AN-7533-BRBT
Laser Mouse, Proof of Concept Design

Application Note 5370

Introduction

This document describes the design of a low power consumption Bluetooth proof of concept laser mouse using the Avago Technologies ADNS-7530 laser sensor and Broadcom BCM2042 Bluetooth chip. The receiver dongle is implemented with a Broadcom BCM2045 Chip. The document starts with the basic operations of a computer mouse peripheral followed by an introduction to the Avago Technologies ADNS-7530 Optical Navigation Sensor and the Broadcom BCM2042 Bluetooth chip.

All schematic diagrams of the BCM2042 Bluetooth chip, the ADNS-7530 optical sensor and buttons of a standard mouse, as well as the receiver dongle, can be found in Appendix A. The ADNS-7530 data sheet is available from the Avago Technologies website at: http://www.avago-tech.com. The Bluetooth device information is available from the Broadcom website at www.broadcom.com. USB documentation can be found at the USB Implementers Forum web site at www.usb.org. For more information regarding Bluetooth, please visit www.bluetooth.com.

Features of AN-7533-BRBT

- Windows® XP and Windows® Vista compatibility
- USB 2.0 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 30 ips and 8 G
- 400, 800, 1200 and 1600 cpi resolution
- A high data rate 2.4 GHz RF link
- Transmission data rate up to 1 Mbps
- 10 meters communication distance
- Self-adjusting power saving modes for long battery life
- Minimal number of passive components
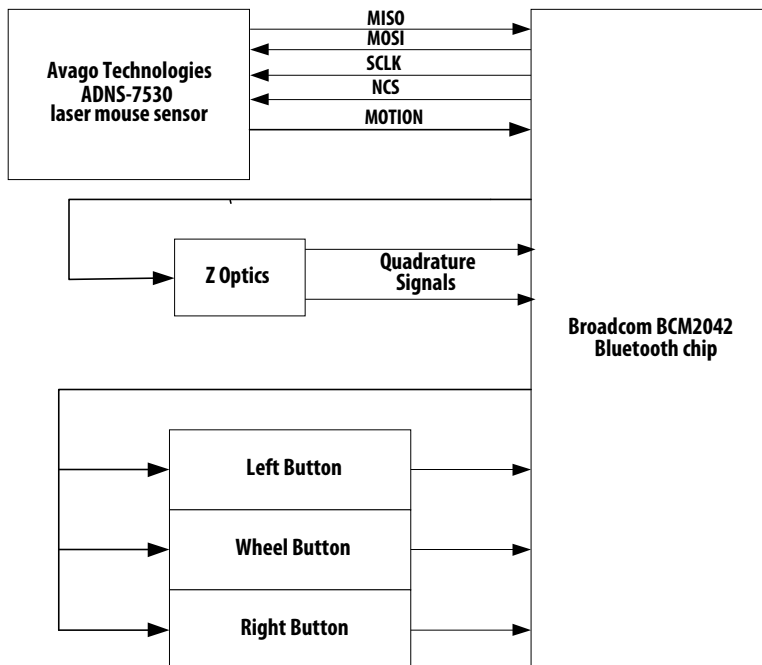- Laser fault detect circuitry on-chip for Eye Safety Compliance

Figure 1. AN-7533-BRBT Proof of Concept Design Mouse Functional Block Diagram

Optical Mouse Basic

The image-based optical mouse sensor takes snapshots 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 dual-channel encoder generates the quadrature Z-wheel movement signals. This design guide illustrates the hardware connection of a laser mouse sensor with standard configuration; as well as the firmware management and the handling of the USB HID and Bluetooth protocols. USB HID protocol provides a standard way of reporting mouse movement and button presses to the PC. The Windows HID with Bluetooth driver interprets the 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 Y and X movements. The mechanical quadrature encoder provides the Z-wheel movement. Each of the button switches is normally pulled up and provides a ground when pressed. The reference design mouse is powered up by two regular AA Alkaline batteries in series.

Mechanical Z-Wheel

Z-wheel motion is detected using the traditional method of decoding the quadrature signal generated by the mechanical encoder. The Z-pinwheel is connected to the Z-encoder through its shaft. The rotational movement of the shaft is decoded into on and off levels in a quadrature output pattern. Every change in the Z-encoder outputs represents a count of mouse movement. Comparing the last state of the Z-encoder to the current state derives direction information. As shown in Figure 2, traveling in a clockwise direction produces a unique set of state transitions, and traveling in a counterclockwise direction produces another set of unique state transitions. In this reference design, only the motion at the Z-wheel is detected using this method.

Mouse Buttons

Mouse buttons are connected as standard switches to the BCM2042 Key-Scan matrix which is designed to autonomously sample button status with the programmable hardware de-bounce and ghost key/glitch filtering and store them into buffer registers without the need for the host microcontroller to intervene. In this reference design there are three switches: left, middle, and right.
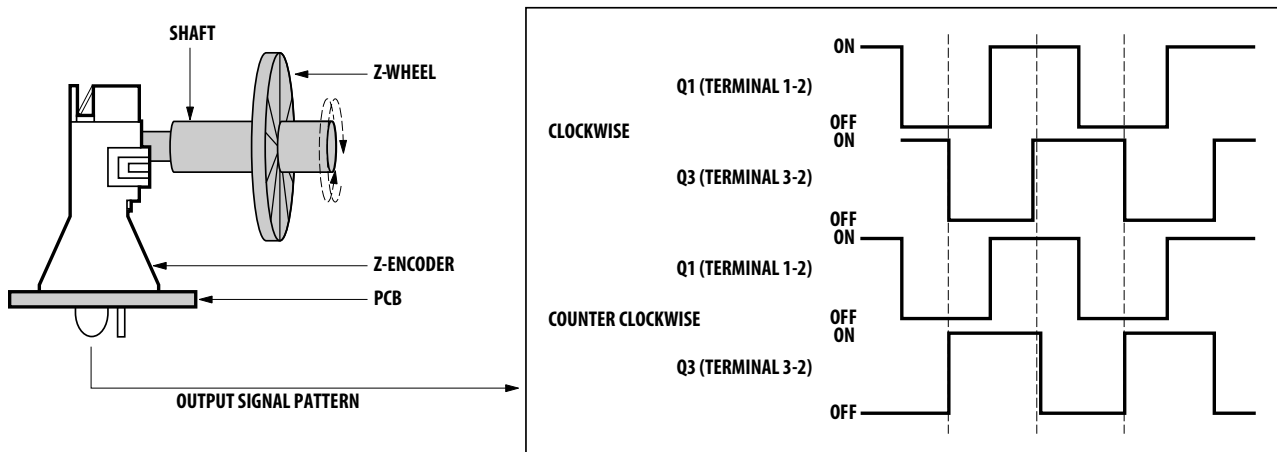

