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February 10th, 2009

Prof. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 305 Functional Specifications for the Nomad Digital Pen

Dear Prof. Leung:

Attached, is a document from TechStyles Inc. describing the functional specifications for the Nomad Digital Pen. TechStyles Incorporation is in the process of design, implementation and calibration of a proof of concept regarding a digital pen that can sense the movements of tip of the pen as per user's hand motion and then store the information on a built-in memory hence providing a stand-alone paper-less solution.

The functional specifications in the document provide a set of high-level standards and requirements for the Nomad pen's functionality. Consistency is being practiced in all levels of product development from the proof-of-concept to the prototype and then to production level. The technical management along with design engineers will make use of this document in research and development activities.

TechStyles Inc. is comprised of the following students: Zhen Gang Xiao, Simran Sarai, Unnati Sapre and Behzad Jazizadeh. The students are from SFU School of Engineering Science pursuing their studies in Systems and Electronics Engineering options. Please contact us by email at *nomadpen@techstyles.ca* should you have any questions or concerns. Alternatively, you may contact out contact person, Behzad Jazizadeh by phone at (604) 518-9152.

Yours Sincerely,

Behzad Jazizadeh
Chief Executive Officer
TechStyles Inc.

Enclosure: Functional Specifications for the Nomad Digital Pen

Executive Summary

The Nomad Digital Pen is proposed to be able to write on virtually any surface with any slope and then store the information in a memory that is built-in. The Nomad Digital Pen has great social and educational benefits. Furthermore this pen eliminates the need for paper of any type, hence virtually eliminates a great portion of paper sheets needed to be manufactured. It is, as a result, a benefit to the society when it just has a fixed cost of purchase and takes off the continuous cost of purchasing paper sheets over its life time. On the other hand knowing the fact that competitive similar products are already in the market mainly targeted to students of any educational level, this pen brings the same writing functionalities with the advantages of being stand-alone, capable of storing data in its built-in memory, being paper-less and over-all being an on-the-go pen.

The design, development and implementation steps of the Nomad Pen proof of concept are going to occur in two phases, in parallel, namely: the hardware requirements and the software requirements. Upon completion of these two phases:

On the hardware part, the following are to be met:

- Capturing the raw data from the sensors
- Analog to digital conversion and data sampling
- Double integration on the raw data to extract the position information from the acceleration data
- Data storage in the built-in memory
- Data transmission capability from the pen to the computer

Further, on the software part, the following requirements are to meet:

- Interpretation of data into corresponding on/off pixels as the tip of the pen moves
- Design and development of a basic Graphical User Interface with a display window and a basic menu.
- Ability of the software application to perform real time data transmission and data display on the screen.

Both phases of the four-month development cycle of this proof of concept are targeted for completion on April 30th 2009. In the case that time and money permits, TechStyles will include indicators for the various operational aspects of the pen. By the end of this development phase, the team shall be able to start for the design of a working prototype, shall prepare a user manual for the targeted prototype. Furthermore, TechStyles Inc. will assure to fully conform to all pertinent standards and guidelines, including those of the CSA, IEC and ISO.

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TechStyles Incorporated

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Glossary

CSA	Canadian Standards Association
ISO	International Organization for Standards
UART	Universal Asynchronous Receiver/Transmitter
LED	Light Emitting Diode
GUI	Graphical User Interface
DC	Direct Current
USB	Universal Serial Bus
RoHS	Restriction of Hazardous Substances
IEC	International Electrotechnical Committee
LCD	Liquid Crystal Display
MCU	Micro Controller Unit
PDIP	Plastic Dual In-line Package
SOIC	Small-Outline Integrated Circuit
SD	Secure Digital
COM	COMmunication port
QA	Quality Assurance
API	Application Peripheral Interface

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1. Introduction

The Nomad Digital Pen is a paper less stand alone solution for capturing data while writing and/or drawing that will have the capability of working on any surface with any slope. The comfort and ease of use that this pen brings to its users would be distinct aspects of this pen which are not found in any other alternatives in the market. Data capturing is done by sensing the position of the tip of the pen as its moves, and then translating the raw data into useful information for the graphical application use. This smart pen also provides a built-in storage for data such that the user can reliably keep the captured data for later upload. The functional requirements for the Nomad Digital Pen, as proposed by TechStyles Inc., are described and discussed in this document for functional specifications.

