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9-Axis 8-Bit Motion Processing Reference Design User Guide

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1. Revision History

Revision Date	Revision	Description
01/13/2010	1.0	Initial Release

2. Purpose

This document shows basic connections and functional operation of the InvenSense 9-Axis 8-Bit Motion Processing Reference Design (hereafter referred to as reference design). The reference design is programmed with example application firmware for an air-mouse demonstration and a raw-data sending mode. This user guide includes the basic descriptions on the hardware and the software utilities running on the host PC to receive the data and display it. The PC should use Windows XP operating system with USB and Bluetooth radio support. An external USB plug-in Bluetooth adaptor will work if the PC does not have built-in Bluetooth.

2.1 Related documents

The details on the various hardware and software components of the reference design are provided in the following InvenSense documents:

- 9-Axis 8-Bit Motion Processing Reference Design Hardware Functional Description
- 9-Axis 8-Bit Motion Processing Reference Design System Programming Guide
- Motion Processing and Control Software Document

3. Overview of the Reference Design Components

There are three circuit boards in the reference design, which are called the Sensor board, USB/Power board and RF board.

3.1 Sensor Board

The reference design sensor board photographs are shown in Figure 1a and 1b below. In these photo's we show the removable mounting end-tabs still connected to the board. In many cases is not required for mounting holes so the end-tabs may be *gently* broken off.

Figure 1a: Sensor board top view

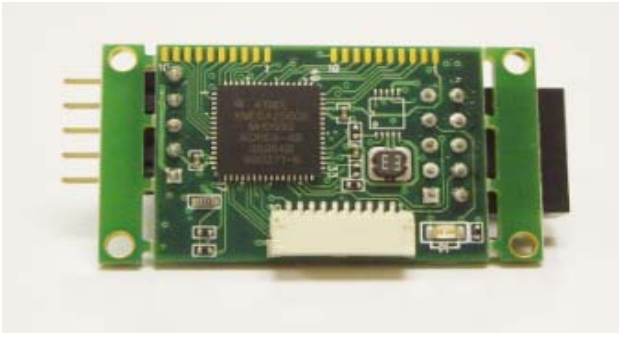

Figure 1b: Sensor board bottom view

The sensor board is partitioned into three major functions:

1. Three motion sensors cover 9 degrees of freedom;

2. The Atmel XMEGA microcontroller in which the embedded firmware does signal processing for the motion sensor data; and
3. A switching power supply is included onboard to ensure the DC supplies of all the main parts.

3.2 USB/Power board

The USB/Power board's main purpose is to manage a Lithium Ion battery for powering the Sensor Board and also provides USB connection to a PC to enable an RS-232 formatted debug port from the sensor board. The external battery can be charged by the USB or a DC adapter (powered from an AC wall plug).

Photographs of Sensor Board, assembled together with the USB/Power board, are shown in Figure 2a and 2b. The USB/Power board has its end-tabs removed but the Sensor Board still has them attached.

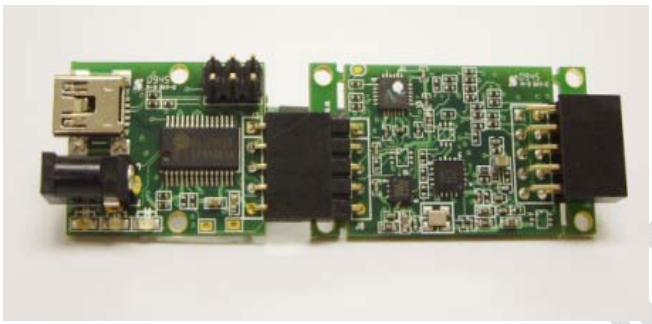

Figure 2a: Board Assembled Top View

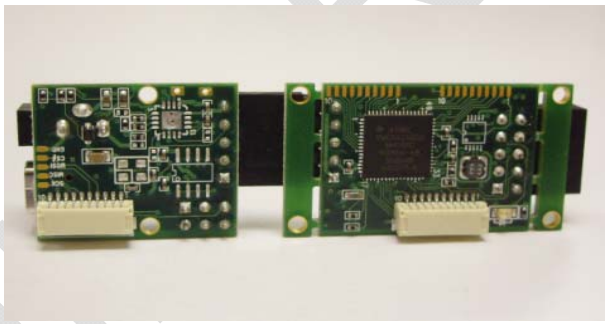

Figure 2b: Board Assembled Bottom View

3.3 RF Board

The RF board provided with the reference design uses a CSR Bluetooth module running in SPP mode. It provides a Bluetooth wireless link with the host PC. A photograph of the RF board is shown in Figure 3.

Figure 3: RF Board

The RF Board plugs into the Sensor Board. Refer to the 9-Axis 8-Bit Motion Processing Reference Design Hardware Functional Description and the System Programming Guide for details on connections and signals between the boards.

3.4 Battery and Electrical Interface Connections

Figure 4 shows where to make external battery connection to the USB/Power Board. Adding an ON-OFF switch is recommended between battery + and PCB pad. The ON-OFF switch will serve to re-boot the Sensor Board microcontroller.

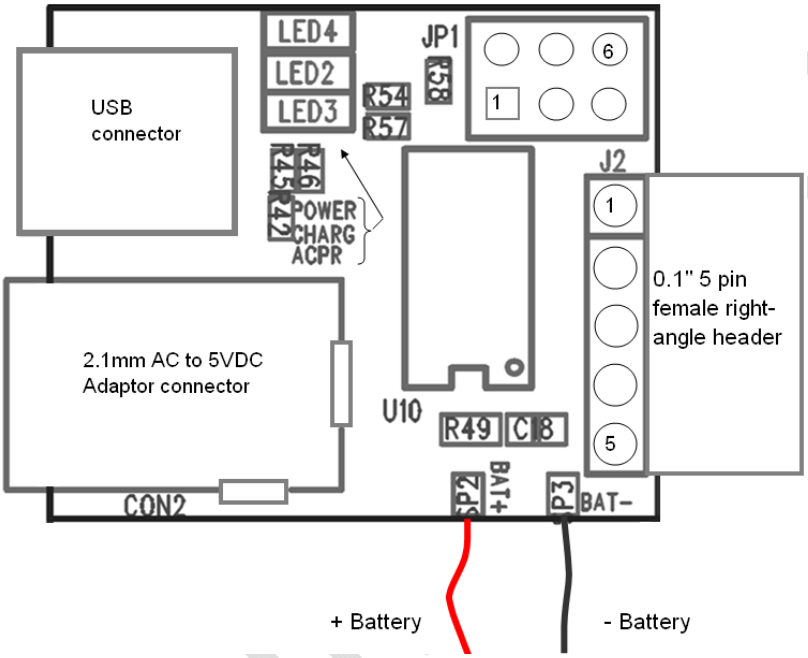

Figure 4: Pad for Battery Connection (+ / -)

Three LEDs are mounted on the USB/Power Board top side, which monitor the battery charging process. Only one LED will be light up under normal battery operations. Another LED will light up when battery is re-charging through USB or DC adapter. Vbattery must be between 2.0V and 3.6V to ensure the system performance, and the equivalent series resistance of the battery or power supply should be less than 1 ohm, capable of delivering at least 300mA peak inrush current during power on.

3.5 Programming the Sensor Board through the USB/Power board

JP1 on the USB/Power Board is a PDI port, reserved for debugging the Atmel XMEGA microcontroller on the Sensor Board. Refer to Figure 4 to locate JP1. For programming and debugging, the user must install the Atmel AVR firmware development environment. Refer to Atmel's extensive website for support on their tool-chain. The Sensor Board powers the PDI port during programming and debugging, providing a constant 2.7VDC.

A 10-wire cable connects the PDI port on the USB/Power Board to a 10-pin connector J3. A short 10-wire cable connects J3 to the Sensor Board at its J4, to couple the PDI port through to the Atmel XMEGA microcontroller on the Sensor Board. Figure 6 below shows the 10-wire connecting cable used for programmer access when the USB/Power Board ios connected to the Sensor Board.

3.6 Completed Demo Kit

A photo of a demonstration kit is shown in Figure 5. This system is ready to connect to a PC and demonstrate its capabilities.

