EM7028 Datasheet

Heart Rate Sensor with I²C Interface

Revision V 1.0

2016-05-03 Updated

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FIGURE LIST

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1. Description

EM7028 is a low-power I²C interface module includes Heart Rate Sensor(HRS) and internal LED Current Drivers with 2 Green LED. It can work in both continuous mode and pulse mode. It is designed for applications of Heart Beat Rate detection esp. such as smart watch etc.

Heart Rate Sensor in continuous mode is designed to monitor heart rate by optical detection. A 16-bit ADC detects the result constantly with adjustable gain and resolution.

Heart Rate Sensor in pulse mode is designed to monitor heart rate by optical detection in low-power. It also acts as a proximity sensor with rejection of ambient light noise. In order to removing component variations and eliminate offset caused by IR reflection, 2 registers were specially defined for compensation and high dynamic range of detection.

HRS in continuous mode stores ADC output result into HRS1 registers, while HRS in pulse mode stores ADC output result into HRS2 registers. All pixels are controlled by analog-MUX in different modes.

2. Features

- Heart-Rate Sensors(HRS) with built-in 2 LED of 525nm wavelength integrated in a single Optical Module
- 50Hz/60Hz Flicker Noise Rejection
- Temperature Compensation
- Higher Sensitivity of Proximity Sensing
- HRS in continuous mode with higher detection rate
- HRS in pulse mode with Ambient Light Rejection
- HRS detect rates is up to 1000/s
- 2048 Steps Programmable LED current driver for flexibility and part-to-part calibration
- 16bits ADC of Heart Rate Sensor
- Offset register adjustment for compensation of DC noise
- Programmable Interrupt modes
- Low Average Operation Power consumption
- Output Type: I²C Bus (HRS2) up to 400K Hz
- Operation Voltage 2.5V ~ 3.6V
- Logic Interface Voltage VBUS=1.8V or VBUS=VDD
- Minimum External Components
- Package: (4.0mmX2.4mmX1.35mm)
- RoHS package

3. Functional Block Diagram

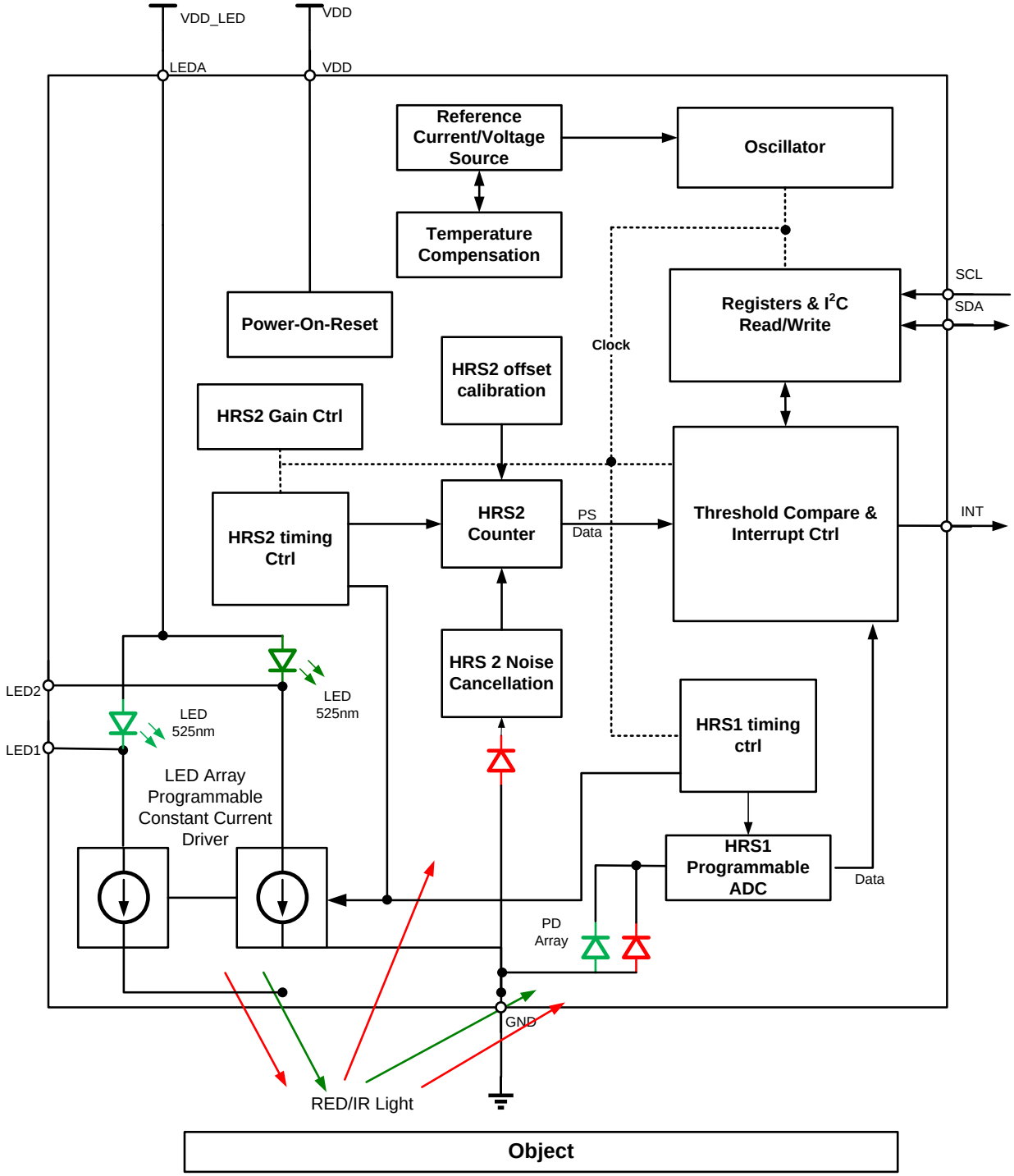
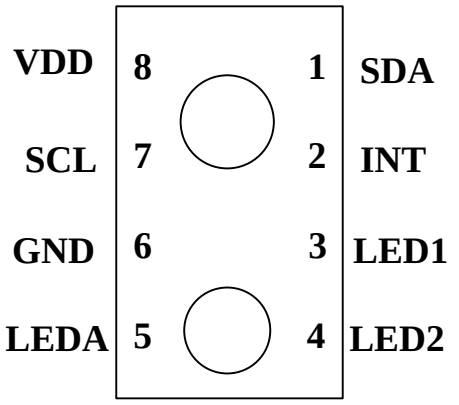
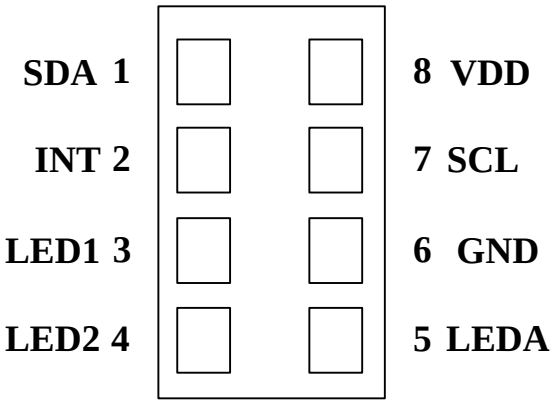


Fig. 1 EM7028 Functional Block Diagram

4. PIN Configuration



Top View



Bottom View

Table. 1 Pin Configuration

Pin No.	Pin Name	Type	Description
1	SDA	I/O(Open Drain)	I²C Serial data I/O terminal -serial data I/O for I²C
2	INT	O(Open Drain)	Interrupt.
3	LED1	O(Open Drain)	LED Current Driver for LED1 - up to 200mA
4	LED2	O(Open Drain)	LED Current Driver for LED2 - up to 12mA
5	LEDA	I	LED Anode, connect to VDD_LED on PCB
6	GND		Power supply ground. All voltages are referenced to GND
7	SCL	I(Open Drain)	I²C serial clock input terminal — clock signal for I²C serial data.
8	VDD		Power Supply voltage

5. Functional Description

5.1 HRS in continuous mode

In Normal HRS mode, one of the LED turns on, and HRS Sensor detects both ambient light and light from green LED. The sensitivity of light is 1 lux/count, and totally 65536lux in full range; The typical resolution of ADC is 16bits and 25ms conversion time.