Figure 2. Mechanical Z-Wheel Output Signal Generation

Hardware Implementation

Laser Mouse Sensor

This proof of concept design mouse features the Avago Technologies ADNS-7530 laser mouse sensor, which is the primary navigation engine. Based on LaserStream™ Technology, the ADNS-7530 contains an Image Acquisition System (IAS), a Digital Signal Processor (DSP) and a four-wire serial port. Its high-performance, low power architecture is capable of sensing high-speed mouse motion while prolonging battery life, two performance areas essential in demanding wireless applications. The BCM2042 chip periodically reads the ADNS-7530's Delta_X and Delta_Y registers to obtain any horizontal and vertical motion information happening as a result of the mouse being moved. The output of the ADNS-7530 laser mouse optical sensor is four-wire serial port.

This motion information will be reported to the PC through the 2.4 GHz Bluetooth and USB protocols to update the position of the cursor. The advantage of using ADNS-7530 laser mouse sensor includes efficient power management, best tracking accuracy and flexibility of programming the optical sensor via the SPI port.

Besides, ADNS-7530 laser mouse sensor performs excellent tracking on difficult surfaces which conventional LED-based technology is unable to track such as glossy and smooth surfaces. In addition, the self-adjusting power-saving modes feature made the ADNS-7530 laser mouse sensor to be the choice of wireless mouse design for longest battery life.

Features

- Low power architecture
- New LaserStream technology
- Self-adjusting power-saving modes for longest battery life
- High speed motion detection up to 20 ips and 8 G
- Enhanced SmartSpeed self-adjusting frame rate for
- Optimum performance
- Motion detect pin output
- Internal oscillator – no clock input needed
- Selectable 400, 800, 1200 and 1600 cpi resolution
- Wide operating voltage: 2.7 V - 3.6 V nominal
- Four wire serial port
- Minimal number of passive components
- Laser fault detect circuitry on-chip for Eye Safety Compliance

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

Broadcom BCM2042 Bluetooth Chip

General Description

The Broadcom BCM2042 is a Bluetooth HID Profile 1.0 compliant product. BCM2042 is ideal for applications in wireless input devices including keyboards, mice, joysticks, and game controllers. The chip is designed to provide low-power, low-cost, robust communications for applications operating in the globally available 2.4 GHz unlicensed ISM band. Please refer to Broadcom's document 2042-AN100-R (GPIO Functional Description for Mouse Reference Designs) for more details.

Main Features:

- Class 2 design with single pole RF I/O.
- Integrated switching regulator to support external sensor to reduce external BOM cost. Dual Voltage output 1.8 V and 3.0 V
- Bluetooth HID profile version 1.0 compliant.
- Supports Adaptive Frequency Hopping (AFH)
- Excellent receiver sensitivity about -85 dbm
- On-chip support for common keyboard and mouse interfaces eliminates external processor.
- Programmable key-scan matrix interface, up to 8x20 key-scanning matrix.
- 3-axis quadrature signal decoder for mouse application, SPI interface, A/D input
- On-chip support for Serial Peripheral Interface (master mode only).
- Integrated 8051 microprocessor core.
- On-chip software control power management unit.

Bluetooth Dongle with BCM2045

Bluetooth dongles is needed only on PCs or laptops without built-in Bluetooth capability. The Bluetooth dongle is tightly integrated with industry-leading WIDCOMM Bluetooth Software (by Broadcom Corporation). To use the dongle, please install the WIDCOMM Bluetooth Software into the PC or laptop. The driver (WIDCOMM Bluetooth Software) can be requested from Broadcom.

The Bluetooth dongle consists of:

- EEPROM/Flash memory
- An "Auto-pair" button for Bluetooth pairing with Broadcom Bluetooth HID devices
- Broadcom BCM2045 Bluetooth chip

Bluetooth Technology Overview

The following description of Bluetooth technology is from the official Bluetooth Special Interest Group (SIG) website:

How Bluetooth Technology Works

Bluetooth wireless technology is a short-range communications system intended to replace the cables connecting portable and/or fixed electronic devices. The key features of Bluetooth wireless technology are robustness, low power, and low cost. Many features of the core specification are optional, allowing product differentiation.

The Bluetooth core system consists of an RF transceiver, baseband, and protocol stack. The system offers services that enable the connection of devices and the exchange of a variety of data classes between these devices.

Overview of Operation

The Bluetooth RF (physical layer) operates in the unlicensed ISM band at 2.4 GHz. The system employs a frequency hop transceiver to combat interference and fading, and provides many FHSS carriers. RF operation uses a shaped, binary frequency modulation to minimize transceiver complexity. The symbol rate is 1 Megasymbol per second (Msps) supporting the bit rate of 1 Megabit per second (Mbps) or, with Enhanced Data Rate, a gross air bit rate of 2 or 3 Mb/s. These modes are known as Basic Rate and Enhanced Data Rate respectively.

During typical operation, a physical radio channel is shared by a group of devices that are synchronized to a common clock and frequency hopping pattern. One device provides the synchronization reference and is known as the master. All other devices are known as slaves. A group of devices synchronized in this fashion form a piconet. This is the fundamental form of communication for Bluetooth wireless technology.

Devices in a piconet use a specific frequency hopping pattern which is algorithmically determined by certain fields in the Bluetooth specification address and clock of the master. The basic hopping pattern is a pseudorandom ordering of the 79 frequencies in the ISM band. The hopping pattern may be adapted to exclude a portion of the frequencies that are used by interfering devices. The adaptive hopping technique improves Bluetooth technology co-existence with static (nonhopping) ISM systems when these are co-located.

