School of Engineering Science
Simon Fraser University
Burnaby, BC

October 14th, 2010

Mr. Mike Sjoerdsma
School of Engineering Science
Simon Fraser University
8888 University Drive, Burnaby, BC
V5A 16S

Re: Proposed Specification of a Music Recognition Device (The Maestro™)

Dear Mr. Sjoerdsma,

Please find enclosed Harmony Innovations' functional specification for a portable sheet music scanner Maestro™. This device will be a prototype for a range of new handheld music recognition technologies.

The purpose of this functional specification is to provide a set of high-level requirements for the system's functionality. This document will be used as a reference for design engineers and a guide for investors.

This document is considered high priority by some of Harmony Innovations' investors and will serve as the basis of the project that they have agreed to fund

Harmony Innovations' is comprised of four students: Nikola Cucuk, Sean Edmond, Veronica Cojocaru and Cristian Panaitiu from SFU Engineering. If you have any questions or comments, please feel free to contact me personally by phone 778-320-5346, or via email at cris.panaitiu@gmail.com

Sincerely,

C. Panaitiu

Cristian Panaitiu
Chief Executive Officer
Harmony Innovations Inc.

Enclosed: Functional Specification for "The Maestro™"

2010

Functional Specification

The Maestro™

Portable Sheet Music Scanner and Player

A project commissioned by Harmony Innovation Inc.

MISSION STATEMENT

At Harmony Innovations, the future is our passion.

By combining musical education with the technological advances of today, Harmony Innovations strives not only to enhance the quality and accessibility of musical education, but also to provide support and technology as a partner to many upcoming musician artists.

Technology has an enormous potential to enhance our lives. This is the guiding principle behind Harmony Innovations' comprehensive approach to musical education.

Date Submitted: October 14th, 2010

Submitted to:
Dr. Andrew Rawicz (ENSC 440)
Michael Sjoerdsma (ENSC 305)

Project Team:
Sean Edmond (301026670)
Nikola Cucuk (301033241)
Cris Panatiu (301032665)
Veronica Cojocaru (301055896)

Executive Summary

Music has always been one of the crown jewels of human achievement. Not just as a form of entertainment, but as a universal language to express deeper meaning that cannot be expressed in any other way.

Harmony Innovations Inc. recognizes the importance of this universal language and strives to create and develop new digital technologies to enhance the process of musical education.

Outlined in this document is the complete functional specification for a music scanning, recognition and playback device. It's intended to help new students with their musical studies by providing a simple example of the musical material. These specifications are divided into categories to specify what stage of development they correspond to. Some specifications that only apply to the proof-of-concept model, whereas others only apply to the finished product. In terms of timeline, the proof-of-concept model will be completed by the end of the year.

Development of the Maestro™ will occur in three phases. Upon completion of all three phases, the portable sheet music scanner will conduct the following processes:

- Acquire sheet music image,
- Process the image (stitch acquired images),
- Perform character recognition,
- Play the music back

Digital electronic solutions for the enhancement of the educational experience can be used by anyone. The guiding principle of Harmony innovations' is based on helping tomorrow's generation better understand and learn music.

Table of Contents

List of Figures

List of Tables

Glossary

MIDI	Musical Instrument Digital Interface. A digital music storage standard, in use across all of the North American music industry.
Standard Music Notation	This term refers to the set of music notation standards published by the Music Publisher's Association of the United States. See reference [1] for details.
Audio Jack	Standardized analog audio technology for use as an audio transmission technology. Low voltage and power consumption.
PCB	Printed Circuit Board. Technology that allows electronic components to be connected on a plastic board. The wires are printed on the board.
RoHS	Reduction of Hazardous Substances. Certification for environmentally friendly electronics manufacturing. RoHS compliant devices are manufactured without lead or mercury.
CSA	Canadian Standards Association. Non-governmental
UL	Underwriter Laboratories. US Standards-setting organization.
TUV	European Standards Organization

1. Introduction

"Music education is the epitaph of human achievement and embodies the desire to understand that which we do not understand through that which we do" – Socrates

Throughout history, humanity has placed enormous value on the creation of music. The ancient Greeks, for example, believed that music is the "subtle, yet complete understanding of human nature and the human existence", devoting much time to the study and composition of music. Like the Greeks, every civilization ancient to contemporary, has devoted enormous energies towards the development of music.

