Digital Output Audio Preamp

Project Proposal and Feasibility Study

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Executive Summary

The Digital Output Audio Preamp is the target of ideas that have been circulating in the past months. The development of such a product was identified as a suitable goal for our senior design team. The need for such a device emanated from two ideas: one was the desire to implement advancements in semiconductor technology in the area of audio recording; the second was to provide a consumer item delivering similar capabilities.

This project was chosen to be a precision, stereo (two channel) preamplifier that can be used to interface a pair of microphones or other analog audio signal sources to a digital recording device, such as a computer or CD-audio recorder. As the idea developed, emphasis was placed on providing connectivity to the popular digital music player, the Apple iPod® using a USB interface. Hence, it finds itself in a unique position, bridging a gap between the realms of professional audio equipment and high-end consumer goods.
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ERRROR! BOOKMARK not defined.
1 Project overview

1.1 Project Objectives

The objective of this design is to construct a battery powered (rechargeable) digital output audio preamp that produces improved recording sound quality outputs from any analog audio inputs passed through the device.

The features to be implemented are mainly a function of integrated circuit improvement. Such advancements will make it possible to produce a product with characteristics comparable to devices that were recently found only in recording studios. As has been the trend with computer technology, performance has been steadily increasing while price has been reducing. Therefore, this product would incorporate a very low noise amplifier, with a high-resolution, low noise analog-to-digital converter in a handheld, battery-powered form priced suitably to be an accessory for a high-end portable music player.

The operation of the Preamp will be rather straightforward. It will have a manual power control, an adjustable gain for both audio inputs, and simple start and stop recording controls. The preamp will have indicators for the analog audio levels and for the states of the digital audio data transfer, i.e. “ready,” “recording,” or “error.”

The team has been researching ways to realize the envisioned features, and have been uncovering many options. The component selection process has given the design some form, but we are still investigating uncertainties regarding communication with an iPod and in USB communication in general.

1.2 Context

This project is being undertaken to satisfy a requirement assigned within the context of a B.S.E. capstone course. The major goal of its existence is to allow the participants to gain experience in design work, project management, and documentation of a product design through the research, feasibility, design, and testing stages. It will culminate in the compilation of a complete production design and the production of a prototype. The product is a high-end consumer audio device.

1.3 Team 2

This team is made up of four members with concentration in Electrical / Computer Engineering:

1. Patrick Avoke from Ghana, West Africa is interested in automation and controls systems. He currently works as technical support personnel in the engineering department labs and this job involves...
installing workstations and software deployment. His goals for the next five year would be to gain some working experience in automatic controls and then go on to graduate school to study for Masters of Science in controls systems.

2. Nate Haveman hails from Jenison, Michigan and minors in Mathematics and Music. He plans on attending graduate school to pursue a Masters degree in Audio Signal Processing. Currently, he is interning at Eaton Aerospace and also pursuing an internship at Audio Bay Recording Studio. He has also done work with many local music venues including The Intersection, The Orbit Room, The Liquid Room, The DAAC, Calvin, and The Van Andel Arena.

3. Nsimah Okonna hails from Nigeria, West Africa. She minors in Mathematics and has interest in power systems and communications which she hopes to pursue in graduate school. She has worked with ExxonMobil Corporation as an electrical technician and a facilities engineering intern. Currently, she works as a grader and lab monitor for Calvin’s Engineering and Mathematics departments.

4. Andrew Wallner, originally from Milwaukee, WI, has ties to its northern neighbor Sheboygan, and to the southern crossroads, Chattanooga, TN. His academic interests include analog electronics, audio signal processing, sound reinforcement and recording. To this project, he brings years of experience operating, constructing, and designing audio systems. Not limited to electronics, Andrew strives to possess competence in a broad range of technical areas, including automation, fabrication, mechanical, and automotive systems. A believer in the benefits of liberal arts education, he values wide perspectives. A personal goal for him is the development of the ability to give, at minimum, an educated guess when asked how anything works.