1.1 Scope

The document that follows describes the functional requirements that must be met by a functioning Nomad Digital Pen. The different sets of requirements fully describe the proof-of concept device and partially describe the fully implemented prototype. The same set of listed requirements will be able to guide the design of the Nomad Digital Pen through the production stage and later will be traceable in future design documents and possible upgrades.

1.2 Intended Audience

The functional specifications document is intended for use by all members of TechStyles Inc. The operations officer and their team shall refer to the functional requirements as a concrete measure of progress throughout the different phases of design, implementation and development. Hardware designers as well as software developers shall refer to the requirements as an overall design reference to be continuously remembered from product design through the implementation. Validation engineers shall use this document to assist them in verifying the similarities of functional aspects in the actual system with the functionalities to be met according to the document. Finally, Ergonomists shall be able to use the functional specifications document to verify the usability of the product and to design user test outlines.

1.3 Classification

Throughout this document, the following convention shall be used to denote the functional requirements:

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[Rn-p] **<“**A functional requirement”>

The above mentioned form of representation is compatible to CSA requirements for referencing.
In which **n** is the functional requirement reference number and **p** is the priority of the functional requirement as denoted by one of following three values: **I**, **II** or **III** corresponding to the following implementation stages:

I. The requirement applies ***only*** to the stage of proof-of-concept.
II. The requirement applies to both of the stages: the proof-of-concept and the final prototype.
III. The requirement applies ***only*** to the final production system.

2 System Requirements

General requirements applicable to the Nomad Digital Pen as a complete system are presented in this section.

2.1 System Overview

The Nomad Digital Pen is a system that can be modeled at a (functionally) high-level as shown in Figure-1 below.

