulator reference. Includes ripples
Supply Noise	V_{Npp}	-	-	100	mV_{p-p}	Peak to peak within 10K – 80 MHz
Serial Clock Frequency	SCK_SPI	-	-	2	MHz	
	SCK_I^2C	-	400[1]	1000[2]	KHz	1. Max value for Fast mode 2. Max value for Fast mode plus

Note: PixArt does not guarantee the performance if the operating temperature is beyond the specified limit.

2.3 Thermal Specifications

Table 4. Thermal Specifications

Parameters	Symbol	Min.	Typ.	Max.	Unit	Notes
Storage Temperature	T_S	-25	-	125	°C	
Lead-free Solder Temperature	T_P	-	-	245	°C	Refer to Package Handling Information document

2.4 DC Characteristics

Table 5. DC Electrical Specifications

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
Peak Power Supply Current	I_{DDM_MAX}	-	-	100	mA	For V_{DDM}
	I_{DDAY_MAX}	-	-	10	mA	For V_{DDAY}
Peak I/O Supply Current	I_{DDIO_MAX}	-	-	1	mA	For V_{DDIO}
Output Supply Current	I_{DDD_MAX}	-	-	80	mA	For V_{DDD}
Output Supply Current	I_{DDA28_MAX}	-	-	20	mA	For V_{DDA28}
Power Consumption						
Supply Current @ Sleep	I_{DDPD}	-	25	75	uA	For sensor only Wakeup by read register
Inrush Current	I_{INRUSH}	-	-	60	mA	
With One Green LED						
Supply Current @ HRD PPG Double Injection Type	I_{DDHRD}	-	1.2	-	mA	For sensor only, not including LED current, without I^2C interface I/O toggle
LED current	I_{DDLED}	-	0.3	-	mA	20 report/sec, LED DAC = 50mA, on yellow skin color
With Two Green LEDs						
Supply Current @ HRD PPG Double Injection Type	I_{DDHRD}	-	1.7	-	mA	For sensor only, not including LED current, without I^2C interface I/O toggle
LED current	I_{DDLED}	-	0.8	-	mA	20 report/sec, LED DAC = 50mA, on yellow skin color
With Two Green LEDs						
Supply Current @ HRD PPG Printing Cover Type	I_{DDHRD}	-	0.6	-	mA	For sensor only, not including LED current, without I^2C interface I/O toggle
LED current	I_{DDLED}	-	0.3		mA	20 report/sec, LED DAC = 50mA, on yellow skin color
With IR Touch Detection						
Supply Current @ Touch Detection mode	$I_{DDtouch}$		45		uA	For sensor only, not including LED current, without I^2C interface I/O toggle
LED current at touch	I_{DDLED}	-	5	-	uA	3.8 report/sec, LED DAC = 50mA, on yellow skin color

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
I/O						
Input High Voltage	V_{IH}	0.7* V_{DDIO}	-	-	V	
Input Low Voltage	V_{IL}	-	-	0.3* V_{DDIO}	V	
Output High Voltage	V_{OH}	V_{DDIO} - 0.4	-	V_{DDIO} + 0.4	V	@I_{OH} = 2mA
Output Low Voltage	V_{OL}	-0.4	-	0.4	V	@I_{OL} = 2mA
LED						
Sink current	I_{LED}	40	50	60	mA	@ LED DAC = 50mA
LED cathode voltage	V_{LED-}	0.4		3.6	V	

Notes:

1. Electrical Characteristics are defined under recommended operating conditions.
2. All the parameters are tested under operating conditions: V_{DDM} = 3.3V, V_{DDIO} = 1.8 and 3.3V, T_A = 25°C

2.5 AC Characteristics

Table 6. AC Electrical Specifications

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
Power Up from V_{DD}↑	t_{PU}	200	300	400	ms	From V_{DD}↑ to valid interface communication
SDI/SDO Read Hold Time	T_{HOLD}	-	3	-	us	Minimum hold time for valid data.
Address and data delay time	t_{delay}	2.75			us	Refer to Serial Interface section
Sensor Pulse Interrupt Width	t_{INT}	0.00625	0.5	16	us	Default 0.5us, can be changed in INT_Pulse_Width register
Rise and Fall Times: SDI/SDO	t_r , t_f	-	30	-	ns	C_L = 30 pF
HW Reset Time	t_{reset}	200	300	400	ms	Reset_N from low to high period

Notes:

1. Electrical Characteristics are defined under recommended operating conditions
2. All the parameters are tested under operating conditions: T_A = 25°C, V_{DDM} = 3.3V, V_{DDIO} = 3.3V for 3.3V IO application and V_{DDIO} = 1.8 V for 1.8V IO application.