1.4 Motivation

The idea of creating a simple digital output preamplifier was first mentioned last spring when Andy, Nate, and Nsimah were working on analog audio projects. Earlier this fall, when the project idea was proposed, we had some reservations about producing another piece of equipment that would be of interest only to professional audio people. We also encountered skepticism about the supposedly straightforward task it would be to assemble such a machine. This was all resolved when Nate had the idea to connect our device to the world’s most popular portable audio device, Apple’s iPod. This opened up a whole new market demand and design complexity.
2 Design Requirements

2.1 Design Objectives
The design objectives include the following:

2.1.1 Accuracy
Improved recording sound quality. Through wider audio bandwidth, greater dynamic range and lower noise than other available, portable, consumer-grade recorders.

2.1.2 Versatility
The device should accept multiple inputs and output format types and operate seamlessly within a variety of contexts.

2.1.3 Modularity
This would be a stand-alone device that does not need to be connected to a computer for it to be functional.

2.1.4 Portability
This would be a compact device of about 12cm by 8cm by 4cm in size.

2.1.5 Design Norms
Design norms are critical standards for successful design engineering. This design seeks to exhibit commitment these, and more fundamentally, to naturally reflect the Christian convictions of the designers. The holistic approach to the engineering process represents the integration of a Reformed theological perspective in the context of a nearly-completed liberal arts education.

2.1.5.1 Cultural Appropriateness
Such a technologically advance appliance comes at a cost. In our present society, there is an almost unquestioned expansion of gadgets and toys to the consumer market. Our convictions regarding cultural appropriateness make us sensitive to how our design fits in to the mainstream anti-frugal middle-class and seeks to offer a sensible presentation of legitimate human creativity.

2.1.5.2 Transparency
Simplifies how people use digital storage.
2.1.5.3 Stewardship

Efficient design, convenient operation. Aesthetically and functionally simple.

2.1.5.4 Integrity

A good, reliable design.

2.1.5.5 Justice

Technological ability made available without extensive technical background; empowerment. This ability still comes at a price, it is a luxury.

2.1.5.6 Caring

Many people will use this machine; others will be affected by its production and use.

2.1.5.7 Trust

We are establishing a reputation.

2.2 Operational description

The device is described as having the following functionality.

2.2.1 Power state selection

When the device is in the power-off state, all functions must be stopped and power consumption must be strictly limited for the preservation of battery charge. A current draw from the battery that is less than a few uA will be permitted if required to maintain the system state. An analysis of current draw for expected standby performance is given in Equation 2.1.

\[
\text{batterycap} := 1500\text{mA-hr} \quad \text{min\_standby\_time} := 30\text{day} \\
\text{desired\_minimum\_charge} := 98\% \\
\frac{\text{batterycap}\cdot(1 - \text{desired\_minimum\_charge})}{\text{min\_standby\_time}} = 41.667 \times 10^{-6} \text{A}
\]

Equation 2.1

Exception: a real-time clock function may be incorporated into the design and will be permitted to maintain functioning on the condition that its current draw in the system power-off state will not be more than 2% of the total system current draw in the system power-on state.
When the device is in the power-off state, the only command resulting in a state change will be a “power-on” command (if a docking connector is used, a sensed iPod® docking, can initiate the “power-on” state.

All commands may be given in the “power-on” state.

When the device is in the power-on state, the audio preamps, audio signal level indicators, ADC, and data buffer will operate.

2.2.2 Gain controls

When either of the gain controls is adjusted, the gain of the corresponding preamplifier must change accordingly. The gain increments will be 3db or smaller. The gain controls must be debounced with a gate of 20 -50 ms. An instruction to increase or decrease gain must be carried out immediately so as not to frustrate the user monitoring the output program material.

2.2.3 Upon USB connection

When a USB peripheral is connected, the device will determine if the connected USB peripheral has at least 1MB data space available for file storage and assert the “ready to record” indicator if there is indeed free space, if there is not, the “error” indicator is asserted. It is ultimately the user’s responsibility to monitor the capacity of the storage device. Basic file management functionality might be included in future models of the Digital Output Audio Preamp.

