ADNK-3043-ND24
2.4GHz RF Wireless USB Optical Mouse Designer's Kit

Design Guide

Introduction

This design guide describes the design of a low power consumption optical mouse using the Texas Instrument MSP430F1222 microcontroller, the Avago ADNS-3040 optical sensor and a Nordic nRF2402 2.4 GHz transmitter. The receiver dongle is implemented with a Nordic nRF2401 in conjunction with a Cypress CY7C63231 USB controller. The document discusses the reference design hardware and the firmware implementation. Included in Appendix A is the schematic for this reference design mouse. The software section of this document describes the architecture of the firmware required to implement the mouse functions. The MSP430F1222 data sheet is available on the TI web site at www.ti.com. The ADNS-3040 data sheet is available from the Avago web site at www.avagotech.com. USB controller data sheet can be found on the Cypress web site: www.cypress.com. The Nordic transmitter and receiver data sheets are available on www.nordicsemi.no

Key reference design objectives:

1. Highlight the low-power benefit of the ADNS-3040
2. Demonstrate a design with a RF daughter board to facilitate experimentation with different RF technologies
3. Feature a Flash-based development environment to facilitate rapid firmware changes

Features

- Complete LED mouse reference design kit
- Windows® 98SE, Windows 2000 and Windows XP compatibility
- USB 1.0 low-speed compliance
- User identity code to avoid conflict with other devices
- High reliability
- Smooth surface navigation
- Enhanced SmartSpeed self-adjusting frame rate for optimum performance
- High speed motion detection up to 20 ips and 8 g
- 800 cpi resolution
- No mechanical moving parts
- A high data rate 2.4GHz RF link
- Transmission data rate up to 1Mbps
- 15 meters communication distance
- Self-adjusting power-saving modes for longest battery life
- Minimal number of passive components

Reference Design Overview

The image-based optical mouse sensor takes snap shots of the surface it is navigating on. It measures changes in position by comparing the sequential images (frames) and mathematically determines the direction and magnitude of movement. The traditional duel-channel optical encoder generates the quadrature Z-wheel movement signals. This design guide illustrates the hardware connection of a LED-based optical mouse with standard configuration; as well as the firmware management and the handling of the USB protocols. USB protocol provides a standard way of reporting mouse movement and button presses to the PC. The Windows HID driver interprets the USB data and performs the cursor movements and mouse clicks.

The functional block diagram of the reference design mouse is shown in Figure 1. The optical sensor detects the X and Y movements. An optical quadrature encoder provides the Z-wheel movement. Each of the button switches is pulled up normally and provides a Ground when pressed. The MAX1722 boost regulator maintains the 2.7 V operating voltage for the reference design mouse from two regular AA Alkaline batteries in parallel.

Theory of Operation

Navigation Technology

The heart of the ADNS-3040 navigation sensor is a CMOS image array. An LED and an optical system illuminate the surface that the ADNS-3040 is navigating on. The texture of the surface casts bright and dark spots forming distinct images as the sensor is moved across the surface. A Digital Signal Processing (DSP) engine and its built-in algorithm evaluate these images and determine the magnitude and direction of the movement. The motion data is made available in the delta_X and delta_Y registers for the system controller to retrieve. An extensive power saving topology is implemented within the ADNS-3040 navigation engine. A Motion pin (output) is available to act as the system interrupt. As long as there is no motion the system can remain in Sleep mode allowing maximum battery power saving. Based on the last detected motion the ADNS-3040 navigation engine enters various power saving modes when no new motion occurs. These power saving features make the ADNS-3040 ideally for wireless applications.

