

Synchronized Audio indexed Note Taker (SAiNT)

Sponsor: Resource Center for Persons with Disabilities

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Design Team 1:

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Executive Summary

People with disabilities face many challenges while completing their collegiate studies. Reviewing lecture materials poses to be very challenging for visually impaired students. There is a need for students to be able to efficiently review specific topics in a lecture recording. This eliminates the need for the student to repeatedly press rewind and fast forward to find the topic of interest. Stephen Blosser, one of the technical staff from Resource Center for Persons with Disabilities (RCPD), has approached ECE 480 Design Team 1 at MSU to design a device to solve this problem. Specific aims for the project include that it be low cost, accessible, and portable.

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Introduction

The Synchronized Audio indexed Note Taker (SAiNT) is being designed for the MSU Resource Center for people with disabilities. The purpose of SAiNT is to assist the disabled with class work and note taking during lecture. Specifically, accessibility to blind students will be considered due to the fact that they have difficulty taking notes during lecture, and then later listening to audio recordings of specific lecture topics. SAiNT will help the end user record entire lectures as well as type notes concurrently. SAiNT will automatically synchronize these notes to the recording. Later the lecture and text will be downloaded to a computer, allowing for the user to search the notes and begin playback of the lecture at the time specific notes were taken. In other words, the device will record audio, record synchronized text, and allow for file transfer to a PC for playback

Background

Various products on the market enable synchronization of audio and text. However, there is a premium price for these devices. Solutions that currently exist include applications for the iPhone (Apple Corporation) and the smart pen (Live Scribe). The iPhone applications work by recording lectures and allowing students to type notes on the phone during lecture. The student can then find these notes later and begin listening to the lecture at the point in time the notes were taken. The smart pen is a similar device. However, the smart pen allows for the user to write notes on a special type of notebook while the pen tracks where notes are taken. The pen will record lecture as well as the location on the page the notes were written. This allows for students to place the pen at a specific point in the notes and begin audio playback from when those notes were taken. Visual depictions of both of these designs are seen below in Figure 1.



Figure 1: iPhone and Smart Pen, with its required notebook for note taking

There is one common feature that these two products are lacking aside from being priced at over \$200. These devices are not accessible to everyone. This is where there is a need for SAI^{NT}. The keyboard will be a standard sized QWERTY layout, allowing anyone familiar to use it. The device should also have a buzzer and LED to notify users if the device is actively recording or not. SAI^{NT} will simultaneously record audio and text. The audio and text will be synchronized in time as well.

Various karaoke devices also utilize similar technology to what we are trying to implement. The karaoke industry has developed a file standard for synchronizing lyrics with music files. It is known as the .lrc file standard, and is very similar to how subtitles are added to videos. SAI^{NT} will create an .lrc file, or something similar, as the lecture is being recorded. This will effectively synchronize all of the notes with the time in lecture they were typed.

Key components of the system include storing text and the time the text was entered, as well as being able to record sound from an on board microphone. The .lrc file and the sound file then need to be exported via USB connection to a computer. The computer will be able to play the audio file, including the text, and then search the text file for key words that were typed during lecture. The user will select the desired word or phrase and audio playback will begin at that marker.

Various devices on the market are able to record keystrokes from a keyboard and simultaneously time stamp them. This technology could be useful because we are essentially attempting to do the same thing (KeeLog). The difference is SAI^{NT} will keep track of the position in lecture instead of the time of day. There are also microcontroller projects that involve recording keystrokes and exporting them to a remote computer. This same technique could be adapted to SAI^{NT}, except instead to store the keystrokes to the devices memory.

One of the designs main objectives is that it be low cost. Therefore, the ultimate goal is to use a single microcontroller to coordinate all of the components. The microcontroller must be able to interface with a keyboard, analog source, and an external data storage device. Another design objective will be to operate on battery power allowing for students to take the device to class.

Objectives of Design Specifications

The goal of the Synchronized Audio indexed Note Taker is to provide a low cost solution to help reduce note taking impediments. This device will not only help those who are visually impaired, but will also be

an attractive solution for everyone. Several important factors will be taken into consideration during the development of this device, most importantly: safety, reliability, cost, portability, power consumption, usability, and robustness.