2.2.4 Recording controls

When the “initiate recording” command is given in the not error state, the device must create a file on the storage device and write audio data from the ADC to that file until the “stop recording” command is given or the storage device filled to within 1MB of capacity. An “initiate recording” command is invalid in the “error” state

When the “stop recording” command is given, the device must cease writing audio data to the storage device. Outside of the “recording” state, the stop recording command is invalid.

2.3 Requirements specification

2.3.1 Inputs

The device is to be used with input signals described within these listed operating conditions. The continued operation or reliable performance is not guaranteed if the device is subject to signals outside of those given as “non-operating.”
2.3.1.1 Preamp Gain Range and Frequency Response

10dB to 65dB

10 Hz - 20 kHz, +/- 0.5 dB microphone input to recorded file, relative to 997Hz

2.3.1.2 Analog Microphone Input

Input impedance 2K ohm

Non operating:-60V to +60V

Operating: max RMS input voltage to register 0 dBfs at min gain, 45mV, at max gain: 7mV

\[
\text{dBu} := 20 \log \left( \frac{1V}{0.775V} \right) \quad \text{dBu} = 2.214 \frac{V}{V}
\]

\[
V_{\text{maxADCin}} := 1.0V \quad \text{min\_amp\_gain} := 10\text{dBu}
\]

\[
\frac{V_{\text{maxADCin}}}{\text{min\_amp\_gain}} = 0.045V \quad \frac{V_{\text{maxADCin}}}{\text{max\_amp\_gain}} = 6.949 \times 10^{-3} V
\]

Equation 2.2

2.3.1.3 Analog Line Input

Input impedance 100K ohm

Non operating:-60V to +60V

Operating: max RMS input voltage to register 0 dBfs at median gain, 0.25V, at max gain: 8mV

\[
\frac{V_{\text{maxADCin}}}{\text{max\_amp\_gain} \text{ - tape\_in\_pad}} = 8.813 \times 10^{-3} V
\]

Equation 2.3

2.3.1.4 Analog Noise Tolerance

>100 dB SNR

\[
\text{max\_range\_of\_values} := 2^{16}
\]

\[
\text{dB\_dynamic\_range} := 20\log(\text{max\_range\_of\_values})
\]

\[
\text{dB\_dynamic\_range} = 96.33
\]

Equation 2.4
2.3.2 Outputs

2.3.2.1 Headphone

Max output level for 0dBfs audio signal: 3 V rms into 600 ohm load

2.3.2.2 Digital audio

A digital audio output must conform to the Sony/Philips Digital Interconnect Format (S/PDIF) interface as specified in (IEC-958) and is summarized as follows:

<table>
<thead>
<tr>
<th>Connector</th>
<th>RCA (phono)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal level</td>
<td>0.5 to 1V</td>
</tr>
<tr>
<td>Modulation</td>
<td>biphase-mark-code</td>
</tr>
<tr>
<td>Max. Resolution</td>
<td>24 bit</td>
</tr>
</tbody>
</table>

2.3.2.3 Serial data

2.3.3 Physical

The device should be of similar form to a PDA.

2.3.4 Environmental

The device must be operated within these listed operating conditions. The continued operation or reliable performance is not guaranteed if the device is subject to conditions outside of those given as “non-operating.”

Operating temperature: 32 – 95 degrees Fahrenheit.
Non-operating temperature: -4 – 113 degrees Fahrenheit.
Relative humidity: 5% - 95% non-condensing
Maximum operating altitude: 10,000 feet.

2.4 Implementation considerations

2.4.1 Standard manufacturing procedures

The design should be such that it can be manufactured using typical manufacturing procedures.
2.4.2 Prototype Considerations

It is desirable that the design is such that it can be prototyped using resources available to the team. This does not limit the design possibilities, but should be a guideline for comparing technologies.

