

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
 - I²C
 - Four-Wire SPI
- I²C 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: <ul style="list-style-type: none"> ▪ 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
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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 I²C 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.

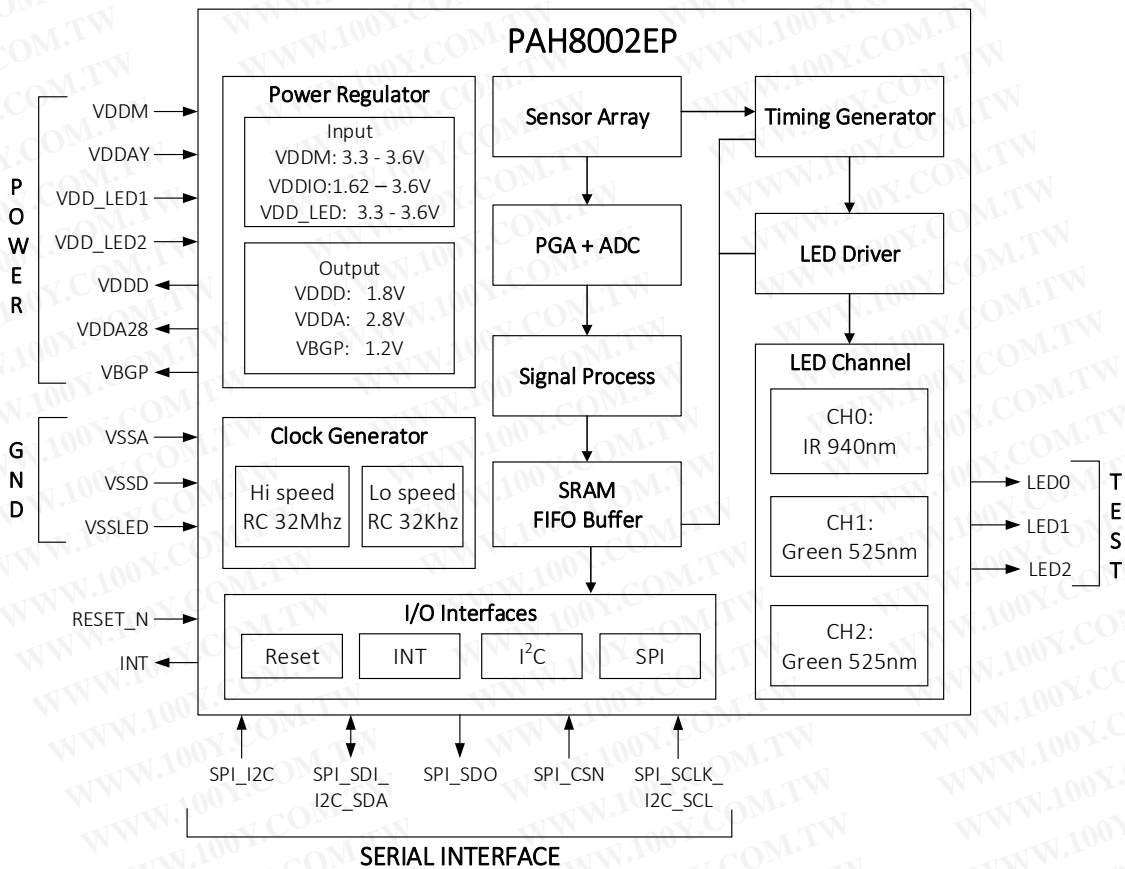


Figure 1. Functional Block Diagram

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

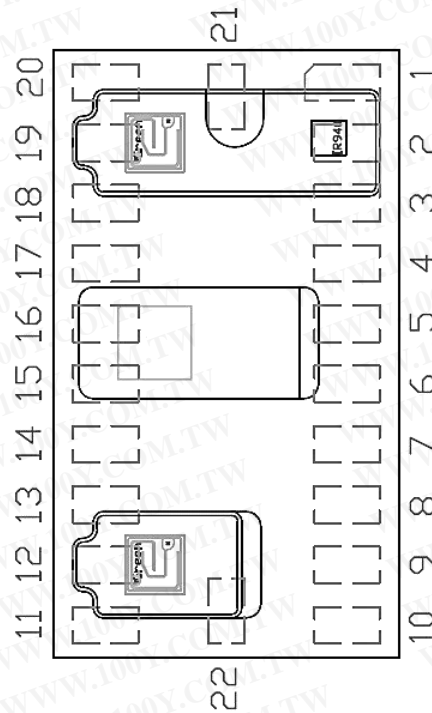


Figure 2. Pin Configuration

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 ² C: 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 ² C: 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 ² C: 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 ² C | - | 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_{DDO_MAX} | - | - | 80 | mA | For V_{DDO} |
| 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 ² C 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 ² C 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 ² C 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 ² C 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 $3.3V$, $T_A = 25^{\circ}C$