The physical channel is sub-divided into time units known as slots. Data is transmitted between Bluetooth enabled devices in packets that are positioned in these slots. When circumstances permit, a number of consecutive slots may be allocated to a single packet. Frequency hopping takes place between the transmission or reception of packets. Bluetooth technology provides the effect of full duplex transmission through the use of a time-division duplex (TDD) scheme.

Above the physical channel there is a layering of links and channels and associated control protocols. The hierarchy of channels and links from the physical channel upwards is physical channel, physical link, logical transport, logical link and L2CAP channel.

Within a physical channel, a physical link is formed between any two devices that transmit packets in either direction between them. In a piconet physical channel there are restrictions on which devices may form a physical link. There is a physical link between each slave and the master. Physical links are not formed directly between the slaves in a piconet.

The physical link is used as a transport for one or more logical links that support unicast synchronous, asynchronous and isochronous traffic, and broadcast traffic. Traffic on logical links is multiplexed onto the physical link by occupying slots assigned by a scheduling function in the resource manager.

A control protocol for the baseband and physical layers is carried over logical links in addition to user data. This is the link manager protocol (LMP). Devices that are active in a piconet have a default asynchronous connection-oriented logical transport that is used to transport the LMP protocol signaling. For historical reasons this is known as the ACL logical transport. The default ACL logical transport is the one that is created whenever a device joins a piconet. Additional logical transports may be created to transport synchronous data streams when this is required.

The link manager function uses LMP to control the operation of devices in the piconet and provide services to manage the lower architectural layers (radio layer and baseband layer). The LMP protocol is only carried on the default ACL logical transport and the default broadcast logical transport.

Above the baseband layer the L2CAP layer provides a channel-based abstraction to applications and services. It carries out segmentation and reassembly of application data and multiplexing and de-multiplexing of multiple channels over a shared logical link. L2CAP has a protocol control channel that is carried over the default ACL logical transport. Application data submitted to the L2CAP protocol may be carried on any logical link that supports the L2CAP protocol.

Hardware Implementation

PCB Layout and Design Guidelines

Special details should be taken into consideration while working on the PCB layout. By following the guidelines below, performance of the BCM2042 chip and antenna can be maximized:

- Place voltage regulator close to the battery terminals.
- Smaller value bypass capacitors should be placed as close to the chip feed in/out as possible, while the larger value capacitors can be conveniently placed further away.
- Sufficient number of GND via holes is important. Length of GND traces must be minimized.
- Use short, wide and low inductance traces for all power supply traces.
- The power supply traces used for digital and analog circuit blocks should be separated.
- The location of decoupling capacitors should be as close as possible to device's supply input pins (VDD / VSS or VCC / GND).

Please refer to Broadcom's document 2042-AN200-R (Layout and Design Guidelines for the BCM2042 Mouse PCB) for sample mouse PCB with suggested placements, as well as the antenna keep out areas. Document 2042-AN500-R (Switching Regulator Design Guide) outlines more on BCM2042 design considerations and configurations using a switching regulator.

Firmware Implementation

The Bluetooth firmware includes the core firmware and configuration file. The Bluetooth firmware implements the general Bluetooth protocol functionality including Bluetooth Baseband, LMP, GAP, L2CAP, general HID functionality, SDP query, default mouse/keyboard implementation, etc.

The HID device can be modified or customized by the following methods:

1. Configuration entries

    HID Configuration records including device name, Product ID, Vendor ID, HID report descriptor.

2. Application firmware code

    This firmware code overrides relevant default HID functionality in the BCM2042 chip on the module. Special functionality that is not included in the core firmware can be implemented through this.

BlueTool Overview

BlueTool is a software developed by Broadcom for several Bluetooth chip programming and debugging.

Getting Started and Setting Up the Device

Please refer to Broadcom's document 92042-UM100-R (Crystal Tuning Using BlueTool and a Spectrum Analyzer) and document 92042-UM200-R (RX Receive Test Using Blue-Tool and a Spectrum Analyzer). Standard HCI Command Summary and BCM2042 Vendor Specific Commands are listed in document 2042-TI100-R (Blutonium® Standard HCI and Vendor Specific Commands).

Programming Mouse Firmware into Flash/EEPROM

Please refer to Broadcom's document 2042-PG100-R (Firmware Programming) and document 92042-UM300-R (Development Board – Firmware Image Programming).

Laser Calibration Using myBTC.exe

Please refer to Broadcom's document 2042-QSG100-RDS (Automated Laser Calibration guide) for details on Avago-Broadcom co-developed GUI software "myBTC.exe".

Please note that this is to be used in mouse manufacturer factory only, not meant for end users.

Power Saving Algorithm

The diagram below shows the general power saving algorithm used in the AN-7533-BRBT proof of concept design mouse. Sniff intervals and inactivity time out are programmable. However, there is a trade off between performance (for example, motion or wake up latency) and battery life.

For details, please refer to Broadcom BCM2042 Firmware Development Kit (FDK).
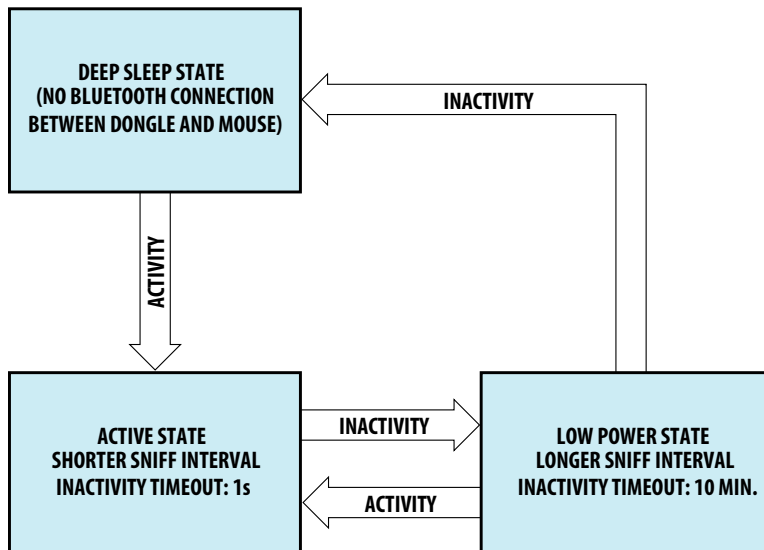
Bluetooth Mouse Pairing Process

For users with built-in Bluetooth PCs or laptops, follow these steps to pair the AN-7533-BRBT to your PC or laptop for the first time:

1. Press, hold and release the "Discovery" connect button on the back of the AN-7533-BRBT mouse
2. Wait for the driver to discover the mouse
3. Select the discovered mouse to be paired

For users with conventional PCs or laptops, follow these steps to pair the AN-7533-BRBT to your PC or laptop for the first time:

1. Press, hold and release the "Auto-Pair" button on the dongle till the blue LED is blinking.
2. Press, hold and release the "Discovery" connect button on the back of the AN-7533-BRBT mouse
3. Wait for the driver to discover the mouse
4. Select the discovered mouse to be paired

Once these steps are completed, connection is then accomplished.

