ADNK-9503-SL11

USB LaserStream™ Gaming Mouse Designer's Kit

Design Guide

Introduction

The evolution of PC's cyber games has made gaming mouse an essential gadget in the game battle. Avago Technologies has introduced new LaserStream gaming sensor, ADNS-9500 with enhanced gaming features to meet the needs of PC The ADNS-9500, comprises of sensor and VCSEL in single chip-on-board (COB) package is designed to be used with ADNS-6190-002 lens forming a compact navigation system that enabled for high performance LaserStream gaming mouse application.

The ADNK-9503-SL11 consists of an ADNS-9500 USB reference design gaming mouse, ADNS-9500 sensors and ADNS-6190-002 lens sample units and CD-ROM with all relevant technical literatures, software and hardware files. The reference design gaming mouse unit allows users to evaluate the performance of the ADNS-9500 Tracking Engine over the USB solution. This kit also enables users to understand the recommended mechanical assembly.

The ADNK-9503-SL11 design guide describes how a USB corded gaming mouse can be built using the Avago Technologies' ADNS-9500 LaserStream gaming sensor and Silicon Laboratories' C8051F347 USB microcontroller. The document starts with the basic operations of a USB HID Gaming mouse peripheral followed by an introduction to the Avago Technologies' ADNS-9500 LaserStream gaming sensor and the Silicon Laboratories' C8051F347 USB microcontroller and how to connect to and manage a standard configuration of gaming mouse hardware, as well as handle the USB protocols.

Features

- ADNS-9500 LaserStream gaming sensor with integrated VCSEL
- LaserStream™ navigation technology
- USB 2.0 Full Speed Compliant
- Compliance to IEC/EN 60825-1 Class 1 Eye Safety
- High speed motion detection at 150-200 inches per second (ips) and acceleration up to 30g
- 16-bit USB motion data reporting
- 500 Hz USB rate
- Frame rate up tot 11,750 fps
- Mechanical Z-Wheel interface for vertical scroll
- 3 standard input buttons for Left, Right and Middle
- 2 input buttons for On-the-Fly resolution: 56 settings from 90-5040 cpi
- LED indicators for resolution setting
- Programmable lift detection
- On-board memory to store profile and SROM
- Read/Write access to ADNS-9500's registers for customizable setting
- In-circuit firmware upgrade

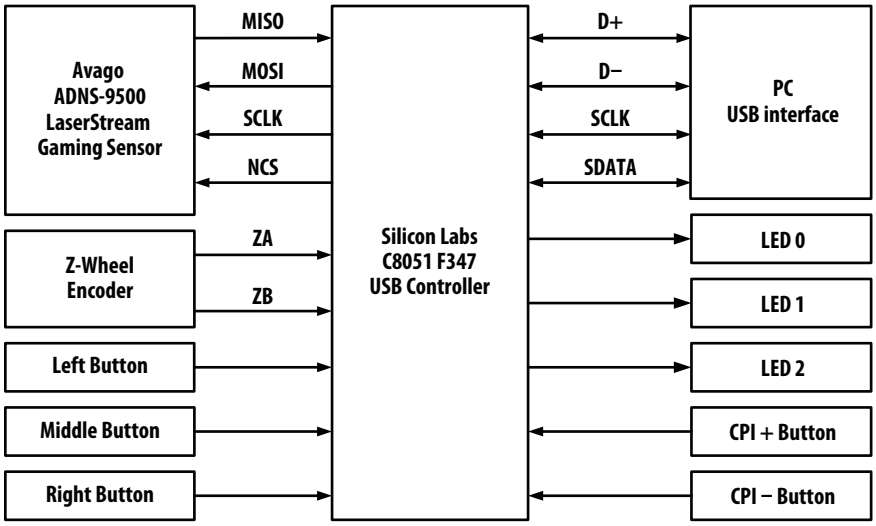


Figure 1. ADNK-9503-SL11 USB LaserStream Gaming Mouse Block Diagram

USB HID Gaming Mouse Basic Operations

The standard hardware to implement a USB HID gaming mouse is shown in Figure 1. The X and Y movement is generated by the Avago ADNS-9500 LaserStream gaming sensor. The Z-wheel movement is detected by a mechanical Z-encoder that outputs quadrature signals. For each button, there is a switch that is pulled up internally by the built-in pull up resistors. CPI+ or CPI- button press triggers state change of resolution setting as well as turn on the respective LED indicators: LED0, LED1 and LED2. All the input and output data are handled by the Silicon Labs C8051F347 Controller and converted to USB data packet via USB protocols to the computer.

ADNS-9500

The ADNS-9500 Laser-Stream gaming sensor is the tracking engine that measures changes in position by optically acquiring sequential surface images (per frames) and mathematically determining the direction and magnitude of motion movement. 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. 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 output to the USB controller via SPI interface and then converted to USB motion data that translate into the motion of a cursor pointer on a screen display on PC.

Serial Peripheral Interface (SPI)

The Silicon Labs C8051F347 Controller provides SPI to communicate with ADNS-9500 and 25 digital I/O ports for buttons and LED indicators. The SPI circuit supports byte serial transfer in either Master or Slave mode. In the mouse application, the Silicon Labs C8051F347 is the Master, while ADNS-9500 is the Slave device.

Buttons

The standard button inputs for HID mouse is corresponding to left, right and middle button click. Button inputs are connected as standard switches. When the user presses a button, the switch will be closed and the pin will be pulled LOW to GND. A LOW state at the pin is interpreted as the button being pressed. A HIGH state is interpreted as the button has been released or the button is not being pressed. Normally, the time between button presses is 6-9 ms.