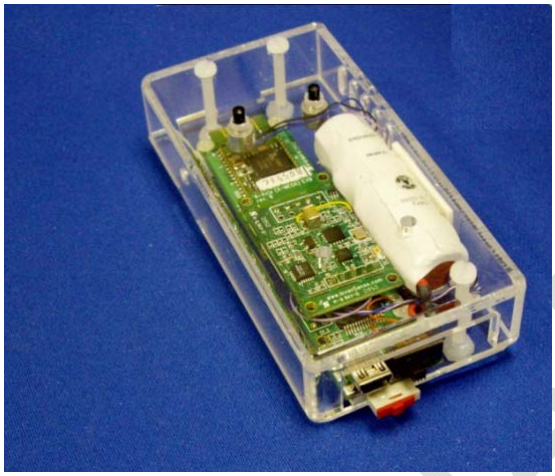

Figure 5: Photo of a Demonstration Kit

To make a demonstration kit, two mouse control buttons (left and right) and a software-mode switch are added. Refer to Figure 6 below, and to the 9-Axis 8-Bit Reference Design Hardware Functional Description and the System Programming Guide for details on connections and signals between the boards and switches.

The Mode switch is used to configure the format of data stream to the host PC. The Sensor Board firmware has two operation modes, one called “raw-data” mode and the other called “air-mouse” or pointer” mode.

When the Mode Switch pin is pulled down to ground, the raw-data mode is enabled.

Mouse Button 1, (also called “Left Button”) is active when connected to ground, through a momentary push-button switch. Mouse Button 2, (also called “ Right Button”) works the same way.

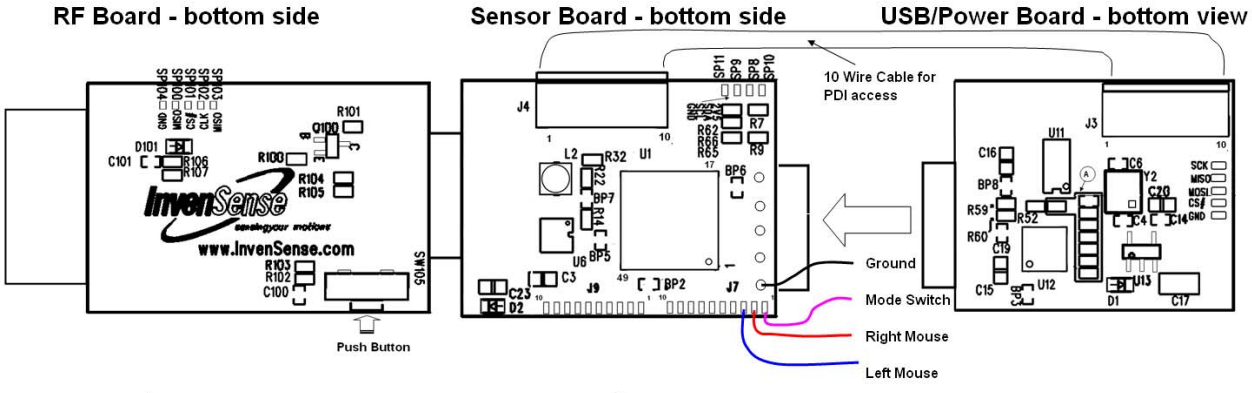

Figure 6: The Pin Locations of the Switch Connections and Wires to Sensor Board

When in pointer (air-mouse) mode (Mode switch pin is left open) the reference design behaves like a three-dimensional air-mouse controlling a PC cursor.

Raw-data mode (Mode switch pin is pulled down to ground) is used for test and debugging purpose. The raw data is transported to the host PC via USB or BT RF link. In addition, InvenSense has several interesting PC-based motion processing demonstration applications that can be controlled through raw-data mode.

4. The Bluetooth Link Setup

The reference design provides Bluetooth wireless link to the host PC running Windows XP. The serial port profile (SPP) Bluetooth runtime environment is used, along with a virtual serial port utility that runs on the PC. The reason to use SPP is that it provides virtual RS-232 formatted serial link which is very flexible, rather than HID (human interface device) profile that only passes mouse or audio data. A dedicated wireless mouse design will often use the HID profile which is plug and play, however the SPP profile allows the reference design to also drive existing InvenSense PC graphical applications as well as provide sensor datalogging. A detailed software/device driver installation procedure for the SPP Bluetooth is provided in this section.

It is very important to note that connecting an SPP Bluetooth link to a PC COM port involves more steps and can be more frustrating or troublesome than connecting an HID Bluetooth mouse to a PC mouse driver.

Connecting an HID Bluetooth mouse involves:

1. PC must have Bluetooth loaded and running
2. PC discovers the HID packet stream from the Bluetooth driver, and pairs with the mouse
3. PC associates it with its mouse driver. Now the wireless mouse controls the cursor.

SPP Bluetooth link to a mouse via a PC COM port driver involves:

1. PC must have Bluetooth loaded and running
2. Manual pairing is required. There are two ways to pair:
    a. The right way where the SPP channel connects to the SIOControlHID utility
    b. The wrong way where the SPP channel connects to a COM port. *Mouse will not work.*
3. PC must have SIOControlHID utility loaded, in order to convert the Bluetooth SPP serial data into HID data format. If paired the right way, when the SIOControlHID utility starts, the mouse will work.

Bluetooth also does not manage SPP links very well, and two odd behaviors have been discovered:

- If paired the wrong way, the only sure remedy to repair is to shut off the reference design, un-pair the Bluetooth device, and search (discover) for Bluetooth devices with the reference design off. Then power on again and restart the discovery and re-pairing process. This takes time to do.
- The secret encryption key to enter for pairing is 0000 (four zero's) which is not very secure.

However, the value of using an SPP link is that it provides a very flexible serial-port link which enables the reference design to be used for a large variety of PC based applications.

4.1 I/O Gear Bluetooth Adaptor Software Installation

A Bluetooth USB adaptor should be installed on the host PC if there is no built-in Bluetooth support on the host PC. There are many different brands of Bluetooth adapters in the market. In this section, we will use an I/O Gear Bluetooth adaptor installation to a Windows XP PC. I/O Gear is a widely popular external Bluetooth dongle vendor. Below is the desk-top icon for the I/0 Gear Bluetooth service.

Figure 8 shows the GUI for the IOGEAR Bluetooth adaptor software installation.

Figure 8: I/O Gear Bluetooth Adaptor Device Driver Installation GUI

To get started, switch the Reference Design mode to 3D Mouse mode. Then, Turn on the power. Now it will become the target device to pair with. At this time, the RF module LED will blink, which means that the Bluetooth module in the Reference Design is in search mode.

Accept the default settings during the installation procedure. Click the “next” button as shown in Figure 9.

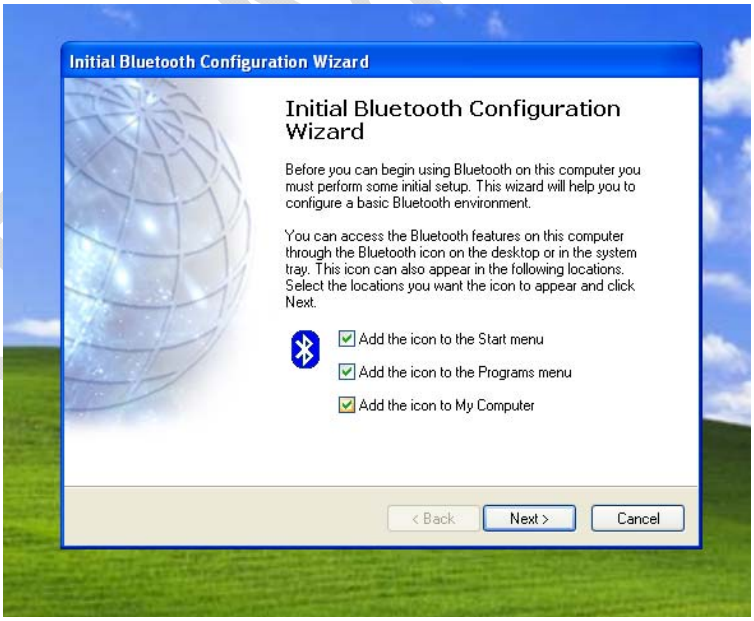

Figure 9: The Bluetooth Adaptor Software Installation Procedure

Make sure the Bluetooth serial port service option is selected during the installation procedure as shown in Figure 10.

