

PAH8005EI-2G: Optical Heart Rate Detection Sensor

General Description

The PAH8005EI-2G is a high performance and low power CMOS-process optical sensor integrated with a Green LED and Digital signal processor serving as a Heart Rate Detection (HRD) sensor. It is based on optical technology which measures the variation of human blood movement in the vessel.

Key Features

- Heart rate detection function
- Ultra-low power consumption with power saving modes during no touch movement period
 - LPT sleep1
 - LPT sleep2
- Flexible sleep rate control
- Flexible communication interfaces
 - I²C
 - 4-wire SPI
 - 2-wire SPI
- I²C interface up to 1 Mbit/s
- SPI interface up to 1 Mbit/s
- Hardware reset support
- Hardware power down support
- Integrated chip-on-board LED with wavelength of 525nm

Applications

- Healthcare wearable device
- Photoplethysmogram waveform

*Disclaimer:

The PAH8005EI-2G 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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Preliminary: This product is still under product development where the product specifications are subjected to change upon product release.

Key Parameters

Parameter	Value
Operating Junction Temperature	-20 to +60 °C
Interfaces	I ² C, 2-Wire SPI, 4-Wire SPI
Input Clock	6.8MHz
Supply Voltage	V _{DDM} : 3.3 – 3.6 V V _{DDIO} : 1.62 – 3.6 V Note: Including ripples
Average Current of Sensor and LED without I/O toggling	HRD Low Power Mode: 260 μA HRD Normal Mode: 710 μA Power Down: 15 μA
Frame Rate	Up to 3000 fps
Heart Rate Measurement Range	30 - 240 bpm
Package Size	3.0 x 4.7 x 1.0 mm

Ordering Information

Part Number	Package Type
PAH8005EI-2G	16-pin LGA Package



Lead (Pb) Free
RoHS 6 fully
compliant



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1.0 Signal Description

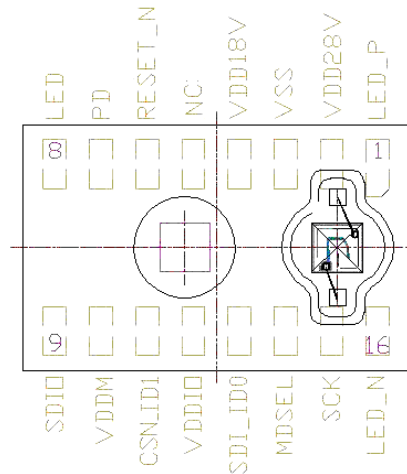


Figure 1. Pin Configuration

Table 1. Signal Pins Description

Pin No.	Signal Name	Type	Description
Functional Group:		Power Supplies	
1	LED_P	Power	LED Anode. Provide VDDM supply voltage
2	VDD28V	Power	Analog circuit power regulator output. Must connect a 0.1μF capacitor to GND
3	VSS	Ground	Chip Ground
4	VDD18V	Power	Analog and digital circuit power regulator output. Must connect a 0.1μF capacitor to GND
10	VDDM	Power	Power supply for internal power regulator. VDDM: 3.3 – 3.6 V
12	VDDIO	Power	I/O power supply. VDDIO: 1.62 – 3.6 V
16	LED_N	LED	LED Cathode. Must connect to LED
Functional Group:		Control Interface	
9	SDIO	BiDir	4-Wire SPI: Data Output pin 2-Wire SPI: Data In-Out pin I ² C: Data In-Out pin
11	CSN_ID1	Input	4-Wire SPI: Chip Select (Active Low) I ² C: Address Set ID1 (Tri state IO)
13	SDI_ID0	Input	4-Wire SPI: Data Input pin I ² C: Address Set ID0 (Tri-State IO)
15	SCK	Input	2-Wire SPI/ 4-Wire SPI/ I ² C: Serial Clock pin
Functional Group:		Functional I/O	
6	RESET_N	Input	Hardware control to enter Reset mode Level High: Exit Reset mode Level Low: Enter Reset mode Set to High when not in used

