PAW3212DB-TJDT

ULTRA LOW POWER WIRELESS MOUSE SENSOR

Lead (Pb) Free
RoHS 6 fully
compliant

General Description

The PixArt PAW3212DB-TJDT is optimized for red LED based wireless mouse applications. It has low power architecture, high precision surface tracking ability, automatic power management modes, flexible programmable resolutions, configurable sleep and wake-up time which make it suitable for power-sensitive wireless mouse application. The PAW3212DB-TJDT is capable of high-speed motion detection up to the velocity of 30 inches/sec and acceleration of 10g.

General Features

- Single power with wide voltage range
  Low Voltage Segment : 1.7V to 2.1V (VDD, VDDA short)
  High Voltage Segment : 2.1V to 3.6V (VDDA should connect a capacitor to GND)
- Selectable 3-wired (default) or 2-wired SPI serial interface
- Selectable 8-bit (default) or 12-bit motion data length for Delta_X and Delta_Y
- Selectable resolution up to 2400cpi with 38 cpi/ step (based on x1 lens magnification)
- Motion detection interrupt output
- Tracking speed up to 30ips (inches/sec) and 10g acceleration
- Built-in Low Power Timer (LPT) for Sleep1/ Sleep2/ Sleep3[1] mode
- Adaptive frame rate control for extra power saving during moving at different speeds

Key Specifications

Supply Voltage	1.7V ~ 2.1V (VDD,VDDA short) 2.1V ~ 3.6V (VDDA should connect a capacitor to GND)
Interface	3-wired or 2-wired SPI Max clock speed : 2 MHz
Tracking Speed	Up to 30ips
Acceleration	Up to 10g
CPI Resolution	Up to 2400cpi with 38 cpi/step
Frame Rate	Adaptive frame rate Max : 4000 fps (frames per sec)
Operating Current	VDD=2.7V Run Avg : 0.25mA[2] Sleep1 : 16uA Sleep2 : 7uA Sleep3 : 4uA Power down : 3uA * Not including LED current
Package	iDIP 8

Note :
1. In default, Sleep3 is not enabled and it can be enabled by changing the setting in register 0x06 through SPI interface
2. An average current based on 85% weighting for sensor moving at speed ≦5ips and 15% weighting for speed >5ips

1. Functional Block Diagram and Operation

PAW3212DB-TJDT is a high performance and ultra low power CMOS-processed optical image sensor with integrated digital image process circuits. It is based on an optical navigation technology which measures changes in position by optically acquiring sequential surface images (frames) and mathematically determining the speed, the direction and the magnitude of motion. The displacement delta_X and delta_Y information are available in registers which are accessible through SPI serial interface. A host controller reads and translates the data from the SPI serial interface into RF signals before sending them to the host PC. The word "sensor", instead of PAW3212DB-TJDT, is used in the document.

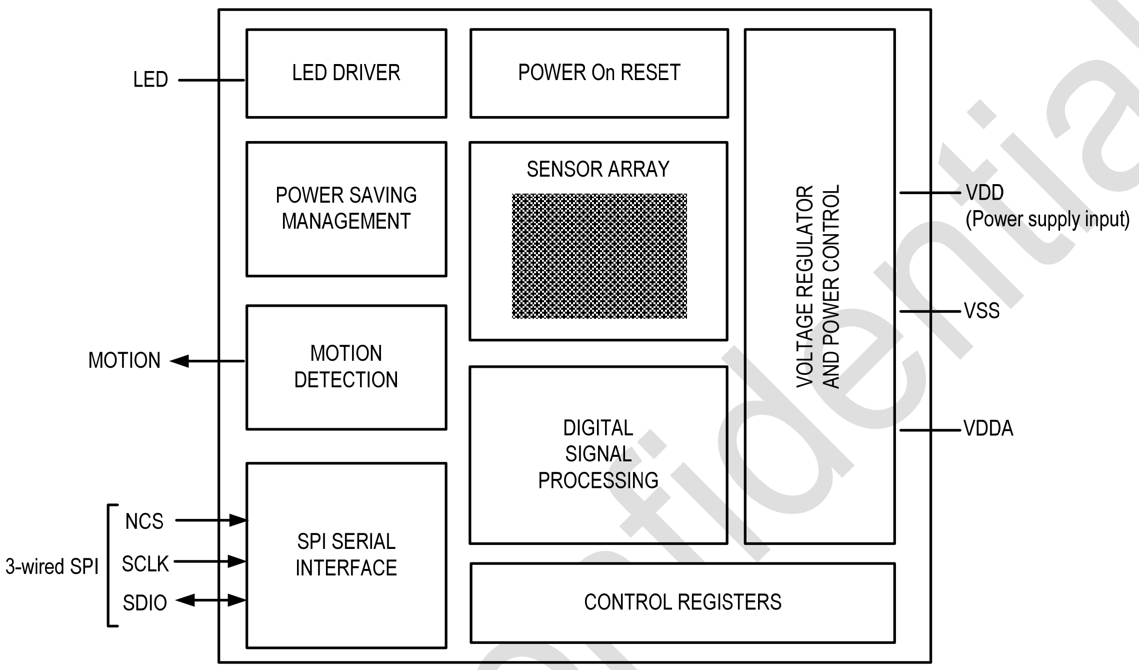


Figure 1. Function Block Diagram

2. Pin Descriptions and Sensor Orientation

Pin Descriptions

Pin	Name	Type	Definition
1	NCS	IN	Chip select for 3-wire SPI (active low). When using 2-wire SPI, this pin should tie to low
2	MOTION	OUT	Motion detection output (active low output)
3	SDIO	I/O	Bi-directional I/O for SPI
4	SCLK	IN	Clock input for SPI
5	LED	OUT	LED control
6	VSS	GND	Chip ground
7	VDD	PWR	VDD is the power supply input High Voltage Segment (VDD : 2.1V ~ 3.6V) : in this case, VDDA is the 1.8V regulator output and should connect a 4.7uF capacitor to GND. Low Voltage Segment (VDD : 1.7V ~ 2.1V) : VDDA should connect to VDD directly.
8	VDDA	PWR	

