

# LoopKore

## Computer Engineering Senior Project Proposal

Matt Steadman - matt@loopkore.com

Paymon Saebi - p.saebi@utah.edu

Kevin Faerber - kevfa317@gmail.com

[www.loopkore.com](http://www.loopkore.com)

## Table of Contents

Table of Contents.....	2
Introduction .....	3
Simplified Schematic.....	4
User Interface .....	5
Digital Audio Playback.....	6
Digital Audio looping.....	7
Analog Effects .....	7
Analog input recording .....	8
Analog Looping .....	9
Stacking multiple loops.....	9
Storage of recorded sessions onto a thumb drive.....	12
Risks .....	12
Schedule.....	13
Integration/Testing Strategy.....	14
Group Communication.....	14
Bill of Materials .....	15
Conclusion.....	15

## Introduction

LoopKore is an all-in-one electrical instrument looping station, with several key features. The LoopKore has been inspired by two devices that up until now have only existed in two separate units; a looping station and a digital music player/recorder. Looping stations are very popular tools for many musicians today, and there is a broad array of looping stations currently available on the market. They are usually packaged like an effect pedal, and are by far one of the most expensive pedals that most musicians will purchase. The basic looping station is the Boss RC-2 which comes in just shy of \$200, and can only record a total of 16-minutes of audio. The top of the line is also from Boss and is the RC-50. The RC-50 adds a huge variety of features including the ability to record completely separated loops. This \$500 pedal has a limit of 49-minutes of recording time. There are custom solutions available on the market that provide slight upgrades to the options of the RC-50, but musician's who need something beyond the RC-50's capabilities can expect to pay nearly \$2000. The LoopKore is planned to have a 2GB memory which enables it to store over 200 minutes of audio.

At first glance when one considers the length of common songs even a 16-minute limit seems more than sufficient. Although there are very few common songs that are longer than 16-minutes when looping is involved this time frame becomes very important. With a looping station, a musician is able to tap a button which starts recording the input from an instrument, after which the musician can press a button to stop the recording and immediately start play back from the start of the recording. The musician is then able to lay down track after track of music directly on top of this, but each loop is kept separate in the system which enables the musician to fade in and out separate loops and change the song as time progresses. Due to the large memory capacity of the LoopKore, the musician is able to fully explore sounds and music. In a one-man-band scenario loop stations are very useful because they enable the musician to play the parts of multiple instruments at different times but listen to the recordings at the same time, with the 200 minute capacity of the LoopKore the one-man-band has the opportunity to be a one-man-orchestra.

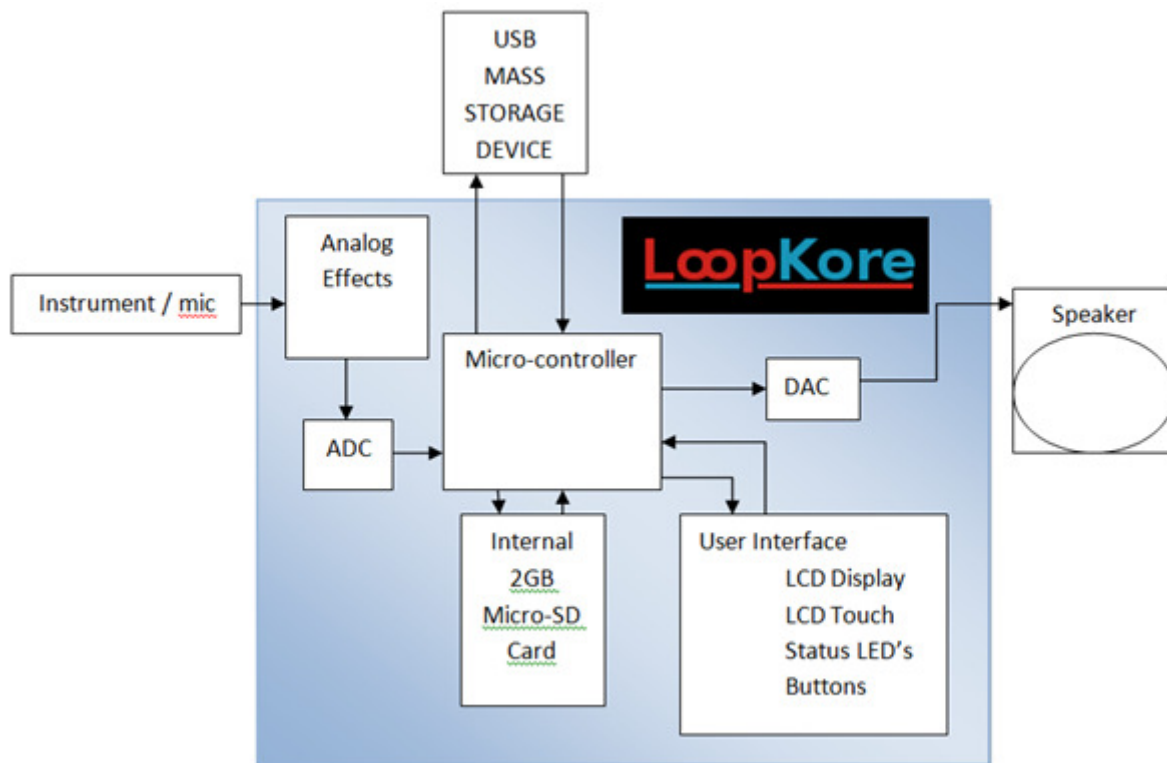
The additional capabilities that the LoopKore has over other looping stations extend far beyond the amount of audio that can be recorded. The system is designed to be able to read and write files from a musician's USB flash drive. This means that a musician can pre-load a thumb drive with mp3 or wave formatted audio files (other formats of audio data may be added), and use the looping station to incorporate this pre-recorded music into their own creations. The musician is able to extract segments from the pre-recorded data in create loops from these tracks as well as their own