Pin No.	Signal Name	Type	Description
7	PD	Input	Hardware control to enter Power Down mode with internal 1M Ω pull-down resistor Level High: Enter power down mode Level Low: Exit power down mode Set to Low when not in used
8	LED	Output	LED driver connection. Must connect to LED_N
14	MDSEL	Input	Tri state IO. For mode selection of 2-Wire SPI, 4-Wire SPI or I ² C I ² C: Pull down. Pull down to GND 4-Wire SPI: Floating 2-Wire SPI: Pull high. Pull high to VDDIO
Functional Group:		Reserved Pin	
5	NC	-	No connection

2.0 Operating Specifications

2.1 Absolute Maximum Ratings

Table 2. Absolute Maximum Ratings, T = 25°C

Parameters	Symbol	Min.	Max.	Unit	Notes
DC Supply 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
ESD	ESD _{HBM}	-	2	kV	Human Body Model

Notes:

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

2.2 Recommended Operating Conditions

Table 3. Recommended Operating Conditions

Parameters	Symbol	Min.	Typ.	Max.	Unit	Notes
Operating Temperature	T _{OT}	-20	25	60	°C	
Power Supply Voltage	V _{DDM}	3.3		3.6	V	
IO Supply Voltage	V _{DDIO}	1.62	1.8	3.6	V	
			3.3			
Supply Noise	V _{Npp}	-	-	100	mV _{p-p}	Peak-to-peak within 10K – 80MHz
Serial Clock Frequency	SCK	SPI	-	1000	kHz	
		I ² C	-	400		

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 _{STG}	-40	-	85	°C	
Lead-free Temperature Surface-mount Process	T _{SOL}	-	245	-	°C	Refer to Package Handling Information for details

2.4 DC Characteristics

Table 5. DC Electrical Specifications

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
Type: Power						
Average Supply Current @ HRD Low Power mode	$I_{DDHRDLP}$	-	0.16	-	mA	For PAH8005 chip only. Not including LED current.
Average Supply Current @ HRD Normal mode	I_{DDHRDN}	-	0.42	-	mA	No SPI interface and I/O toggling
Supply Current @ Power Down	I_{DDPD}	-	15	-	μ A	
LED Current @ HRD Low Power mode	I_{LEDHRD}	-	0.1	-	mA	Average LED current @ LED_Step = 10
LED Current @ HRD Normal mode	I_{LEDHRD}	-	0.29	-	mA	Typical is tested on Asian Light skin color
Inrush Current	I_{INRUSH}	-	-	60	mA	For VDDM, VDDIO, VDD18V, VDD28V with 0.1 μ F
Type: IO						
Input Voltage HIGH	V_{IH}	$0.7 \cdot V_{DDIO}$	-	$V_{DDIO} + 0.4$	V	
Input Voltage LOW	V_{IL}	-0.4	-	0.48	V	@ VDDIO \geq 1.7V
		-0.4	-	0.44		@ VDDIO \geq 1.62V
Output High Voltage	V_{OH}	$V_{DDIO} - 0.4$	-	$V_{DDIO} + 0.4$	V	@ $I_{OH} = 2$ mA
Output Low Voltage	V_{OL}	-0.4	-	0.4	V	@ $I_{OL} = 2$ mA
Type: LED						
LED Sink current	I_{LED}	7.5	15	22.5	mA	@ LED_Step = 10
LED cathode voltage	V_{LED}	0.6	-	$V_{DDIO} + 0.3$	V	At LED register setting of 15mA

Notes: DC Electrical Characteristics are defined under recommended operating conditions. Typical $T_A = 25^\circ\text{C}$, $V_{DDM} = 3.3\text{V}$ and $V_{DDIO} = 1.8\text{V} - 3.3\text{V} \pm 5\%$.