Sensor Orientation

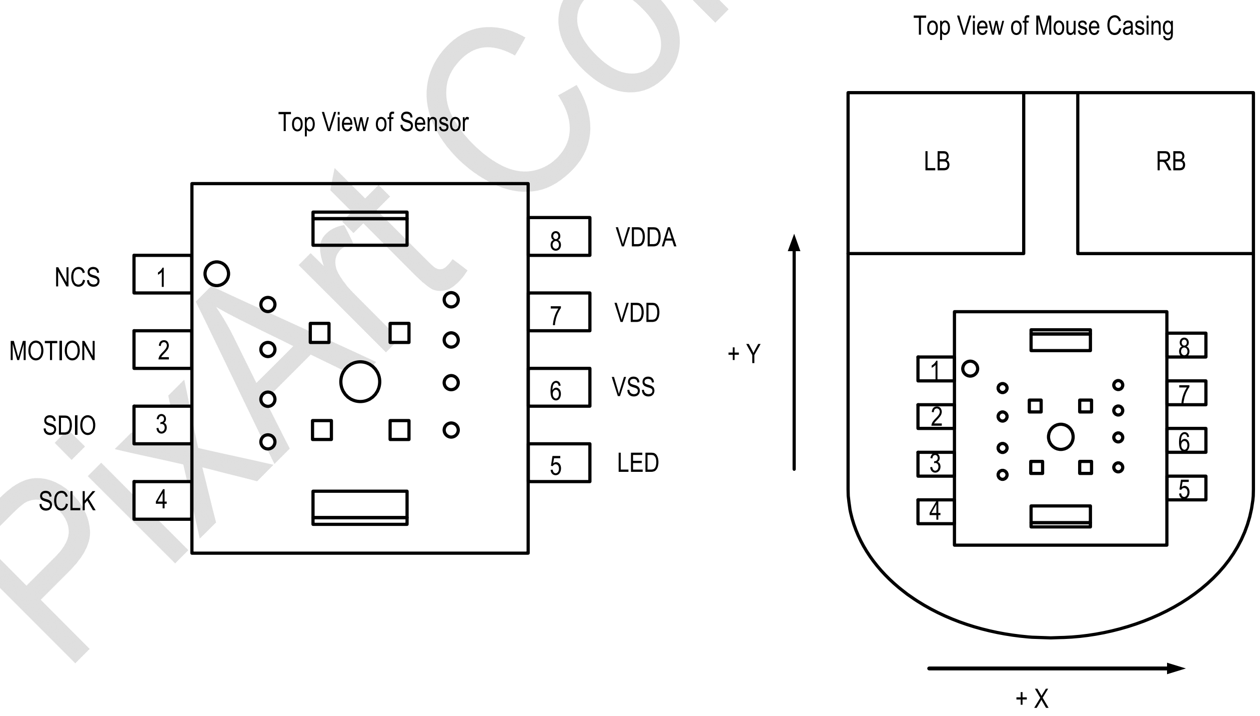


Figure 2. Orientation Relationship between Sensor and Mouse

3. Z and 2D/3D Assembly

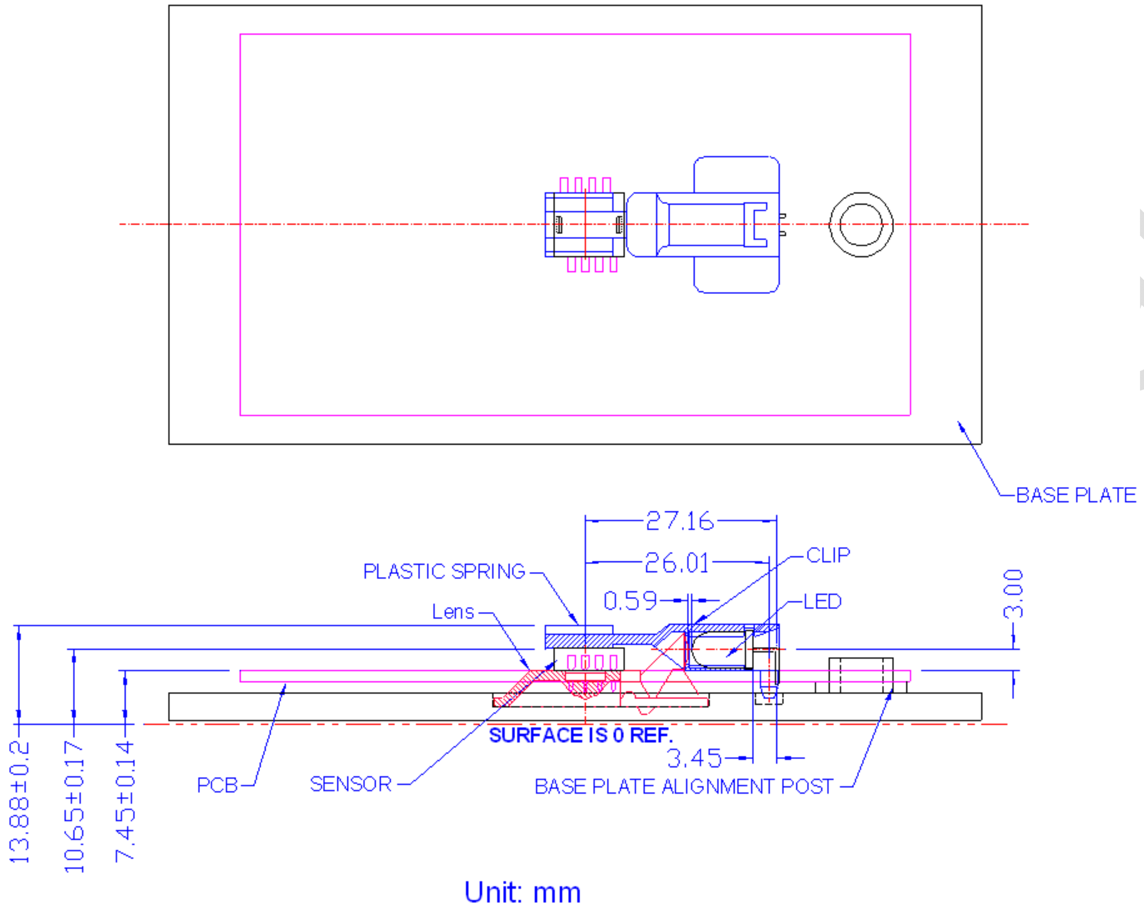


Figure 3. 2D Assembly

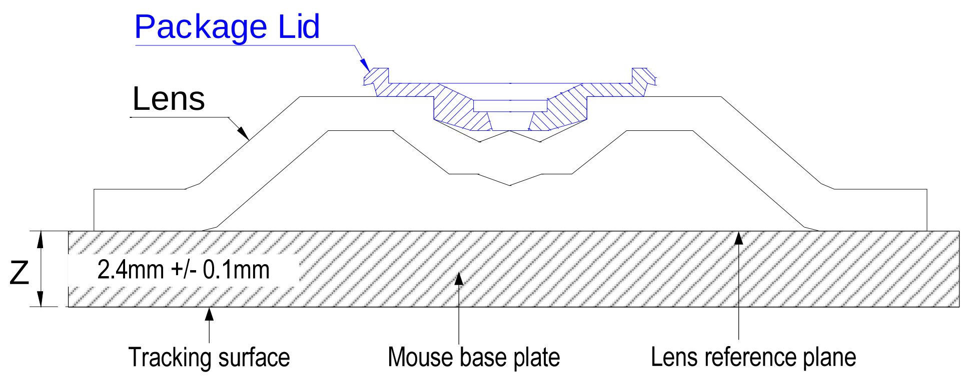
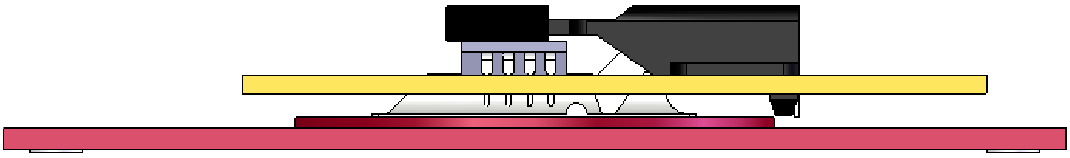


Figure 4. Distance from Lens Reference Plane to Tracking Surface



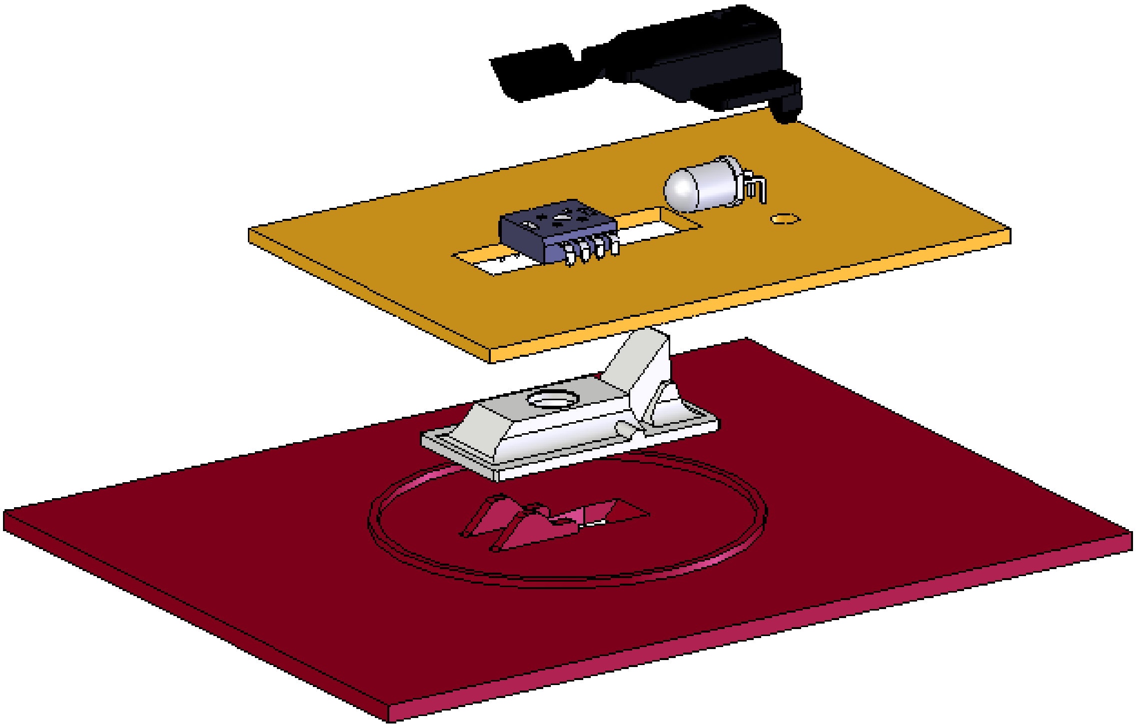
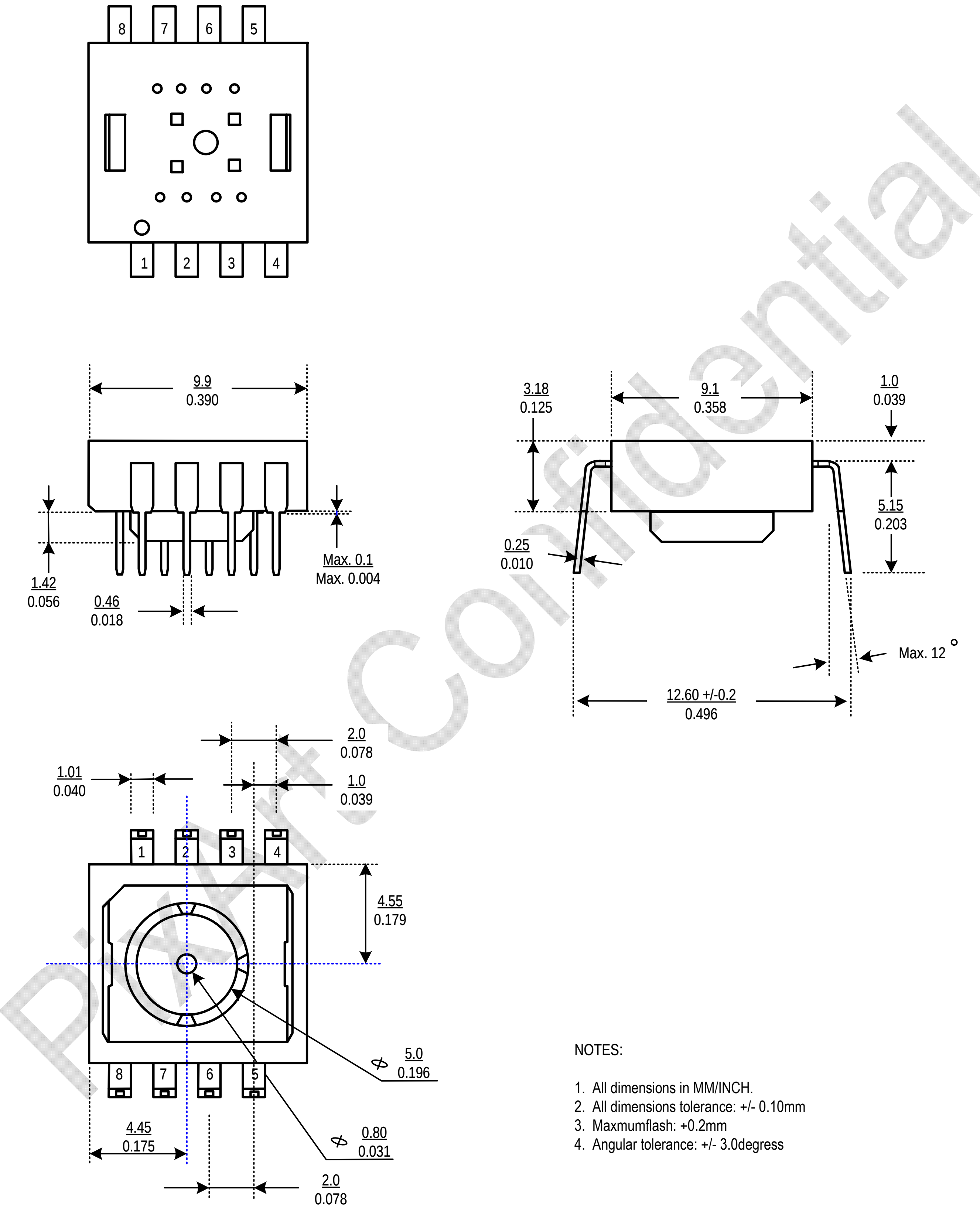