In low-lux mode, 8 times of ADC gain is chosen for receiving light. The detect range is 0.125lux to 8192lux.

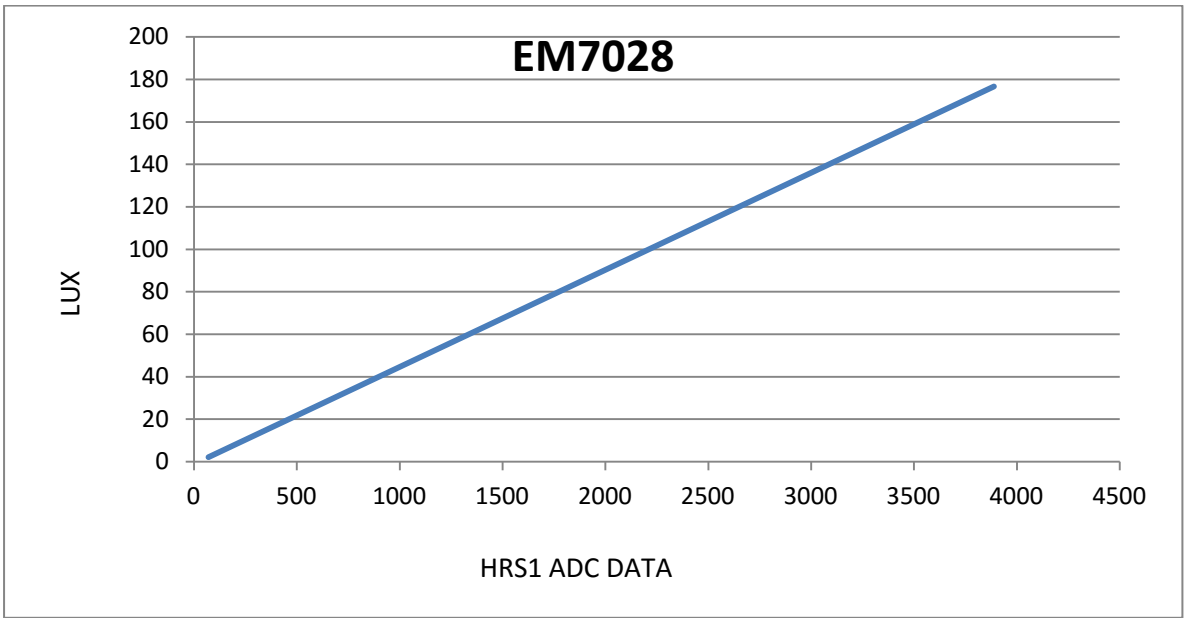


Fig. 2 EM7028 HRS value vs. receiving light lux

5.2 HRS in pulse mode

The Heart Rate Sensor in pulse mode detects reflected light with LED turned on in pulse.

5.3 Typical performance chart

HRS value typically reflect heart beat status as illustrated in Fig.3

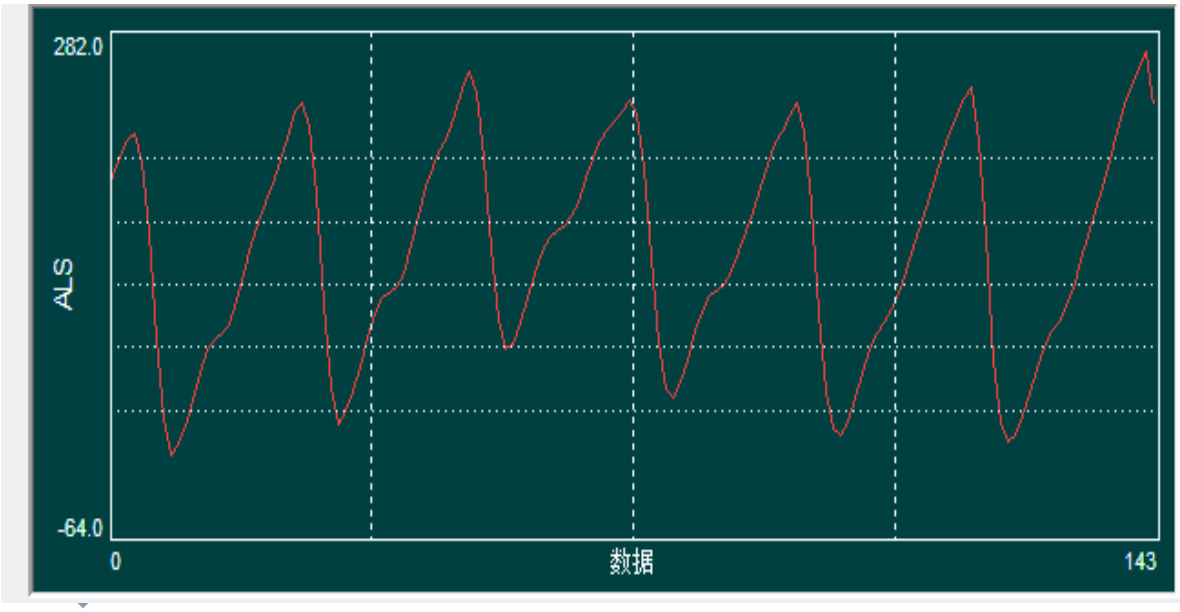


Fig. 3 EM7028 HRS wave

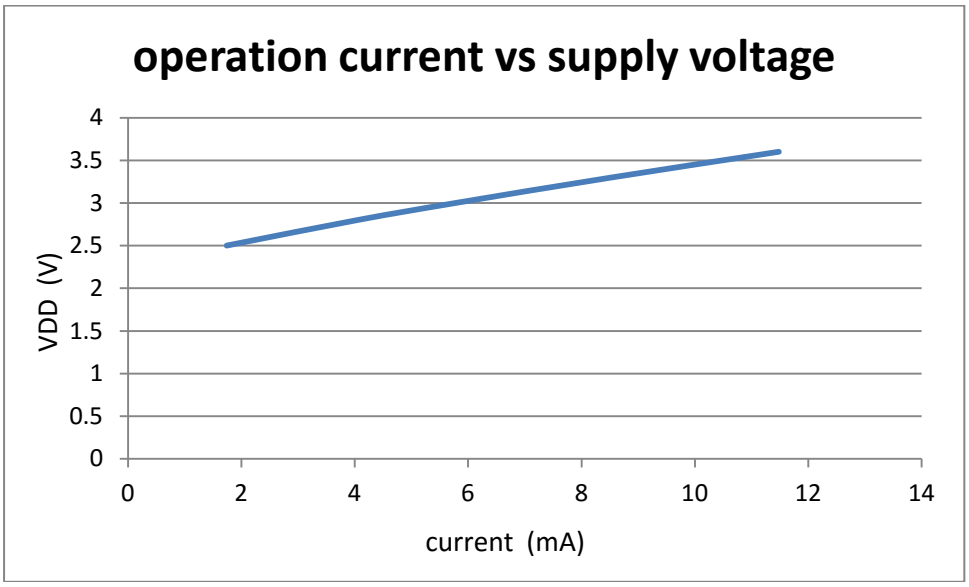


Fig. 4 Operation current vs. supply voltage in continuous mode w/o current-limiting resistor, and the current is controlled by VDD_LED and current-limiting resistor. Typical operation current for heart rate detection is around 1mA.

TBD

Fig. 5 Operation current vs. supply voltage in pulse mode w/i current controlled by resisters.