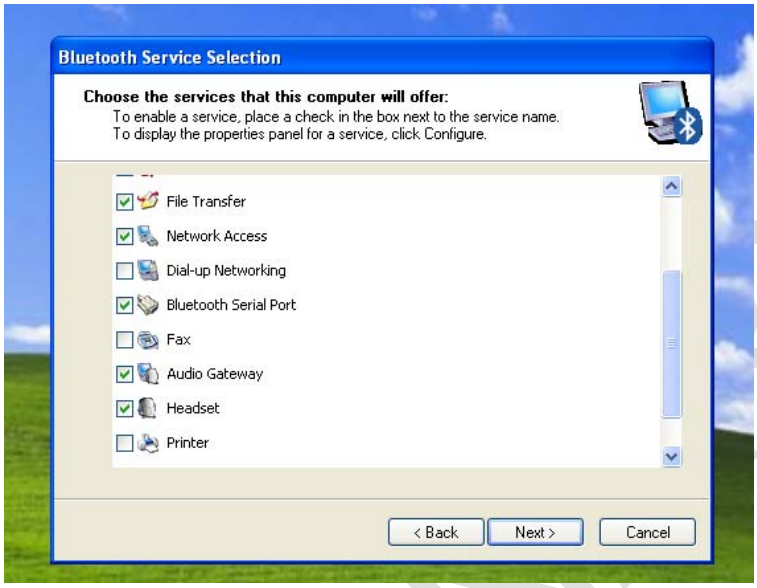

Figure 10: The Bluetooth Service Options – I/O Gear Bluetooth Adaptor Software Installation

Figure 11: The Bluetooth Adaptor Software Installation is Completed

When the Bluetooth installation shows the "setup a connection" window as in Figure 11, click "Skip" to finish the installation, as shown in Figure 12. We will be connecting to our custom utility SIOControlHID. The Bluetooth serial port configuration will be conducted separately from the Bluetooth adaptor setup, which is described later on.

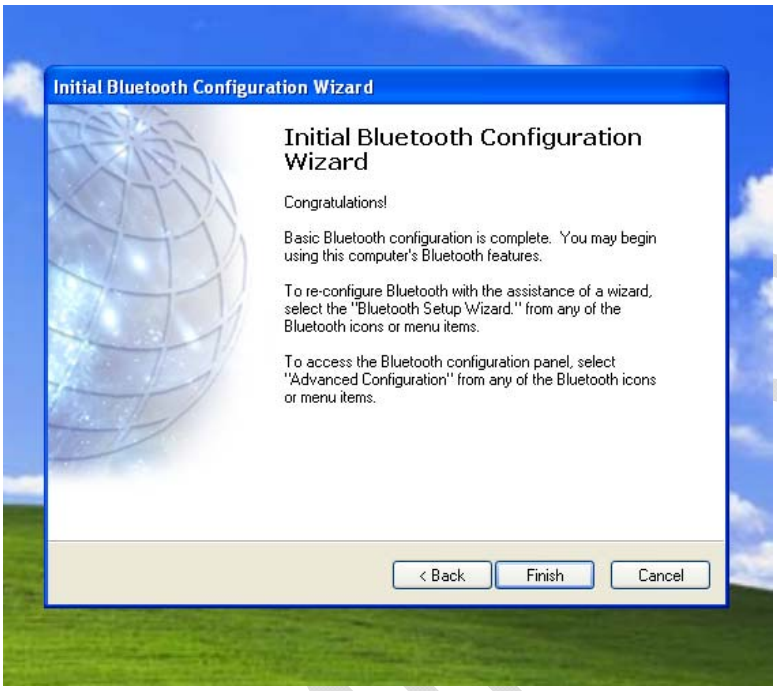

Figure 12: The I/O Gear Bluetooth Adaptor Software Installation is Completed

Now you should place a “My Bluetooth Places” icon on your PC desktop for fast access. Also you should place a shortcut to Windows XP Control Panel since you will need to access the device manager, looking at and changing COM port numbers.

4.2 Pairing the Reference Design Kit to Host PC with the I/O Gear Bluetooth

On the Windows XP desktop, click the “My Bluetooth Places” icon, and “Entire Bluetooth Neighborhood” window should pop up. Double click the InvenSense SPP Device icon and the popup menu is shown up in Figure 13.

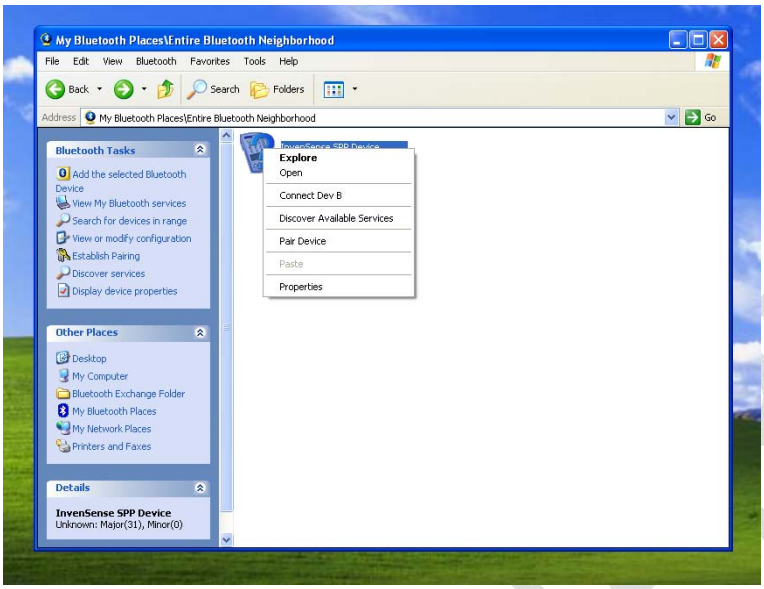

Figure 13: Pair the Device Through Double Clicks

Click on the “Pair Device” button, the device pairing window is shown up. Setting the Bluetooth security code as “0000” as shown in Figure 14, the click “OK”.

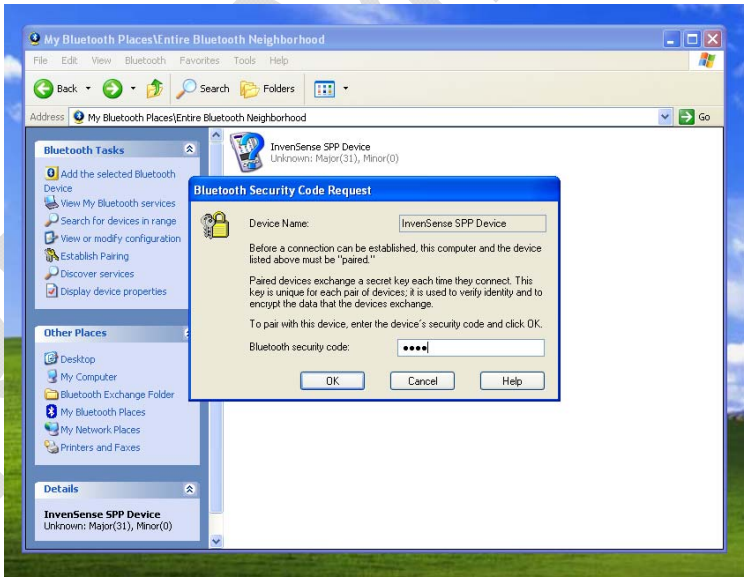

Figure 14: Setting the I/O Gear Bluetooth Security Code as “0000” in the Pairing Window

The InvenSense SPP Device icon will become the one shown in Figure 15.

Now the pairing procedure will be successfully performed. The icon with the red check-mark next to it indicates that the pairing is available, but the actual link is not active. This is what you should see.

