ADNS-2700

Single Chip USB Optical Mouse Sensor

Data Sheet



Description

The ADNS-2700 is a compact, one chip USB optical mouse sensor designed for implementation of a non-mechanical tracking engine in computer mice.

It is based on optical navigation technology that measures changes in position by optically acquiring sequential surface images (frames) and mathematically determining the direction and magnitude of movement.

The sensor is in an 8-pin optical package that is designed to be used with the ADNS-5100-001 trim lens, LED clip and the HLMP-EG3E-xxxxx LED. Together, these parts provide a complete and compact mouse sensor. There are no moving parts and precision optical alignment is not required, thus facilitating high volume assembly.

The output format is USB. This device meets HID Revision 1.11 specification and is compatible with USB Revision 2.0 specification.

Frame rate is varied internally to the sensor to achieve tracking and speed performance, eliminating the need for the use of many registers.

Default resolution is specified as 1000 counts per inch, with rates of motion up to 30 inches per second.

A complete mouse can be built with the addition of a PC board, switches and Z-wheel, plastic case and cable.

NOTE: ADNS-2700 will be referred to as "sensor", ADNS-5100-001 as " trim lens" and HLMP-EG3E as "LED" hereafter.

Features

- One chip USB mouse sensor
- USB 2.0 Low Speed Compliance
- 12 bits USB motion data reporting
- Meets HID Revision 1.11
- Single 5.0 volts power supply
- High speed motion detection at 30 inches per second (ips) and acceleration up to 8 g
- Input buttons: 3 buttons
- Z-Wheel interface for vertical scroll
- Integrated oscillator
- Integrated USB D- pull-up resistor
- Product string is set to “USB Optical Mouse”
- On-chip OTP memory for device configuration flexibility without any external software driver:
  - Programmable resolution from 500 to 1250 counts per inch (cpi) with 250 cpi step.
  - Programmable sensor orientation
  - Programmable VID and PID.

Applications

- Corded optical mice
- Trackballs
- Integrated input devices

Theory of Operation

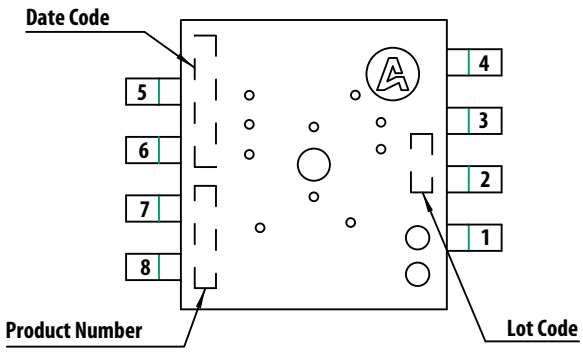
The sensor is based on Optical Navigation Technology. It contains an Image Acquisition System (IAS), a Digital Signal Processor (DSP) and USB stream output.

The IAS acquires microscopic surface images via the lens and illumination system provided by the trim lens. The clip and LED. These images are processed by the DSP to determine the direction and distance of motion. The DSP generates the Δx and Δy relative displacement values which are converted to USB motion data.

Table 1. Pin Name Description

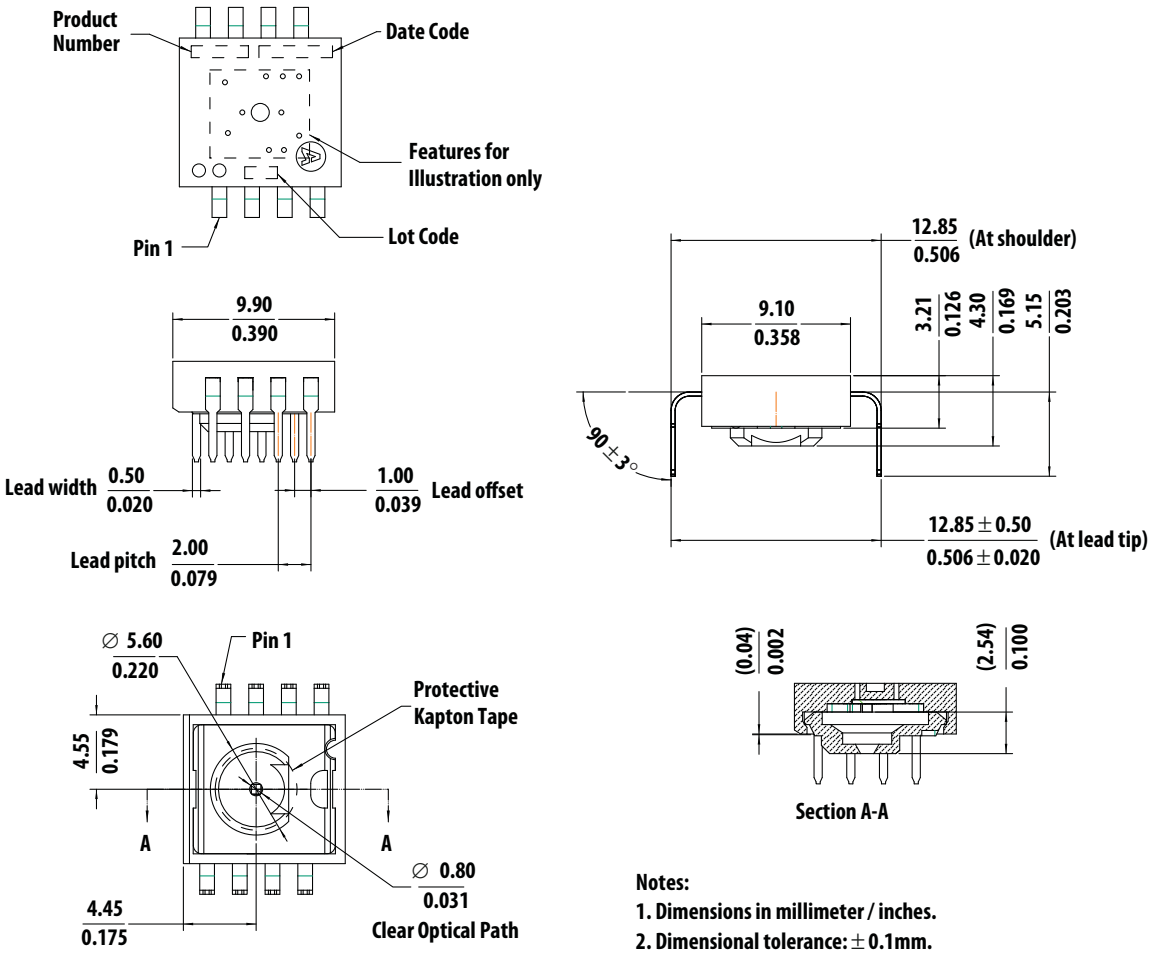
Pin Name	Input/Output	Description
XY_LED	I	XY_LED
VDDA5	–	5-Volt Power
ZB	I	Z-Wheel quadrature input
ZA	I	Z-Wheel quadrature input
SW	–	3-in-1 button pin. Do not force any voltage into this pin
GND	–	Ground
D-	I/O	USB D- line
D+	I/O	USB D+ line

Package Pinout



Item	Marking	Remarks
Product Number	A2700	
Date Code	XYYWWZ	X = Subcon Code YYWW = Date Code Z = Sensor Die Source E = Wafer Revision
Lot Code	VVV	Numeric

Figure 1. Package outline drawing (top view)



Notes:

1. Dimensions in millimeter / inches.
2. Dimensional tolerance: ±0.1mm.
3. Coplanarity of leads: 0.1mm.
4. Lead pitch tolerance: ±0.15mm.
5. Non-cumulative pitch tolerance: ±0.15mm.
6. Angular tolerance: ±3°
7. Maximum flash: 0.2mm.
8. Brackets () indicate reference dimension.
9. Document Number: LED_DIFF_8B_PKG_002

Figure 2. Package Outline Drawing

CAUTION: It is advised that normal static precautions be taken in handling and assembling of this component to prevent damage and/or degradation which may be induced by ESD.

Overview of Optical Mouse Sensor Assembly

Avago Technologies provides an IGES file drawing describing the base plate molding features for lens and PCB alignment. The sensor is designed for mounting on a through-hole PCB. There is an aperture stop and features on the package that align to the lens. The lens provides optics for the imaging of the surface as well as the illumination of the surface at the optimum angle. Features on the lens align it to the sensor, base plate, and clip with the LED. The clip holds the LED in relation to the lens. The LED must be inserted into the clip and the LED's leads formed prior to loading on the PCB.

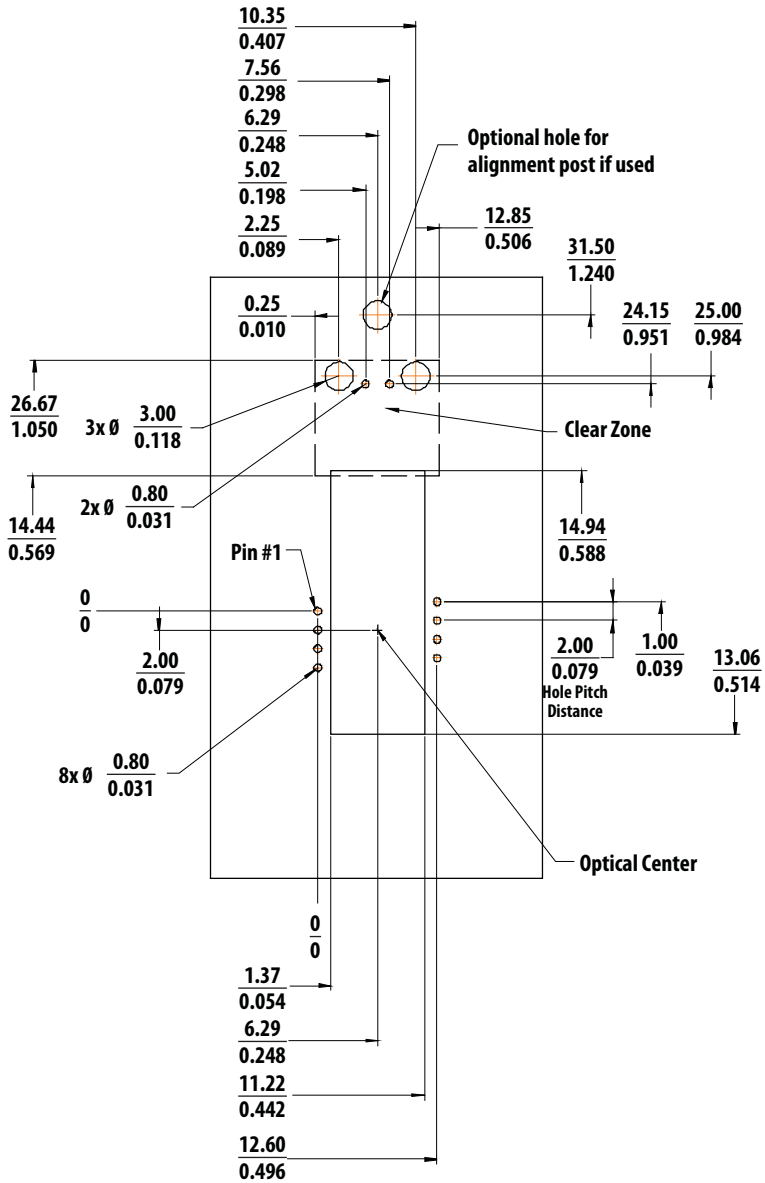
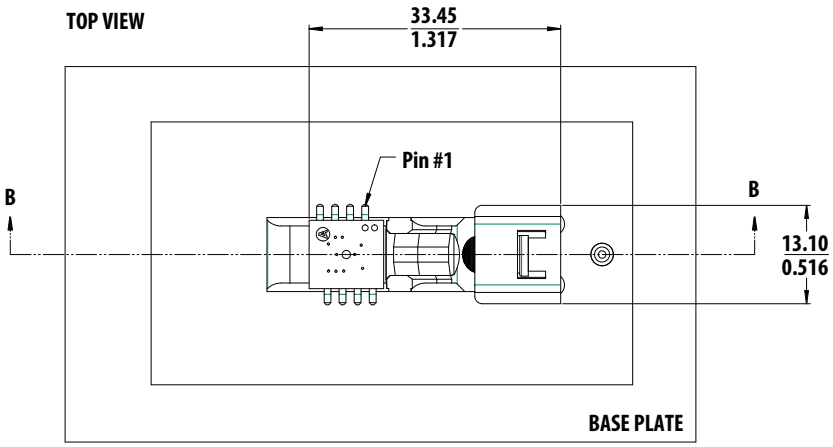
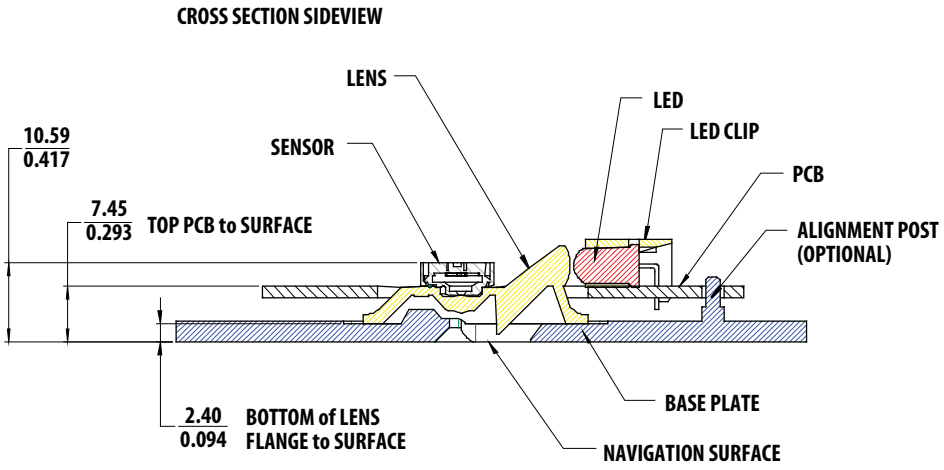