2.5 AC Characteristics

Table 6. AC Electrical Specifications

| Parameters | Symbol | Min. | Typ. | Max. | Unit | Conditions |
|---------------------------------|-------------|---------|------|------|------|---|
| Power Up from $V_{DD} \uparrow$ | t_{PU} | 200 | 300 | 400 | ms | From $V_{DD} \uparrow$ 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: $T_A = 25^{\circ}C$, $V_{DDM} = 3.3V$, $V_{DDIO} = 3.3V$ for 3.3V IO application and $V_{DDIO} = 1.8 V$ for 1.8V IO application.

3.0 Mechanical Specifications

3.1 Mechanical Dimension

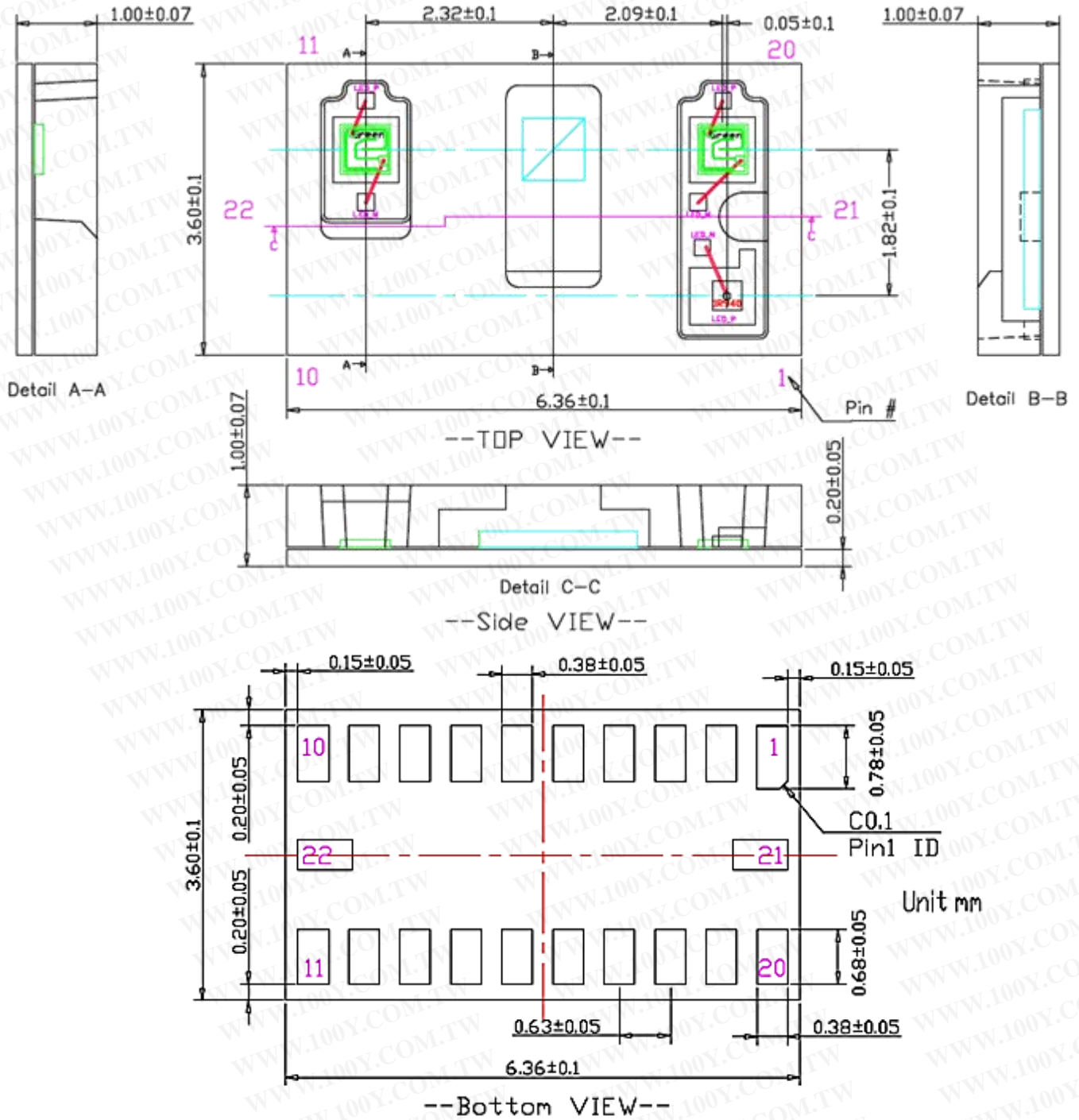


Figure 3. Package Outline Diagram

3.2 Package Marking

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

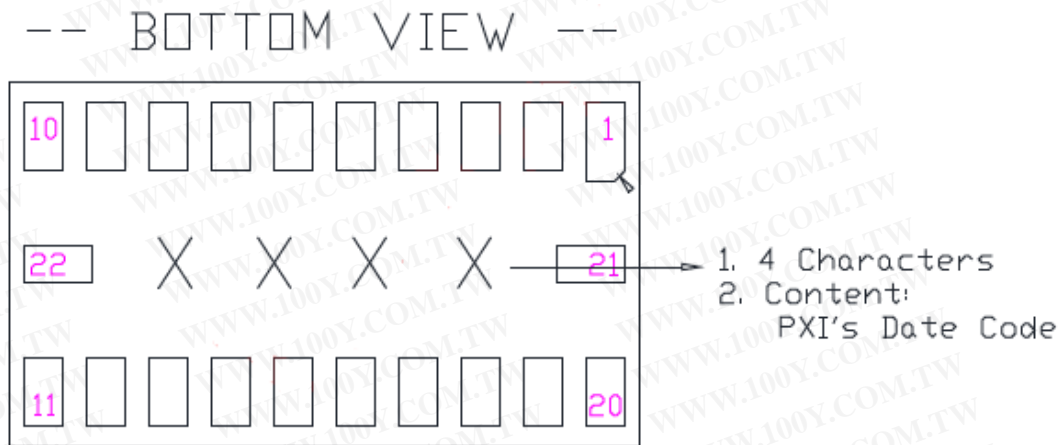


Figure 4. Package Marking

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.