3.0 Mechanical Specifications

3.1 Mechanical Dimension

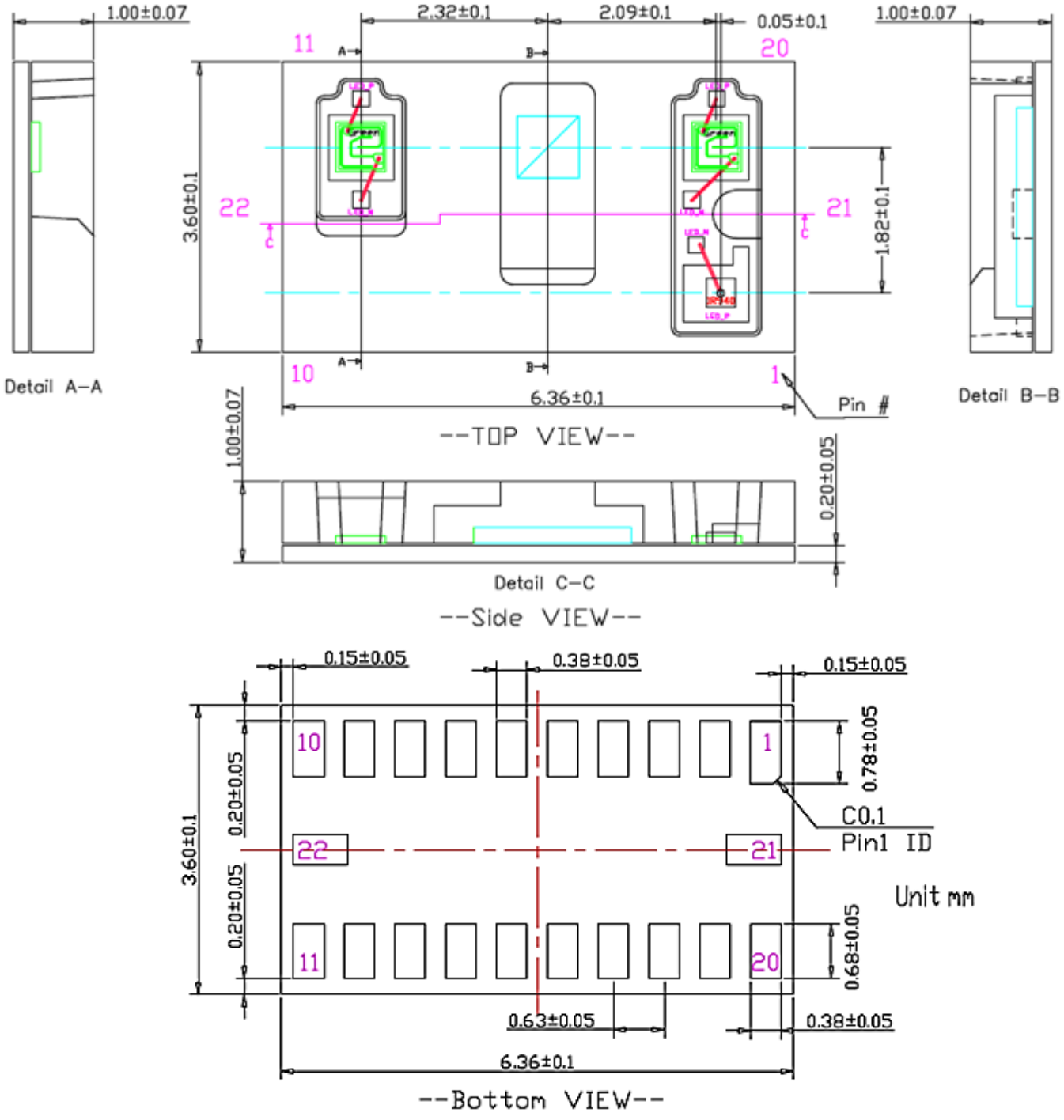

Figure 3. Package Outline Diagram

3.2 Package Marking

Refer to Figure 4. Package Marking for the code marking location on the device package.

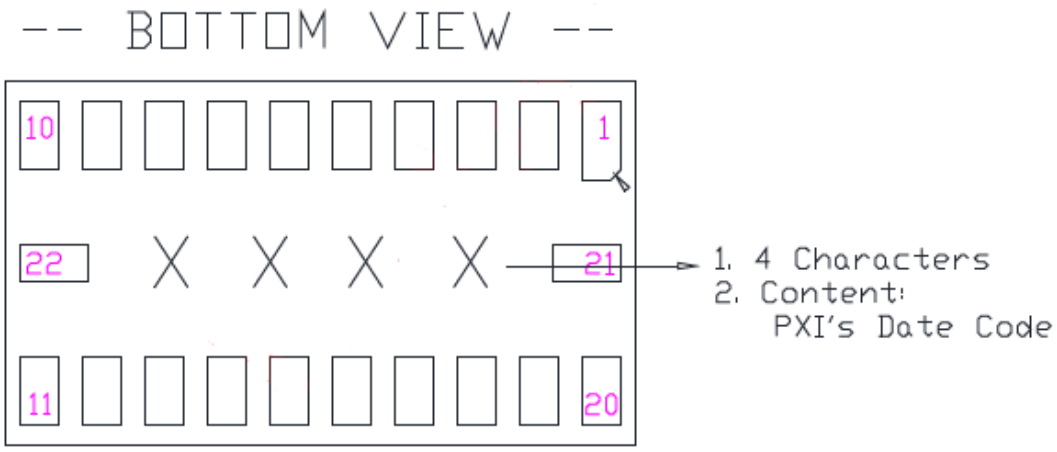

Figure 4. Package Marking

Table 7. Code Identification

Marking	Description
XXXX	PixArt Date Code

4.0 System Level Description

4.1 System Overview

This section describes on how the sensor being used to make up a complete system including the explanation on the 3rd party components and how they work with the sensor.