Safety

Safety is the most important aspect of this design. The electrical components of SAiNT must be carefully controlled and designed to prevent any risk of electrical shock or burns to the user. Since the device will be made to operate for long periods of time, temperature monitoring will be a critical task during development. In addition, due to the targeted audience of the device, all the physical aspects of the device must also be designed to prevent against injuries such as piercing of skin or flesh.

Reliability

Reliability is another important design criterion. In order to meet consumer expectation, the device must be able to withstand a reasonable level of usage without error. The device needs to record both audio and text without failing. The user may not know or notice if the device has failed, making reliability even more important. Components must be selected and tested to withstand several scenarios of usage while maintaining an expected level of functionality.

Cost

SAiNT falls under the category of an accessibility device. As a result, a low cost design is desired to make the device obtainable for any interested consumer. Profit will not be taken into consideration during development. However, meeting other design specifications will take higher priority in financial decisions. Any parts that will be needed to complete the project, such as microcontrollers, must be selected carefully to ensure that unnecessary features do not drive up the cost.

Portability

This device must be small and lightweight, as it is meant to be used in a variety of different environments where space may be a factor. A battery charging system will eliminate the need to be near an electrical wall socket and decrease the amount of necessary cables. Memory will also be an important consideration as this will increase the amount and length of sessions the device can be used for without a need to download recordings to a computer.

Power Consumption

As a result of the portability design criteria, power consumption will be one of the higher priorities during development. The amount of time SAiNT will last between charges will play an important role in consumer satisfaction. The goal of the design is to allow the device to be used several times throughout the day without the need for new batteries. The electrical components must be configured and designed to minimize power consumption while maintaining a satisfactory level of functionality.

Usability

SAiNT must be easy to use for those who are visually impaired. In addition, the design should be accessible regardless of the user's age. In order to meet these criteria, the interaction between the device and the consumer must be implemented in a simple, intuitive way. The only switch needed for the device will be an On/Off switch. The device will indicate when it has been turned on by using both an audio signal as well as an LED.

Robustness

The design of SAiNT will be very robust. The design will feature the ability to add any USB keyboard. This will allow for easier troubleshooting and cheaper repair. Microphone and audio recording quality will also be important during design to increase robustness.