Some details on AN-7533-BRBT

The AN-7533-BRBT proof of concept design mouse allows users to evaluate the performance of the Optical Tracking Engine (sensor and lens) over a USB connection, using a BCM2042 Bluetooth chip and receiver dongle. This proof of concept design also enables users to understand the recommended mechanical assembly. (See Appendix C, D, and E)

System Requirements

PCs using Window XP with standard 3-button HID driver loaded. For PC or laptops without embedded Bluetooth, the dongle driver or Bluetooth stack should be installed.

Functionality

3-button, scroll wheel combo-mouse.

USB Operating Mode

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

To Disassemble the AN-7533-BRBT Unit

The AN-7533-BRBT comprises of the plastic mouse casing, printed circuit board (PCB), lens, and buttons (See Figure 5). Unscrewing few screws located at the base of the unit can open the AN-7533-BRBT unit. Lifting and pulling the PCB out of the base plate can further disassemble the mouse unit.

While reassembling the components, please make sure that the Z height (Distance from lens reference plane to surface) is valid. Refer to Figure 6.
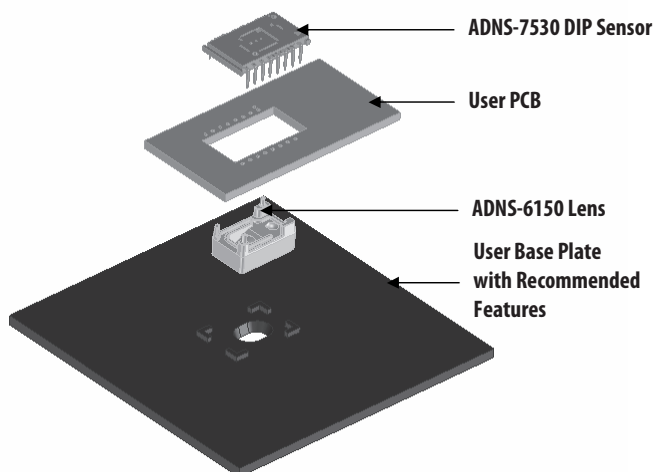
Component Summary

Below is the summary of the components contained in the AN-7533-BRBT Proof of Concept Design.

Laser Mouse Sensor and Lens

Technical information on the sensor and lens are contained in the ADNB-7532 Bundle Datasheet. Additional application notes regarding Eye Safety Requirements are also available at Avago Technologies website.

Broadcom BCM2042 Bluetooth Chip

For technical information about the hardware implementation, please refer to the BCM2042 chip datasheet. For Bluetooth dongle related information, please refer to BCM2045 chip datasheet.

As for mouse software support, please refer to the document located inside Broadcom's BCM2042 Firmware Development Kit (FDK). For further information, please contact Broadcom Corporation.

Base Plate Feature – IGES File

The IGES file 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.

Proof of Concept Design Documentation – Gerber File

The Gerber File presents detailed schematics used in AN-7533-BRBT 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.

ADNS-7530 DIP Sensor

User PCB

ADNS-6150 Lens

User Base Plate with Recommended Features

Figure 5. Exploded view drawing of optical tracking engine with ADNS-7530 optical mouse sensor.

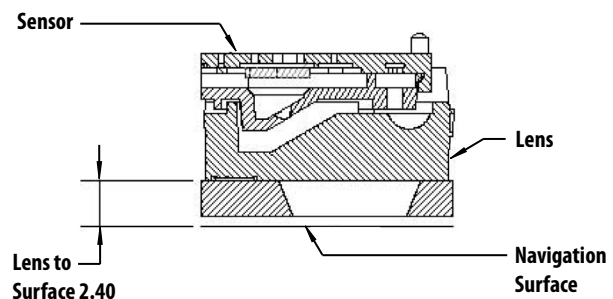
Sensor

Lens

Lens to Surface 2.40

Navigation Surface

Figure 6. Distance from lens reference plane to surface.