6. Parameters

Table. 2 I²C bus timing characteristics

Symbol	Parameters	Minimum	Typical	Maximum	Units	Condition
f_{clk}	SCL clock frequency	10k		100k	Hz	Normal Mode
		10k		400k	Hz	Fast Mode
t_{SUDAT}	data set up time	250			ns	Normal Mode
		100			ns	Fast Mode
t_{HDDAT}	data hold time			300	ns	Normal Mode
				90	ns	Fast Mode
t_{rise}	clock/data rise time			1000	ns	Normal Mode
				300	ns	Fast Mode
t_{fall}	clock/data fall time			300	ns	Normal Mode
				300	ns	Fast Mode
t_{LOW}	I²C clock (SCL) low cycle	4.7			µs	Normal Mode
		1.3			µs	Fast Mode
t_{HIGH}	I²C clock (SCL) high cycle	4.0			µs	Normal Mode
		0.6			µs	Fast Mode
t_{BUF}	Bus free time between the start and stop state	4.7			µs	Normal Mode
		1.3			µs	Fast Mode
t_{HDSTA}	(repeat) started state holding time	4.0			µs	Normal Mode

	after this period produce the first clock	0.6			μs	Fast Mode
t_{SUSTA}	Repeat the start state set up time	4.7			μs	Normal Mode
		0.6			μs	Fast Mode
t_{SUSTO}	Stop state set up time	4.0			μs	Normal Mode
		0.6			μs	Fast Mode
$t_{TIMEOUT}$	Low detection clock/data timeout time	25	35		ms	Normal Mode
					ms	Fast Mode
C_{load}	The capacitive load for each bus line			400	pF	
R_{BUS}	Pull up resistors SDA and SCL system bus	1		-	KΩ	
t_{VD}	Data valid time			0.9	μs	
t_{VDACK}	Data valid acknowledge time			0.9	μs	

Table. 3 Electrical Characteristics

Symbol	Min	Typ	Max	Units	Introductions
V_{DD}	2.6		3.6	V	Supply voltage
I_{DD}				μ A	DC power supply current (with LED turned off)
VDD_I²C	1.6		3.6	V	I²C power supply voltage
VDD_LED	2.6		4.5	V	LED power supply voltage
I_{DD_SD}				nA	Shut Down Current
T_A	-40		85	°C	Recommended operating temperature
V_{IL}			0.54	V	SCL/SDA Input low voltage
V_{IH}	1.25			V	SCL/SDA Input high voltage

Table. 4 Optical Characteristics

Parameters	Min	Typ	Max	Units	Descriptions (Ta = +25 ℃)
Full scale HRS1 ADC count value			65536	counts	HRS register maximum count in continuous mode
HRS detect range			65536	lux	HRS detection range
Full scale HRS2 ADC count value			65536	counts	HRS ADC maximum count in pulse mode

HRS2 LED drive	2.5		200	mA	HRS2 LED drive current
HRS2 LED duty cycle		1/500			LED duty cycle, cycle of HRS2 at 100 ms
V_F			TBD	V	LED Forward Voltage, I_F =20 mA
V_R				V	LED Reverse Voltage, I_R =1 μA
P_O	0.8			mW	LED Radiant Power, I_F =20 mA
λp		525		nm	LED Peak Wavelength, I_F =100 mA
Δλ		30		nm	Spectrum Width of Half Value, I_F =20 mA
T_R				ns	LED Optical Rise Time, I_F =20 mA
T_F				ns	LED Optical Fall Time, I_F =20 mA

7. Spectral Response Range

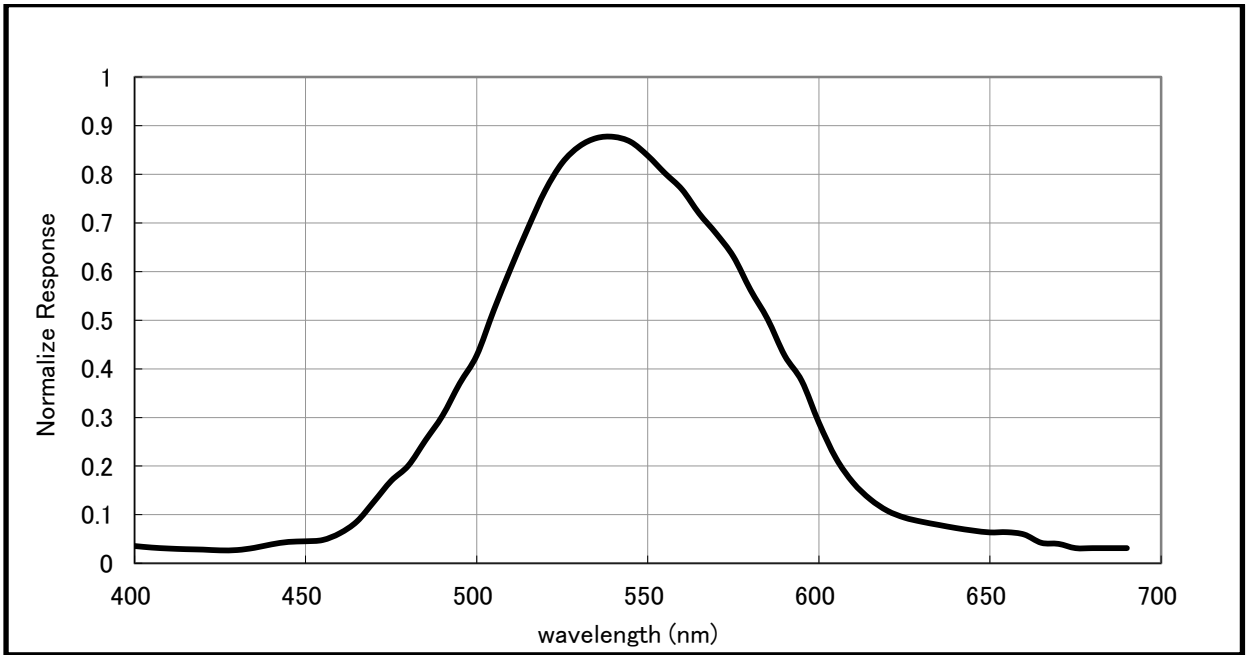


Fig. 6 LED1/LED2 Spectral Response Range (The peak wavelength may change without notification)

LED2 has the same spectral response as LED1

8. Absolute Maximum Ratings

Table. 5 Absolute Maximum Ratings

Parameters	Symbol	Min.	Max.	Units	Condition
Storage Temperature	T_S	-40	85	°C	
Operation Temperature	T_A	-40	85	°C	
Supply Voltage	V_{DD}	2.25	3.6	V	