Figure 5. 3D Assembly for Mounting Instructions

4. Package Information

Package Outline Drawing



NOTES:

1. All dimensions in MM/INCH.
2. All dimensions tolerance: +/- 0.10mm
3. Maxmumflash: +0.2mm
4. Angular tolerance: +/- 3.0degress

Figure 6. Package Outline Drawing

Recommended PCB Mechanical Cutouts and Spacing

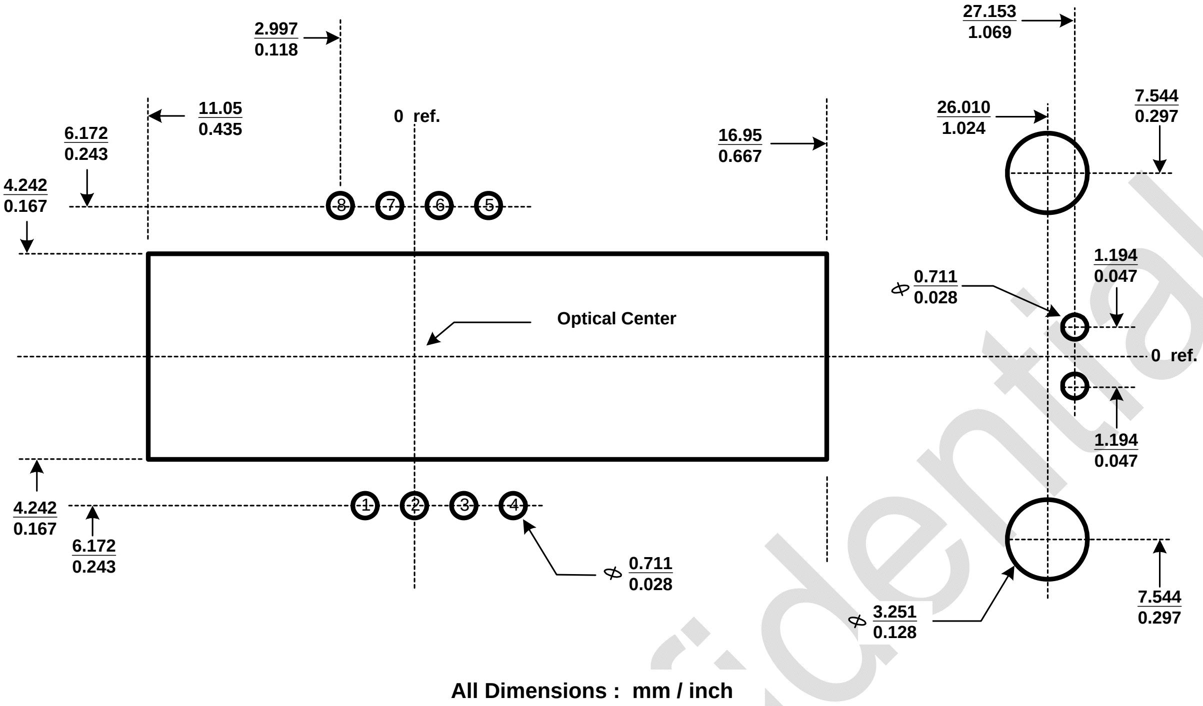


Figure 7. Recommended PCB Mechanical Cutouts and Spacing

5. Reference Circuit Schematics

The reference circuit below is an example for a wireless red LED based mouse application with single AA or AAA battery, a DC/DC output at 2.7V and a Nordic RF IC as a host controller. This example is designed based on the High Voltage Segment configuration (2.1V ~ 3.6V).

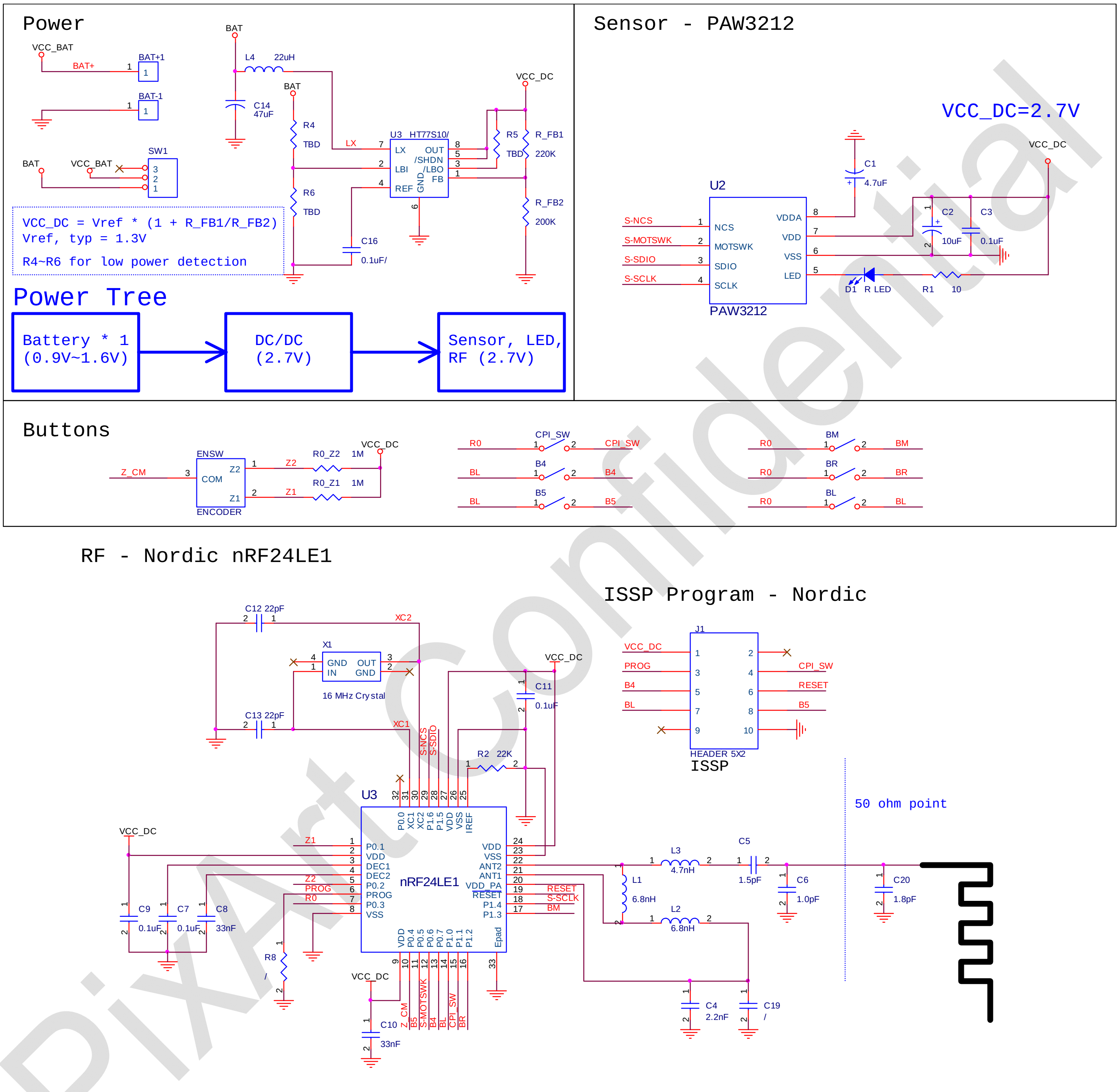


Figure 8. One Battery Application with DC/DC Output at 2.7V

6. Specifications

Absolute Maximum Ratings

Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are the stress ratings only and functional operation of the device at these or any other condition beyond those indicated for extended period of time may affect device reliability.

Symbol	Parameter	Min	Max	Unit	Notes
T_{STG}	Storage Temperature	-40	85	°C	
TA	Operating Temperature	-15	55	°C	
V_{DC}	DC Supply Voltage	-0.2	2.3	V	For Low Voltage Segment
		-0.3	3.9	V	For High Voltage Segment
V_{IN}	DC Input Voltage	-0.3	V_{DC}	V	All I/O pin
	Lead Solder Temp	-	260	°C	For 10 seconds, 1.6mm below seating plane.
ESD		-	2.0	kV	All pins, human body model MIL 883 Method 3015

Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit	Notes
T_A	Operating Temperature	0	-	40	°C	
V_{DD}	Power Supply Voltage	1.7	1.8	2.1	V	Low Voltage Segment
		2.1	2.7	3.6		High Voltage Segment
V_{NPP}	Supply Noise	-	-	100	mV	Peak to peak voltage within 10kHz - 80 MHz
SCLK	SPI Clock Frequency	-	-	2	MHz	
FR	Frame Rate	-	4000	-	frames/s	@ Run mode, +/- 5% tolerance
SP	Tracking speed	0	-	30	inches/s	
AC	Tracking acceleration	0	-	10	g	

