

PAJ7620U2: Integrated Gesture Recognition Sensor

General Description

The PAJ7620U2 is a highly integrated gesture recognition sensor module. It integrates the gesture sensor chip, optics lens, and the IR LED in a small form factor LGA package. The sensor module captures the IR image @940nm, and the embedded algorithm (in hardware) analyzes the IR image to obtain the object coordinates, size, and brightness information. Based on interpreting the object movement information, 9 gesture results such as moving up, down, left, right, forward, backward, circle-clockwise, circle-counter-clockwise, and waving are supported. It also offers built-in proximity detection in sensing approaching or departing objects from the sensor. The gesture results and object information are output through the I²C interface.

The PAJ7620U2 is designed with great flexibility in the power-saving mechanism, well suited for low-power battery-operated HMI devices. With the built-in IR LED, it can work in totally dark environments. The on-chip optical bandpass filter can filter out the ambient light, making PAJ7620U2 have good ambient light resist capability.

Key Features

- Gesture/Cursor/Image modes
- Support 9 types of gesture results: moving up, down, left, right, forward, backward, circle-clockwise, circle-counter-clockwise, and waving
- Support object information read out
- Built-in proximity detection
- Gesture speed is 60 to 600°/s (15.3 to 153cm/s @ Distance 15cm) in Normal Mode and 60 to 1200°/s (15.3 to 306cm/s @ Distance 15cm) in Fast Mode
- Flexible power saving scheme
- I²C interface up to 400 Kbit/s
- Good Ambient light resistance
- Ambient light noise cancellation

Applications

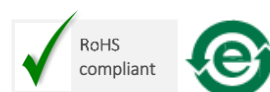
- Smart home devices
- Tablet Personal Computer
- Automobile Application
- Contactless control devices

Key Parameters

Parameter	Value
Active Array Size	30 x 30 pixels
Pixel Size	20 x 20 μm^2
Max Frame Rate	720 fps @ 240Hz report rate
Supply Voltage	VDD: 2.8 to 3.6V VBUS: 1.8 to 3.3V VLED: 3.0 to 4.2V
Current Consumption	Operation State: 2.82 mA Standby 1 State: 2.3mA Standby 2 State: 1.5mA
Package Dimensions	5.2 x 3 x 1.88 mm ³

Ordering Information

Part Number	Package Type
PAJ7620U2	13-pin LGA Module



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1.0 Sensor Overview

1.1 Gesture Mode

For Gesture Mode, there are 9-gesture recognition being embedded in the sensor, including move up, move down, move left, move right, move forward, move backward, circle-clockwise, circle-counter clockwise, and wave. These gestures information can be simply accessed by register reading via the I²C bus. The normal gesture is detecting range from 5 to 15 cm from where PAJ7620U2 is located through the operating view angle of diagonally 60° respectively. Additionally, The PAJ7620U2 can be configured as Normal Mode (Gesture speed is 60°/s to 600°/s (15.3 to 153cm/s @ Distance 15cm)) or Fast Mode (Gesture speed is 60°/s to 1200°/s (15.3 to 306cm/s @ Distance 15cm)) for different applications. The PAJ7620U2 also offers built-in proximity detection to sense objects approaching or departing.

Table 1. Gesture Detecting Range and View Angle

Part Number	Detecting Range	View Angle (Diagonal)
PAJ7620U2	5 to 15 cm	60°

1.2 Image Mode

For image mode, the typical report rate is 120Hz, with an image pixel size of 30 x 30. The depth of pixel data depth is 9-bit and output through the SPI bus. The SCK rate of the SPI bus is equal to the external SPI clock input ranging from 22 to 48 MHz. The module can perform on-chip report rate, exposure time and gain adjustment by programming the internal register set via the I²C serial control bus.

1.3 Architecture Block Diagram

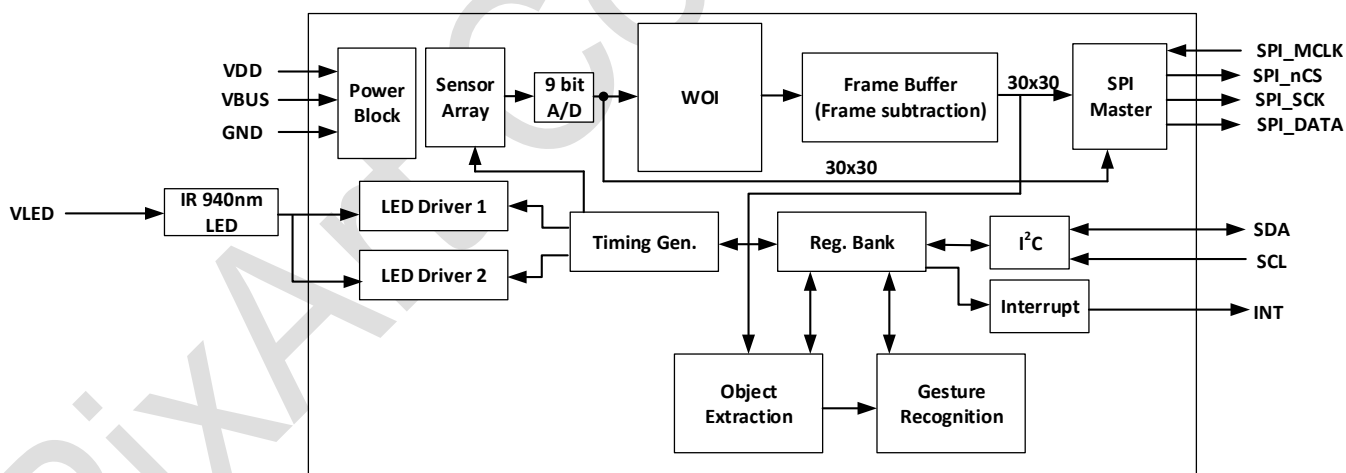


Figure 1. Architecture Block Diagram

1.4 Signal Description

Table 2. Signal Description

Signal Name	Description
SDA	I ² C data pin
SCL	I ² C clock pin
INT_N	Interrupt pin (Active low) for Gesture Mode
GPIO3(SPI_DATA)	Data out of SPI master for image mode
GPIO2(SPI_SCK)	SCK signal of SPI master for image mode
GPIO1(SPI_nCS)	nCS signal of SPI master for image mode
GPIO0(SPI_MCLK)	External clock input of SPI master for image mode

1.5 Pin Configuration

Table 3. PAJ7620U2 Pin Definition

Pin No.	Symbol	Type	Description
1	VBUS	Power	BUS power supply
2	SDA	I/O	I ² C data pin (Open Drain)
3	INT_N	Output	Interrupt pin (Active low) (Open Drain)
4	TESTMD	Input	For Module Test Only
5	SCL	Input	I ² C clock pin (Open Drain)
6, 10	GND	Ground	Ground
7	GPIO3 (SPI_DATA)	SPI Mode: Output GPIO Mode: I/O	SPI Mode: Data out of SPI master GPIO Mode: GPIO
8	GPIO2 (SPI_SCK)	SPI Mode: Output GPIO Mode: I/O	SPI Mode: SCK signal of SPI master GPIO Mode: GPIO
9	GPIO1 (Spinks)	SPI Mode: Output GPIO Mode: I/O	SPI Mode: Chip select signal of SPI expert (Active Low) GPIO Mode: GPIO
11	VLED	Power	LED power input
12	VDD	Power	Main power supply
13	GPIO0 (SPI_MCLK)	SPI Mode: Input GPIO Mode: I/O	SPI Mode: External clock input for SPI GPIO Mode: GPIO

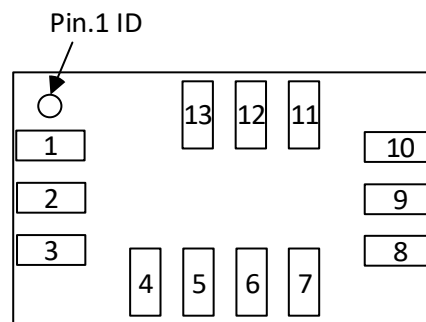


Figure 2. PAJ7620U2 Module Pin Configuration (Bottom View)

2.0 Mechanical Specification

2.1 Package Dimension

Unit: mm

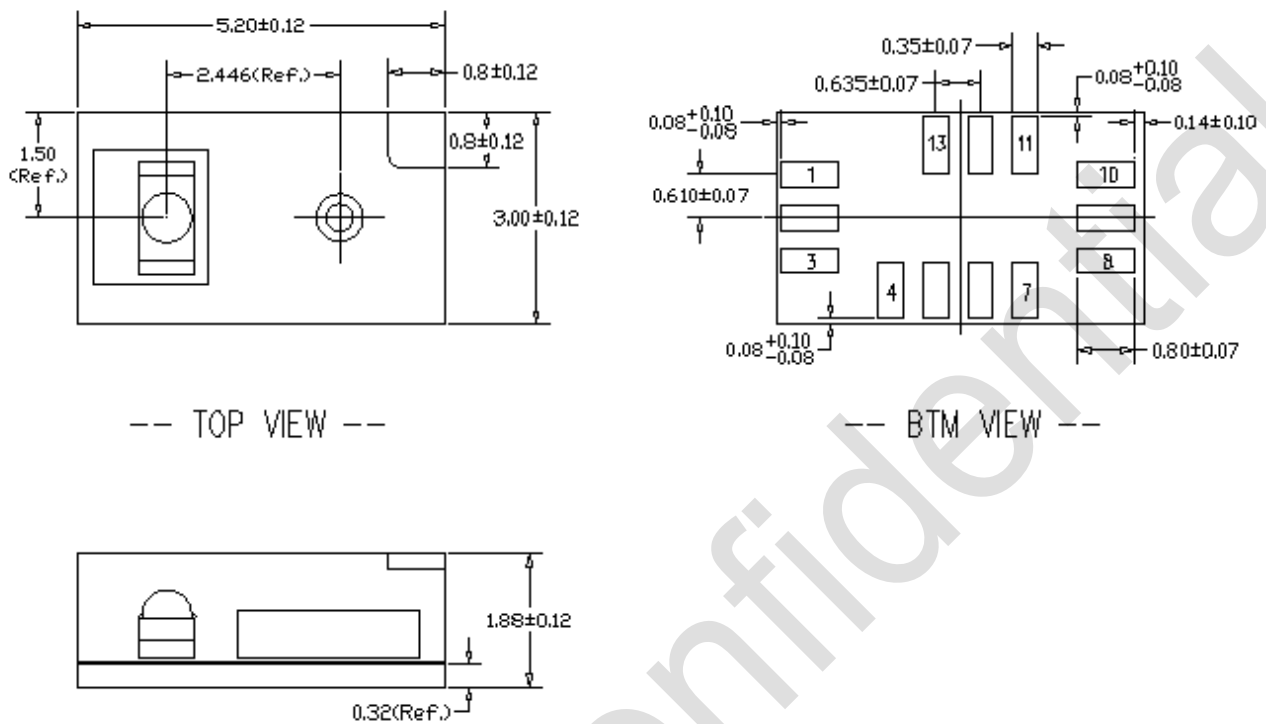


Figure 3. PAJ7620U2 Package Outline Diagram

2.2 IR Reflow Recommendation

2.2.1 Recommended Pb-free Solder Paste

- Almit LFM-48W TM-HP
- Senju M705-GRN360-K

2.2.2 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 as shown in Figure 4 below.

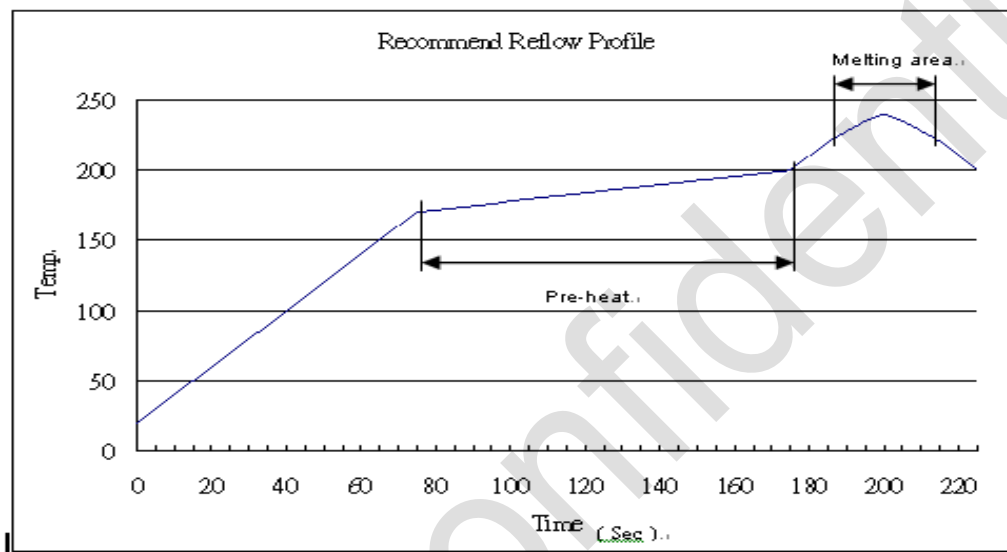


Figure 4. IR Reflow Profile

Reflow Profile:

Average Ramp-up Rate (30°C to preheat zone): 1.5 to 2.5 °C / Sec)

Preheat zone:

- Temperature ramp from 170 to 200 °C
- Exposure time: 90 ± 30 sec

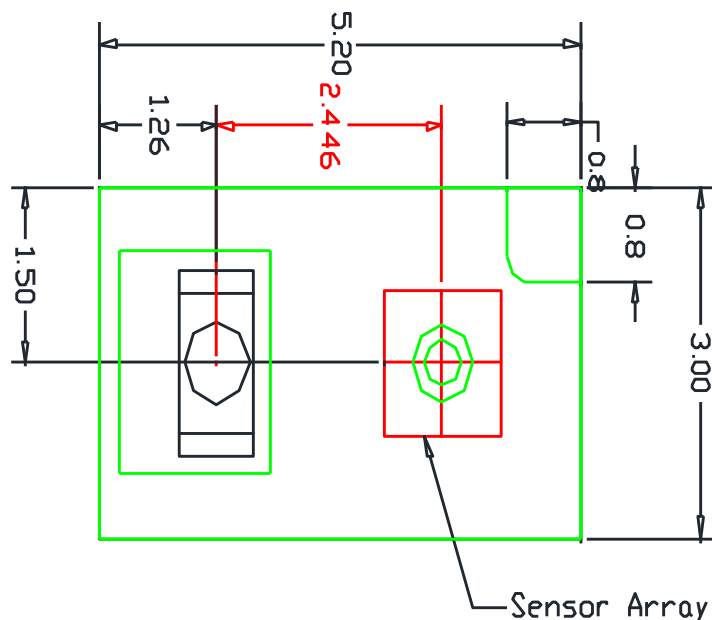
Melting zone:

- Melting area temp > 220 °C for at least 30 to 50 sec
- Peak temperature: 245 °C

2.3 Recommend Mechanical Design

PXI suggest mechanical design as below to optimize the performance.

Unit: mm



Note:

1. Recommended Cover Glass Material: Glass or PC
2. Clear Glass Part Transparency: > 90%
3. Cover Glass Thickness $\leq 0.7\text{mm}$
4. Cover Glass and PAJ7620U2 are close as much as possible. Air Gap $\leq 0.2\text{mm}$

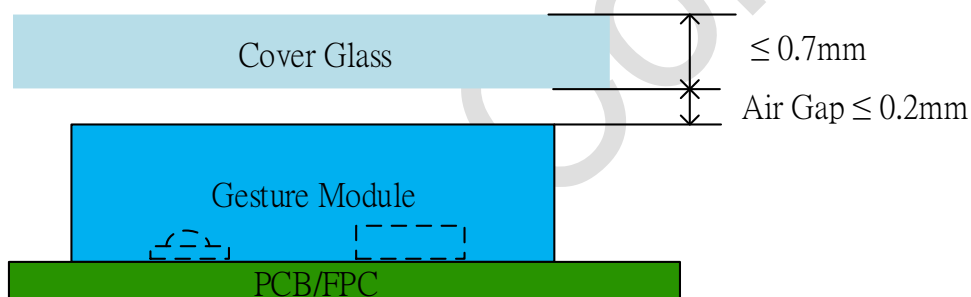


Figure 5. PAJ7620U2 Mechanical Design Guide

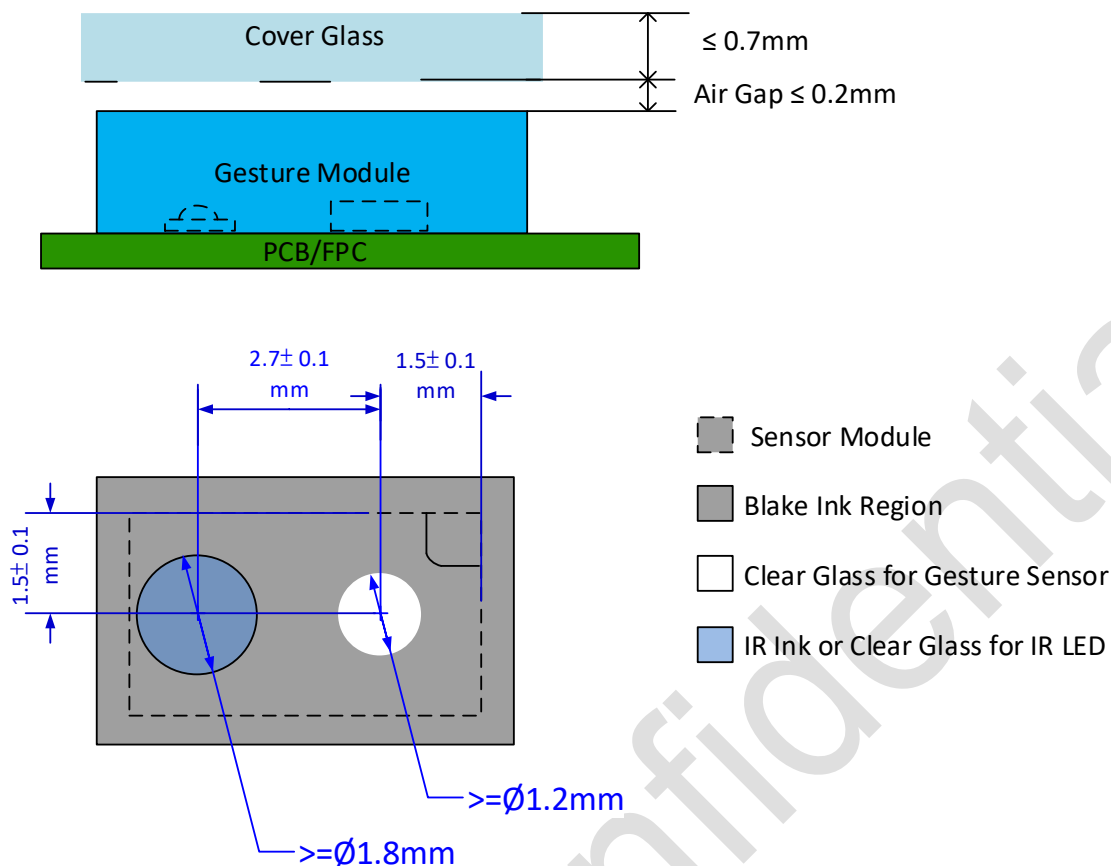


Figure 6. PAJ7620U2 Mechanical Design Guide (IR Ink Suggestion)

Note:

1. If thickness of cover glass $\leq 0.7\text{mm}$, and Air Gap $\leq 0.2\text{mm}$, the black Ink region is not necessary.
2. For appearance reason, Ink on cover may be necessary. Please follow the recommended IR Ink spectrum.