ESD	V_{ESD}	2K		V	HBM
ESD	V_{ESD}	200		V	MM

9. I²C State Machine

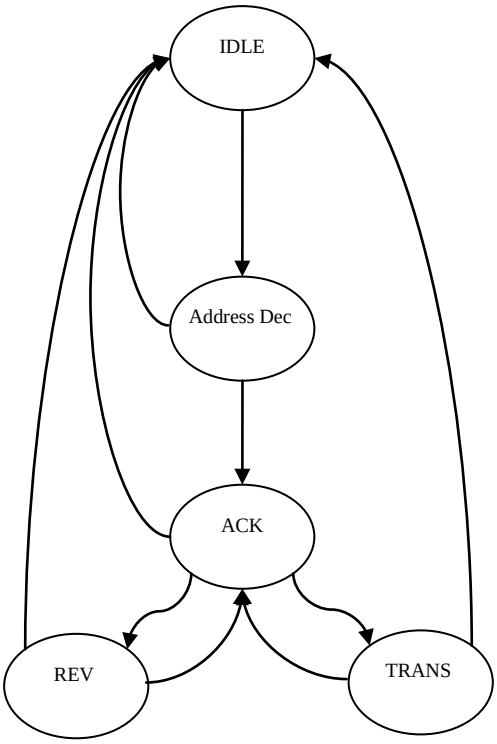


Fig. 7 Slave State Machine

10.Timing

MSB	6	5	4	3	2	1	LSB

Fig. 8 Data Structure

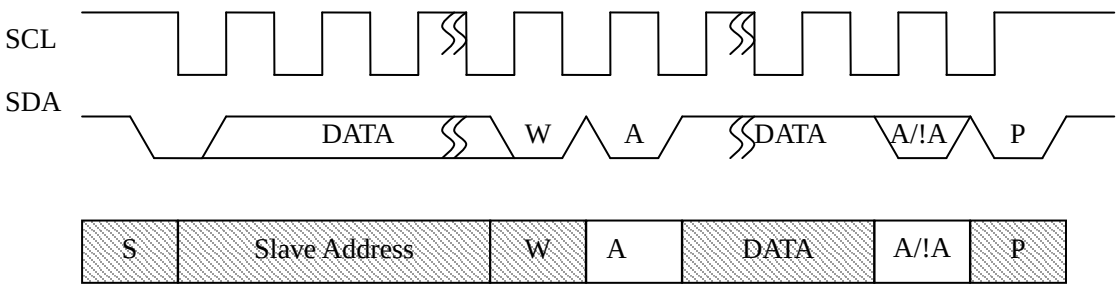


Fig. 9 Write waveform

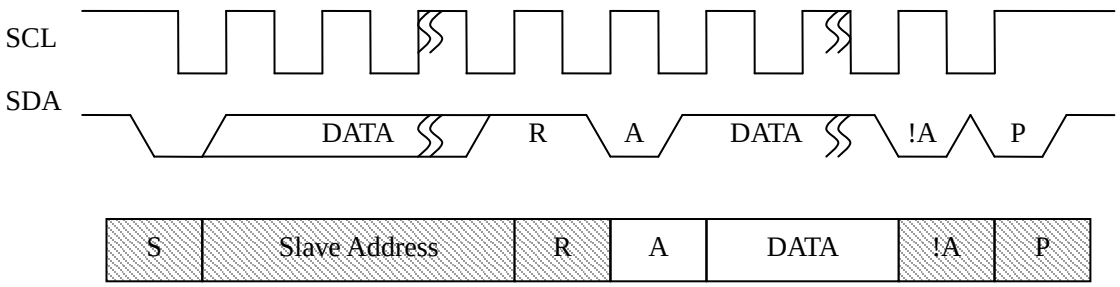


Fig. 10 Read waveform

11.Registers Operation

Fig. 11 Register random write operation

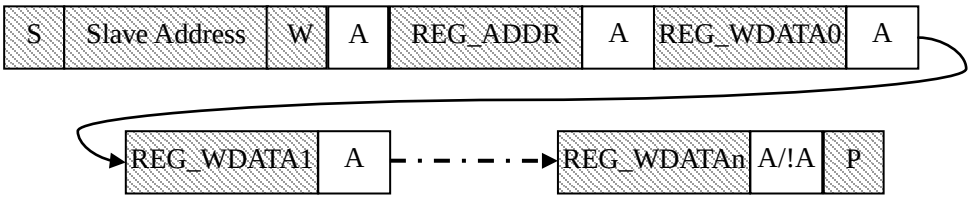


Fig. 12 Register page write operation

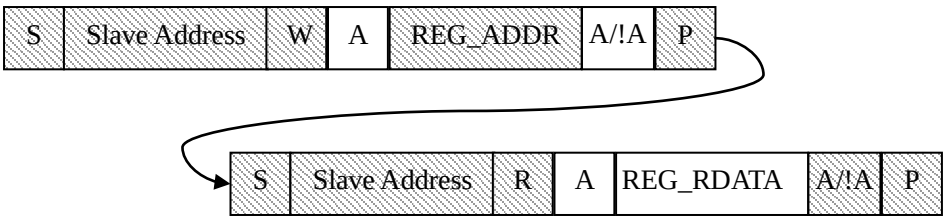


Fig. 13 Register random read operation

12.Registers Definition

Function Modes:

1. HRS1 (Heart Rate Measurement in Continuous Mode)
2. HRS2 (Heart Rate Measurement in Pulse Mode)

Table. 6 REGISTER DESCRIPTION

Address	R/W	Bit7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Default
0(0x00)	R	PID								0x36
1(0x01)	R/W	HRS2_EN	Reserved	Reserved	Reserved	HRS1_EN	Reserved	Reserved	Reserved	0x00
2(0x02)	R/W	HRS2_FLAG	HRS2_PRST[1:0]		Reserved	HRS1_FLAG	HRS1_PRST[1:0]		INT_CTRL	0x00
3(0x03)	R/W	HRS_LT[7:0]								0x00
4(0x04)	R/W	HRS _LT[15:8]								0x00
5(0x05)	R/W	HRS _HT[7:0]								0xFF
6(0x06)	R/W	HRS _HT[15:8]								0xFF
7(0x07)	R/W	LED_CAL[7:0]								0x80
8(0x08)	R/W	HRS2_DATA_OFFSET[7:0]								0x00
9(0x09)	R/W	Reserved	HRS2_TIME[2]	HRS2_TIME[1]	HRS2_TIME[0]	LED_WIDTH[1]	LED_WIDTH[0]	LED_CNT[1]	LED_CNT[0]	0x40
10(0x0A)	R/W	HRS2_GAIN	HRS2_POS[6]	HRS2_POS[5]	HRS2_POS[4]	HRS2_POS[3]	HRS2_POS[2]	HRS2_POS[1]	HRS2_POS[0]	0x01
11(0x0B)	R	SIGN	Reserved							0x00
12(0x0C)	R	SIGN	Reserved							0x00
13(0x0D)	R/W	HRS_GAIN	HRS_RANGE	HRS_FREQ[2:0], 40960Hz to 2.62144MHz			HRS_RES[1:0], 10b, 12b, 14b, 16b		IR_MODE	0x32
14(0x0E)	R/W	INT_EN	INT_MODE1	INT_MODE2	INT_MODE3	Reserved	HRS2_DR[2:0], Programmed LED Current			0x90
15(0x0F)	R/W	SOFT_RESET[7:0]								0x00
32(0x20)	R	HRS2_DATA0[7:0],								0x00
33(0x21)	R	HRS2_DATA0[15:8]								0x00
34(0x22)	R	HRS2_DATA1[7:0]								0x00
35(0x23)	R	HRS2_DATA1[15:8]								0x00
36(0x24)	R	HRS21_DATA2[7:0]								0x00
37(0x25)	R	HRS2_DATA2[15:8]								0x00
38(0x26)	R	HRS2_DATA3[7:0]								0x00
39(0x27)	R	HRS2_DATA3[15:8]								0x00
40(0x28)	R	HRS1_DATA0[7:0]								0x00
41(0x29)	R	HRS1_DATA0[15:8								0x00
42(0x2A)	R	HRS1_DATA1[7:0]								0x00
43(0x2B)	R	HRS1_DATA1[15:8]								0x00
44(0x2C)	R	HRS1_DATA2[7:0]								0x00
45(0x2D)	R	HRS1_DATA2[15:8]								0x00
46(0x2E)	R	HRS1_DATA3[7:0]								0x00
47(0x2F)	R	HRS1_DATA3[15:8]								0x00
48(0x30)	R	HRS1_DATA0[7:0]								0x00
49(0x31)	R	HRS1_DATA0[15:8]								0x00

Table. 7 REGISTER 0x00 (RESERVED)

BIT #	ACCESS	Default	Name	FUNCTION/OPERATION
7:0	RO	0x36	PID	Product ID - readable

Table. 8 REGISTER 0x01 (CONFIGURE) - PROX/HRS CONFIGURATION

BIT#	R/W	Default Value	Name	Name/operation description
7	RW	0	HRS2_EN	When= 0, heart rate sensing in pulse mode is disabled; When= 1, heart rate sensing in pulse mode is enabled; The enabled HRS2 pixels are defined by HRS2_POS, and HRS2 ADC gain is defined by HRS2_GAIN;
6	RW	0	Reserved	Reserved
5	RW	0	Reserved	Reserved