AC Operating Conditions

Electrical Characteristics over recommended operating conditions. Typical values at 25 °C, V_{DD} = 2.7 V.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Notes
F_{SCLK}	SCLK frequency	-	-	2	MHz	SPI max. operation frequency
t_{NCSPU}	NCS Low Time After Power-up	1	-	-	ms	NCS min. low time after power-up
$t_{SCLK-HI}$	SCLK High Time	250	-	-	ns	SCLK min. high time
$t_{SCLK-LO}$	SCLK Low Time	250	-	-	ns	SCLK min. low time
$t_{NCS-LEAD}$	NCS Enable Lead Time	1	-	-	us	From NCS falling to first SCLK falling
$t_{NCS-LAG}$	NCS Enable Lag Time	1	-	-	us	From Last SCLK rising to NCS rising
t_{NCS-HI}	NCS min. High Time	2	-	-	us	From previous NCS rising to next NCS falling
$t_{SETUP-WR}$	SDIO Write Setup Time	250	-	-	ns	SDIO data valid before SCLK rising
$t_{HOLD-WR}$	SDIO Write Hold Time	250	-	-	ns	SDIO data valid after SCLK rising
t_{DLY-RD}	SDIO delay after SCLK	-	-	50	ns	From SCLK falling to SDIO data valid, no load conditions
$t_{HOLD-RD}$	SDIO Read Hold Time	250	-	-	ns	SDIO data valid after SCLK rising
t_{SDIO-R}	SDIO Rise Time	-	30	-	ns	@C_L = 30 pF
t_{SDIO-F}	SDIO Fall Time	-	30	-	ns	@C_L = 30 pF
t_{RESYNC}	SPI Re-Sync pulse width	1.0	-	-	us	Only for 2-wired SPI
t_{WDT}	SPI Watch Dog Timer	1.7	-	-	ms	Only for 2-wired SPI
t_{QB}	Quick Burst Pulse Width	2	-	100	us	Only for 2-wired SPI

DC Electrical Characteristics

Electrical Characteristics over recommended operating conditions. Typical values at 25 °C, V_{DD} = 2.7 V (Not including LED current)

Symbol	Parameter	Min.	Typ.	Max.	Unit	
Operation current of VDD pin						
I_{DDNM}	Run mode Current	-	250	-	uA	85% weighting for speed ≦5ips and 15% weighting on speed >5ips
I_{DDS1}	Sleep1 Current	-	16	-	uA	Based on the setting in register 0x0A Slp1_Freq[3:0] =7 (32ms)
I_{DDS2}	Sleep2 Current	-	7	-	uA	Based on the setting in register 0x0B Slp2_Freq[3:0] = 1 (128ms)
I_{DDS3}	Sleep3 Current	-	4	-	uA	Based on the setting in register 0x0C Slp3_Freq[3:0] = 7 (512ms)
I_{DDPD}	Power Down Current	-	3	-	uA	
NCS, SCLK, SDIO, MOTION pins						
V_{IH}	Input Voltage High	VDD*0.7	-	-	V	
V_{IL}	Input Voltage Low	-	-	VDD*0.3	V	
V_{OH}	Output Voltage High	VDD-0.4	-	-	V	@I_{OH} = 2mA
V_{OL}	Output Voltage Low	-	-	0.4	V	@I_{OL} = 2mA
LED pin						
V_{OL}	Output Voltage Low	-	-	100	mV	@I_{OL} = 10mA
I_{LEDS}	LED Sink Current	-	-	50	mA	

7. Power Supply Configuration

The sensor has 2 segments for power supply configuration, the High Voltage Segment and the Low Voltage Segment. With these two segments, the sensor provides the flexibility to applications with different power consideration. For High Voltage Segment, which means the power supply voltage ranges from 2.1V to 3.6V, the power pins VDD and VDDA of the sensor should be connected as shown in Figure 9. For Low Voltage Segment, which means the power supply voltage ranges from 1.7V to 2.1V, the power pins VDD and VDDA of the sensor should be connected as shown in Figure 10.

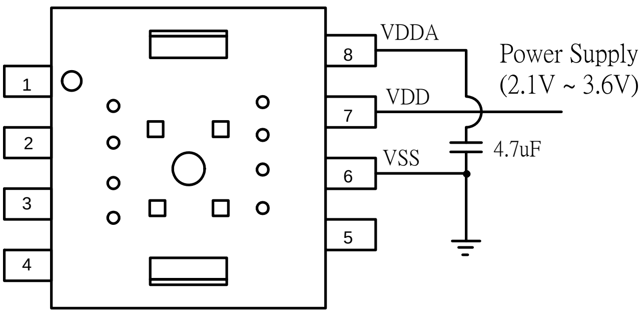


Figure 9. High Voltage Segment

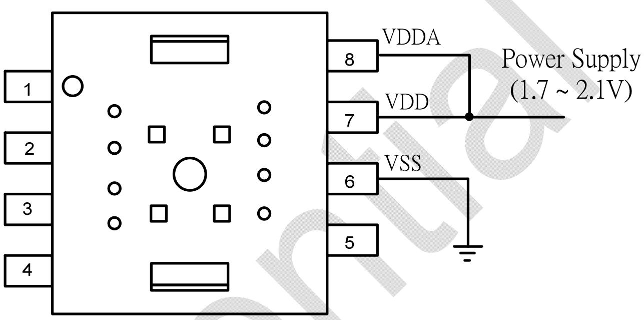


Figure 10. Low Voltage Segment

The sensor's power-up default settings are for the High Voltage Segment. If users want to use the Low Voltage Segment, one sensor register (address 0x4B) should be set (value 0x40) after the power-up sequence. If this register is not set properly, the sensor would consume extra power due to the current leakage of the internal regulator.

Write address 0x09 = 0x5A; *to disable Write Protect*
Write address 0x4B = 0x04; *to turn off internal regulator for Low Voltage Segment*
Write address 0x09 = 0x00; *to enable Write Protect*

8. 3-wired SPI Serial Interface

The sensor supports 3-wired Serial Peripheral Interface (SPI). The host controller can use the SPI to write and read registers in the sensor, and to read out the motion information. The host controller always initiates communication; the sensor never initiates data transfers. NCS, SCLK and SDIO may be driven directly by the host controller. SDIO may also be driven by the sensor when data is read out from sensor registers.

- NCS : Chip select input (active low). NCS needs to be low to activate the SPI; otherwise, SDIO will be at high-Z state and SCLK will be ignored. NCS can also be used to reset the SPI in case a communicational error happens.
- SCLK : Clock input. It is always generated by the host controller.
- SDIO : Bi-directional input/output data

NCS Low at Power-up Stage

In order to keep the 3-wired SPI function work correctly, the host controller MUST force NCS pin to low during the power-up stage and continues forcing for at least 1ms after the VDD power is stable. The host controller should always keep NCS pin high when SPI interface is idle.

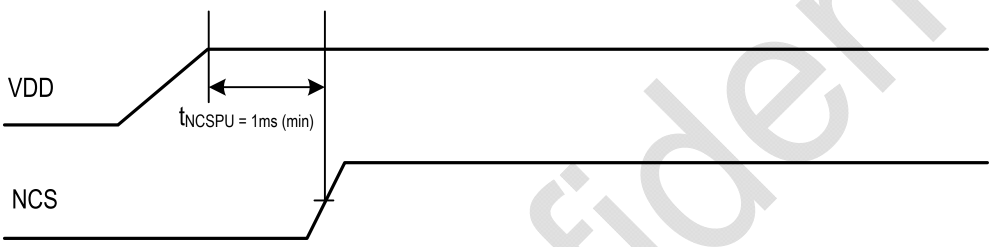


Figure 11. NCS Low at Power-up Sequence

Transmission Protocol

The transmission protocol is a 3-wired link, half duplex protocol between the host controller and the sensor. All data changes on SDIO are initiated by the falling edge on SCLK. The host controller always initiates communication; the sensor never initiates data transfers. The transmission protocol consists of the following two operation modes.

- Write Operation
- Read Operation

Both of the two operation modes consist of two bytes. The first byte contains the address (seven bits) and has a bit-7 as its MSB to indicate data direction. The second byte contains the data.

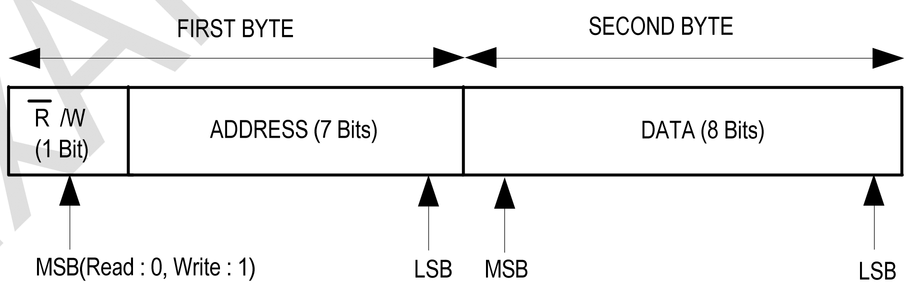


Figure 12. Transmission Protocol

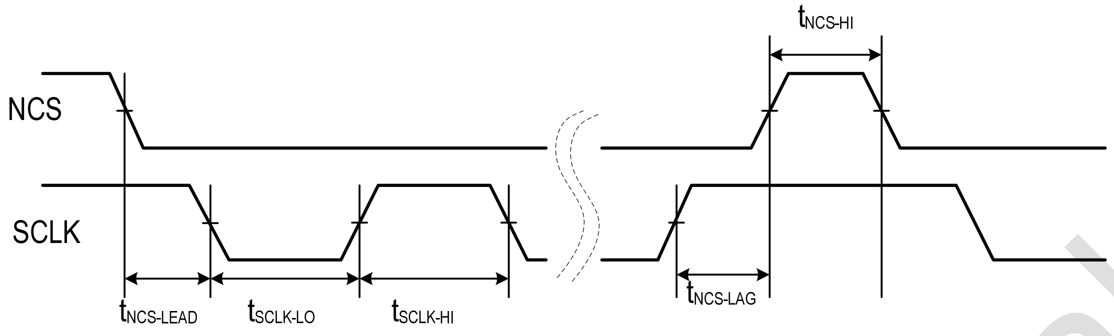


Figure 13. NCS vs SCLK Timing Requirement

Write Operation

A write operation, defined as data is going from the host controller to the sensor, is always initiated by the host controller and consists of two bytes. The first byte contains the address (seven bits) and has a "1" as its MSB to indicate data direction. The second byte contains the data. The communication is synchronized by SCLK. The host controller changes SDIO on the falling edges of SCLK and the sensor reads SDIO on the rising edges of SCLK.