original recordings. By mixing these two elements into one unit we are able to give the musician a whole new array of opportunities to create new and original creations. The musician is also able to store these creations onto the flash drive to preserve and rework their creations.

This additional functionality, which is beyond anything currently available in the industry, can present a significant learning curve for the musician. To aid in overcoming this obstacle there will be a large clear LCD touch-screen for interfacing with the musician. This display helps the system communicate with the musician in ways that have never been done before in previous looping stations. With the intuitive LCD touch-screen the musician will be able to take full advantage of the capabilities of the LoopKore with a minimal learning curve.

## Simplified Schematic

In this simplified Schematic view of the LoopKore we can see each component of the system and how they relate to one another. The Instrument / microphone, USB Mass Storage Device, and speaker are all external to the LoopKore. The LoopKore contains an analog effect unit that will be able to modify an incoming analog signal from the instrument / microphone, and that signal is then passed into the ADC converter so that the Micro-controller can interpret the data. The micro-controller also interfaces with

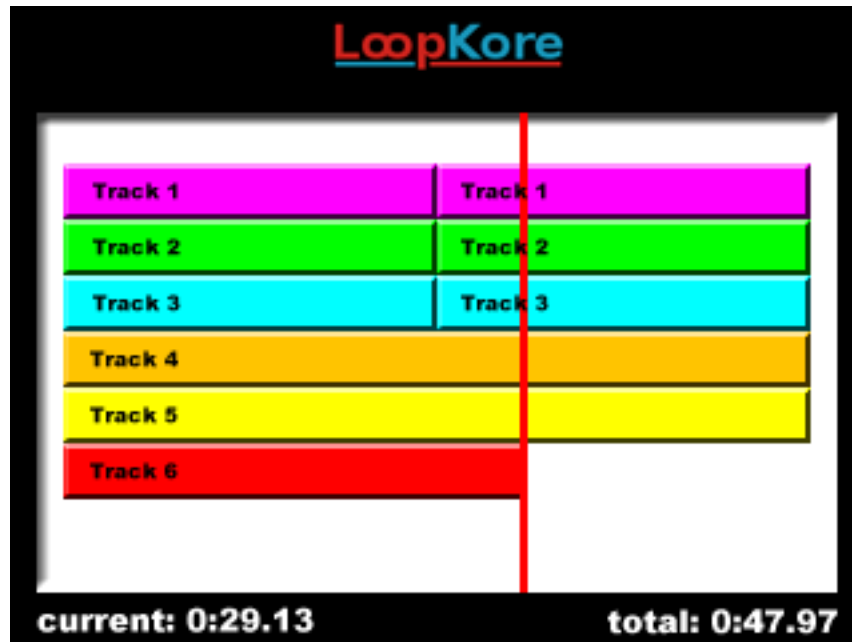


the musician's USB mass storage device, reading audio files from the device, and storing recording sessions back onto it. The LoopKore has an internal 2GB memory which is facilitated by a Micro-SD card. The musician Interface consists of an LCD Display screen and LED's to get information to the musician, and the touch functions of the LCD screen and other on board buttons to get information from the musician. The digital audio data created by the LoopKore is sent through a DAC and this signal is available for the musician to plug in any compatible speaker that they wish.