4	RW	0	Reserved	Reserved
3	RW	0	HRS1_EN	When= 0, Heart Beat Measurement is disabled; When= 1, Heart Beat Measurement is enabled with LED1 turned on and only Red Light Sensor and IR sensor enabled. When LED1 turned on, the result stores to HRS_DATA0;
2	RW	1	Reserved	Reserved
1	RW	1	Reserved	Reserved
0	RW	1	Reserved	Reserved

Only one of HRS1/HRS2 modes is enabled in a time

Table. 9 REGISTER 0x02 (INTERRUPT) - PROX/GES/HRS INTERRUPT CONTROL

BIT #	ACCESS	Default	BIT Name	Function/Operation
7	FLAG	0	HRS2_FLAG	When=0, no proximity interrupt event has occurred since power-on or last "clear" When=1, a proximity interrupt event occurred. Clearable by writing "0"
6 : 5	RW	00	HRS2 Persist	When=00, 1 times of HRS2 value transfer threshold value; When=01, 2 times of HRS2 value transfer threshold value; When=10, 4 times of HRS2 value transfer threshold value; When=11, 8 times of HRS2 value transfer threshold value;
4	FLAG	0	Reserved	Reserved
3	FLAG	0	HRS1_FLAG	When=0, no HRS1 interrupt event has occurred since power-on or last "clear" ; When=1, an HRS1 interrupt event occurred. Clearable by writing "0"
2:1	RW	00	HRS1 Persist	When=00, 1 times of HRS1 value transfer threshold value; When=01, 2 times of HRS1 value transfer threshold value; When=10, 4 times of HRS1 value transfer threshold value; When=11, 8 times of HRS1 value transfer threshold value;
0	RW	0	INT_CTRL	When=0, only HRS2 interrupt is enabled, unless INT_EN=0; When=1, only HRS interrupt is enabled, unless INT_EN=0;

Table. 10 REGISTER 0x03 (HRS_LT) - INTERRUPT LOW THRESHOLD FOR HRS2/HRS1

BIT #	ACCESS	Default	BIT Name	Function/operation
7:0	RW	0x00	HRS_LT (HRS2/HRS1 Low Threshold)	Low 8-bit interrupt low threshold for HRS sensing.

Table. 11 REGISTER 0x04 (HRS _LT) - INTERRUPT LOW THRESHOLD FOR HRS2/HRS1

BIT #	ACCESS	Default	BIT Name	Function/operation
7:0	RW	0x00	HRS_LT	High 8-bit interrupt low threshold for HRS sensing.

			(HRS2/HRS1 Low Threshold)	

Table. 12 REGISTER 0x05 (HRS _HT) - INTERRUPT LOW THRESHOLD FOR HRS2/HRS1

BIT #	ACCESS	Default	BIT Name	Function/operation
7:0	RW	0xFF	HRS_HT (HRS2/HRS1 High Threshold)	Low 8-bit interrupt high threshold for HRS sensing.

Table. 13 REGISTER 0x06 (HRS _HT) - INTERRUPT LOW THRESHOLD FOR HRS2/HRS1

BIT #	ACCESS	Default	BIT Name	Function/operation
7:0	RW	0xFF	HRS_HT (HRS2/HRS1 High Threshold)	High 8-bit interrupt high threshold for HRS sensing.

Table. 14 REGISTER 0x07 (LED_CURRENT) – HRS2 LED CURRENT FOR HRS2

BIT #	ACCESS	Default	BIT Name	Function/operation
7:0	RW	0x80	LED CAL	**When=0x00, LED current is 256/512 of full range;** **When=0x01, LED current is 257/512 of full range;** **When=0x02, LED current is 258/512 of full range;** **...** **When=0xff, LED current is of full range to maximum;** **This function serves for LED calibration;**

Table. 15 REGISTER 0x08 (HRS2_DATA_OFFSET) – HRS2 DATA OFFSET

BIT #	ACCESS	Default	BIT Name	Function/operation
7	RW	0X0	Reserved	N/A
6:0	RW	0x00	HRS2_ OFFSET	**When=0x00, no offset;** **When=0x01, HRS2 data subtract by 8 counts(6.25n);** **When=0x02, HRS2 data subtract by 16 counts(12.5n);** **...** **When=0x8f,** **HRS2 data subtract by 1016 counts (793.75n);**

Table. 16 REGISTER 0x09 (HRS2_CTRL) - HRS2 CONTROL

BIT #	ACCESS	Default	BIT Name	Function/operation
7	RW	0x0	Reserved	When=0, HRS2 conversion is continuous; When=1, HRS2 conversion is divided by WAIT time specified in HRS2_TIME;
6:4	RW	0b100	HRS2_WAIT_TIME	When=000, HRS2 WAIT TIME = 0, continuous detect; When=001, HRS2 WAIT TIME = 1.5625ms.;

				When=010, HRS2 WAIT TIME = 6.25ms; When=011, HRS2 WAIT TIME = 25ms; When=100, HRS2 WAIT TIME = 100ms; When=101, HRS2 WAIT TIME =400ms ; When=110, HRS2 WAIT TIME = 1.6s; When=111, HRS2 WAIT TIME = 6.4s;
3:2	RW	0b10	LED_WIDTH	**When=00, LED WIDTH = 8 counts;** **When=01, LED WIDTH = 32 counts;** **When=10, LED WIDTH = 128 counts;** **When=11, LED WIDTH = 512 counts;**
1:0	RW	0b00	LED_CNT	**When=00, LED COUNT = 1;** **When=01, LED COUNT =4;** **When=10, LED COUNT = 16;** **When=11, LED COUNT = 64;**

Table. 17 REGISTER 0x0A (HRS2_GAIN_CTRL) - PROXIMITY SENSOR GAIN CONTROL

BIT #	ACCESS	Default	BIT Name	Function/operation
7	RW	0b0	HRS2_GAIN	When=0, HRS2 GAIN = 1; **When=1, HRS2 GAIN = 10;**
6:0	RW	0x01	HRS2_POS[6:0]	Each bit mark one pixel;

Table. 18 REGISTER 0x0B (Reserved)

Table. 19 REGISTER 0x0C (Reserved)

Table. 20 REGISTER 0x0D (HRS1_CTRL) – HRS1 CONTROL

BIT #	ACCESS	Default	BIT Name	Function/operation
7	RW	0x1	HRS_GAIN	When = 0, HRS1 GAIN =1; **When =1, HRS1 GAIN =5;:**
6	RW	0x1	HRS_RANGE	When = 0, HRS1 RANGE =1; When =1, HRS1 RANGE =8;
5:3	RW	0b110	HRS_FREQ	When=000, HRS1 FREQ = 2.62144MHz (1.5625ms); When=001, HRS1 FREQ = 1.31072MHz(3.125 ms); When=010, HRS1 FREQ = 655,360Hz(6.25 ms); When=011, HRS1 FREQ = 327,680Hz(12.5ms); When=100, HRS1 FREQ = 163,840Hz(25ms); When=101, HRS1 FREQ = 81,920Hz(50ms); When=110, HRS1 FREQ = 40,960Hz(100ms); When=111, HRS1 FREQ = 20,480Hz(200ms) ;
2:1	RW	0b01	HRS_RES	When=00, HRS1 RES = 10 bits; When=01, HRS1 RES = 12 bits; When=10, HRS1 RES = 14 bits;

				When=11, HRS1 RES = 16 bits;
0	RW	0b1	IR_MODE	When=0, IR mode; When=1, HRS1 mode;