2.5 Design deliverables

2.5.1 Fall semester

Team definition
Project definition
Project objectives
Alternative solutions
Task specification
Evaluation of feasibility
Budget
Project schedule
PPFS

2.6 System test plan, preliminary

Unless explicitly stated, all tests shall be performed:

- at ambient conditions of 20°C, 60% r.h, non-condensing, 1atm
- with measurement equipment calibrated and traceable to NIST standards
- upon products assembled with components identical to those used in standard production
- upon products unaltered, undamaged, and not under influences not encountered in normal operation, including, but not limited to: high energy RFI or EMI, atmospheric compositions hazardous to human life, contamination by liquids or vapors

2.6.1 Basic functionality test

Verification of operational functions listed above
2.6.2 Audio dynamics test
Verification of maximum and minimum input and output voltages

2.6.3 Audio bandwidth test
Verification of system frequency response

2.6.4 Audio phase response test
Verification of system frequency response

2.6.5 Audio analog noise figure measurement
Measurement of front-end noise

2.6.6 Audio digital noise figure measurement
Measurement of noise present in recorded digital audio

2.6.7 Audio sample period stability calculation
Analytical calculation to estimate accumulated or short term clock inaccuracy

2.6.8 Battery life test
Measurement of battery life under minimal, typical, and maximum power loading conditions
3 Design Development

3.1 Alternative solutions

There are other ways to address the problem statement.

3.1.1 Analog Output Preamp

One alternative solution for solving the problem could involve the use of an analog storage device such as the magnetic tape as the main storage of the audio signal input. This alternative could employ a high quality preamp, but no analog to digital converter, since the sound would be stored on a magnetic tape rather than a digital input storage device.

This solution however would come short of achieving all of our intended design objectives. It is provided only as a comparison to an existing method of audio recording. It would not allow the end user to take advantage of the fidelity and storage capacity of readily available digital audio storage devices. First, using an analog storage device would introduce all of the degrading effects associated with that medium. Second, using a traditional analog recording format, would most likely reduce the speed at which recorded audio could be manipulated after the initial recording. Furthermore it would be undesirably cumbersome to attempt incorporating the use of such cumbersome equipment alongside the streamlined and largely digital accessories available, such as an Apple iPod.

3.1.2 Commercially available alternatives providing connectivity to the I-pod

Some commercially available audio products such as the Apple I-pod and I-talk can be used for sound recording. The I-Talk by Griffin or Universal Microphone Adaptor by Belkin allow digital recording directly to the I-pod, but only at a telephone-quality sample rate of 8 kHz at 16 bit resolution, monaural. The I-Talk for instance allows digital recording directly to the I-pod, but only at a telephone-quality sample rate of 8 kHz at 16 bit resolution, monaural. Although this may be a plausible solution for spoken word recording, the single channel and limited sampling rate make it unsuitable for capturing true-to-life stereo audio. These products are also limited to use with the I-pod, not other USB devices.

3.1.3 Commercially available alternatives providing desired audio specifications

Many devices exist that meet our requirements for high audio fidelity. However, the majority of these devices are not designed for handheld, pocket, or other very-portable use. Tascom’s Cassette Recorder and Fostek’s Digital Recorder are examples of devices that provide excellent sound capturing ability but are not portable.
3.1.4 Commercially available alternatives providing desired audio specifications and connectivity

Currently, there are no known devices that provide our desired level of audio quality, portability, and connectivity. There are portable audio input devices available, but none that provide an interface to the Apple I-pod. The Sony MD Walkman is the nearest device to our specifications. It is a portable device that can record to a MiniDisc at good quality. This product was designed to function as a media player similar to a portable CD player. Our design would provide a cheaper alternative that would record to a single USB mass storage device instead of multiple MiniDiscs.

3.2 Research

The project design was divided into major blocks and each team member is responsible in carrying out research on the different components in a block, interface requirements and block specifications.