The effort to express through music is by no means exhausted today, especially with the advent of new technologies through which music can be more easily created. Musical education, however, has not benefited sufficiently from the progress made in digital music technologies: most learning is still done through a process of demonstration and practice by a teacher and a student.

While a teacher should not be replaced, students can make their practice more efficient with the help of digital technology. Harmony Innovations is proud to present the Maestro™ - a revolutionary new line of musical education aid.

Maestro™ is a sheet music scanner. It is designed for novice musicians to help them accelerate in their music education. Some musicians learn music better by ear, which is why Maestro™ will bridge the gap between old fashion music learning techniques and novice musicians.

1.1 Scope

The scope of this document is to provide a complete functional specification and unambiguously outline Maestro™'s capabilities and features

These capabilities and features will be divided into three categories as follows

I – Prototype Specification – Features that will only appear during the prototype stage

II – Prototype and Production Specifications – Features that will appear in both prototype and production models

III – Production Specifications – Features that will only appear in production models

With this specification convention, the document provides a list of solutions that the design team needs to create, as well as a list of features that classify the project in relation to other products on the market.

1.2 Intended Audience

This document is intended for engineers and design technicians involved in the Maestro™ project. The functional criteria of this device will be practically implemented by the design team. Project managers and designers should refer to this document during every stage of development to guarantee that the final design meets the predefined function requirements.

1.3 Classification

The numbering convention of this document is as follows:

'R' is an abbreviation for requirement, 'n' is the functional requirement number and 'p' stands for one of the three development phase:

I. Proof-of-concept stage.
II. Ongoing developing stage
III. Final production stage

2 System Requirements

2.1 System Overview

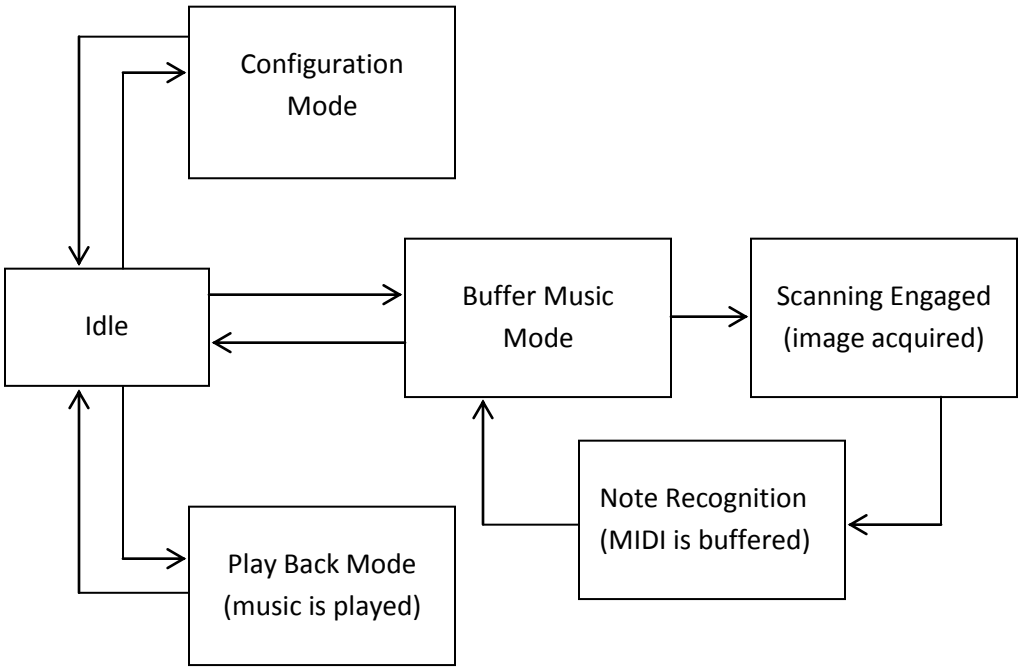


Figure 1 - System Overview

Our proof of concept model will be a fully operational device. Capable of recognizing standard sheet music notation and playing it back with the correct pitch and rhythm. A simple user interface will assist in configuration and operation of the device. The device will employ three distinct modes of operation.

The configuration mode will allow the user to select any key signature, clef, timing scheme (4/4, 3/4, etc), and tempo (the speed at which the music will be played back at).

The user will be able to "buffer" music using the buffer music mode of the device. The user will scan the section of music they'd like to buffer. After each scan, the music will be interpreted and stored in MIDI format. The user can continue to buffer music until they have scanned the section they would like to play back. The playback mode will play the music, with selected configurations, through a standard headphone jack.

Our device will support MIDI as it's the industry standard for representing electronic music and will allow for a seamless integration with MIDI compatible devices for added features or additional products.

The production model of Maestro™ will be a battery operated handheld device that will contain the image acquisition, processing and sound modules in one device. However, our proof of concept model will be considerably more bulky. The image acquisition module will be handheld and will interface with our processing module via jumper cables.

2.2 General Requirement

R1-III The Maestro™ must have a retail price under $100 CDN

R2-II The Maestro™ must be able to scan sheet music and output sound.

R3-III Maestro™ must contain an intuitive user interface

2.3 Physical Requirements

R4-II The Maestro™ must have a rigid case.

R5-II The Maestro™'s weight must not exceed 500g.

R6-III Maestro™ should be less then 25cm long.

R7-III Maestro™ should be less then 15cm wide

R8-II Image scanner part should be no larger than 5 cm.

R9-III Maestro™ should be fully recyclable device.

R10-III Maestro™ should have a good hand grip.

R11-III Maestro™ should have a blue color.

2.4 Electrical Requirements

R12-II There must be a way to power on/off the Maestro™.

R13-II The Maestro™ needs to operate on standard 5 volt continuous current power supply

R14-III The Maestro™ should have a battery pack

R15-III The Maestro™ battery will be rechargeable

R16-III The Maestro™ will have at least 10 hours of battery life with heavy usage

R17-III The Maestro™ will have at least 50 hours of standby/idle battery life

R18-III The Maestro™ will have a dedicated circuit for battery testing and charge cycle optimization

R19-III The Maestro™ will be made of electrically insulated materials so that it can be safe in steamy conditions

R20-III The Maestro™ will be made of high quality conductor material, and manufactured using durable PCB manufacturing technologies

R21-III The Maestro™ will be an energy smart device

R22-III The Maestro™ will contain an indicator for low battery and charging statuses

R23-III The internal electronics of the Maestro™ will be shielded from short circuits due to bumps and drops.

2.5 Mechanical Requirements

R24-II All movable parts must be self-adjusting

R25-I All components shall be easily accessible for adjustment and change

2.6 Environmental Requirements

R26-I Maestro™ shall operate normally under typical household temperatures (15 – 30 degrees C)

R27-II Maestro™ shall operate normally under typical household humidity conditions (50%).

R28-II Noise generated by Maestro™ during periods of scanning and playback shall be minimized and must not prevent the user from hearing the music as it's being played back.

R29-II Maestro™ must be used indoors only.

2.7 Standards

R30-III The Maestro™ shall meet ANSI standards

R31-III The Maestro™ shall meet CSA requirements for electrical devices.