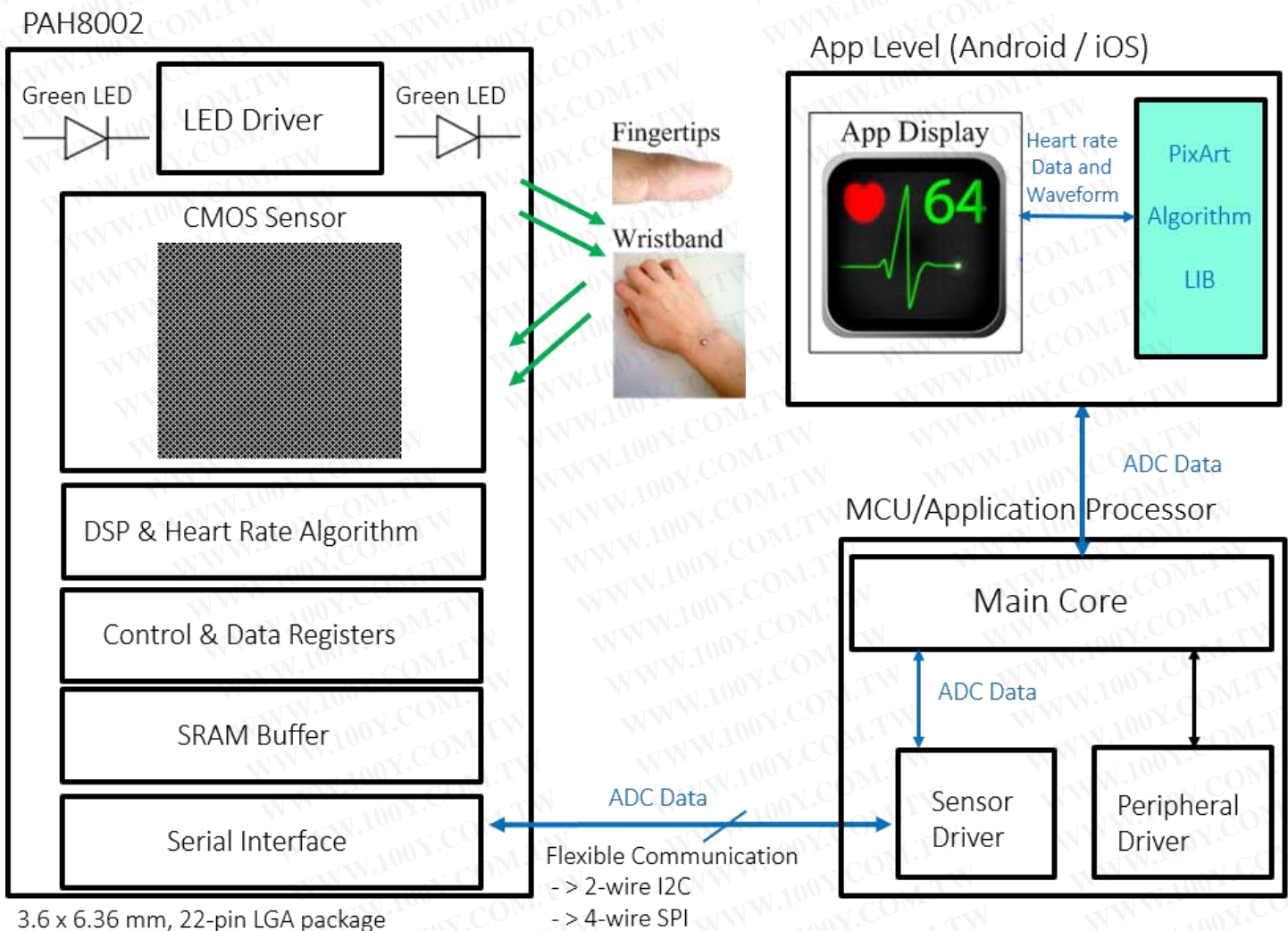


Figure 5. System Design for App Level

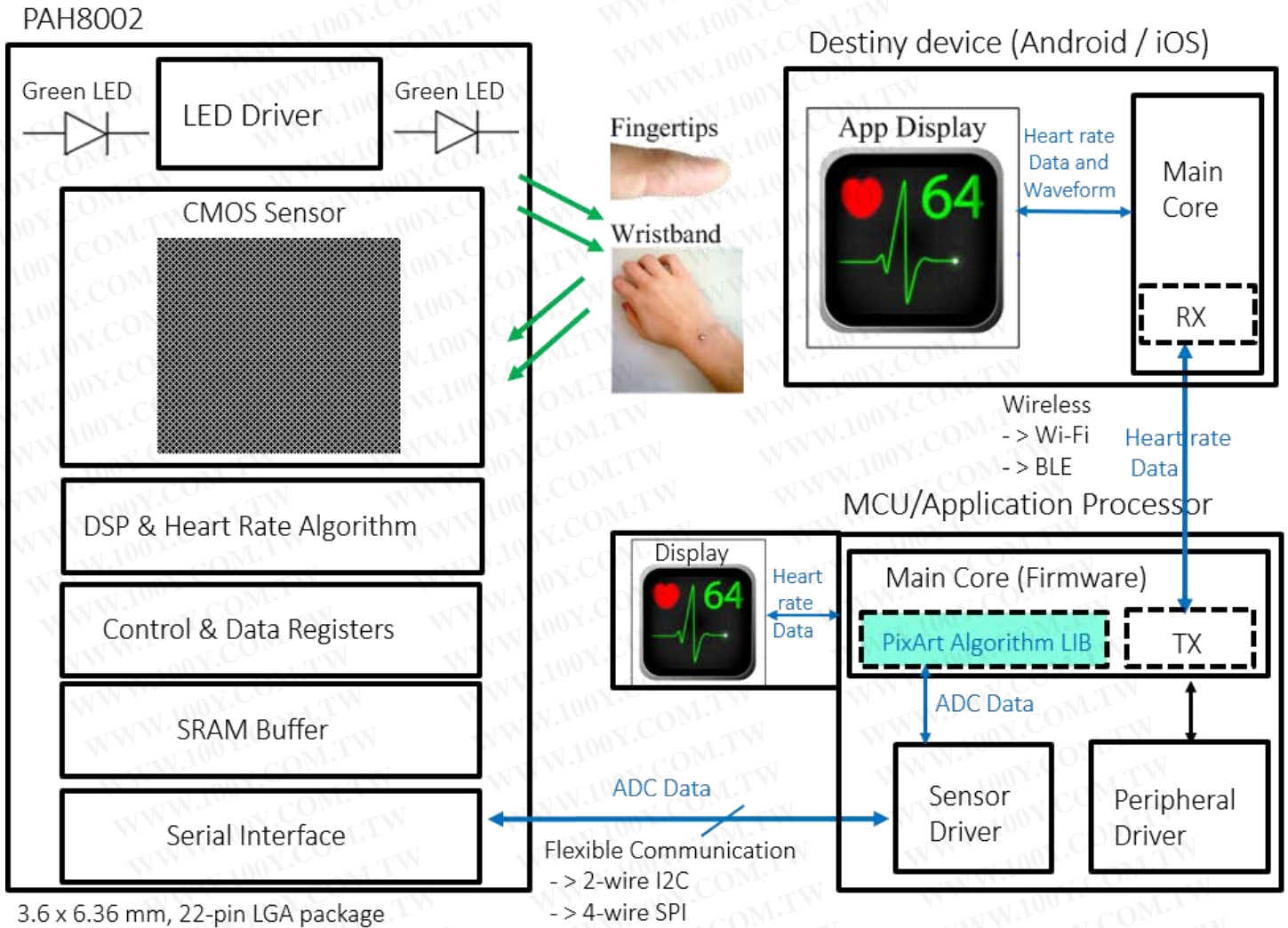


Figure 6. System Design for Firmware Level

4.2 Reference Schematic

4.2.1 Schematic Design- Double Injection Type