Nsimah is responsible for the preamp block, Andy is responsible for the ADC and output blocks, Patrick and Nate are responsible for both the Ipod communication and control blocks. So far, research on the preamp, ADC and output blocks are almost concluded but still having some problems with the USB block.
3.3 Preliminary Design Concept

3.3.1 Block diagram
3.3.2 Concept Drawing

Figure 3.1 artistic representation of device appearance

3.3.3 Analog front end

This block is essential for gain control of the line input or microphone input to the Digital Output Audio Preamplifier. It consists of three smaller blocks namely:

1. 48V block
2. Selection block
3. Differential amplifier block
3.3.4 48V block

This is the phantom power that is required by the internal electronics of microphones. It is 48V DC power supply in which its positive terminal is connected to both signal leads of a microphone and its negative terminal to the ground connection. This requirement would be met by using a DC to DC converter to convert our 6V power supply voltage to 48V for this block. The maximum short circuit current for each microphone input is given in Equation 3.1

\[ V_{\text{phantom}} := 48V \quad R_{\text{balance}} := 6100\Omega \]

\[ I_{\text{phantomMAX}} := \frac{V_{\text{phantom}}}{2R_{\text{balance}}} = 3.934 \times 10^{-3} \text{ A} \]

Equation 3.1

3.3.5 Selection block

This is made up of a selector that is used in connecting the analog signal and the microphone output as inputs to the differential amplifier. The line input requires a 3.5mm tip ring sleeve (TRS) phone jack connector while the microphone input requires a female three pin XLR connector. The selection block also incorporates a switch which is used to switch between both inputs.

This requirement would be met by using a single combination (selector) that has connections for both inputs and also incorporates an internal switch.

Suggested product is from Neutrik with model number: NCJ9FI – H – O

3.3.6 Differential amplifier

This is made up of the preamplifier that is used for gain control. It takes in either the line input or microphone input and amplifies it, depending on the required gain. Gain range is between 0dB to 90dB.

This requirement would be met by using a digitally controlled preamplifier. Reasons for choosing the digitally controlled preamplifier include:

- It does all its amplification in this single chip.
- Eliminates the time required to put different circuits together.
- Draws less power.
- Reduces space required in placing all the components.
- Does not require additional buffers, decoders or multiplexers.
- Eliminates the cost of the afore mentioned components
Suggested product is from Texas instruments with model number: TI PGA2500.

3.3.7 A/D conversion/ digital audio

3.3.7.1 Digital Audio circuitry

Clock

Analog to Digital Conversion

Digital Signal Formatting

3.3.7.2 Requirements to be met

This functional block is comprised of circuitry to provide the following: a system master clock, analog to digital conversion, and digital signal encoding.

3.3.7.3 System clock

The system clock will generate the master time-base for all digital operations. The clock shall operate within the physical constraints typical of a device such as the DOAP. The clock shall have provision to output multiple frequencies based on the requirements of the dependant hardware. The clock shall exhibit the best available period stability.

3.3.7.4 Analog to Digital Converter, ADC

The ADC will generate the digital pulses to represent the analog signals from the preamplifier outputs. The ADC shall have two analog inputs and a single digital output. The analog input ratings must be compatible with the output ratings of the preamplifier circuitry; this will likely be accomplished by modification of the preamp output specifications. The digital output will be a clocked serial-mode I2R Left justified PCM type.

The ADC must operate at a sample rate compatible with digital audio standard formats. If the option is given for using multiple formats, the sample frequencies will be 32, 44.1, and 48 kHz. If a fixed rate is used, it will be the CD-audio standard, 44.1 kHz. For all output rates, the data should be over-sampled by, at minimum, 32x. Our research indicates that this provision will sufficiently minimize the effects of quantization noise in our design.
3.3.7.5 Component options

A number of solutions for our presented needs were found to be available from three main suppliers. Analog Devices, Philips Semiconductor, and Texas Instruments all have comparable products. It was found that Texas Instruments has the most comprehensive offering of products and support, especially for new product development.