2.4 Recommended IR Ink Spectrum

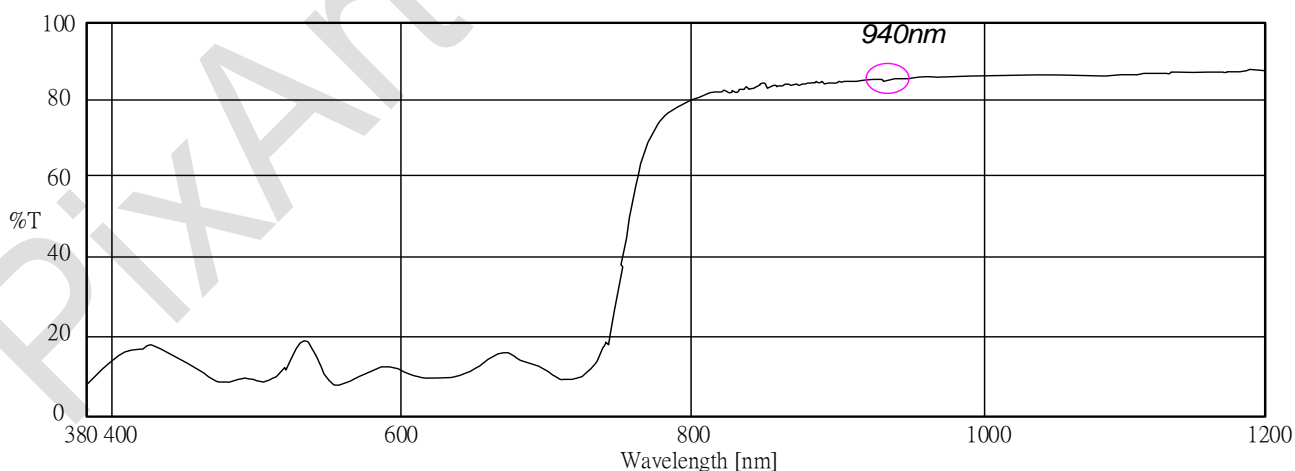


Figure 7. IR Ink Spectrum

3.0 Reference Schematic

3.1 Reference Schematics for Gesture/Cursor Mode

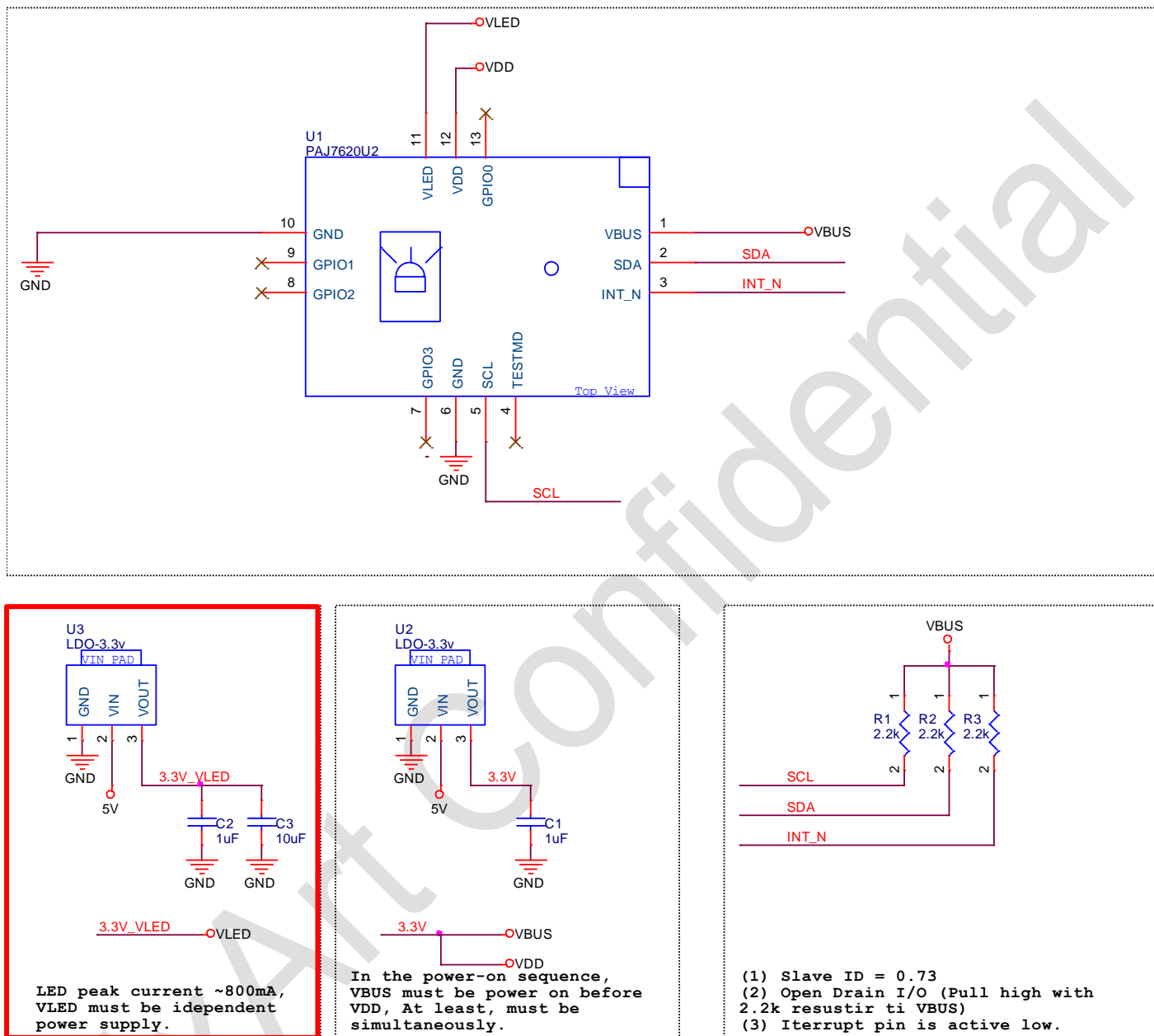


Figure 8. PAJ7620U2 Application Circuit for Gesture/Cursor Mode

3.2 Reference Schematics for Image Mode

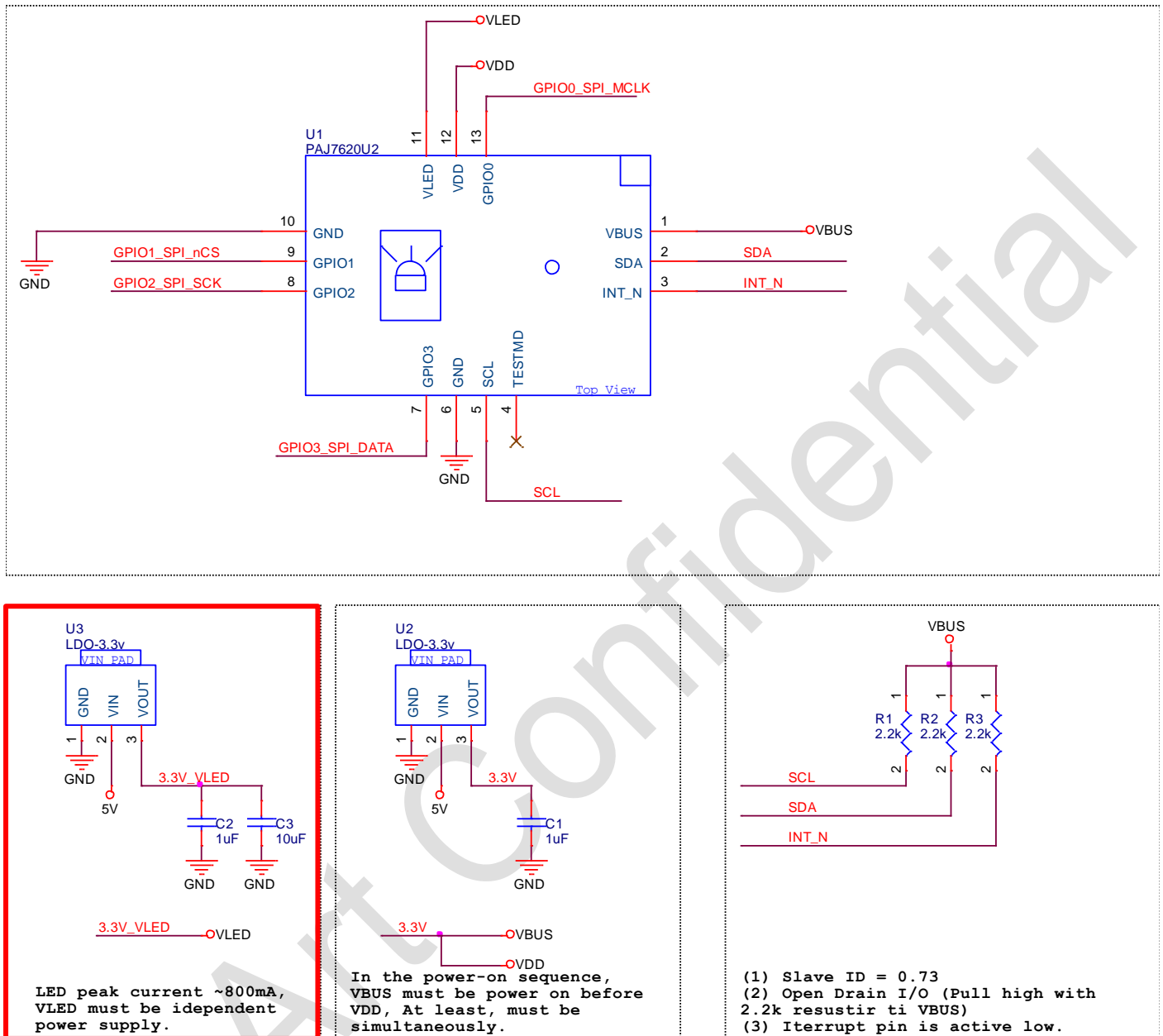


Figure 9. PAJ7620U2 Application Circuit for Image Mode

4.0 Sensor Specification

4.1 Absolute Maximum Rating, $T_A = 27^\circ\text{C}$

Parameter	Symbol	Min.	Max.	Unit	Note
Supply Voltage	VDD	-	4	V	
LED Supply Voltage	VLED	-	4.6	V	
LED Pulse Current	I_{LED}	-	2	A	Pulse Width < 500 μs , Duty Cycle < 5%
I ² C Pin, INT_N Pin Voltage	VBUS	-0.3	VDD+0.3	V	SCL, SDA, INT_N
I ² C Pin, INT_N Pin Current	I_{BUS}	-	10	mA	SCL, SDA, INT_N
I/O Pin Voltage	V _{DDIO}	-0.3	VDD+0.3	V	SPIM_CLK, SPI_SCK, SPI_DATA, SPI_nCS
I/O Pin Current	I_{DDIO}	-	10	mA	SPIM_CLK, SPI_SCK, SPI_DATA, SPI_nCS
ESD, human body model	ESD _{HBM}	-	2	kV	
ESD, Machine model	ESD _{MM}	-	200	V	

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.
3. Functional operation under absolute maximum-rated conditions is not implied. Functional operation should be restricted to the Recommended Operating Conditions.

4.2 Recommended Operating Condition

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Supply Voltage	VDD	2.8	-	3.6	V	
LED Supply Voltage	VLED	3	-	4.2	V	
Peak LED Driver 1/ 2 Current Pulse	I_{LED}	-	360	430	mA	Pulse Width < 500 μs , Duty Cycle < 5%
I ² C Pin, INT_N Pin Voltage	VBUS	1.8	-	3.3	V	SCL, SDA, INT_N
I ² C Pin, INT_N Pin Current	I_{BUS}	-	-	5	mA	SCL, SDA, INT_N
I/O Pin Voltage	V _{DDIO}	1.8	-	3.3	V	SPIM_CLK, SPI_SCK, SPI_DATA, SPI_nCS
I/O Pin Current	I_{DDIO}	-	-	5	mA	SPIM_CLK, SPI_SCK, SPI_DATA, SPI_nCS
Frequency of external SPI clock input	f_{SPI}	22	-	48	MHz	
Operating Temperature	T_{op}	-40	-	85	$^\circ\text{C}$	
Storage Temperature	$T_{storage}$	-40	-	125	$^\circ\text{C}$	

4.3 Electrical Specification, VDD=2.8V, T_A = 27°C

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Supply Voltage	VDD	2.8	-	3.6	V	
LED Supply Voltage	VLED	3.0	-	4.2	V	LED Supply Voltage
I ² C, INT_N Pin Pull-up Voltage	VBUS	1.8	-	3.3	V	
Current Consumption for Operation Modes	I _{DD}	-	2.82	-	mA	Under Normal Mode. Including LED current (Peak = 760mA)
Suspend Current	I _{DD_SUS}	-	15	-	μA	
Current Consumption for Standby State 1	I _{DD_ST1}	-	2.3	-	mA	Refer to Operating Principle 1. Under Normal Mode
Current Consumption for Standby State 2	I _{DD_ST2}	-	1.5	-	mA	2. S ₁ , Response Factor =0.5 3. S ₂ , Response Factor =0.25 4. Including LED current @ Peak = 760mA
Current Consumption for Proximity Detection	I _{PS}		0.2		mA	Detecting Rate = 10Hz LED peak current = 600mA LED on time = 6.8μs
I ² C Bus Input High Voltage	V _{IH_I2C}	0.7 x VBUS	-	VBUS +0.3	V	
I ² C Bus Input Low Voltage	V _{IL_I2C}	-0.3	-	0.3 x VBUS	V	
Output Low Voltage	V _{OL_SDA} V _{OL_INT_N}	-	-	0.1 x VBUS	V	For INT_N, SDA
I/O Input High Voltage	V _{IH}	0.7 x V _{DDIO}	-	V _{DDIO} +0.3	V	
I/O Input Low Voltage	V _{IL}	-0.3	-	0.2 x V _{DDIO}	V	
I/O Output High Voltage	V _{OH}	V _{DDIO} - 0.3	-	-	V	
I/O Output Low Voltage	V _{OL}	-	-	0.3	V	

4.4 Gesture Functional Specification

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Gesture Detecting Range	d _{OP}	5	-	15	cm	Calculated from PAJ7620U2 sensor center
Gesture Detecting View Angle	θ _{OP}	-	60	-	degree	Calculated diagonally
Gesture Speed Response	ω	60		600	degree /s	Angular velocity under Normal Mode (15.3 to 153cm/s @ Distance 15cm)
		60		1200		Angular velocity under Fast Mode (15.3 to 306cm/s @ Distance 15cm)
Gesture Update Rate	f _{Update}	-	120	240	Hz	120 Hz for Normal Mode 240 Hz for Fast Mode
LED View Angle	2θ _{1/2}		60		degree	
LED Peak Wavelength	λ		940		nm	

4.5 Interface AC Specification

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
I ² C Speed	S _{I2C}	-	100	400	kbit/s	
Frequency of External SPI Clock Input		22	-	48	MHz	For Image Mode

5.0 Serial Interface Communication

5.1 I²C Interface

SDA (serial data) and SCL (serial clock) form a two-wire serial interface compatible with I²C. The PAJ7620U2 is implemented as a slave-only device so it never drives SCL. It drives SDA during (host) read cycles and transmission of the Acknowledge bit. PAJ7620U2 uses 7-bit addressing and does not support clock stretching. The SDA and SCL pins are open-drain structure requiring external pull-up resistors.