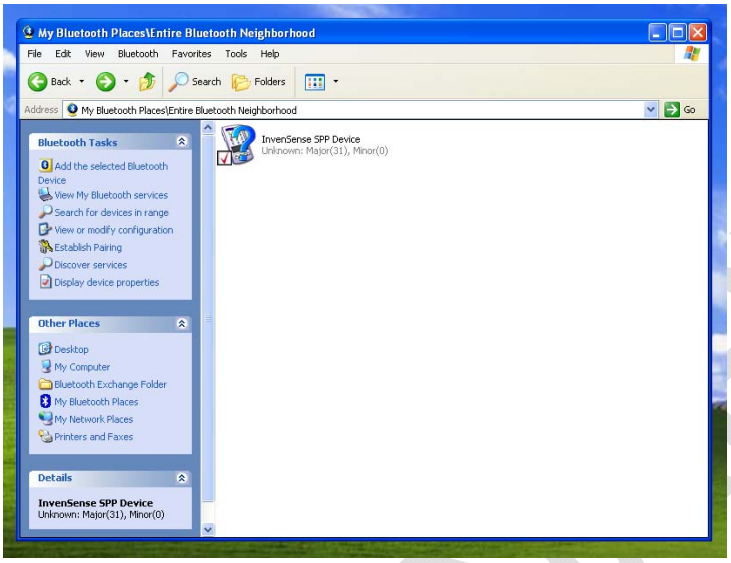

Figure 15: The Invensense SPP Device Icon for Successful Pairing

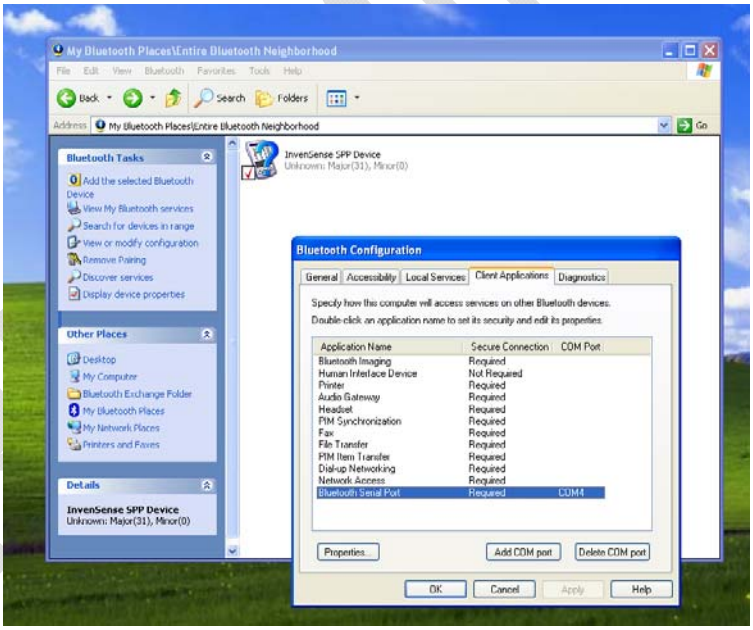

Figure 16: How to Find the Serial Port Number for the Bluetooth Link

Highlight the InvenSense SPP Device, then click the “View or modify configuration” in the upper left menu, the following window will popup, as shown in Figure 16. For our example installation, the serial port for the Bluetooth link is COM port 4.

The baud rate for the serial port needs to be set to 115,200 Baud which is the data-rate coming from the reference design. By default the Bluetooth link is set at this baud rate.

4.3 Gear-Head Bluetooth Adaptor Software Installation

A Bluetooth USB adaptor should be installed on the host PC if there is no built-in Bluetooth support on the host PC. There are many different brands of Bluetooth adapters in the market. In this section, we will use an Gear-Head Bluetooth adaptor installation to a Windows XP PC. Gear-Head uses the Toshiba automated pairing software. Below is the desk-top Icon for Gear-Head.

Figure 17 shows the GUI for the Gear-Head Bluetooth new-device settings window. The ‘device’ refers to the USB dongle. This is the opening window for setting up your connection.

Figure 17: I/O Gear Bluetooth Adaptor Device Driver Installation GUI

To get started, switch the Reference Design mode to 3D Mouse mode. Then, Turn on the power for the reference design kit. Now it will become the target device to pair with. At this time, the RF module LED will blink, which means that the Bluetooth module in the Reference Design is in search mode.

Accept the default settings during the installation procedure. Click the “New Connection” button as shown in Figure 18. Now you will enter the Add a New Connection Wizard.

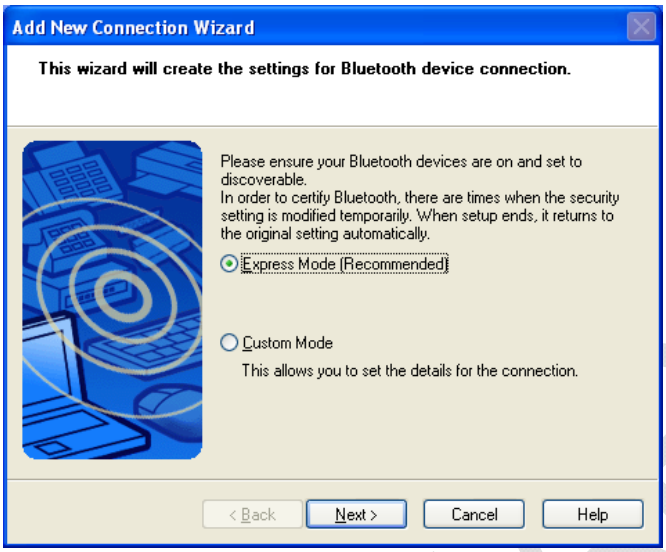

Figure 18: Gear-Head Bluetooth – Add a New Connection Wizard

Make sure the Express option is selected during the installation procedure as shown in Figure 18.

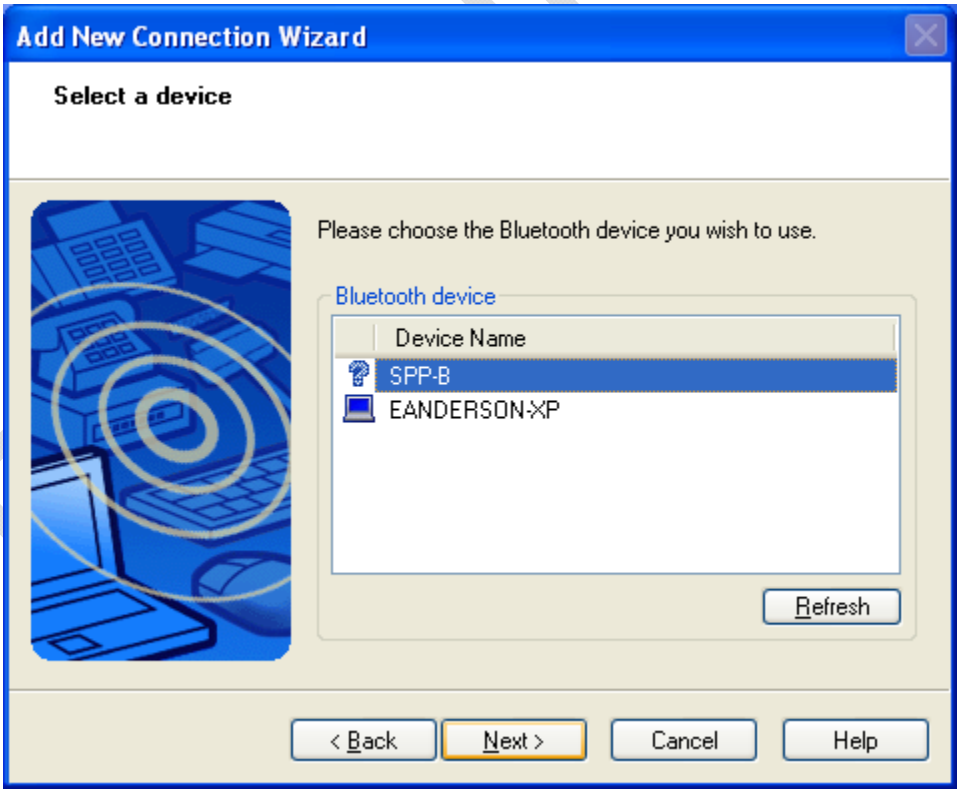

Figure 19: Gear-Head Bluetooth – Add a New Connection Wizard finding new devices

When the Bluetooth installation shows the “Select a device” window as in Figure 19, click “?SPP-B” device. This is the Reference Design Bluetooth that you want to connect (pair) with. Next, the wizard will automatically assign you to a PC COM Port number – in this case COM 40.