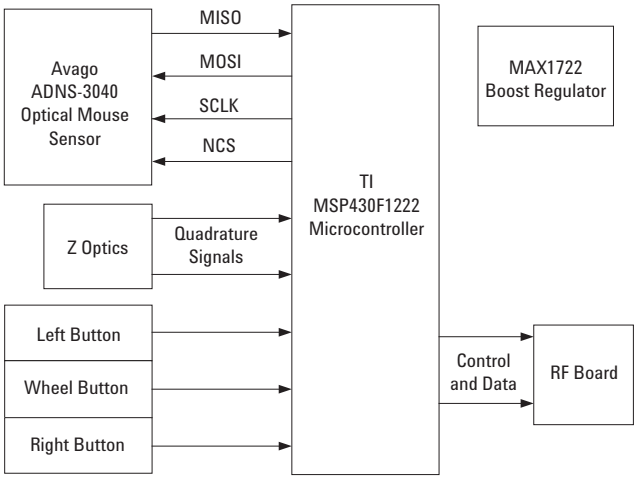

Figure 1. ADNK-3043-ND24 Reference Design Mouse functional Block Dia-

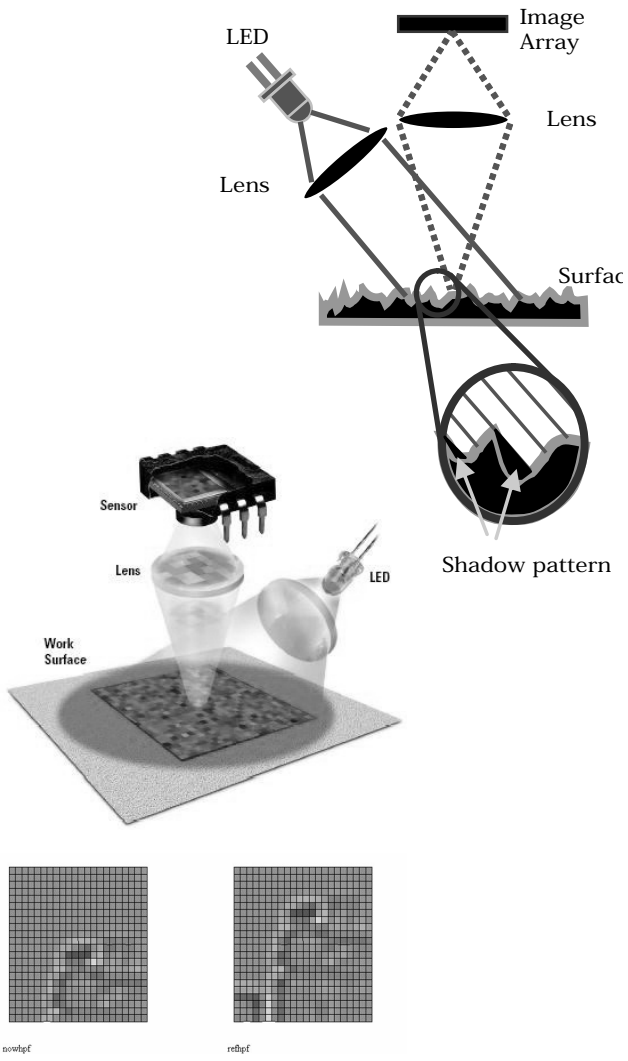

Figure 2. Illustration of Optical Navigation technology

Z-Wheel

The motion of Z-wheel is detected using the quadrature signal generated by optical sensors. Two phototransistors are connected in a source-follower configuration forming Channel A and Channel B. An infrared LED shines, causing the phototransistors to turn on. In between the phototransistors and LED is a pinwheel that turns on the mouse ball rollers. The fan of this pinwheel is mechanically designed to block the infrared light such that the phototransistors are turned on and off in a quadrature output pattern. Every change in the phototransistor outputs represents a count of mouse movement. Comparing the last state of the optics to the current state derives directional information. As shown in Figure 3. below, rotating the wheel forward produces a unique set of state transitions, and rotating the wheel backward produces another set of unique state transitions.

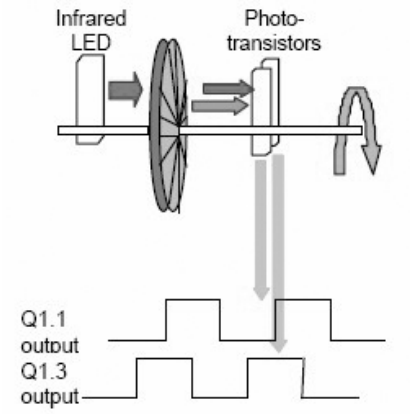

Figure 3. Optics Quadrature Signal Generation

Mouse Buttons

Mouse buttons are connected as standard switches. These switches are pulled up by the pull up resistors inside the microcontroller. 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 switches are debounced in firmware for 15-20ms. In this reference design there are three switches: left, Z-wheel, and right.

Hardware Implementation

Optical Mouse Sensor

This reference design features the ADNS-3040 optical navigation engine. It contains an Image Acquisition System (IAS), a Digital Signal Processor (DSP), and a three-wire Serial Peripheral Interface consists of the serial clock (SCLK), the master-in/slave-out (MISO) and the master-out/slave-in (MOSI). In addition a fourth signal, Motion, is an output intended to act as an interrupt to the microcontroller whenever the ADNS-3040 senses motion. When the mouse is moved the ADNS-3040 alerts the system controller by activating the Motion signal triggering an interrupt service routine. At the same time the ADNS-3040 accumulates the horizontal and vertical displacements (count per inch, or cpi) in its Delta_X and Delta_Y registers respectively. The ADNS-3040 deactivates the Motion signal as soon as movement stops. The SmartSpeed technology automatically optimizes the frame rate by examining the acquired images of the surface. It also manages the integrated LED driver to coordinate with the shutter.

The system controller reads the motion information and reports it to the PC to update the cursor position.

The advantages of using ADNS-3040 optical sensor are the efficient power management, high tracking accuracy, and efficient communications with the optical sensor via the full duplex SPI port.

To learn more about sensor's technical information, please visit the Avago web site at http://www.avagotech.com

Microcontroller

The Texas Instruments MSP430 family of ultra-low power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that attribute to maximum code efficiency. The Digitally Controlled Oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6 µsec.

The specific device used in this reference design is the MSP430F1222 with 28 pin to accommodate ample amount of I/O. It is an ultra-low power mixed-signal microcontrollers with a built-in 16-bit timer, 10-bit A/D converter with integrated reference and Data Transfer Controller (DTC), and 14 (20 pin package) or 22 (28 pin package) general purpose I/O pins. The MSP430x12x2 series microcontrollers have built-in communication capability using asynchronous (UART) and synchronous (SPI) protocols.

Serial Peripheral Interface (SPI)

The MSP430F1222 provides a dedicated hardware-based Serial Peripheral Interface (SPI). The three-wire interface supports byte serial communication in either Master or Slave mode. In this reference design the MSP430F1222 always acts as the master and initiates all SPI communications with external SPI device(s), in this case the ADNS-3040 and the nRF2401.

Z-Wheel Quadrature Encoder

A standard two-channel, incremental optical quadrature encoder and an IR LED provide the scroll wheel function. The MSP430F1222 manages the IR LED directly. Since achieving low-power consumption is one of the main objectives, the optical LED is only enabled when the MSP430 needs to read the output states of the optical quadrature encoder to the MSP430 port pins while in ACTIVE mode. The optical LED is pulsed on for approximately 40 µsec every 2 msec while in ACTIVE mode to read the current position of the scroll wheel, thus saving power since the optical LED is only on for a duty cycle of 2%. The outputs of the two-channel quadrature encoder are squarewaves that are 90° out of phase. The phase relationship of these signals encodes the directions of scroll wheel rotations. Within the MSP430, an internal Quadrature Encoder Pulse (QEP) state machine interprets these signals and increments or decrements a counter based on the direction and movement of the scroll wheel.

Wireless RF Technology

In order to provide the maximum flexibility the reference design mouse utilizes two circuit boards. The main board consists of the ADNS-3040 navigation sensor/LED, the MSP430F1222 microcontroller, the scroll wheel and button switches. A 10-pin header connects the main board to the RF daughter card. The Nordic nRF2401 2.4 GHz transmitter and its associated circuit including the antenna resides on the daughter card. The 10-pin header provides the SPI, regulated Vdd and unregulated battery voltage (for possible future applications). The nRF2402 is a single-chip transmitter for the world wide 2.4-2.5 GHz ISM band. The transmitter consists of a fully integrated frequency synthesizer, a power amplifier, a crystal oscillator and a modulator. The output power and channel are programmed through the SPI. Chip Select (CS) is used to enable the nRF2402 when the microcontroller is ready to pass it the motion or button switch data. Once the data has been loaded into its input buffer the nRF2402 manages the transmission and returns to power down mode to conserve battery power. Typical power consumption is 10 mA at -5 dBm of output power.