- Start and stop condition: SDA high to low transition while SCL is high defines a Start condition. SDA low to high transition while SCL is high defines a Stop condition. (Refer to Figure 10)
- Valid data: The data on SDA line must be stable during high period of SCL. MSB is always transferred first for each byte. LSB of the first byte is Read / Write control bit. (Refer to Figure 11)
- Both master and slave can transmit and receive data from the bus.
- Acknowledge: The receiving device should pull down SDA during high period of the 9th clock (SCL) after a complete byte has been received from the transmitter. In the case of the master receiving data from the slave, the master does not generate an Acknowledge bit after the last byte to indicate the end of a master read cycle.

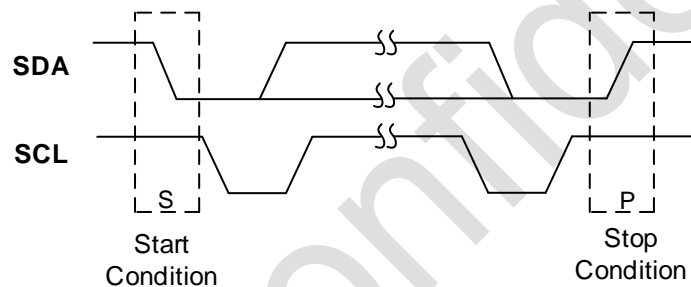


Figure 10. Start and Stop Conditions

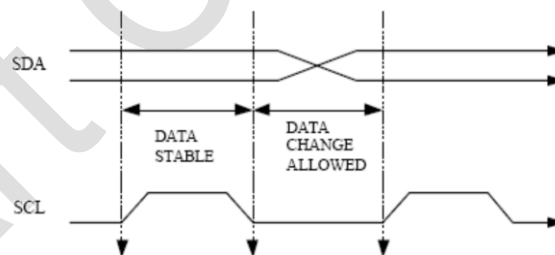


Figure 11. Valid Data

5.1.1 I²C Protocol

The I²C Slave ID is using 7 bit addressing protocol: 0x13, 0x1B, 0x23, 0x2B, 0x5B, 0x63, 0x6B, 0x73 and default is 0x73.

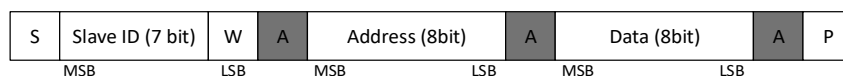


Figure 12. Single Write Protocol

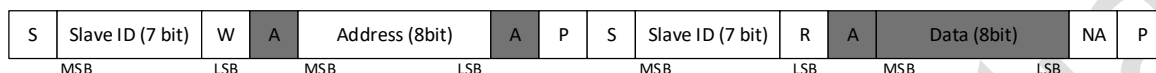


Figure 13. Single Read Protocol

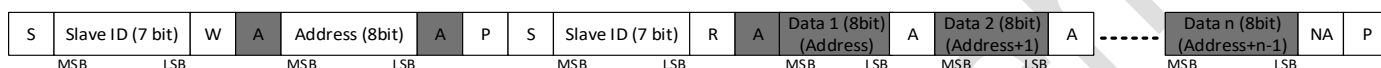


Figure 14. Burst Read Protocol

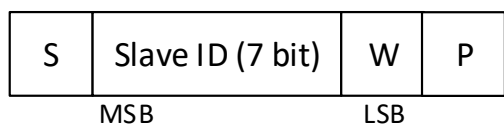


Figure 15. I²C Wake-up Command Protocol

- A** Acknowledge (0 for an ACK)
- NA** Non-acknowledge (1 for an NACK)
- P** Stop condition
- Master to Slave
- S** Start condition
- W** Write (0 for write)
- R** Read (1 for read)
- Slave to Master

5.1.2 I²C Timing Parameter

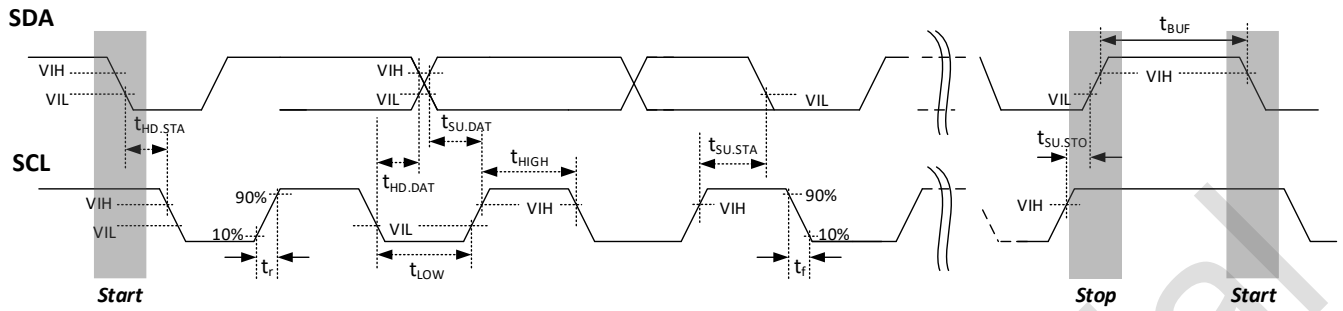


Figure 16. I²C Timing Diagram

Parameter	Symbol	STANDARD MODE		FAST MODE		Unit
		Min.	Max.	Min.	Max.	
SCL clock frequency.	f_{scl}	10	100	10	400	kHz
Hold time for Start/Repeat Start. After this period, the first clock pulse is generated.	$t_{HD.STA}$	4		0.6		μs
Set-up time for a repeated Start.	$t_{SU.STA}$	4.7		0.6		μs
Low period of SCL clock.	t_{LOW}	4.7		1.3		μs
High period of SCL clock.	t_{HIGH}	4		0.6		μs
Data hold time.	$t_{HD.DAT}$	0		0		μs
Data set-up time.	$t_{SU.DAT}$	250		100		ns
Rise time of both SDA and SCL signals.	t_r		1000	-	300	ns
Fall time of both SDA and SCL signals.	t_f		300	-	300	ns
Set-up time for STOP condition.	$t_{SU.STO}$	4		0.6		μs
Bus free time between a STOP and START.	t_{BUF}	4.7		1.3		μs

Note: Maximum current is 5mA and capacitance load spec. =100pF

5.2 Four-Wire SPI Interface (For Image Mode Only)

5.2.1 SPI Master Protocol

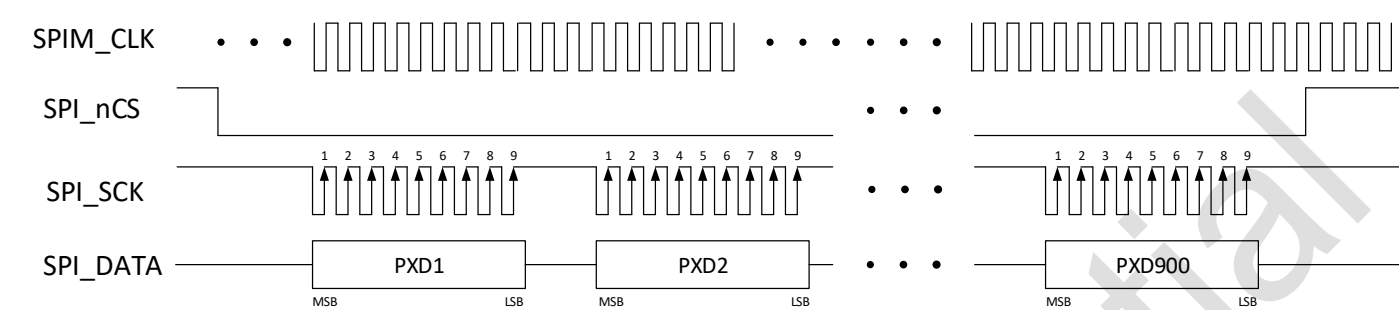


Figure 17. SPI Master Protocol

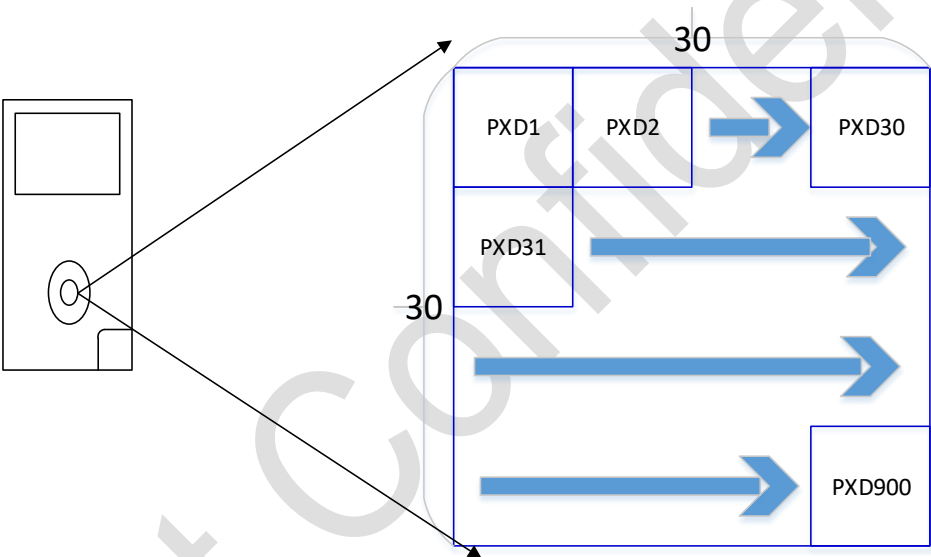


Figure 18. Method to Read the Image Data Output

5.2.2 SPI Timing Parameter

Parameter	Symbol	Typ. (measured)	Unit
SCK clock frequency. ($f_{sck} = 1/t_p$)	f_{sck}	24	MHz
Low period of SCK clock.	t_{LOW}	15.5	ns
High period of SCL clock.	t_{HIGH}	12.5	
Data output valid time.	$t_{V(MO)}$	20.3	
Data output hold time.	$t_{H(MO)}$	20.8	
Rise time of SCK clock	t_r	8	
Fall time of SCK clock	t_f	8	

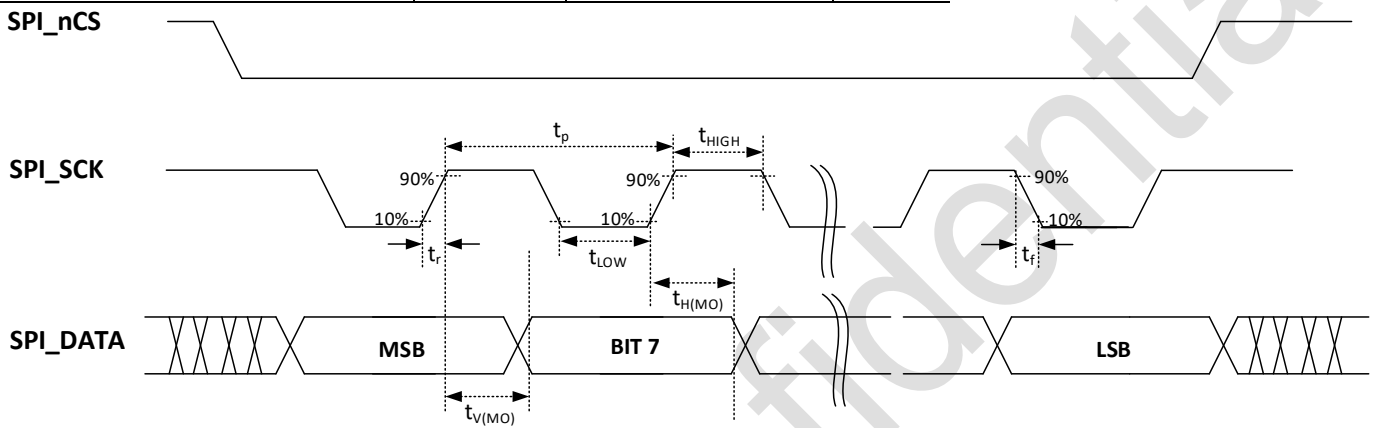


Figure 19. SPI Timing Diagram

6.0 Operation Principles

6.1 Gesture mode

6.1.1 Module Orientation

The sensor module package should be placed in the correct orientation to have the gesture direction as per Figure 20.

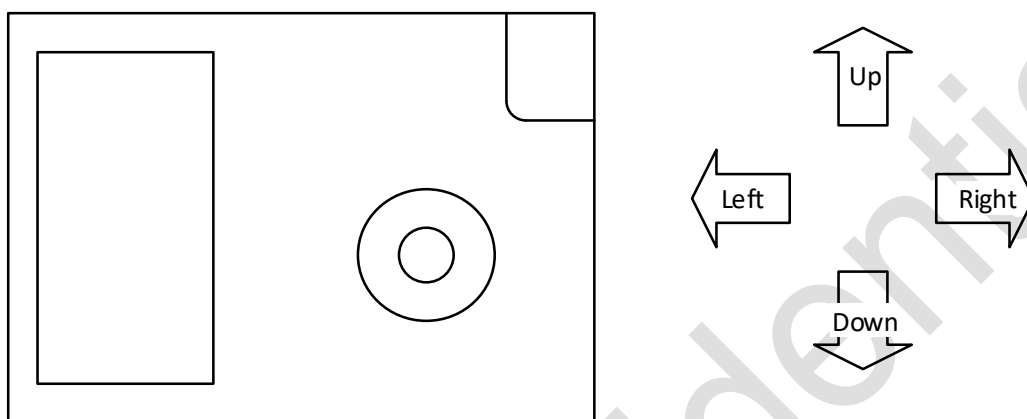


Figure 20. Module Orientation of PAJ7620U2 (Front View)

If the sensor module package is rotated to a different angle, the direction of gesture detection interrupt flag mask (Register Bank 0, ADDR 0x41) and gesture detection interrupt flag (Register Bank 0, ADDR 0x43) needs to be re-mapped.

Bank	Address	Register Name	Default Value	R/W	Description
0	0x41	R_Int_1_En	0xFF	R/W	Interrupt flag mask control. Bit[7] Counter-Clockwise Mask Bit[6] Clockwise Mask Bit[5] Backward Mask Bit[4] Forward Mask Bit[3] Up Mask Bit[2] Down Mask Bit[1] Right Mask Bit[0] Left Mask
0	0x43	IntFlag_1	0x00	R/W	Interrupt flag. Bit[7] Counter-Clockwise Bit[6] Clockwise Bit[5] Backward Bit[4] Forward Bit[3] Up Bit[2] Down Bit[1] Right Bit[0] Left

6.1.2 Power-On Sequence

In the power-on sequence, The V_{BUS} Must be power on before V_{DD} . After power on, wait T_1 μs for PAJ7620U2 to stabilize and then write slave ID (0x73) to process I²C wake-up (Refer to topic "I²C Interface"). After T_2 μs , write the initial settings and the different modes settings to PAJ7620U2. Lastly, enable PAJ7620U2 by writing Register Bank1, Addr0x72 with 0x01. The gesture data can now be accessed through the I²C bus.

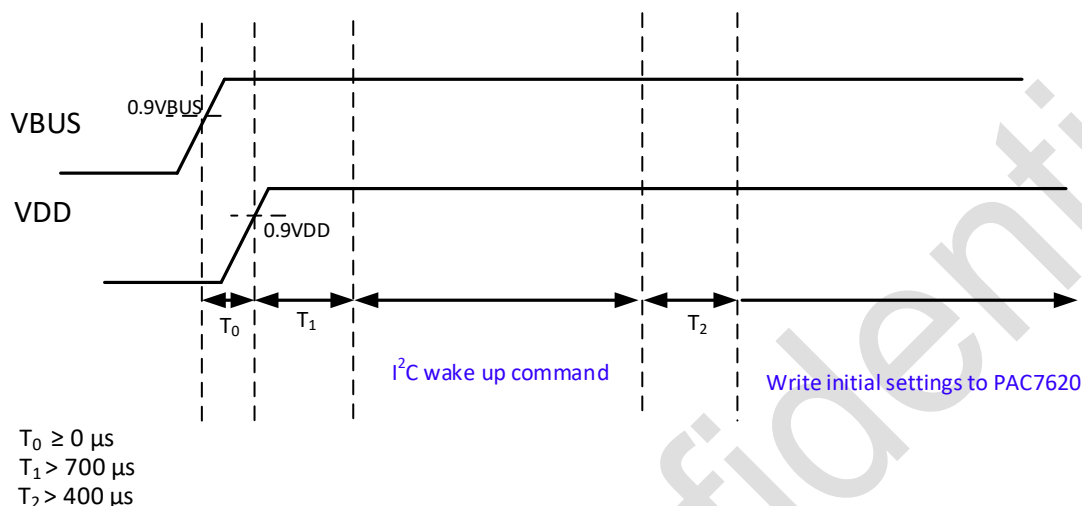


Figure 21. PAJ7620U2 Power-On Timing Diagram

6.1.3 Gesture Detection Operating State

6.1.3.1 Operation State (OP state)

When in operation state, the gesture update rate is 120Hz for Normal Mode and 240Hz for Fast Mode respectively. The gesture result can be accessed by interrupt mechanism or continuous polling the gesture detection interrupt flag (Register Bank 0, Addr0x43).