## **User Interface**

The LoopKore will have several different ports. In accordance with traditional guitar pedals we will use the 1/4" jack for input and output. For the majority of audio jacks, audio signals are electrically identical regardless of what type of connection is being made. This makes the addition of many options for the musician to use to send their source signal in very easy from an engineering standpoint. Therefore we would like to enable the musician to use a 1/8" (3.5 mm), XLR, or RCA connection as well. The fact that the system is very close to a miniaturized recording studio also inspires us to have these additional options for output to the speakers.

The musician will mainly interact with the LoopKore through buttons and a touch screen LCD. The LoopKore is able to communicate back to the musician using LED's and the display of the touch screen LCD. The touch screen LCD is the main interface to the musician. The LCD will display different things depending on what the pedal is actually doing at any given time. When a USB flash drive has been connected the LCD will display a list of tracks that the musician can choose from to extract loops. Once a track is selected the LCD will also display the status of loading the mp3 file from a USB drive into working memory. The musician then will be able play it, and extract a loop from it. While the system is playing music and recording loops the LCD will display information about the current time, the total time of the current loop, and the number of tracks being played concurrently. The full color LCD enables the musician to very easily access each loop that has been recorded and control what is actually heard. In the simulated Screen-shot on the next page we can see that the musician has recorded several tracks and is in the process of recording another. The red vertical line shows clearly how far along the recording has progressed and can help to serve as a visual cue to assist the musician even further than the audio cues that they would have recorded into the track while they played each loop. At any time the user can stop recording new tracks and use the LCD merge tracks, save a selected track to the musician's USB drive, or trash the session. There is also a recording mode that the user can select where they can store the mixed output of all tracks as a single track to



the USB drive. The LCD will display a status bar the status of storing the finished track onto the USB drive.

During a recording session the musician will interact with two large pedal style buttons. The primary of these two buttons is dedicated to telling the system when to start recording, stop recording, and when to start a new loop. The second pedal is for user specified events. There are several options that have been discussed such as a double length feature which will signify to the system that the subsequent loops being recorded will be twice the length of earlier loops. The result of this is simulated in the screen shot at the top of this page. Other possible effects could be switching to an entirely different set of loops that have been setup in the system, dropping a particular loop from the playback, or other features.

LEDs will also be used to communicate the status of the system to the user. A red "REC" LED lights up whenever a recording session is taking place. LED's are used to show when the USB drive is being written to or read from. LED's are used to show volume level coming into the system and going out from the system.

## Digital Audio Playback

When the musician inserts their USB drive into the LoopKore, the LoopKore reads the file system and pulls a list of all compatible audio tracks, (.mp3 .wav) to display on the LCD. The musician can then select one of the audio tracks to playback. If the selected track is an mp3, the LoopKore will decode the mp3 converting it into the wave format. The Decoding of the mp3 can be done with an external mp3 decoder chip, or via software. Our micro-controller has pre-built libraries for mp3 conversion but it

may prove useful to instead use a conversion chip to decode the file using software. The wave format will be saved in the LoopKore's memory. Once the mp3 has been decoded the musician can start playback of the track. If the selected track is already in the wave format the file is copied directly into the LoopKore's memory. All processing and mixing of audio data within the LoopKore uses a Wave file format to enable for easy mixing and to allow the data to be sent directly through a 16-bit audio quality DAC.

## **Digital Audio looping**

Looping an mp3 file proves to be very difficult due to the way mp3 is compressed. To achieve looping of an mp3 the LoopKore does not playback mp3s directly as described in the previous section. The mp3 is first converted into a wave format. Due to the uncompressed nature of wave formatted audio, the wave format allows the LoopKore to equate a specific place in the file to a specific playback time of the audio. This allows the musician to select a period in the audio to have loop repeatedly by selecting the beginning point and ending point. The LoopKore will store the begin point and end point as pointers into the file. When playback reaches the end point, playback will jump and start at the begin point. The data will need to be transferred frequently to and from the Micro-SD card due to the limited space of active memory on the micro-controller. This is discussed later after the need to allow for many tracks to be handled in this manner at once has been introduced.