2.5 AC Characteristics

Table 6. AC Electrical Specifications

Parameters	Symbol	Min.	Typ.	Max.	Unit	Conditions
PD Pulse Register	t_{PDR}	-	-	1.9	ms	2 frames time maximum after setting PD_enh bit in the <i>Configuration</i> register
Power Up from $V_{DD} \uparrow$	t_{PU}	10	-	38	ms	From $V_{DD} \uparrow$ to valid touch signal
SDIO Read Hold Time	T_{HOLD}	-	3	-	μs	Minimum hold time for valid data
Address and data delay time	t_{delay}	2.75	-	-	μs	Refer to Serial Interface section
Serial Interface RESYNC	t_{RESYNC}	1	-	-	μs	Refer to Serial Interface section
Serial Interface Watchdog Timer Timeout	t_{SIWTT}	-	1	-	ms	2/4 wire SPI: Refer to Serial Interface section
		-	18	-	ms	1 ms for Ready mode
Sensor Wakeup Interrupt Time	t_{SWKINT}	-	310	-	μs	
Rise and Fall Times: SDIO	t_r, t_f	-	30	-	ns	$C_L = 30 \text{ pF}$

Notes: AC Electrical Characteristics are defined under recommended operating conditions. Typical values at 25 °C, $V_{DDM} = 3.3V$, $V_{DDIO} = 3.3V$ for 3.3V IO application and $V_{DDIO} = 1.8V$ for 1.8V IO application.

2.6 Heart Rate Detection Performance

Table 7. Heart Rate Detection Specification

Parameters	Value	Unit	Conditions
Heart Rate Measurement Range	30 - 240	bpm	Beats per minutes
Heart Rate Tolerance ¹ of Root Mean Square (RMS)	±3	bpm	@ Room temperature for steady state: 0 km/hr.
	±5	bpm	@ Room temperature for motion state: 0 – 9 km/hr on the treadmill.
Response Time	8 - 10	second	@ Heart Rate = 72/bpm

Notes:

- Based on the heart rate monitoring mechanism of PPG sensor, PAH8005 is tested to be functioning well in the following scenario.
 - Static mode
 - Normal casual walk
 - Regular jogging (up to 9km/hr)
- PAH8005 can provide heart rate measurement. However, it is not for medical device usage.
- For usage of heart rate detection sensor on the wearable device that to be put on the wrist, finger or palm,
- The sensor must be placed securely and in-contact with the skin surface as well as keeping it stable without any motion during measurement in acquiring accurate heart rate measurement.
- When using in heart rate monitor, do not wear the device directly on the wrist bone. It should be worn on the higher position of wrist bone or forearm, especially for those with a smaller wrist.
- Sensor's performance is optimized with good blood flow. It is recommended to have light exercise for a few minutes to increase your blood flow before turning on the heart rate monitor.
- On cold weather condition or user is having poor blood circulation (e.g.: cold hands, fingers and feet), the sensor performance (heart rate accuracy) could be effected as the blood flow is slower in the measuring spot position. It is recommended to activate the heart rate monitor in indoor use.
- If the sensor is having problem to read heart rate, may try to swap it on the other side of hand wrist to repeat the measurement.
- For continuous heart rate reading, do minimize hand movement and extreme bending of the wrist during measurement period.