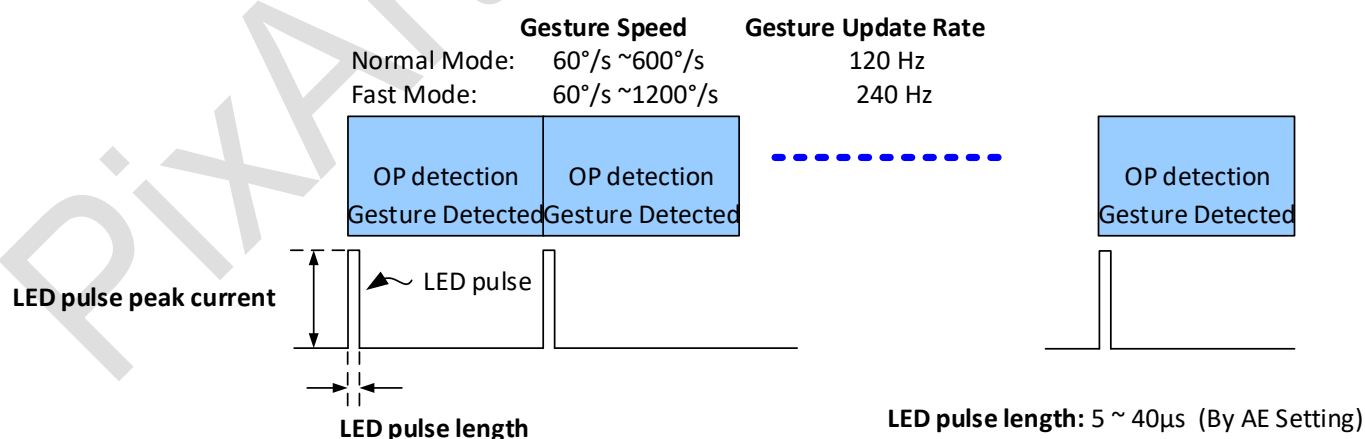


Figure 22. Operation State (OP state) Diagram

6.1.3.2 Standby 1 State (S1 state)

When in Standby1 state, the object detection rate equals $S_{1, \text{Response Factor}}$ multiply the gesture update rate of Normal Mode or Fast Mode.

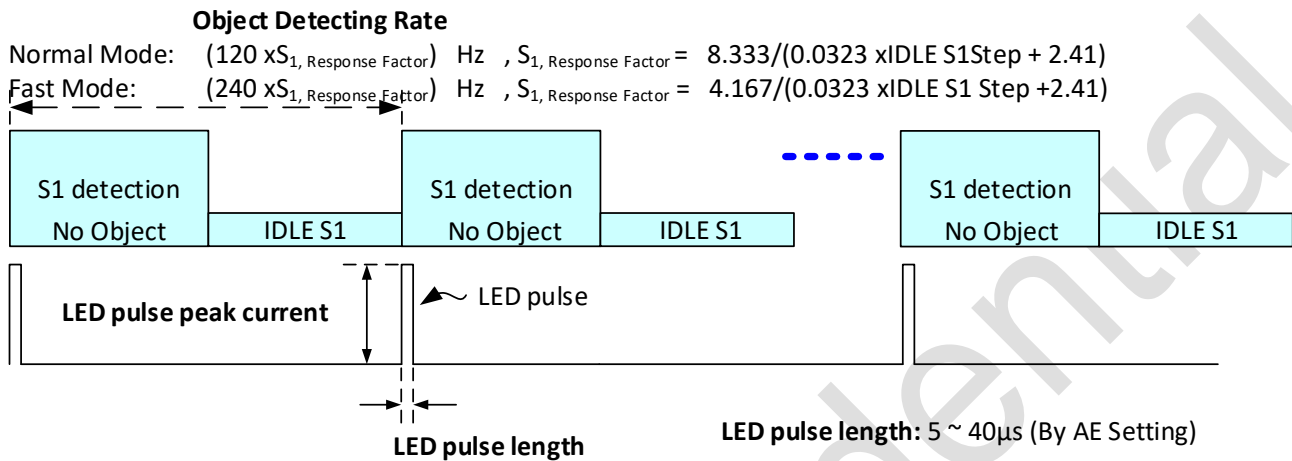


Figure 23. Standby 1 State (S1 state) Diagram

6.1.3.3 Standby 2 State (S2 state)

When in Standby 2 state, the object detection rate equals $S_{2, \text{Response Factor}}$ multiply the gesture update rate of Normal Mode or Fast Mode.

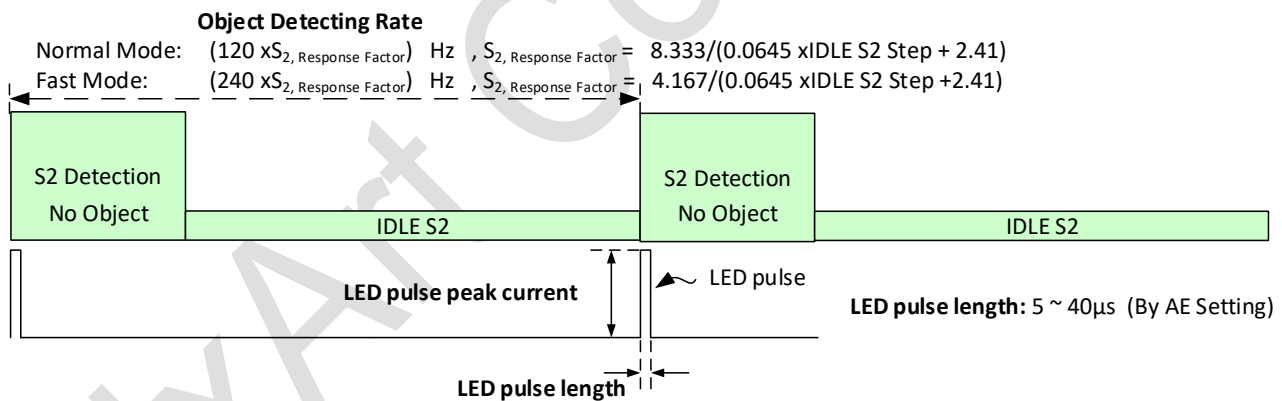


Figure 24. Standby 2 State (S2 state) Diagram

6.1.3.4 Suspend State (SUS state)

To enter the suspend state, first disable the PAJ7620U2 by writing Register Bank 1, ADDR 0x72 with 0x00 then process the I²C suspend command by writing Register Bank 0, ADDR 0x03 with 0x01.

To exit the suspend state, first process the I²C wake-up command by writing the slave ID (Refer to topic “I²C Bus Timing Characteristics and Protocol”) then enable the PAJ7620U2 by writing Register Bank 1, ADDR 0x72 with 0x01.

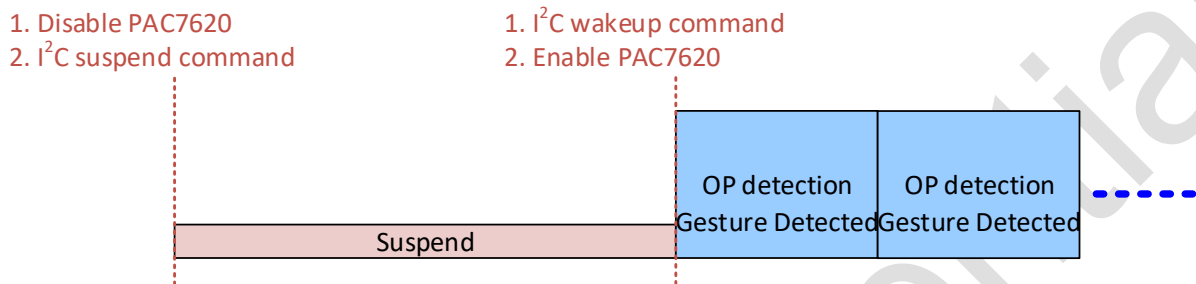


Figure 25. Suspend State (SUS state) Diagram

6.1.3.5 State Machine

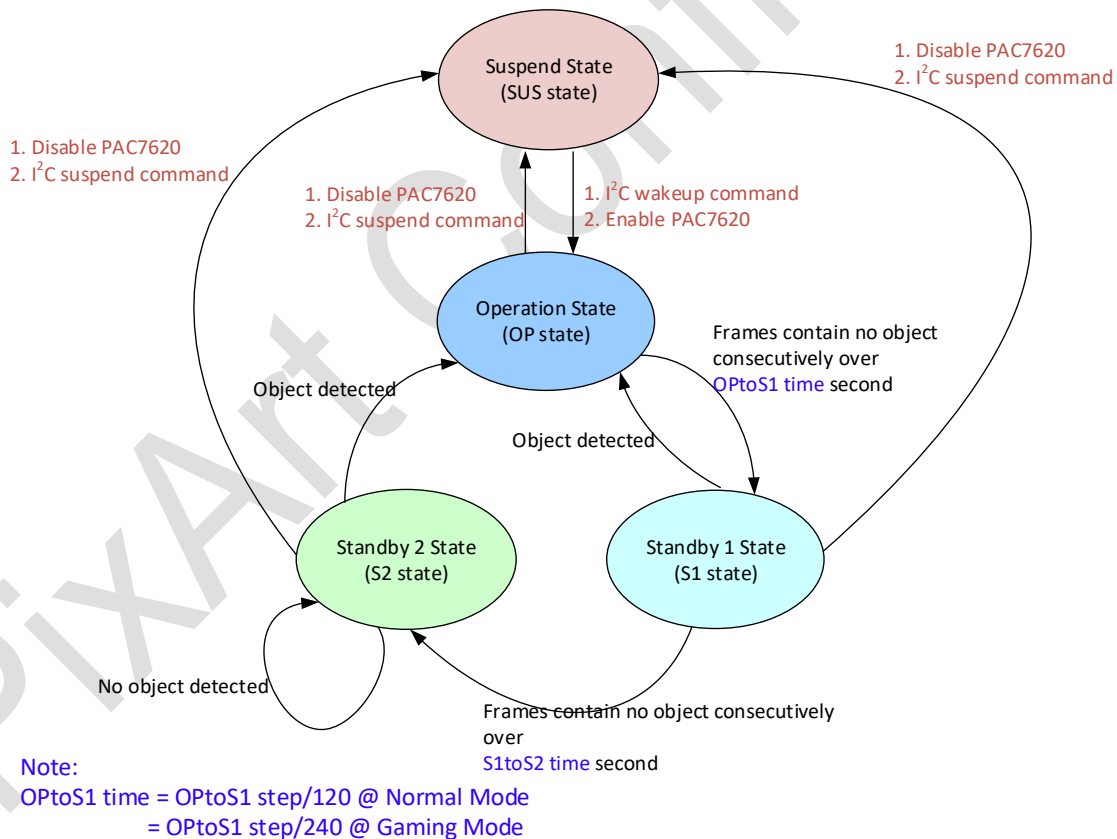


Figure 26. State Machine of Gesture Detection

6.2 Image mode

6.2.1 Output Image Timing

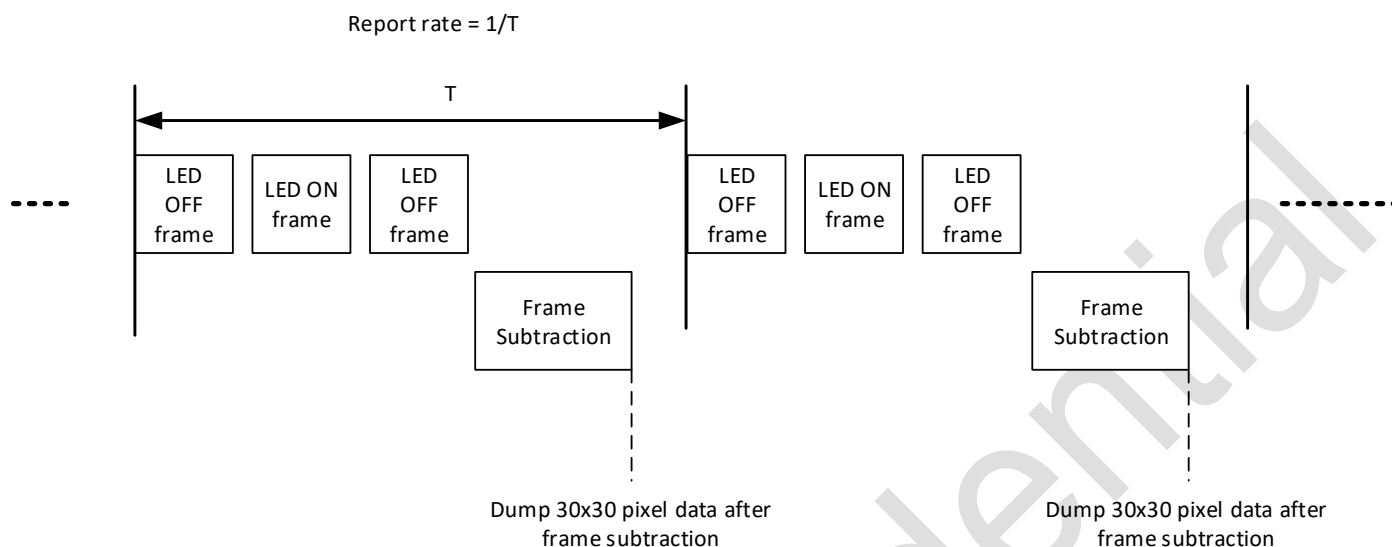


Figure 27. Timing of Output Image

6.2.2 Suspend State

To enter the suspend state, first disable the SPI output by writing Register Bank 1, ADDR 0x7E with 0x00. Second, disable the PAJ7620U2 by writing Register Bank 1, ADDR 0x72 with 0x00 then process the I²C suspend command by writing Register Bank 0, ADDR 0x03 with 0x00.

To exit the suspend state, first process the I²C wake-up command by writing the slave ID (Refer to topic "I²C Interface"). Second, enable the PAJ7620U2 by writing Register Bank 1, ADDR 0x72 with 0x01 then enable the SPI output by writing Register Bank 1, ADDR 0x7E with 0x01.

1. Disable SPI output (for Image Mode Only)
2. Disable PAC7620
3. I²C suspend command

1. I²C wakeup command
2. Enable PAC7620
3. Enable SPI output (For Image Mode Only)

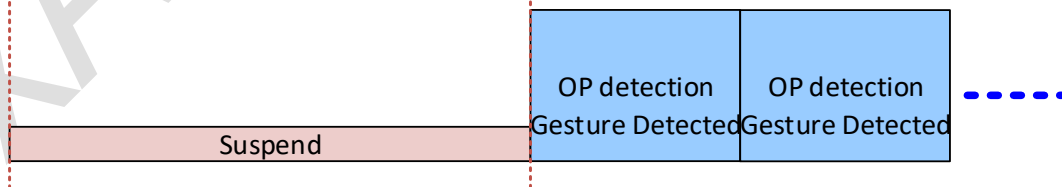


Figure 28. Suspend State (SUS state) Diagram

6.3 Proximity Detection Mode

Refer to Figure 29 on how to set the Proximity Sensing (PS) hysteresis window and the interrupt mechanism of proximity detection.

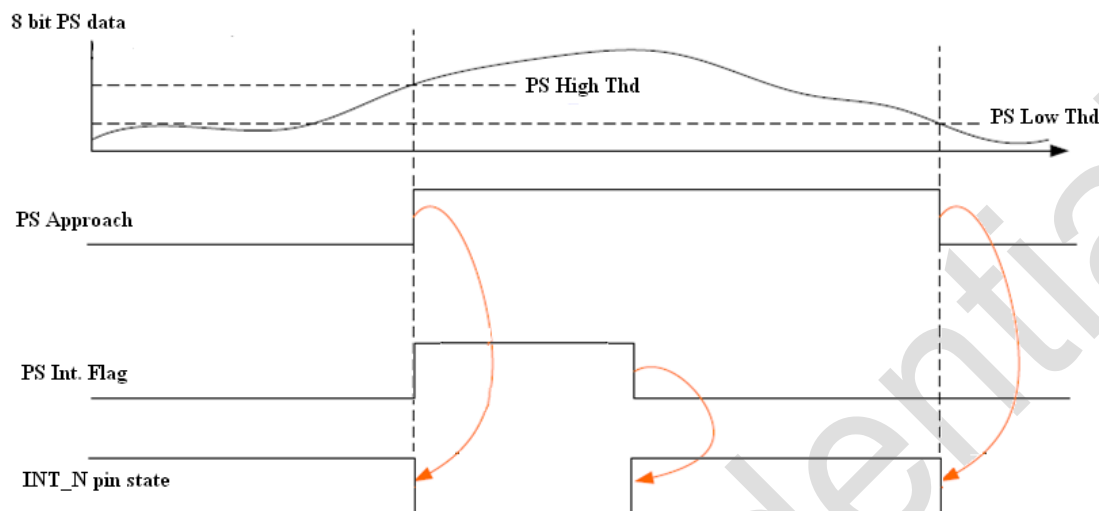


Figure 29. Proximity Sensing Functional Diagram

6.3.1 Proximity Detection Operating State

6.3.1.1 Proximity Operation State (PS OP state)

When in operation state, the update rate is 10Hz and the LED on time is 8μs. The LED peak current is 760 mA.