R32-III The electronics of the Maestro™ will be UL compliant

R33-III The electronics of the Maestro™ will be TUV compliant

R34-III Maestro™ will be RoHS certified for green technology

R35-III The Maestro™ will be an environmentally friendly device

R36-III The Maestro™ will be made of biodegradable plastics

R37-III The Maestro™'s PCB will be biodegradable

R38-III The Maestro™ will comply with goodwill agreements regarding user friendliness and child-safe certification

2.8 Reliability and Durability

R39-III The Maestro™ should be able to withstand the physical and electrical stresses when subject to normal operation.

R40-III The Maestro™ must be resistant to breakage when dropped form a height off less than 1m.

R41-III The user interface must maintain its usability and functionality for the lifetime of the product.

R42-III Assuming normal operation, the MTTF (Mean Time To Failure) should be no less than 10000 hours of use.

2.9 Safety Requirements

R43-II Maestro™ must not cause bodily harm to the user while being used.

R44-II Maestro™ must not overheat while in use.

R45-III Maestro™ must have a fail-safe in case of electrical failure.

2.10 Performance Requirements

R46-II During its operation, the Maestro™ must not heat up to a point where it will be uncomfortable to hold (the specific temperature depends on the material chosen for the case).

R47-II The power supply shall be sufficient to support scanning and playing of 50 regular pages.

R48-II Maestro™ should process 25 cm of scanned music in less then four second.

2.11 Usability Requirements

R49-II User will be required to scan music on a horizontal flat surface

R50-II	Sheet music will have to be in good condition with no creases or pencil/pen markings
R51-III	User will be familiar and confortable with user interface after 3 hours of use
R52-II	The Maestro™ must operate as a standalone device, without the need to interface with a computer.
R53-I	Maestro™ must have an interface with a PC in order to change its software.
R54-II	There must be an indication that the Maestro™ is powered on.
R55-III	Maestro™ shall enter a state of energy conservation after 5 minutes of inactivity.
R56-III	Maestro™'s firmware shall be upgradeable by the user.
R57-II	Maestro™ should warn the user if the scanning speed is too fast.
R58-II	Maestro™ should have a display such as LCD screen
R59-II	Maestro™ should have self elimination for scanning
R60-III	Display should light up under dark conditions.
R61-III	Maestro™ should be designed for both left and right handed people

3 Image Acquisition Requirements

Image acquisition block enables Maestro™ to scan sheet music. Once the image is acquired it is sent to the microprocessor for post processing and character recognition. A digital camera would be a good choice for this block.

There are several important design aspects which need to be addressed while designing a scanner. Parameters such as: focal length, frames per second, resolution, window size, field of view and illumination are crucial in acquiring a good quality image.

This camera module will be raised and enclosed in a box, which will hold the camera above the scanning surface. To acquire a focused and a clear image from a distance of 4-8cm the camera has to have its focal length in a clearly defined range. Resolution choice is related to the character recognition. To process a character a 20x20 pixel window is the minimum requirement for one music notation recognition, this is why we have a predefined resolution range for our module. Because the module will be enclosed, a light source will significantly improve the acquired image quality. Furthermore, the interface of the module should be digital for easier integration with the rest of the Maestro™ system. These are just a few design considerations of the image acquisition module.

The functional requirements for the image acquisition block are specified as per following sub-sections:

3.1. General Requirements

R62-II Focal length should be less then f10.0mm & F2.

R63-II Image resolution should be between 640x480 and 320x240.

R64-II The camera should be able to size the window inside the image resolution.

R65-II This module should have a digital interface for easier integration with the microcontroller.

R66-II Image capturing speed should not be less than 30 fps.

R67-II A black and white camera should be used for lower data rates

R68-II A sensor for detecting position velocity and acceleration should be integrated in this camera module. This position data will be useful for knowing the position and the distance between two adjacent images captured.

3.2. Physical Requirements

R69-II The module should be enclosed in a box raised 4-8cm from the surface.

R70-II This box should have its own illumination for better image acquisition.