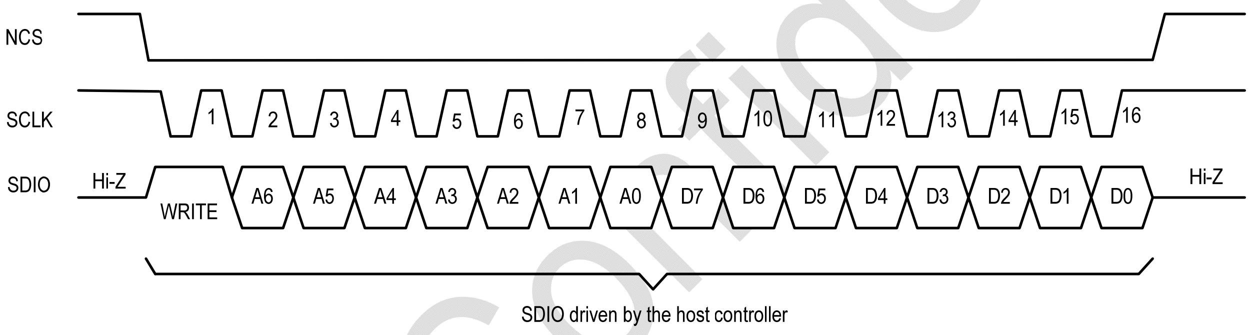


Figure 14. Write Operation

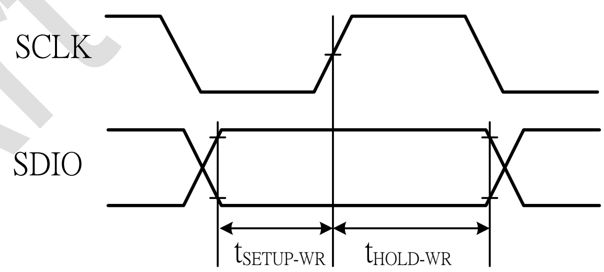


Figure 15. SDIO setup and hold time during write operation

Read Operation

A read operation is initiated by the host controller and consists of two bytes. The first byte contains the address specified by the host controller and has a “0” as its MSB to indicate data direction. The second byte contains the data which is outputted by the sensor. The communication is synchronized by SCLK. SDIO is changed on the falling edges of SCLK and is read on every rising edge of SCLK. The host controller must release SDIO bus and handover the control of SDIO bus to the sensor on the falling edge of last address bit.

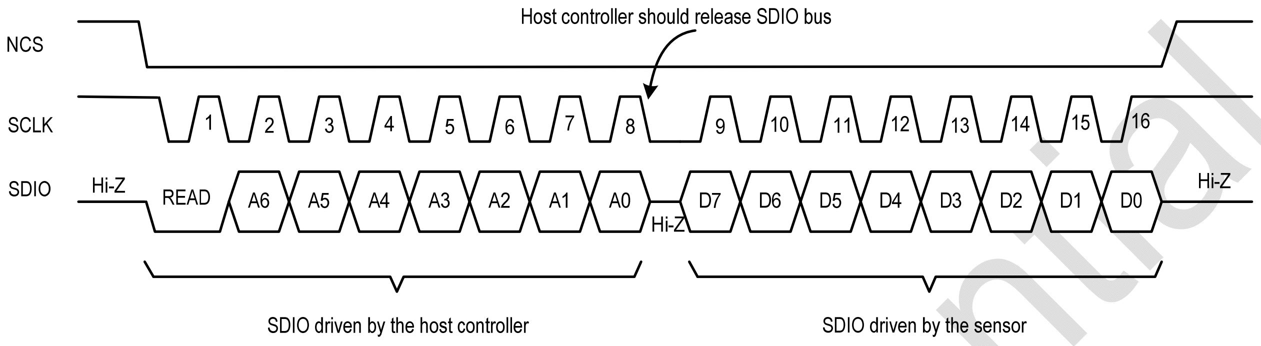


Figure 16. Read Operation

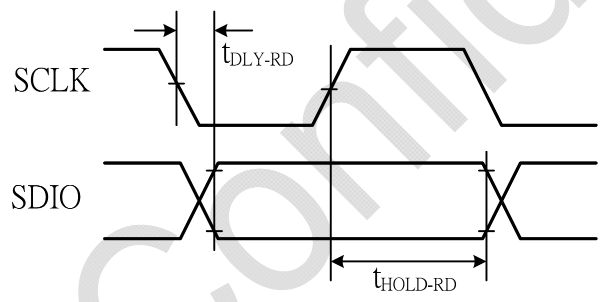


Figure 17. SDIO delay and hold time during read operation

9. 2-wired SPI Serial Interface

To be compatible to PixArt previous generation mouse sensors, the sensor reserves 2-wired SPI interface mode (SCLK, SDIO). All the transmission protocols are exactly the same as 3-wired SPI except the NCS pin is ignored in 2-wired SPI mode.

Switching to 2-wired SPI Mode

Since the 3-wired SPI is the power-on default setting of the sensor, the host controller has to write sensor registers to switch the sensor from 3-wired SPI mode to 2-wired SPI mode after the sensor power-up sequence. By forcing the NCS pin to low, the host is able to write the registers below to switch to 2-wired SPI mode. Without writing the registers below, the re-synchronization mechanism will be invalid.

Write address 0x09 = 0x5A; *to disable Write Protect*
Write address 0x26 = 0x34; *to switch to 2-wired SPI and disable NCS pin function*
Write address 0x09 = 0x00; *to enable Write Protect*

Re-synchronization of the SPI

Two possible conditions listed below might cause the 2-wired SPI being out of synchronization and the host controller will not be able to correctly access the registers of the sensor.

- Wrong system power-up sequence – The host controller begins to toggle the SPI while the sensor has not finished the power-up sequence.
- Unexpected ESD event – When ESD event happens, the SCLK signal might be destroyed by electric surge and causes the SPI being out of synchronization.

Since there is no NCS function to reset the SPI bus when SPI communication is being out of synchronization, a special mechanism is needed to reset the SPI. To recover the correct communication of SPI, the host controller can de-assert the SCLK for at least t_{RESYNC} (1us min), and then keep SCLK asserted for a certain time interval t_{WDT} (1.7ms, min) as shown in Figure 17. to force the SPI control circuits of the sensor to reset. This method of re-synchronization is called "watchdog timer timeout". The re-synchronization will only reset the SPI circuits of the sensor, and the existing sensor register values will keep unchanged. Be noticed that this re-synchronization is NOT valid when the sensor is at power down mode. If users perform re-synchronization during power down mode, the SPI will be out of synchronization. To make sure if the 2-wired SPI interface is back to synchronization, the host controller could read register address 0x00 to check if the value is 0x30. If the value is not correct, please perform re-synchronization again until the correct value (0x30) has been read.

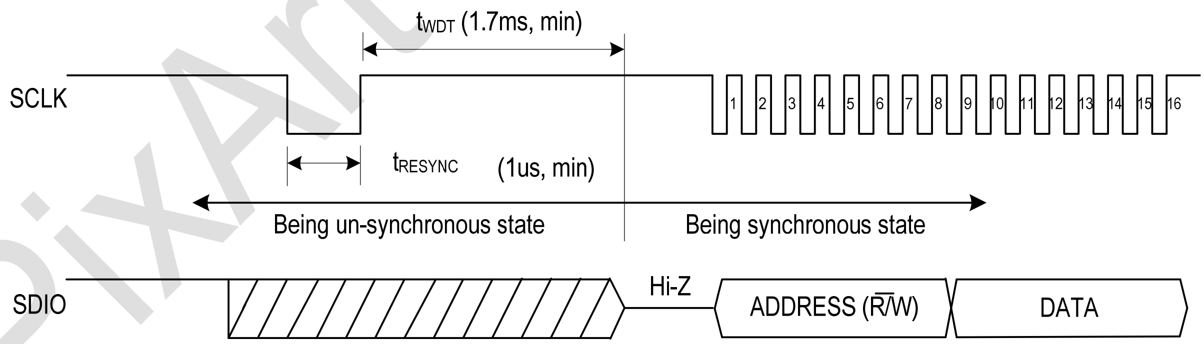


Figure 18. Re-synchronization the SPI Using Watchdog Timer

10. Pin1 Functions in 2-wired SPI Mode

After the sensor has been successfully switched to 2-wired SPI mode, the NCS pin will lose its original function in 3-wired SPI mode. Thus the NCS pin (Pin1) can be further switched to the following three different functions according to Pin1_Sel bits (bit 5 and 4) in register SPI_Sel (address 0x26).

Hardware Reset Function

The host controller can assert Pin1 to reset the sensor. A full chip reset will thus be executed, just like the effect of using Software Reset Function. After the reset, all the recommended register settings must be reloaded to ensure the sensor works properly.

Quick Burst (QB) Function

This function is to reduce the host controller SPI access time thus to save the power of the host controller. In QB mode, the host controller doesn't need to specify the sensor address through SPI interface to get sensor motion data.