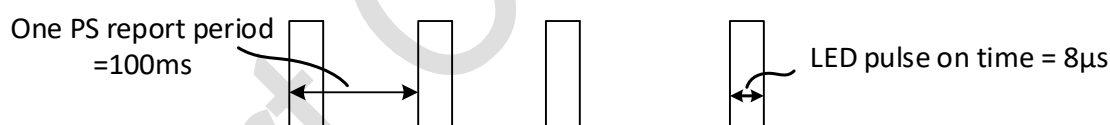


Figure 30. Proximity Operation State (PS OP state) Diagram

6.3.1.2 Suspend State (SUS state)

1. Disable PAC7620
2. I²C suspend command

1. I²C wakeup command
2. Enable PAC7620

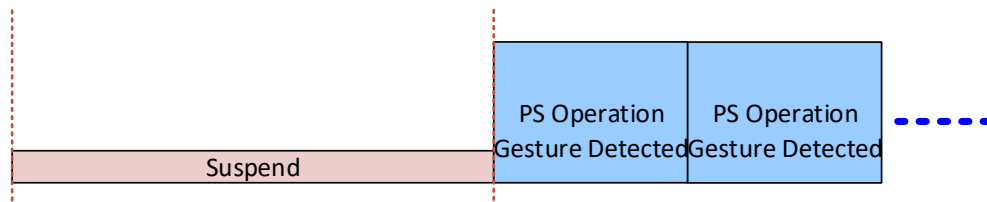


Figure 31. Suspend State (SUS state) Diagram

6.3.1.3 State Machine

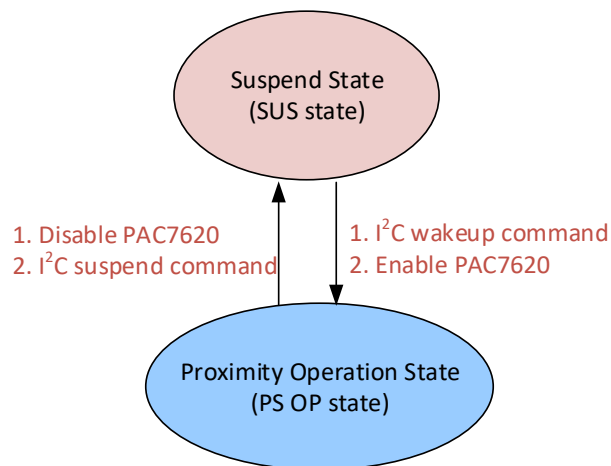


Figure 32. State Machine of Proximity Detection

7.0 Register Tables

7.1 Register Bank Select

Bank	Address	Register Name	Default Value	R/W	Description
0/1	0xEF	R_RegBankSel[0]	0x00	R/W	Register Bank Select. 0 : Register Bank 0 1 : Register Bank 1
1	0x7F	R_RegBankSel[0]	0x00	R	Register Bank Select. 0 : Register Bank 0 1 : Register Bank 1

7.2 AE/AG Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x46	R_AELedOff_UB[7:0]	0x60	R/W	Decrease exposure time, If AE_LED_Off_YAvg (Bank 0, Reg 0x58) > R_AELedOff_UB
0	0x47	R_AELedOff_LB[7:0]	0x20	R/W	Increase exposure time, If AE_LED_Off_YAvg (Bank 0, Reg 0x58) < R_AELedOff_LB
0	0x48	R_AE_Exposure_UB[7:0]	0x20	R/W	Auto exposure time up bound, Exposure time (μs) = R_AE_Exposure_UB / 4
0	0x49	R_AE_Exposure_UB[15:8]	0x03	R/W	
0	0x4A	R_AE_Exposure_LB[7:0]	0xC8	R/W	Auto exposure time low bound, R_AE_Exposure_LB = R_AE_Exposure_UB / 2 (important)
0	0x4B	R_AE_Exposure_LB[15:8]	0x00	R/W	
0	0x4C	R_AE_Gain_UB[7:0]	0x14	R/W	Auto gain up bound, Gain = 1+ R_AE_Gain_UB/16
0	0x4D	R_AE_Gain_LB[7:0]	0x00	R/W	Auto gain low bound, Gain = 1+ R_AE_Gain_LB/16
0	0x4E	R_AE_Gain_Step[3:0]	0x0A	R/W	Gain stage adjust step, new gain stage = current gain stage - this
0	0x4E	R_StandbyAEAG_AutoDisable[4]	0x01	R/W	Under standby, if Gain Stage is at UB, disable wakeup AE mode. Wake up AE mode: when standby, AE/AG will be set to higher value.
0	0x4F	R_AE_Gain_Default[6:0]	0x14	R/W	Gain stage default value at AE turning on.
0	0x50	R_Exp_Sel[2:0]	0x00	R/W	At R_Manual_Exposure_Default=1, Exp = R_AE_Exposure_UP/2^(R_Exp_Sel)
0	0x51	R_Manual_GG[0]	0x01	R/W	1: Gain Manual mode, ggh gain= R_ggh, global gain=R_glogal. 0: Gain Auto mode

Bank	Address	Register Name	Default Value	R/W	Description
0	0x51	R_Manual_Exposure[1]	0x00	R/W	1: Exposure Manual mode, exposure time = R_AE_Exposure_UB. 0: Auto Exposure mode
0	0x51	R_Manual_Exposure_Default[2]	0x01	R/W	Exp Manual Mode, Exp = $R_AE_Exposure_UP/2^{(R_Exp_Sel)}$
0	0x51	R_AE_EnH[4]	0x00	R/W	1: AE Enable 0: AE Disable
0	0x54	AG_stage_GG[7:0]	-	R	Gain Stage, gain for analog = $2^{AG_stage_GG[7:4]}$
0	0x55	Reg_ExposureNum[7:0]	-	R	Currently exposure time, Exposure time (us) = Reg_ExposureNum/4
0	0x56	Reg_ExposureNum[15:8]	-	R	
0	0x57	Reg_ggh[1:0]	-	R	ggh gain 0:1x, 2:2x, 3:4x
0	0x57	Reg_global[3:0]	-	R	Bit[7:4] : global gain 0:1x, 8:2x Total gain = ggh*global = $2^{AG_stage_GG[7:4]}$
0	0x58	AE_LED_Off_YAvg[8:1]	-	R	Bit[7:0]: OFF Frame average brightness
0	0x59	AE_Dec[0]	-	R	AE decrease identifier
0	0x59	AE_Inc[1]	-	R	AE increase identifier
0	0x5A	AE_Normal_Factor[2:0]	-	R	AE normalize factor, DSP data = sensor image data * $2^{AE_Normal_Factor}$
1	0x42	R_global[3:0]	0x08	R/W	Bit[7:4]: PGA global gain in gain manual mode
1	0x44	R_ggh[1:0]	0x00	R/W	Bit[7:6]: PGA ggh gain in gain manual mode

7.3 GPIO Setting

Bank	Address	Register Name	Default Value	R/W	Description
0	0x80	Im_GPIO0	-	R	Bit[0] : GPIO0 Stats at input mode Bit[1] : 0: set GPIO0 as output Bit[2] : 0: set GPIO0 as input
0	0x80	Tm_GPIO0_OEL	0x01	R/W	Bit[3] : GPIO0 default value at output mode. To set GPIOX as Input, X=0~3: Set: Tm_GPIOX_OEL=1, Tm_GPIOX_IEB=0.
0	0x80	Tm_GPIO0_IEB	0x01	R/W	At this time, Im_GPIOX = GPIO Stats. To set GPIOX as Output, X=0~3: Set: Tm_GPIOX_OEL=0, Tm_GPIOX_IEB=1.
0	0x80	R_GPIO0	0x01	W	At this time, Tm_GPIOX = R_GPIOX
0	0x80	Im_GPIO1	-	R	Bit[4] : GPIO1 Stats at input mode Bit[5] : 0: set GPIO1 as output Bit[6] : 0: set GPIO1 as input
0	0x80	Tm_GPIO1_OEL	0x01	R/W	Bit[7] : GPIO1 default value at output mode.
0	0x80	Tm_GPIO1_IEB	0x01	R/W	
0	0x80	R_GPIO1	0x01	W	
0	0x81	Im_GPIO2	-	R	Bit[0] : GPIO2 Stats at input mode Bit[1] : 0: set GPIO2 as output Bit[2] : 0: set GPIO2 as input
0	0x81	Tm_GPIO2_OEL	0x01	R/W	Bit[3] : GPIO2 default value at output mode.
0	0x81	Tm_GPIO2_IEB	0x01	R/W	
0	0x81	R_GPIO2	0x01	W	
0	0x81	Im_GPIO3	-	R	Bit[4] : GPIO3 Stats at input mode Bit[5] : 0: set GPIO3 as output Bit[6] : 0: set GPIO3 as input
0	0x81	Tm_GPIO3_OEL	0x01	R/W	Bit[7] : GPIO3 default value at output mode.
0	0x81	Tm_GPIO3_IEB	0x01	R/W	
0	0x81	R_GPIO3	0x01	W	
0	0x82	Im_INT	-	R	Bit[0] : INT pin status Bit[1] 0: set INT as output Bit[2] : 0: set INT as input
0	0x82	Tm_INT_OEL	0x00	R/W	Bit[3] : INT default value at output mode. To set INT as Input: Set Tm_INT_OEL=1, Tm_INT_IEB=0.
0	0x82	Tm_INT_IEB	0x01	R/W	At this time, Im_INT = INT_N Stats.
0	0x82	Tm_INT	0x01	W	To set INT as Output: Set: Tm_INT_OEL=0, Tm_INT_IEB=1. At this time, Tm_INT = INT_N

7.4 Interrupt Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x40	R_MCU_IntFlagGClr	0x01	R/W	Bit[1] 1: Auto clean intflag_1/intflag_2 after I ² C readout.
0	0x40	R_MCU_IntFlagInv	0x00	R/W	Bit[4] 1: INT pin high active, 0:INT pin low active
0	0x41	R_Int_1_En[7:0]	0xFF	R/W	If the corresponding bit is 1: the corresponding interrupt event is enabled Bit[0] Up Bit[1] Down Bit[2] Left Bit[3] Right Bit[4] Forward Bit[5] Backward Bit[6] Clockwise Bit[7] Counterclockwise
0	0x42	R_Int_2_En[7:0]	0xFF	R/W	If the corresponding bit is 1: the corresponding interrupt event is enabled Bit[0] Wave, wave mode use only Bit[1] Proximity, proximity mode use only Bit[2] Has Object, cursor mode use only Bit[3] Wake up trigger, trigger mode use only Bit[4] N/A Bit[5] N/A Bit[6] N/A Bit[7] No Object, cursor mode use only
0	0x43	IntFlag_1[7:0]	-	R	When interrupt event happens, the corresponding bit is set to 1 Bit[0] Up Bit[1] Down Bit[2] Left Bit[3] Right Bit[4] Forward Bit[5] Backward Bit[6] Clockwise Bit[7] Counterclockwise

Bank	Address	Register Name	Default Value	R/W	Description
0	0x44	IntFlag_2[7:0]	-	R	When interrupt event happens, the corresponding bit is set to 1 Bit[0] Wave, wave mode use only Bit[1] Proximity, proximity mode use only Bit[2] Has Object, cursor mode use only Bit[3] Wake up trigger, trigger mode use only Bit[4] N/A Bit[5] N/A Bit[6] N/A Bit[7] No Object, cursor mode use only

7.5 Gesture Mode Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x83	R_LightThd[7:0]	0x20	R/W	Brightness Threshold Only when the pixel > this value, it would be taken as the part of object. Ex: Pixel array: [10 10 40 40 40 10], R_LightThd=32 => Object array: [0 0 40 40 40 0]
0	0x84	R_GestureStartTh[7:0]	0x20	R/W	When the object size is larger than this, state machine goes to has object state
0	0x85	R_GestureStartTh[9:8]	0x00	R/W	Bit[1:0]
0	0x86	R_GestureEndTh[7:0]	0x10	R/W	When the object size is less than this, state machine goes out of has object state
0	0x87	R_GestureEndTh[9:8]	0x00	R/W	Bit[1:0]
0	0x88	R_ObjectMinZ[4:0]	0x05	R/W	Z direction minimum threshold. It is effective on Push/Pull, comparing the object size on the z-axis with MaxZ/MinZ, if object size > MaxZ or < MinZ, the object size value will be replaced as MaxZ or MinZ. It is used to avoid the Push/Pull false detection under near distance or far distance.
0	0x89	R_ObjectMaxZ[5:0]	0x18	R/W	Z direction maximum threshold Please refer to above.
0	0x8C	R_ProcessResolution[1:0]	0x03	R/W	Bit[5:4] Object of gesture detection resolution

Bank	Address	Register Name	Default Value	R/W	Description
					This is used in cursor mode.
0	0x8D	R_TimeDelayNum[7:0]	0x00	R/W	The duration between this gesture and the next gesture. It starts to count after No_MotionCountThd (or NoObjectCountThd) time is finished. The unit is $(2 * (R_TimeDelayNum) / \text{report rate})$ seconds.
0	0x8E	R_Disable45Degree	0x00	R/W	Bit[0] 0 : enable 45 degree gesture detection constraint 1 : Disable 45 degree gesture detection constraint 
0	0x8E	R_45DegreeRatio[3:0]	0xF0	R/W	Bit[7:4] The ratio to define 45 degree Please refer to above, set the ratio of constraint area. If the trace outside the area, it will not count as effective trace.
0	0x8F	R_XtoYGain	0x01	R/W	Bit[0] X and Y direction gain inverse 0: Inverse 1: Not inverse
0	0x8F	R_XYGainRatio[3:0]	0x08	R/W	Bit[7:4] X and Y direction gain ratio. XYGainRatio is the X,Y trace gradient adjustment. If R_XtoYGain bit set to 1, trace X / trace Y \geq XYGainRatio/8 , then the gesture judgement is X, otherwise the judgement is Y. If R_XtoYGain bit set to 0, trace X / trace Y \geq 8 / XYGainRatio, the the gesture judgement is X, otherwise the judgement is Y.
0	0x90	R_NoMotionCountThd[6:0]	0x0C	R/W	No motion counter threshold to quit has motion state The unit is $(1 / \text{report rate})$ sec. It means the object exists but no motion, if the no motion time > the threshold, then stop to detect gesture. If the object keeps moving, then the

Bank	Address	Register Name	Default Value	R/W	Description
					NoMotionCount will not start to count. The gesture result output after the NoMotionCount time is over.
0	0x91	R_NoObjectCountThd[6:0]	0x06	R/W	No object counter threshold to quit has object state The tolerance time when the object disappears during the movement. The unit is (1/report rate) sec. If Wave and CW/CCW move over FOV, then increase this value will help to make the trace more complete.
0	0x92	R_NormalizedImageWidth [4:0]	0x1E	R/W	Image normalized factor
0	0x93	R_XDirectionThd[4:0]	0x0D	R/W	Gesture detection horizontal threshold Setting the X direction movement threshold. Setting 15 means the object trace need to over 15 pixels to count as a gesture. Maximum value is 30°
0	0x94	R_YDirectionThd[4:0]	0x0A	R/W	Gesture detection vertical threshold Setting the Y direction movement threshold. Setting 15 means the object trace need to over 15 pixels to count as a gesture. Maximum value is 30°
0	0x95	R_ZDirectionThd[4:0]	0x0C	R/W	Gesture detection z direction threshold This setting is to set the object size difference threshold to determine the Push/Pull sustain. Basically, the value set smaller will be easier to trigger Push/Pull. Note that if the value is set too small, the push/pull may be false triggered when doing other gesture. The object size difference will depend on the operating distance (ex: related to exposure time setting). Default value 13, the z-direction route is about 13cm.
0	0x96	R_ZDirectionXYThd[4:0]	0x0A	R/W	Gesture detection x and y threshold to detect forward or backward When Push/Pull, the object xy coordinate will slightly change. The ZDirectionXYThd is used to define the tolerance of the xy movement to treat it as no movement. When

Bank	Address	Register Name	Default Value	R/W	Description
					ZDirectionXYThd is larger, push/pull is more easier to be triggered, but up/down/left/right is not easier to be triggered. The unit is pixel number.
0	0x97	R_ZDirectionAngleThd[3:0]	0x04	R/W	Gesture detection angle threshold to detect forward or backward ZDirectionAngleThd is related to push/pull. ZDirectionAngleThd is used to define the tolerance of the angle to treat it as no movement. When ZDirectionAngleThd is larger, push/pull is more easier to be triggered, but rotation is not easier to be triggered. The unit is quadrant.
0	0x98	R_RotateAngleThd[5:0]	0x0A	R/W	Gesture detection angle threshold to detect rotation If R_RotateContiEnh = 0, CW/CCW judgement will refer to this register, and will not accumulate the angle.
0	0x99	R_RotateContiEnh	0x01	R/W	Bit[0] Continuous rotation gesture detection enable 1 : Enable
0	0x99	R_RotateContiThd[5:0]	0x00	R/W	Bit[5:1] Continuous rotation gesture detection angle threshold If R_RotateContiEnh = 1, CW/CCW will accumulate the rotate angle, when the accumulated angle > R_RotateContThd, CW/CCW is triggered.
0	0x9A	R_RotateXYThd[4:0]	0x0A	R/W	Gesture detection x and y threshold to detect rotation When the value set larger, the easier to trigger rotate, but more difficult to valid X/Y.
0	0x9B	R_RotateZThd[4:0]	0x0A	R/W	Gesture detection z threshold to detect rotation When the value set larger, the easier to trigger rotate, but more difficult to valid Z.
0	0x9C	R_FilterWeight[1:0]	0x03	R/W	Bit[1:0] IIR filter weight between frame position distance

Bank	Address	Register Name	Default Value	R/W	Description
					Internal filter setting, not suggest to change.
0	0x9C	R_FilterDistThd[4:0]	0x0A	R/W	Bit[6:2] IIR filter frame position distance threshold Internal filter setting, not suggest to change.
0	0x9D	R_StartDistThd[3:0]	0x03	R/W	Bit[3:0] Object position difference between frames threshold to enter the process state. When the object movement pixel number larger than this threshold, the gesture detection starts to count. When this value is larger, then the speed of the movement needs to be faster to make the gesture detection process begin.
0	0x9D	R_EndDistThd[2:0]	0x03	R/W	Bit[6:4] Object position difference between frames threshold to quit the process state When the object movement pixel number larger than this threshold, the gesture detection stops to count. When this value is larger, then the speed of the movement needs to be faster to make the gesture detection process know the movement is still on going.
0	0x9F	R_RotateEnh	0x01	R/W	Bit[4] Rotate gesture detection enable
0	0x9F	R_ZDirectionEnh	0x01	R/W	Bit[5] Backward and Forward gesture detection enable
0	0x9F	R_YDirectionEnh	0x01	R/W	Bit[6] Up and down gesture detection enable
0	0x9F	R_XDirectionEnh	0x01	R/W	Bit[7] Left and right gesture detection enable
0	0xA5	R_FilterImage	0x01	R/W	Bit[0] ref to R_FilterAverage_Mode Internal filter setting, not suggest to change.
0	0xA5	R_FilterAverage_Mode	0x00	R/W	Bit[3:2] Image filter mode: 0: weak average, 1: strong average, 2: 3 out of 9 median average. Internal filter setting, not suggest to change.