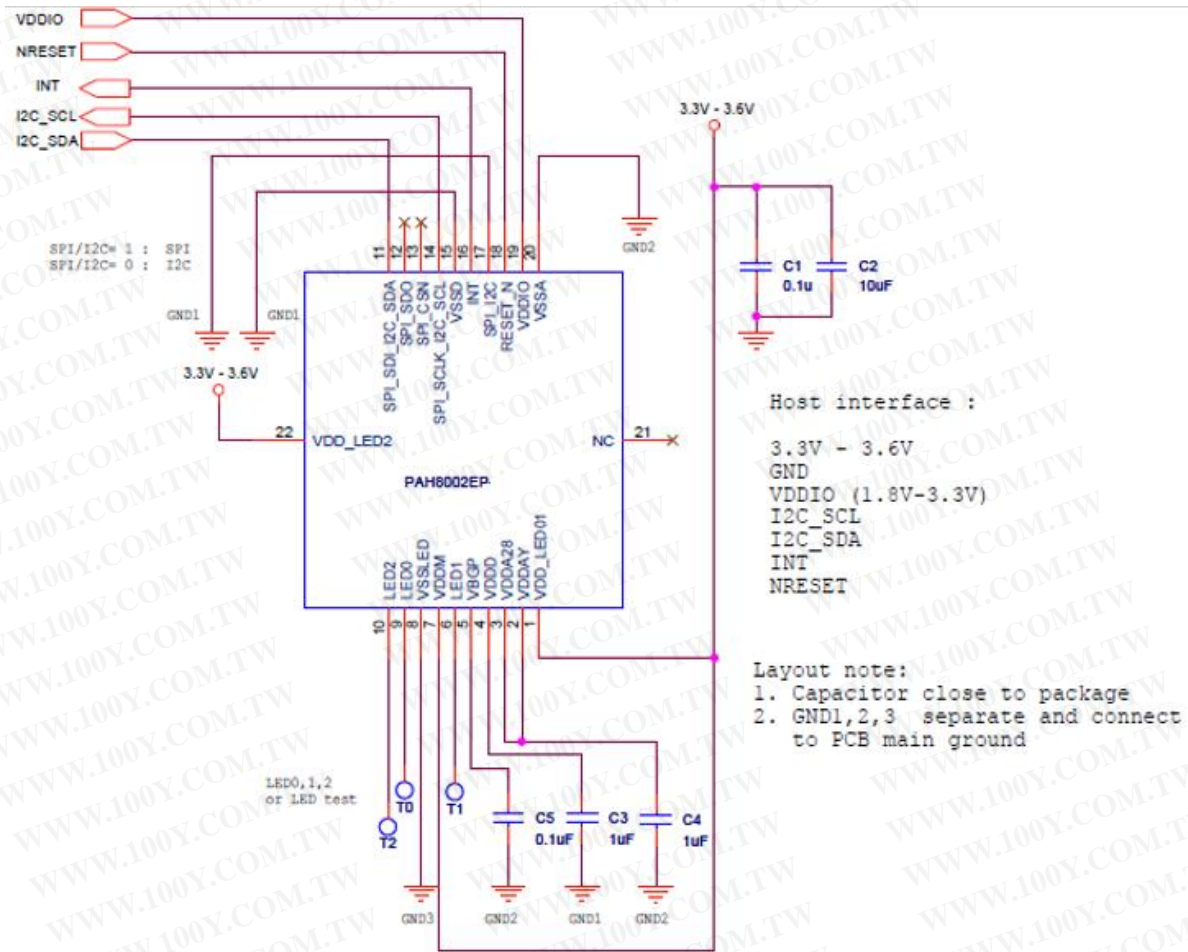


Figure 7. Reference Application Circuit –Double Injection Type

4.2.2 Schematic Design- Printing Cover Type

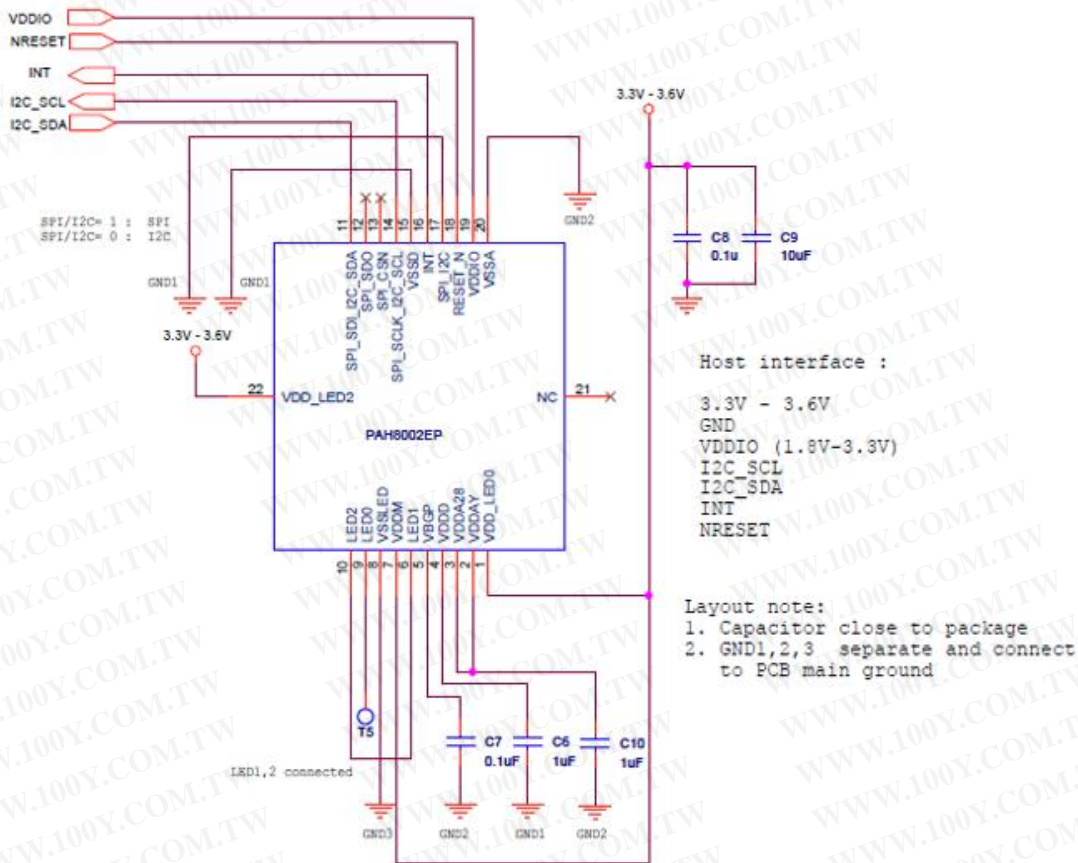