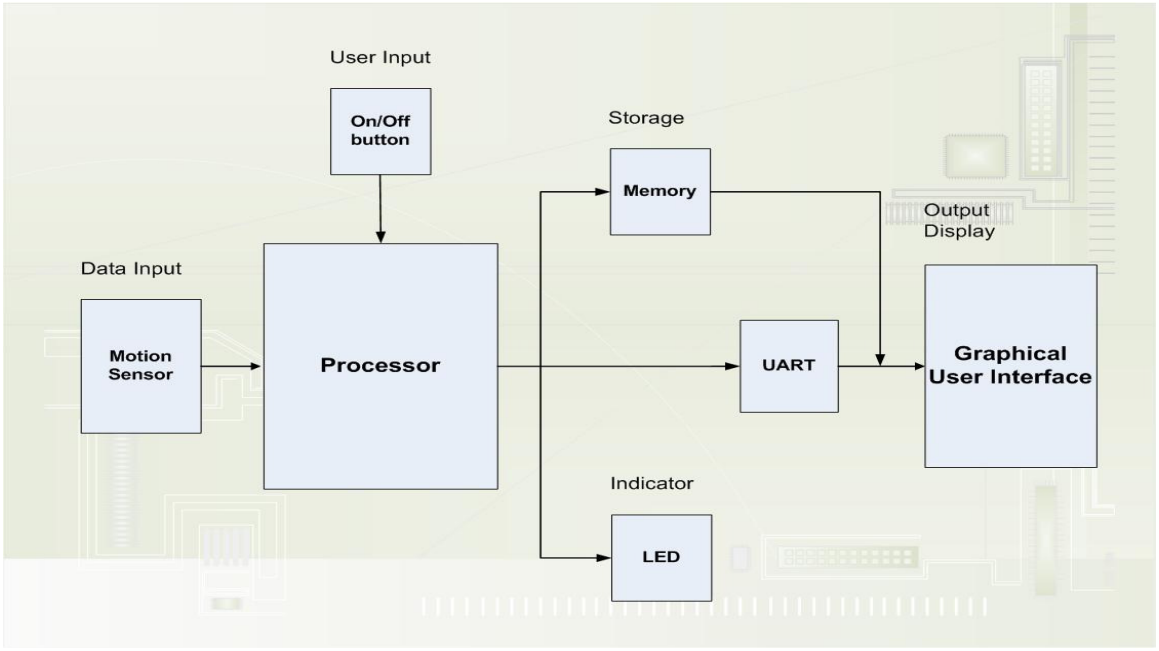

Figure-1: High-Level Functional Block Diagram

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Due to time and budget constraints in the proof-of-concept stage of development, only selected functionality aspects of the Nomad Pen will be designed and implemented. The proof of concept compensates for more fundamental aspects of data capturing, interpretation and information extraction for the hardware phase and graphical display and real time data transfer for the software phase.

The pen is turned on by the user by pushing the On/Off button located on the pen close to the tip. While writing on a surface, the analog raw data will be captured by the three axis accelerometer and the three axis gyro-meter (three single-axis gyroscopes). The accelerometer is the motion sensor for translational movements along the X, Y and Z-axis. The gyro-meters compensate for the rotational (angular) movements about the X, Y and Z-axis. Attempt is made to locate the sensors as close to the tip of the pen as possible within the mechanical constraints. This will guarantee sufficiently small reading errors by the sensors to compensate for the movement of the tip and not other points on the pen. The analog data is then sent to the processor where the conversion is first made to change the analog data to the digital form. The conversion is being done continuously over the course of an on/off session. The digital data is stored, in small blocks, in a buffer in the processor and from there is transmitted out to other units.

From the processor there are both control lines and data lines going out to all units on the board. One set of the control lines are input to the LED indicator. The indicator gives visual illustration about the status of the pen at any given time according to the following scheme:

- Steady Red: *Battery Low*
- Flashing Red: *Charging*
- Steady Green: *ON / Charged*
- Flashing Green: *Normal Operation*

Another set of control lines set the control inputs to the storage unit (memory). At the same time the data lines start transferring data from the buffer inside the processor to the memory unit. This also happens continuously over the course of a session. Data is sent to memory in blocks as large as the buffer capacity.

The data also is transferred to the Universal Asynchronous Receiver/Transmitter and from the UART buffer to the computer (display application). There the user can see the real time display of data on the screen via the graphical user interface. Also, ergonomically speaking, the data display in real time would be the most effective way of giving user the feedback for what they are writing/drawing. Figure-2 on the next page illustrates a schematic draft of the Nomad Digital Pen from a user's perspective.

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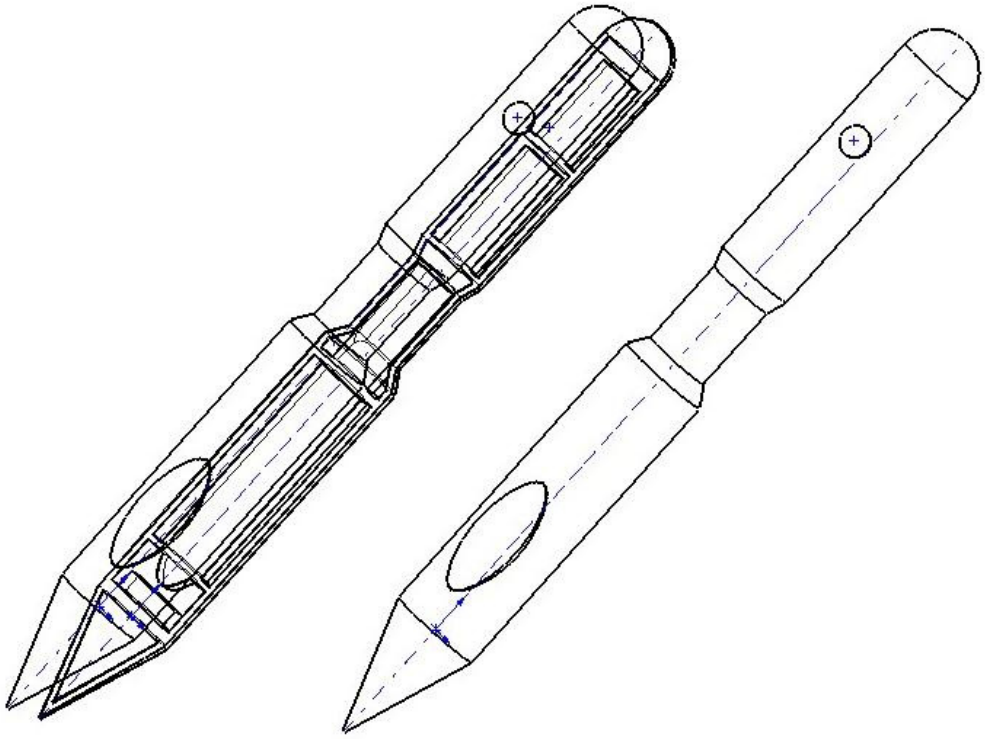