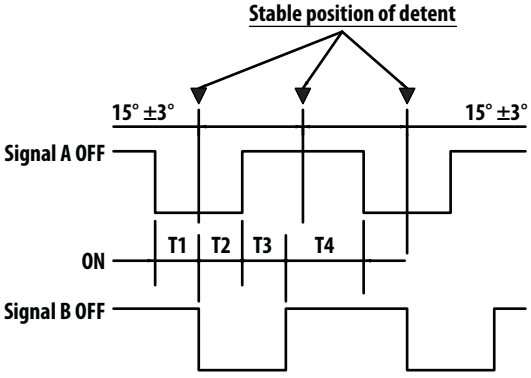


Figure 2. Z-Wheel Quadrature Signal Generation

Z-Wheel

The motion of Z-wheel is detected using traditional method by encoding quadrature signal generated by the mechanical or optical Z-encode and to be interpreted as vertical scrolling. The Z-wheel is connected to the ZA and ZB pins with the common pin connected to VDD5. The ZA and ZB are to be configured as input pin with internal pulldown and provide a nominal pulldown current to pull the output down when the Z-wheel switch opens. As shown in Figure 2, traveling along the quadrature signal to the right produces a unique set of state transitions, and traveling to the left produces another set of unique state transitions. Each set of state transition represents the up or down scroll.

Introduction to ADNS-9500

The ADNS-9500 LaserStream gaming sensor comprises of sensor and VCSEL in a single chip-on-board (COB) package. ADNS-9500 provides enhanced features like programmable frame rate, programmable resolution, configurable sleep and wake up time to suit various PC gamers' preferences. The ADNS-9500 has flexibility with operating voltages of either 5 V or 3 V mode, which made it suits for both USB corded and battery-operated cordless device applications. The advanced class of VCSEL provides a laser diode with a single longitudinal and a single transverse mode.

This LaserStream gaming sensor is in 16-pin integrated chip-on-board (COB) package and designed to be used with ADNS-6190-002 small form factor (SFF) gaming laser lens to achieve the optimum performance. These parts provide a complete and compact navigation system without moving part and laser calibration process is NOT required in the complete mouse form, thus facilitating high volume assembly.

The ADNS-9500 must be operated with externally loaded SROM after a sensor power-up sequence. Two different SROMs are to be used for 5 V and 3 V modes respectively. The standard 5V mode's SROM enables the ADNS-9500 to run in full force, while the 3 V mode's SROM is enabled with power save mode to minimize current consumption for battery life saving on cordless devices.

Features

- Small form factor chip-on-board package
- Dual power supply selections, 3 V or 5 V
- VDDIO range: 1.65 – 3.3 V
- 16-bits motion data registers
- High speed motion detection at 150 ips and acceleration up to 30 g
- Advanced technology 832-865nm wavelength VCSEL
- Single mode lasing
- No laser power calibration needed
- Compliance to IEC/EN 60825-1 Eye Safety
  - Class 1 laser power output level
  - On-chip laser fault detect circuitry
- Self-adjusting frame rate for optimum performance
- Motion detect pin output
- Internal oscillator – no external clock input needed
- Enhanced Programmability
  - Frame rate up to 11,750 fps
  - 1 to 5 mm lift detection
  - Resolution up to 5000 cpi with ~90 cpi step
  - X and Y axes independent resolution setting
  - Register enabled Rest Modes
  - Sleep and wake up times

Introduction to C8051F347

The Silicon Laboratories' C8051F347 device is fully integrated mixed-signal System-on-a-Chip MCU designed specifically for USB applications. It is built in with high-speed 8051 µC core and compliant to USB specification 2.0 supporting both full-speed and low speed operations with eight flexible endpoints. The 32 kB flash memory provides flexibility to be reprogrammed and allows upgrades of firmware.

Features

- Analog Peripherals
  - 10-Bit ADC: ±1 LSB INL; no missing codes, Programmable throughput up to 200 ksps, Up to 17 external inputs; programmable as single-ended or differential, Built-in temperature sensor (±3° C)
  - Two Comparators
  - Internal Voltage Reference: 2.4 V
  - POR/Brown-out Detector
- USB Function Controller
  - USB specification 2.0 compliant
  - Full-speed (12 Mbps) or low-speed (1.5 Mbps) operation
  - Integrated clock recovery; no external crystal required for either full-speed or low-speed operation
  - Supports eight flexible endpoints
  - Dedicated 1 kB USB buffer memory
  - Integrated transceiver; no external resistors required
- On-Chip Debug
  - On-chip debug circuitry facilitates full speed, non-intrusive in-system debug (no emulator required)
  - Provides breakpoints, single stepping
  - Inspect/modify memory, registers, and USB memory
  - Superior performance to emulation systems using ICE-chips, target pods, and sockets
- Temperature Range: -40 to +85° C
- High-Speed 8051 µC Core
  - Pipelined instruction architecture; executes 70% of instructions in 1 or 2 system clocks
  - Up to 25 MIPS throughput with 25 MHz Clock
  - Expanded interrupt handler
- Memory
  - 2304 bytes data RAM (256 + 2 kB)
  - 32 kB Flash; in-system programmable in 512-byte sectors (512 bytes are reserved)
- Digital Peripherals
  - 25 port I/O; all are 5 V tolerant
  - Hardware SMBus™ (I2C™ compatible), SPI™, and UART serial ports available concurrently
  - 4 general-purpose 16-bit counter/timers
  - Programmable 16-bit counter array with 5 capture/compare modules
- Clock Sources
  - Internal oscillator: 0.25% accuracy with clock recovery enabled; supports all USB and UART modes
  - External oscillator: Crystal, RC, C, or Clock
  - On-chip clock multiplier: up to 48 MHz
- Voltage Regulator
  - On-chip voltage regulator supports USB bus-powered operation
  - Regulator bypass mode supports USB self-powered operation

System Requirements

PCs using Windows 2003/ Windows XP/ Windows Vista with standard USB mouse driver loaded.