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

Appendix A. Schematic Diagram of the Mouse Main Board
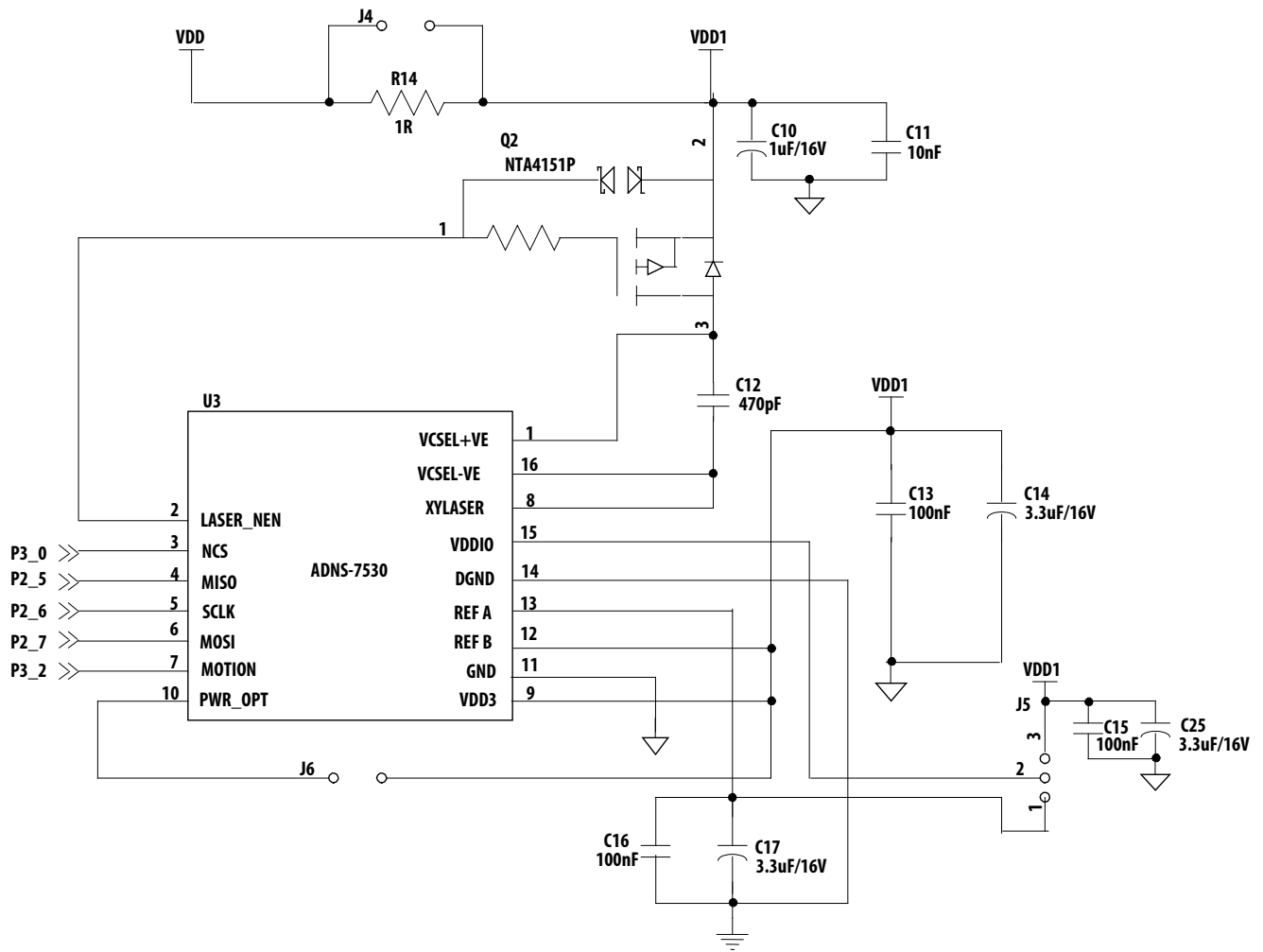

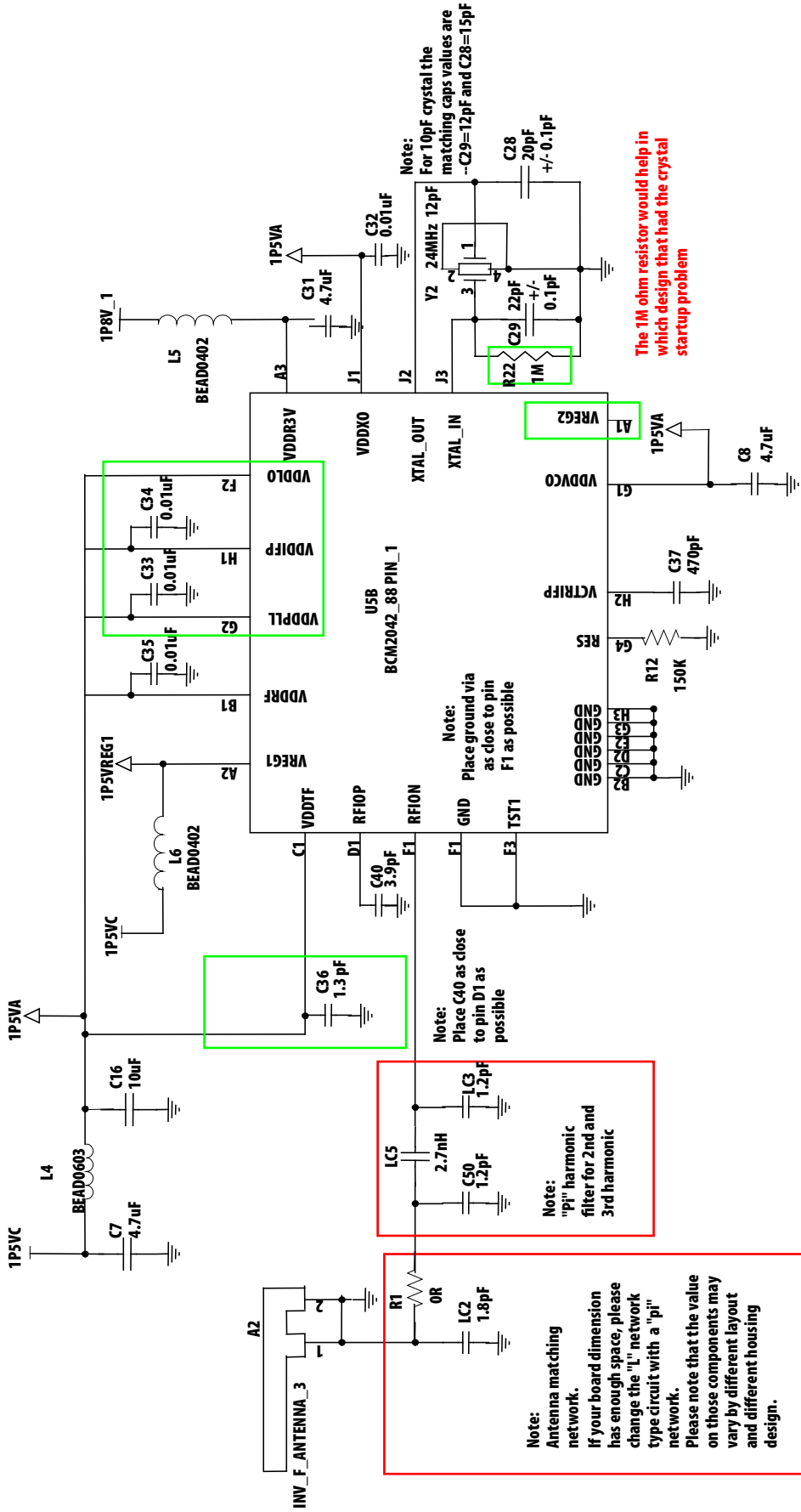Figure A1. Schematic Diagram of Optical Mouse Sensor