Figure 3. Recommended PCB Mechanical Cutouts and Spacing





NOTE: Dimensions in mm/Inches
Important Note: Pin 1 of sensor should be located nearest to the LED

Figure 4. 2D Assembly drawing of sensor (Top and Side View)

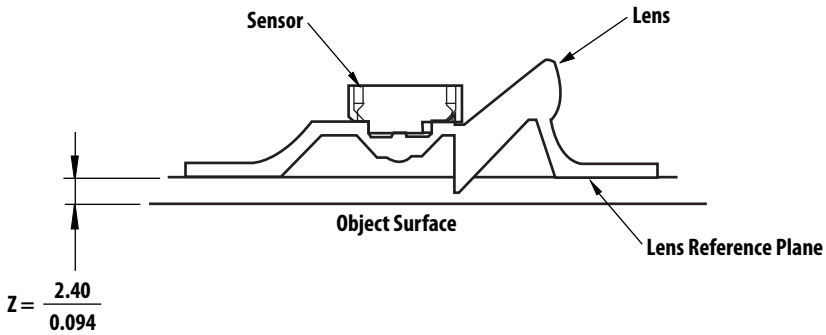
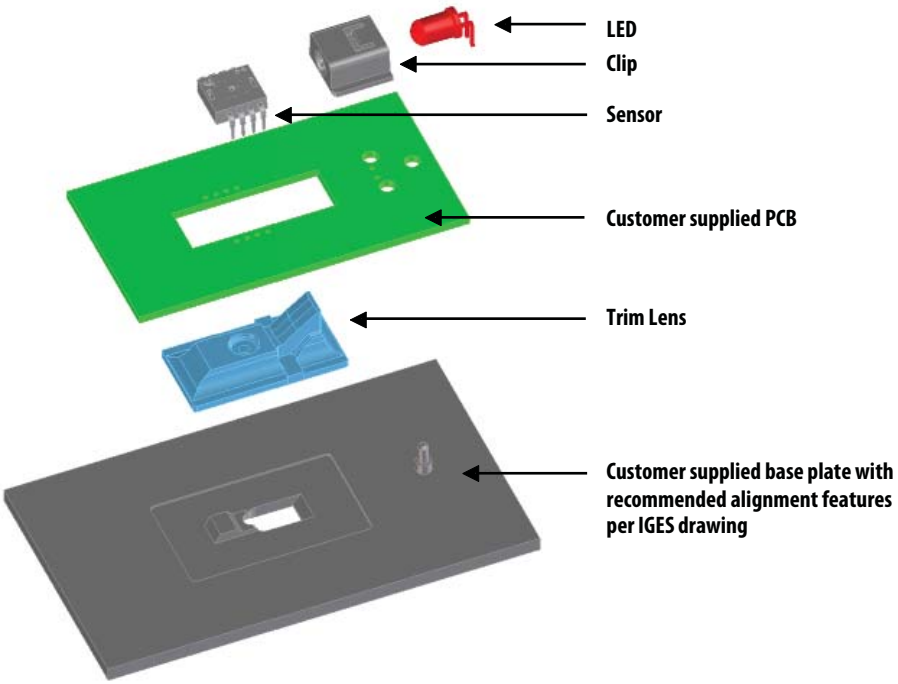


Figure 5. Distance from lens reference plane to tracking surface (Z)



IMPORTANT NOTE: P-bin LED or better is recommended.

Figure 6. Exploded View of Assembly

PCB Assembly Considerations

1. Insert the sensor and all other electrical components into PCB.
2. Insert the LED into the assembly clip and bend the leads 90 degrees.
3. Insert the LED clip assembly into PCB.
4. This sensor package is only qualified for wave-solder process.
5. Wave solder the entire assembly in a no-wash solder process utilizing solder fixture. The solder fixture is needed to protect the sensor during the solder process. It also sets the correct sensor-to-PCB distance as the lead shoulders do not normally rest on the PCB surface. The fixture should be designed to expose the sensor leads to solder while shielding the optical aperture from direct solder contact.
6. Place the lens onto the base plate.
7. Remove the protective Kapton tape from optical aperture of the sensor. Care must be taken to keep contaminants from entering the aperture. Recommend not to place the PCB facing up during the entire mouse assembly process. Recommend to hold the PCB first vertically for the Kapton removal process.
8. Insert PCB assembly over the lens onto the base plate aligning post to retain PCB assembly. The sensor aperture ring should self-align to the lens.
9. The optical position reference for the PCB is set by the base plate and lens. Note that the PCB motion due to button presses must be minimized to maintain optical alignment.
10. Install mouse top case. There MUST be a feature in the top case to press down onto the PCB assembly to ensure all components are interlocked to the correct vertical height.

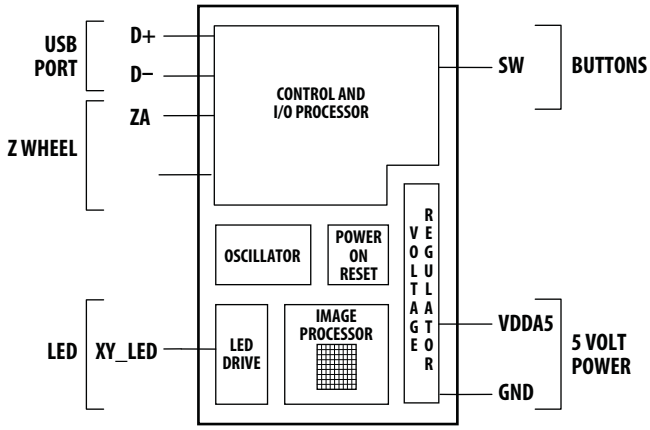


Figure 7. Block diagram of optical mouse

Design considerations for improving ESD Performance

The table below shows typical values assuming base plate construction per the Avago Technologies supplied IGES file trim lens. Stand-off of the base plate shall not be larger than 5 mm.

Typical Value	Distance (mm)
Creepage	17.9 mm
Clearance	9.2 mm

Note that the lens material is polycarbonate or polystyrene HH30, therefore, cyanoacrylate based adhesives should not be used as they will cause lens material deformation

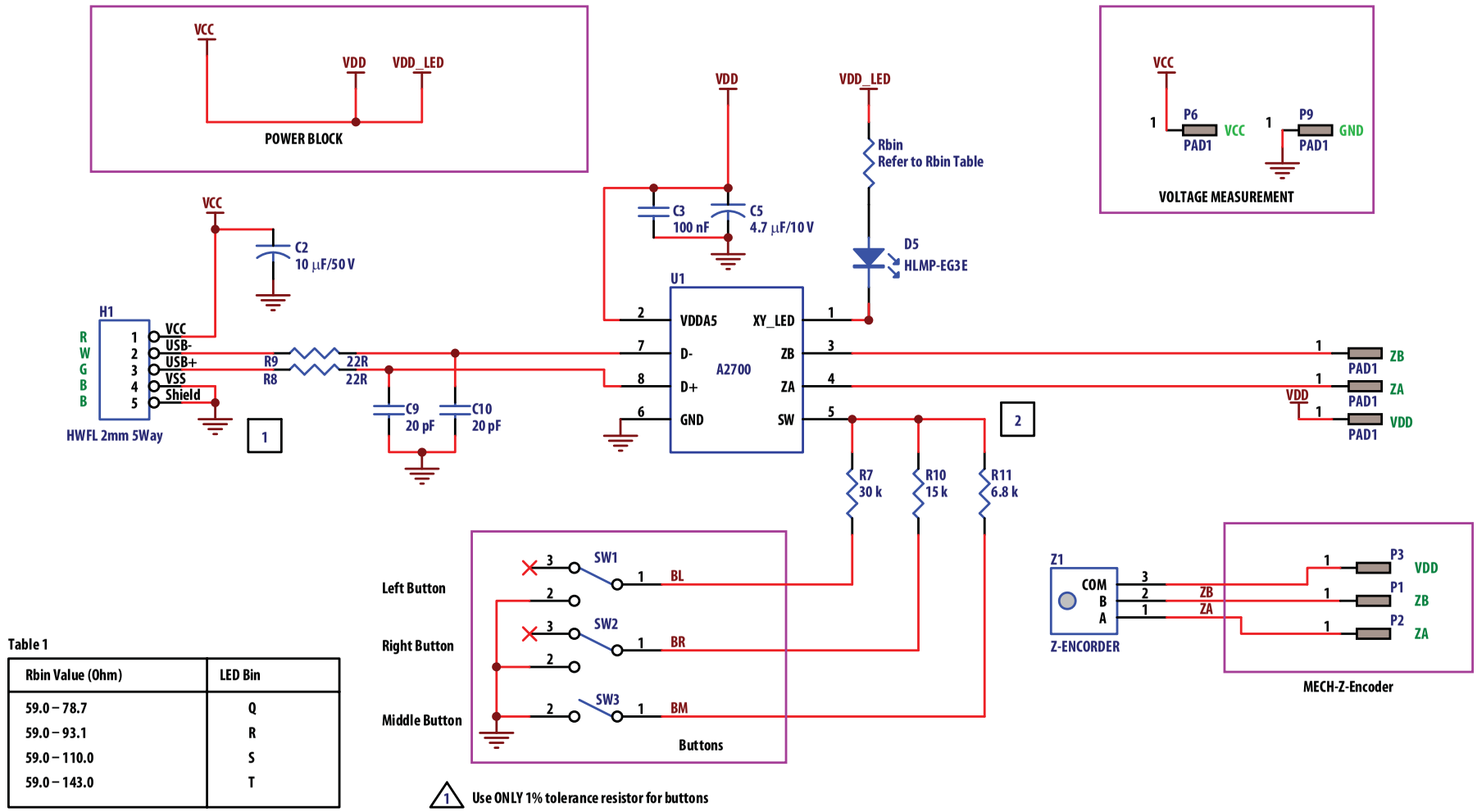


Table 1

Rbin Value (Ohm)	LED Bin
59.0 – 78.7	Q
59.0 – 93.1	R
59.0 – 110.0	S
59.0 – 143.0	T

1 Try to shield the HWEL with a SHIELD Plane (USB pin 5) similar size of HWFL before connect to GND. Isolate the Shield island with GND plane

2 Don't use jumper wire. Use resistor to jump instead. Keep the trace wide.
Keep (pin 5) away from noisy traces, GND plane and Power plane.
The 3 button trace for SW pin need to be same width, length.