## **Analog Effects**

Since the LoopKore provides a raw analog input for electric instruments, the addition of a few analog sound effects seems very suitable. A few commonly used sound effects circuitry that are not very complex and are possible to build within the scope of our project will be added to give the musician more flexibility and options for a quick and hassle free recording session or practice. A four stage effect system seems appropriate for our purposes. First, a compression stage is needed to even out the incoming signal, more specifically a high output instrument. This compression is also very important to other effects such as distortion and overdrive that come next. For example, a compressed signal passing through the op-amp clipping loop of a distortion stage will sound much fuller and warmer. After the distortion stage the signal needs to be put through a pre-amplifier stage to raise the levels of the distorted signal or just to make a regular signal louder. In the last stage the signal needs to be equalized for sound coloration and some noise cancellation. For this purpose a three band amplitude equalizer seems to be adequate. We really wished that we could implement a delay circuit as well but that is a whole new project by itself. Therefore, we have decided that

we may use the internal circuitry of a consumer delay pedal and add it as the fifth stage of our effect system.

For each effect the musician will have one footswitch style push button that is used for floor and rack-mount devices. The musician will be able to turn any of the five effects stage off and use them as desired. These push buttons will be designed to be true bypass in order to preserve the incoming instrument signal from losing its tone if the musician wishes not to use any effects. The musician will also have several knobs to control the levels of various sound altering parts within each effects stage. There will also be LED's to indicate the status of each stage along with the push buttons.

The output of the effects unit will then be split into two via appropriate amplifiers. One signal will be made available as an output to a external guitar amp and cabinet and the other will be fed into the microcontroller via the 24 bit analog-to-digital converter available on our board. The digital signal is the available for playback, looping, and mixing with other recorded tracks.

## **Analog input recording**

In order for the LoopKore to perform it's primary looping function it needs to be able record an incoming audio signal so that it can play the recorded music back in a loop. This recording is performed by periodic sampling of the incoming signal from the source. Microphones and Guitar pickups transform physical vibrations into a voltage. Sending this voltage into an Analog Digital Converter enables a computer to get digital readings of the voltage. Because the loopkore is intended to be able to create CD quality sound this means that the LoopKore needs to convert the analog reading at a 44.1 KHz sample rate. Every time a new reading is made this reading is stored in a sequential location in memory.

This will require some very efficient and reliable dynamic memory management techniques. In embedded systems it is generally considered bad form to have any dynamic memory allocation and any situation where-in the exact amount of memory required to perform any particular operation is unknown. This rule is in place because embedded systems need to be very reliable and stable systems, and dynamic memory allocation tends to be complex enough to break these systems. Dynamic memory allocation also tends to create unpredictable timing situations. The LoopKore is an embedded system, and it is an embedded system that has essential timing requirements that must be met in order for the system to function properly. But it's core functionality requires that this rule regarding dynamic memory allocation be broken for maximum efficiency and usability. Although we have yet to specifically decide on



exactly how we plan to manage this issue, it has been discussed and several methods handling this issue have been considered.

## **Analog Looping**

Once the system is able to actually record an analog input the next important step is to loop that recording. The basic idea here is that the LoopKore's primary pedal button will be used to start the recording process, as well as mark the end of the recording process and in turn start playing the recording from the beginning. This loop of recorded audio data will then be continuously repeated and sent to the output of the system, until the musician says otherwise.

This is where the importance of the memory management algorithm previously mentioned becomes most evident. Our micro-controller only has a certain amount of on board memory that the processor can directly access, all other data will need to be stored in the 2GB micro SD card that is connected to the board. This means that we will need to be certain that the processor's memory never overflows, and that any data from a recording is available for playback at the very moment that it is needed. Although wave formatted audio is lossless and produces the most realistic sounds possible by any digital means, it presents a very ominous obstacle because it is a very large format. Just one minute of mono sound at a 16-bit bit depth requires 5 MB of data. Yet our micro-controller only has 256 KB of flash memory, and 128 KB of RAM. Our ability to get the data into the micro-controller fast enough for it to be sent out through the DAC to the speaker without losing anything will be essential to the success of the system.