R71-III The box should have an opening such that the user can see the path he/she is sliding the camera on.

R72-III The image acquisition module which is enclosed in the box should have two lasers for guidance purposed. These lasers will help the user to align the sheet music border lines with the laser for a more accurate scanning.

R73-II Module size less than 50 x 50 mm

5. Requirements for Micro-controller board

The microcontroller will be used for image processing and character recognition. A user will also be able to interface with the microcontroller using action buttons as and the LED display. Once the processing of the scanned sheet music is done the microcontroller will pass a MIDI format file to the sound module and the user will be able to hear the scanned music.

5.1: General Requirements

R74-II The operating voltage for the microcontroller shall not exceed 9 Volts.

R75-II Microcontroller shall not consume more than 20mA in active mode.

R76-II Microcontroller must have at least 20 GPIO I/O channels (or pins).

R77-II Microcontroller must be at least 60MHz.

R78-II Microcontroller must have a USB, SPI, TWI and RS232 interfaces.

R79-II The controller should be able to use internal interrupts to read available sensor data.

R80-II Microcontroller must have large enough serial flash to store the sensor data

5.2: Environmental Requirements

R81-II The controller should be operational in temperatures within the range -10 to 45 degrees Celsius.

R82-II The enclosure of the microcontroller along with other components must be closed.

5.3: Physical Requirements

R83-II The dimensions of the microcontroller shall not exceed 15cm X 15 cm.

R84-II The controller shall not weight more than 200g.

4 Music Specific Requirements

4.1 Supported Key Signatures

R85-II Maestro™ will support all standard music notation written in the keys displayed in Figure 2 (in treble and bass clef)

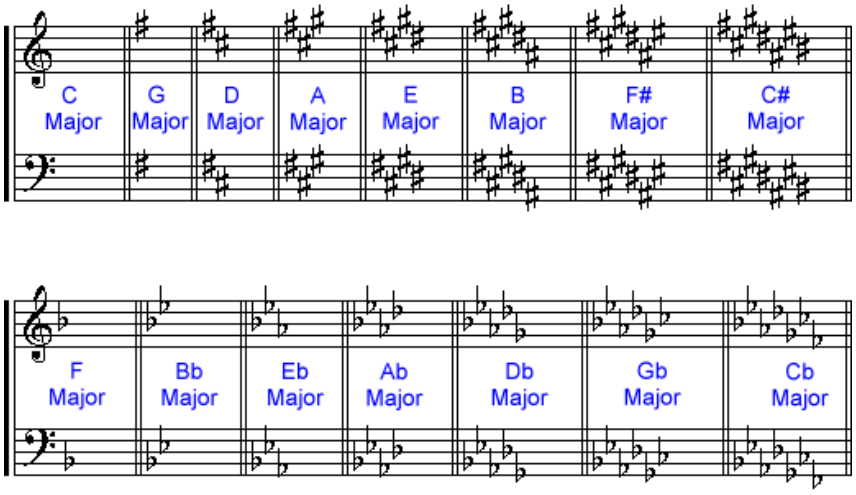


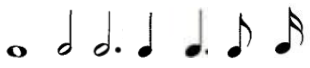
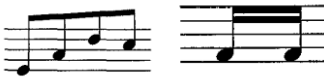
Figure 2 - Required Supported Key Signatures

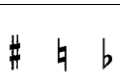
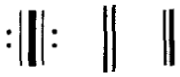
4.2 Supported Music Notation

R86-III Production model will support standard music notation format as prescribed by the Music Publishers Association. See reference [1] for details.

The proof of concept will only support music notation specified in Table 1.

Table 1 - Music Notation Supported by Proof of Concept Software

Stem direction		**R87-II** Single notes below the mid line will have stem to the right of the note in the upward direction. Notes above the midline will contain to the left of the note in the downward direction
Pith Range		**R88-II** Note in the range of E (pictured left) to B (pictured right) will be supported.
Note Durations		**R89-II** Notes of durations of whole, half, dotted half, quarter, dotted quarter, eighth and sixteenth will be supported (displayed from left as listed)
Beams		**R90-II** Beams may connect adjacent notes of the same rhythm in the case of eighth (uses 1 beam) and sixteenth notes (uses two beams).