Functionality

3 -button, mechanical Z-wheel mouse

Operating (For USB Mode)

Hot pluggable with USB port. The PC does not need to be powered off when plugging or unplugging the evaluation mouse.

To Disassemble the Mouse Unit

The ADNK-9503-SL11 mouse unit comprises of plastic mouse casing, printed circuit board assembly (PCBA), lens, Z-wheel and USB cable. Unscrewing the screw located at the base of the casing, can open the ADNK-9503-SL11 mouse unit. Unscrew the PCB to lift it out of the base plate can further disassemble the mouse unit.

Caution: The lens is not permanently attached to the sensor and will drop out of the assembly.

While reassembly the components, please make sure that the Z-height (Distance from lens reference plane to surface) is valid. The Z-height is from 2.3 to 2.5 mm with a nominal of 2.4 mm as shown in Figure 4.

Overall circuit

A schematic of the overall circuit is shown in Appendix A of this document. Appendix B lists the bill of materials.

PCB Layout & Gerber File

The Gerber File presents detailed schematics used in ADNK-9503-SL11 in PCB layout form. See Appendix C for more details.

3D Model Files

The 3D model files on the CD-ROM provides recommended 3D modeling of sensor, lens, PCB and base plate molding features to ensure optical alignment. See Appendix D for details.

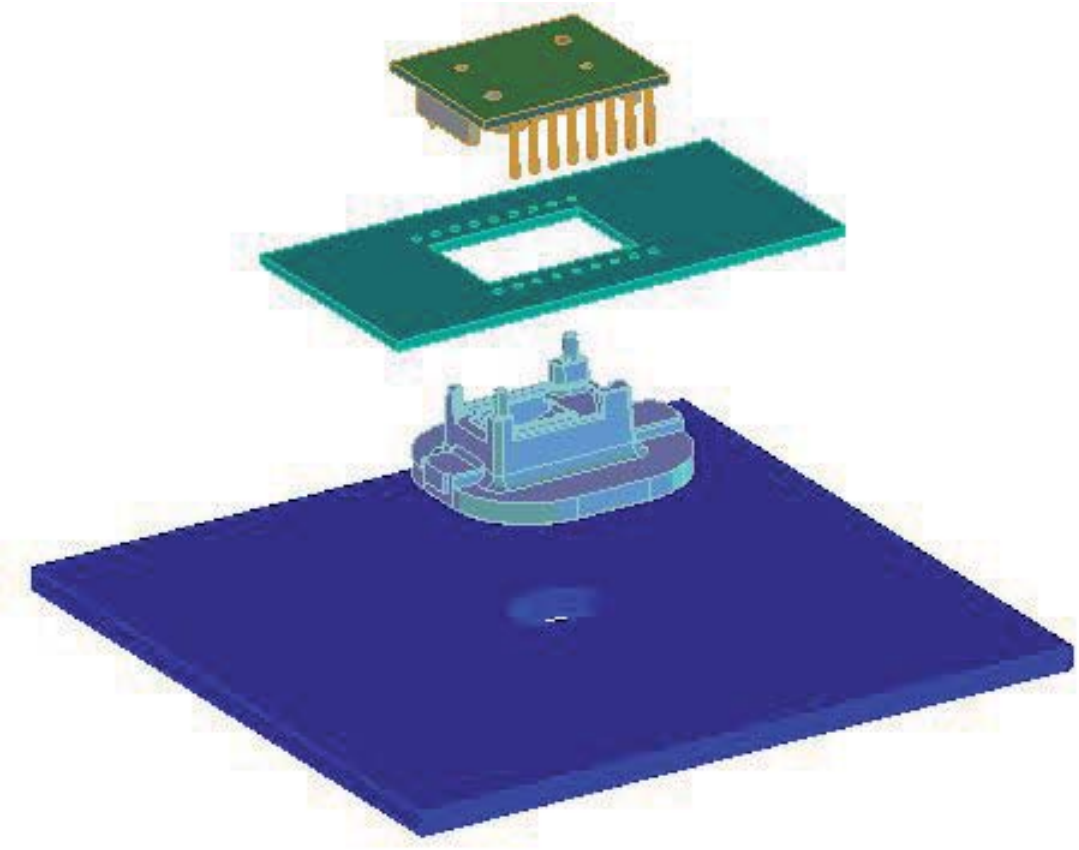


Figure 3. Exploded view drawing of ADNS-9500 sensor coupled with ADNS-6190-002 lens, PCB & base plate

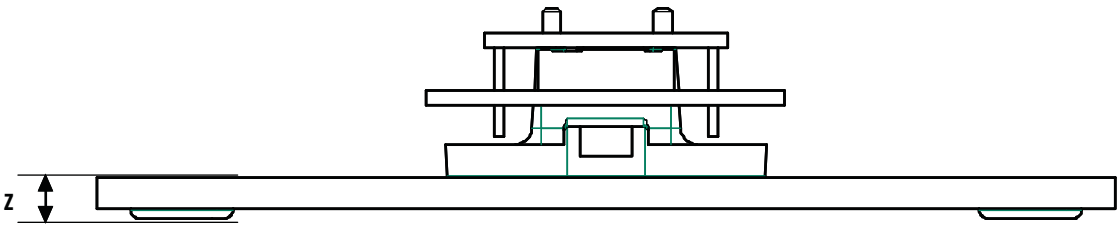


Figure 4. Distance from lens reference plane to object surface, Z

Firmware Implementation

The firmware for this reference design is written in the C language by using Silicon Laboratories IDE and Keil Compiler. The following files are required to compile the mouse.