3.3.7.6 Comparison Matrix

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Manufacture</th>
<th>Model</th>
<th>PCMax fs max (kHz)</th>
<th>sys clk typ (MHz)</th>
<th>Jitter (ps)</th>
<th>SNR (dB)</th>
<th>Vcc (V)</th>
<th>Vdd (V)</th>
<th>Vin_a (V)</th>
<th>Power packagelow mW</th>
<th>Package price</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI high perf ADC Burr Brown</td>
<td>PCM4202</td>
<td>24</td>
<td>192</td>
<td>33.8688</td>
<td>N/A</td>
<td>105</td>
<td>5</td>
<td>3.3</td>
<td>5.0</td>
<td>300 SSOP-28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLL Burr Brown</td>
<td>PLL1700</td>
<td>N/A</td>
<td>N/A</td>
<td>27</td>
<td>150</td>
<td>5/3.3</td>
<td>5/3.3</td>
<td>110 SSOP-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>power amp TI</td>
<td>TPA6111A2</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>100</td>
<td>5</td>
<td>N/A</td>
<td>130 .35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TI high integ CODEC</td>
<td>Codeas InstrumTLV320AIC23B</td>
<td>32</td>
<td>96</td>
<td>18.43</td>
<td>90</td>
<td>3.3</td>
<td>3.3</td>
<td>1.0</td>
<td>100+ PQFP-28, TSSOP-32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philips integ CODEC</td>
<td>PhilipsUDA1380</td>
<td>24</td>
<td>55</td>
<td>19.2</td>
<td>85</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>100+ TSSOP-32</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.8 USB communication

Product Alternative:

Below is a list of other USB controllers that could work well for the digital output audio preamp.

Philips: Package version-SOT414-1, Package name-LQFP64. (http://www.semiconductors.philips.com/package/SOT414-1.html), Type number-ISP1161A1BM.

Philips: Package version-SOT314-2, Package name-LQFP64 (http://www.semiconductors.philips.com/package/SOT314-2.html), Type number-ISP1161A1BD.


NB: Based on what I found through research, we might want to consider selection of some microcontrollers in case we have to use some microcontroller.

The above specifications are mainly for the USB controllers (chips). Other alternatives could be to acquire a USB board that has the controller already in place. The demerit of this choice is that we would be stuck with the original controller even if it does quite meet our specifications.

Below are some ideas for board:

USBSIMM Board. ([http://www.usb-by-example.com/Examples/devboards.htm](http://www.usb-by-example.com/Examples/devboards.htm)) -----$70.00


<table>
<thead>
<tr>
<th>Make</th>
<th>Package name</th>
<th>Type/Product number</th>
<th>Package Version</th>
<th>Costs</th>
<th>Feasibility</th>
<th>Size</th>
<th>Ease of Use</th>
<th>Total</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
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<td>ISP1161A1BM</td>
<td>SOT414-1</td>
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<td>4</td>
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<td>5</td>
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<td>too costly. $495</td>
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<td>EZ USB DEV KIT</td>
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<td>CCS USB PROTO KIT</td>
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<td></td>
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<td></td>
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<td>0</td>
<td></td>
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</tbody>
</table>

Table 3.1 a decision matrix for choosing USB controllers
3.3.9 Power distribution

3.3.10 User interface

3.4 System description

3.5 System analysis
3.6 Project Plan

3.6.1 Group Organization

Divided work for individuals to concentrate on.

3.6.2 Time Schedule

See appendix a

3.7 Contingencies

What if we can’t do iPod? What if we can’t do USB?

There are many things that could go wrong with our project. Listed below are some of the safeguards we’ve taken to avoid these possible problems.

Loss of Data

We have backed up all of our files onto multiple mediums so that any loss of data will be easily replaced.

Sickness

We have scheduled the workload in such a way that if one of our team mates were to get sick, we would be able to accomplish their tasks before specified deadlines.