The nRF2402 has two transmit modes:

- ShockBurst™
- Direct Mode

In this reference design ShockBurstTM is used to capitalize on its benefit. It utilizes the on-chip FIFO to accept SPI data at the microcontroller operating rate but transmit at very high rate (up to 1 Mbps). The short transmission time enables extreme power saving. For detailed description of the ShockBurstTM technology please refer to: www.nordicsemi.no/

High-frequency PCB layout:

A well-designed PCB is necessary to achieve good RF performance. A fully qualified RF layout for the nRF2402 and it's surrounding components, including matching networks for the antenna can be downloaded from:

www.nordicsemi.no

A PCB with a minimum of two layers including a ground plane is recommended for optimum performance. The nRF2402 dc supply should be well filtered and decoupled as close as possible to the Vdd pins with high performance RF capacitors. Specifically a high-grade SMD tantalum capacitor (e.g. 4.7 µF) should be used in parallel with the smaller-value high-frequency bypassing capacitors. The nRF2402 should have its own branch of well-filtered supply voltage, routed separately from the supply voltage for the digital circuitry.

Full swing digital signals should not be routed close to the crystal or the power supply lines.

Some details on ADNK-3043-ND24

The ADNK-3034-ND24 reference design kit allows users to evaluate the performance of the Optical Tracking Engine (sensor, lens, LED assembly clip, LED) over a RF connection. This kit also enables users to understand the recommended mechanical assembly. (See Appendix C, D, and E)

System Requirements

PCs using Windows® 95/ Windows® 98/ Windows® NT/ Windows® 2000 with standard 3-button USB mouse driver loaded.

Functionality

This reference design is an optical mouse with three buttons and a scroll wheel.

USB Operating Mode

The receiver dongle is hot pluggable into the USB port. The PC does not need to be powered off when plugging or unplugging the receiver dongle for the evaluation mouse.

To Disassemble the ADNK-3043-ND24 Unit

The ADNK-3034-ND24 comprises of the plastic mouse casing, a main printed circuit board (PCB), lens, buttons, and a 2.4 GHz RF daughter card, and a 2.4 GHz USB receiver dongle. (See Figure 4.) Removing the screws located at the base of the unit separate the top and the bottom of the mouse casing. Removing the PCB assembly from the base plate further disassembles the mouse unit. Be careful with the battery terminals while separating the PCB assembly with the bottom casing.

While reassembling the components, please make sure that the Z height (Distance from lens reference plane to surface) is maintain. Refer to Figure 5.

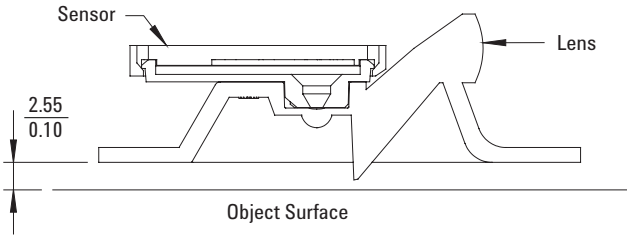

Figure 5. Distance from lens reference plane to surface

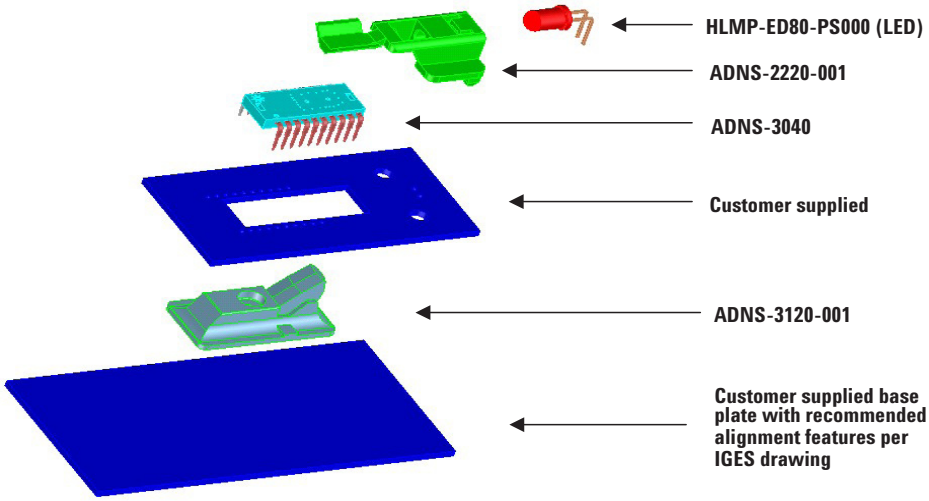

Figure 4. Exploded view of the ADNS-3040 optical tracking engine

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

Regulatory Requirements

- Passes FCC B and worldwide analogous emission limits when assembled into a mouse with unshielded cable and following Avago recommendations.
- Passes EN61000-4-4/IEC801-4 EFT tests when assembled into a mouse with unshielded cable and following Avago recommendations.
- UL flammability level UL94 V-0.
- Provides sufficient ESD creepage/clearance distance to avoid discharge up to 15kV when assembled into a mouse according to usage instructions above.
- For eye safety consideration, please refer to the document, Eye Safety Calculation AN1228 available on the web site, http://www.avagotech.com/opticalnavigation

Below is the summary of the components contained in the ADNK-3034-ND24 Designer's Kit.

Sensor

The sensor technical information is contained in the ADNS-3040 Data Sheet.

Other system components

Technical information on the TI MSP430F1222 microcontroller is contained in the TI Data Sheet. Please contact your local TI office for theMSP430 development tools. These tools will allow the designer to make changes and recompile the source code; perform In-Circuit Emulation and debug new code for added features.

Programming support and programmer adaptors for the MSP430 can be found through TI or through other 3rd party programming tool companies. For further information on this product, please contact Texas Instrument.

Cypress Semiconductor provides extensive development tools for the CY7C63231 USB controller used in the receiver dongle.

Lens

The lens technical information is contained in the ADNS-3120-001 Data Sheet.