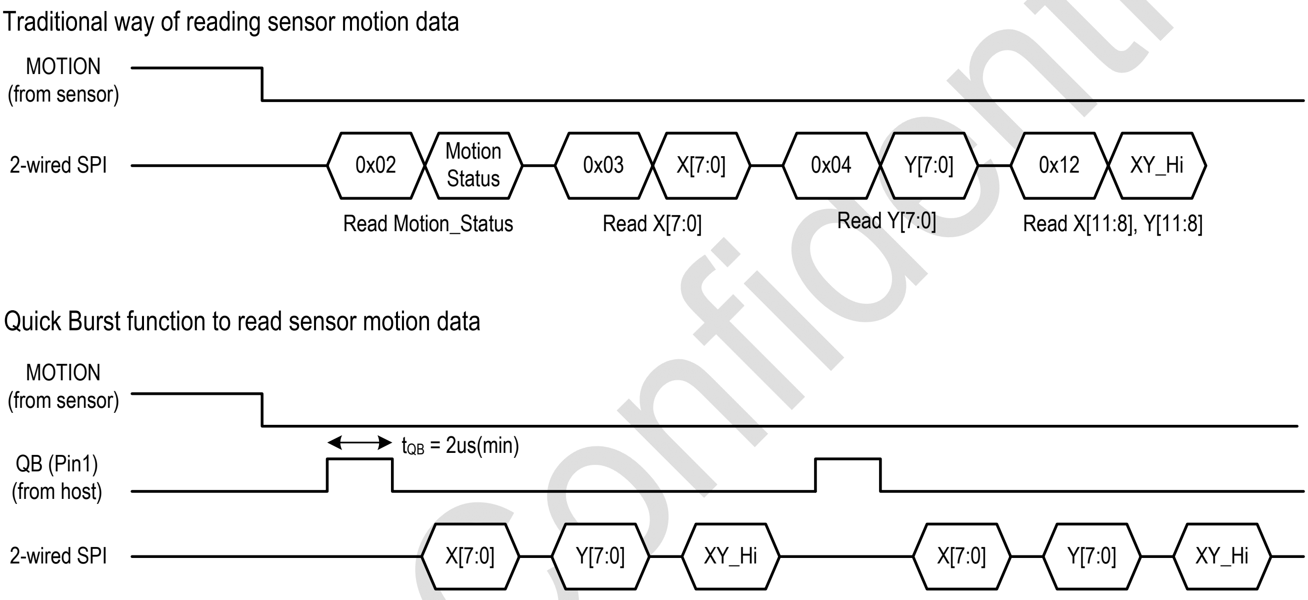


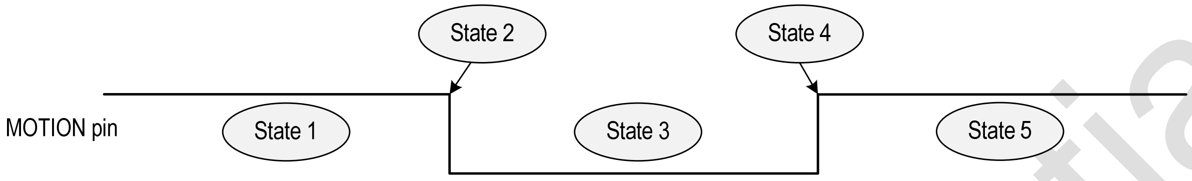
Figure 19. Reading motion data via Quick Burst function and traditional function

Hardware Power-Down Function

The host controller can assert Pin1 to force the sensor operated at extremely low power state, just like the effect of using Software Power-Down function.

11. MOTION Pin Function

The MOTION pin will go from high to low or keep low whenever the sensor detects the occurrence of motion. The MOTION pin can be used to monitor whether if the sensor motion data has been cleared. If the motion data is not cleared, MOTION pin will remain low. After all the motion data is read out by the host controller (i.e. Motion bit, Delta_X and Delta_Y are all zero), the MOTION pin will go high. When a mouse system is working at an idle state where the sensor is at Sleep1/Sleep2/Sleep3 mode and the host controller is at idle mode, and when the sensor detects the occurrence of motion, the MOTION pin will go low. The falling edge on MOTION pin can be used as an interrupt event to wake up the host controller.



State 1 : No motion detected. Register Motion, Delta_X and Delta_Y are all zero.
State 2 : Motion detected. Register Motion =1 and Delta_X and Delta_Y are available to read (non-zero values).
State 3 : Motion continues. Register Motion =1 and Delta_X and Delta_Y are available to read (non-zero values).
State 4 : Motion stops and the last reports of motion have been read out. Register Motion, Delta_X and Delta_Y are all zero.
State 5 : No motion detected. Register Motion, Delta_X and Delta_Y are all zero.

Figure 20. Motion Function

12. Power Management Modes

The sensor has three power-saving modes (Sleep1, Sleep2 and Sleep3). Each mode has a different motion detection period to detect the motion periodically. When left idle, the sensor automatically changes from Run mode to Sleep1 mode, to Sleep2 mode and finally to Sleep3 mode which consumes the least current. Be noticed that the current consumption is the lowest at Sleep3 mode and highest at Sleep1 mode, however the time required for the sensor to "wake up" to Run mode from Sleep1 mode is the shortest and longest from Sleep3 mode. The entering time (Slp1_Etm, Slp2_Etm, Slp3_Etm) is the elapsed time from the time when the sensor is idle to Sleep modes. The sampling frequency time (Slp1_Freq, Slp2_Freq, Slp3_Freq) is the time period to detect the motion under Sleep modes. The relationship between the entering time and the sampling frequency time is shown in figure below.

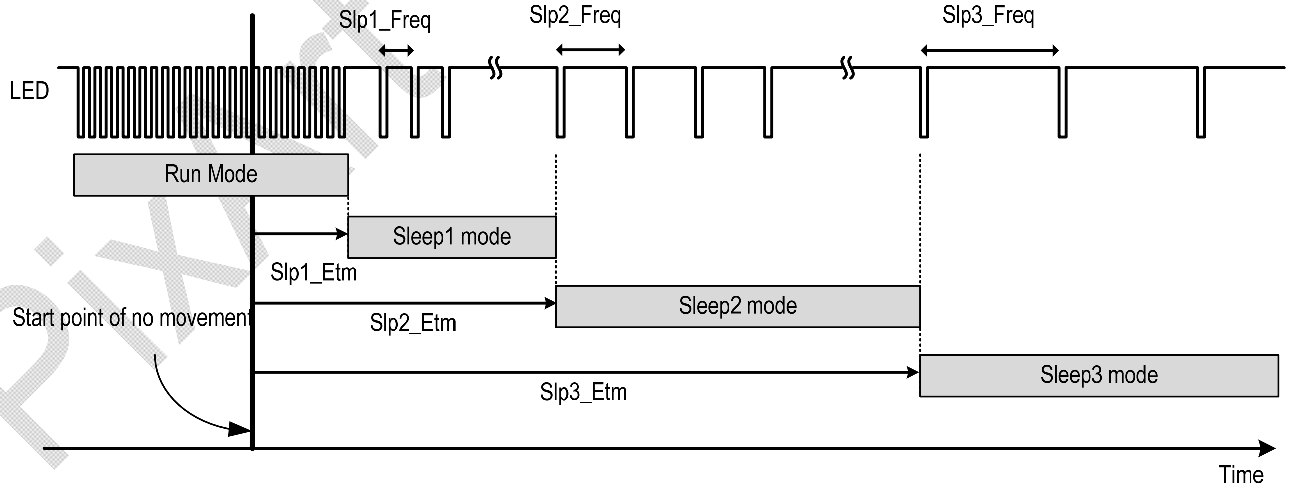


Figure 21. Power-Saving Modes

13. Software Power-Down Function

The sensor can be placed in an extremely low power state (power-down mode) by setting PD_enh bit (bit 3) in the register Configuration (address 0x06) through SPI interface. In power-down mode, all the sensor register settings are retained and can be accessed through SPI interface as well. To get the sensor out of the power-down mode, please just reset the PD_enh bit. To get more accurate motion reports, it is recommended that the host controller should wait at least 3ms before reading the motion reports after resetting the PD_enh bit.

14. Software Reset Function

During power-up, the sensor does not need an external power-on reset as there is an internal circuitry that performs power-on reset function in the sensor. However the sensor can also be reset by setting the Reset bit (bit 7) of register Configuration (address 0x06). A full chip reset will thus be executed and all the registers will be reset to power-on default values. After the reset, all the recommended register settings must be reloaded to ensure the sensor works properly.

15. Optical Criterion

Recommended Red LED Angle Criterion

Recommend using Chang-Yu LED goniophotometer V110 to measure the LED viewing angle.

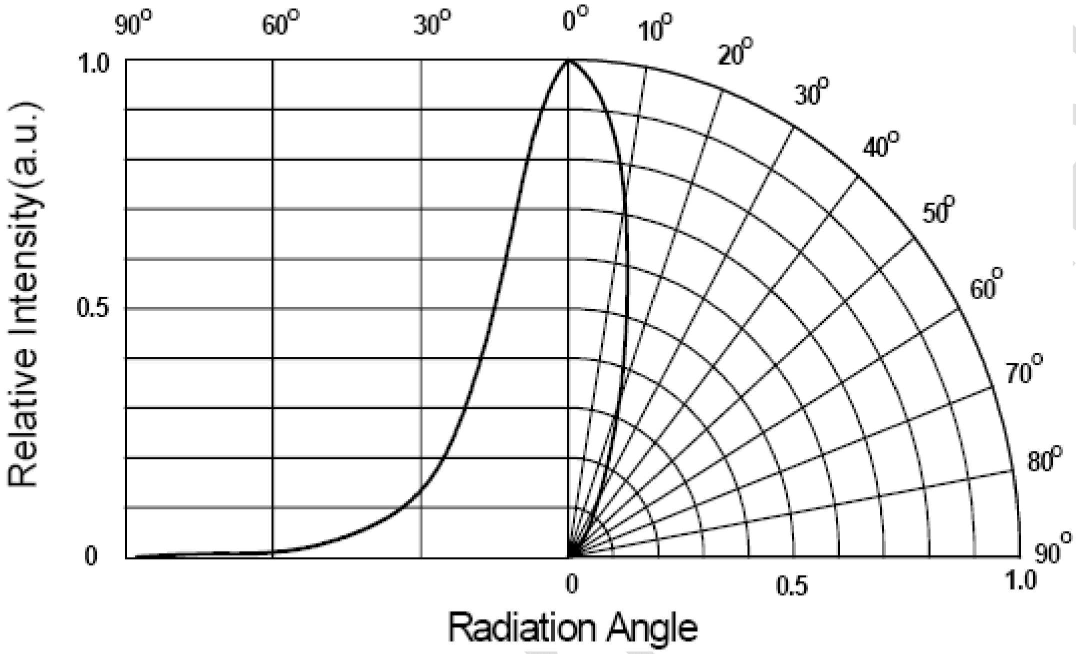


Figure 22. Radiation Characteristics

LED Viewing Angle	Min.	Typ.	Max.
2θ1/2	24	30	36

Recommended Red LED Optical Power

In order to optimize the tracking performance and minimize the LED power consumption, PixArt recommends the LED optical power conform with the table listed below. LED optical power is measured through the base plate opening of the mouse casing with the LED set to continuous mode. Recommend using ADCMT power meter 8230E to measure the LED optical power. The sequence to set LED to continuous mode is as followed.