Figure 8. Application Circuit with sensor

Regulatory Requirements

- Passes FCC B and worldwide analogous emission limits when assembled into a mouse with shielded cable and following Avago Technologies recommendations.
- Passes EN61000-4-4/IEC801-4 EFT tests when assembled into a mouse with shielded cable and following Avago Technologies recommendations.
- UL flammability level UL94 V-0.
- Provides sufficient ESD creepage/clearance distance to withstand discharge up to 8 kV when assembled into a mouse with trim lens according to usage instructions above.

Absolute Maximum Ratings

Parameter	Symbol	Minimum	Maximum	Units	Notes
Storage Temperature	T_S	-40	85	°C	
Operating Temperature	T_A	-15	55	°C	
Lead Solder Temperature			260	°C	For 10 seconds, 1.6 mm below seating plane.
Supply Voltage	V_{DDA5}	-0.5	5.5	V	
ESD			2	kV	All pins, human body model JESD22-A114
Input Voltage	V_{IN}	-0.5	V_{DDA5} +0.5	V	All I/O pins except D+, D-
		-1.0	4.6	V	D+, D-, AC waveform, see USB specification (7.1.1)
Input Short Circuit Voltage	V_{SC}	0	V_{DDA5}	V	D+, D-, see USB specification (7.1.1)

Recommended Operating Condition

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Operating Temperature	T_A	0		40	°C	
Power Supply Voltage	V_{DDA5}	4.25	5.0	5.25	V	For accurate navigation and proper USB operation
	V_{ddm}	4.0	5.0	5.25	V	Maintains communication to USB host and internal register contents.
Power Supply Rise Time	V_{RT}	0.1		6	ms	
Supply Noise	V_N			100	mV	Peak to peak within 0-100 MHz bandwidth
Velocity	Vel		30		ips	
Acceleration	Acc		8		g	0.5 g from Rest
Serial Port Clock Frequency	f_{SCLK}			1	MHz	50% duty cycle
Distance from Lens Reference Plane to Surface	Z	2.3	2.4	2.5	mm	See Figure 9
Light Level onto IC	IRR_{INC}	80		25000	MW/m^2	λ = 639 nm
Frame Rate			2400		fps	Internally adjusted by sensor

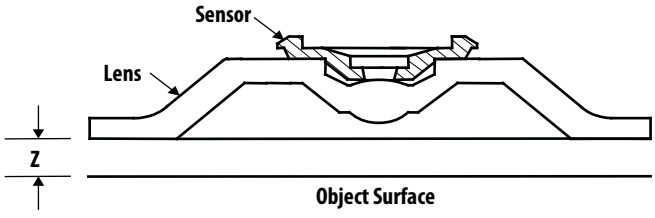


Figure 9. Distance from lens reference plane to object surface

AC Electrical Specifications

Electrical Characteristics over recommended operating conditions. Typical values at 25° C, V_{DDA5} = 5.0 V.

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Wakeup Delay from Rest Mode Due to Motion	T_{WUPP}		1	2	ms	
Power Up Delay	T_{PUP}			50	ms	
Debounce Delay on Button Inputs	T_{DBB}	5	9	17	ms	"Maximum" specified at 8 ms polling rate.
Scroll Wheel Sampling Period	T_{SW}	150	200	300	µs	ZA PIN
Transient Supply Current	I_{DDT}			60	mA	Max. supply current during a V_{DDA5} ramp from 0 to 5.0 V with > 500 µs rise time. Does not include charging currents for bypass capacitors.

USB Electrical Specifications

Electrical Characteristics over recommended operating conditions.

Parameter	Symbol	Minimum	Maximum	Units	Notes
Output Signal Crossover Voltage	V_{CRS}	1.5	2.0	V	C_L = 200 to 600 pF (see Figure 10)
Input Signal Crossover Voltage	V_{ICRS}	1.2	2.1	V	C_L = 200 to 600 pF (see Figure 10)
Output High	V_{OH}	2.8	3.6	V	with 15 kΩ to Ground and 7.5 kΩ to V_{BUS} on D- (see Figure 11)
Output Low	VOL	0.0	0.3	V	with 15 kΩ to Ground and 7.5 kΩ to V_{BUS} on D- (see Figure 11)
Single Ended Input	V_{SEI}		0.8	V	
Input High (Driven)	V_{IH}	2.0		V	
Input High (Floating)	V_{IHZ}	2.7	3.6	V	
Input Low	V_{IL}		0.8	V	7.5 kΩ to VDDA5
Differential Input Sensitivity	V_{DI}	0.2		V	|(D+)-(D-)| See Figure 12
Differential Input Common Mode Range	V_{CM}	0.8	2.5	V	Includes V_{DI}, See Figure 12
Single Ended Receiver Threshold	V_{SE}	0.8	2.0	V	
Transceiver Input Capacitance	C_{IN}		12	pF	D+ to V_{BUS}, D- to V_{BUS}

USB Timing Specifications

Timing Specifications over recommended operating conditions.

Parameter	Symbol	Minimum	Maximum	Units	Notes
D+/D- Transition rise time	T_{LR}	75		ns	C_L = 200 pF (10% to 90%), see Figure 10
D+/D- Transition rise time	T_{LR}		300	ns	C_L = 600 pF (10% to 90%), see Figure 10
D+/D- Transition fall time	T_{LF}	75		ns	C_L = 200 pF (90% to 10%), see Figure 10
D+/D- Transition fall time	T_{LF}		300	ns	C_L = 600 pF (90% to 10%), see Figure 10
Rise and Fall time matching	T_{LRFM}	80	125	%	T_R/T_F; C_L = 200 pF; Excluding the first transition from the Idle State
Wakeup delay from USB suspend mode due to buttons push	T_{WUPB}		17	ms	Delay from button push to USB operation Only required if remote wakeup enabled
Wakeup delay from USB suspend mode due to buttons push until accurate navigation	T_{WUPN}		50	ms	Delay from button push to navigation operation. Only required if remote wakeup enabled
USB reset time	T_{reset}	18.7		µs	
Data Rate	t_{LDRATE}	1.4775	1.5225	Mb/s	Average bit rate, 1.5 Mb/s +/- 1.5%
Receiver Jitter Tolerance	t_{DJR1}	-75	75	ns	To next transition, see Figure 13
Receiver Jitter Tolerance	t_{DJR2}	-45	45	ns	For paired transitions, see Figure 13
Differential to EOP Transition Skew	t_{LDEOP}	-40	100	ns	See Figure 14
EOP Width at Receiver	t_{LEOPR}	670		ns	Accepts EOP, see Figure 14
Source EOP Width	t_{LEOPT}	1.25	1.50	µs	
Width of SE0 interval during Differential Transition	t_{LST}		210	ns	See Figure 11.
Differential Output Jitter	t_{UDJ1}	-95	95	ns	To next transition, see Figure 15
Differential Output Jitter	t_{UDJ2}	-150	150		For paired transitions, see Figure 15