LED Assembly Clip

The information on the assembly clip is contained in the ADNS-2200 Data Sheet.

LED

The LED technical information is contained in the HLMP-ED80-PS000 Data Sheet and Application Note AN-1228. Additional application notes regarding Eye Safety Requirements are also available at Avago's website.

Base Plate Feature – IGES File

The IGES file on the CD-ROM provides recommended base plate molding features to ensure optical alignment. This includes PCB assembly diagrams like solder fixture in assembly and exploded view, as well as solder plate. See Appendix D for details.

Reference Design Documentation – Gerber File

The Gerber File presents detailed schematics used in ADNK-3034-ND24 in PCB layout form. See Appendix C for more details.

Overall circuit

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

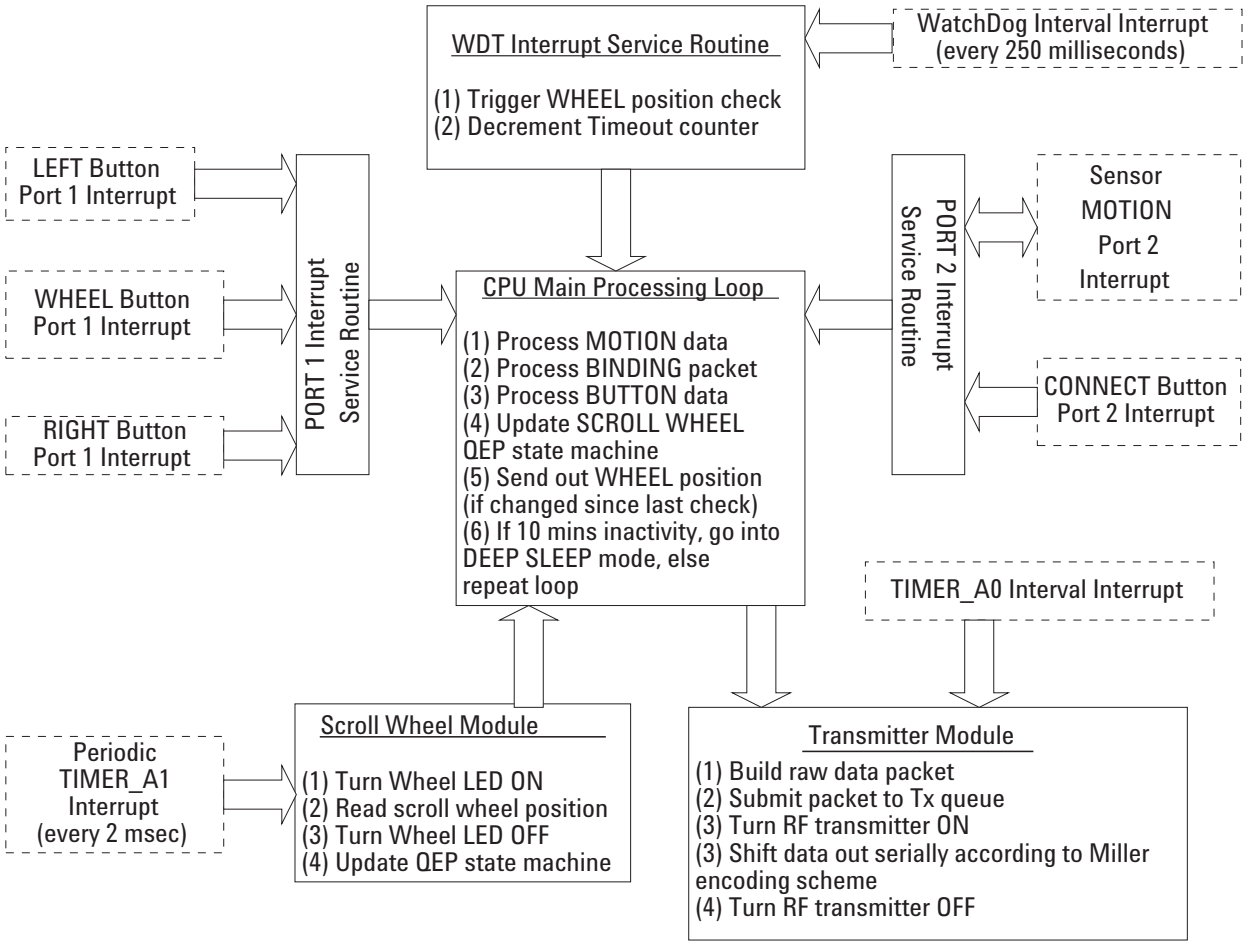

Figure 6. Reference Design Mouse Software Architecture

Firmware Implementation

The firmware for this reference design is written in the C language.

The following files are required to compile the mouse firmware.

- MSP430_AVAGO_ADNS-3040.c – main mouse firmware
- CRC-8.c – Routines for CRC-8 generation
- wm430_buttons.c – used to store button state data for tx message
- wm430_system.c
- wm430_transmitter.c – mplements the RF transmitter protocol
- wm430_wheel.c – Implements the logic to detect scroll wheel movement
- _FSKDATAPLUSENCODING – used to enable MSP430 to shift data out via FSK scheme by toggling the RF_DATA line at specific bit periods

The user should insert the receiver dongle into an available USB port at the computer. Install two AA alkaline batteries into the battery compartment. Pay special attention to the polarities of the two batteries. The reference design mouse is designed to work with two AA batteries in parallel or just one AA battery. Press the connect button on the receiver dongle and while the LEDs are flashing press the connect button at the underside of the mouse. When the mouse is properly "connected" to the dongle every time it receives a transmission from the mouse the green LED lights up.