Write address 0x09 = 0x5A; *to disable Write Protect*
Write address 0x5B = 0x63; *to set LED to continuous mode*

Parameter	Min.	Typ.	Max.	Unit
Red LED Optical Power	1600	-	-	uW

16. Register Summary and Descriptions

The sensor internal registers are accessible through SPI serial interface. The registers not listed in the table below and the registers which are marked as RSVD are NOT allowed to perform write operation in any case.

Register Summary

Address	Name	R/W	PWR On Default	Brief description
0x00	Product_ID1	R	0x30	Product Identifier [11:4]
0x01	Product_ID2	R	0x02	Upper 4 bits for Product Identifier, PID [3:0] Lower 4 bits for Product Version, VID [3:0]
0x02	Motion_Status	R	-	Motion Status information
0x03	Delta_X	R	-	Eight bits 2's complement number for X-axis motion data
0x04	Delta_Y	R	-	Eight bits 2's complement number for Y-axis motion data
0x05	Operation_Mode	R/W	0xB8	Operation mode selection
0x06	Configuration	R/W	0x11	Software power down and reset
0x09	Write_Protect	R/W	0x00	Write Protect to avoid mis-writing registers
0x0A	Sleep1	R/W	0x77	Sleep1 configuration
0x0B	Sleep2	R/W	0x10	Sleep2 configuration
0x0C	Sleep3	R/W	0x70	Sleep3 configuration
0x0D	CPI_X	R/W	0x1B	CPI setting for X axis
0x0E	CPI_Y	R/W	0x1B	CPI setting for Y axis
0x12	Delta_XY_Hi	R	-	Upper 4 bits of Delta_X and Delta_Y for 12-bit data format
0x13	IQC	R	-	Image Quality Complement
0x14	Shutter	R	-	Index of LED shutter time
0x17	Frame_Avg	R	-	Average brightness of a frame
0x19	Mouse_Option	R/W	0x00	Mouse orientation selection
0x26	SPI_Mode	R/W	0xB4	3-wired or 2-wired SPI interface

Detailed Register Descriptions

Product_ID1 Address: 0x00
Access: Read Only Default Value: 0x30

Bit	7	6	5	4	3	2	1	0
Field	PID_{11}	PID_{10}	PID_9	PID_8	PID_7	PID_6	PID_5	PID_4

Data Type: Eight-bit number.

Usage: It can be used to check if the communication of the SPI link is valid.
PID[11:4] = Product Identifier[11:4].

Product_ID2 Address: 0x01
Access: Read Only Default Value: 0x02

Bit	7	6	5	4	3	2	1	0
Field	PID_3	PID_2	PID_1	PID_0	VID_3	VID_2	VID_1	VID_0

Data Type: Four-bit number.

Usage: It can be used to check if the communication of the SPI link is valid.

Field Name	Description
PID [3:0]	Product Identifier[3:0]
VID [3:0]	Product Version[3:0]

Motion_Status Address: 0x02
Access: Read Only Default Value: NA

Bit	7	6	5	4	3	2	1	0
Field	Motion	Reserved	Reserved	DYOVF	DXOVF	Reserved	Reserved	Reserved

Data Type: Bit field.

Usage: Typically in the motion detection routine, the host controller will poll the sensor for valid motion data by checking the Motion bit. If the Motion bit is set, the motion data in Delta_X and Delta_Y registers are valid and ready to be read. Be sure to read Motion bit first before reading out Delta_X and Delta_Y registers. DXOVF bit and DYOVF bit show whether if the motion report buffers have overflowed since last read out.

Field Name	Description
Motion	Motion detected since last report 0 = No motion (Default) 1 = Motion detected, data in Delta_X and Delta_Y registers are valid and ready to be read out
DYOVF	Delta_Y overflowed since last read out 0 = No overflow (Default) 1 = Overflow occurred
DXOVF	Delta_X overflowed since last read out 0 = No overflow (Default) 1 = Overflow occurred

Delta_X					Address: 0x03			
Access: Read Only					Default Value: NA			
Bit	7	6	5	4	3	2	1	0
Field	X_7	X_6	X_5	X_4	X_3	X_2	X_1	X_0

Data Type: Eight-bit 2's complement number.

Usage: Delta_X register is the X-axis motion in counts after reading Motion_Status register. Absolute value is determined by the resolution setting CPI_X. Reading this register clears the content of this register. Report range –128 ~ +127. The MSB bit represents the sign bit.

Delta_Y					Address: 0x04			
Access: Read Only					Default Value: NA			
Bit	7	6	5	4	3	2	1	0
Field	Y_7	Y_6	Y_5	Y_4	Y_3	Y_2	Y_1	Y_0

Data Type: Eight-bit 2's complement number.

Usage: Delta_Y register is the Y-axis motion in counts after reading Motion_Status register. Absolute value is determined by resolution setting CPI_Y. Reading this register clears the content of this register. Report range –128 ~ +127. The MSB bit represents the sign bit.

Operation_Mode				Address: 0x05				
Access: Read/Write				Default Value: 0xB8				
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	Slp_Enh	Slp2_Enh	Slp1mu_Enh	Slp1mu_Enh	Wakeup

Data Type: Bit field.

Usage: Operation_Mode register allows users to change the sensor operation modes. The various combinations of bit4~bit0 are listed below.

"0xxxx" = Sleep1 and Sleep2 mode are all disabled
"10xxx" = Sleep1 mode is enabled but Sleep2 mode is disable
"11xxx" = Sleep1 and Sleep2 modes are all enabled
"11100" = Force sensor to enter Sleep2 mode
"1x010" = Force sensor to enter Sleep1 mode
"1x001" = Make sensor wake up from Sleep mode to Run mode

For Slp2mu_Enh / Slp1mu_Enh / Wakeup bit, only one of them can be set to 1 at the same time and the bit which is set will be reset automatically. To force sensor always stay at Run mode, please set Slp_Enh=0, Slp2_Enh=0 and Wakeup=1 simultaneously.

Field Name	Description
Slp_Enh	Enable/Disable Sleep mode (including Sleep1 and Sleep2) 0 = Disable 1 = Enable (Default)
Slp2_Enh	Enable/Disable Sleep2 mode 0 = Disable 1 = Enable (Default)
Slp2mu_Enh	Force to enter Sleep2 mode. Set "1" to enter Sleep2, and then it will be reset to "0" automatically
Slp1mu_Enh	Force to enter Sleep1 mode. Set "1" to enter Sleep1, and then it will be reset to "0" automatically
Wakeup	Wakeup sensor from Sleep mode. Set "1" to wake up and then it will be reset to "0" automatically

Configuration					Address: 0x06			
Access: Read/Write					Default Value: 0x11			
Bit	7	6	5	4	3	2	1	0
Field	Reset	Reserved	Slp3_Enh	Reserved	PD_Enh	Reserved	Reserved	Reserved

Data Type: Bit field.

Usage: Configuration register allows users to change the configuration of the sensor.

Field Name	Description
Reset	Full chip reset. This bit will be de-asserted automatically. 0 = Normal operation mode (Default) 1 = Full chip reset (to reset all the sensor's internal registers and states)
Slp3_Enh	Enable/Disable Sleep3 mode 0 = Disable (Default) 1 = Enable
PD_Enh	Power down mode for lowest power consumption 0 = Normal operation (Default) 1 = Power down mode (but retain the sensor register settings)

Write_Protect					Address: 0x09			
Access: Read/Write					Default Value: 0x00			
Bit	7	6	5	4	3	2	1	0
Field	WP_7	WP_6	WP_5	WP_4	WP_3	WP_2	WP_1	WP_0

Data Type: Eight-bit number.

Usage: Write Protect register is used to avoid host controller mis-writing the registers after address 0x09.
0x00 = Enable (Default), registers after address 0x09 are read only
0x5A = Disable, registers after address 0x09 can be read/write

Sleep1					Address: 0x0A			
Access: Read/Write					Default Value: 0x77			
Bit	7	6	5	4	3	2	1	0
Field	$Slp1\_Freq_3$	$Slp1\_Freq_2$	$Slp1\_Freq_1$	$Slp1\_Freq_0$	$Slp1\_Etm_3$	$Slp1\_Etm_2$	$Slp1\_Etm_1$	$Slp1\_Etm_0$

Data Type: Four-bit number.

Usage: Sleep1 register allows users to set the sampling frequency time during Sleep1 mode and the entering time from Run mode to Sleep1 mode.

Field Name	Description
Slp1_Freq[3:0]	Each step is equivalent to 4ms. Relative to its value 0 ~ 15, the sampling frequency time is 4ms ~ 64ms. Default Slp1_Freq[3:0] =7 (32ms)
Slp1_Etm[3:0]	Each step is equivalent to 32ms. Relative to its value 0 ~ 15, the entering time is 32ms ~ 512ms. Default Slp1_Etm[3:0] = 7 (256ms)

Sleep2					Address: 0x0B			
Access: Read/Write					Default Value: 0x10			
Bit	7	6	5	4	3	2	1	0
Field	$Slp2\_Freq_3$	$Slp2\_Freq_2$	$Slp2\_Freq_1$	$Slp2\_Freq_0$	$Slp2\_Etm_3$	$Slp2\_Etm_2$	$Slp2\_Etm_1$	$Slp2\_Etm_0$

Data Type: Four-bit number.