Figure-2, design schematic for the Nomad Pen from a user's perspective

2.2 General Requirements

[R1-II] The Nomad Pen shall have an idle state in which there is no capture of data and no data display. This idle state shall be considered for the pen when it is in off state.
[R2-II] Sensors and actuators shall be minimally intrusive to the user.
[R3-III] The suggested retail price of the Nomad Pen shall be under CDN$200.

2.3 Physical Requirements

[R4-III] The length of the Nomad Pen when the cap is on shall not exceed 250 mm.
[R5-III] The inner diameter of the pen varies, going from the tip of the pen to the tail. The minimum inner diameter shall be no smaller than 10 mm and the maximum inner diameter shall be no larger than 14 mm.
[R6-III] The Nomad Pen shall be appearing similar to a regular executive pen.
[R7-III] The inner diameter of the pen at the tip is 2 mm.

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2.4 Electrical Requirements

[R8-II] The internal/external power supply shall be sufficient to support the simultaneous operation and interaction of the entire internal circuitry.
[R9-I] The internal/external power supplied to the circuitry shall be no more than 5.0 V of DC (Direct Current) power.
[R10-I] External power supplied to the circuit shall be from the special-purpose programmer which in turn adapts the output power of the computer.
[R11-III] Internal power supplied to the circuit shall be from the coin batteries connected together in series.
[R12-III] Batteries along with the power consumption of the circuit shall be designed so that the pen can operate for at least 4 hours.
[R13-III] Coin batteries shall be replaced at the end of their useful life, with new batteries. Rechargeable batteries shall not be used for this purpose.
[R14-III] The Nomad Pen shall enter the stand-by mode for the purpose of energy conservation after 10 minutes of being idle (inactive).
[R15-II] Key voltage nodes and main current traces shall be easily accessible on the board for measurement purposes, troubleshooting, and debugging.
[R16-III] The pen shall be able to be recharged thought an external power adaptor
[R17-III] The pen shall be able to be recharged through the USB cable for the luxury version.
[R18-III] The rechargeable battery shall be operational for at least 5 years before requiring replacement.

2.5 Mechanical Requirements

[R20-III] The mechanical components of the Nomad Pen shall not be visually or physically obtrusive.
[R21-III] The cap of the pen shall be able to attach easily and tightly.
[R22-III] The pen shall use standard mini USB-B connector
[R23-III] The ink chamber shall be air tight.

2.6 Environmental Requirements

[R22-II] The Nomad Pen shall operate normally within an elevation range of 2000 m above the sea level.
[R23-II] The Nomad Pen shall operate normally under typical room temperature range of 0°C to 50°C[1].

[1] This range is the result of an overlap of all core components of the Digital Pen. Further info is available at [1], [2] and [3].

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[R24-II] The Nomad Pen shall operate normally under typical room humidity conditions of about 50%.
[R25-II] The Nomad Pen is ideal and practical for use in indoors and outdoors.
[R26-II] The Nomad Pen shall be silent when it is inactive (off state).
[R27-II] Noise generated during periods of activity (on state) shall be minimized.
[R28-III] Noise generated during periods of activity shall be below 50 dB.