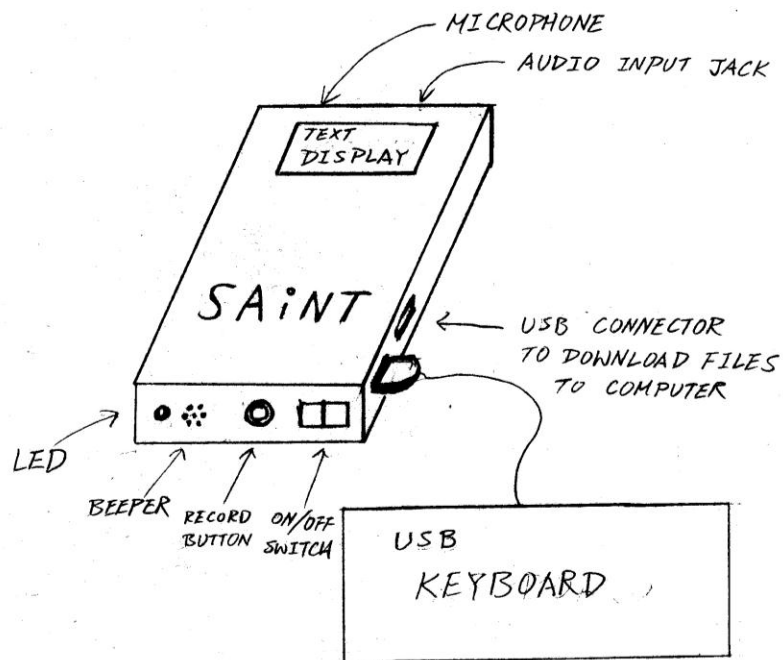


Figure 2: Conceptual design of SAiNT

FAST Diagram

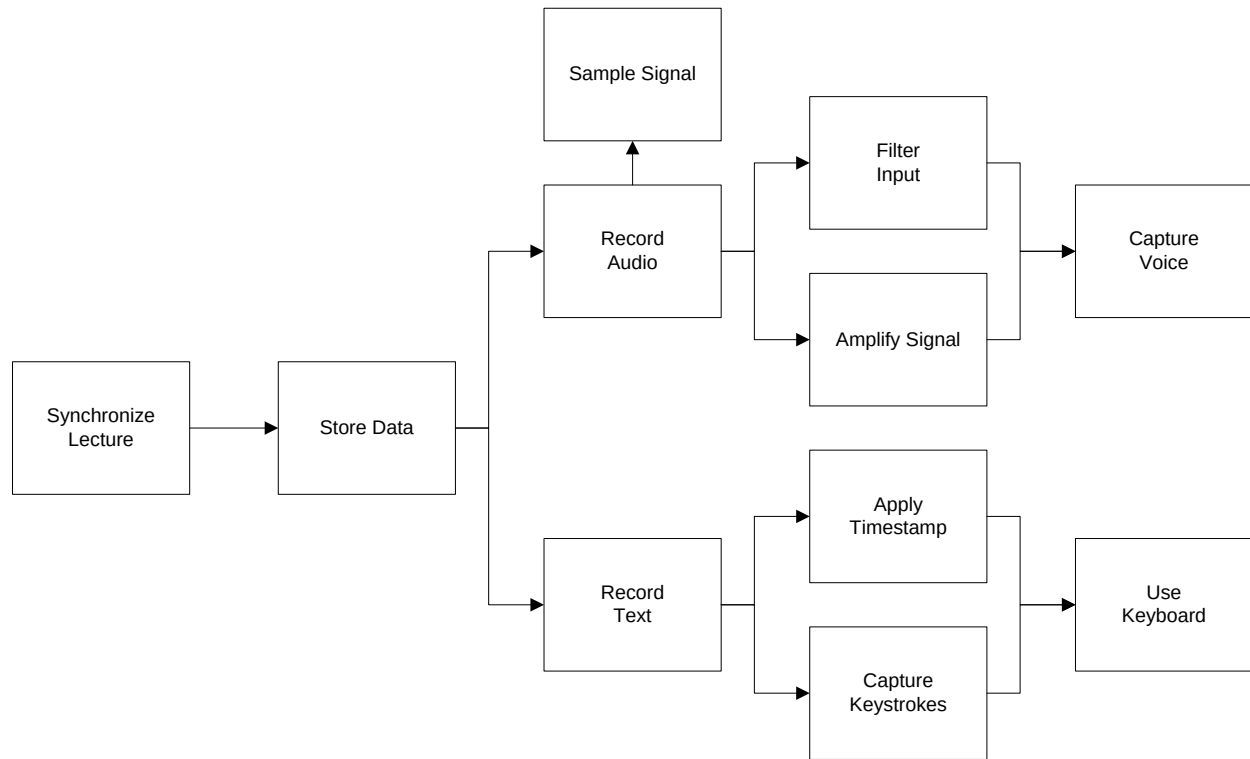


Figure 3: FAST Diagram

Conceptual Design Descriptions

Both of the conceptual designs require many similar features. The designs must be low cost, include synchronized audio and text input, as well as being portable and battery powered. These solutions also must be able to download the acquired data to a computer allowing for playback and text search routines to be performed. A basic overview of the required task is can be seen below in Figure 4.