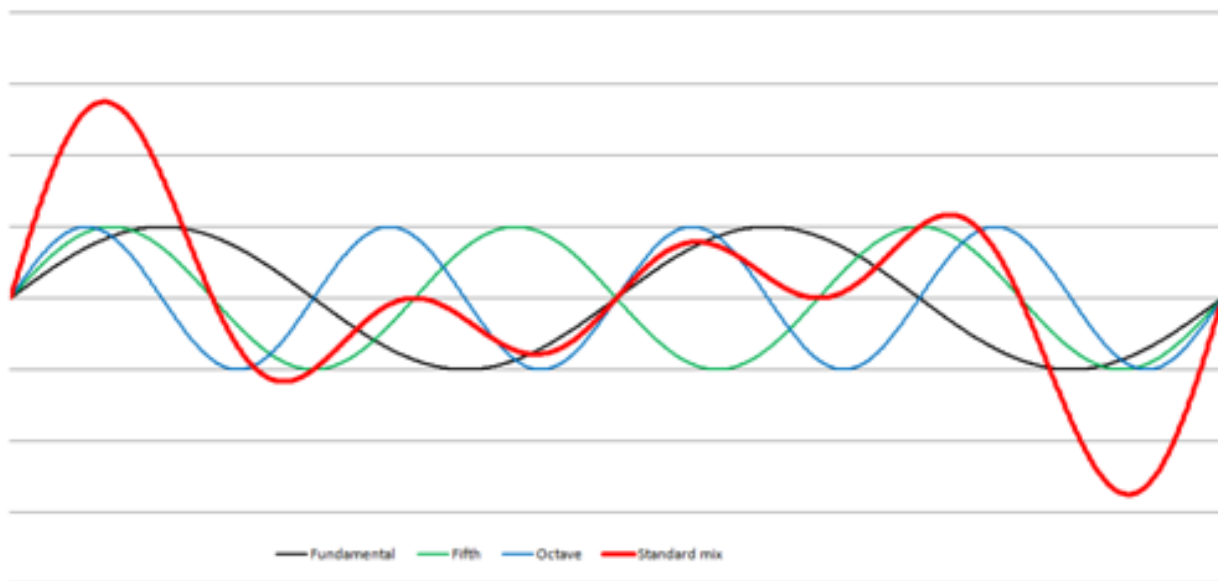
## **Stacking multiple loops**

By this point we have discussed how the system is able to decode and playback pre-recorded MP3 format audio tracks from the musician's USB mass storage device as well as record and playback analog audio signals. The next step is mixing these loops together and stacking them one upon the other so that the musician can hear all of the recordings at once. This can be done easily because of the simple data format of wave audio. In order to calculate the resulting sound wave of two or more waves laid on top of each other one simply has to add the values of the waves together. This may seem like an oversimplification to many people at first, but this is the most accurate representation of what happens in real life.

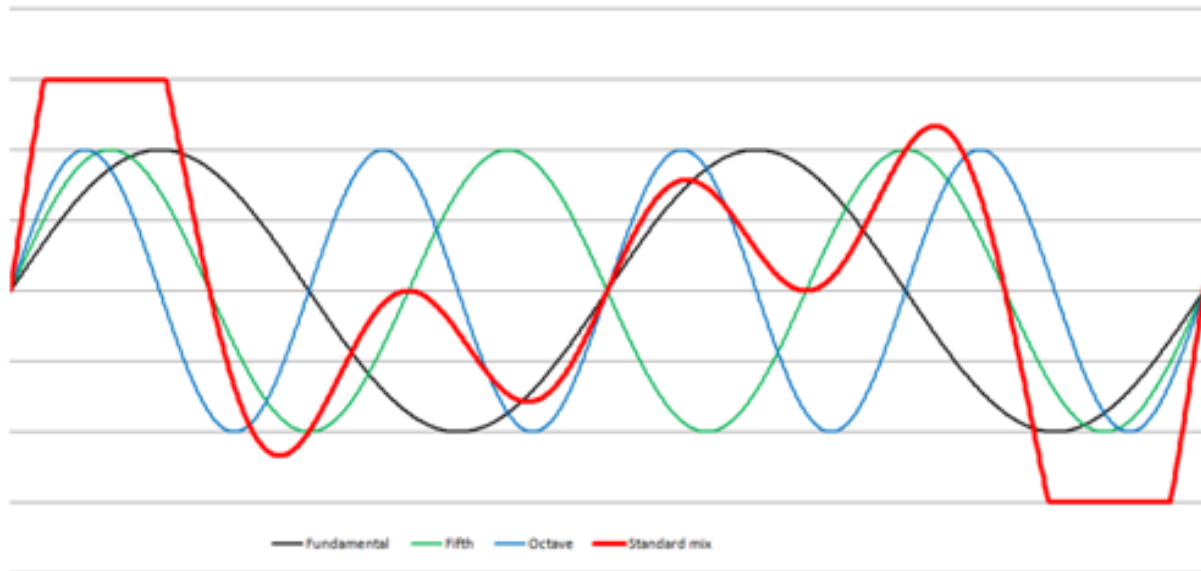
Since at this point all of the audio data that has been recorded is in a standard wave audio format, the mixing by addition is very easy to implement. If there are three

tracks that are being mixed, we simply need to grab the readings from each of the three waves that are supposed to happen at the same time, add these values together and pass this value through to the DAC to produce the output from the system.