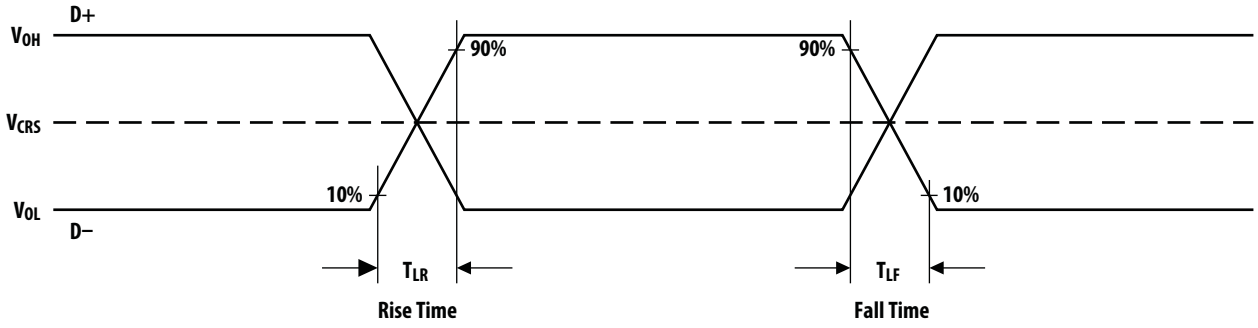


Figure 10. Data Signal Rise and Fall Times

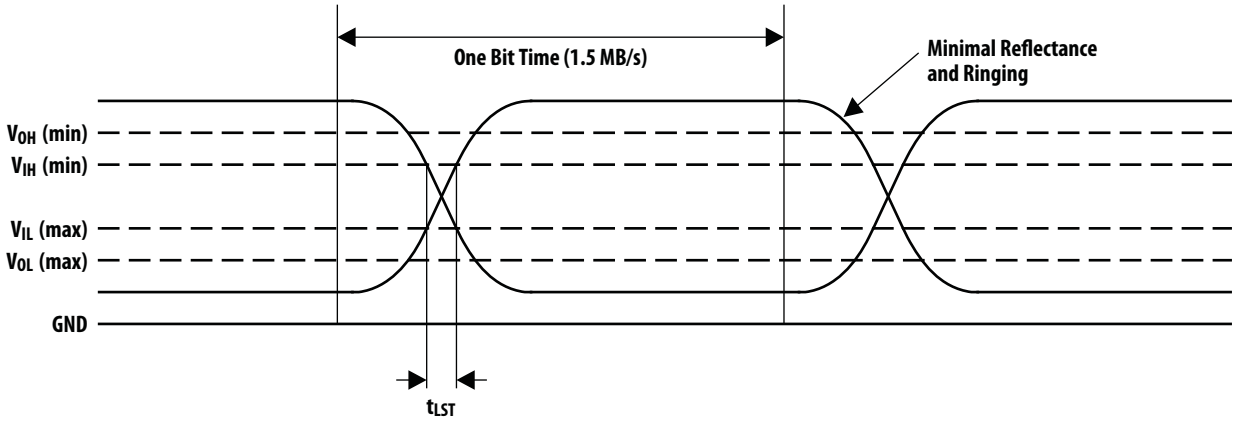


Figure 11. Data Signal Voltage Levels

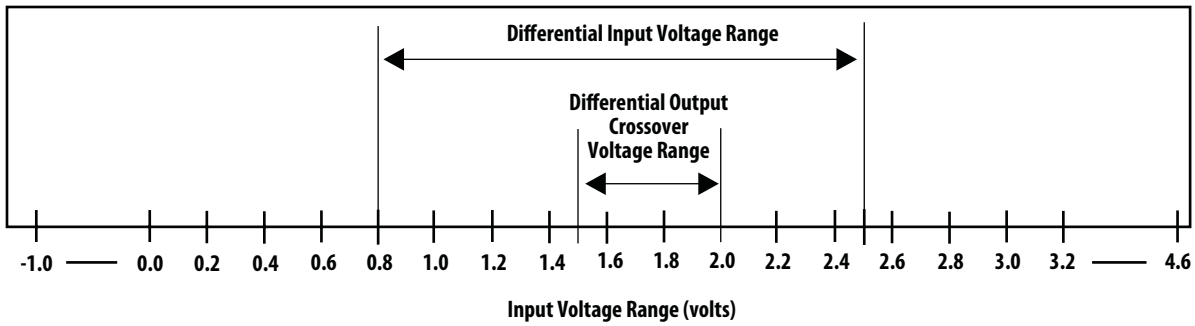


Figure 12. Differential Receiver Input Sensitivity vs. Common Mode Input Range

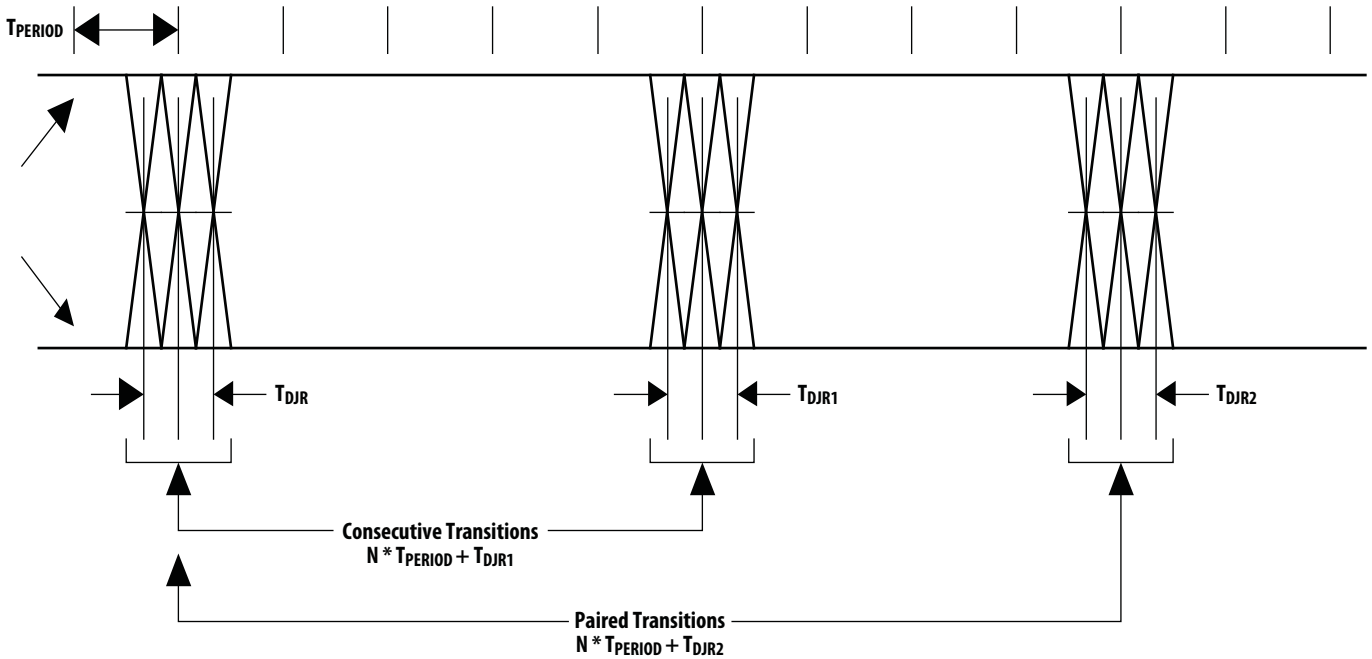


Figure 13. Receiver Jitter Tolerance

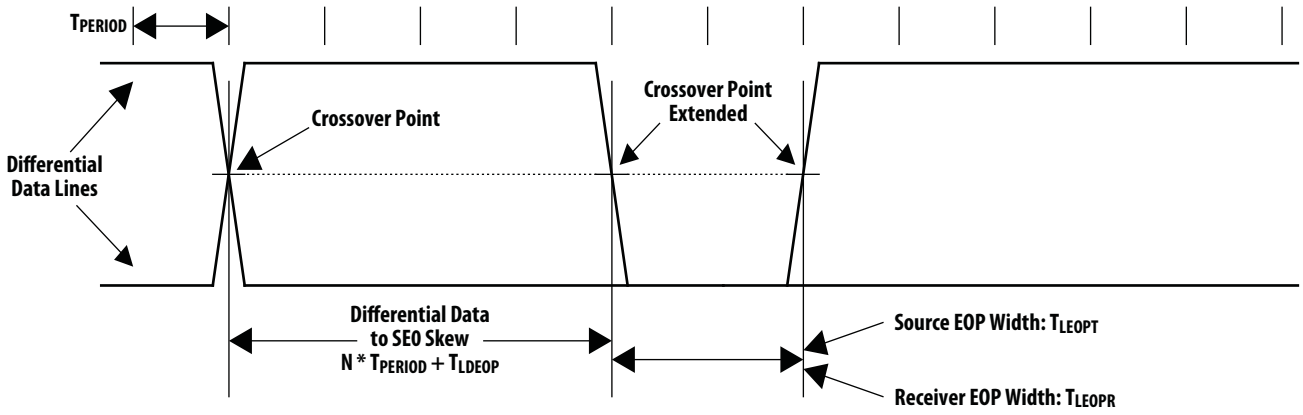


Figure 14. Differential to EOP Transition Skew and EOP Width

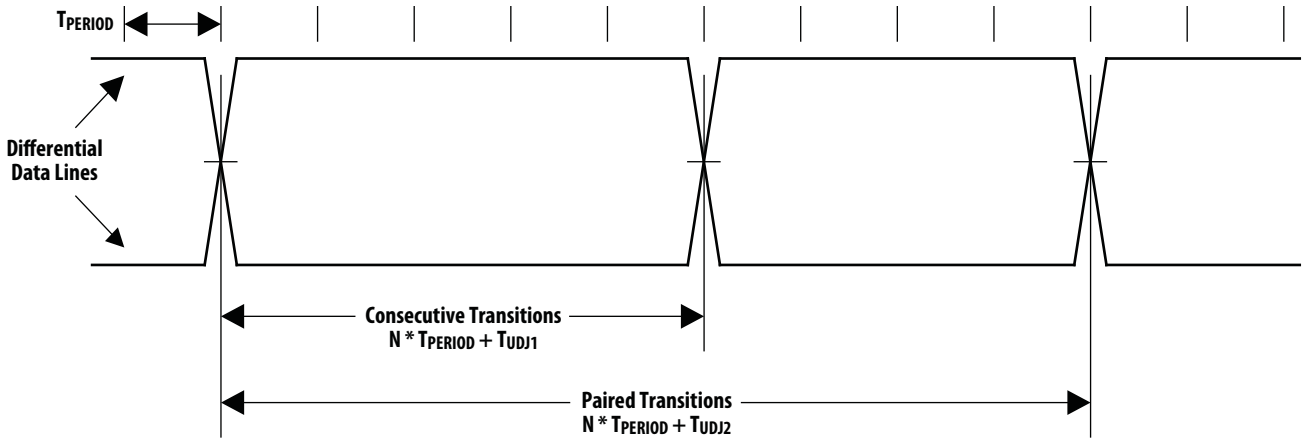


Figure 15. Differential Output Jitter

DC Electrical Specifications

Electrical Characteristics over recommended operating conditions. Typical values at 25° C, V_{DDA5} = 5.0 V.

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
System Current, Mouse Moving	I_{DD5}		35	50	mA	Includes XY_LED current
System Current, Mouse Not Moving	I_{DD5N}		15	30	mA	Includes XY_LED current
System Current, USB Suspend Mode, Remote Wakeup Enabled	I_{DD5S}			500	µA	Includes XY_LED current and D- pullup resistor.
Supply Current (Sensor only), Mouse Moving	I_{DDS}		4.5	8	mA	No load on SW, XY-LED, ZA, ZB, D+, D-
Supply Current (Sensor only), Mouse Not Moving	I_{DDSN}		3.9	7.5	mA	No load on SW, XY-LED, ZA, ZB, D+, D-
Sensor Supply Current, USB Suspend Mode	I_{DDSS}			320	µA	No load on SW, XY-LED, ZA, ZB, D+,D-
XY_LED Current	I_{LED}			30	mA	
XY_LED Output Low Voltage	V_{OL}			1.1	V	
Input Low Voltage	V_{IL}			0.5	V	Pins: ZA, ZB V_{IL} max of 0.5 V_{DC} is at V_{DDA5} min of 4 V_{DC}, with a typical of 0.8 V_{DC} at V_{DDA5} of 5 V_{DC}
Input High Voltage	V_{IH}	0.6*V_{DDA5}			V	Pins: ZA, ZB

One-Time-Programmable (OTP) Memory

The on chip OTP memory allows device configuration flexibility to override the default setting of sensors without any external software driver. Once the OTP operation is enabled, all OTP registers must be programmed accordingly as the default values of un-program OTP registers are always zero when L1_USE_OTP register setting is not zero value. Tips: OTP write to the OTP register can be skipped if the setting is zero value (0x00) in order to save the OTP programming time.

OTP address space is from 0xDF to 0xE8. OTP can be programmed via USB interface using Set Vendor Test and Get Vendor Test commands.

OTP Byte Write Operation

OTP write operation flow chart is shown in Figure 16.

1. Set OTP Clock enable bit in OTP_CLOCK register, 0x42: OTP_CLOCK_EN = 1.
2. Set OTP enable bit in OTP_CONFIG register, 0x51: OTP_EN = 1.
3. Write the OTP register address byte to OTP_ADDR register, 0x52.
4. Write the OTP data byte to OTP_DATA register, 0x53.
5. Set write enable bit in OTP_CTRL register, 0x54 to enable write command to OTP: WR = 1.
6. Read the write enable bit status in OTP_CTRL register, 0x54. If WR = 1, repeat reading the bit status until it is clear.
7. Read the write status bit in OTP_CTRLSTAT register, 0x58.
   a. If WR_OK = 1, OTP write operation is completed. Repeat Step 2 for more OTP byte write operations.
   b. If WR_OK = 0, repeat Step 5.
8. If Step 6b is repeated up to 10 times, OTP write operation is failed and the chip is confirmed as defective unit.

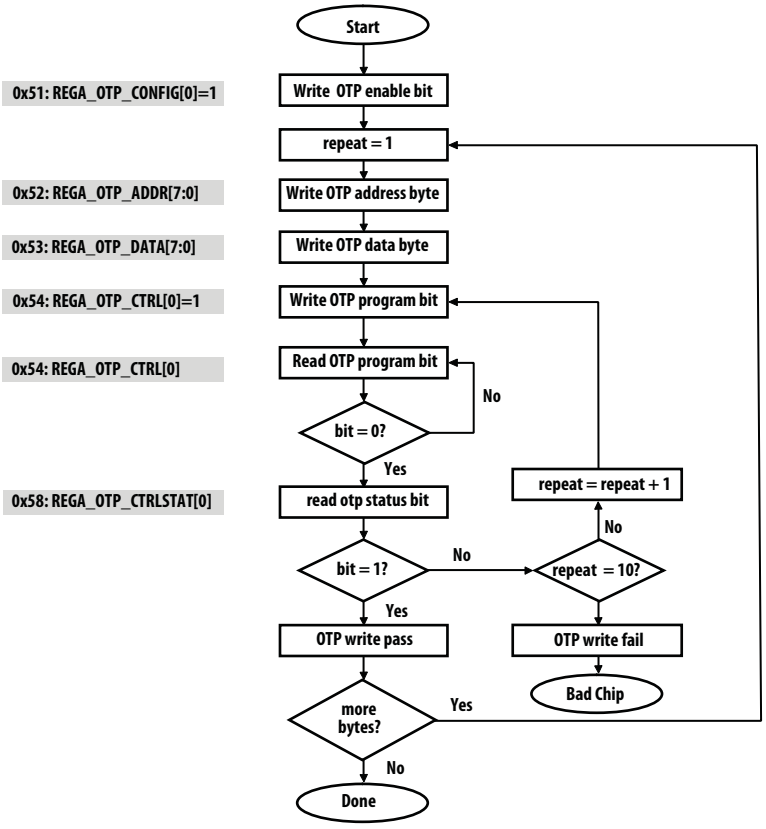


Figure 16. OTP Byte Write Flow Chart

OTP Byte Read Operation

OTP read operation flow chart is shown in Figure 17.