The PAH8002 is based on CMOS image sensor technology. It is designed to meet the requirements as heart rate monitor accessories and wearables like smart watch or wrist band device. Figure 5 illustrates a system design for App Level diagram. The processor is accessing PPG data from 8002 sensor, then pass it to App level. APP level applies PixArt provided algorithm library to determine the heart rate data and waveform. Figure 6. System Design for Firmware Level illustrates a system design for Firmware Level diagram. The processor will also access PPG data from 8002 sensor, then perform heart rate calculation with PixArt algorithm library and send result to display or end device.

PAH8002 can be configured to generate different frame rate settings up to 50K fps.

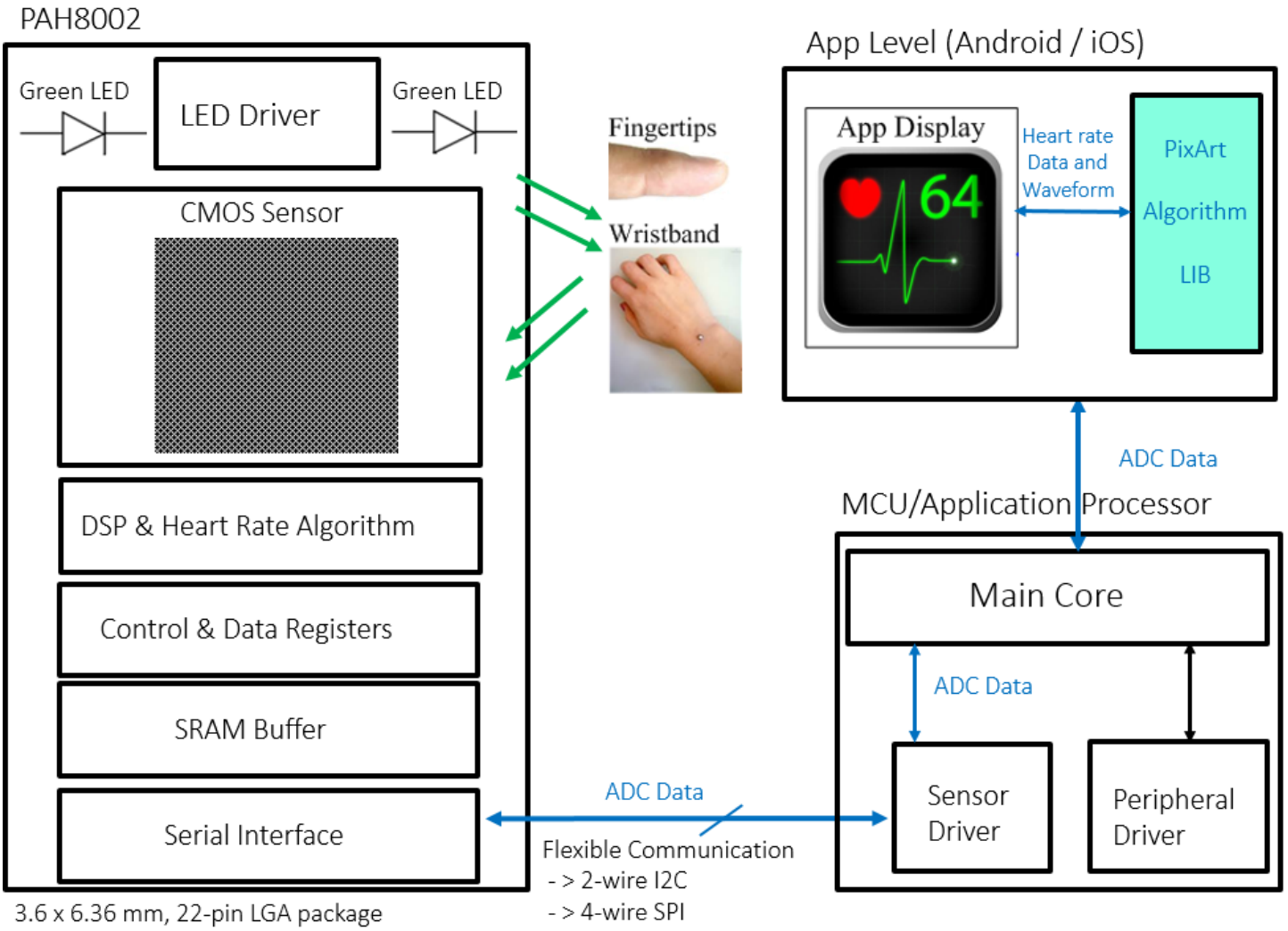

Figure 5. System Design for App Level

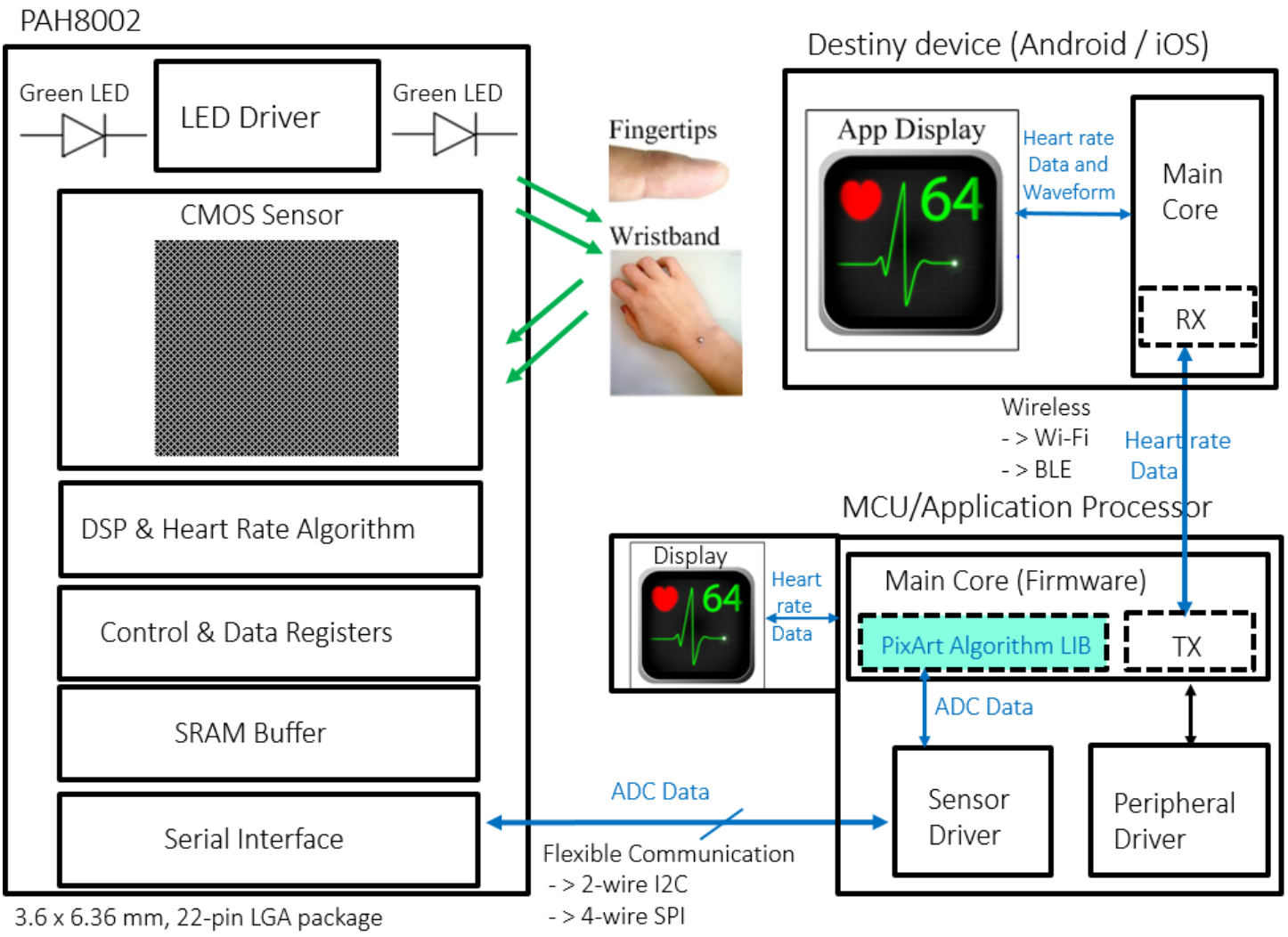

Figure 6. System Design for Firmware Level

4.2 Reference Schematic

4.2.1 Schematic Design- Double Injection Type

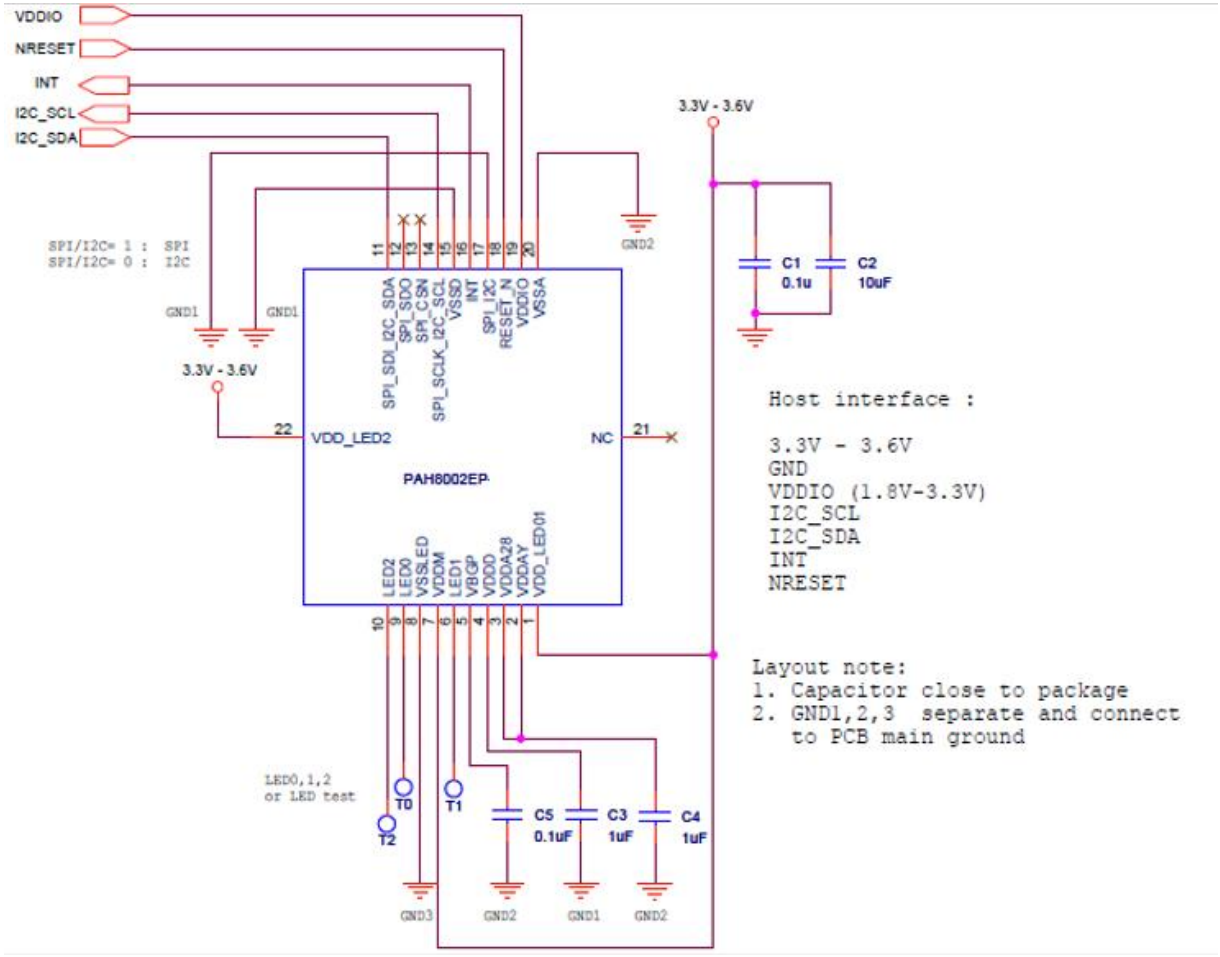

Figure 7. Reference Application Circuit –Double Injection Type

4.2.2 Schematic Design- Printing Cover Type

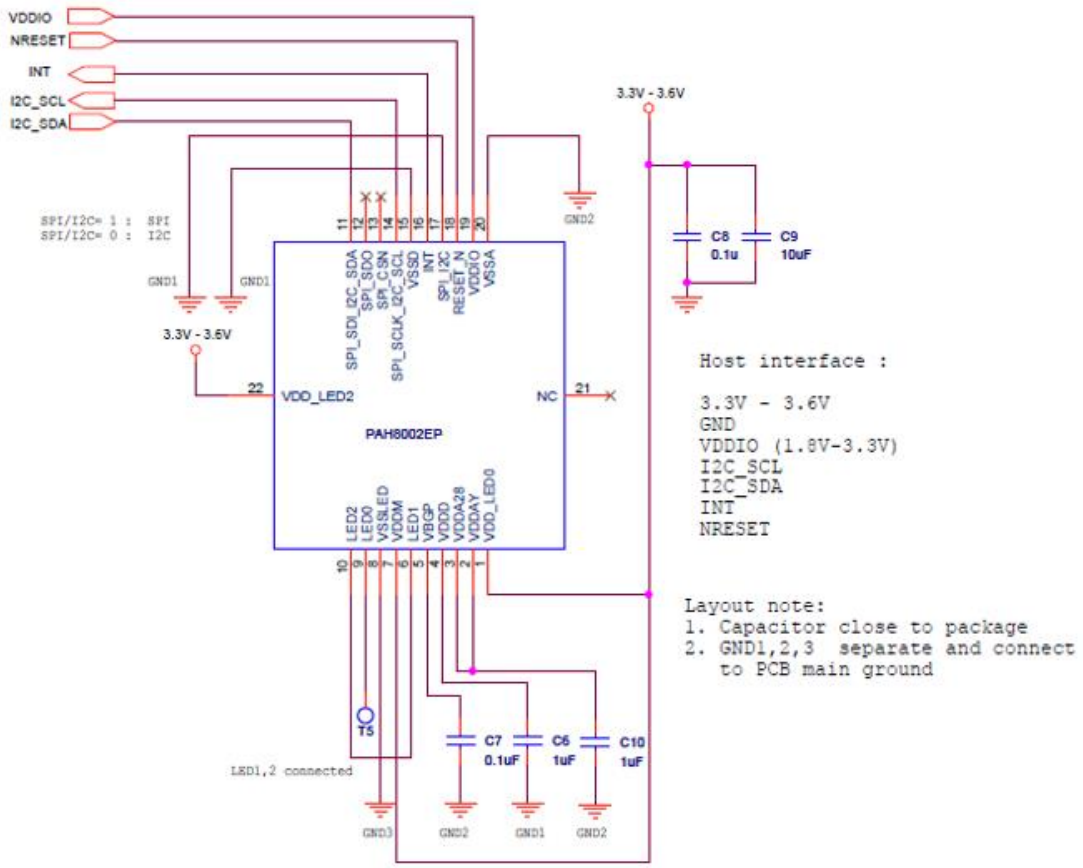

Figure 8 Reference Application Circuit–Printing Cover Type

4.3 Design Guidelines

4.3.1 Schematic Design

1. VDDM & VDDIO: 3.3V~3.6V (for 3.3V System)
2. VDDM: 3.3V~3.6V, VDDIO: 1.62V~1.98V (for 1.8V System)