2.7 Standards

[R43-III] The Nomad Pen shall conform to RoHS (Restriction of Hazardous Substances) directive 2002/95/EC with exemption to batteries.
[R43-III] The Nomad Pen shall conform to CAN/CSA-ISO 9241-9-00 (R2005) [7].
[R43-III] The Nomad Pen shall conform to CAN/CSA-ISO 9241-8-00 (R2005) [6].
[R43-III] The Nomad Pen shall conform to ISO 14915-1:2002 [5].
[R43-III] The Nomad Pen shall conform to IEC 60194 Ed. 5.0 [4].

2.8 Reliability and Durability

[R33-III] The Nomad Pen shall be able to withstand rough handling.
[R37-III] The Nomad Pen shall be able to remain on for 8 hours when running on the portable battery inclusive in the pen.
[R36-III] The Nomad Pen shall be resistant to electronic damage caused by spills on the Nomad Pen.
[R36-III] The Nomad Pen shall be able to operate in rain and snow conditions.
[R35-III] The Nomad Pen shall be serviceable by trained technicians.
[R34-III] The user interface shall be able to recover documents under unexpected system failure.
[R34-III] The user interface software shall be able to auto save drafts every 3 minutes.
[R34-III] The Nomad Pen rechargeable battery shall have a useful life expectancy of 60,000 recharging counts.

2.9 Safety Requirements

[R43-II] The Nomad Pen shall not cause fire hazard in case of malfunction.
[R42-II] The Nomad Pen shall not cause bodily harm to the user while it is operating.
[R42-III] The Nomad Pen battery leaks shall halt the functionality of the pen.
[R42-III] The Nomad Pen shall contain power overload circuitry and prevent electric shock.
[R45-III] The electronic components and power connections shall be placed inside an enclosure.

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2.10 Performance Requirements

[R49-III] The manual On/Off (by pressing the push button) on Nomad Pen shall respond to the user instantaneously.
[R50-II] The indicator LED on the Nomad Pen shall instantaneously reflect the internal operation status of the pen upon being active (On state).
[R51-II] The user shall be able to see the feedback from the drawing on the Graphical User Interface screen in real time.
[R53-III] Data Storage unit shall be accessible by the microcontroller or other memory reading devices at all times.
[R54-II] Size of Data Storage unit shall be sufficient for at least 8 hours of normal operation.

2.11 Usability Requirements

[R55-III] The gripping diameter and the length of the Nomad Pen shall not affect the comfort of the hand.
[R56-III] The Nomad Pen shall not exceed 200g in order to be light enough for the user to write with it for extended period of time.
[R57-III] The Nomad Pen shall have the placement of the switch at a handy location for the user to easily turn it on/off.
[R58-III] The Nomad Pen shall have clear and proper labeling.
[R59-III] The Nomad Pen shall have an indicator to indicate the current status of the pen

2.12 Advanced Functions and Upgrades

[R60-III] Bluetooth transmitter module shall be implemented as an advanced feature
[R61-III] An LCD display shall be included in the pen.
[R62-III] The software shall include handwriting recognition feature.
[R63-III] The Nomad Pen shall include solar energy as an alternative power supply.
[R64-III] The Nomad Pen shall include biometric locking mechanism.
[R65-III] The Nomad Pen shall have different ink cartridges.

3. Motion Sensor Requirements

The motion sensor comprises of one 3-D accelerometer and three 1-D gyro-meters. The accelerometer is responsible for capturing translational acceleration and gyro-meters are responsible for capturing angular velocity. The position information is generated based on the raw acceleration data

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3.1. General Requirements

[R66-II] The accelerometer shall be sufficiently sensitive to record the acceleration for hand-writing movements.
[R67-II] The accelerometer shall be able to detect translational acceleration within the range from -2g to +2g.
[R68-II] The gyro-meter shall be able to detect angular velocity within the range from -100deg/s to +100deg/s.
[R69-II] The motion sensor shall output signal in the form of analog or digital.
[R70-II] The total power consumption by the motion sensors shall be no more than 50 mW.