1. Set OTP Clock enable bit in OTP_CLOCK register, 0x42: OTP_CLOCK_EN = 1.
2. Set OTP enable bit in OTP_CONFIG register, 0x51: OTP_EN = 1.
3. Write the OTP register address byte to OTP_ADDR register, 0x52.
4. Set read enable bit in OTP_CTRL register, 0x54 to enable write command to OTP: RD = 1.
5. Read the read enable bit status in OTP_CTRL register, 0x54. If RD = 1, repeat reading the bit status until it is clear. Read the OTP data byte from OTP_DATA register, 0x53 to complete the OTP read operation.
6. Read the OTP data byte from OTP_DATA register, 0x53 to complete the OTP read operation.
7. Repeat Step 2 for more OTP read operations

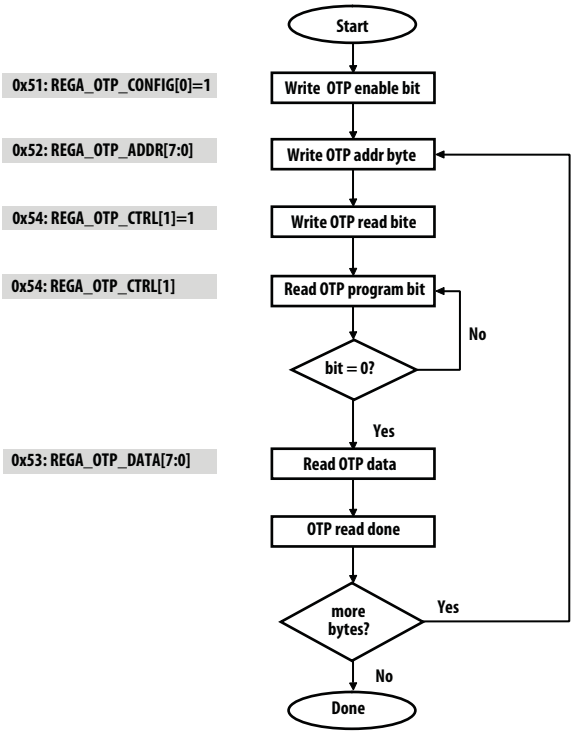


Figure 17. OTP Byte Read Flow Chart

OTP Lock Operation

OTP lock operation MUST be performed once OTP write to OTPLOCK1 register for the sensor to function. DO not reset or power up the chip right after OTP write to OTPLOCK1 register, otherwise the chip will be malfunction. The OTP lock operation flow chart is shown in Figure 18.

1. Set OTP Clock enable bit in OTP_CLOCK register, 0x42: OTP_CLOCK_EN = 1
2. After OTP write to OTPLOCK1 register, set OTP enable bit in OTP_CONFIG register, 0x51: OTP_EN = 1.
3. Set OTP lock bit in OTP_CTRL register, 0x54 to enable OTP lock command: LOCK_L1 = 1.
4. Read the OTP lock bit status in OTP_CTRL register, 0x54. If LOCK_L1 = 1, repeat reading the bit status until it is clear.
5. Read the lock status and CRC bits in OTP_CTRLSTAT register, 0x58.
   a. If both L1_LOCK_OK and L1_CRC_OK = 1, OTP lock operation is completed.
   b. If either L1_LOCK_OK or L1_CRC_OK = 0, repeat Step 2 until both bits are set.
6. If Step 4b is repeated up to 10 times, OTP lock operation is failed and the chip is confirmed as defective unit.
7. Read the CRC result stored in register 0xE9, 0xEA, 0xEB, 0xEC, if four register values not 0x00 means CRC has been generated correctly and verified as lock operation success.

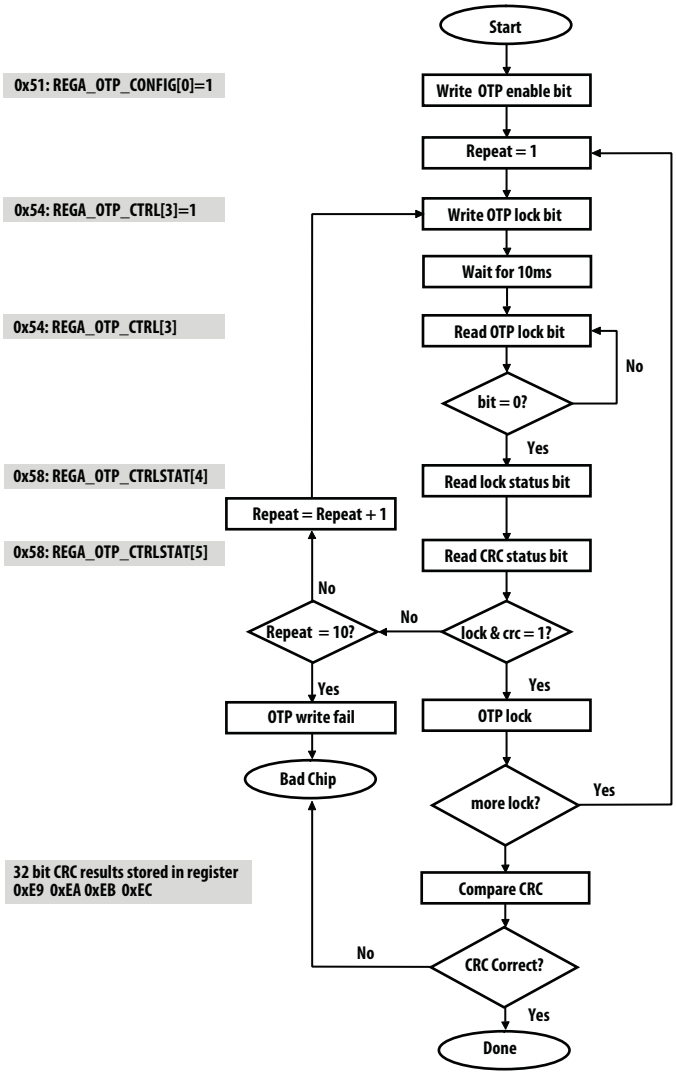


Figure 18. OTP Byte Lock Flow Chart

Buttons

The minimum time between button pressed is T_{DBB}. The button connection is described in Figure 19

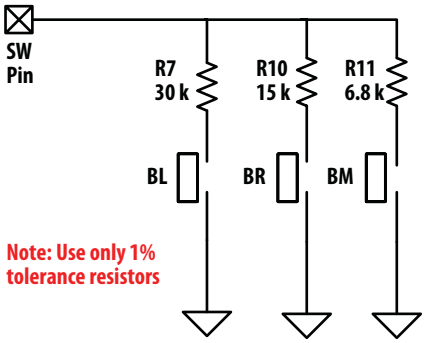


Figure 19. Button connections

Debounce Algorithm

- Button inputs B1, B2, and B3 are sampled every 6ms.
- Two consecutive low values create a button press event.
- Three consecutive high values create a button release event.

Configuration after Power up (Data Values)

Signal Function	State from Figure 9-1 of USB spec: Powered or Default Address or Configured	State from Figure 9-1 of USB spec: Suspended from Any Other State
SW	Output voltage at 1.16 V (Typ)	Output voltage at 2.7 V (Typ)
D-	USB I/O	Hi-Z Input
D+	USB I/O	Hi-Z Input
XY_LED	Always ON / Pulsing	Pulled HIGH (OFF)
ZB	Hi-Z Input	Output HIGH
ZA	Hi-Z Input	Output HIGH

Typical Performance Characteristics

Performance Characteristics over recommended operating conditions. Typical values at 25° C, V_{DD} = 5.0 V, 24 MHz

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Path Error (Deviation)	P_{Error}		0.5		%	Average path error as percent of total 2.5" travel on various standard surfaces

The following graphs are the typical performance of the sensor, assembled as shown in the 2D assembly drawing with trim lens, clip, and LED.

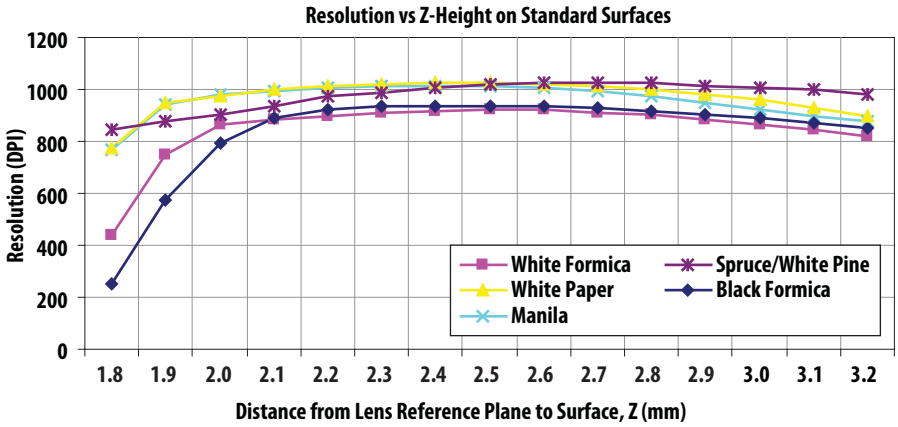


Figure 20. Typical Resolution vs. Z Height

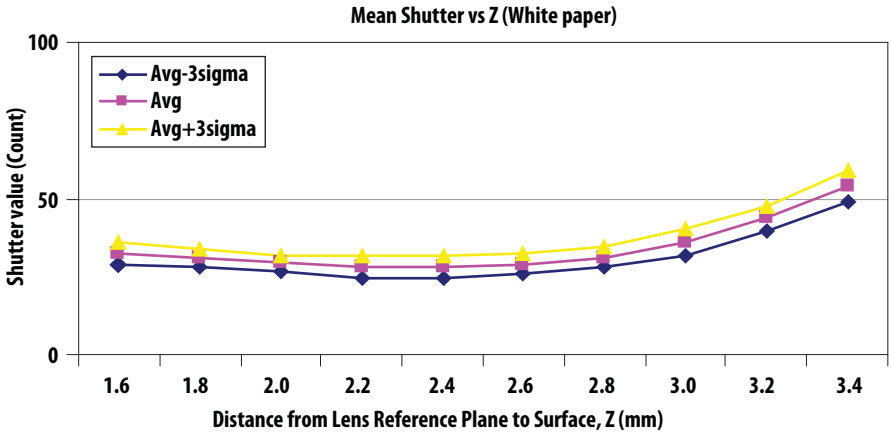


Figure 21. Mean shutter vs Z height over white paper

Notes:
1. The sensor is designed for optimal performance when used with the specified LED.
2. Z = distance from Lens Reference Plane to Surface.