		We will not support beams connecting together notes with different rhythms.
Accidentals		**R91-II** Accidentals placed to the left of note will change their pitch accordingly
Chords		**R92-II** Only single note at a time operation is supported (no chords)
Rests		**R93-II** Rests of whole note, quarter note and eighth note duration will be ignored
Bowing marks		**R94-II** Bowing marks will not affect music recognition
Slurs		**R95-II** Slurs will not affect music recognition
Beginning of bar notation		**R96-II** Clef, key signature and timing notation will not affect music recognition (these are user inputted parameters)
Bar lines		**R97-II** Repeats, end of section, and end of line indications will not be exercised, but will not inhibit music recognition

All other notation such as dynamics markings, text, trills, etc. will not be supported in the proof of concept design.

4.3 Miscellaneous Music Specific Requirements

R98-II Will only support recognition of published music (no handwritten music)

R99-II Required to be capable of playing tempos between 20 beats per minute (*Larghissimo: very, very slow)* and 200 beats per minute (*Prestissimo: extremely fast*). This will allow the user to speed up or slow down the music within a large selectable range.

R100-II Recognition of notes will occur independent of note spacing, image scale (these are not standard features of music)

5 Sound Requirements

5.1 Sound Quality

R101-II The playback sound quality of the Maestro™ will be comparable to 192 kbps mp3 audio

R102-III The playback of the Maestro™ will be on a high quality speaker

R103-II The Maestro™ playback device will have a wide spectrum

R104-II The Maestro™ playback device will have the capability to play low frequency sounds

R105-II The Maestro™ will have the capability to play drum patterns from its playback device

R106-II The Maestro™ will automatically lower the volume in low battery operation

5.2 Electrical Standards

R107-II The Maestro™ will have a standard audio output jack for playback on large speakers

R108-II The Maestro™'s audio jack will not supply an amplified signal to the audio jack

R110-II The Maestro™ will provide a maximum of 10 mA to the audio jack

R111-III The Maestro™ will not provide playback during low battery conditions

R112-III The Maestro™ will provide a maximum of 10 mA to the embedded speaker

5.3 Standards Used

R113-II The musical image acquired and interpreted to digital form will be stored in MIDI format

R114-III The MIDI controller in the playback device will have different instrument samples for the user to select.

R115-II The user will be allowed to adjust volume on the playback device

R116-II The Maestro™ will be protected from power surges from unprotected speaker amplifiers

R117-II The Maestro™ will be able to send audio output in wave format to speakers through its audio jack

R118-II The Maestro™'s audio jack will be at the base of the case, below where the user's hand will hold the device

6 User Interface Requirements

R119-III The Maestro™ will have a simple to understand user interface

R120-II User interface will provide a mechanism for inputting clef, key signature, and timing

R121-II User interface will provide modes for configuration, scanning and playback

R122-II Visual feedback will inform the user of the device's current state, and assist in configuration selection

R123-II Device can recover from an error condition and will allow for correctable user action.

R124-II User interface will simple enough to learn with the assistance of a user guide

R125-II Buttons shall be placed in convenient locations

7 User Guide Requirements

R126-III User documentation shall include a website with general and technical support information and a user manual, both written in English, French, German and Spanish.

R127-III The user manual shall be written for an audience with minimal knowledge

R128-III The Maestro™ will have a good user support system for end users

8 System Test Plan

The system test plan is separated into specific module test and integrated testing. Module testing will be performed separately before system integration.

8.1 Module Testing

Camera:

- Test image acquisition using quick and slow had movements. Are the images acquired "good quality"
- Is the interface between processor and camera quick enough to acquire the image?