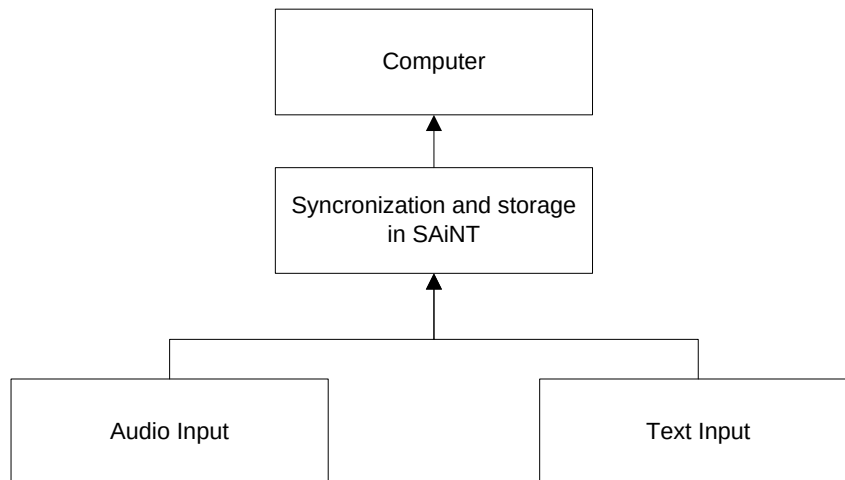


Figure 4: Block diagram of system requirements

Hardware

Design 1

Design 1 uses a microcontroller interface to write both audio and keyboard data to a source of non-volatile memory, such as an SD card or USB thumb drive. Both the microphone and keyboard will be interfaced with the microcontroller and the data will be simultaneously saved to the memory source. This could pose problems however, since two separate files would have to be saved simultaneously with a single microcontroller. There may not be enough processing power within the microcontroller to accomplish this task.

Design 2

Design 2 consists of utilizing two separate microcontrollers to handle the audio and text acquisition separately. Separating the circuits will allow for each one to be developed in parallel as well as eliminating any problems associated with processing power. This solution is more expensive since it will have two separate microcontrollers. However, due to the low cost of a microcontroller, it will not significantly increase the cost of the final product.

Software

The software solution will include both microcontroller programming as well as a simple computer interface. One microcontroller will be used to handle audio processing and a separate microcontroller will be used to handle the text input. The microcontroller software needs to allow for saving the data to non-volatile memory. The computer interface will allow for any post processing needed to generate usable data, audio playback, and a simple search function.

Ranking of Conceptual Designs

Design Criteria	Weight	Design 1	Design 2
Safety	7	5	5
Reliability	6	4	5
Cost	2	3	2
Portability	4	5	5
Power Consumption	3	4	3
Usability	5	4	4
Robustness	1	3	4
Total		120	122

Table 1: Ranking of Conceptual Designs

Design two has a slight edge over design one. However, since the score is so close between the two, the decision will ultimately depend on which one is simpler to implement. In this case, a two circuit design will be ideal because each circuit can be developed independently. This design will also eliminate any issues with processing power since the audio and text capture will be completed separately.

Proposed Design Solution

Hardware

Hardware will be used to implement an audio pre-amp. The pre-amp will amplify and apply a band pass filter to the microphone input, producing an optimal signal to be recorded. At first a 741 op-amp will be used with a 200- 4000 Hz band pass filter. If the audio recording is not satisfactory, a higher quality op-amp will be used to decrease the signal to noise ratio of the recording. Normal speech falls in the frequency range of 200 – 4000 Hz, which determined the parameters for the filter (Don Davis). Since the highest frequency needed for recording is 4000 Hz, application of the Nyquist Theorem leads to a sampling speed of 8000 Hz (Maichen).

A Texas Instruments MSP430 will be used as microcontroller on the audio circuit. TI provides all of the communication protocol necessary to read and write to an SD card. This also led to the design decision to implement an SD card as the source of non-volatile memory. The MSP430 (Texas Instruments) is also very low cost, around 1\$, and fast, 16 MHz, making it ideal for the project. The microcontroller will be programmed to convert the analog signal from the pre-amp to a digital signal using a sampling frequency of 8000 Hz for reasons stated above. After conversion the signal will be stored to the SD card.