USB Commands

Mnemonic	Command	Notes
USB_RESET	D+/D- low > 18.7 μs	Device Resets; Address=0
USB_SUSPEND	Idle state > 3 mS	Device enters USB low-power mode
USB_RESUME	Non-idle state	Device exits USB low-power mode
Get_Status_Device	80 00 00 00 00 00 02 00	Normally returns 00 00, Self powered 00 00, Remote wakeup 02 00
Get_Status_Interface	81 00 00 00 00 00 02 00	Normally returns 00 00
Get_Status_Endpt0	82 00 00 00 xx 00 02 00	OUT: xx=00, IN: xx=80 Normally returns 00 00
Get_Status_Endpt1	82 00 00 00 81 00 02 00	Normally returns 00 00, Halt 00 01
Get_Configuration	80 08 00 00 00 00 01 00	Return: 00=not config., 01=configured
Get_Interface	81 0A 00 00 00 00 01 00	Normally returns 00
Get_Protocol	A1 03 00 00 00 00 01 00	Normally returns 01, Boot protocol 00
Get_Desc_Device	80 06 00 01 00 00 nn 00	See USB command details
Get_Desc_Config	80 06 00 02 00 00 nn 00	See USB command details
Get_Desc_String	80 06 xx 03 00 00 nn 00	See USB command details
Get_Desc_HID	81 06 00 21 00 00 09 00	See USB command details
Get_Desc_HID_Report	81 06 00 22 00 00 nn 00	See USB command details
Get_HID_Input	A1 01 00 01 00 00 nn 00	Return depends on motion & config
Get_Idle	A1 02 00 00 00 00 01 00	Returns rate in multiples of 4 ms
Get_Vendor_Test	C0 01 00 00 xx 00 01 00	Read register xx
Set_Address	00 05 xx 00 00 00 00 00	xx = address
Set_Configuration	00 09 xx 00 00 00 00 00	Not configured: xx=00 Configured: xx=01
Set_Interface	01 0B 00 00 00 00 00 00	Only one interface supported
Set_Protocol	21 0B xx 00 00 00 00 00	Boot: xx=00, Report: xx=01
Set_Feature_Device	00 03 01 00 00 00 00 00	Enable remote wakeup
Set_Feature_Endpt0	02 03 00 00 xx 00 00 00	Halt. OUT: xx=00, IN: xx=80
Set_Feature_Endpt1	02 03 00 00 81 00 00 00	Halt
Clear_Feature_Device	00 01 01 00 00 00 00 00	Disable Remote wakeup
Clear_Feature_Endpt0	02 01 00 00 xx 00 00 00	Clear Halt; OUT: xx=00, IN: xx=80
Clear_Feature_Endpt1	02 01 00 00 81 00 00 00	Clear Halt
Set_Idle	21 0A 00 rr 00 00 00 00	rr = report rate in multiples of 4 ms
Set_Vendor_Test	40 01 00 00 xx yy 00 00	Write yy to address xx
Poll_Endpt1		Read buttons, motion, & Z-wheel

Note:
The last two bytes in a command shown as "nn 00" specify the 16-bit data size in the order of "LowByte HighByte." For example a two-byte data size would be specified as "02 00." The sensor will not provide more bytes than the number requested in the command, but it will only supply up to a maximum of 8 bytes at a time. The sensor will re-send the last packet if the transfer is not acknowledged properly.

USB COMMAND DETAILS

USB_RESET	D+/D- low for an extended period
USB Spec:	A device may reset after seeing an SE0 for more than 18.7 uS, and definitely after 10 mS.
Notes:	After power up and prior to Reset, the device will not respond to any USB commands. After the device has been given a USB Reset, the device's address will be reset to zero and the device will be in the Default state. The chip will default to Report protocol and any pending output will be flushed. All registers will be reset to a state that matches power-on-reset with the following exceptions: USB State register will be "Default" instead of "Attached".
USB_SUSPEND	Idle state for an extended period
USB Spec:	A device may suspend after seeing an idle for more than 3 mS, and definitely after 10 mS.
Notes:	The chip will take a minimum of 5 mS to start Suspend, though will definitely start after 6 mS. The chip may finish the current frame if necessary before stopping the clock. Thus, an additional frame time may be used to reach Suspend mode.
USB_RESUME	Non-idle state
USB Spec: Notes:	Remote Resume signalling from a device must be between 1 mS and 15 mS. The host is required to send Resume signaling for 20 mS plus 10 mS of resume recovery time in which it does not access any devices. This allows devices enough time to wake back up.
	The chip can cause a Resume if Remote Wakeup is enabled and a button has been pressed. Remote resume signalling from the chip will last 11.45 mS to 12.45 mS.
Get_Status_Device	80 00 00 00 00 00 02 00
Returns:	xx yy xx[0] = Self Powered xx[1] = Remote Wakeup xx[7:2] = 0 yy = 00 (Reserved)
Default:	Accept (undefined in USB Spec)
Addressed:	Accept
Configured:	Accept
Notes:	Use Set_Feature_Device/Clear_Feature_Device to set/clear remote wakeup.
Get_Status_Interface	81 00 00 00 00 00 02 00
Returns:	00 00
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Accept
Notes:	Both return bytes are reserved and currently 00.

Get_Status_Endpt0	82 00 00 00 xx 00 02 00 82 00 00 00 00 00 02 00 82 00 00 00 80 00 02 00 xx = 00 = Endpt0 OUT xx = 80 = Endpt0 IN
Returns:	xx yy xx[0] = Halt xx[7:1] = 0 yy = 00 (Reserved)
Default:	Accept (undefined in USB Spec)
Addressed:	Accept
Configured:	Accept
Notes:	Use Set_Feature_Endpt0/Clear_Feature_Endpt0 to (try to) set/clear Halt bit. According to USB, "It is neither required or recommended that the Halt feature be implemented for the Default Control Pipe." Since a new SETUP command will clear any Endpt0 halt bit, it is impossible to tell if there really is a halt bit.
Get_Status_Endpt1	82 00 00 00 81 00 02 00
Returns:	xx yy xx[0] = Halt xx[7:1] = 0 yy = 00 (Reserved)
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Accept
Notes:	Use Set_Feature_Endpt1/Clear_Feature_Endpt1 to set/clear Halt bit.
Get_Configuration	80 08 00 00 00 00 01 00
Returns:	xx xx = config value
Default:	Accept (undefined in USB Spec) – returns 00
Addressed:	Accept – returns 00
Configured:	Accept – returns 01
Notes:	Use Set_Configuration to change.
Get_Interface	81 0A 00 00 00 00 01 00
Returns:	00
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Accept – returns 00
Notes:	Command has no alternate interfaces, so only valid value is 00

Get_Protocol	A1 03 00 00 00 00 01 00
Returns:	xx xx = 00 = Boot protocol xx = 01 = Report protocol
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	Defaults to Report protocol after USB Reset. Use Set_Protocol to change.
Get_Desc_Device	80 06 00 01 00 00 nn 00 80 06 00 01 00 00 12 00
Returns:	12 01 00 02 00 00 00 08 vv vv pp pp dd dd mm PP ss 01
Example:	vv vv = vendor id pp pp = product id (vendor specified) dd dd = device id (vendor specified) (bcd rev_id byte) mm = iManufacturer PP = iProduct ss = iSerialNumber (00 – no string)
Example for Multi-button:	12 01 00 02 00 00 00 08 6D 04 pp pp 00 54 01 02 00 01 // Device Descriptor | 12 // bLength (18 decimal) | 01 // bDescriptorType | 00 // bcdUSB (Release ##.## = 02.00) | 02 | 00 // bDeviceClass | 00 // bDeviceSubClass | 00 // bDeviceProtocol | 08 // bMaxPacketSize0 | 2F // idVendor | 19 // idVendor | 16 // idProduct // based on #buttons & wheel | 09 // idProduct | 00 // bcdDevice (Dev Rel 54.00) | 54 | 00 // iManufacturer | 02 // iProduct | 00 // iSerialNumber | 01 // bNumConfigurations
Default:	Accept
Addressed:	Accept
Configured:	Accept Get_Desc_String will return "stall" if Manufacturer string is queried when iManufacturer = 0x00.

Get_Desc_Config	80 06 00 02 00 00 nn 00 80 06 00 02 00 00 22 00
Returns:	09 02 22 00 01 01 00 A0 32 09 04 00 00 01 03 01 02 00 09 21 11 01 00 01 22 rr 00 07 05 81 03 05 00 0A rr = HID Report descriptor length 47 = 12 bit motion reporting
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	This is the concatenation of 4 descriptors: Configuration Interface HID Endpt
Get_Desc_String	80 06 xx 03 00 00 nnl nnh xx= 00 Language String 01 Manufacturer String 02 Product String
Command Option:	xx= 00 => Language String 01 => Manufacturer String 02 => Product String Nnl nnh = varies with the string length
Returns:	ss 03 “unicode string” ss = String descriptor length
For xx = 00:	04 03 09 04 // Language ID
For xx = 01:	default: stall

Product String (xx=02)

Product String	Returns
USB Optical Mouse	24 03 55 00 53 00 42 00 20 00 4f 00 70 00 74 00 69 00 63 00 61 00 6c 00 20 00 4d 00 6f 00 75 00 73 00 65 00
Synopsys cmd:	No
Default:	Accept
Addressed:	Accept
Configured:	Accept

Notes:
1. A request for any other string will STALL.
2. Returned string depends on the manufacturer string section via OTP.

Get_Desc_HID	81 06 00 21 00 00 09 00
Returns:	09 21 11 01 00 01 22 rr 00 rr = HID Report descriptor length 40 = 12bit reporting
Get_Desc_HID_Report	81 06 00 22 00 00 nn 00
Returns:	This returns a report descriptor that describes how many buttons and x, y, z data.
12 bit reporting:	05 01 09 02 A1 01 09 01 A1 00 05 09 19 01 29 03 15 00 25 01 75 01 95 03 81 02 75 05 95 01 81 01 05 01 09 30 09 31 16 01 F8 26 FF 07 75 0C 95 02 81 06 09 38 15 81 25 7F 75 08 95 01 81 06 C0 C0 // HID Report | 05 01 // USAGE_PAGE (Generic Desktop) | 09 02 // USAGE (Mouse) | A1 01 // COLLECTION (Application) | 09 01 // USAGE (Pointer) | A1 00 // COLLECTION (Physical) | 05 09 // USAGE_PAGE (Button) | 19 01 // USAGE_MINIMUM (Button 1) | 29 03 // USAGE_MAXIMUM (Button #3) | 15 00 // LOGICAL_MINIMUM (0) | 25 01 // LOGICAL_MAXIMUM (1) | 75 01 // REPORT_SIZE (1) | 95 03 // REPORT_COUNT (3) | 81 02 // INPUT (Data,Var,Abs) | 75 05 // USAGE PAGE | 95 01 // REPORT COUNT(1) | 81 01 // INPUT (CNST,ARR,ABS) | 05 01 // USAGE PAGE (Generic Desktop) | 09 30 // USAGE (X) | 09 31 // USAGE (Y) | 16 01 F8 // LOGICAL MINIMUM (-127) | 26 FF 07 // LOGICAL MAXUMUN (128) | 75 0C // REPORT_SIZE (12) | 95 02 // REPORT_COUNT (2) | 81 06 // INPUT (Data,Var,Rel) | 09 38 // USAGE (Zwheel) | 15 81 // LOGICAL MINIMUM(-127) | 25 7F // LOGICAL MAXIMUM(127) | 75 08 // REPORT_SIZE(8) | 95 01 // REPORT_COUNT(1) | 81 06 // INPUT(Data,Var,Rel) | C0 // END_COLLECTION | C0 // END_COLLECTION
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	The length of this report is needed in the HID descriptor.