3.0 Mechanical Specifications

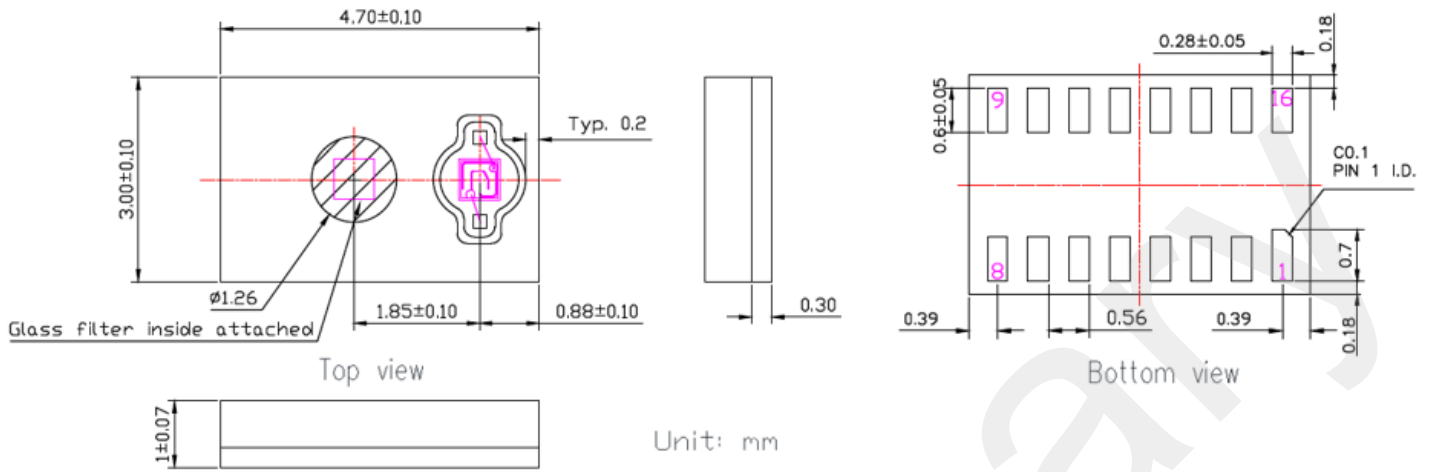


Figure 2. Package Outline Diagram

4.0 Reference Schematics

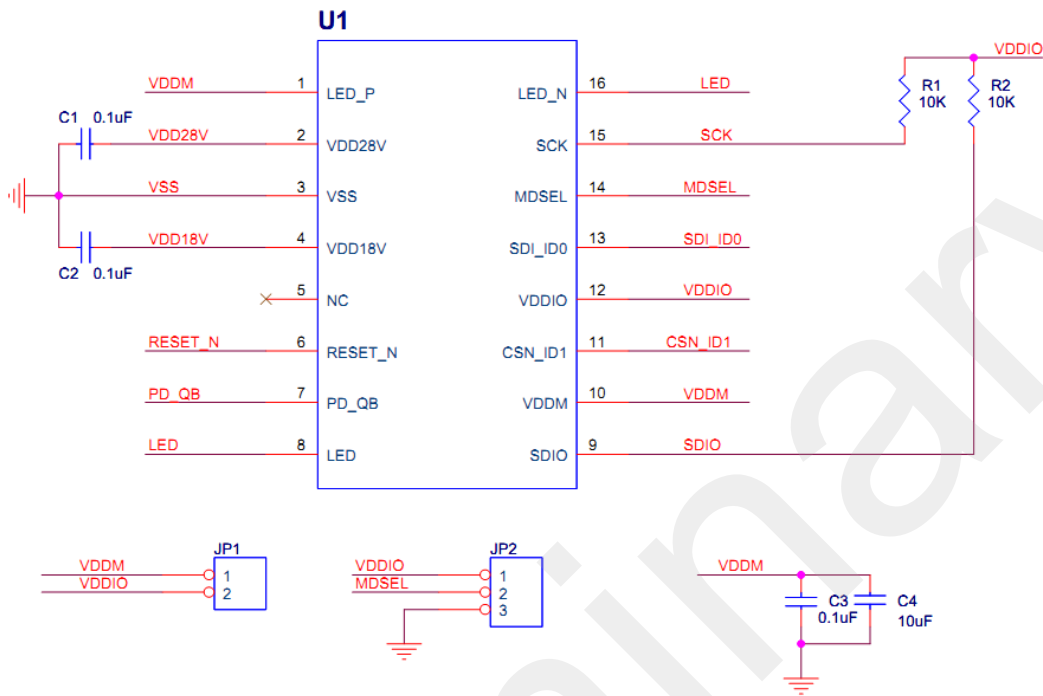


Figure 3. Application Circuit of PAH8005

Design Notes:

1. VDDM & VDDIO = 3.3V~3.6V (for 3.3V System) -> JP1 Short
2. VDDM = 3.3V~3.6V, VDDIO: 1.62V~1.98V (for 1.8V System) -> JP1 Open
3. Connect R1 and R2 with 10KOhm resistor for I²C Only.
4. VDD28V and VDD18V must have 0.1μF bypass capacitor connected to GND.
5. VDDM and VDDIO power noise must be under 100mV.
6. Tie MDSEL to VDDIO on JP2 for 2-Wire SPI, leave JP2 floating for 4-Wire SPI, and tie to GND for I²C.
7. ID0 and ID1 can be directly tied to VDDIO or GND based on your I²C ID selection.
8. At power on, VDDM and VDDIO must be powered on at the same time or VDDIO to be powered on first before VDDM.
9. At power off, VDDM and VDDIO must be powered off at the same time or VDDIO to be powered off first before VDDM.

5.0 Registers List

The optical heart rate detection sensor can be programmed through registers and heart rate relational data can be read from registers. All registers not listed are reserved, and should never be written by firmware. Note that the user should write address 0x09 with 0x5A if he/she would like to modify the value of register. Besides, the user should write address 0x7F with 0x01 if he/she would like to modify the value of Bank1 register and write address 0x7F with 0x00 to return to Bank0.

Table 8. Register Bank 0

Note: Switch to Register Bank-0 by writing 0x00 to Reg-0x7F

Address	Register Name	Access	Reset	Data Type
0x00	Product_ID1	R	0x30	Eight bits number for the upper 8 bits of Product Identifier, PID[11:4]
0x01	Product_ID2	R	0xDX	Eight bits number with MSB [7:4] for the lower 4 bits of Product Identifier, PID[3:0], while LSB[3:0] is the Chip Version Identifier, VID[3:0]
0x05	Operation_Mode	R/W	0xB8	Bit field
0x06	Configuration	R/W	0x02	Bit field
0x09	Write_Protect	R/W	0x00	Bit field
0x0A	Sleep1_Setting	R/W	0x21	Bit field
0x0B	Enter_Time	R/W	0x37	Bit field
0x0C	Sleep2_Setting	R/W	0x71	Bit field
0x20	AE_EnH	R/W	0x0F	Bit field
0x32	Exposure_Time_L	R	-	Bit field
0x33	Exposure_Time_H	R	-	Bit field
0x4D	Touch_Resolution	R/W	0x1A	Bit field
0x59	Touch_Detection	R	-	Bit field

Table 9. Register Bank 1

Note: Switch to Register Bank 1 by writing 0x01 to Reg0x7F

Address	Register Name	Access	Default	Data Type
0x1A	HR_Data_Algo_A	R	-	Eight bits unsigned integer
0x1B	Frame_Average	R	-	Eight bits unsigned integer
0x1C	HR_Data_Algo_C	R	-	Eight bits unsigned integer
0x23	Touch_TH	R/W	0x28	Bit field
0x25	Touch_TH_S_L	R/W	0x00	Bit field
0x26	Touch_TH_S_H	R/W	0x02	Bit field
0x38	LED_Step	R	0xF2	Bit field
0x64	HR_Raw Data_A	R	-	Eight bits unsigned integer
0x65	HR_Raw Data_B	R	-	Eight bits unsigned integer
0x66	HR_Raw Data_C	R	-	Eight bits unsigned integer
0x67	HR_Raw Data_D	R	-	Eight bits unsigned integer
0x68	HR_Data_Ready	R	-	Eight bits unsigned integer

Document Revision History

Revision Number	Date	Description
0.8	19 Feb 2016	1 st Creation - Preliminary version based on DS v0.8

Preliminary