Note Recognition Software:

- Does software recognize all supported features listed in Table 1?
- Are notes recognized independent of scale and note spacing and tilt/skew of acquired image?
- All preliminary software testing will be performed with prototyped code in Matlab

Sound Module

- Does sound module understand our implementation of MIDI format?
- Is the interface between the sound module able keep up with real time requirements for playing music?
- Does the sound module support all pitches and rhythms outlined in Table 1?
- Does the sound module support playing music at tempos listed in RX-99?
- Does the sound module allow for volume control within an acceptable audible range?

8.2 Integrated Testing

Integrated testing will involved 3 components. The first phase of testing will involve using basic music that printed by the test engineers specifically for that purpose. The second phase will involve using real examples of printed sheet music. The third phase of testing will involve stress testing the device to determine its usability limitations.

8.2.1 Basic Standard Music Testing

The following set of tests will be performed on specifically printed music from music notation writing software. These will not include any dynamic markings and will be printed in the chosen size.

Scales tests:
Use the configuration mode to change the key signature for the scale. Use the scan mode to buffer the desired scale. Use play back mode to play the scale back (verifying the pitch of each note). Test major and minor scales in all supported key signatures, and in treble and bass clef, verifying the pitch of each note. This will provide coverage for every possible pitch.

Tempo Test
Set the tempo using the configuration mode. Use the buffer music mode to scan a section of music. While playing the music back with playback mode, verify the tempo using a separate metronome. Test for 20 beats per minute, 200 beats per minutes and a few randomly selected tempos.

Rhythm Test
Test the rhythms mentioned in Table 1 . Also test rests of all rhythms.

Accidentals test
Test flat, sharp and natural accidental markings for each supported note.

8.2.2 Genuine Sheet Music Testing

Samples of genuine sheet music will also be tested, however, extensive testing will have to be done on different samples of printed music ensuring to cover the following test points:
- Size of music (larger or smaller notes)
- Different note spacing
- Different staff line spacing
- Ignore all features mentioned in Table 1 (such as dynamic markings)

8.2.3 Device Usage Stress Testing

All tests mention previously will be performed using careful reliable scanning by the user. However, we will also have to stress test our device by testing:

- minimum and maximum rate of scanning (at constant rate)
- Non-constant rate of scanning
- Constant camera rotation (rotation is with respect to the page)
- Changing camera rotation
- Varying lighting conditions
- Creased/crumpled pages
- Bumpy surface

9 Conclusion

Harmony Innovation Inc. is on a mission to provide an easy-to-use solution to help student musicians learn by converting sheet music to audio. Our device, the Maestro™ is the first-of-its-kind portable sheet music scanner and player. The functional specification unambiguously outlines the features of the Maestro™ and its incorporated technologies, both for the proof-of-concept system and for the final production model. This description is through means of a functional specification that defines exactly all the requirements that are palpable to the end user, as well as those required by the engineering and design teams to create a design platform to implement all the functionality described. The proof-of-concept model is expected to be finished by the end of December 2010.

10 References

[1] Music Publisher's Association of the United States: Standard Music Notation Practise. [Online]. Available: http://mpa.org/music_notation/standard_practice.pdf [accessed October 8, 2010]

[2] Hui, O. James, T.L. Iannson, A. B. C.(2010, May 5). *How to certify a device RoHS compliant*. Retrieved from http://www.interfacebus.com/How_to_Specify_an_Equipment_Chassis-RoHS.html

[3] Midi manufacturer's association. (2008, May 5).
Retrieved from http://www.midi.org/techspecs/midispec.php

[4] Reliability Engineering for Electronics Design. Fuqua, N.B., 1987.

[5] Quality & Standards in Electronics. Tricker, R, 1987.

[6] Association of Professional Engineers and Geoscientists of British Columbia, "Code of Ethics," Online document, 2004, Retrieved from http://www.apeg.bc.ca/library/actbylawscode.html