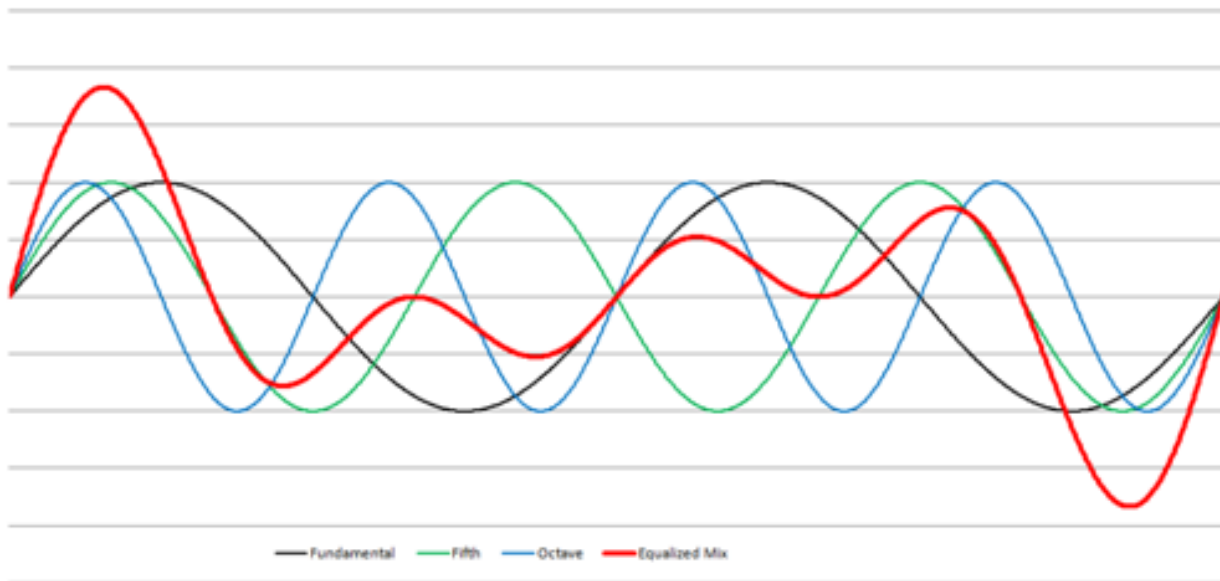
There is one issue that comes about by mixing signals in this way and that is what is known as clipping. Clipping occurs when a signal has gone over the maximum output value that an audio system is able to produce. An example of this is shown in the next two images showing an example of what the mix of a power chord looks like. ( A power chord is a common chord in rock music consisting of a fundamental tone, the fifth note above it in a standard major scale, and the octave above the fundamental.



Here we see an example of what is actually perceived by the human ear when multiple sounds waves are played simultaneously. But suppose that the sound was being played through a system whose maximum output was 1.5 times the amplitude of the three incoming signals. What would result is clipping as we see in the next figure.



The large flat area that is seen in the first peak and the last peak are clipping. This is something that does not actually occur in the natural world, and colors the tone considerably. Since the looping station is not supposed to color the sound some equalization must be done to ensure that clipping does not change the sound.



This is an example of an equalized mix. Equalization is used to ensure that clipping does not occur in the final output of electrical audio systems.

## **Storage of recorded sessions onto a thumb drive**

The LoopKore will give the musician the option to have a final recording track consist of any number of mixed tracks or any recording that the musician may want to listen to later from another device be put on a thumb drive. This is very convenient in a case where the musician happens to come up with an improvisation and would want to remember what it was later. The musician will most likely interface with the thumb drive storage capability through the LCD screen.