Figure 8 Reference Application Circuit–Printing Cover Type

4.3 Design Guidelines

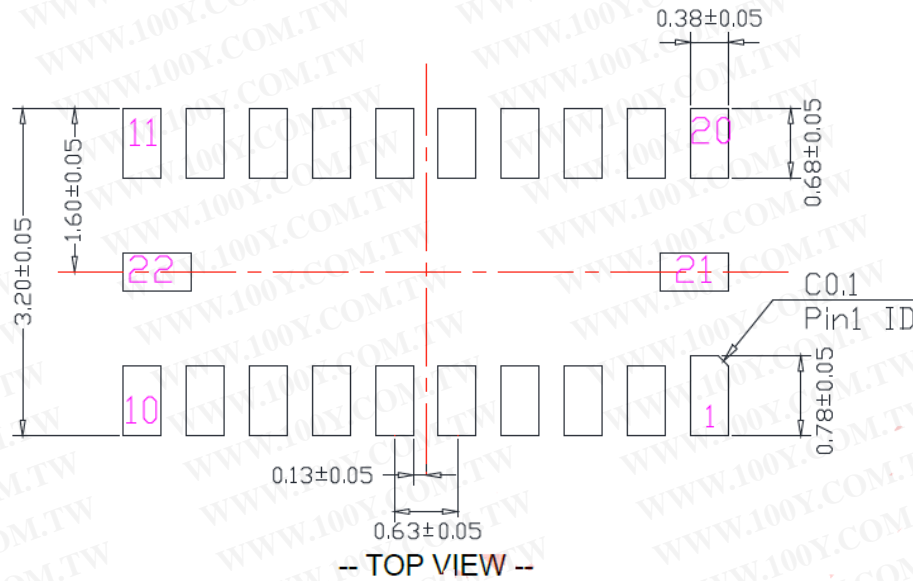
4.3.1 Schematic Design

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 I²C Only
5. VDDD, VDDA28 must have 1μF and VBGPD 