1. Application Header Files
   - ADNS9500.h
   - adns9500_srom_91.h
   - config_init.h
   - delay.h
   - spi.h
   - timer.h
2. Application Source Files
   - ADNS9500.c
   - delay.h
   - sequence.c
   - spi.h
   - timer.h

3. Header Files
   - c8051F340.h
   - c8051f3xx.h
   - F340_FlashPrimitivies.h
   - Fxx_USB0_Descriptor.h
   - Fxx_USB0_InterruptServiceRoutine.h
   - Fxx_USB0_Mouse.h
   - Fxx_USB0_Register.h
   - Fxx_USB0_ReportHandler.h
4. Source Files
   - F340_FlashPrimitivies.c
   - Fxx_USB0_Descriptor.c
   - Fxx_USB0_InterruptServiceRoutine.c
   - Fxx_USB0_Main.c
   - Fxx_USB0_Mouse.c
   - Fxx_USB0_ReportHandler.c
   - Fxx_USB0_Standard_Requests.c
   - STARTUP.A51

USB Requests – Endpoint 0

Endpoint 0 acts as the control endpoint for the host. On power-up endpoint 0 is the default communication channel for all USB devices. The host initiates Control-Read and Control-Write (see Chapter 8 of the USB specification) to determine the device type and how to configure communications with the device. In this particular design, only Control-Read transactions are required to enumerate a mouse. For a list of valid requests, see Chapter 9 of the USBG specification. In addition to the standard "Chapter 9" requests, a mouse must also support all valid HID class requests for a mouse.

USB Requests – Endpoint 1

Endpoint 1 is the data transfer communications channel for mouse button, wheel, and movement information. Requests to this endpoint are not recognized until the host configures endpoint 1. Once this endpoint is enabled, then interrupt IN requests are sent from the host to the mouse to gather mouse data. When the mouse is left idle (i.e. no movement, no new button presses, no wheel movement) the firmware will NAK requests to this endpoint. Data is only reported when there is a status change with the mouse.

Two HID report formats are used in this design. The boot protocol, as defined by the HID specification, is the default report protocol that all USB enabled systems understands. The boot protocol has a three-byte format, and so does not report wheel information. The HID report descriptor defines the report protocol format. This format is four bytes and is the same as the report format with the exception of the fourth byte, which is the wheel information. Appendix F of this document lists the USB Data Reporting Format.

USB Interface

All USB Human Interface Device (HID) class applications follow the same USB start-up procedure. The procedure is as follows

1. Device Plug-in

When a USB device is first connected to the bus, it is powered and running firmware, but communications on the USB remain non-functional until the host has issued a USB bus reset.

2. Bus Reset

The host recognizes the presence of a new USB device and initiates a bus reset to that device.

3. Enumeration

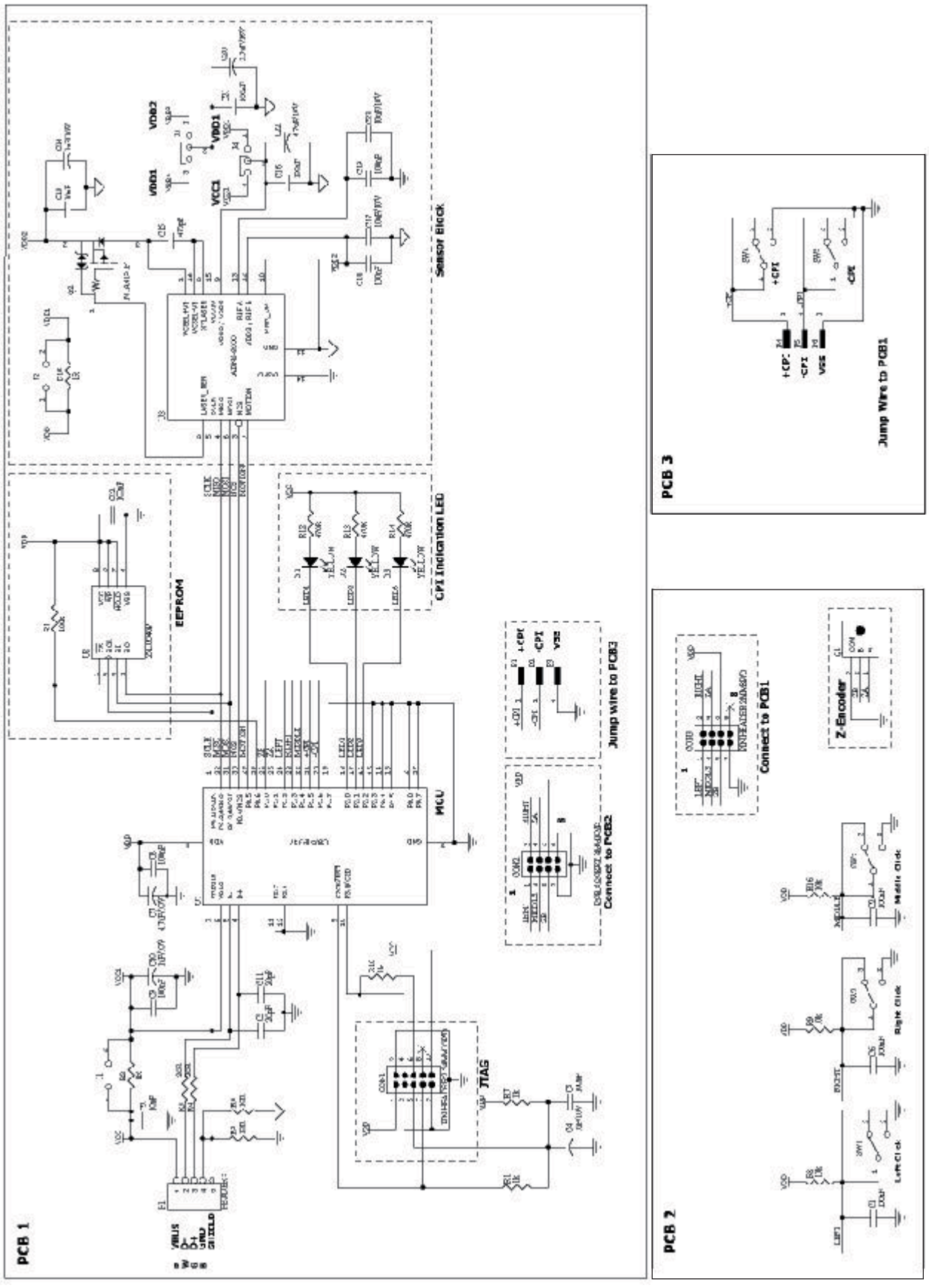
The host initiates SETUP transactions that reveal general and device specific information about the mouse. When the description is received, the host assigns a new and unique USB address to the mouse. The mouse begins responding to communication with the newly assigned address, while the host continues to ask for information about the device description, configuration description and HID report description. Using the information returned from the mouse, the host now knows the number of data endpoints supported by the mouse (2). At this point, the process of enumeration is completed.