3.2. Physical Requirements

[R71-III] The dimensions of each of the motion sensors shall be no greater than $(5x5x3)\,mm^3$.
[R72-III] The total weight for the motion sensors shall have negligible effect on the operation of the pen.

4. Microcontroller

Microcontroller (MCU) is the brain of the Digital Pen. It is responsible for establishing and maintaining the communication between the processor and different sensor components, such as accelerometer and gyro-meters. The controller also should be able to interface the memory unit and data transfer module.

4.1. General requirement

[R73-II] MCU shall have sufficient programming memory to support all the required operation
[R74-II] MCU shall support the following communication protocols: SPI, I2C and UART
[R75-III] MCU shall contain at least 2 I/O pins for general purpose
[R76-III] The power consumption for MCU shall be no more than $1\,\mu$W in standby mode.
[R77-II] The power consumption for MCU shall be no more than 1 W in normal operation mode.
[R78-II] MCU shall contain at least one internal oscillator.

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4.2. Physical requirement

[R79-III] MCU shall fit into the pen. The dimensions for the MCU shall be no larger than $(8x4)\,mm^2$.
[R80-I] The chip on board for MCU shall use the 40-Lead PDIP packaging [MCU reference].
[R81-III] The chip on board for MCU shall use the 28-Lead SOIC packaging [MCU reference].

5. Memory

This pen will employ a modular storage unit to store the output data of the sensors. The ideal solution would be a standard Micro-SD memory chip, because of its popularity and large data storage capacity. Memory unit provides for the stand-alone solution

5.1. General requirement

[R82-III] Storage unit shall be accessible by the microcontroller or other memory reading device.
[R83-II] The size of the memory unit shall depend on the time for operation.
[R84-II] Storage capacity shall be sufficient for at least 8 hours of normal operation.
[R85-III] The Storage unit shall be removable from the pen
[R86-II] The memory unit shall have a power consumption range from 3.3 mW to 6.6 mW.

5.2. Physical requirement

[R87-III] The memory chip shall have the dimensions no greater than $(16x12x2)\,mm^3$.

6. Data transfer module

To transfer data to a computer, a data transfer module is required. In the prove-of-concept stage, a serial data transfer module could be used; and for final product development, USB and/or Bluetooth data transfer module could be implemented.

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6.1. General requirement

[R88-I] Serial data transfer module shall operate at a standard baud rate, such as 9600 bits/sec; it will be connected to PC COM port, or a USB-to-Serial adaptor.
[R89-III] The USB data transfer module shall compile the USB 2.0 standard
[R90-III] The USB data transfer module shall operate at a minimum data rate of 8MBytes/sec
[R91-III] The Bluetooth transmitter module shall be no farther than 5 m away from the Bluetooth receiver of a computer.
[R92-III] The data transmission through the Bluetooth connection shall be encrypted to provide maximum security.

6.2. Physical requirement

[R93-III] The data transfer module shall fit inside the pen.
[R94-III] The USB connector shall be firmly connected to the computer USB port.
[R95-I] The Serial connection socket shall be firmly connected to the computer COM port.

7. Battery

Battery is the heart of the pen, which provides energy for the operation. There are many difference types of batteries that could be used, and each has its own special advantages. The Digital Pen will use non-rechargeable batteries; however using rechargeable batteries would be a future feature.

7.1. General requirement

[R96-III] Battery shall be of non-rechargeable type.
[R97-III] Battery shall not contain any harmful material.
[R98-III] Battery shall provide long lasting power; at least for 8 hours for continuous operation.
[R99-III] Must not over heat during normal operation, a cooling component should be placed.

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7.2. Physical requirement

[R100-III] Should only be at most 20% of the pen size.
[R101-III] Minimum weight must not cost discomfort for the user during operation.

8. Cap of the pen

The cap of the pen does not only provide protection for the tip when the pen is not in operation, it also serves as a stylus which allows the user to use the pen with out the ink.

8.1. General requirement

[R102-III] The cap shall be made of strong molding, the same texture as the rest of the pen case.
[R103-III] The cap shall be having a pointer shape, but shall have a smooth head.