## **Risks**

There are a few risks that have been previously discussed that at this point have been resolved. This resolution primarily from our selection of a micro-controller/project board solution that we have determined is ideally suited for our project. This is the Atmel EVK 1104 evaluation kit. This board comes with a full color LCD, A micro-SD slot, pre-written libraries for USB interfacing and MP3 decoding, and the Atmel AT32UC3A3256 micro-controller. The LCD screen on the project board is actually a touch screen, although this has not been connected internally. This is actually new risk. We have decided that we would like to utilize the touch functionality of this device, but this is going to require hand soldering the touch interface pins of the LCD device to the available pins on the project board. This new risk has been considered to be well worth the risk because of the additional functionality that a touch screen provides.

In early stages of our design there were two parts that stood out immediately as the most risky. These parts were the interfacing with a USB mass storage device, and the other was interpreting mp3 audio data. Our project board, the Atmel EVK 1104, already has libraries that have been written for these two tasks. This is a great relief to us and this should enable us to add more additional features to the project than we had originally thought possible.

We have previously considered using an analog mixer to help maintain a more natural response and sound. We have since decided that this is not a reasonable constraint because it would require that we have a separate analog output from the system for every track that is being mixed. Since the number of loops that can be overlaid is intended to be virtually infinite this approach is not reasonable. An all digital environment with digital mixing is ideally suited for this type of an application.

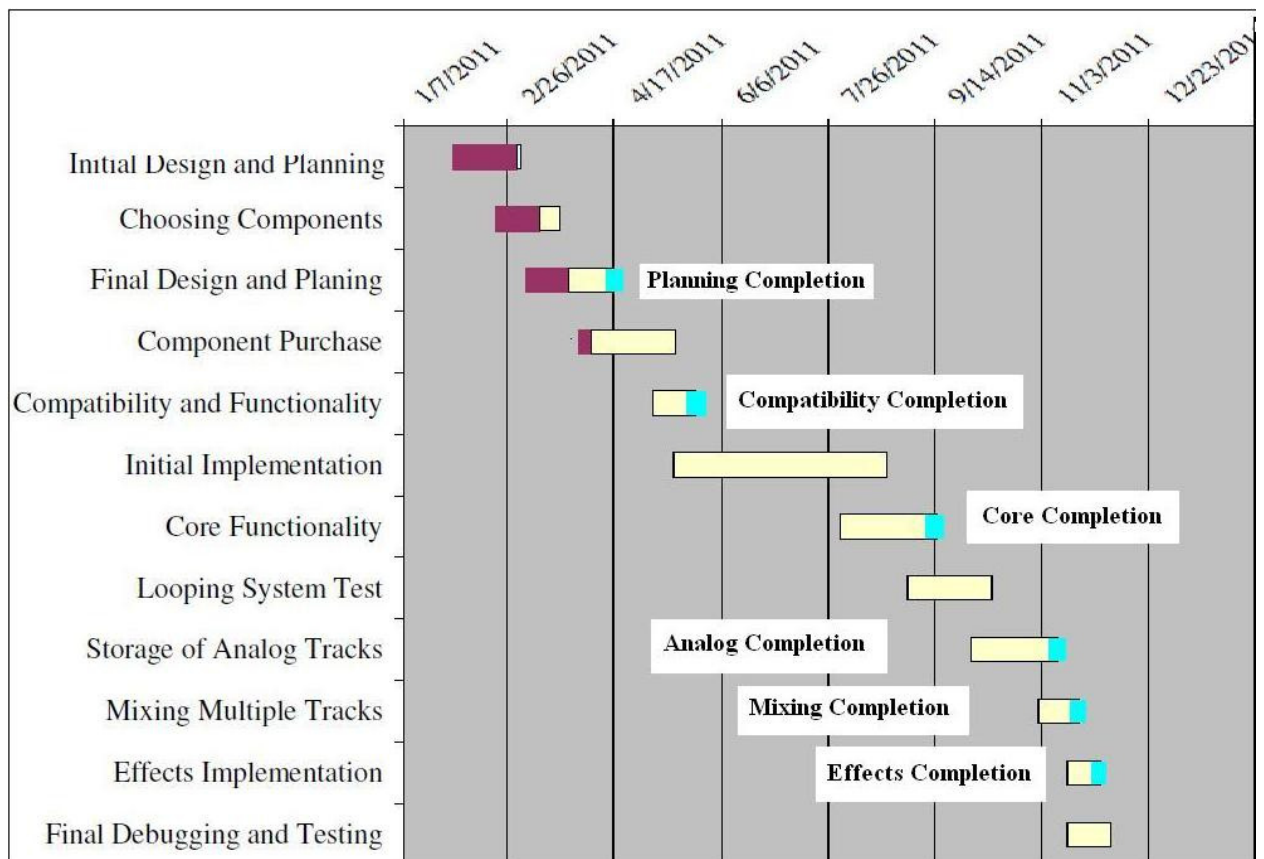
The raw analog input and its effects unit present a risk of damage to the MCU board as it is designed to work with 5v power and there is a limit on the input voltage levels of the converter. Also it is important to mention that the effects unit will require 9v

and 12v sources in order to operate, and they will be very closely placed and connected to the MCU board which could cause serious problems. Since we have to give the musician the option to be able to connect to a cabinet, the risk of back EMF exists with the amplifier on the external cabinet. This risk could also arise from the amplifying stage of the effects unit.