Table. 21 REGISTER 0x0E (INT_CTRL) –INTERRUPT CONTROL

BIT #	ACCESS	Default	BIT Name	Function/operation
7	RW	0b1	INT_EN	When=1, INT mode is enabled
6	RW	0b0	INT_MODE1	When=0, INT_MODE1 is disabled; When=1, INT pin is drive "low" and interrupt flag is set to "1" when register value up transfer the high threshold, and INT pin is pulled "high" and interrupt flag reset "0" when register value down transfer the low threshold.
5	RW	0b0	INT_MODE2	When=0, INT_MODE2 is disabled; When=1, INT pin is drive "low" and interrupt flag is set to "1" when register value larger than the high threshold, and INT pin is pulled "high" and interrupt flag reset "0" when register value is lower than the low threshold.
4	RW	0b1	INT_MODE3	When=0, INT_MODE3 is disabled; When=1, INT pin is drive "low" and interrupt flag is set to "1" when register value is larger than the high threshold or lower than the low threshold, otherwise INT pin is pulled "high" and interrupt flag reset "0" .
3	RW	0b0	Reserved	Reserved
2:0	RW	0b000	HRS2_DR[2:0]	Peak current for LED1 of IR light, the average current for LED1 is 1/500 of programmed current configured, while the internal duty cycle is 1/500 **When=000, LED programmed current = 2.5mA;** **When=001, LED programmed current = 5.0mA;** **When=010, LED programmed current = 7.5mA;** **When=011, LED programmed current = 12.5mA;** **When=100, LED programmed current = 25mA;** **When=101, LED programmed current = 50mA;** **When=110, LED programmed current = 100mA;** **When=111, LED programmed current = 200mA;**

Table. 22 REGISTER 0x0F (SOFT_RESET) – SOFT RESET BIT

Write any data to the SOFT_RESET register will reset the chip. No need to set a real register.

Table. 23 I²C Device address

operation	I²C Device address								
	7	6	5	4	3	2	1	0	address
Write Register	0	1	0	0	1	0	0	0	0x48H
Read Register	0	1	0	0	1	0	0	1	0x49H

The I²C Interface and 7-bit slave address is 0x24.

13.Sample Application

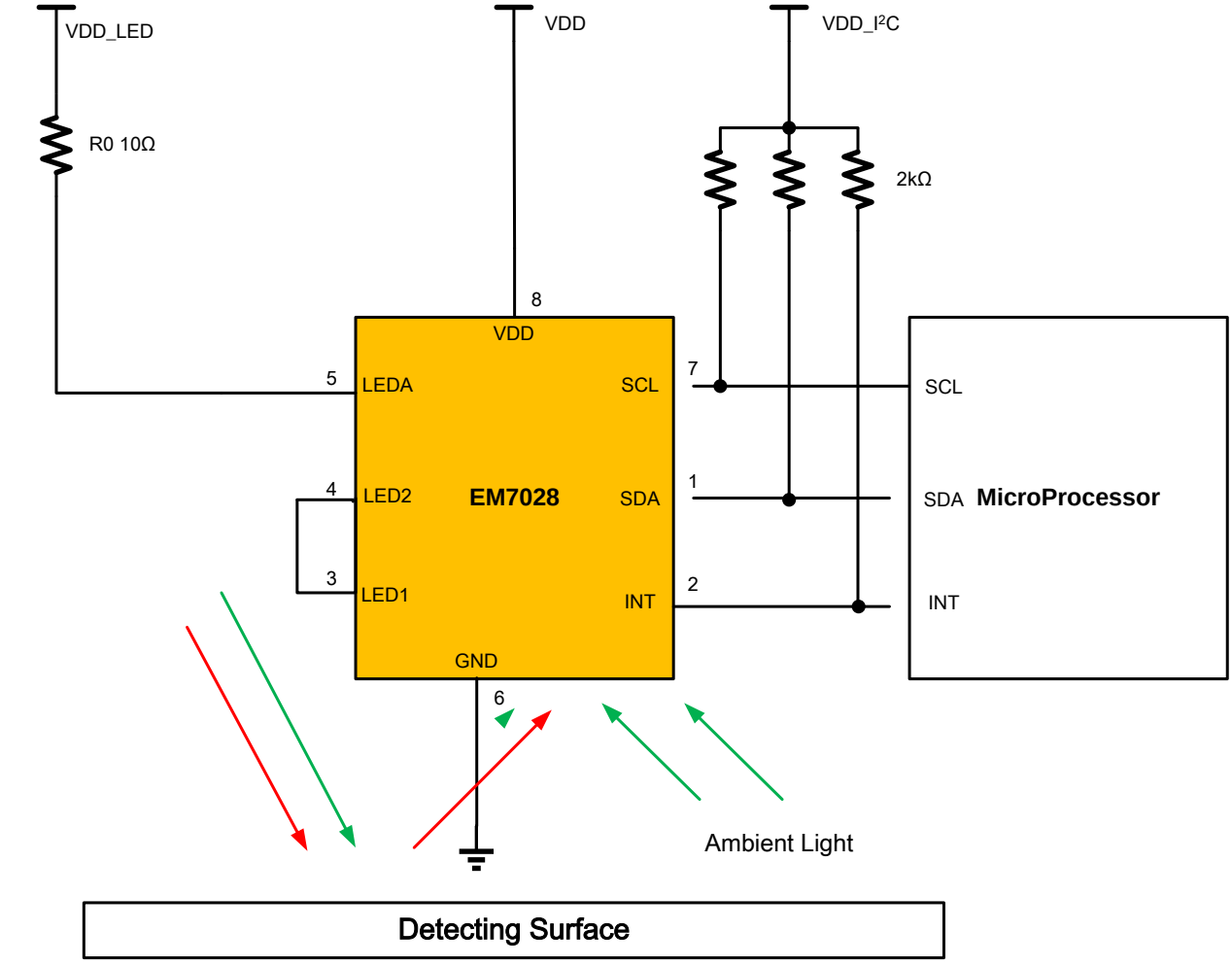


Fig. 14 Typical Application Circuit in pulse mode of HRS2 ((VDD 2.6~3.6V, VDD_I²C 1.6~3.6V, VDD_LED 2.6~4.5V)