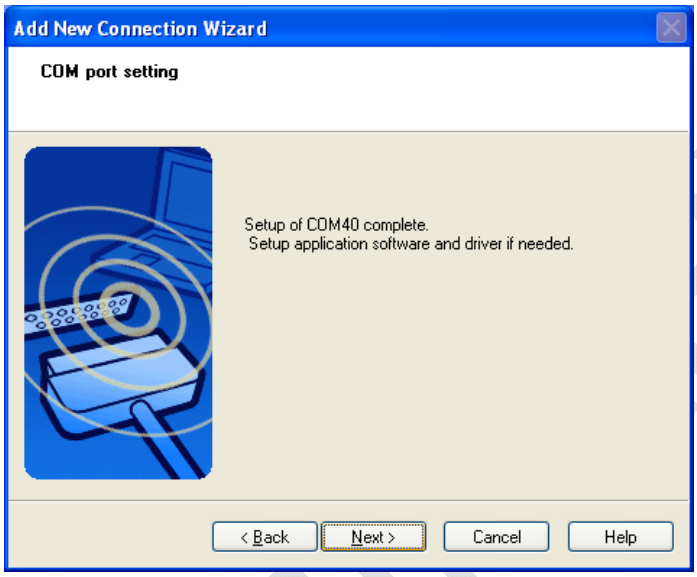

Figure 20: Gear-Head Bluetooth Adaptor Software assigns a COM Port

If not done automatically by the install wizard, you should place a “My Bluetooth Places” icon on your PC desktop for fast access. Also you should place a shortcut to Windows XP Control Panel since you will need to access the device manager, looking at and changing COM port numbers.

4.4 Pairing the Reference Design Kit to Host PC with the Gear-Head Bluetooth

Gear-Head Bluetooth will not pair until the SPP application is enabled. For 3D Mouse mode, you must install, and launch the SIOcontrolHID utility first, and then pair with the Gear-Head Bluetooth dongle.

Refer to Section 5 below, “Setting up the SIOControlHID Utility” chapter. Set its COM Port to the port that the Gear-Head Bluetooth automatically assigned (in this example port 40). Then return to this section.

Place the Reference Design flat on a desk or table to allow initial sensor calibration. On the Windows XP desktop, click the “SIOControlHID” icon, and “Bluetooth Manager – Bluetooth Security” window should pop up. Enter the Reference Design bluetooth Passkey (PIN) 0000 and the connection should pair, as shown in Figure 20.

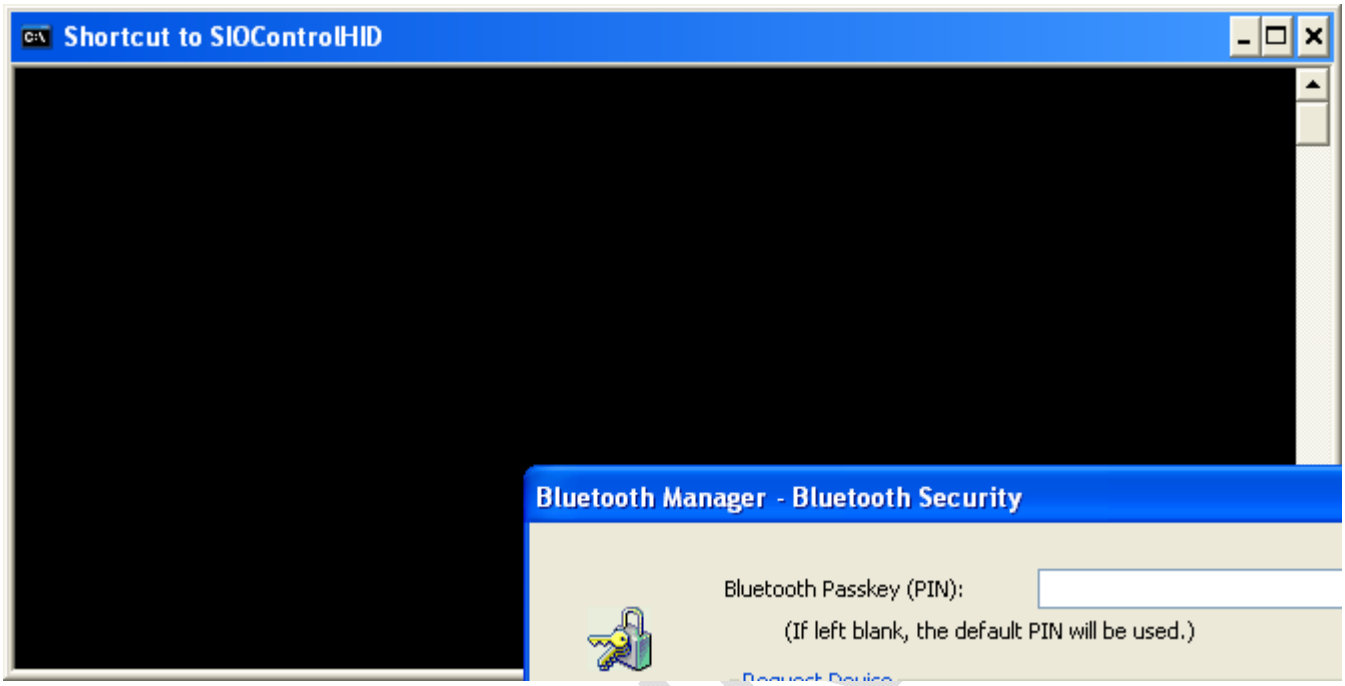

Figure 20: Pair the Device by entering 0000 Passkey (PIN)

Now the Bluetooth Settings window will show the connection paired (green-yellow link), and the SIOcontrolHID will allow the Reference Design to take over the PC mouse cursor.

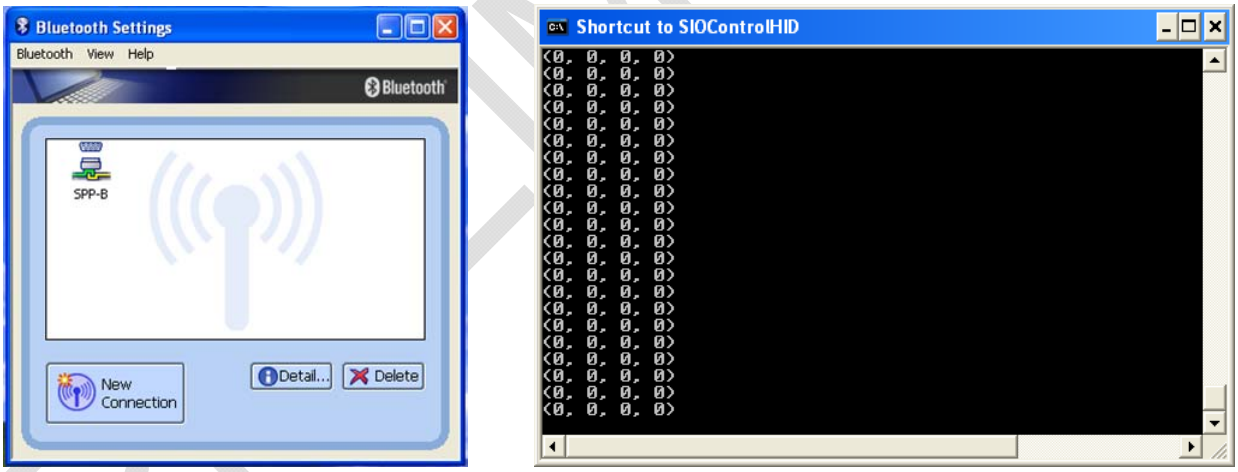

Figure 21: The result of Successful SPP Pairing – a link, and cursor position numbers displayed.

5. PC Software Utilities

This chapter describes the PC utilities required to operate the reference design.