In the professional industry every effect pedal is encased in a metal box to ensure that ambient noises from other sources are blocked out, using the box as a Faraday cage. This is a great idea and we would like to take the industries queue and do something along the same lines. This unfortunately applies two additional issues that we will need to be prepared for. The first is that we will need to ensure that our unit physically fits into whatever sized box we are able to acquire. The second is that, depending on the components used, we may also need to provide some sort of ventilation or other thermal control to ensure that our components do not overheat.

## Schedule

The following chart displays the tentative deadlines and duration of tasks. More



tasks will be added and the deadline and duration of each will be refined throughout the summer. By the end of this semester all parts will be purchased. At the beginning of the summer semester they will be tested and during the middle of summer the schedule will stay somewhat stale as the team experiments and commences the initial implementation of the core system. Towards the end of summer the core implementation will be in full gear and will continue into the first month of the fall semester. Afterwards tasks will fall back to back determining whether there is time to add more functionality and tasks than intended. Testing of individual function will be done throughout the fall semester, but major tests will be done at certain time for multiple functions.

## **Integration/Testing Strategy**

In order to demonstrate the functionality of the LoopKore a brief recording and looping session is appropriate. A piece of music will be selected or will be written by Matt and Paymon to be used for the demonstration. The plan is to have someone play the drum track and another person plays the bass track. These two will then be mixed together and made into mp3 format. On the demo day, a period of the recorded drum and bass mix will be selected by the LoopKore and played back. Paymon will have his electric guitar and Matt will have his keyboard. Each will record a track on top of the drum and bass tracks then mix them together. The final track with all four instruments will then be played back to the audience.

Another crowd pleasing possibility is to also have the people from the audience to try the LoopKore first hand. They could select a song and put it on a flash drive and try out out the playback and the period selected looping system. Some could also try to play something on the instruments available and loop while they play something on top of it and hear it all mixed together.

## **Group Communication**

During the spring semester, the team usually meets on Mondays for a couple of hours, but additional meetings have been scheduled to work on the project proposal, presentations and design. The team communicates via phone, email, text message, LoopKore website, and google docs.

Paymon will be traveling to Iran during the summer for a period of no less than a month and no more than two months. During this time team communication will be established through online chat software with video and audio such as Yahoo messenger and ooVoo. The latter provides very low time delay in video and audio and

is more suitable for a Middle Eastern internet connection. This way Paymon can participate in any team meeting during this time with good time difference scheduling.

During the fall semester the team will have regular meetings at least twice a week, once to meet with the advisor and once to discuss and plan for further parts of the project. Extra meetings will be scheduled as needed depending on the overlapping of tasks, problems, and deadlines. The team will continue to communicate through the previously mentioned methods.

## **Bill of Materials**

The bulk of our materials are included in the Atmel EVK 1104 evaluation kit. This includes our processor, touch-screen, audio DAC, USB interface, and Micro-SD slot. This kit can be acquired from Atmel directly, Digi-key, Mouser, and most other electronics suppliers. The analog effects section will be built out of basic electrical components that we will be able to acquire from the ECE stock room at the University. The exact components will vary based on the effects that we actually use. The audio jacks are available at many electronics suppliers. Before we acquire the faraday cage the analog effects and all other hardware will need to be assembled, then it will simply be a matter of finding a metal box of sufficient size. Since this is a prototype the esthetic appeal of the box is not a concern, rather we are simply concerned with the actual effect of the box as a faraday cage. If there is not a large amount of noise being picked up from external sources. We may omit the box entirely.

## **Conclusion**

Building the LoopKore will be a significant challenge, which will require good software design and development techniques from the ground up. The time sensitivities and memory limitations will constantly need to be monitored, and showing useful and accurate data to the user will be difficult. The touch screen will also be a new and challenging device to interface with. In the end we think that it will all be worth it because the final result will be both cool and impressive.