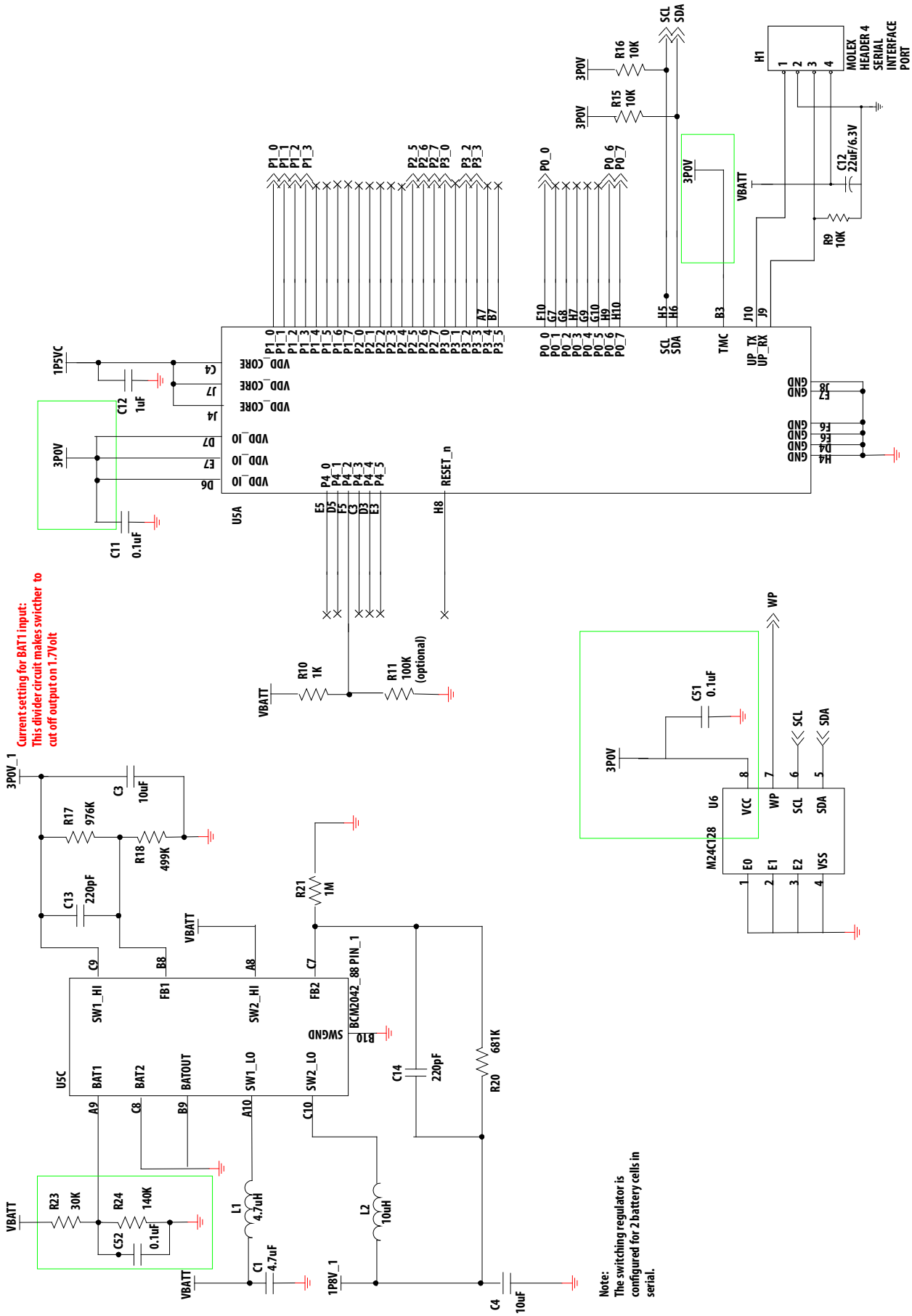Figure A2. Schematic Diagrams of RF portion
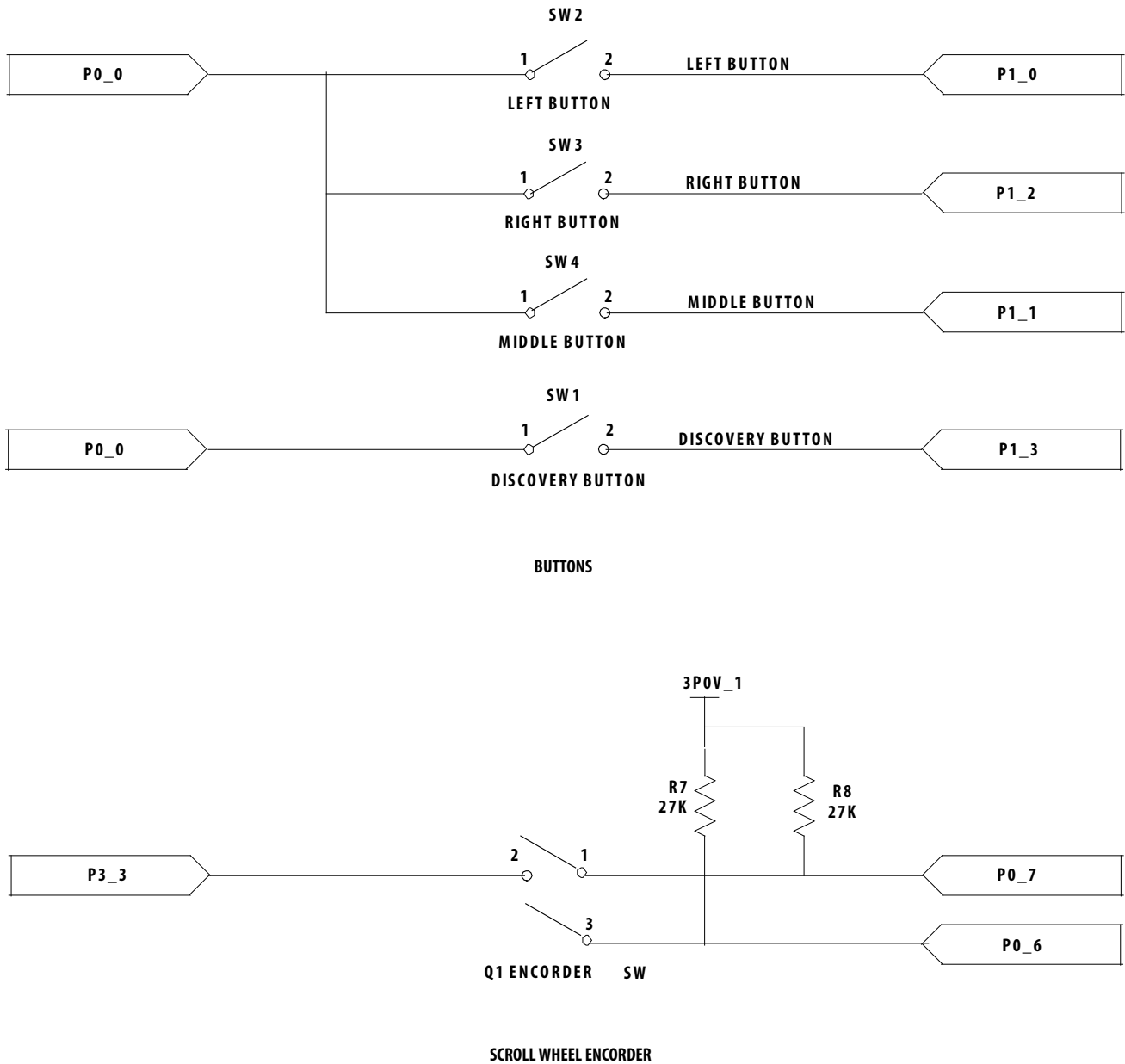
Figure A3. Schematic Diagram of Bluetooth Baseband