Get_HID_Input	A1 01 00 01 00 00 nn 00 nn = 06 (12 bit reporting)
Returns:	bb xx yx yy zz bb = button byte xx = X motion byte yx = XY motion byte yy = Y motion byte zz = Z motion byte
Default:	Stall
Addressed:	Stall
Configured:	Accept
Notes:	If the device is configured, it will always respond with a report for this command, even if no motion or button changes have occurred. In this case, it would report 00 for motion and simply report the current button state. If a report is pending on endpt1, the data there will be reported and the report on endpt1 cleared. The mouse will only create new button/motion packets when it is in the Configured state

USB Data Packet Format

Bit	7	6	5	4	3	2	1	0
Byte 1	0	0	0	0	0	B3(MB)	B2(RB)	B1(LB)
Byte 2	X7	X6	X5	X4	X3	X2	X1	X0
Byte 3	Y3	Y2	Y1	Y0	X11	X10	X9	X8
Byte 4	Y11	Y10	Y9	Y8	Y7	X6	X5	X4
Byte 5	Z7	Z6	Z5	Z4	Z3	Z2	Z1	Z0
Byte 6	0	0	0	0	0	0	0	0

Get_Idle	A1 02 00 00 00 00 01 00
Returns:	rr rr = rate in multiples of 4 mS
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	The third byte of the command is to select the Report ID. There is only one for the mouse – so, using 00 or 01 will work. See also Set_Idle.
Get_Vendor_Test	C0 01 00 00 xx 00 01 00 ii = ignore xx = address of register to read
Returns:	rr (depends on register read)
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	Address range (xx) is datasheet register range

Set_Address	00 05 xx 00 00 00 00 00 xx = new device address, from 00 to 7F
Default:	Accept
Addressed:	Accept
Configured:	Accept (undefined in USB Spec) Chip gets new address, but stays in "Configured" mode.
Notes:	If device is not configured, the device will be given the new address and put in the addressed state (or default if new address = 00). If the device is already configured, the device will be given the new address state and remain configured.
Set_Configuration	00 09 xx 00 00 00 00 00 xx = 00 = not configured xx = 01 = configured
Default:	Accept (undefined in USB Spec)
Addressed:	Accept
Configured:	Accept
Notes:	Invalid config values will cause stall. Chip will stall invalid value in configured mode, and leave device in old (configured) mode.
Set_Interface	01 0B 00 00 00 00 00 00
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Accept
Notes:	Mouse has only one valid interface (00) and alternate setting (00). Invalid values will cause stall. Chip retains previous (valid) interface state after executing this command in configured mode even if invalid values are given and command was stalled.
Set_Protocol	21 0B xx 00 00 00 00 00 xx = 00 = Boot protocol xx = 01 = Report protocol
Default:	Accept (Not in USB Spec)
Addressed:	Accept (Not in USB Spec)
Configured:	Accept
Notes:	3 byte data packets will be reported in boot mode. These bytes are button, XX data, and YY data.
Set_Feature_Device	00 03 01 00 00 00 00 00
Default:	Accept (undefined in USB Spec)
Addressed:	Accept
Configured:	Accept
Notes:	This sets the remote wakeup bit.
Set_Feature_Endpt0	02 03 00 00 xx 00 00 00 02 03 00 00 00 00 00 00 02 03 00 00 80 00 00 00 xx = 00 = Endpt0 OUT xx = 80 = Endpt0 IN
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Stall
Notes:	This (tries to) sets the halt bit. The chip always stalls the status stage for this command. The chip never reports the halt bit set for Endpt0 with the Get_Status_Endpt0 command, as any new SETUP command will clear Endpt0 stall.

Set_Feature_Endpt1	02 03 00 00 81 00 00 00
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Accept
Notes:	Sets the halt bit for Endpt1.
Clear_Feature_Device	00 01 01 00 00 00 00 00
Default:	Accept (undefined in USB Spec)
Addressed:	Accept
Configured:	Accept
Notes:	This clears the remote wakeup bit.
Clear_Feature_Endpt0	02 01 00 00 xx 00 00 00 02 01 00 00 00 00 00 00 02 01 00 00 80 00 00 00 xx = 00 = Endpt0 OUT xx = 80 = Endpt0 IN
Default:	Accept (undefined in USB Spec)
Addressed:	Accept
Configured:	Accept
Notes:	The chip does NOT stall like it does for Set_Feature_Endpt0.
Clear_Feature_Endpt1	02 01 00 00 81 00 00 00
Default:	Stall (undefined in USB Spec)
Addressed:	Stall
Configured:	Accept
Notes:	See Set_Feature_Endpt1.
Set_Idle	21 0A 00 rr 00 00 00 00 rr = rate in multiples of 4 mS
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	The third byte of the command is to select the Report ID. There is only one for the mouse – so, using either 00 or 01 will work. The fourth byte of the command sets the rate in multiples of 4 mS. The initial value for mice will be x00 which means "infinite" – that is packets only come out when there is a change in data. Data will only be allowed to come out when the device is configured. However, the chip will accept the command in Default or Addressed mode and use that value when the device is later configured.
Set_Vendor_Test	40 01 00 00 xx yy 00 00 xx = address yy = data
Default:	Accept
Addressed:	Accept
Configured:	Accept
Notes:	Address range for "xx" should be 0x00 to 0x3F. Addresses above this are reserved for possible future use. See also Get_Vendor_Test.

Poll_Endpt1	
Returns:	bb xx yx yy zz bb = button byte xx = X motion byte yx = XY motion byte yy = Y motion byte zz = Z motion byte (if Z-Wheel)
Default:	Ignore request
Addressed:	Ignore request
Configured:	Accept (NAK if no data; Send packet if available)
Notes:	See also Get_HID_Input. Endpt will only stall if halt bit is set by Set_Feature_Endpt1. Details of data packet are below. Endpt1 should be polled at least every 10 frames (mS). It is typically polled every 8 frames on Windows machines. For internal testing, Endpt1 can be continuously polled if desired. The chip will not generate any report packets unless in the Configured state. If Endpt1 is currently empty, any motion or button change will be loaded into the Endpt1 buffers. Once the Endpt1 buffers are full, any further motion events will get accumulated. When the Endpt1 buffers are later polled and emptied, the current accumulated X/Y/Z values will be loaded into the Endpt1 buffers. After transferring their data, the accumulation registers are reset so they are ready to start accumulating new motion events. Button information is handled a bit differently. If the Endpt1 buffers are empty, and a button change event occurs, the new button state is put into the Endpt1 buffers. At the same time, the button state that is put in Endpt1 is copied for later use. While Endpt1 is full, changes in button state are essentially ignored. When Endpt1 is emptied, if the current button state is different than that which was last loaded into Endpt1, then the new state will be loaded and a new copy saved. Basically, the button state that is loaded into Endpt1 is always the current button state at that point in time. It should also be noted that there is hardware on the chip to help de-bounce the buttons.
Special note on wLength:	The wLength paramater in commands specifies the maximum number of bytes a device should send back. The commands listed below are not able to handle a wLength of 0 correctly. Get_Status_Device Get_Status_Interface Get_Status_Endpt0 Get_Status_Endpt1 Get_Configuration Get_Interface This chip will send one byte of data rather than none when wLength = 0 is requested for the above commands.

Registers

The sensor can be programmed through registers, via the USB port, and configuration and motion data can be read from these registers. The registers will be "disabled" by V_{DDA5} going low or sending a USB reset command.

Address	Register Name	Register Type	Access	Reset Value
0x00	PROD_ID	Device	Read only	0x2b
0x01	REV_ID	Device	Read only	0x01
0x02	MOUSE_STAT	Device	Read only	Undefined
0x03	DELTA_X_L	Device	Read only	0x00
0x04	DELTA_Y_L	Device	Read only	0x00
0x05	DELTA_XY_H	Device	Read only	0x00
0x06	DZ	Device	Read only	0x00
0x07	SQUAL	Device	Read only	0x00
0x08	SHUT_HI	Device	Read only	0x00
0x09	SHUT_LO	Device	Read only	0x32
0x0A	PIX_MAX	Device	Read only	0x00
0x0B	PIX_ACCUM	Device	Read only	0x00
0x0C	PIX_MIN	Device	Read only	0x00
0x0D	PIX_GRAB	Device	Read only	0x00
0x40	INV_REV_ID	Device	Read only	0xFE
0x42	OTP_CLOCK	Device	Read/Write	0x00
0x51	OTP_CONFIG	Device	Read/Write	0x00
0x52	OTP_ADDR	Device	Read/Write	0x00
0x53	OTP_DATA	Device	Read/Write	0x00
0x54	OTP_CTRL	Device	Read/Write	0x00
0x56	OTP_RUNSTAT	Device	Read only	Undefined
0x58	OTP_CTRLSTAT	Device	Read only	Undefined
0xDF	L1_USE_OTP	OTP	Read/Write	0x00
0xE0	DPI	OTP	Read/Write	0x04
0xE2 : 0xE3	PID1 : PID0	OTP	Read/Write	0x0916
0xE4 : 0xE5	VID1 : VID0	OTP	Read/Write	0x192F
0xE8	OTPLOCK1	OTP	Read/Write	0x00

PROD_ID Address: 0x00 Type: Device

Access: Read only Reset Value: 0x2b

Bit	7	6	5	4	3	2	1	0
Field	PID_7	PID_6	PID_5	PID_4	PID_3	PID_2	PID_1	PID_0

Data Type: 8-bit number with the product identifier.

USAGE: The value in this register does not change; it can be used to verify that the sensor communications link is OK.

REV_ID Address: 0x01 Type: Device

Access: Read only Reset Value: 0x01

Bit	7	6	5	4	3	2	1	0
Field	RID_7	RID_6	RID_5	RID_4	RID_3	RID_2	RID_1	RID_0

Data Type: 8-bit number with current revision of the IC.

USAGE: This register contains the IC revision. It is subject to change when new IC versions are released.

BUT_STAT Address: 0x02 Type: Device

Access: Read only Reset Value: Undefined

Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	Reserved	Reserved	BUT_3	BUT_2	BUT_1

Data Type: Bit field.

USAGE: This register is included for *test purposes only*. For navigation use, use the USB HID defined commands. The button status bits reported are for the debounce signals.

Field Name	Description
BUT_3	Reports the status of B3 0 = Open 1 = Button Pressed
BUT_2	Reports the status of B2 0 = Open 1 = Button Pressed
BUT_1	Reports the status of B1 0 = Open 1 = Button Pressed

DELTA_X_L Address: 0x03

Access: Read Reset Value: 0x00

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: Bit field.

USAGE: The value in this register reflects the last USB delta X (lower 8 bits) data output or data queued for output. This register is included for *test purposes only*. For navigation use, use the HID defined commands. Data is 2's complement. Absolute value is determined by the currently set resolution.

Register 0x03 must be read before register 0x04 (Delta_Y_L) and 0x05 (Delta_XY_H)

DELTA_Y_L Address: 0x04

Access: Read Reset Value: 0x00

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: Bit field.

USAGE: The value in this register reflects the last USB delta Y (lower 8 bits) data output or data queued for output. This register is included for *test purposes only*. **Register 0x03 should be read before register 0x04 (Delta_Y_L) and 0x05 (Delta_XY_H), else Delta_Y_L will return 0.** For navigation use, use the HID defined commands. Data is 2's complement. Absolute value is determined by the currently set resolution.

DELTA_XY_H Address: 0x05

Access: Read Reset Value: 0x00

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: Bit field.

USAGE: The value in this register reflects the last USB delta X and Y (upper 4 bits) data output or data queued for output. This register is included for *test purposes only*. **Register 0x03 should be read before register 0x04 (Delta_Y_L) and 0x05 (Delta_XY_H), else Delta_XY_H will return 0.** For navigation use, use the HID defined commands. Data is 2's complement. Absolute value is determined by the currently set resolution.

DZ Address: 0x06

Access: Read Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	Z_7	Z_6	Z_5	Z_4	Z_3	Z_2	Z_1	Z_0

Data Type: Bit field.

USAGE: This register contains the Z-wheel count. Range is from -127 to 127 decimal.

SQUAL Address: 0x07

Access: Read Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	SQ_7	SQ_6	SQ_5	SQ_4	SQ_3	SQ_2	SQ_1	SQ_0

Data Type: Eight bit number.

USAGE: SQUAL is a measure of the number of features visible by the sensor in the current frame. The maximum value is 128. Since small changes in the current frame can result in changes in SQUAL, slight variations in SQUAL on one surface is expected.

SHUT_HI Address: 0x08 Type: Device

Access: Read only Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	S_{15}	S_{14}	S_{13}	S_{12}	S_{11}	S_{10}	S_9	S_8

SHUT_LO Address: 0x09 Type: Device

Access: Read only Reset Value: 0x64

Bit	7	6	5	4	3	2	1	0
Field	S_7	S_6	S_5	S_4	S_3	S_2	S_1	S_0

Data Type: 16-bit number.