5.1 Datalogger and SIOControlHID Utilities Setup

The reference design includes software that allows the Sensor Board to send raw sensor data to PC applications via a virtual serial port, which can be provided either through SPP Bluetooth or via a USB wired connection. Datalogging is valuable for recording the sensor outputs while designing application software, to know what signal levels to expect.

The two software utilities are DOS Command Prompt programs which can be found in the 9-Axis 8-Bit Reference Design software release package:

1. A data logging program, which is called “Datalogger.exe”. It sets up a log ascii file for raw-data mode.
2. An executable COM port utility, which is called “SIOControlHID.exe”, and is used for air-mouse mode.

The reference design software package has the following file structure:

\9-Axis 8-Bit Reference Design\Bin\COM utility

\Datalog

\ExampleApplication

The Datalogger.exe stays in \Datalog subdirectory and SIOControlHID.exe is in the \COM utility subdirectory.

5.2 Configuring for Raw-Data Mode

The data logger is a DOS utility, which only works in raw-data mode. It receives the raw data from the Sensor Board through virtual serial port. Therefore it has one input argument to specify the serial port number.

A shortcut of this program should be placed on the Windows XP desktop in order to run this application. The COM port number configuration for the shortcut icon is shown in Figure 22. Change the number at the end of the text in the ‘Target’ line entry, to set the COM port number, leaving one space before the number.

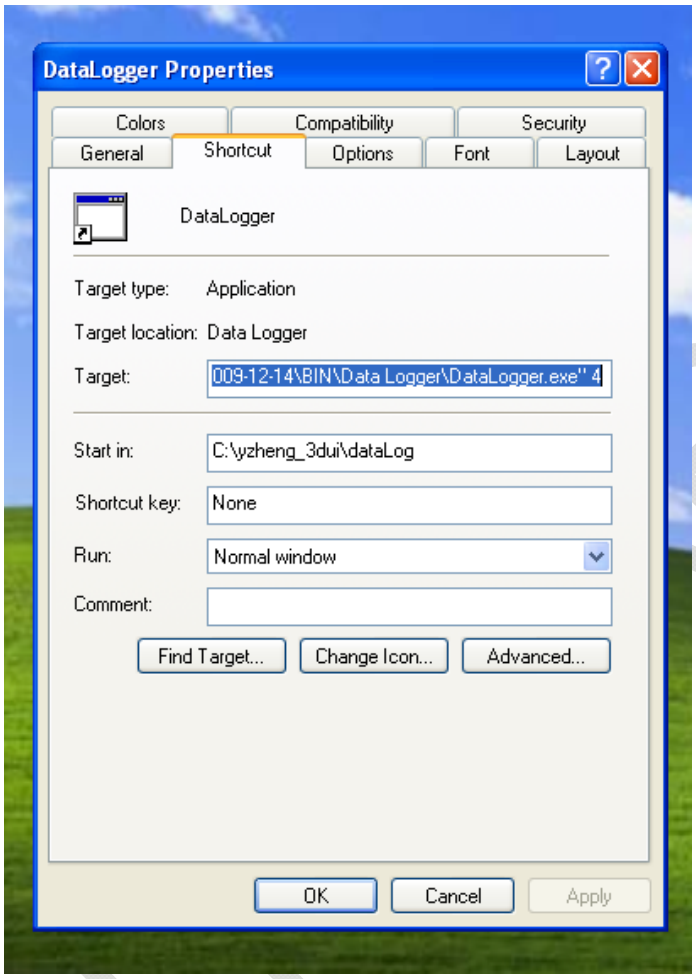

Figure 22: How to Set the Serial Port Configuration for DOS Program

When the program “Datalogger” is running, incoming the data will be dumped into an ascii text file “datalog.txt” in the directory specified in “Start in:” line in Figure 18. In this example we start the datalog.txt file in C\yzheng_3dui\datalog.

5.3 How to Put the Sensor Board into Raw-Data Mode

As covered previously, the reference design outputs sensor raw-data out directly whenever raw-data mode was selected. The data format is listed as follow:

Total 17 bytes:

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

| $ | 2 |G-X-H|G-X-L|G-Y-H|G-Y-L|G-Z-H|G-Z-L|A-X-H|A-X-L|A-Y-H|A-Y-L|A-Z-H|A-Z-L|B1|\n|\r|

To run raw-data mode, follow the steps described in the previous section. The datalog.txt file will capture the data obtained simultaneously. A description of the data contents will be covered in a later section.

5.4 What you Should See in Raw-Data Mode

When the raw-data mode is enabled, the sensor raw data will be transported to the host PC. A datalog.txt file will be generated synchronously to log the data changes, and stored in the folder. The user can use any text editor to view the ASCII based data in this file, which is shown in Figure 23.

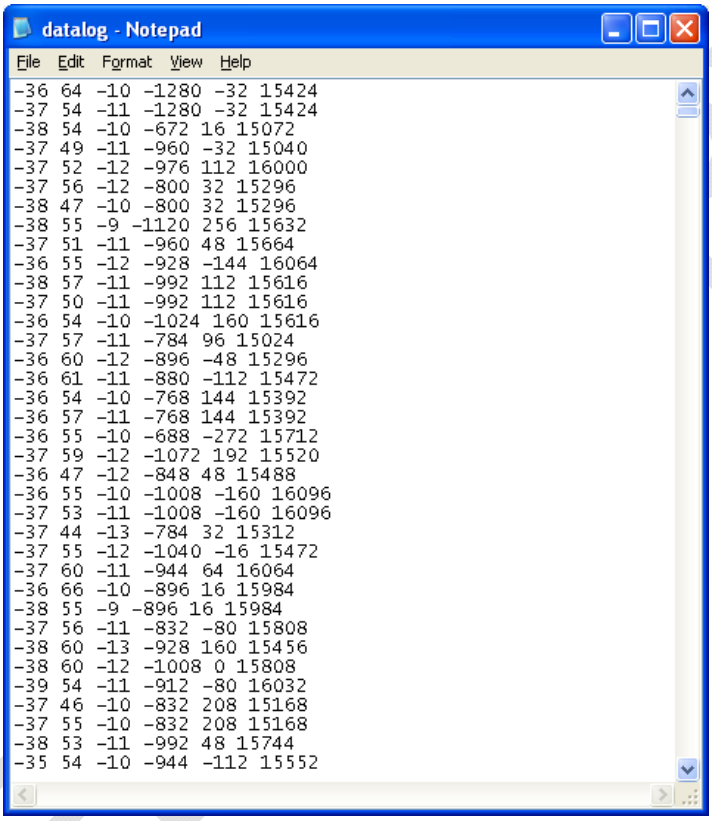

Figure 23: Screen Shot of the datalog.txt File

The data reads in sequence as follows:

X gyro Y gyro Z gyro X accelerometer Y accelerometer Z accelerometer

The accelerometer data is 16 times the correct value because it was left-justified 4 bits to fill the 16-bit word in the sensor sampling software. For example, the data taken in Figure 20 has average Z accelerometer level of 15,800. When divided by 16, this becomes approximately 1000. The 12-bit accelerometer scale is 1mg/LSB (ADC counts in least significant bits, or LSBs) so this data was taken with the Z axis at 1g force. Therefore we measure that the Sensor Board was laying approximately flat on the bench so that Z axis measures gravity.

Note that the datalog.txt will become very large in file size if the DataLogger.exe executed for a long time (several MB over a few minutes).

5.5 Analyzing Sensor Data Captured in the Datalog File

The sensor data showed in the ascii Datalog text file is aligned as:

1. X gyro
2. Y gyro
3. Z gyro

Gyro data is from InvenSense ITG3200 3-axis digital gyroscope

1. X accelerometer
2. Y accelerometer
3. Z accelerometer

Accelerometer data is from the Kionix KXTF9 3-axis digital accelerometer. The accelerometer data is 16 times the correct value because it was left-justified 4 bits to fill the 16 bit word in the sensor sampling software

These data can be used to develop motion processing algorithms and applications. For example, by importing these numbers into Excel, advanced users can plot out the distribution diagrams for analysis of motion processing, as shown in the Figure 24 below.