Since an MSP430 will be used to program the audio side of the system, it is a logical design decision to also use it for the decoding and storing text circuit. Text will be captured using a USB keyboard that plugs into the SAiNT module. SAiNT will then decode the keystrokes. Once the USB keyboard input is decoded, it will be time synchronized and also stored into memory. This will be stored in memory as a file similar to the .lrc file discussed earlier. Figure 1 below is an example of the synchronization file.

```
[000:00.0] Notes corresponding to time on left  
[002:51.9] Notes corresponding to next portion of lecture
```

Figure 5: example .lrc file to synchronize text

SAiNT also requires a battery power supply. This design will include either removable batteries or a rechargeable battery pack. A voltage regulator may also be needed in order to supply a stable voltage source in order for the microcontrollers to operate properly. Several other voltage dividers may be needed if other circuit components require different operating voltages.

Software

There are several software approaches that can be taken to interface the SAiNT with a user's personal computer. The first decision is to decide what platform to target. Targeting the Microsoft Windows platform may be the most economical decision since the majority of personal computers use this. Development would also be simpler because of the maturity of the Windows API. This would allow for easier implementation of a graphical user interface and audio playback. Alternatively, a cross platform solution may be implemented with the help of some open source packages. Fast Light Toolkit (FLTK) (Spitzak) and irrKlang (Amiera) are both powerful cross platform, open source libraries. FLTK can be used to construct a GUI and irrKlang will provide the audio functionality. The second decision is to decide what high level programming language to use. Due to the complexity of the software solution, an object oriented language will be necessary. Two strong candidates are C++ and C#. The Windows platform approach would allow for the use of C#, which has larger library support. Additionally C# requires no memory management. On the other hand, C++ can be used to allow for better performance and finer tuning capabilities. In addition, C++ can be compiled on any platform. However, using C++ will be much more complex and if not written carefully, will lead to an unstable application.

Implementation

The following diagram, as seen in Figure 6, is a visual representation of the design task. Audio and text will be handled separately and then stored in a common location. Files will then be downloaded to a computer to present the data.