USAGE: The combination of SHUT_HI and SHUT_LO is a 16-bit number. This is the number of clocks the shutter was open for the last image taken. The unit is in main clock count (nominally 12MHz). To avoid split read issues, read SHUT_Hi first.

PIX_MAX Address: 0x0A Type: Device

Access: Read only Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	0	MX_6	MX_5	MX_4	MX_3	MX_2	MX_1	MX_0

Data Type: Eight bit number.

USAGE: This is the maximum pixel value from the last image taken.

PIX_ACCUM Address: 0x0B Type: Device

Access: Read only Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	AC_7	AC_6	AC_5	AC_4	AC_3	AC_2	AC_1	AC_0

Data Type: High 8bits of 17-bit unsigned integer.

USAGE: This is the accumulated pixel value from the last image taken. For the 19x19 pixels, only the 8 most prominent bits are reported ([15:8]). To get the true average pixel value, divide this register value by 1.41.

PIX_MIN Address: 0x0C Type: Device

Access: Read only Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	0	MN_6	MN_5	MN_4	MN_3	MN_2	MN_1	MN_0

Data Type: 8-bit number.

USAGE: This is the minimum pixel value from the last image taken.

PIX_GRAB Address: 0x0D Type: Device

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	VALID	PG_6	PG_5	PG_4	PG_3	PG_2	PG_1	PG_0

Data Type: 8-bit number.

USAGE: The pixel grabber captures 1 pixel per frame. If there is a valid pixel in the grabber when this is read, the MSB will be set, an internal counter will incremented to captured the next pixel and the grabber will be armed to capture the next pixel. It will take 361 reads to upload the completed image.

Any write to this register will reset and arm the grabber to grab pixel 0 on the next image. See pixel array numbering in Figure 20.

342	323	304	285	266	247	228	209	190	171	152	133	114	95	76	57	38	19	0
343	324	305	286	267	248	229	210	191	172	153	134	115	96	77	58	39	20	1
344	325	306	287	268	249	230	211	192	173	154	135	116	97	78	59	40	21	2
345	326	307	288	269	250	231	212	193	174	155	136	117	98	79	60	41	22	3
346	327	308	289	270	251	232	213	194	175	156	137	118	99	80	61	42	23	4
347	328	309	290	271	252	233	214	195	176	157	138	119	100	81	62	43	24	5
348	329	310	291	272	253	234	215	196	177	158	139	120	101	82	63	44	25	6
349	330	311	292	273	254	235	216	197	178	159	140	121	102	83	64	45	26	7
350	331	312	293	274	255	236	217	198	179	160	141	122	103	84	65	46	27	8
351	332	313	294	275	256	237	218	199	180	161	142	123	104	85	66	47	28	9
352	333	314	295	276	257	238	219	200	181	162	143	124	105	86	67	48	29	10
353	334	315	296	277	258	239	220	201	182	163	144	125	106	87	68	49	30	11
354	335	316	297	278	259	240	221	202	183	164	145	126	107	88	69	50	31	12
355	336	317	298	279	260	241	222	203	184	165	146	127	108	89	70	51	32	13
356	337	318	299	280	261	242	223	204	185	166	147	128	109	90	71	52	33	14
357	338	319	300	281	262	243	224	205	186	167	148	129	110	91	72	53	34	15
358	339	320	301	282	263	244	225	206	187	168	149	130	111	92	73	54	35	16
359	340	321	302	283	264	245	226	207	188	169	150	131	112	93	74	55	36	17
360	341	322	303	284	265	246	227	208	189	170	151	132	113	94	75	56	37	18

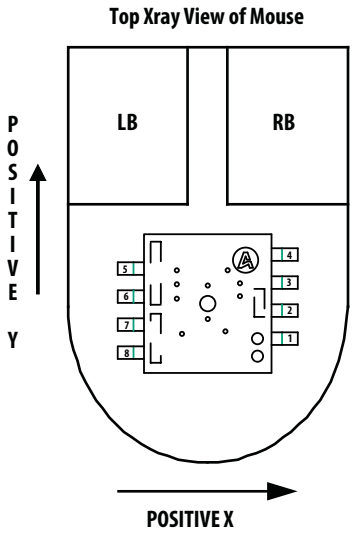


Figure 20. Pixel Map. Sensor looking at the navigation surface through the lens from top of mouse.

INV_REV_ID Address: 0x40

Access: Read Reset Value: 0xfe

Bit	7	6	5	4	3	2	1	0
Field	$RRID_7$	$RRID_6$	$RRID_5$	$RRID_4$	$RRID_3$	$RRID_2$	$RRID_1$	$RRID_0$

Data Type: Eight bit number.

USAGE: Contains the inverse of the revision ID which is located in register 0x01.

OTP_CONFIG Address: 0x51 Type: Device

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	OTP_EN

Data Type: Bit field.

USAGE: OTP commands enable/disable. Refer to OTP programming section.

Field Name	Description
OTP_EN	OTP commands 1 = Enabled **0 = Disabled**

OTP_ADDR Address: 0x52 Type: Device

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	OTP_ $ADDR_7$	OTP_ $ADDR_6$	OTP_ $ADDR_5$	OTP_ $ADDR_4$	OTP_ $ADDR_3$	OTP_ $ADDR_2$	OTP_ $ADDR_1$	OTP_ $ADDR_0$

Data Type: 8-bit number.

USAGE: This register is the container of OTP address in OTP read/write command. Refer to OTP programming section.

OTP_DATA Address: 0x53 Type: Device

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	OTP_ $DATA_7$	OTP_ $DATA_6$	OTP_ $DATA_5$	OTP_ $DATA_4$	OTP_ $DATA_3$	OTP_ $DATA_2$	OTP_ $DATA_1$	OTP_ $DATA_0$

Data Type: 8-bit number.

USAGE: This register is the container of OTP data value in OTP read/write command. Refer to OTP programming section.

OTP_CRTL Address: 0x54 Type: Device

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	Reserved	LOCK_L1	Reserved	RD	WR

Data Type: Bit field.

USAGE: This register controls the read, write and lock commands of OTP. The commands are auto clear for status check. Refer to OTP programming section.

Field Name	Description
WR	Enable write command to OTP 1 = Write to OTP **0 = Write command is completed**
RD	Enable read command to OTP 1 = Read from OTP **0 = Data is ready to be read from OTP_DATA register**
LOCK_L1	Enable OTP lock command 1 = Lock OTP space **0 = Lock command is completed**

OTP_RUNSTAT Address: 0x56 Type: Device

Access: Read only Reset Value: Undefined

Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	Reserved	Reserved	Reserved	L1_ CHECKED	L1_ LOCKED	L1_USED

Data Type: Bit field.

USAGE: This register shows the OTP run status. Refer to OTP programming section.

Field Name	Description
L1_USED	OTP space status 1 = Used 0 = Unused
L1_LOCKED	OTP space locking status 1 = Locked 0 = Open
L1_CHECKED	OTP status check 1 = Checked 0 = Unchecked

OTP_CTRLSTAT Address: 0x58 Type: Device

Access: Read only Reset Value: Undefined

Bit	7	6	5	4	3	2	1	0
Field	Reserved	Reserved	L1_CRC_ OK	L1_LOCK_ OK	DEVICE_ DONE	DEVICE_ RDY	WR_ DENIED	WR_OK

Data Type: Bit field.

USAGE: This register shows the OTP control status. Refer to OTP programming section.

Field Name	Description
WR_OK	OTP write status 1 = OK 0 = Failed
WR_DENIED	OTP write access status 1 = Denied 0 = OK
L1_LOCK_OK	OTP lock status 1 = OK 0 = Failed
L1_CRC_OK	CRC test status 1 = OK 0 = Failed

L1_USE_OTP Address: 0xDF Type: OTP

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	L1_USE_ OTP_7	L1_USE_ OTP_6	L1_USE_ OTP_5	L1_USE_ OTP_4	L1_USE_ OTP_3	L1_USE_ OTP_2	L1_USE_ OTP_1	L1_USE_ OTP_0

Data Type: 8-bit field.

USAGE: Bypass OTP configuration if all bits are zero. MUST write non-zero value to this register to enable OTP operation. Once enabled, all OTP registers must be written as the default values are zero value.

DPI Address: 0xE0 Type: OTP

Access: Read/Write Reset Value: 0x54

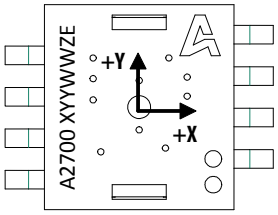
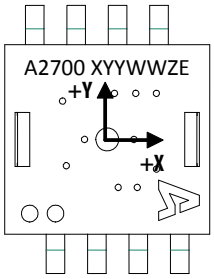
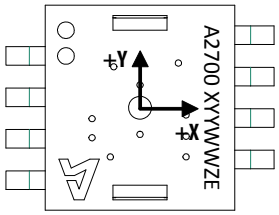
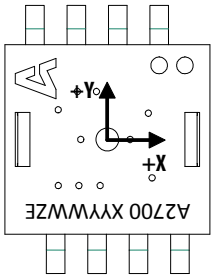
Bit	7	6	5	4	3	2	1	0
Field	Reserved	SwapXY	INV_X	INV_Y	Reserved	DPI_2	DPI_1	DPI_0

Data Type: Bit field.

USAGE: These registers are used to customize the device's DPI.

Field Name	Description
SwapXY	To swap x and y **0 = no swap** 1 = swap
INV_X	To invert x direction **0 = not inverted** 1 = inverted
INV_Y	To invert y direction **0 = not inverted** 1 = inverted
DPI	Device status 010 = 500 dpi 011 = 750 dpi 100 = 1000 dpi (default) 101 = 1250 dpi

Note: Sensor orientation setting by changing bit 6,5 and 4. The SwapXY operation is always performed before INV_X and INV_Y inversion operations.

Rotation	0°	90°	180°	270°
Bit[6:4]	101	000	110	011
Motion Reporting Direction				

PID0 Address: 0xE2 Type: OTP

Access: Read/Write Reset Value: 0x16

Bit	7	6	5	4	3	2	1	0
Field	PID_7	PID_6	PID_5	PID_4	PID_3	PID_2	PID_1	PID_0

PID1 Address: 0xE3 Type: OTP

Access: Read/Write Reset Value: 0x09

Bit	7	6	5	4	3	2	1	0
Field	PID_{15}	PID_{14}	PID_{13}	PID_{12}	PID_{11}	PID_{10}	PID_9	PID_8

Data Type: 16-Bit number.

USAGE: These registers are used to customize device USB PID. **Default is Avago's PID = 0x0916**.

VID0 Address: 0xE4 Type: OTP

Access: Read/Write Reset Value: 0x2F

Bit	7	6	5	4	3	2	1	0
Field	VID_7	VID_6	VID_5	VID_4	VID_3	VID_2	VID_1	VID_0

VID1 Address: 0xE5 Type: OTP

Access: Read/Write Reset Value: 0x19

Bit	7	6	5	4	3	2	1	0
Field	VID_{15}	VID_{14}	VID_{13}	VID_{12}	VID_{11}	VID_{10}	VID_9	VID_8

Data Type: 16-Bit number.

USAGE: These registers are used to customize device VID. **Default is Avago's VID = 0x192F**.

OTPLOCK1 Address: 0xE8 Type: OTP

Access: Read/Write Reset Value: 0x00

Bit	7	6	5	4	3	2	1	0
Field	$OTPLOCK1_7$	$OTPLOCK1_6$	$OTPLOCK1_5$	$OTPLOCK1_4$	$OTPLOCK1_3$	$OTPLOCK1_2$	$OTPLOCK1_1$	$OTPLOCK1_0$

Data Type: 8-bit field.

USAGE: Must write 0xFF in this register to lock the OTP configuration.

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AV02-2723EN - April 17, 2012