3. It is recommended to separate the power system for VDDM to avoid power interference.
4. SPI_SDI_I2C_SDA and SPI_SCLK_I2C_SCL pull high to VDDIO with resistor for I^2C Only
5. VDDD, VDDA28 must have 1μF and VBGP must have 0.1μF capacitor connecting to GND and place closely to 8002.
6. The GND1, GND2 and GND3 must be separated and connected to PCB main GND.
7. INT pin is recommended to be connected to MCU HW INT as data ready INT for power saving.
8. Ensure that the VDDM and VDDIO's power noise should be under 100mV (with 0.1μF and 10μF capacitor)
9. Tie SPI_I2C pin to VDDIO for SPI or tie to GND for I^2C.
10. At power on, VDDM and VDDIO must be powered on at the same time or VDDIO to be powered on first before VDDM.
※When VDDIO to be powered on first before VDDM, host should prevent using the I^2C interface (Connected with 8002) to switch the LDO providing VDDM voltage.
11. At power off, VDDM and VDDIO must be powered off at the same time or VDDM to be powered off first before VDDIO.

4.3.2 PCB Layout Design

4.3.2.1 Recommended Layout PCB

Recommended Stencil Thickness: 0.1mm. PCB Layout can be refer to Figure 9. Recommend Layout PCB.

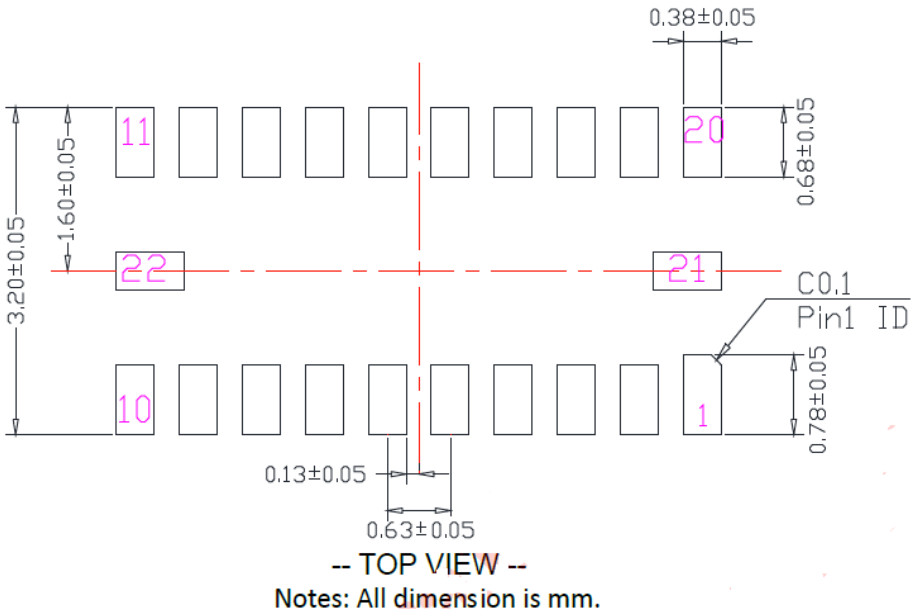

Figure 9. Recommend Layout PCB

4.3.2.2 Recommended Stiffener type for FPC (Flex) back-side (at Sensor package area)

1. If use FPC (Flex) board, need add stiffener onto the back - side to enhance the Flex strength.
2. Recommended Stiffener type: FR4 or stainless steel or equivalent material.