Appendix A: Schematic Diagram of the Main Board

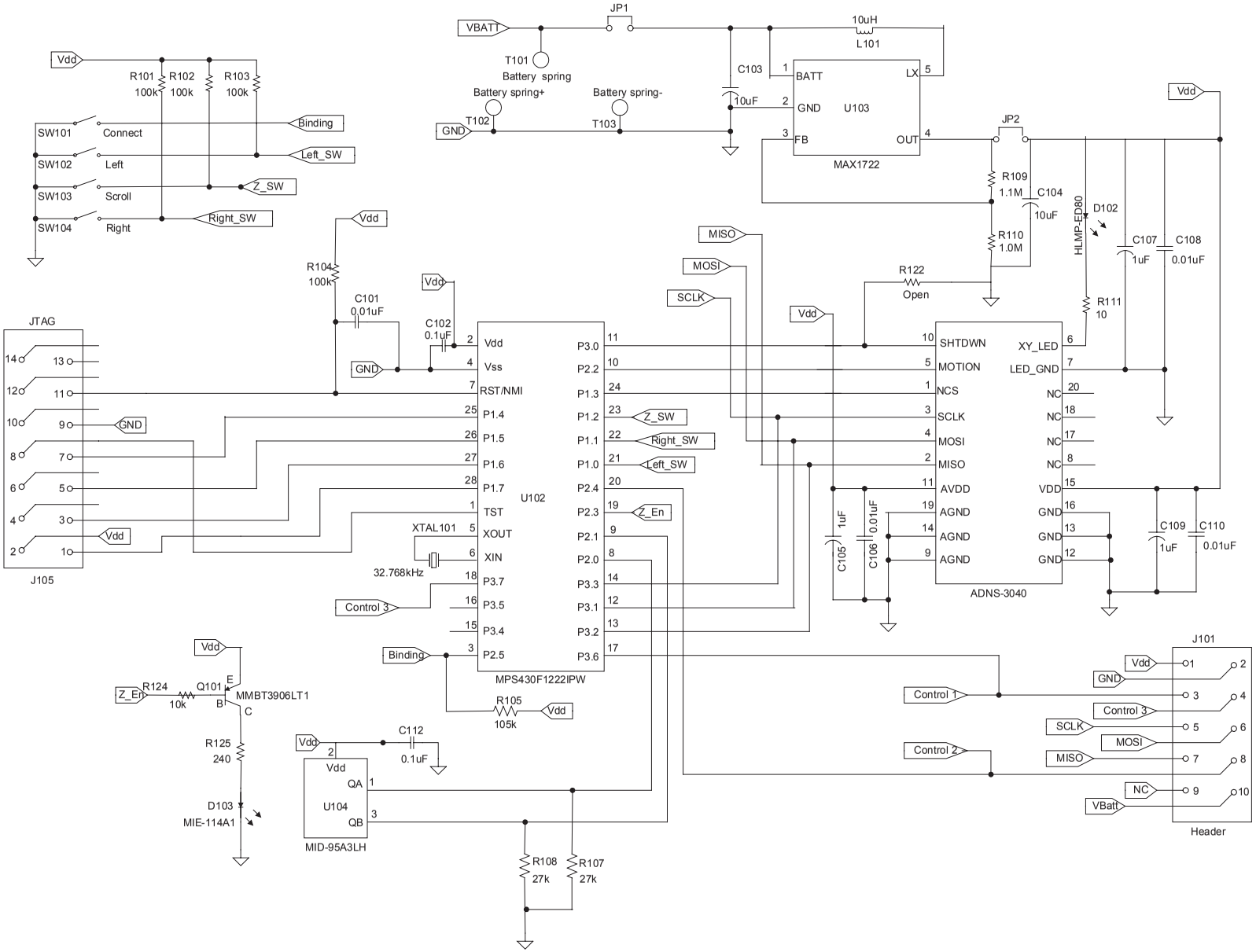

Figure A1. Schematic Diagram of Sensor and Microcontroller main Board

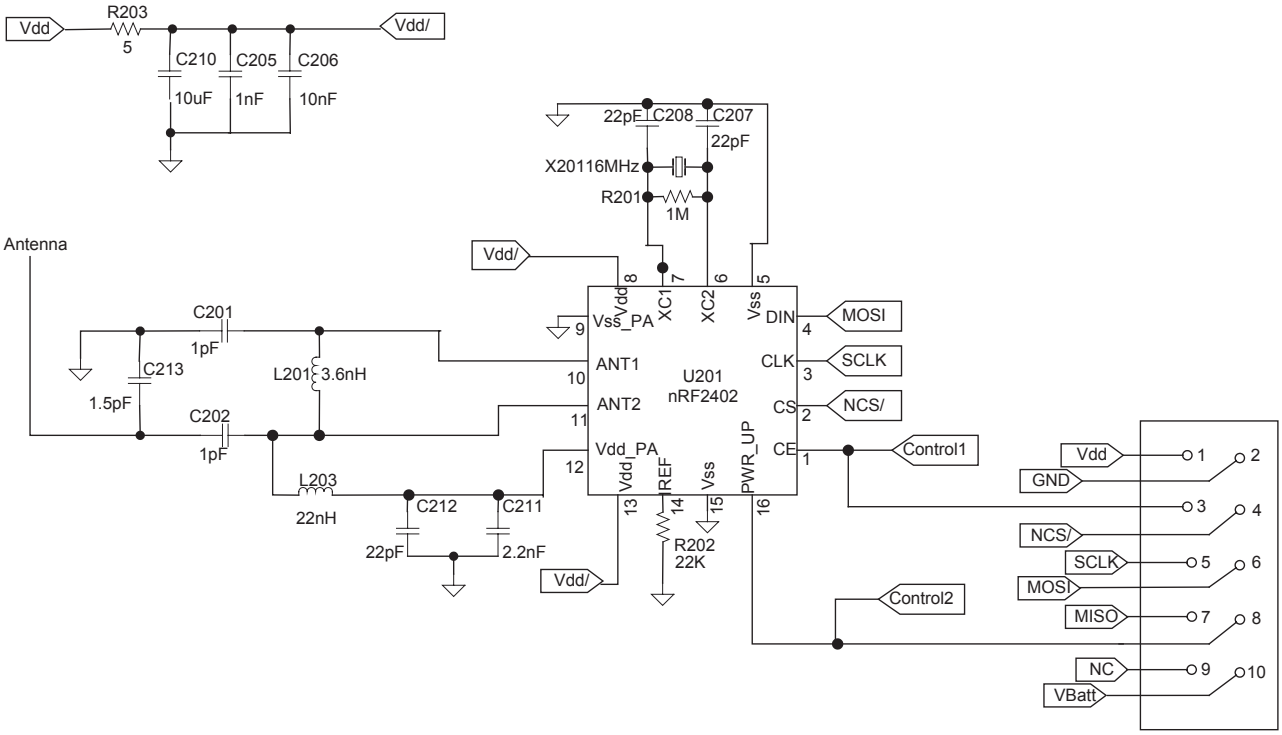

Figure A2. Schematic Diagram of RF Transmitter Daughter Board

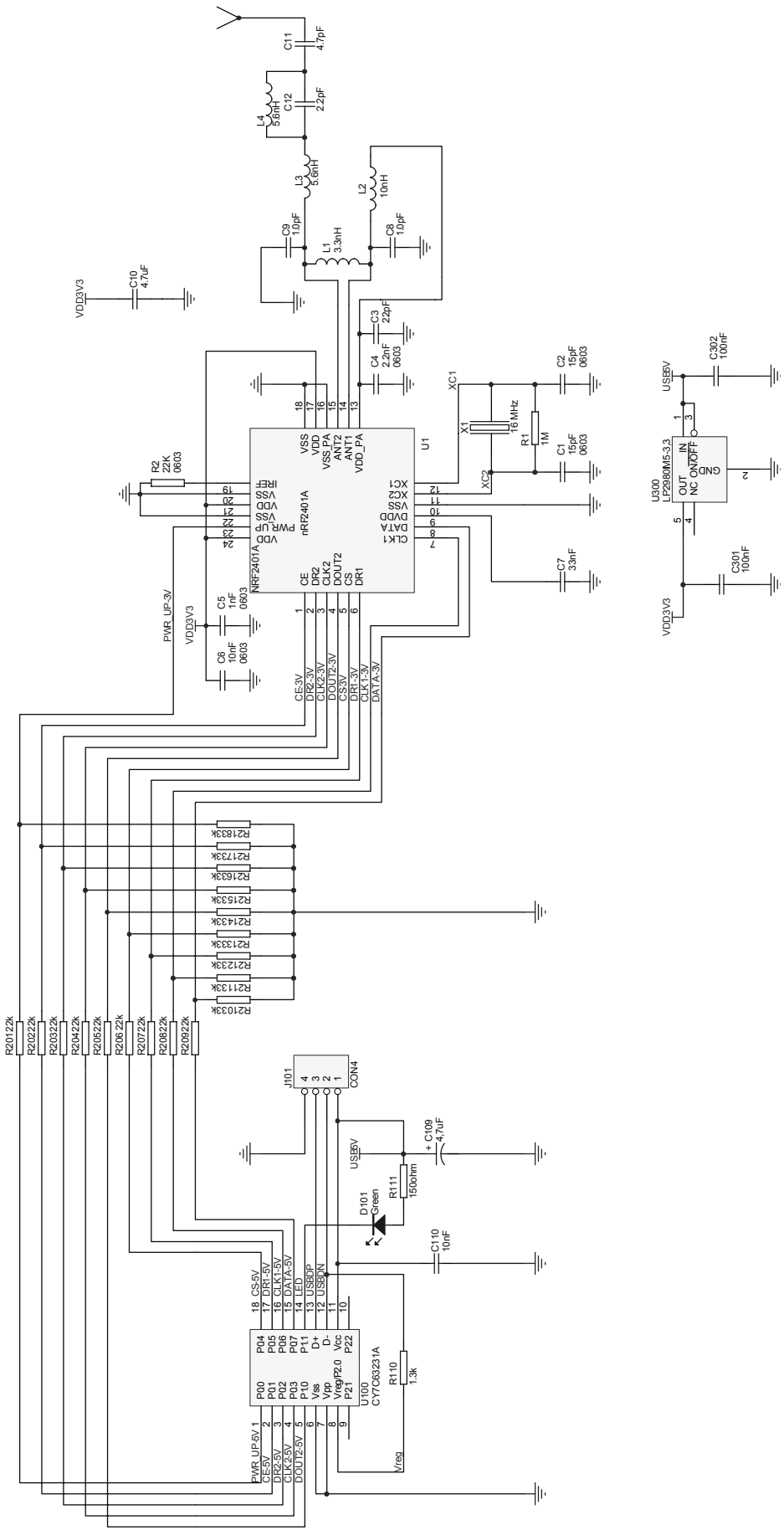

Figure A3. Schematic Diagram of USB Dongle

Appendix B: Bill of Materials (BOM)

Table B1. BOM for Components Shown on Schematic: Sensor and Microcontroller Main Board

Part Type	Value	Quantity	Designators
Optical Sensor Device		1	U101
Optical Sensor LED		1	D102
Optical Sensor Lens		1	Not shown on schematic
Optical Sensor Clip		1	Not shown on schematic
Microcontroller		1	U102
DC/DC Converter		1	U103
Z LED		1	D103
Z Encoder	3 PIN	1	U104
Resistor (0805)	100 k	5	R101, R102, R103, R104, R105
Resistor (0805)	3.3M	1	R124
Resistor (0805)	240	1	R125
Resistor (0805)	27K	2	R107, R108
Resistor (0805)	1.1 M	1	R109
Resistor (0805)	1.0 M	1	R110
Resistor (0805)	10	1	R111
Resistor (0805)	0	1	R106
Resistor (0805)	No Load	1	R122
Ceremic capacitor (0603)	.01UF 50V	4	C101, C106, C108, C110
Ceremic capacitor (0603)	.1UF 25V	2	C102, C112
Tantalum capacitor	1 uF 50V	3	C105, C107, C109
Tantalum capacitor	10uF 25V	2	C103, C104
NPN T RANSISTOR	MMBT3906LT1	1	Q101
Switch	SPDT	3	SW101, SW102, SW103
Switch, light touch	6mmx6mmx4.3mm	1	SW104
Inductor	10 uH	1	L101
Crystal	32.768 kHz	1	XTAL101
Header, pins 2mm	2x5	2	J101
Header, socket, 2mm	2 x 7	2	J105
Battery Spring, common	2X7	1	T101
Battery spring +		1	T102
Battery spring -		1	T103