Note:
1. idVendor should be changed to the value as supplied by the USB-IF
2. idProduct should be assigned for specific product.
3. MaxPower value should be changed as per specific circuit's current draw.

4. Post Enumeration Operation

Once communication between the host and mouse is established, the peripheral now has the task of sending and receiving data on the control and data endpoints. In this case, when the host configures endpoint 1, the mouse starts to transmit button and motion data back to the host when there is data to send. At any time the peripheral may be reset or reconfigured by the host.

Appendix A: Application Circuits



Appendix B: Bill of Materials (BOM)

Main Board							
No	**Description**	**Foot Print**	**Manufacturer**	**Manufacturer Part No.**	**RoHS**	**Qty**	**Designator**
01.	Resistor 1R 1%	0603 [SMD]	PHYCOMP	232270461008	Yes	2	R2, R15
02.	Resistor 10R 1%	0603 [SMD]	MULTICOMP	MC 0.063W 0603 1% 10R	Yes	2	R5, R6
03.	Resistor 20R 1%	0603 [SMD]	MULTICOMP	MC 0.063W 0603 1% 20R	Yes	2	R3, R4
04.	Resistor 470R 1%	0805 [SMD]	MULTICOMP	MC 0.1W 0805 1% 470R	Yes	3	R12, R13, R14
05.	Resistor 1 k 1%	0603 [SMD]	MULTICOMP	MC 0.063W 0603 1% 1 K	Yes	3	R1, R7, R10
06.	Resistor 100 k 1%	0603 [SMD]	MULTICOMP	MC 0.063W 0603 1% 100 K	Yes	1	R11
07.	Capacitor Ceramic 20 pF	0603 [SMD]	ROHM	MCH185A200JK	Yes	2	C3, C11
08.	Capacitor Ceramic 470 pF	0805 [SMD]	PHYCOMP	2238 861 15471	Yes	1	C15
09.	Capacitor Ceramic 10 nF	0603 [SMD]	PHYCOMP	2238 916 15636	Yes	2	C2, C13
10.	Capacitor Ceramic 100 nF	0603 [SMD]	PHYCOMP	2238 786 15649	Yes	8	C5, C8, C9, C12, C16, C18, C19, C21
11.	Capacitor Ceramic 1 μF, 10 V	0603 [SMD]	TAIYO YUDEN	LMK107BJ105KA-T	Yes	3	C4, C10, C14
12.	Capacitor Tantalum 3.3 μF, 16 V	Case A	AVX	TAJA335K016R	Yes	1	C20
13.	Capacitor Tantalum 10 μF, 10 V	Case A	NICHICON	F931A106MAA	Yes	2	C17, C23
14.	Capacitor Ceramic 4.7 μF, 10 V	0603 [SMD]	PANASONIC	ECJ-1VB0J475M	Yes	2	C7, C22
15.	IC Sensor ADNS-9500	16 pin-COB	AVAGO TECHNOLOGIES	ADNS-9500	Yes	1	U3
16.	IC SMD C8051F347-GQ	LQFP-32	SILICON LABORATORIES	C8051F347-GQ	Yes	1	U1
17.	IC SMD 25LC040/SN	SOIC-8 (Narrow)	MICROCHIP	25LC040/SN	Yes	1	U2
18.	Mosfet-P NTA4151PT1G	SOT-416	ON S EMICONDUCTOR	NTA4151PT1G	Yes	1	Q2
19.	PCB Socket Straight 8 Way D.Row	2 mm	–	–	Yes	1	CON2
20.	Pin Header Straight 10 Way D.Row	2.54 mm	–	–	Yes	1	CON1
21.	Cable – USB 1 meter	5 Way	–	–	Yes	1	H1
22.	LED Yellow	5 mm x 2 mm	SPC TECHNOLOGY	MC20462	Yes	3	D1, D2, D3

Appendix B: Bill of Materials (BOM) (Continued)

Button Board

No	Description	Foot Print	Manufacturer	Manufacturer Part No.	RoHS	Qty	Designator
01.	Resistor 10k 1%	0603 [SMD]	MULTICOMP	MC 0.063W 0603 1% 10K	Yes	2	R8, R9, R16
02.	Capacitor Ceramic 100 nF	0603 [SMD]	PHYCOMP	2238 786 15649	Yes	3	C1, C6, C24
03.	Pin Header Straight 8 Way D.Row	2mm	–	–	Yes	1	CON3
04.	Switch – Micro OMRON 3 Way	DIP	OMRON	–	Yes	3	SW1, SW2, SW3
05.	Mechanical Encoder	DIP	–	–	Yes	1	Q1