Bank	Address	Register Name	Default Value	R/W	Description
0	0xA5	R_UseLightWeight	0x01	R/W	Bit[4] Use pixel brightness as weight to calculate center enable Internal filter setting, not suggest to change.
0	0xA9	R_DiffAngleThd[3:0]	0x04	R/W	Frame angle accumulation threshold Internal filter setting, not suggest to change.
0	0xAC	ObjectCenterX[7:0]	-	R	Horizontal Object Center
0	0xAD	ObjectCenterX[12:8]	-	R	Bit[4:0] Horizontal Object Center
0	0xAE	ObjectCenterY[7:0]	-	R	Vertical Object Center
0	0xAF	ObjectCenterY[12:8]	-	R	Bit[4:0] Vertical Object Center
0	0xB0	ObjectAvgY[8:1]	-	R	Object brightness, Max 255.
0	0xB1	ObjectSize[7:0]	-	R	Object size, Max 900.
0	0xB2	ObjectSize[11:8]	-	R	Bit[3:0] Object size, Max 900.
0	0xB3	Gx[5:0]	-	R	Gesture x direction movement
0	0xB4	Gy[5:0]	-	R	Gesture y direction movement
0	0xB5	Gz[6:0]	-	R	Gesture z direction movement
0	0xB6	GestureResult[3:0]	-	R	Bit[3:0] Gesture result: 1:up, 2:down, 3:left, 4:right, 5:forward, 6:backward, 7:clockwise, 8:counterclockwise, 9:wave, 10:abort, result no keep, debug use only
0	0xB6	State[1:0]	-	R	Bit[5:4] DSP FSM state: 0:Initial ,1: Process, 2:End
0	0xB7	WaveCount[3:0]	-	R	Bit[3:0] Wave gesture counter
0	0xB7	AbortCount[2:0]	-	R	Bit[6:4] Abort gesture counter
0	0xB8	NoObjectCount[7:0]	-	R	No object counter
0	0xB9	NoMotionCount[7:0]	-	R	No motion counter
0	0xBA	LightCount[5:0]	-	R	Bright object counter
0	0xBB	LightAcc[7:0]	-	R	Object brightness accumulation
0	0xBC	LightAcc[9:8]	-	R	Bit[1:0] Object brightness accumulation
0	0xBD	TimeAcc[7:0]	-	R	Gesture time period
0	0xBE	TimeAcc[12:8]	-	R	Bit[4:0] Gesture time period
0	0xBF	GxAcc[7:0]	-	R	Gesture x direction movement accumulation, debug use only
0	0xC0	GxAcc[9:8]	-	R	Bit[1:0] Gesture x direction movement accumulation, debug use only
0	0xC1	GyAcc[7:0]	-	R	Gesture y direction movement accumulation, debug use only
0	0xC2	GyAcc[9:8]	-	R	Bit[1:0] Gesture y direction movement accumulation, debug use only

Bank	Address	Register Name	Default Value	R/W	Description
0	0xC3	VelX[7:0]	-	R	Gesture x direction velocity, debug use only
0	0xC4	VelX[11:8]	-	R	Bit[3:0] Gesture x direction velocity, debug use only
0	0xC5	VelY[7:0]	-	R	Gesture y direction velocity, debug use only
0	0xC6	VelY[11:8]	-	R	Bit[3:0] Gesture y direction velocity, debug use only
0	0xC7	AngleAcc[7:0]	-	R	Gesture angle accumulation
0	0xC8	AngleAcc[10:8]	-	R	Bit[2:0] Gesture angle accumulation
0	0xC9	CurAngle[4:0]	-	R	Current gesture angle, debug use only
0	0xCA	XGainValue[7:0]	-	R	45 degree gesture detection x direction parameter
0	0xCB	YGainValue[7:0]	-	R	45 degree gesture detection y direction parameter
0	0xCC	R_YtoZSum[5:0]	0x1A	R/W	Z direction mapping parameter Internal setting, not suggest to change.
0	0xCD	R_YtoZFactor[5:0]	0x0D	R/W	Z direction mapping parameter Internal setting, not suggest to change.
0	0xCE	R_PositionFilterLength[2:0]	0x03	R/W	IIR Filter length for cursor object center Internal setting, not suggest to change.
0	0xCE	R_ProcessFilterLength[2:0]	0x00	R/W	Bit[6:4] IIR Filter length for gesture object center Internal setting, not suggest to change.
0	0xCF	R_WaveCountThd[3:0]	0x03	R/W	Wave gesture counter threshold
0	0xCF	R_WaveAngleThd[3:0]	0x06	R/W	Bit[7:4] Wave gesture angle threshold When WaveAngleThd set larger, the angle of wave hand needs larger to make wave count plus on, so it is more difficult to trigger wave.
0	0xD0	R_AbortCountThd[2:0]	0x22	R/W	Bit[2:0] Abort gesture counter threshold Internal setting, not suggest to change.
0	0xD0	R_AbortXYRatio[4:0]		R/W	Bit[7:3] Abort gesture X and Y direction ratio Internal setting, not suggest to change.
0	0xD1	R_AbortLength[6:0]	0x0F	R/W	Abort gesture movement distance threshold Internal setting, not suggest to change.
0	0xD2	R_AbortIntervalCountThd [5:0]	0x88	R/W	Abort gesture gap duration threshold Internal setting, not suggest to change.
0	0xD2	R_ConfirmMode		R/W	Bit[6] Confirm mode enable

Bank	Address	Register Name	Default Value	R/W	Description
					Internal setting, not suggest to change.
0	0xD2	R_WaveEnh		R/W	Bit[7] Wave gesture detection enable Internal setting, not suggest to change.
0	0xD3	PositionFilterCenterX[7:0]	-	R	Horizontal Object Center after IIR filter for cursor mode
0	0xD4	PositionFilterCenterX[11:8]	-	R	Bit[3:4] Horizontal Object Center after IIR filter for cursor mode
0	0xD4	PositionFilterCenterY[11:8]	-	R	Bit[7:4] Vertical Object Center after IIR filter for cursor mode
0	0xD5	PositionFilterCenterY[7:0]	-	R	Vertical Object Center after IIR filter for cursor mode
0	0xD6	PositionFilterAvgY[7:0]	-	R	Object brightness after IIR filter for cursor mode
0	0xD7	PositionFilterAvgY[8]	-	R	Bit[0] Object brightness after IIR filter for cursor mode
0	0xD7	PositionFilterSize[9:8]	-	R	Bit[5:4] Object size after IIR filter for cursor mode
0	0xD8	PositionFilterSize[7:0]	-	R	Object size after IIR filter for cursor mode
0	0xD9	ProcessFilterSize[9:8]	-	R	Bit[1:0] Object size after IIR filter for cursor mode
0	0xD9	ProcessFilterAvgY[8]	-	R	Bit[2] Object brightness before IIR filter for cursor mode
0	0xD9	AbortIntervalCount[9:8]	-	R	Bit[5:4]
0	0xDA	ProcessFilterCenterX[7:0]	-	R	Horizontal Object Center after IIR filter for gesture detection
0	0xDB	ProcessFilterCenterX[11:8]	-	R	Bit[3:0] Horizontal Object Center after IIR filter for gesture detection
0	0xDB	ProcessFilterCenterY[11:8]	-	R	Bit[7:4] Vertical Object Center after IIR filter for gesture detection
0	0xDC	ProcessFilterCenterY[7:0]	-	R	Vertical Object Center after IIR filter for gesture detection
0	0xDD	ProcessFilterSize[7:0]	-	R	Object size after IIR filter for gesture detection
0	0xDE	ProcessFilterAvgY[7:0]	-	R	Object brightness after IIR filter for gesture detection
0	0xDF	AbortIntervalCount[7:0]	-	R	Abort gesture gap duration

7.6 Cursor Mode Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x32	R_CursorUseTop	0x01	R/W	Bit[0] 1: Enable cursor center function, when enable this, the cursor object information would involve R_CursorTopRatio in calculation. Refer to R_CursorTopRatio.
0	0x32	R_CursorUseBGModel	0x00	R/W	Bit[1] 1: If cursor center function is enabling, involve background model in calculation
0	0x32	R_CursorInvertY	0x00	R/W	Bit[2] 1: Horizontal cursor center inverse
0	0x32	R_CursorInvertX	0x01	R/W	Bit[3] 1: Vertical cursor center inverse
0	0x32	R_CursorTopRatio[1:0]	0x02	R/W	Bit[5:4] Use the first R_CursorTopRatio/8 part of the object to calculate center. Ex: If original object size is 100, then the cursor object size would be 25 at R_CursorTopRatio = 2. Also, cursor center would move from center of the object to upper 1/4 part.
0	0x33	R_PositionFilterStartSizeTh [7:0]	0x01	R/W	As object size>this threshold, use the object information after IIR filter for cursor
0	0x34	R_PositionFilterStartSizeTh[8]	0x00	R/W	Bit[0]
0	0x35	R_ProcessFilterStartSizeTh[7:0]	0x01	R/W	As object size>this threshold, use the object information after IIR filter for gesture detection
0	0x36	R_ProcessFilterStartSizeTh[8]	0x00	R/W	Bit[0]
0	0x37	R_CursorClampLeft[4:0]	0x09	R/W	Minimum cursor horizontal center value, if the data is less than this, clamp at 0. Otherwise, clamp at data- (R_CursorClampLeft<<R_PositionResolution) Ex: R_CursorClampLeft=9, R_CursorClampRight=21, R_PositionResolution=0 X=5 => X'=0 X=10 => X'=10-9=1 X=25 => X'=20-1-9=10 Ex: If R_CursorInvertY=0 R_CursorClampRight=20 R_PositionResolution=2

Bank	Address	Register Name	Default Value	R/W	Description
					and Y=50 Then when setting R_CursorInvertY=1, R_CursorClampRight=20 R_PositionResolution=2 $\Rightarrow Y' = 20 \cdot (2^2) - 50 = 30$
0	0x38	R_CursorClampRight[4:0]	0x15	R/W	Maximum cursor horizontal center value, if the data is larger than this, clamp at this -1
0	0x39	R_CursorClampUp[4:0]	0x0A	R/W	Minimum cursor vertical center value, if the data is less than this, clamp at 0 Otherwise, clamp at data- (R_CursorClampUp << R_PositionResolution)
0	0x3A	R_CursorClampDown[4:0]	0x12	R/W	Maximum cursor vertical center value, if the data is larger than this, clamp at this -1
0	0x3B	CursorClampCenterX[7:0]	0x00	R	Clamping Center X[7:0]
0	0x3C	CursorClampCenterX[11:8]	0x7D	R	Bit[3:0] Clamping Center X[11:8]
0	0x3D	CursorClampCenterY[7:0]	0x0F	R	Clamping Center Y[7:0]
0	0x3E	CursorClampCenterY[11:8]	0xA0	R	Bit[3:0] Clamping Center Y[11:8]
0	0x8B	R_Cursor_ObjectSizeTh[7:0]	0x10	R/W	The object size threshold for cursor mode. If cursor object size > this, trigger cursor has object interrupt
0	0x8C	R_PositionResolution[2:0]	0x07	R/W	Object of cursor mode resolution, Ex:(x,y)=(1000,1000) at R_PositionResolution=7 means real (x',y') = $(1000/2^7, 1000/2^7) = (7.8125, 7.8125)$ which maps to 30x30 scale

7.7 Proximity Mode Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x69	R_Pox_UB[7:0]	0xC8	R/W	Proximity Up Bound
0	0x6A	R_Pox_LB[7:0]	0x40	R/W	Proximity Low Bound
0	0x6B	S_State	-	R	PS approach state, S_State. Approach = 1, (S_AvgY >= R_Pox_UB) Not Approach = 0, (S_AvgY <= R_Pox_LB) (Only functional at proximity detection mode)
0	0x6C	S_AvgY[8:1]	-	R	Proximity object average brightness

7.8 EFuse Program Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x70	R_EFuse_A[5:0]	0x00	R/W	Bit[5:0] EFuse Address
0	0x70	R_EFuse_READ	0x00	R/W	Bit[6] EFuse Read
0	0x70	R_EFuse_ENB	0x01	R/W	Bit[7] EFuse Enable
0	0x71	R_EFuse_SEL[2:0]	0x00	R/W	Bit[2:0] EFuse Select
0	0x71	R_PROGRAM_BitsCnt[3:0]	0x00	R/W	Bit[7:4] Program Bit Count
0	0x72	R_EFuse_PROGRAM_En	0x00	R/W	Bit[0] EFuse Program Enable
0	0x72	EFuse_PROGRAM	0x00	R	Bit[7] EFuse Program Identifier
0	0x73	R_EFuse_PROGRAM_CLKCnt[14:8]	0x00	R/W	Bit[7:0] EFuse Program Clock Count
0	0x74	R_EFuse_PROGRAM_CLKCnt[7:0]	0xF0	R/W	Bit[7:0] EFuse Program Clock Count
0	0x75	R_EFuse_PROGRAM_Data[7:0]	0x00	R/W	EFuse Program Data
0	0x76	EFuse_Dout[63:56]	-	R	Bit[7:0] EFuse Data
0	0x77	EFuse_Dout[55:48]	-	R	Bit[7:0] EFuse Data
0	0x78	EFuse_Dout[47:40]	-	R	Bit[7:0] EFuse Data
0	0x79	EFuse_Dout[39:32]	-	R	Bit[7:0] EFuse Data
0	0x7A	EFuse_Dout[31:24]	-	R	Bit[7:0] EFuse Data
0	0x7B	EFuse_Dout[23:16]	-	R	Bit[7:0] EFuse Data
0	0x7C	EFuse_Dout[15:8]	-	R	Bit[7:0] EFuse Data
0	0x7D	EFuse_Dout[7:0]	-	R	Bit[7:0] EFuse Data

7.9 Background Control

Bank	Address	Register Name	Default Value	R/W	Description
0	0x9F	R_UseBGModel	0x01	R/W	Bit[0] Background model enable
0	0x9F	R_BGUseDiffWeight	0x00	R/W	Bit[1] During calculating object center, use the weight between background and pixel.
0	0x9F	R_BGUpdateAtProcess	0x00	R/W	Bit[2] Update background at process state
0	0x9F	R_BGUpdateMaxIntensity_En	0x01	R/W	Bit[3] Background up bound threshold enable
0	0xA0	R_BGUpdateMaxIntensity[7:0]	0x03	R/W	Background up bound threshold. If pixel data is > this*2, update this pixel to BG SRAM
0	0xA1	R_BGFilterLengthUp[1:0]	0x01	R/W	Bit[1:0] The IIR filter weight of updating background not at process state. IIR Filter Out (X: previous data, X':current date) =

Bank	Address	Register Name	Default Value	R/W	Description
					$\{X \cdot 2^{(R_BGFilterLength-1)} + X\} / 2^{R_BGFilterLength}$
0	0xA1	R_BGFilterLengthDown[1:0]	0x10	R/W	Bit[5:4] The IIR filter weight of updating background at process state
0	0xA2	R_BGDiffThd[5:0]	0x08	R/W	Only if the difference between BG and pixel > this, it would be taken as the part of object
0	0xA3	R_BGUpdateFreq[7:0]	0x00	R/W	Update background per this number frames
0	0xA4	R_BGUpdateFreq[9:8]	0x03	R/W	Bit[1:0] Update background per this number frames
0	0xA4	R_BGResolution[1:0]	0x03	R/W	Bit[5:4] Background resolution, BG data = pixel data << R_BGResolution

7.10 Lens Shading Compensation

Bank	Address	Register Name	Default Value	R/W	Description
1	0x04	R_LS_Comp_DAvg_V	0x00	R/W	Bit[7] Lens Shading for digital vertical average
1	0x25	R_LensShadingComp_EnH	0x00	R/W	Lens Shading compensation enable, active high
1	0x26	R_OffsetX[6:0]	0x00	R/W	horizontal offset of lens (s+6, -63~63)
1	0x27	R_OffsetY[6:0]	0x00	R/W	vertical offset of lens (s+6, -63~63)
1	0x28	R_LSC[6:0]	0x40	R/W	A, R2 coefficient, (un-signed, 0~127)
1	0x29	R_LSFT[3:0]	0x0A	R/W	shift amount of A*R2(un-signed, 0~15)