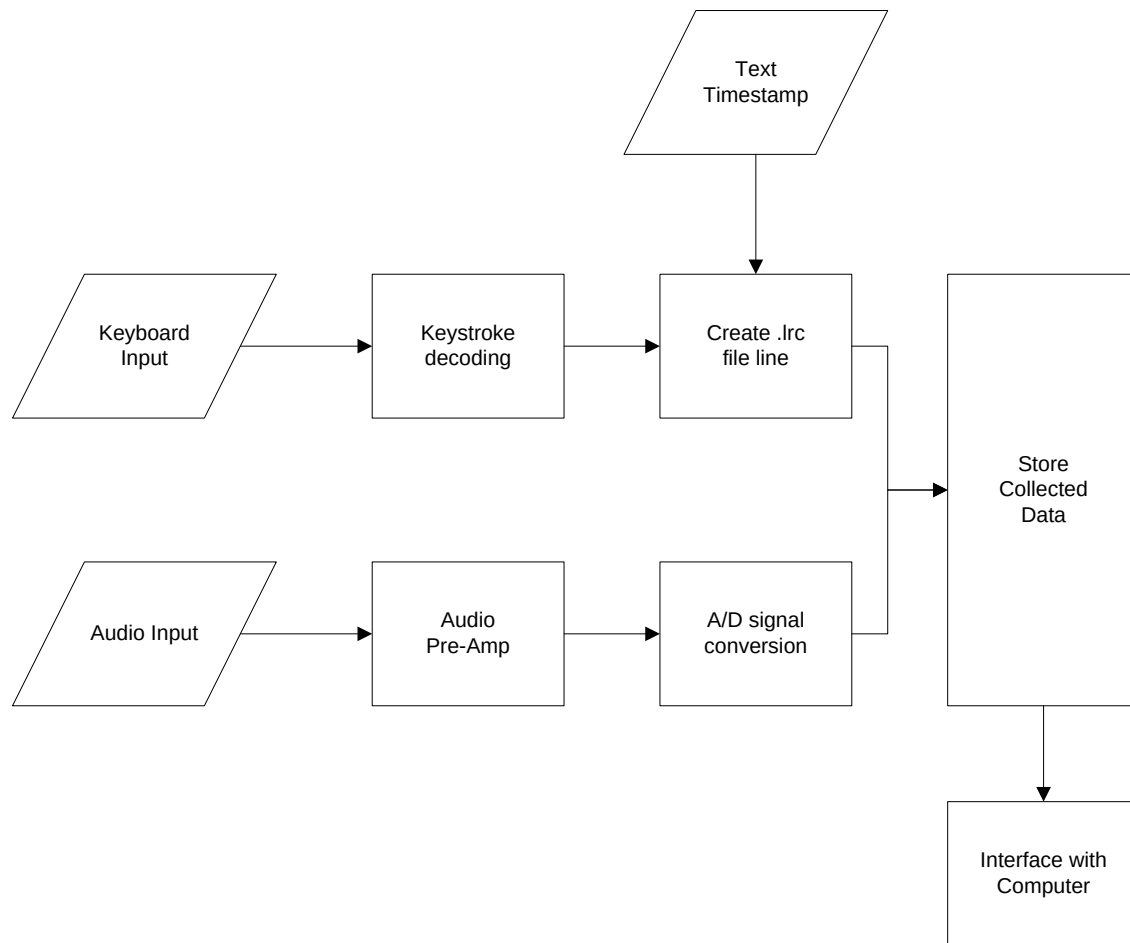


Figure 6: Block diagram of the proposed solution

Validation

Validation of SAiNT will include verifying both the final audio file and .lrc file. This will be done by downloading the files from the device to a computer. Once downloaded, the audio file will be played with a media player and the .lrc file will be validated with a text editor. After validation of both files independently, synchronous playback will be completed by searching a keyword and initiating audio playback from the corresponding point.

Risk Analysis

Audio Recording

SAINT will be used to record lectures in a variety of different scenarios. There is the inherent risk that the room will have unfavorable acoustical properties and induce distortion into the recording. There is also the risk that the input gain will be too loud or too quiet for recording, leaving the audio file

unusable and the data recorded essentially useless. Therefore, care must be taken while designing the microphone circuit to allow for high quality audio recordings.

Text Recording

SAiNT must be able to create and continuously add text to a file. The .lrc file format is preferred considering it was designed to synchronize audio with text. Without reliable text recording the device will not be able to function as intended.

Battery Life

SAiNT is going to be used as a portable note taking device. Therefore, having the device use battery power would be ideal. On the contrary, the device will also increase in cost if this is implemented. SAiNT will need to have a battery life of at least four hours since many lectures can be several hours long. Without this functionality, SAiNT will not be usable for all situations and could also unintentionally stop recording mid-lecture.

Memory

SAiNT will need to have enough non-volatile memory to store at least four hours of audio recordings. This is necessary because it is unrealistic to assume the user will be able to download audio files between each use. Also, some lectures can last several hours and the device would not be useful if it were unable to record the entire session.

Project Management Plan

Technical Roles

Huan Lin – Power source design and microcontroller programming

Li-Shian Chen – Keyboard input microcontroller programming and circuit

Christopher Johnson – Audio input microcontroller programming and circuit

Trieu Nguyen – Computer interface and microcontroller programming

Non-Technical Roles

Huan Lin - management

Li-Shian Chen – lab coordination, presentation prep

Christopher Johnson – documentation prep

Trieu Nguyen – website

Estimated Budget

The estimated cost of several design components can be seen below. The total budget allowed for development is \$500. Several parts may also be obtained for no charge through the ECE shop.

Component	Estimated Price
Audio Circuit	
Microcontroller (1)	\$2
Microphone (1)	\$5
Speaker (1)	\$5
Amplifier to build the microphone (1)	\$5
Resistors (several)	\$1
Capacitors (several)	\$1
Memory	\$10
USB flash or SD	\$10
LED (two for on/off)	\$1
Wires (several)	\$2
Text Circuit	
Microcontroller (1)	\$2
Resistors (several)	\$1
Capacitors (several)	\$1
USB host or device (1 or 2)	\$10
LED (two for on/off)	\$0
Wires (several)	\$0
Power Source	
Battery	\$10
Voltage Regulator	\$2
Resistors and Capacitors	\$1
Other Components	
Circuit Board	\$10
Device Housing	\$10
Keyboard	\$20
TOTAL	\$109

Table 2: Estimated Budget

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