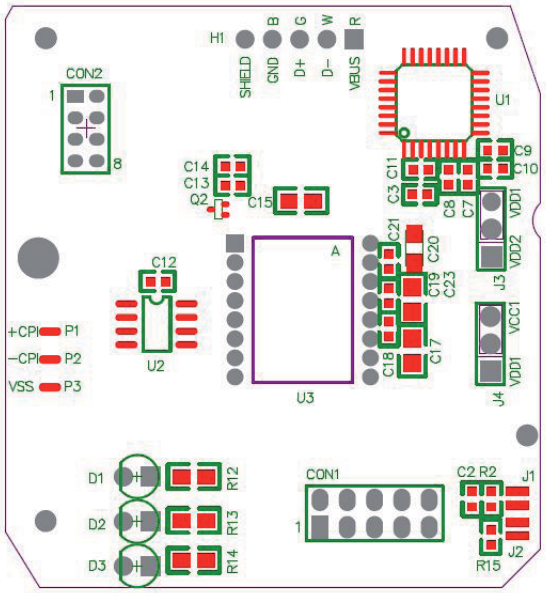
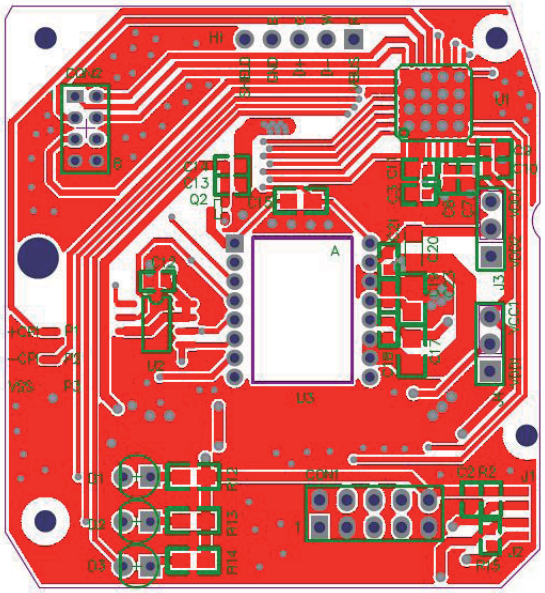
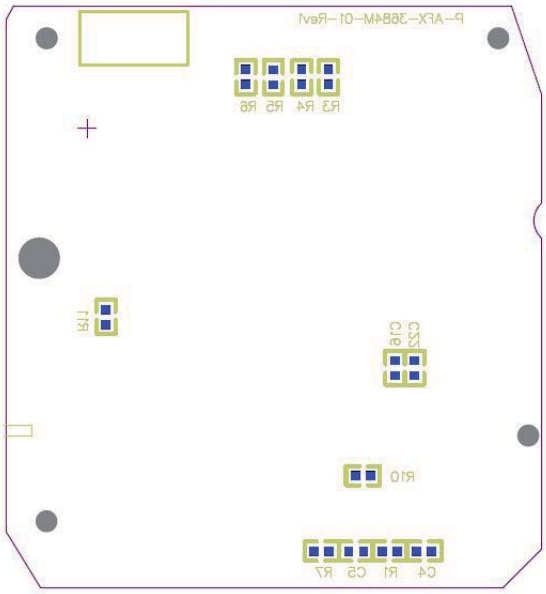
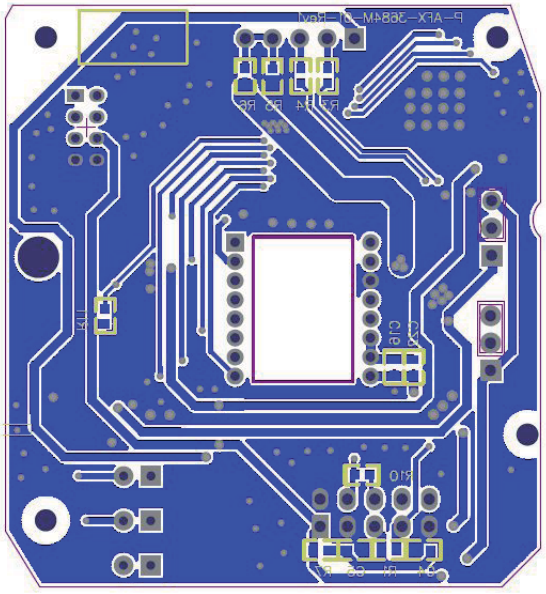
CPI Button Board

No	Description	Foot Print	Manufacturer	Manufacturer Part No.	RoHS	Qty	Designator
01.	Switch – Micro OMRON 3 Way	DIP	OMRON	–	Yes	2	SW4, SW5