8.2. Physical requirement

[R104-III] The cap shall fit in the pen case.

9. User Interface

9.1. Hardware Requirements

A push-button will be used by the user for controlling the pen. The user will get an instant feedback from one bidirectional LED indicator for the push-button.

9.1.1. General Requirements

[R105-III] One push-button shall be designed on the Nomad Digital Pen to enable the. user to switch the pen on/off.
[R106-III] One LED shall be used to indicate the current state of the pen.

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9.1.2. Usability Requirements

[R107-III] The button shall not be too rigid or too sensitive.
[R108-III] The LED shall be visible to the user under normal lighting conditions.
[R109-III] The position of the button shall be such that it will be away from the grip of the hand and not cause any accidental on/off.

9.1.3. Physical Requirements

[R110-III] The button shall not be more than 4mm in diameter.

9.2. Software Requirements

A Graphical User Interface (GUI) will be designed for the Nomad Digital Pen to display the movement of the pen. When the pen is connected to the computer, all its movements will be displayed in the GUI window. The GUI also presents the option of connecting to the desired COM port, saving the session, opening an existing text file and exiting the interface.

9.2.1. General Requirements

[R111-II] The user interface shall get the input from the microcontroller.
[R112-II] The user interface shall display movements of the pen on the screen in real time.
[R113-III] The user interface shall also provide the user the option of importing already saved data from the pen's in-built memory.

9.2.2. Usability Requirements

[R114-II] The user interface shall give the user options like "Save As…" for saving the current session or "Open" for opening previously saved sessions for editing.
[R115-III] The user interface shall be easy to understand and easy to use.

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9.2.3. Physical Requirements

[R116-III] The user interface should show up immediately (without any delay) as soon as the user opens it
[R117-II] The interface should clearly display all the movements of the pen on the screen

10. OS Requirements

[R118-II] The User Interface shall use Microsoft Windows XP/ Windows Vista as the platform.

11. User Documentation

[R119-III] User documentation shall include a website with information about the company and the Nomad Digital Pen including its pricing and a user manual
[R120-III] The user manual shall be written for an audience with minimal knowledge of electrical and technical terms
[R121-III] User documentation shall be provided in English, French and Spanish.

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12. System Test Plan

The test approach adopted for the Nomad Pen shall follow the funnel approach (see figure 1) where each module shall be tested in accordance with functional specifications iteratively during the design process. The individually tested modules shall then be integrated and another testing will be done for verification of the desired specifications. Once all the modules are integrated together, the whole unit shall be tested in adherence to the design and functional specifications. After the system testing, a final QA (quality assurance) shall be performed to verify any faulty device.