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 I²C.
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 I²C 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.



Notes: All dimension is mm.

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.

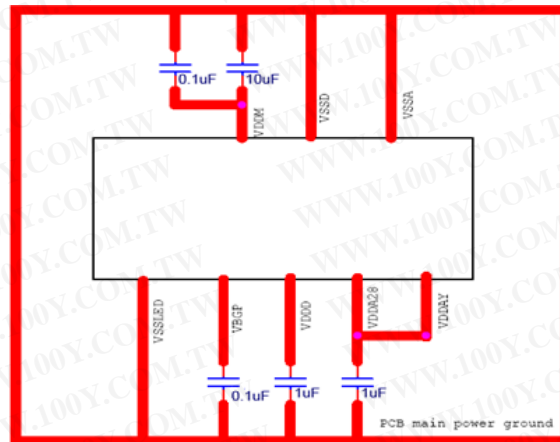


Figure 10. PCB Layout Guide

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:

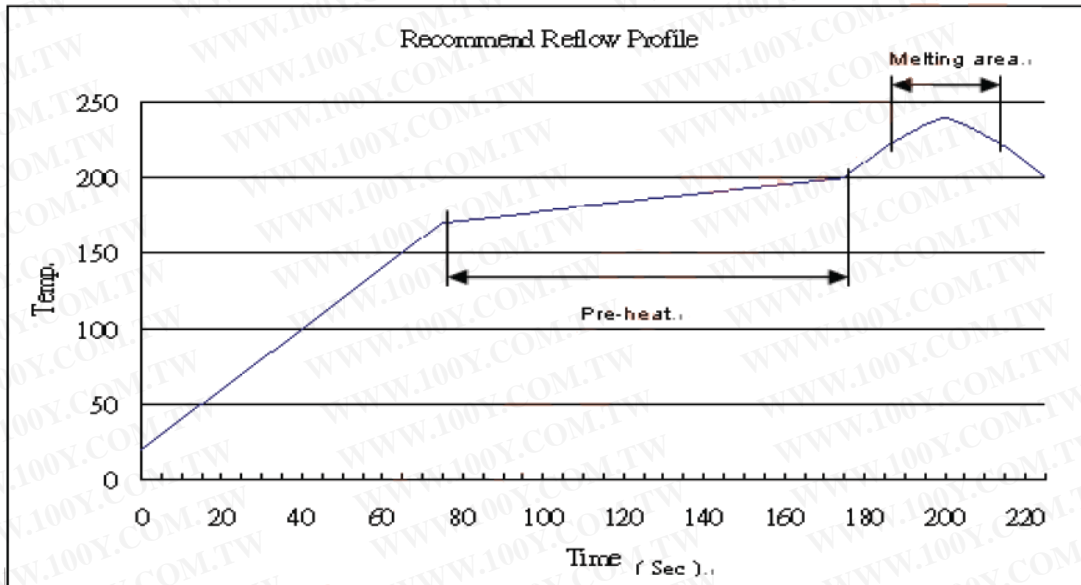


Figure 11. IR Reflow Soldering Profile

Note:

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

MS Level: MS Level 3

4.5 Package Information

4.5.1 Carrier Tape Drawing

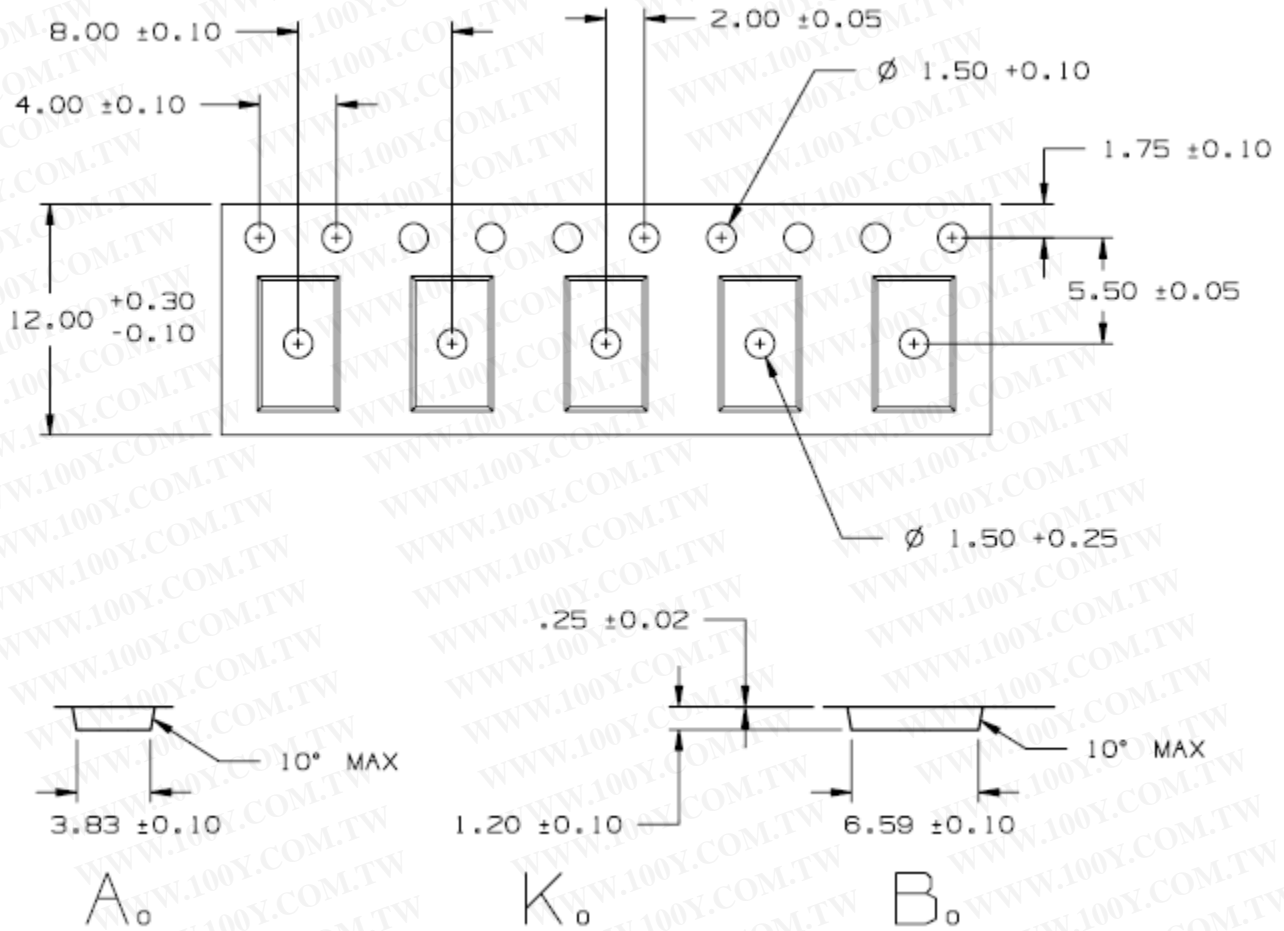


Figure 12. Carrier Tape Drawing

4.5.2 Unit Orientation

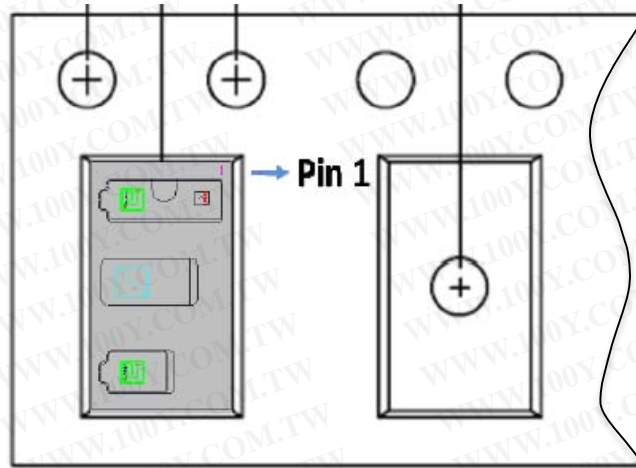


Figure 13. Unit Orientation

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 | 1 st Creation |

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