Note:
The switching regulator is configured for 2 battery cells in serial.

Current setting for BAT1 input:
This divider circuit makes switcher to cut off output on 1.7Volt

Connectors / headers

H1 — MOLEX HEADER 4 SERIAL INTERFACE PORT

Components (labels)

- R16 10K — 3P0V
- R15 10K — 3P0V
- R9 10K
- C12 22uF/6.3V
- SCL / SDA
- 3P0V — VBATT
- R10 1K — VBATT
- R11 100K (optional)
- C5 0.1uF
- C11 0.1uF
- C12 1uF — 1P5VC
- C51 0.1uF — 3P0V
- R17 976K
- C3 10uF — 3P0V_1
- R18 499K
- C13 220pF
- R21 1M
- C7
- R20 681K
- C14 220pF
- L1 4.7uH
- C1 4.7uF — VBATT
- L2 10uH — 1P8V_1
- C4 10uF
- R23 30K — VBATT
- R24 140K
- C52 0.1uF

U5A pins (labels)

P1_0, P1_1, P1_2, P1_3, P1_4, P1_5, P1_6, P1_7, P2_0, P2_1, P2_2, P2_3, P2_4, P2_5, P2_6, P2_7, P3_0, P3_1, P3_2, P3_3, P3_4, P3_5

P0_0, P0_1, P0_2, P0_3, P0_4, P0_5, P0_6, P0_7

SCL, SDA, TMC, UP_TX, UP_RX

VDD_CORE, VDD_IO, RESET_n, GND

P4_0, P4_1, P4_2, P4_3, P4_4, P4_5

U6 — M24C128
VCC, WP, SCL, SDA, E0, E1, E2, VSS
WP, SCL, SDA

U5C — BCM2042_88 PIN_1
SW1_HI, FB1, SW2_HI, FB2, SWGND, BAT1, BAT2, BATOUT, SW1_LO, SW2_LO

SW 2

P0_0

1   2   LEFT BUTTON   P1_0

LEFT BUTTON

SW 3

1   2   RIGHT BUTTON   P1_2

RIGHT BUTTON

SW 4

1   2   MIDDLE BUTTON   P1_1

MIDDLE BUTTON

SW 1

P0_0

1   2   DISCOVERY BUTTON   P1_3

DISCOVERY BUTTON

BUTTONS

3P0V_1

R7
27K   R8
27K

P3_3

2   1   P0_7

3   P0_6

Q1 ENCORDER   SW

SCROLL WHEEL ENCORDER

Figure A4. Sub-schematic Diagram of buttons

Appendix B. Bill of Materials for AN-7533-BRBT Proof Of Concept Mouse Kit

Table B1. Bill of Materials for AN-7533-BRBT Proof of Concept Mouse Main Board

No.	Descriptions	Designators	Qty.
1	Resistor 0R 1% 0.125 W	R1	1
2	Resistor 1 kΩ 1% 0.125 W	R10	1
3	Resistor 10 kΩ 1% 0.125 W	R9, R15, R16, R100	4
4	Resistor 30 kΩ 1% 0.125 W	R23	1
5	Resistor 100 kΩ 1% 0.125 W	R11	1
6	Resistor 140 kΩ 1% 0.125 W	R24	1
7	Resistor 150 kΩ 1% 0.125 W	R12	1
8	Resistor 499 kΩ 1% 0.125 W	R18	1
9	Resistor 681 kΩ 1% 0.125 W	R20	1
10	Resistor 976 kΩ 1% 0.125 W	R17	1
11	Resistor 1 MΩ 1% 0.125 W	R21, R22	1
12	Multilayer ceramic cap 1.3 pF, 50 V	C36	1
13	Multilayer ceramic cap 1.8 pF, 50 V	C50, LC2, LC3	2
14	Multilayer ceramic cap 3.9 pF, 50 V	C40	1
15	Multilayer ceramic cap 20 pF, 50 V	C28	1
16	Multilayer ceramic cap 22 pF, 50 V	C29	1
17	Multilayer ceramic cap 220 pF, 50 V	C13, C14	2
18	Multilayer ceramic cap 10 nF, 25 V	C32, C33, C34, C35	4
19	Multilayer ceramic cap 100 nF, 16 V	C11, C12, C37, C51, C52	5
20	Multilayer ceramic cap 4.7 uF, 10 V	C1, C7, C8, C31	4
21	Multilayer ceramic cap 10 uF, 16 V	C3, C4, C18	3
22	Tantalum Electrolytic 22 uF, 6.3 V	C9	1
23	Tantalum Electrolytic 68 uF, 10 V	C2	1
24	Inductor 2.7 nH	LC5	1
25	Inductor 4.7 uH	L1	1
26	Inductor 10 uH	L2	1
27	Ferrite Chip Bead BLM15AG121SN1	L5, L6	1
28	Ferrite Chip Bead EXC3BB102H	L4	1
29	Connector - Pin Header Single Row	H1	1
30	Connector - Pin Header Double Row	J1, J2	2
31	Crystal 24 MHz	Y2	1
32	IC AT24C128N	U1	1
33	IC BCM2042	U5	1