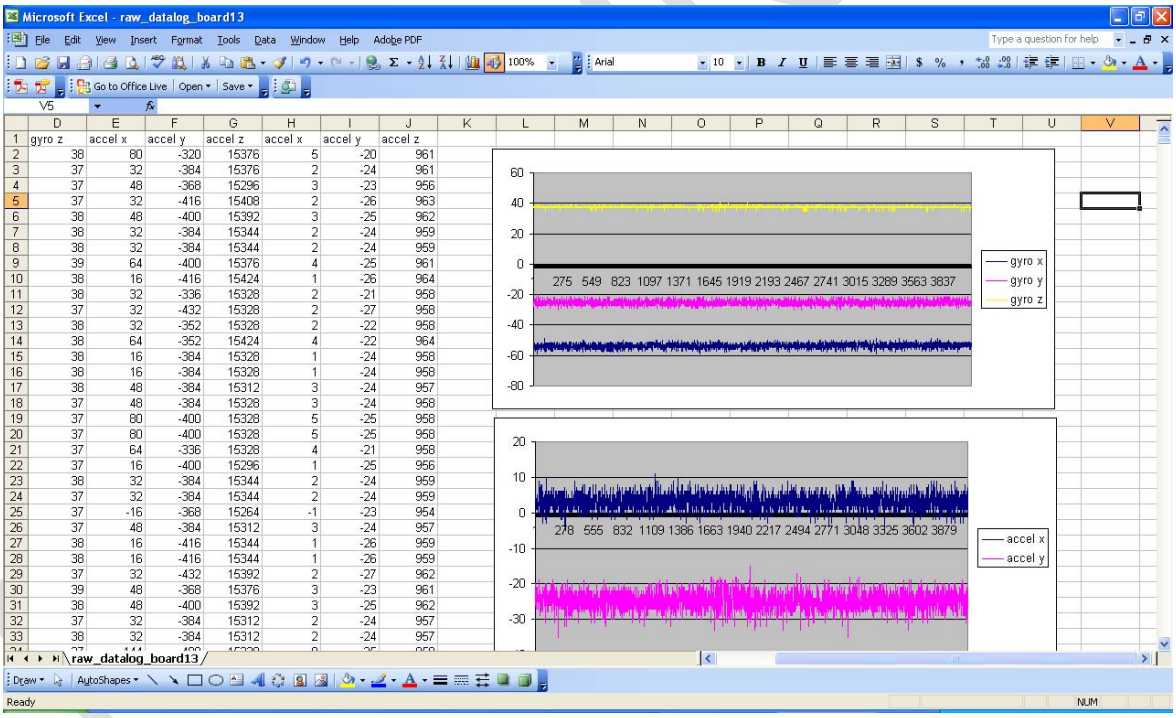

Figure 24. A Screen Shot of Data Analysis Diagram in Microsoft Excel 2003

5.6 Setting up the SIOControlHID Utility

SIOControlHID is a Windows DOS utility which calls up the DOS Command Prompt screen when executed. A ‘shortcut’ should be created on the Windows XP desktop and its properties modified to include the COM

port number that the reference design's SPP Bluetooth device will communicate on. Figure 25 shows the Windows COM port number has been set to 4 in this example, by editing the last number on the 'Target:' line entry.

Once the COM port number is set up, run the DOS command "SIOControlHID" by clicking the desktop icon. The DOS window will show either air-mouse data or raw data depending on the software Mode switch setting of the Sensor Board.

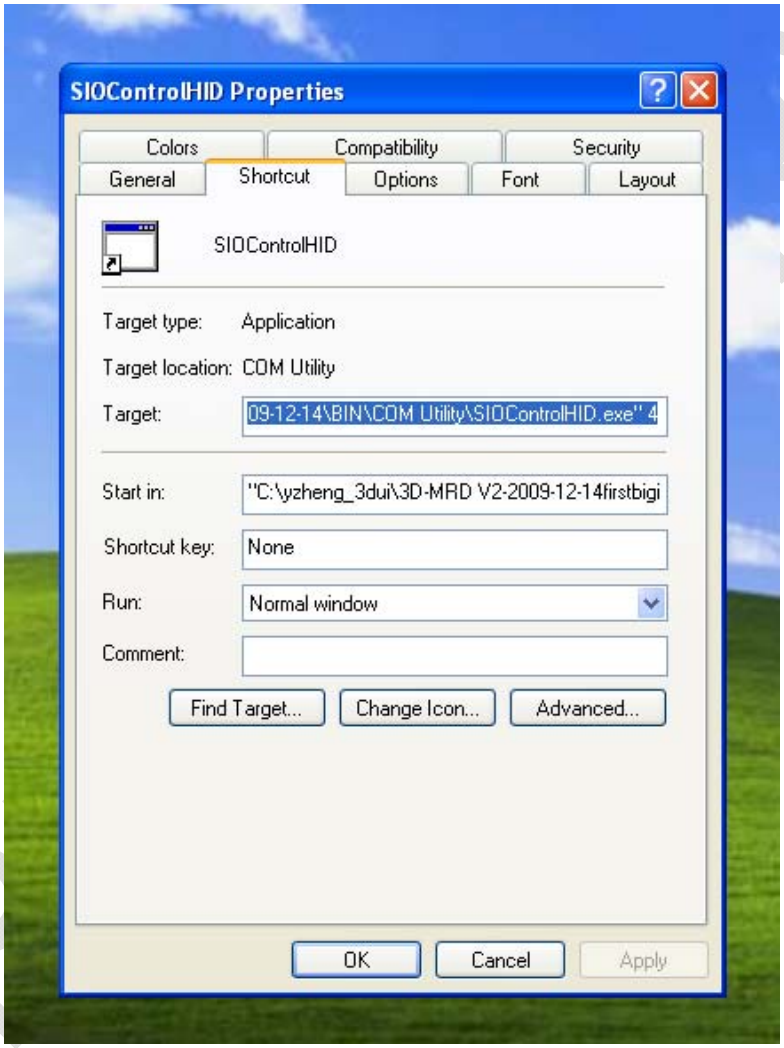

Figure 25. How to Set the Serial Port Configuration for DOS Command Line

5.7 Setting the Sensor Board to Air-Mouse Mode

The Sensor Board should be powered down, mode switch set to Mouse (ie. the switch active pin is left open, not connected to Ground) and then powered up again. In air-mouse software mode, the ATMEL XMEGA MCU processes the motion sensors' raw data, and then outputs a standard Microsoft-mouse formatted data

to the host PC. The mouse data packets include cursor delta x values, cursor delta y values and button status.

5.8 What you Should See in Air-Mouse Mode

The data output format of pointer mode is: delta_X, delta_Y, R_Button, L_Button. After receiving the Bluetooth data from the reference design, the SIOControlHID utility will convert it to mouse-cursor movement data. as you can see in Figure 26below.