Usage: Sleep2 register allows users to set the sampling frequency time during Sleep2 mode and the entering time from Run mode to Sleep2 mode.

Field Name	Description
Slp2_Freq[3:0]	Each step change is equivalent to 64ms. Relative to its value 0 ~ 15, the sampling frequency time is 64ms ~ 1024ms. Default Slp2_Freq[3:0] = 1 (128ms)
Slp2_Etm[3:0]	Each step is equivalent to 20.48sec. Relative to its value 0 ~ 15, the entering time is 20.48sec ~ 327.68sec. Default Slp2_Etm[3:0] = 0 (20.48sec)

Sleep3					Address: 0x0C			
Access: Read/Write					Default Value: 0x70			
Bit	7	6	5	4	3	2	1	0
Field	$Slp3\_Freq_3$	$Slp3\_Freq_2$	$Slp3\_Freq_1$	$Slp3\_Freq_0$	$Slp3\_Etm_3$	$Slp3\_Etm_2$	$Slp3\_Etm_1$	$Slp3\_Etm_0$

Data Type: Four-bit number.

Usage: Sleep3 register allows users to set the sampling frequency time during Sleep3 mode and the entering time from Run mode to Sleep3 mode.

Field Name	Description
Slp3_Freq[3:0]	Each step is equivalent to 64ms. Relative to its value 0 ~ 15, the sampling frequency time is 64ms ~ 1024ms. Default Slp3_Freq[3:0] = 7 (512ms)
Slp3_Etm[3:0]	Each step change is equivalent to 20.48sec. Relative to its value 0 ~ 15, the entering time is 20.48sec ~ 327.68sec. Default Slp3_Etm[3:0] = 0 (20.48sec)

CPI_X					Address: 0x0D			
Access: Read/Write					Default Value: 0x1B			
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	CPI_X_5	CPI_X_4	CPI_X_3	CPI_X_2	CPI_X_1	CPI_X_0

Data Type: Six-bit number.

Usage: This register is the CPI resolution of sensor for X axis. Each step is equivalent to 38 counts based on x1 lens magnification. Default value is 27 (CPI = 1026). Target CPI = 38 * CPI_X. Recommended range : 16 ~ 63 (CPI = 608 ~ 2394)

CPI_Y Address: 0x0E
Access: Read/Write Default Value: 0x1B

Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	CPI_Y_5	CPI_Y_4	CPI_Y_3	CPI_Y_2	CPI_Y_1	CPI_Y_0

Data Type: Six-bit number.

Usage: This register is the CPI resolution of sensor for Y axis. Each step is equivalent to 38 counts based on x1 lens magnification. Default value is 27 (CPI = 1026). Target CPI = 38 * CPI_Y. Recommended range : 16 ~ 63 (CPI = 608 ~ 2394).

Delta_XY_Hi Address: 0x12
Access: Read Only Default Value: NA

Bit	7	6	5	4	3	2	1	0
Field	X_{11}	X_{10}	X_9	X_8	Y_{11}	Y_{10}	Y_9	Y_8

Data Type: Four-bit number.

Usage: The upper 4 bits of Delta_X[11:0] and Delta_Y[11:0] for 12-bit data format.

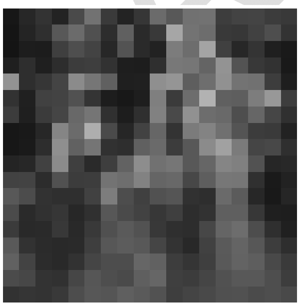
Field Name	Description
X[11:8]	the upper 4 bits of Delta_X[11:0] for 12-bit data format
Y[11:8]	the upper 4 bits of Delta_Y[11:0] for 12-bit data format

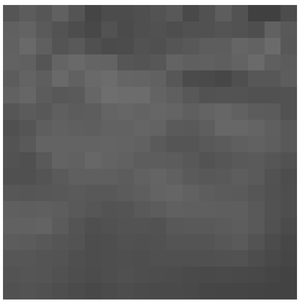
IQC Address: 0x13
Access: Read Only Default Value: NA

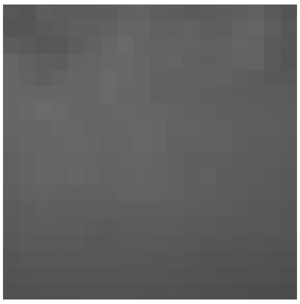
Bit	7	6	5	4	3	2	1	0
Field	IQC_7	IQC_6	IQC_5	IQC_4	IQC_3	IQC_2	IQC_1	IQC_0

Data Type: Eight-bit number.

Usage: IQC means Image Quality Compliment. This register represents the fuzziness of a surface viewed by the sensor. The smaller the index is, the easier for the sensor to have a good tracking on the surface. IQC ranges from 0 ~ 255.


IQC = 20


IQC = 50


IQC = 150

Shutter					Address: 0x14			
Access: Read Only					Default Value: NA			
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	$Shutter_4$	$Shutter_3$	$Shutter_2$	$Shutter_1$	$Shutter_0$

Data Type: Five-bit number.

Usage: Shutter register is an index of LED shutter time. It is automatically controlled by the sensor's internal auto-exposure algorithm. Value ranges from 0 ~ 28. Shutter time is approximately to (*Shutter* + 1) x 7.1us

Frame_Avg					Address: 0x17			
Access: Read Only					Default Value: NA			
Bit	7	6	5	4	3	2	1	0
Field	FA_7	FA_6	FA_5	FA_4	FA_3	FA_2	FA_1	FA_0

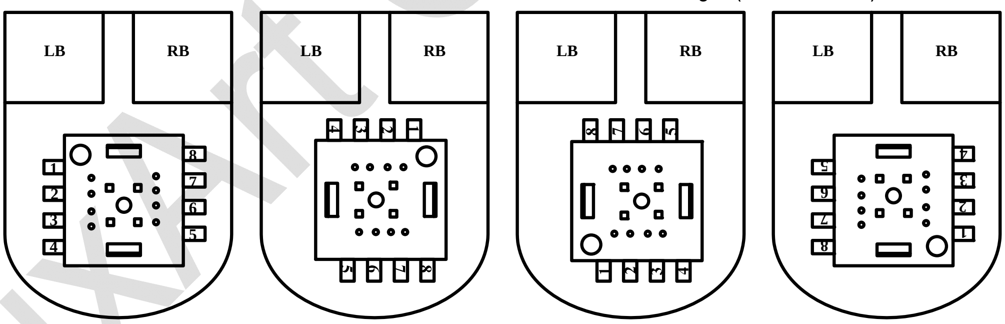
Data Type: Eight-bit number.

Usage: Frame_Avg register represent s the average brightness of all pixels within a frame (324 pixels). This value ranges from 0 to 255.

Mouse_Option					Address: 0x19			
Access: Read/Write					Default Value: 0x00			
Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Movxy_SW	Movy_Inv	Movx_Inv	XY12bit_Enh	Reserved	Reserved

Data Type: Bit field.

Usage: To select the mouse X/Y direction and Delta_X, Delta_Y motion data length (8-bit or 12-bit).



0x19[5:3] = 0 0x19[5:3] = 6 0x19[5:3] = 5 0x19[5:3] = 3

Field Name	Description
Movxy_Sw	To swap the XY direction. Default is 0.
Movy_Inv	To invert the Y direction. Default is 0.
Movx_Inv	To invert the X direction. Default is 0.
XY12bit_Enh	To select 8-bit or 12-bit motion data length. Default is 0 (8-bit mode)

SPI_Mode					Address: 0x26			
Access: Read/Write					Default Value: 0xB4			
Bit	7	6	5	4	3	2	1	0
Field	SPI_Sel	Reserved	Pin1_Sel1	Pin1_Sel0	Reserved	Reserved	Reserved	Reserved

Data Type: One-bit and Two-bit numbers.

Usage: To select 3-wired or 2-wired SPI interface, and to select the Pin1 function when the 2-wired SPI mode has been chosen.

Field Name	Description
SPI_Sel	To select 3-wired or 2-wired SPI interface. 0 = 2-wired SPI mode. 1 = 3-wired SPI mode (default).
Pin1_Sel[1:0]	To select Pin1 function when SPI is in 2-wired SPI mode 0 = Hardware Reset function. 1 = Quick Burst (QB) function. 2 = Hardware Power-Down function. 3 = No function (default).

17. Sensor Registers Initialization Sequence

- High Voltage Segment with 3-wired SPI
  No sensor settings are required

- High Voltage Segment and 2-wired SPI
  Write address 0x09 = 0x5A;   to disable Write Protect
  Write address 0x26 = 0x34;   to switch to 2-wired SPI
  Write address 0x09 = 0x00;   to enable Write Protect

- Low Voltage Segment with 3-wired SPI
  Write address 0x09 = 0x5A;   to disable Write Protect
  Write address 0x4B = 0x04;   to turn off internal regulator for Low Voltage Segment
  Write address 0x09 = 0x00;   to enable Write Protect

- Low Voltage Segment with 2-wired SPI
  Write address 0x09 = 0x5A;   to disable Write Protect
  Write address 0x26 = 0x34;   to switch to 2-wired SPI
  Write address 0x4B = 0x04;   to turn off internal regulator for Low Voltage Segment
  Write address 0x09 = 0x00;   to enable Write Protect

18. Revision History

Revision No.	Date	Notes
R1.0	22.07.2014	New creation
R1.1	15.08.2014	1. Added chapter 10 to introduce the Pin1 Function in 2-wired SPI Mode, including Quick Burst read function 2. Added register SPI_Mode (address 0x26) in register table 3. Added t_{QB} specification in AC Operation Conditions table
R1.2	19.11.2014	Added "NCS Low at Power-up Stage" section in chapter 8.