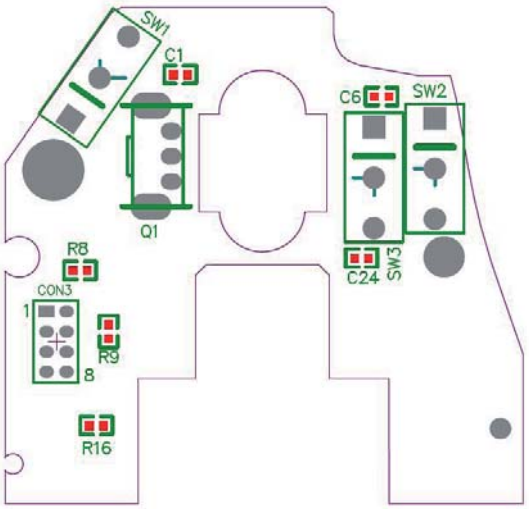
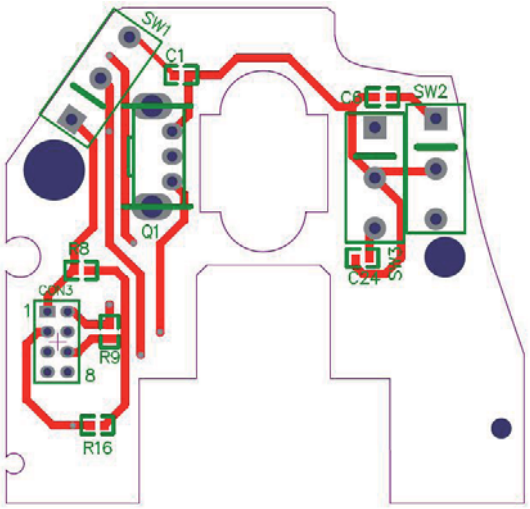
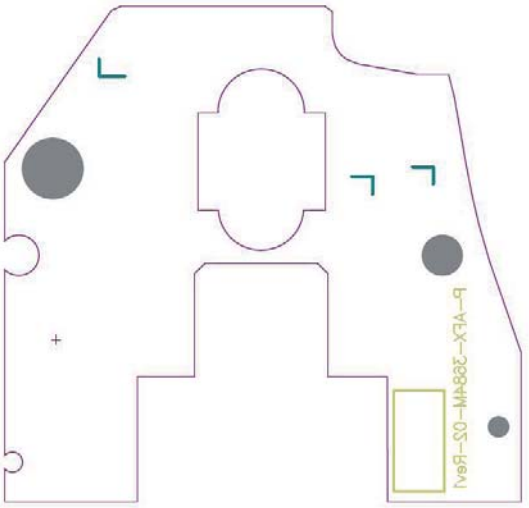
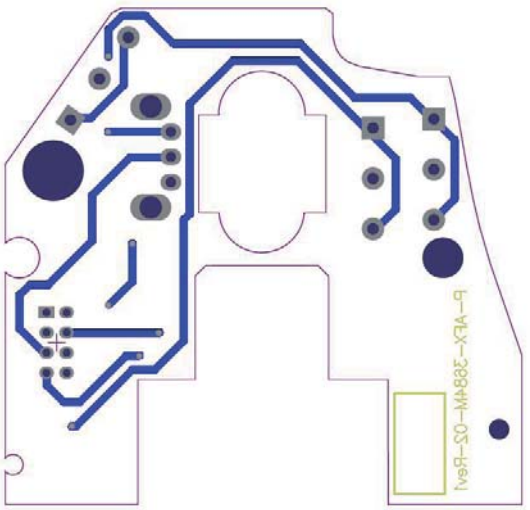
Assembly Materials

No	Description	Foot Print	Manufacturer	Manufacturer Part No.	RoHS	Qty	Designator
01.	Casing Top DS2180	–	–	–	Yes	1	–
02.	Casing Bottom DS2180	–	–	–	Yes	1	–
03.	Z-Wheel	–	–	–	Yes	1	–
04.	Screw	–	–	–	Yes	4	–
05.	Lens ADNS-6190-002	–	AVAGO TECHNOLOGIES	ADNS-6190-002	Yes	1	–
06.	Mouse Foot DS2180	–	–	–	Yes	4	

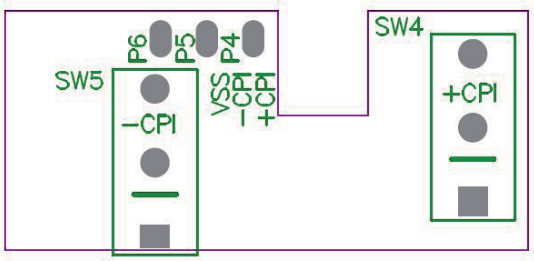
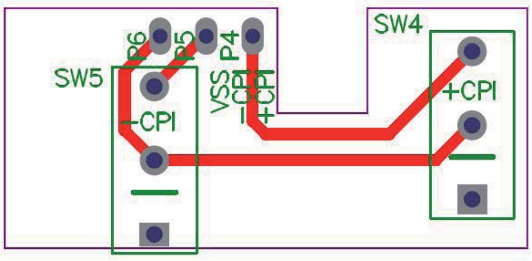
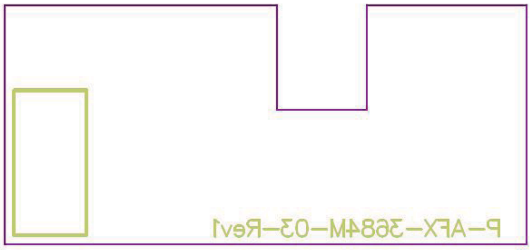
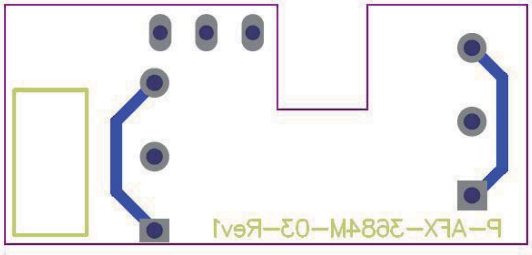
Appendix C. PCB Layout

Main Board	Assembly	Routing
Top Layer		
Bottom Layer		

Appendix C. PCB Layout (Continued)