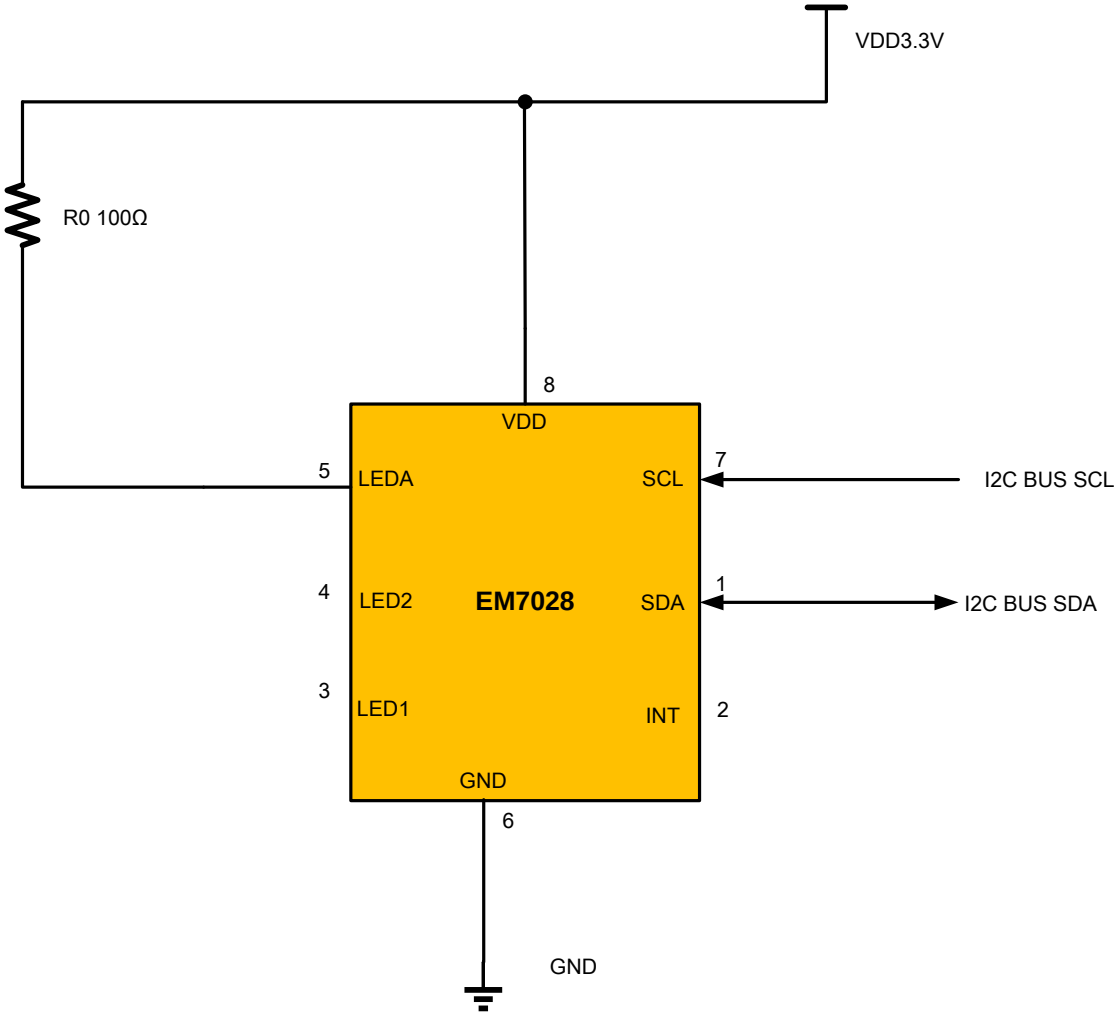


Fig. 15 Typical Application Circuit in continuous mode of HRS1

VDD, VDD_I²C, VDD_LED can be connected together as VDD3.3V to 3.3V voltage.

VDD3.3V should connect 0.1uF capacitor to ground.

INT can be disconnected if no need of interrupt mode.

R_0 is LED2 adjust resistor, and the typical value of R0 is 100Ω.

14.PCB Design

Suggested PCB pad layout guidelines for the Dual Flat No-Lead surface mount package are shown below.

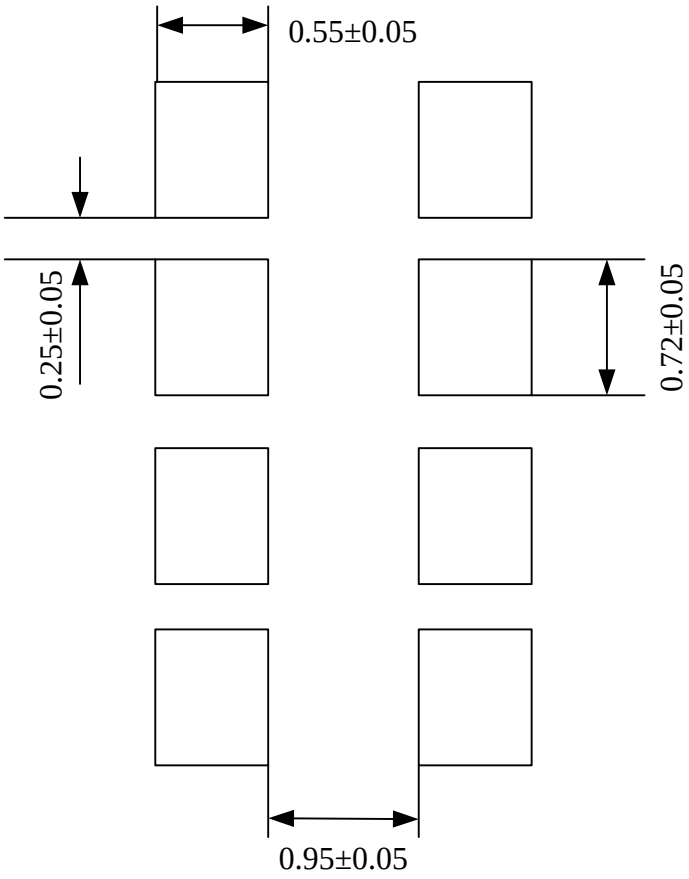


Fig. 16 PCB layout design guide (all linear dimensions are in mm)