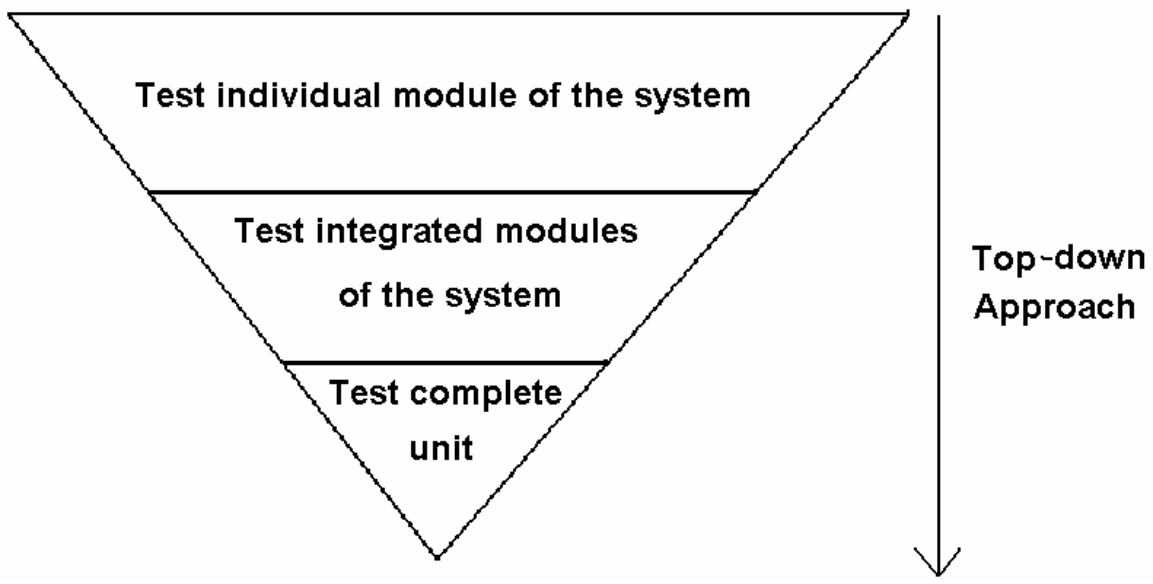

Figure-3, Funnel Approach to system test plan of Nomad Pen

12.1. Test individual modules

The following test plans shall be conducted to verify the design and functional specifications of individual modules

1. Application peripheral interface (API): A test shall be performed to determine the bit error rate introduced in communication channel. Failure to communicate shall be detected.
2. GUI interface: A test shall be performed to verify all the functions of the GUI i.e. save as, exit, connection to the com port, etc.
3. Axis position accuracy testing: A test shall be performed to test the movement of the pen in x-axis, y-axis and z-axis. The accuracy shall be determined by the display of data on the computer screen.

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4. Angular velocity accuracy testing: A test shall be performed to determine any rotational movement of the pen while writing.

12.2. Test integrated modules

The following test plans shall be conducted to verify the design and functional specifications of the integrated modules

1. API and GUI interface: A test shall be performed to verify that the data is received from the pen as well as displayed on the PC screen simultaneously.
2. Axis position and Angular Velocity integration: A test shall be performed to determine that the angular rotation as well as the straight motion of the tip of the pen are computed together to give the final position of the tip of the pen.

12.3. Test complete unit

A set of test plans have been provided below that would verify the overall requirements of the functional specifications of the Nomad Pen:

1. Battery charging time: Record the time it takes to charge a completely discharged battery and test if it was completely charged.
2. Maximum power consumption: The power consumption testing shall be performed based on the three different modes of operation of the Nomad Pen:
    a. Standby mode: This is the mode of least power consumption. Therefore, other than the functionality of this mode, no testing would be performed for power consumption.
    b. Normal mode with real time display: The maximum power consumption shall be tested using this mode. The pen shall be directly connected to the PC while writing.
    c. Normal mode with data storage: The maximum power consumption shall be tested using this mode where data collected by the pen will be directly stored in the memory of the pen.
3. Battery life: A test shall be performed to determine the duration of the battery life before it has to be recharged again.
4. Power switch: A test shall be performed on the functionality of the power on/off switch by turning the switch on and off repeatedly.
5. Delay test: A test shall be performed on the time delay it would take for the data to be displayed on the screen while the pen works in Normal mode with real time.

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12.4. Typical Usage Scenario:

Designed to be used on any surface with any slope, the following typical usage scenario describes the steps that a user would go through to use the Nomad Digital Pen

- The user switches on the power and the session starts
- The user removes the cap of the pen to operate it with ink or leaves the cap on to operate in without ink mode
- The user determines to operate the pen in real time mode or the memory storage mode
  - Real time mode:
    - The user opens the Graphical Interface to capture the writing
    - The user removes the battery lid to activate Bluetooth transmitter
  - Memory storage mode:
    - The user uses the pen as a standalone device without any connection to the computer
    - Later, when the access to the computer is available, the user can upload the data from the pen using Bluetooth or USB.
- To complete the session, the user turns off the power using the switch

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13. Conclusion

The functional specifications described in the preceding document clearly define the functionalities, capabilities and requirements of the Nomad Digital Pen. Design, development and implementation of the final proof of concept will take place in two distinct phases, both of which are proceeded in parallel. The initial-idea model is well on its way to completion and it is confidently expected that all functional requirements outlined above applying to the proof of concept model that are represented by **I** or **II** will be completed by the target date of April 30th 2009.

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14. Citations and References

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