BOM for nRF2402 Reference Design: RF Board

Table B2. BOM for Components Shown on Schematic: RF Transmitter Daughter Board

Part Description	Value	Quantity	Reference
Resistor (0402)	22k	1	R202
Resistor (0402)	5.1	1	R203
Resistor (0402)	1 M	1	R201
Ceramic Capacitor, 50v X7R (0402)	1nF	1	C205
Ceramic Capacitor, 50v X7R (0402)	10nF	1	C206
Ceramic Capacitor, 50v NPO (0402)	1.5pF	1	C213
Ceramic Capacitor, 50V. NPO (0402)	1pF	2	C201, C202
Ceramic Capacitor, 50v NPO (0402)	22pF	3	C208, C207,C212
Ceramic Capacitor, 50v X7R (0402)	2.2 nF	1	C211
Ceramic Capacitor, 50V. X7R (0402)	10uF	1	C210
Inductor	3.6 nH	1	L201
Inductor	22 nH	1	L203
nRF2402	nRF2402		U201
10-PIN Header	2x5 pin, 1mm pitch (M)	1	P201
Crystal, Ceramic, Model 405	16 MHz (M1)	1	X201

*Note: Must be programmed before assembly

Table B3. BOM for Components Shown on Schematic: USB Dongle

Part Description	Value	Quantity	Designator
Capacitor (C0G (NP0), 50 V, ±5 %, 0603)	15pF	2	C1,C2
Capacitor (C0G (NP0), 50 V, ±5 %, 0603)	22pF	1	C3
Capacitor (X7R, 16 V, ±10 %, 0603)	2.2nF	1	C4
Capacitor (X7R, 16 V, ±10 %, 0603)	1nF	1	C5
Capacitor (X7R, 16 V, ±10 %, 0603)	10nF	1	C6
Capacitor (X7R, 16 V, ±10 %, 0603)	33nF	1	C7
Capacitor (±0.1pF, 50 V, NPO, 0603)	1.0pF	1	C8, C9
Tantal Capacitor (10uF ±20%, 3216)	4.7uF	2	C10, C109
Capacitor (C0G (NP0), 50 V, ±5 %, 0603)	4.7pF	1	C11
Capacitor (±0.1pF, 50 V, NPO, 0603)	2.2pF	1	C12
Capacitor (X7R, 16 V, ±10 %, 0603)	10nF	1	C110
Capacitor (X7R, 16 V, ±10 %, 0603)	100nF	2	C301,C302
LED (1206)	Green	1	D101
ACON USB Plug (Freber: FCMP04208)	CON4	1	J101
Panasonic ELJRE3N3ZF2	3.3nH	1	L1
Panasonic ELJRE10NJF2	10nH	1	L2
Panasonic ELJRE5N6JF2	5.6nH	1	L3
Panasonic ELJRE5N6JF2	5.6nH	1	L4
Resistor (0.1W, 1%, 0603)	1M	1	R1
Resistor (0.1W, 1%, 0603)	22K	1	R2
Resistor (0.1W, 1%, 0603)	1.3k	1	R110
Resistor (0.1W, 1%, 0603)	150	1	R111
Resistor (0.1W, 1%, 0603)	22k	9	R201, R202, R203, R204, R205, R206, R207, R208, R209
Resistor (0.1W, 1%, 0603)	33k	8	R210, R211, R212, R213, R214, R215, R216, R21, R218
Nordic Semiconductor Transceiver	nRF2401A	1	U1
Cypress USB Controller*	CY7C63231A	1	U100
3.3V Regulator	LP2980IM5-3,3	1	U300
Crsytal (LxWxH = 4.0x2.5x0.8, Cl=9pF, tol + drift =30 ppm)	16 MHz	1	X1