Parts

We have determined multiple sources as well as multiple possibilities for many of the parts we are using in our design. If a particular distributor failed to deliver our order, we would be able to switch to a different distributor or slightly alter our design.
4 Feasibility

4.1 Marketability

This device seeks to fill a gap in the present consumer-audio electronics marketplace. Currently, we have not found a commercially available device which has all the features of our intended design. We hope to satisfy a desire of many musicians and audio enthusiasts who want to be able to easily make good quality live recordings. This ability could benefit many other areas such as in the documentation of events in business, education, government, and churches. We have all witnessed how the ability to transfer and playback digital audio has increased dramatically in the last five years, but the ability to easily create such content by average people has not grown as drastically. Our plan is to eliminate the need for a personal computer in the audio-file creation process. We would like to make it as easy to create CD-quality audio recordings as it is to press a button on a cassette tape recorder.

Recent market studies show that Apple expects to have sold over 100 million i-pods by the year 2008. With current sales of over $264 million this year for the I-pod, and with the numerous similar products in production, digital audio has an enormous, fast growing following. Current CD sales have fallen slightly to $656.2 million making room for MP3 sales, showing that music enthusiasts are still prevalent but many are switching to portable MP3 players over compact discs. Also, ½ of all households have at least 1 person that plays a musical instrument. With the introduction of the software programs Garage Band and Acid 3.0, sales for home recording software have also risen over the last year.

4.2 Product Feasibility

4.2.1 Cost Estimates

Project cost, prototype cost, production cost. Funding. Budget.
<table>
<thead>
<tr>
<th>Development Cost</th>
<th></th>
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</thead>
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<td>evaluation boards</td>
<td>200.00</td>
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<td>lab/shop consumables</td>
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<td>publication expenses</td>
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<td>miscellaneous expenses</td>
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<td><strong>Sub Total</strong></td>
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</table>

<table>
<thead>
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<th>Per Unit Costs</th>
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<td>digital control op amp</td>
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</tr>
<tr>
<td>clock pll</td>
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</tr>
<tr>
<td>adc</td>
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</tr>
<tr>
<td>usb codec</td>
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<tr>
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<tr>
<td>passive components</td>
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<td>connectors</td>
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<td>hardware</td>
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<td>enclosure</td>
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<tr>
<td><strong>Sub Total</strong></td>
<td><strong>$146.50</strong></td>
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</tbody>
</table>

**Total Project Cost**

$596.50
5 References

5.1 Useful reading


Klein, Paul M. Compression Techniques Encode Audio Signals For Digital Processing. EDN: October 13, 1994

5.2 Internet resources

http://www.pcworld.idg.com.au

http://www.macminute.com/

http://www.macnn.com/
5.3 Professional Consultation

Our overseeing faculty arranged a meeting for us with an industrial consultant from a local engineering company. We met with Mr. Tim Theriault from a nearby branch of Smiths Aerospace. Mr Theriault is a Director of Hardware Technology, and has much experience in project management. He graciously examined our project and offered useful suggestions to help us address our project demands more successfully. We anticipate positive results from his specific suggestions about establishing an expert contact to assist our USB development, and recommendation that we establish verifiable sub-goals to quantify our progress.

We have also been in frequent communication with Mr. Carl Hordyk. Mr. Hordyk, is the Manager of Technical Services at Calvin College. He has been a continuing source of ideas and practical information regarding audio equipment and recording. We owe thanks to him for his recommendation that we pursue development of support for all mass-storage class USB devices.
6 Appendix

a. Time schedule

<table>
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<tr>
<th>Task Name</th>
<th>Duration</th>
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<td>Declare component specification</td>
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<td>Make a parts list</td>
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<td>Identify viable design alternatives</td>
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<td>Develop prototype implements</td>
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<td>Use available CAD tools</td>
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<tr>
<td>Test PCB prototype</td>
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<td>Sat 10/31/04</td>
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<td>Refine circuitry for final prototype</td>
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<td>Define enclosure requirement</td>
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