7.11 LED Controls

Bank	Address	Register Name	Default Value	R/W	Description
1	0x30	R_LED_SoftStart_time[7:0]	0x03	R/W	LED soft start time before TS_ab falling
1	0x31	R_LED2_DAC_EnL	0x00	R/W	Bit[5] 0=turn on the LED_DAC2 1=turn off the LED_DAC2
1	0x31	R_LED1_DAC_EnL	0x00	R/W	Bit[4] 0=turn on the LED_DAC1 1=turn off the LED_DAC1
1	0x31	R_LED2_DAC_manual	0x00	R/W	Bit[1] LED2 manual enable, active high 0:TS_LED2_EnL/Tm_LEDC2_DAC controlled by digital

Bank	Address	Register Name	Default Value	R/W	Description
					1:TS_LED2_EnL/Tm_LEDC2_DAC controlled by R_LED2_EnL/R_LED2_DAC_UB
1	0x31	R_LED1_DAC_manual	0x00	R/W	Bit[0] LED1 manual enable, active high 0:TS_LED1_EnL/Tm_LEDC1_DAC are controlled automatically by digital 1:TS_LED1_EnL/Tm_LEDC1_DAC are controlled manually by R_LED1_EnL/R_LED1_DAC_UB
1	0x32	R_LED1_DAC_UB[4:0]	0x14	R/W	LED1 upper bound
1	0x33	R_LED2_DAC_UB[4:0]	0x14	R/W	LED2 upper bound
1	0x34	R_LEDC_Step_Up[4:0]	0x07	R/W	step up : B_LEDC_Step_Up[4:0]=0, let TS_LED1_thermo[30:0] & TS_LED2_thermo[30:0] all current DAC off B_LEDC_Step_Up[4:0]=1, let TS_LED1_thermo[30:0] & TS_LED2_thermo[30:0] starts from thermo<0> sequentially
1	0x35	R_LEDC_Step_Down[4:0]	0x07	R/W	step down : B_LEDC_Step_Up[4:0]=0, let TS_LED1_thermo[30:0] & TS_LED2_thermo[30:0] all current DAC off B_LEDC_Step_Up[4:0]=1, let TS_LED1_thermo[30:0] & TS_LED2_thermo[30:0] starts from thermo<31> sequentially

7.12 Standby Mode

Bank	Address	Register Name	Default Value	R/W	Description
0	0x45	StandbyMode_Status[1:0]	-	R	Indicate operation status, 0: normal, 1: weak standby, 2: deep standby. normal operation: use R_IDLE_TIME for IDLE weak standby: use R_IDLE_TIME_STANDBY_1 for IDLE deep standby:

Bank	Address	Register Name	Default Value	R/W	Description
					use R_IDLE_TIME_STANDBY_2*2 for IDLE See R_IDLE_TIME
0	0x52	R_StandbyAE1[1:0]	0x00	R/W	Bit[7:6] At weak standby, 1:Exp'=Exp*2 , 2:Exp'=Exp*4, other: Exp'=Exp Wake up AE mode setting. Only active under standby status
0	0x52	R_StandbyAE2[1:0]	0x00	R/W	Bit[5:4] At deep standby, 1:Exp'=Exp*2 , 2:Exp'=Exp*4, other: Exp'=Exp Wake up AE mode setting. Only active under standby status
0	0x52	R_StandbyAG1[1:0]	0x00	R/W	Bit[3:2] At weak standby, 1:Gain'=Gain*2, 2:Gain'=Gain*4, other: Gain'=Gain Wake up AE mode setting. Only active under standby status
0	0x52	R_StandbyAG2[1:0]	0x00	R/W	Bit[1:0] At deep standby, Gain'=Gain*2 , 2:Gain' Gain*4, Gain' = Gain Wake up AE mode setting. Only active under standby status
1	0x65	R_IDLE_TIME[7:0]	0x00B4	R/W	idle time for normal operation Unit: T= 256/System CLK = 32us Ex: 1 report time = (77+R_IDLE_TIME)T Report rate 120 fps: R_IDLE_TIME=1/(120*T)-77=183 Report rate 240 fps: R_IDLE_TIME=1/(240*T)-77=53
1	0x66	R_IDLE_TIME[15:8]			
1	0x67	R_IDLE_TIME_STANDBY_1[7:0]	0x0168	R/W	idle time for weak standby In weak standby status, using this idle time. Report Rate = 120*8.333/(0.0323*R_IDLE_TIME_STANDBY_1+X), X=2.41
1	0x68	R_IDLE_TIME_STANDBY_1[15:8]			
1	0x69	R_IDLE_TIME_STANDBY_2[7:0]	0x02D0	R/W	idle time for deep standby, 2X

Bank	Address	Register Name	Default Value	R/W	Description
1	0x6A	R_IDLE_TIME_STANDBY_2[15:8]			In deep standby status, using this idle time*2. Report Rate = $120 * 8.333 / (0.0646 * R_IDLE_TIME_STANDBY_2 + X)$, X=2.41
1	0x6B	R_Obj_TIME_1[7:0]	0x04B0	R/W	Weak standby enter time, unit: one report frame time.
1	0x6C	R_Obj_TIME_1[15:8]			
1	0x6D	R_Obj_TIME_2[7:0]	0x0960	R/W	Deep standby enter time, unit: two report frame time.
1	0x6E	R_Obj_TIME_2[15:8]			
1	0x6F	R_TG_INIT_TIME[7:0]	0x32	R/W	fine tune of idle time for normal operation, unit: 4μs
1	0x71	R_TG_POWERON_WAKEUP_TIME	0x00	R/W	wakeup time after TG_START for Analog CDS power on stable, unit: 4μs
1	0x72	R_TG_EnH	0x00	R/W	TG enable, after setting all parameters, enable this at last.
1	0x73	R_AUTO_STANDBY_Mode1	0x00	R/W	Bit[1:0] The way goes to weak standby, 0: No motion standby, 1: No object standby
1	0x73	R_AUTO_STANDBY_Mode2	0x00	R/W	Bit[3:2] The way goes to deep standby, 1: No object standby
1	0x73	R_AUTO_WakeUP_Mode	0x00	R/W	Bit[5:4] The way to wake up, bit[4]: 0: motion wake up at weak standby, 1: object wake up at weak standby bit[5]: 0: motion wake up at deep standby, 1: object wake up at deep standby
1	0x74	R_WakeUpSig_Sel[1:0]	0x00	R/W	Bit[5:4] 1: GPIO0 output TG_Start signal, 2: GPIO0 output TG_Finish signal

7.13 Clock Controls

Bank	Address	Register Name	Default Value	R/W	Description
0	0x3F	R_oscrpcpd	0x00	R/W	Internal Osc. Control
0	0x5C	R_SenClkPrd[5:0]	0x02	R/W	Analog or TG CLK = System CLK/R_SenClkPrd. System CLK=8MHz
0	0x5D	R_SENCLK_Control	0x00	R/W	Sensor Clock Control
0	0x5E	R_Other_CLK_manual	0x00	R/W	Clock Manual Mode Controls
0	0x5F	R_CLK_manual	0x7F	R/W	Clock Manual Mode Controls
0	0x60	TS_osc_code[6:0]	-	R	OSC code in use

Bank	Address	Register Name	Default Value	R/W	Description
0	0x61	R_osc_code[6:0]	0x34	R/W	OSC code
0	0x63	R_Ref_CLK_Cnt_UB[15:8]	0x03	R/W	OSC bist clock count up bound
0	0x64	R_Ref_CLK_Cnt_UB[7:0]	0xF7	R/W	OSC bist clock count up bound
0	0x65	R_Ref_CLK_Cnt_LB[15:8]	0x03	R/W	OSC bist clock count low bound
0	0x66	R_Ref_CLK_Cnt_LB[7:0]	0xD9	R/W	OSC bist clock count low bound
0	0x67	R_OSC_Wait[7:0]	0x03	R/W	Reference clock sample cycle
0	0x68	T_osc_range[1:0]	0x01	R/W	For Analog Use

7.14 Chip/Version ID

Bank	Address	Register Name	Default Value	R/W	Description
0	0x00	PartID[7:0]	0x20	R	Part ID
0	0x01	PartID[15:8]	0x76	R	
0	0x02	VersionID[7:0]	0x01	R	Version ID

7.15 Suspend/Reset

Bank	Address	Register Name	Default Value	R/W	Description
0	0x03	SW_Suspend_EnL	0x01	W	0: software suspend
0	0xEE	R_RegBank Reset	0x01	W	0: Register Bank 0 reset
0	0xEE	R_TGRegBank_SWRstn	0x01	R/W	0: Register Bank 1 reset
0	0xEE	R_DMSRegBank_SWRstn	0x01	R/W	0: DSP reset

7.16 Test Mode

Bank	Address	Register Name	Default Value	R/W	Description
0	0xE0	R_DSP_TestObj_Size[3:0]	0x01	R/W	Bit[3:0] Test Pattern object size. The square object size is $R_DSP_TestObj_Size^2$.
0	0xE0	R_DSP_Test_Mode[3:0]	0x00	R/W	Bit[7:4] 0: disable test mode 1: reset test mode 2: Object move from LU corner to RU corner 3: Object move from RU corner to LU corner 4: Object move from LU corner to LD corner

Bank	Address	Register Name	Default Value	R/W	Description
					<p>5: Object move from LD corner to LU corner(L,R,U,D corner ref to Addr228~230 note)</p> <p>6: Object move from LU=>RU=>RD=>LD=>LU</p> <p>7: Object move from RU=>LU=>LD=>RD=>RU</p> <p>8: Fix Pattern, object number = $R_DSP_TestObj_Num^2$ Object Position is starting from LU corner.</p> <p>9: Fix Pattern, object number = $R_DSP_TestObj_Num$ Object Position is starting from LU corner.</p>
0	0xE1	R_DSP_TestObj_Hi[7:0]	0x04	R/W	Test Pattern object brightness
0	0xE2	R_DSP_TestObj_Lo[7:0]	0x41	R/W	Test Pattern background
0	0xE3	R_DSP_TestObj_Dist[3:0]	0x06	R/W	<p>Bit[3:0] Test Pattern distance between objects.</p> <p>If object one center is (5,5) and $R_DSP_TestObj_Dist=10$. Then, object two center is (5,15) for horizontal movement or object two center is (15,5) for vertical movement</p>
0	0xE3	R_DSP_TestObj_Speed[3:0]	0x0D	R/W	<p>Bit[7:4] Test Pattern object move speed.</p> <p>If object center is (5,5) at frame one, and $R_DSP_TestObj_Speed = 6$, movement is L to R. Then, object center is (11,5) at frame two.</p>
0	0xE4	R_DSP_TestObj_PosL[5:0]	0x00	R/W	<p>Test Pattern object left position parameter.</p> <p>L corner starting point.</p> <p>Ex: $R_DSP_TestObj_PosL=5$ $R_DSP_TestObj_PosU=6$ $R_DSP_TestObj_Size = 10$ In LU condition, there is a square object from (5,6) to (14,15)</p>
0	0xE5	R_DSP_TestObj_PosR[5:0]	0x8C	R/W	<p>Test Pattern object right position parameter.</p> <p>R corner starting point.</p> <p>Ex: $R_DSP_TestObj_PosR=15$</p>

Bank	Address	Register Name	Default Value	R/W	Description
					R_DSP_TestObj_PosU=6 R_DSP_TestObj_Size = 10 In RU condition, there is a square object from (15,6) to (24,15)
0	0xE6	R_DSP_TestObj_PosU[5:0]	0x4A	R/W	Test Pattern object up position parameter
0	0xE7	R_DSP_TestObj_PosD[5:0]	0x00	R/W	Test Pattern object down position parameter
0	0xE8	R_DSP_TestObj_FrameCnt[5:0]	0x00	R/W	Bit[5:0] Test Pattern gesture frame counter. The active frame number of object movement, which needs to be long enough to cover the movement event. Ex: The object movement: (1,1)=>(1,2)=>(1,3) This frame count should be larger than 3.
0	0xE8	R_DSP_TestObj_Num[1:0]	0x00	R/W	Bit[7:6] Test Pattern object number. In mode 8, R_DSP_TestObj_Num^2 is the number of objects showing on the screen. Otherwise, R_DSP_TestObj_Num is the number of objects showing on the screen.
0	0xE9	R_DSP_Test_Noise_EnH	0x00	R/W	Test Pattern random noise enable. The test pattern would involve random noise

7.17 Reserved Registers List

Bank	Address	Register Name	Default Value	R/W	Description
0	0x5B	Trigger	0x00	R/W	Trigger mode use only, as setting to one, trigger IC to report one frame
0	0x6D	R_SRAM_DS[3:0]	0x04	R/W	SRAM Bist Test
0	0x6E	R_BIST_mode[3:0]	0x00	R/W	
0	0x6F	R_BIST_mode_1[3:0]	0x00	R/W	
0	0x8A	R_LockReg	0x00	R/W	Bit[0] Manually lock the value of specified register
0	0x8A	R_AutoLock	0x10	R/W	Bit[4] Auto lock the value of specified register as read the register

Bank	Address	Register Name	Default Value	R/W	Description
0	0xAA	R_ImageHeight[5:0]	0x1E	R/W	DSP image vertical size
0	0xAB	R_ImageWidth[5:0]	0x1E	R/W	DSP image horizontal size
1	0x00	Cmd_HSize[5:0]	0x1E	R/W	Horizontal size
1	0x01	Cmd_VSize[5:0]	0x1E	R/W	Vertical size
1	0x02	Cmd_HStart[5:0]	0x00	R/W	Horizontal start point
1	0x03	Cmd_VStart[5:0]	0x00	R/W	Vertical start point
1	0x04	Image Skip	0x30	R/W	Bit[5] Cmd_ASkip_V Bit[4] Cmd_ASkip_H Bit[3] Cmd_DAvg_V Bit[1] Cmd_VFlip Bit[0] Cmd_HFlip
1	0x05	Cmd_DebugMode	0x00	R/W	TG debug mode 0: disable (normal mode) 1: ramp 0~255 2: ramp 255~0 3: fixed pattern, Cmd_DebugPattern[8:0]
1	0x06	Cmd_CDS_Timing_Control	0x04B0	R/W	CDS Timing Control
1	0x07	Cmd_CDS_Timing_Control		R/W	CDS Timing Control
1	0x08	Cmd_CDS_Timing_Control	0x0D	R/W	CDS Timing Control
1	0x09	Cmd_CDS_Timing_Control	0x0E	R/W	CDS Timing Control
1	0x0A	Cmd_CDS_Timing_Control	0x0708	R/W	CDS Timing Control
1	0x0B	Cmd_CDS_Timing_Control		R/W	CDS Timing Control
1	0x0C	Cmd_CDS_Timing_Control	0x05	R/W	CDS Timing Control
1	0x0D	Cmd_CDS_Timing_Control	0x0F	R/W	CDS Timing Control
1	0x0E	Cmd_CDS_Timing_Control	0x02	R/W	CDS Timing Control
1	0x0F	Cmd_CDS_Timing_Control	0x12	R/W	CDS Timing Control
1	0x10	Cmd_CDS_Timing_Control	0x02	R/W	CDS Timing Control
1	0x11	Cmd_CDS_Timing_Control	0x02	R/W	CDS Timing Control
1	0x12	Cmd_CDS_Timing_Control	0x00	R/W	CDS Timing Control
1	0x13	Cmd_CDS_Timing_Control	0x01	R/W	CDS Timing Control
1	0x14	Cmd_CDS_Timing_Control	0x05	R/W	CDS Timing Control
1	0x15	Cmd_CDS_Timing_Control	0x07	R/W	CDS Timing Control
1	0x16	Cmd_CDS_Timing_Control	0x05	R/W	CDS Timing Control
1	0x17	Cmd_CDS_Timing_Control	0x07	R/W	CDS Timing Control
1	0x18	Cmd_CDS_Timing_Control	0x01	R/W	CDS Timing Control
1	0x19	Cmd_CDS_Timing_Control	0x04	R/W	CDS Timing Control
1	0x1A	Cmd_CDS_Timing_Control	0x05	R/W	CDS Timing Control
1	0x1B	Cmd_CDS_Timing_Control	0x0C	R/W	CDS Timing Control
1	0x1C	Cmd_CDS_Timing_Control	0x2A	R/W	CDS Timing Control
1	0x1D	Cmd_CDS_Timing_Control	0x01	R/W	CDS Timing Control

Bank	Address	Register Name	Default Value	R/W	Description
1	0x1E	R_TG_Mode	0x00	R/W	Bit[1:0] TG operating mode 0: TG_START followed by 3 frames (OFF -> ON -> OFF) on-(off1+off2)/2 1: TG_START followed by 1 frame (ON/OFF switches) on-off 2: TG_START followed by 1 frame (always ON) on 3: TG_START followed by 1 frame (ON/OFF switches)
1	0x21	R_OnOffNegComp[7:0]	0x00	R/W	pre-compensation for negative of (ON - OFF_avg)
1	0x22	R_OnOffNegComp[8]	0x00	R/W	Bit[0] pre-compensation for negative of (ON - OFF_avg)
1	0x23	R_RowDummyTrailing0_EnH	0x00	R/W	Designed for DSP to cut off object at end of row 0: disable row dummy => output 40x40 1: enable row dummy => output 42x40
1	0x36	R_I2C_AutoResync_EnH	0x01	R/W	I ² C auto re-sync enables, active high
1	0x37	R_I2C_AutoResync_Time[7:0]	0xFF	R/W	time that I2C slave hold SDA after clock in -> re-sync, unit: us, min = 100, max = 255
1	0x38	R_adc_control	0x03	R/W	R_ADC_Control
1	0x39	R_pwrsv_control	0x01	R/W	Power saving mode control
1	0x3A	R_I2CID_Sel[2:0]	0x00	R/W	The I ² C Slave ID is using 7 bit addressing protocol. 0: 0x73 1: 0x13 2: 0x1B 3: 0x23 4: 0x2B 5: 0x5B 6: 0x63 7: 0x6B
1	0x3E	Cmd_DebugPattern[7:0]	0x00	R/W	debug pattern for TG output
1	0x3F	Cmd_DebugPattern[8]	0x00	R/W	Bit[0] debug pattern for TG output
1	0x40	R_cds_mode	0x00	R/W	CDS mode setting
1	0x41	R_dac_control	0x00	R/W	DAC mode setting
1	0x43	R_pga_test	0x00	R/W	Bit[6] PGA test mode
1	0x45	R_adc_test	0x00	R/W	ADC Test mode
1	0x46	R_ScanDAC_Control	0x00	R/W	SCANDAC Test