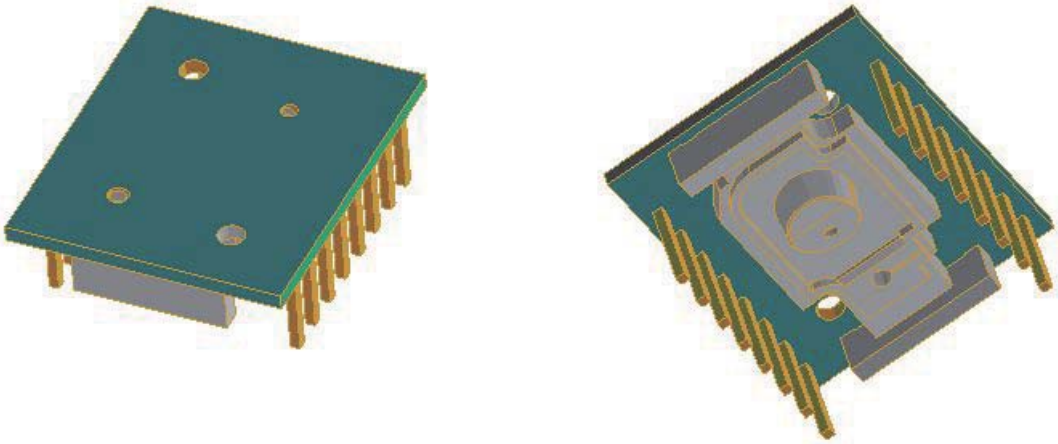
Button Board	Assembly	Routing
Top Layer		
Bottom Layer		

Appendix C. PCB Layout (Continued)

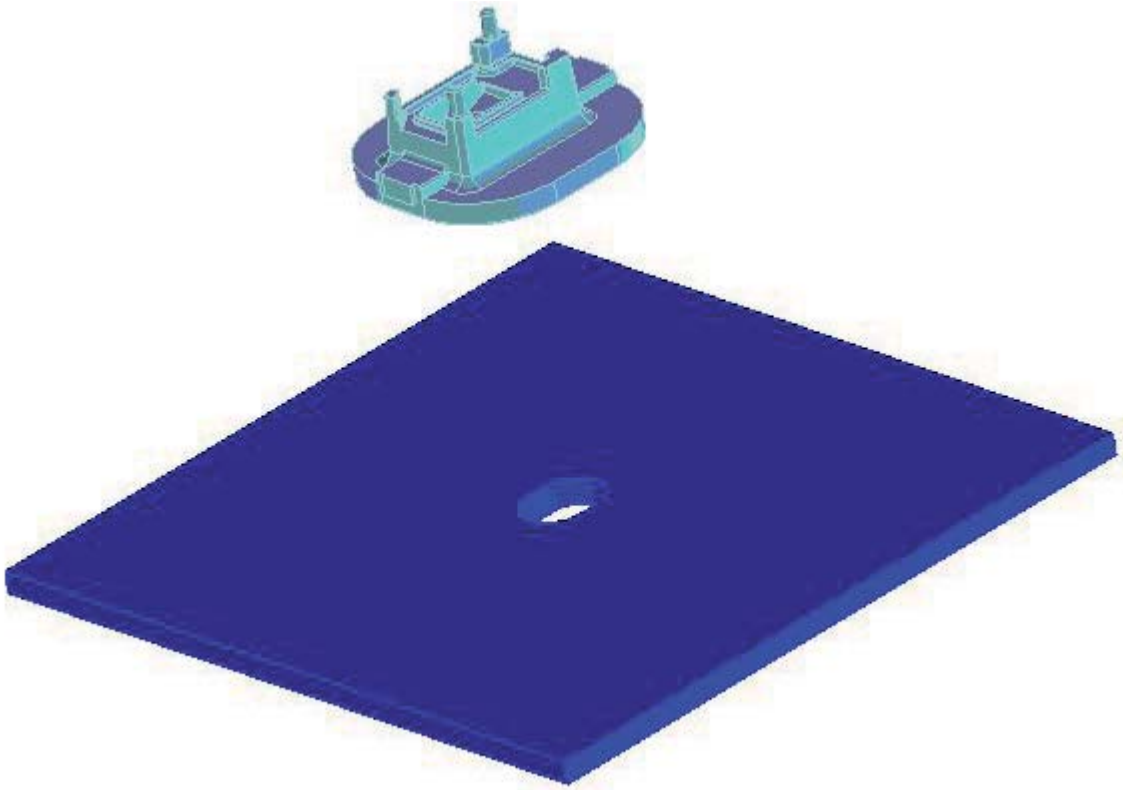
CPI Button Board	Assembly	Routing
Top Layer		
Bottom Layer		

Appendix D: 3D Model Illustrations

ADNS-9500 Sensor



Base plate mounting features for ADNS-6190-002 lens



Appendix E: ADNK-9503-SL11 Kit Components

Part Number	Description	Name	Quantity
ADNK-9503-SL11	USB LaserStream™ Gaming Mouse	Mouse	1
ADNS-9500	LaserStream™ Gaming Sensor	Sensor	5
ADNS-6190-002	LaserStream™ Gaming Round Lens	Lens	5
CD	Includes Documentation and Support Files for ADNK-9503-SL11	CD	1

Documentation

a. ADNS-9500 LaserStream™ Gaming Sensor Data Sheet
b. ADNS-6190-002 LaserStream™ Gaming Round Lens Data Sheet
c. ADNK-9503-SL11 USB LaserStream™ Gaming Mouse Designer's Kit Design Guide
e. ADNS-9500 Eye Safety Application Note
f. ADNK-9503-SL11 User Guide

Hardware Support Files

a. BOM List
b. Schematic
c. Gerber Files
d. 3D Model Files: ADNS-9500, ADNS-6190-002 & Base Plate Feature

Software Support Files

a. C8051F347 Firmware

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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