Table B2. Bill of Materials for AN-7533-BRBT Proof of Concept z-wheel and Button Sub-board

No.	Descriptions	Designators	Qty.
1	Resistor 27 kΩ 1% 0.125 W	R7, R8	2
2	Connector - PCB Socket Double Row	J2	1
3	Omron SPDT Switch	SW2, SW3, SW4	3
4	Mechanical Z-Encorder	Q1	3

Table B3. Bill of Materials for AN-7533-BRBT Proof of Concept Optical Sensor Sub-board

| No.	Descriptions	Designators	Qty.
1	Resistor 1R 1% 0.125 W	R14	1
2	Multilayer ceramic cap 470 pF, 50 V	C19	1
3	Multilayer ceramic cap 10 nF, 25 V	C2	1
4	Multilayer ceramic cap 100 nF, 16 V	C5, C15, C16	3
5	Multilayer ceramic cap 1 uF, 16 V	C10	1
6	Tantalum Electrolytic 22 uF, 6.3 V	C6, C17, C25	3
7	MOSFET P-Channel NTA4151PT1G	Q2	1
8	Connector - PCB Socket Double Row	J1	1
9	Sensor A7530	U3	1
10	Lens A6150	-	1

Appendix C. PCB Layout
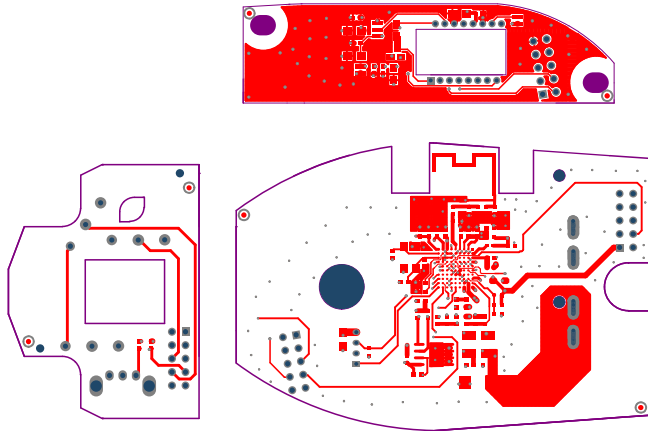
Figure C1. PCB layout for main board, sub-board 1 and sub-board 2 of AN-7533-BRBT proof of concept laser mouse design (top layer)
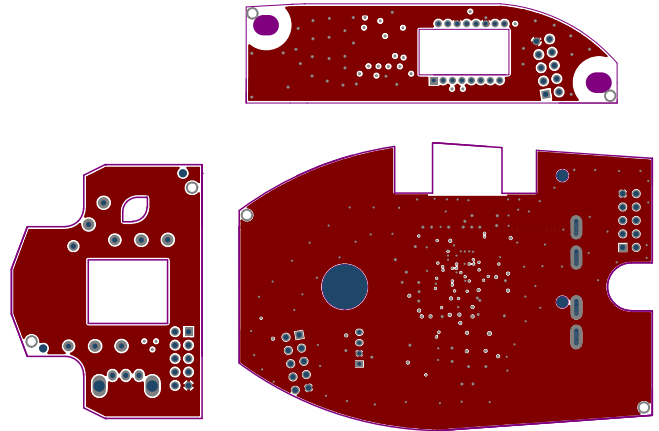
Figure C2. PCB layout for main board, sub-board 1 and sub-board 2 of AN-7533-BRBT proof of concept laser mouse design (middle 1 layer)
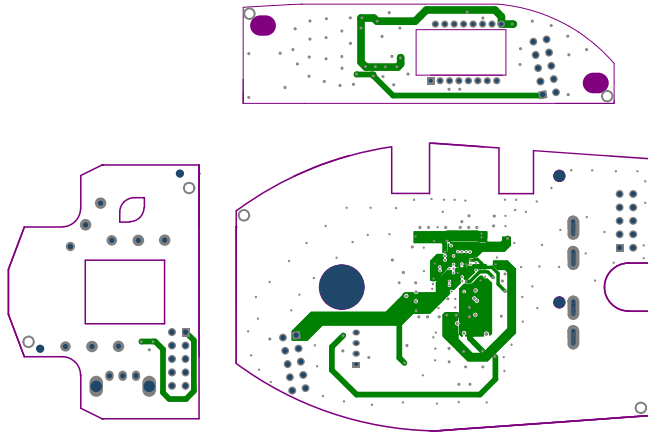
Figure C3. PCB layout for main board, sub-board 1 and sub-board 2 of AN-7533-BRBT proof of concept laser mouse design (middle 2 layer)
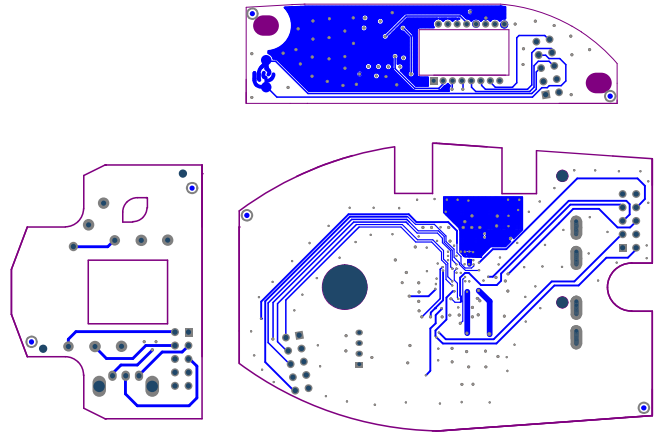
Figure C4. PCB layout for main board, sub-board 1 and sub-board 2 of AN-7533-BRBT proof of concept laser mouse design (bottom layer)

Note: For technical information related to the USB Bluetooth dongle, please contact Broadcom.

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

Avago
T E C H N O L O G I E S