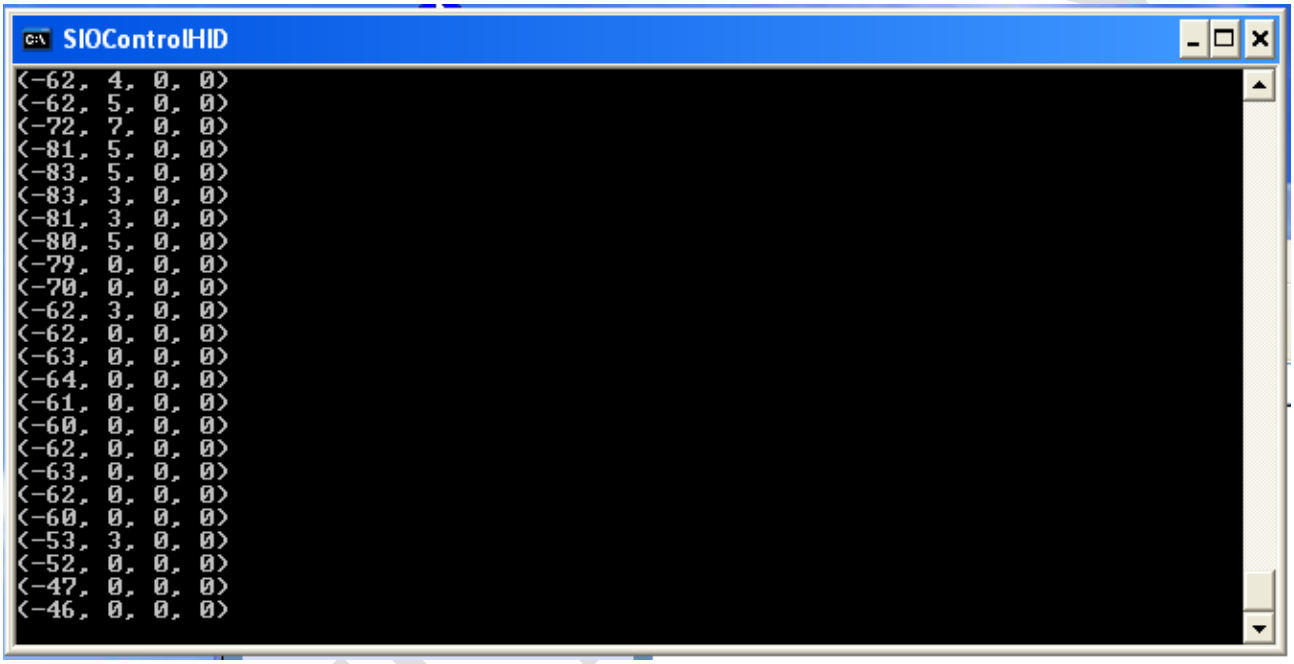

Figure 26. SIOControlHID Utility Window Showing Mouse Cursor Data-Stream

6. FAQ for Bluetooth and USB Connections

The Bluetooth SPP and the USB connections may cause some confusion. Below we list a few Frequently Asked Questions and how to resolve them.

1. The Bluetooth cannot “pair” even after re-installing the device, powering down, rebooting the PC etc.
   a. Check “Device Manager” and delete all Bluetooth COM devices in system registry. This action will require you to reboot the PC.
   b. Enable the Bluetooth driver after rebooting and check its configurations, to make sure all the drivers were renewed.
   c. Repeat the “pair” steps.

2. The Bluetooth can “pair” but shows “unknown service” after double clicks
   a. Check “Device Manager” and delete un-used Bluetooth COM ports in system registry.
   b. Check the Bluetooth configurations and add new Bluetooth COM ports. (Normally, the PC Bluetooth device will display two COM ports, one is for security link and the other one is non-secured.)

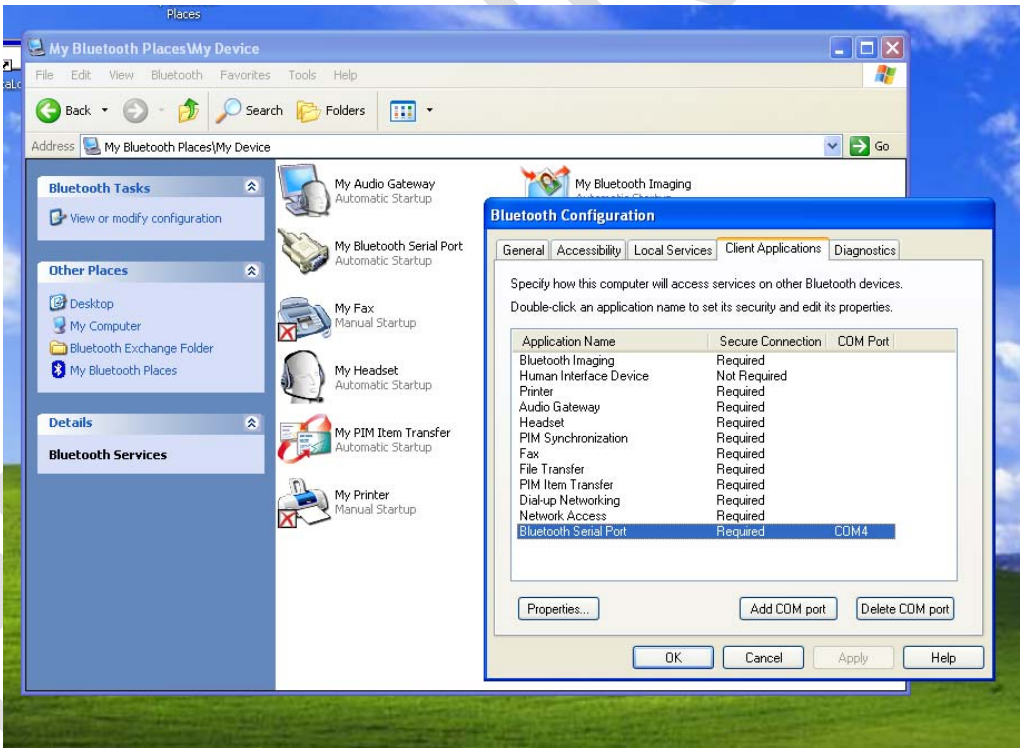

Figure 27: Bluetooth Configuration Menu

   c. Double click the Bluetooth device icon and check if serial port service is available.

3. I want to use USB wired link instead of Bluetooth RF

The USB/Power Board provides a serial port to the Sensor Board, and can be used in place of the Bluetooth RF link for the reference design to communicate with a PC.

a. Go to the internet and download the Prolific USB driver for the PL2302 IC. It is called PL2303_Prolific_DriverInstaller_v110.zip and is located on Prolific's website. http://www.prolific.com.tw/eng/downloads.asp?ID=31

b. Install the driver and plug-in the USB cable. Check "Device Manager" and find the COM port number.

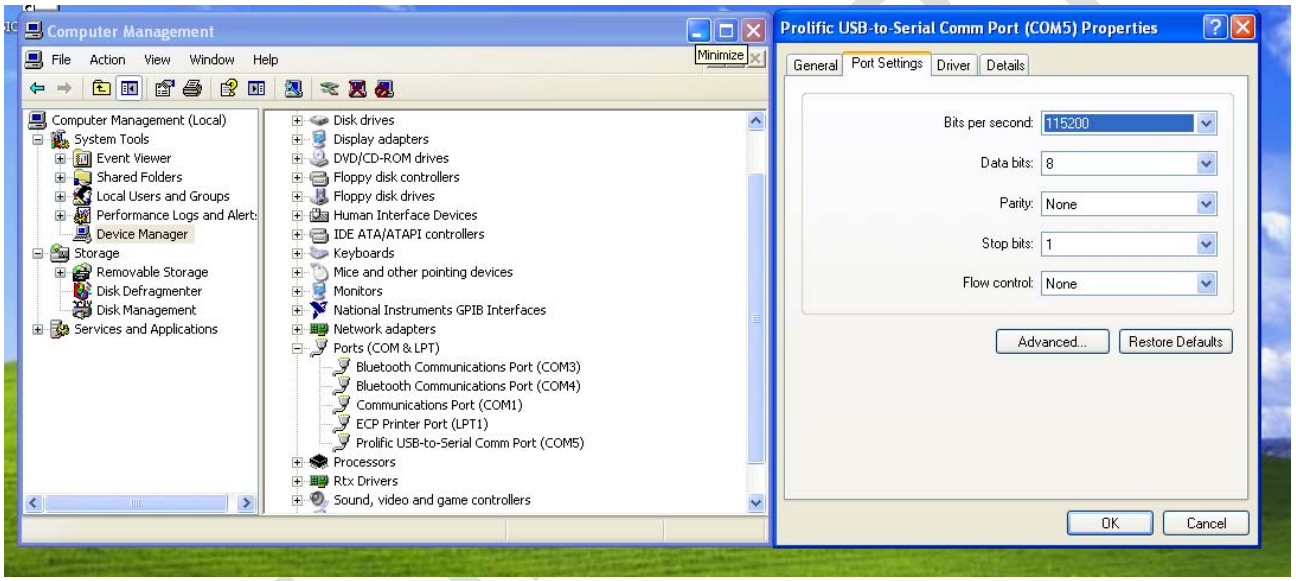

Figure 28: Prolific USB to Serial Configuration Menu

c. Power on the reference design, and run either raw-data or air-mouse software mode.