4.3.2.3 PCB Layout Guidelines

The following guidelines can be refer to Figure 10. PCB Layout Guide.

1. Capacitor 0.1μF and 1μF must be placed close to the sensor package.
2. The GND plane of GND of VSSA, VSSD and VSSLED must be layout separately and connected to the PCB's main GND.

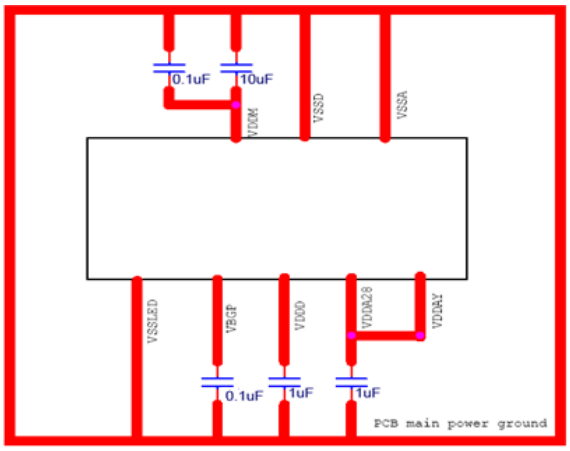

Figure 10. PCB Layout Guide

4.4 Recommend Guideline for PCB Assembly

Recommended vender and type for Pb-free solder paste

1. Almit LFM-48W TM-HP
2. Senju M705-GRN360-K

IR Reflow Soldering Profile can be refer to Figure 11. IR Reflow Soldering Profile.

Temperature profile is the most important control in reflow soldering. It must be fine-tuned to establish a robust process. The typical recommended IR reflow profile is:

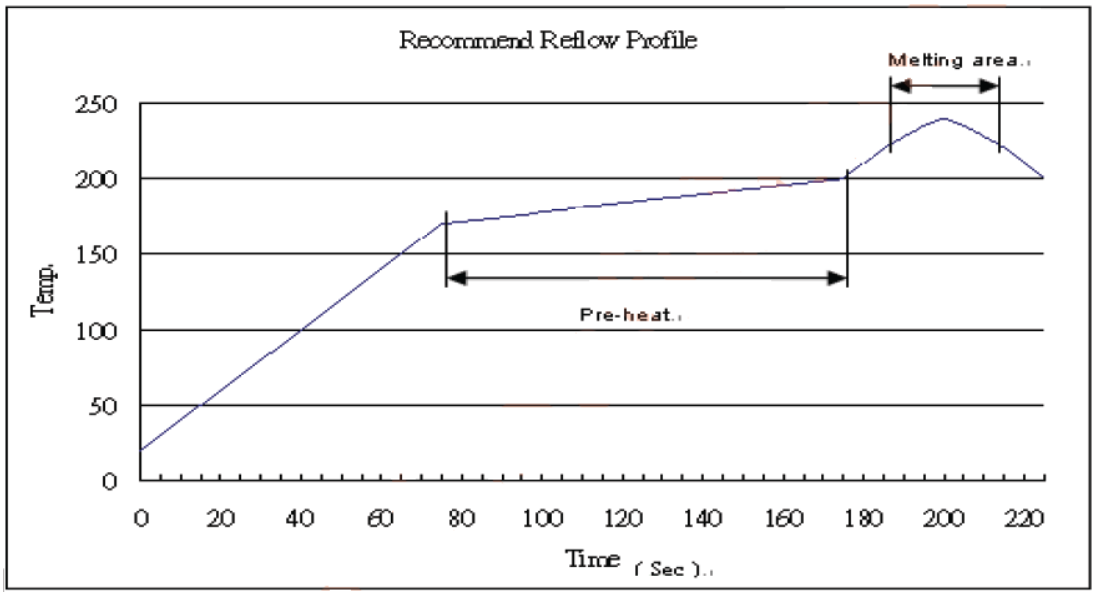

Figure 11. IR Reflow Soldering Profile

Note:
(1) Average Ramp-up Rate (30℃ to preheat zone): 1.5~2.5℃/Sec
(2) Preheat zone:
  (2.1) Temperature ramp from 170~200℃
  (2.2) Exposure time: 90 +/- 30 sec
(3) Melting zone:
  (3.1) Melting area temperature > 220℃ for at least 30~50sec
  (3.2) Peak temperature: 245℃
MS Level: MS Level 3