Appendix C: Base Plate Feature

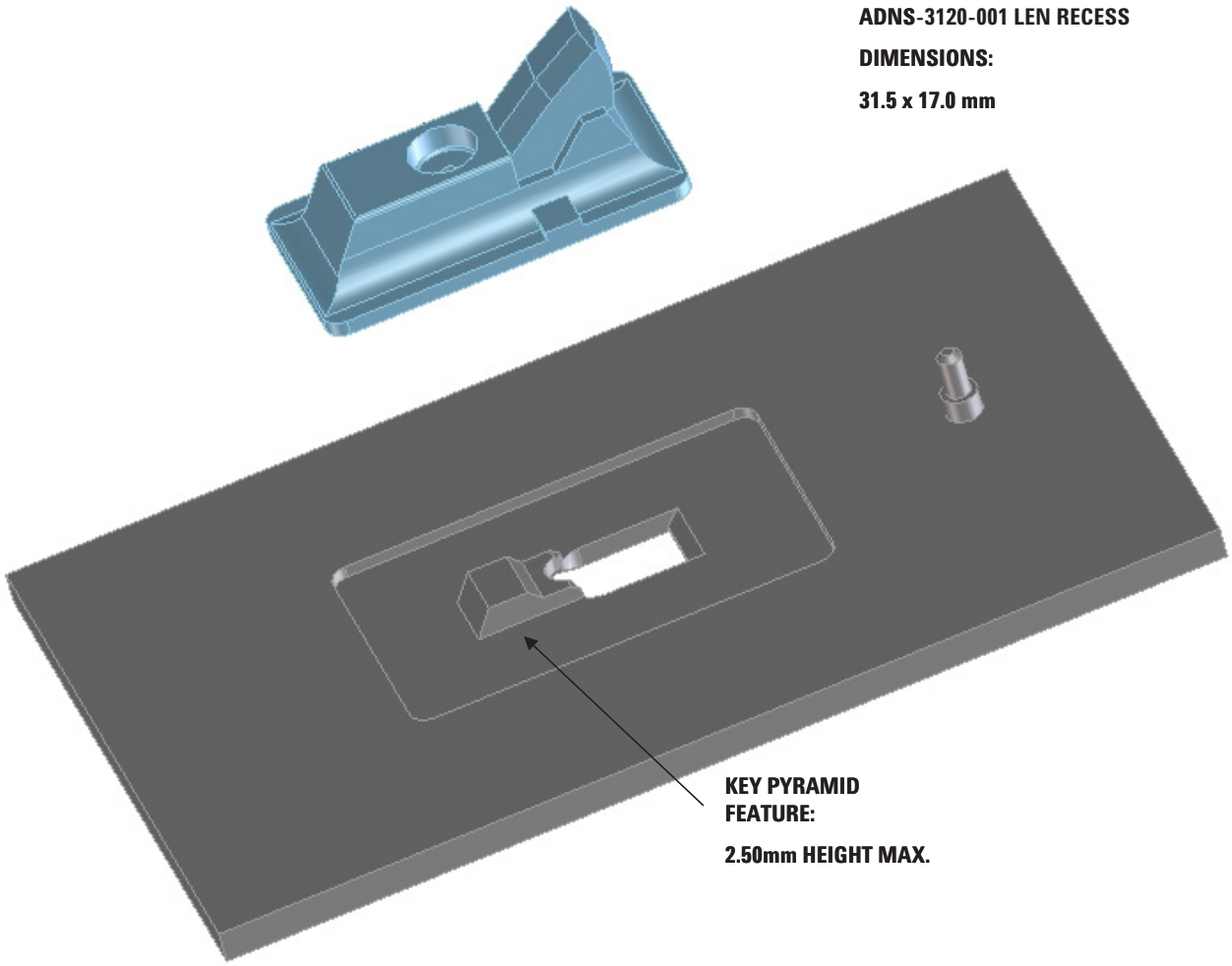

Figure C1. Illustration of base plate mounting features

Appendix D: Sectional view of PCB assembly

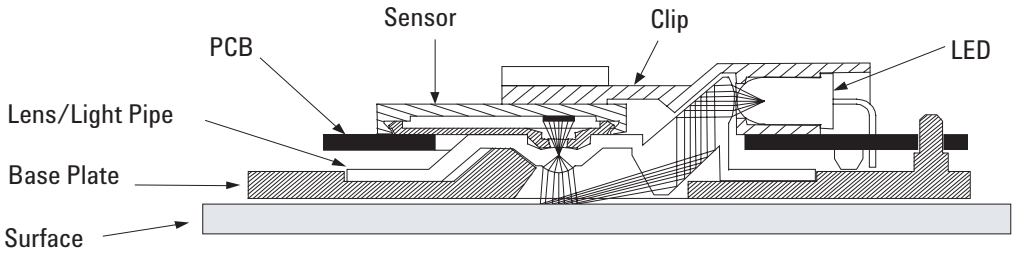

Figure E1: Sectional view of PCB assembly highlighting all optical mouse components (optical mouse sensor, clip, lens, LED, PCB, and base plate).

Appendix E: Receiver dongle Implementation

The USB receiver dongle for this reference design is supplied by Nordic Semiconductor. The following Nordic application note details the hardware design and firmware implementation. The application note can be downloaded from: www.nordicsemi.no

Universal low cost USB DuoCeiver^{TM} nAN24-04 using nRF2401^{TM}

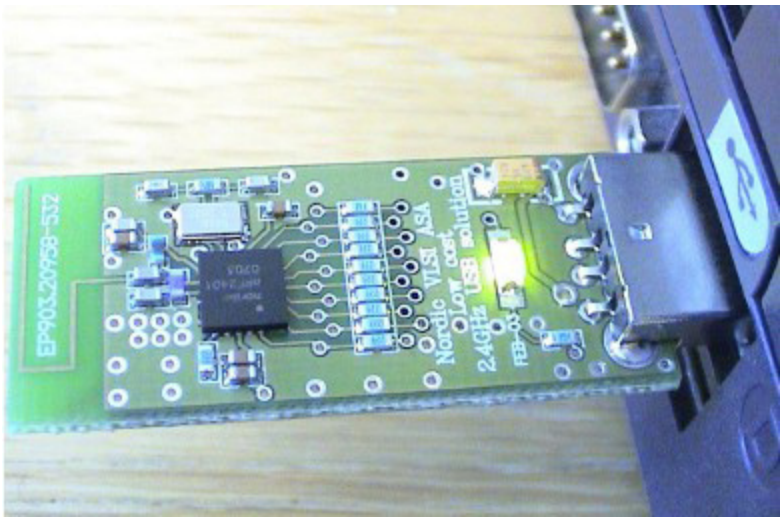

Figure E1. low cost USB DuoCeiverTM

Appendix F: Kit Components

The designer's kit contains components as follows:

Part Number	Description	Name	Quantity
ADNK-3043-ND24 Mouse Set	a. Wireless LED Mouseb. USB Dongle	Reference Design Mouse Set	1
ADNS-3040	LED Mouse Sensor	Sensor	5
ADNS-3120-001	LED Mouse Trim Lens Plate	Lens	5
ADNS-2220	LED Clip	LED Clip	5
HLMP-ED80-PS000	Light Emitting diode	LED	5
ADNK-3043-ND24 CD	Includes Documentation and Support Files for ADNK-3043-ND24 Documentation a. ADNS-3040 Optical Mouse Sensor Data Sheet b. ADNS-3120-001 Trim Lens Data Sheet c. ADNK-3043-ND24 Optical mouse Designer's kit Design Guide d. Battery Life Calculation for an Ultra Low Power Wireless Optical Mouse Application Note 5243 e. Texas Instrument MSP430F1222 Microcontroller Datasheet f. Nordic Semiconductor nRF2401A RF Transceiver Datasheet g. Nordic Semiconductor nRF2402 RF Transmitter Datasheet Hardware Support Files a. ADNK-3043-ND24 BOM List b. ADNK-3043-ND24 Schematic c. ADNK-3043-ND24 Gerber File d. 3D Model IGES Files Software Support Files a. Microcontroller Firmware		1

Ordering Information

For ordering information, please contact your local Avago sales representative.

Avago Technologies' Partners

For partner product information and list of distributors, please go to their respective website.

NORDIC SEMICONDUCTOR

www.nordicsemi.com

Nordic Semiconductor Support
Tel: +47 72 89 89 00
www.nordicsemi.no/sup_com/pro.php

TEXAS INSTRUMENTS

www.ti.com

TI Semiconductor Product Information Center
support.ti.com

MORRIHAN
樺宣國際貿易(上海)有限公司

www.morrihan.com.cn

Morrihan International
Trading (Shanghai) Co., Ltd
Tel : +86 21 58369345
E-mail : support@morrihan.com.cn

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

AV02-0193EN - September 5, 2008

AVAGO TECHNOLOGIES