15.Package Outline Dimensions

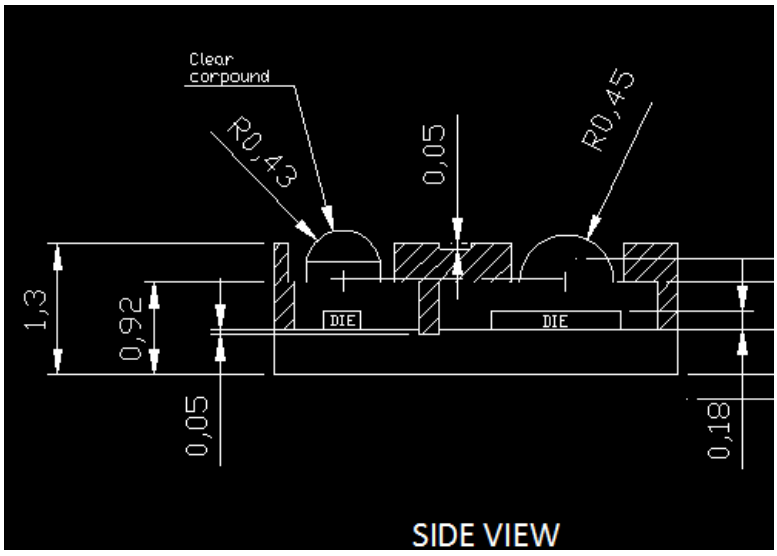


Fig. 17 Side view of package

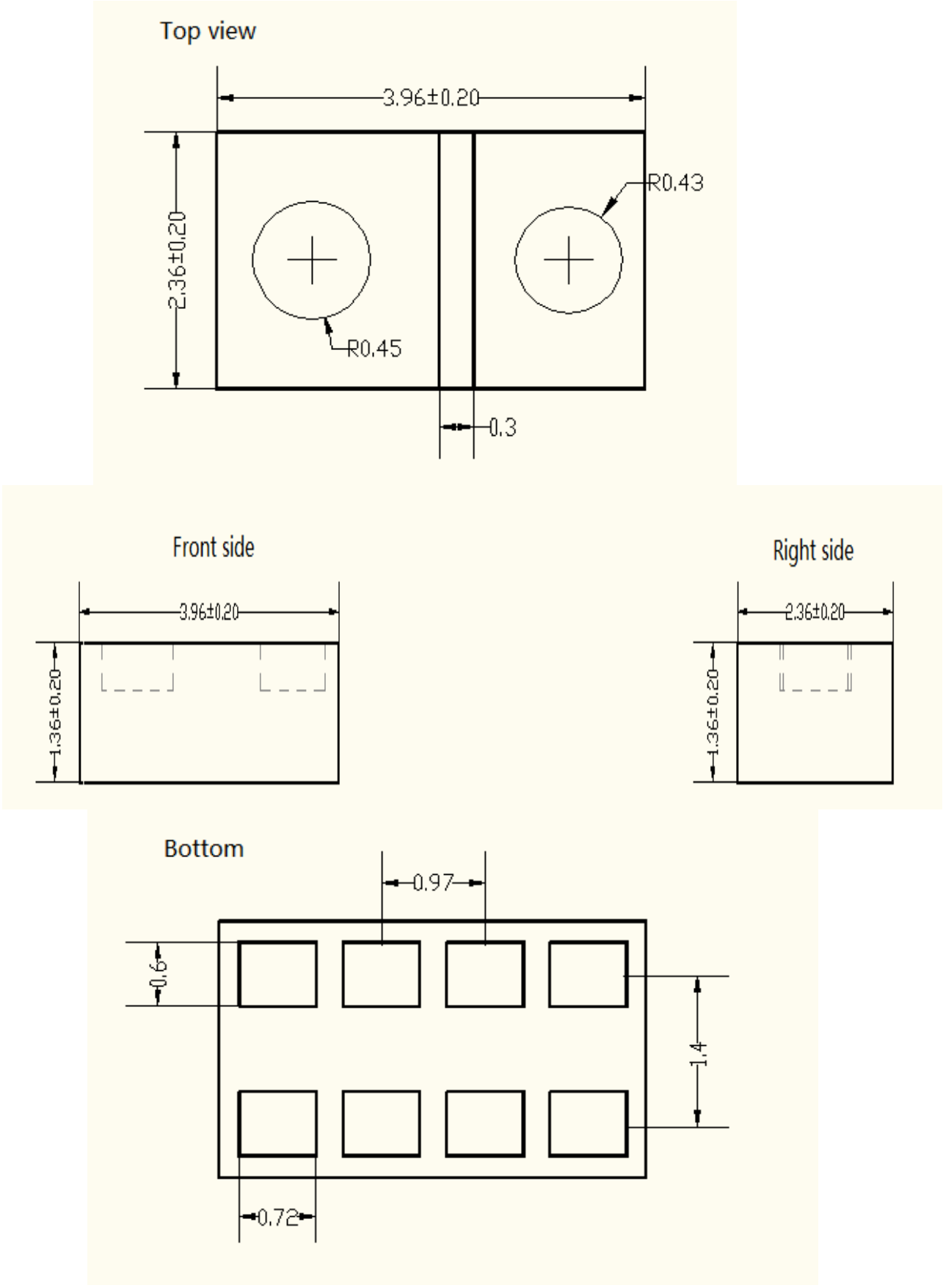
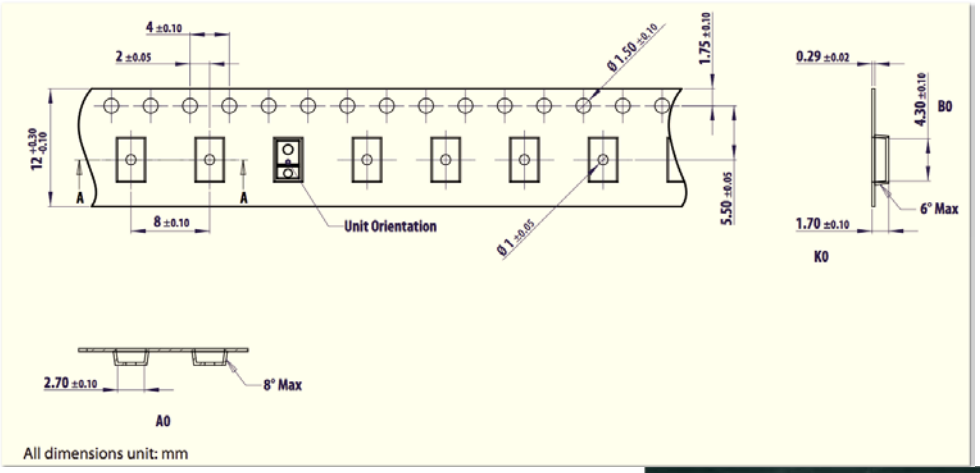


Fig. 18 Package Outline Dimensions

16.Packing

Tape and reel dimensions is compliant to JEDEC MSL 3



Ordering Information	Q'TY/REEL	Q'TY/inside box	Q'TY/outside box	Remark
EM7028 (7' reel)	1000EA	2000EA	20000EA	MBB/Label/Temperature Card/Silica gel

Fig. 19 Tape & Reel Information

17.Recommended Reflow Profile

PARAMETER	REFERENCE	DEVICE
Average temperature gradient in preheating		2.5°C/sec
Soak time	t_{soak}	2 to 3 minutes
Time above 217°C(T_1)	T_1	Max 60 sec
Time above 230°C(T_2)	T_2	Max 50 sec
Time above T_{peak}-10°C(T_3)	T_3	Max 10 sec
Peak temperature in reflow	T_{peak}	260°C
Temperature gradient in cooling		Max-5°C/sec

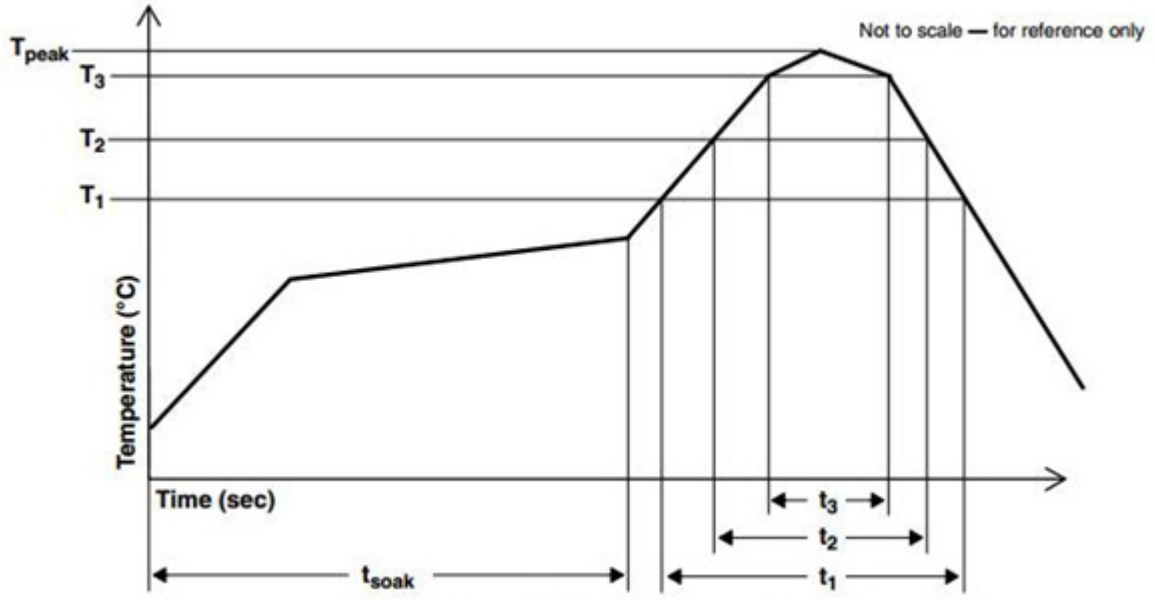
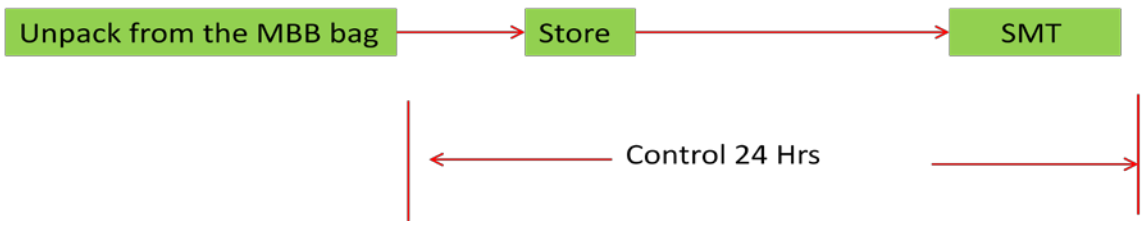


Fig. 20 Recommended Reflow Profile for SMT

The product require to control strictly to prevent moisture absorption into unit. The recommend control is as following. Rebaking of the reel will be required if the devices is unpack from the MBB bag more than 24 hours. If rebaking is required, it should be done at 50℃ for 12 hours.



History

Date	Author	Modification

NOTICE:

1. The information here contained could be changed without notice owing to product and/or technical improvements. Please make sure before using the product that the information you are referring to is up-to-date.

2. No responsibilities are assumed by us for any consequence resulting from any wrong or improper operation, etc. of the product.

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