4.5 Package Information

4.5.1 Carrier Tape Drawing

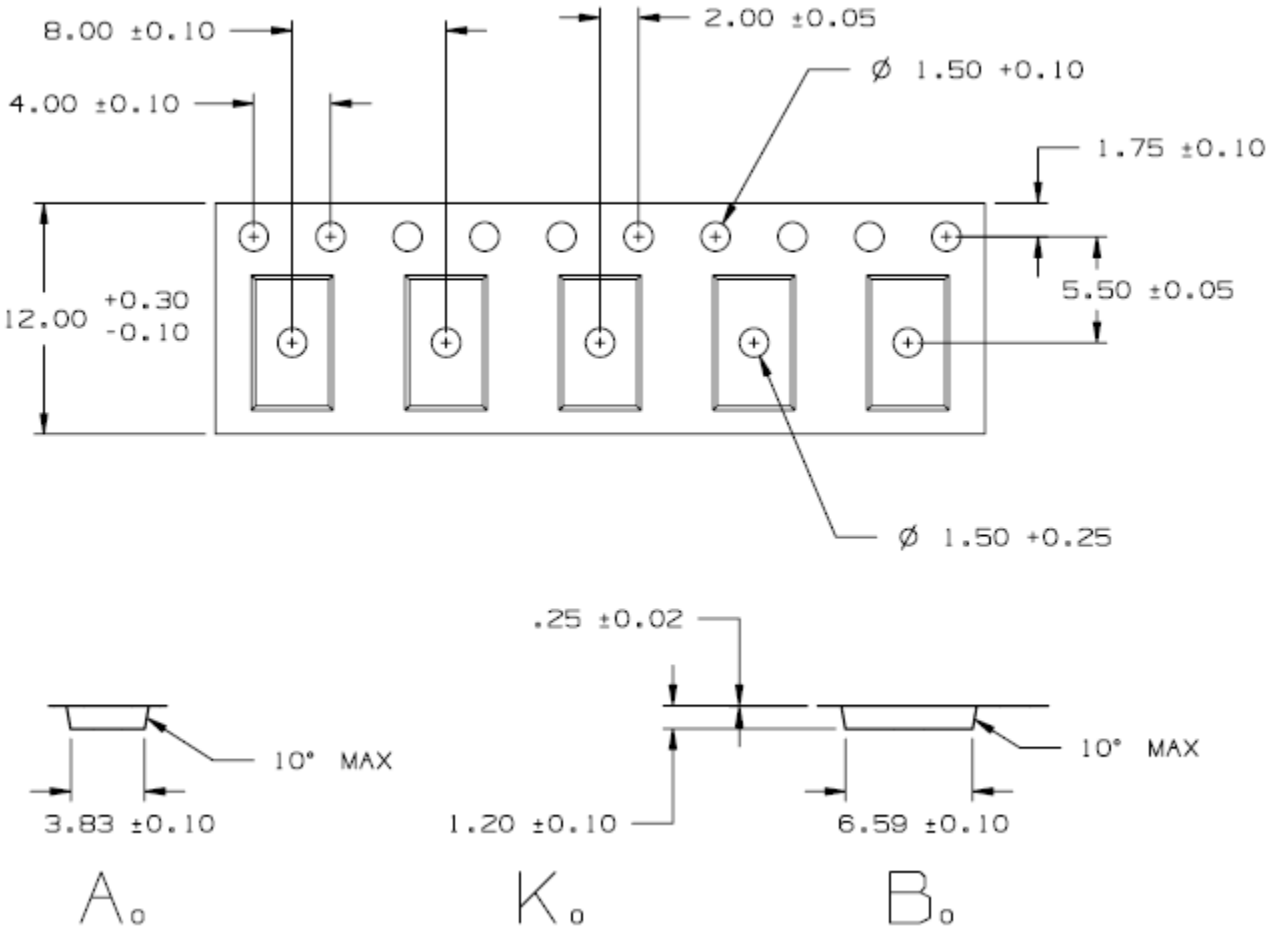

Figure 12. Carrier Tape Drawing

4.5.2 Unit Orientation

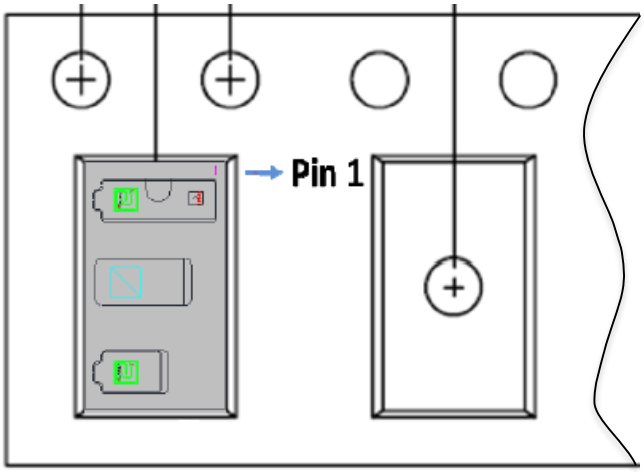

Figure 13. Unit Orientation

The maximum capacity of one packing box for PAH8002EP-2P: One Inner packing box = 2500 units
Note: The Tape and Reel packing with vacuum pack is 1year storage available @ 25°C, 50%RH

Document Revision History

Revision Number	Date	Description
1.0	14 Apr 2016	1st Creation