Bank	Address	Register Name	Default Value	R/W	Description
1	0x47	R_dac_control	0x00	R/W	DAC Control
1	0x48	R_PDN_Test	0x01	R/W	PDN Test Mode
1	0x4A	R_CP_WOI_HSize[5:0]	0x1E	R/W	size of CP image width
1	0x4B	R_CP_WOI_VSize[5:0]	0x1E	R/W	size of CP image height
1	0x4C	R_CP_WOI_HStart[5:0]	0x00	R/W	CP image start column address
1	0x4D	R_CP_WOI_VStart[5:0]	0x00	R/W	CP image start row address
1	0x4E	R_Clamp_control	0xA0	R/W	Clamp Control
1	0x4F	R_WAKE_ivreg_EnL[7:0]	0x80	R/W	power on sequence control timing
1	0x50	R_bgp_control	0x00	R/W	Bgp Control
1	0x51	R_TS_Test	0x00	R/W	TS Mode
1	0x52	R_ref_gen_EnL_Manual	0x00	R/W	1:TS_ref_gen_EnL = R_ref_gen_EnL
1	0x53	R_ref_gen_EnL	0x00	R/W	manual value for TS_ref_gen_EnL
1	0x54	R_ref_gen_forceNoPwrsv_EnH	0x00	R/W	TS_ref_gen_EnL force no power saving
1	0x57	R_WAKE_tg_EnL[7:0]	0x80	R/W	power on sequence control timing
1	0x59	T_ab_blk_EnH	0x01	R/W	ab block function enable
1	0x5A	T_cds_asout_EnH	0x00	R/W	probe out R_gcout through I/O
1	0x5B	T_pixbias[2:0]	0x04	R/W	select 1st source follow bias
1	0x5C	T_pxoset_EnH	0x01	R/W	enable pxoset
1	0x5D	T_tg_allow_EnH	0x00	R/W	Bit[7]all tg turn off
1	0x5E	T_clamp_drv_ctl[1:0]	0x01	R/W	Bit[7:6]Constant gm clamp circuit driver NMOS number select
1	0x5F	T_vdda28_lv[2:0]	0x04	R/W	VDDA28 voltage select: 2.5, 2.58, 2.65, 2.72, 2.82, 2.92, 3.02, 3.18
1	0x60	T_vrtb_shift[1:0]	0x01	R/W	"Vrt-Vrb" voltage com selection: 0.85V, 0.8V, 0.75V, 0.7V
1	0x61	T_flush_lv[2:0]	0x04	R/W	flush voltage selection : 0.8v, 0.9v, 1.0v, 1.1v, 1.2v, 1.3v, 1.4v, 1.5v
1	0x63	T_adc_vcmtest_EnH	0x00	R/W	ADC vcm test signal control
1	0x64	T_GPIO_OPDRV[1:0]	0x00	R/W	Bit[3:2] GPIO driver capability setting.
1	0x74	R_Control_Mode[2:0]	0x00	R/W	Bit[2:0] 0: normal mode 1: wake up mode. 2: Slave gesture mode. 3: Master Cursor Mode 4: Slave Cursor Mode 5: PS Mode
1	0x74	R_GPIO_Probe_En	0x00	R/W	Bit[7:6] GPIO debug probe select, to use this probe, set GPIO as output.
1	0x75	T_ckt_test0	0x00	R/W	Test Circuit
1	0x76	T_I2C_OPDRV[1:0]	0x01	R/W	I ² C driver capability setting.

Bank	Address	Register Name	Default Value	R/W	Description
					T_I2C_OPDRV<1:0>=1
1	0x77	R_SRAM_Read_EnH	0x00	R/W	SRAM read enable, active high
1	0x7C	R_SPIOUT_PXDNUM[7:0]	0x0384	R/W	SPI output pixel amount
1	0x7D	R_SPIOUT_PXDNUM[15:8]		R/W	
1	0x7E	R_SPIOUT_CSN_Mode[1:0]	0x00	R/W	Bit[3:2] 0: follow TG_VsyncO 1: follow IDLE time 2: follow LED 3: reserved
1	0x7E	R_SPIOUT_EnH	0x00	R/W	Bit[0] SPI output enable, active high

8.0 Firmware Guides

This chapter describes how to implement firmware for PAJ7620U2 and the functional applications.

8.1 Initialization of PAJ7620U2

1. Power on the PAJ7620U2 sensor chip. The V_{BUS} must be powered on before V_{DD} .
2. Wait 700 μ s for PAJ7620U2 to stabilize.
3. Write slave ID or I²C read command to process I²C wake-up. It is recommended to read Reg_0x00 for return value of "0x20" to indicate that the wake-up process is completed. There is no-ack from PAJ7620U2 before wake-up process is ready.
4. Write initialization setting to sensor
unsigned char initial_register_array[][2] = {

```
{0xEF,0x00},  
{0x41,0xFF},  
{0x42,0x01},  
{0x46,0x2D},  
{0x47,0x0F},  
{0x48,0x80},  
{0x49,0x00},  
{0x4A,0x40},  
{0x4B,0x00},  
{0x4C,0x20},  
{0x4D,0x00},  
{0x51,0x10},  
{0x5C,0x02},  
{0x5E,0x10},  
{0x80,0x41},  
{0x81,0x44},  
{0x82,0x0C},  
{0x83,0x20},  
{0x84,0x20},  
{0x85,0x00},  
{0x86,0x10},  
{0x87,0x00},  
{0x8B,0x01},  
{0x8D,0x00},  
{0x90,0x0C},  
{0x91,0x0C},  
{0x93,0x0D},  
{0x94,0x0A},  
{0x95,0x0A},  
{0x96,0x0C},  
{0x97,0x05},  
{0x9A,0x14},  
{0x9C,0x3F},  
{0x9F,0xF9},  
{0xA0,0x48},  
{0xA5,0x19},
```

```
{0xCC,0x19},  
{0xCD,0x0B},  
{0xCE,0x13},  
{0xCF,0x62},  
{0xD0,0x21},  
{0xEF,0x01},  
{0x00,0x1E},  
{0x01,0x1E},  
{0x02,0x0F},  
{0x03,0x0F},  
{0x04,0x02},  
{0x25,0x01},  
{0x26,0x00},  
{0x27,0x39},  
{0x28,0x7F},  
{0x29,0x08},  
{0x30,0x03},  
{0x3E,0xFF},  
{0x5E,0x3D},  
{0x65,0xAC},  
{0x66,0x00},  
{0x67,0x97},  
{0x68,0x01},  
{0x69,0xCD},  
{0x6A,0x01},  
{0x6B,0xB0},  
{0x6C,0x04},  
{0x6D,0x2C},  
{0x6E,0x01},  
{0x72,0x01},  
{0x73,0x35},  
{0x74,0x00},  
{0x77,0x01},  
{0xEF,0x00},  
};
```

8.2 Get Gesture Result

1. Set up the Interrupt or I²C polling timer.
2. Read Bank_0_Reg_0x43/0x44 for gesture result if interrupt or timer is triggered.

Note: Gesture result will be cleared after I²C read access.

8.3 Change to PS Mode

Write PS mode setting.

```
unsigned char change_to_proximity_register_array[][2] = {  
    {0xEF,0x00},  
    {0x41,0x00},  
    {0x42,0x02},  
    {0x48,0x20},  
    {0x49,0x00},  
    {0x51,0x13},  
    {0x83,0x00},  
    {0x9F,0xF8},  
    {0x69,0x96},  
    {0x6A,0x02},  
    {0xEF,0x01},  
    {0x01,0x1E},  
    {0x02,0x0F},  
    {0x03,0x0F},  
    {0x04,0x02},  
    {0x41,0x50},  
    {0x43,0x34},  
    {0x65,0xCE},  
    {0x66,0x0B},  
    {0x67,0xCE},  
    {0x68,0x0B},  
    {0x69,0xE9},  
    {0x6A,0x05},  
    {0x6B,0x50},  
    {0x6C,0xC3},  
    {0x6D,0x50},  
    {0x6E,0xC3},  
    {0x74,0x05},  
};
```

8.4 Get PS Approach Status

Read Bank_0_Reg_0x6B for PS approach status or read Bank_0_Reg_0x6C for PS raw data.

8.5 Change to Gesture mode

Write Gesture mode setting to gesture.

```
unsigned char change_to_gesture_register_array[][2] = {  
    {0xEF,0x00},  
    {0x41,0x00},  
    {0x42,0x00},  
    {0xEF,0x00},  
    {0x48,0x3C},  
    {0x49,0x00},  
    {0x51,0x10},  
    {0x83,0x20},  
    {0x9F,0xF9},  
    {0xEF,0x01},  
    {0x01,0x1E},  
    {0x02,0x0F},  
    {0x03,0x0F},  
    {0x04,0x02},  
    {0x41,0x40},  
    {0x43,0x30},  
    {0x65,0xAC},  
    {0x66,0x00},  
    {0x67,0x97},  
    {0x68,0x01},  
    {0x69,0xCD},  
    {0x6A,0x01},  
    {0x6b,0xb0},  
    {0x6c,0x04},  
    {0x6D,0x2C},  
    {0x6E,0x01},  
    {0x74,0x00},  
    {0xEF,0x00},  
    {0x41,0xFF},  
    {0x42,0x01},  
};
```

8.6 Enter Suspend mode

Write Suspend mode setting to gesture.

```
unsigned char suspend_register_array[][2] = {  
    {0xEF,0x01},  
    {0x72,0x00},  
    {0xEF,0x00},  
    {0x03,0x01},  
};
```

8.7 Resume to Gesture Mode

1. Write slave ID or I²C read command to process I²C wake-up.

It is recommended to read Reg_0x00. It will return "0x20" when wake-up finish.

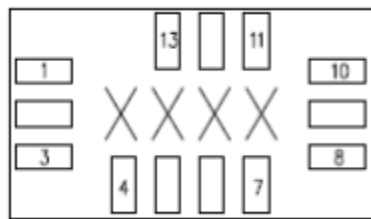
By the way, there is no-ack from PAJ7620U2 before wake-up finish.

2. Write Resume setting to gesture.

```
unsigned char resume_register_array[][2] = {  
    {0xEF,0x01},  
    {0x72,0x01},  
    {0xEF,0x00},  
    {0x5E,0x12},  
    {0xEE,0x03},  
    delay(500); //delay 500us  
    {0xEE,0x07},  
    {0x5E,0x10},  
};
```

9.0 Handling Information

9.1 Marking Information



Marking instruction
1. 4 characters
2. Content: PXI Datecode

Figure 33. Package Marking

9.2 Recommend Layout Information

9.2.1 Pad Dimension on PCB/FPC

9.2.1.1 Pad Size Design

- If use solder mask defined (SMD), pad size mean solder mask opening size.
- If use non-solder mask defined (non-SMD), pad size mean copper metal size.
- Recommended Dimension of Pad is same as PAJ7620U2 module.

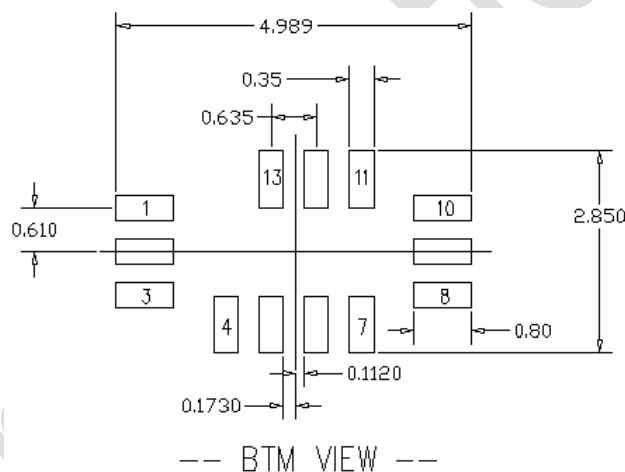


Figure 34. Recommended Dimension of Pad (All dimension is mm)

9.2.2 Trace Routing Specification

1. Recommended the trace width of VDD and VBUS are at least 20mil.
2. Recommended the trace width of VLED is at least 40mil.
3. Recommended the trace follows 3W rule.

9.2.3 FPC Additional Recommendation

Recommended SMT process, stencil thickness from 0.1 to 0.12 mm.

1. The stencil thickness selection will need to consider passive component around the sensor.
2. For surface mounted sensor on FPC, the cover layer and adhesive layer total thickness recommended to be less than 40 μm .

9.2.4 Stiffener Design of FPC

For FPC board design, a stiffener at the FPC bottom is required to strengthen the board.

Recommended stiffener dimension:

1. FR4 with minimum thickness of 0.4mm.
2. Stainless steel with minimum thickness 0.15mm.

9.3 Packing Information

9.3.1 Packing method

- Using 2-inch tray, Module orientation should follow Figure 35 definition.
- Stack 10 trays with one cover tray in a bunch. (see Figure 36)

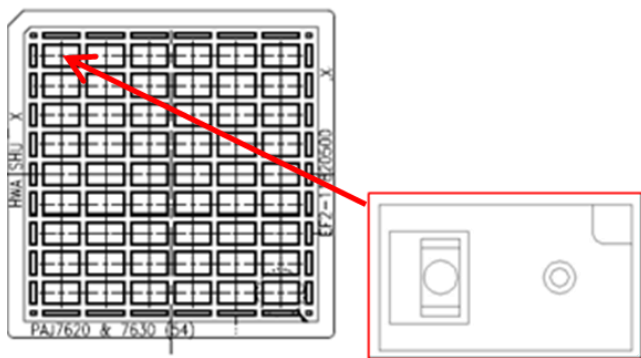


Figure 35. Module Orientation



Figure 36. Stack 10 +1 Tray

- Pack 2 bunches of trays into one aluminum laminate moisture proof bag. (see Figure 37)
- Pack 5 aluminum bags into a packing box (see Figure 38)



Figure 37. Al Packing Bag



Figure 38. Packing Box Recommended PCB Layout

- The maximum capacity of one packing box using tray of PAJ7620U2 :

One packing box	5400 units
Remark	(54ea per tray * 100 tray per box)

9.3.2 Reminder Notes

- Please tap gently on the cover before open the 2"-tray.



Figure 39. Handling Reminder

- When the units are out of dry packing, the units should be kept at : Temperature = $\leq 30^{\circ}\text{C}$, Humidity = $\leq 60\%$ RH
- If units are out of dry packing over 168hrs, before go through IR reflow process, the units must be baked with $125 \pm 5^{\circ}\text{C}$ @24hrs, to remove moisture.
- There are 2 kinds of material type of PAJ7620U2 2-inch tray:
 - For PPE+CP material type (Tray color is "Black"), the type of tray can be baked at 125°C .
 - For ABS material type (Tray color is "Gray"), the type of tray is not heat resistant. To dry packages at high temperatures, therefore remove products from tray and place them in metal or other suitable carrier before baking.



Figure 40. PPE+CP Tray (Black color)



Figure 41. ABS Tray (Gray color)

9.4 Handling Precaution for the Prevention of ESD

The following procedures MUST be taken care of in the PCB fabrication to prevent the electrostatic destruction of semiconductor devices. These are the rules must be obeyed.

9.4.1 General Rules

1. Equalize potentials of terminals when transporting or storing.
2. Equalize the potentials of the electric device, work table, and operator's body that may come in contact with the IC's.
3. Prepare an environment that does not generate static electricity. One method is keeping relative humidity in the work room to about 50%.

9.4.2 Operator

1. The operator should wear wrist straps and must maintain electric contact with bare skin.
2. Wear cotton or antistatic-treated materials clothes and gloves.
3. When a conductive mat will be used, must be ware conductive shoes.
4. Do not touch the IC's leads. Touch the body of IC's when holding.

9.4.3 Equipment and Tools

1. Any electrical equipment and tools located on the work table surface must be isolated from the work table surface, and ground any equipment and tools that are being used.
2. Work table surface must use conductive material or conductive mat and should be grounded through a 1M Ω resistor.

9.4.4 Transporting, Storing and Packing

Use conductive IC's tray, and conductive or shielding bag to store module.

9.4.5 Soldering Operation

1. Use a soldering iron with a grounding wire.
2. When perform manual soldering operation, the operator should wear wrist straps.
3. DO NOT use the de-soldering pump when removing the module from the PCB board. Use a solder-wick or equivalent instead.

Revision History

Revision Number	Date	Description
1.0	13 Feb 2015	Released version
1.1	15 Jan 2016	Updated to new template format
1.2	29 Feb 2016	Added Handling Information
1.3	21 Sep 2020	1. Updated Package Dimension tolerance 2. Add the distance from the ink center to the Sensor module
1.4	04 Jan 2021	Updated initial settings
1.5	05 Jan 2022	1. Add more detailed Gesture mode control register description 2. Updated initial settings 3. The word "sleep" is converted to "standby" 4. Updated "9.0Handling Information"