MusicMan Communications System

Dan Strengier

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

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Senior Project

Table of Contents:

Acknowledgements:

I would like to thank Dr. Dennis Derickson at Cal Poly San Luis Obispo for providing guidance and encouragement to complete this project.

I. Introduction:

The MusicMan portable music mixer is a solution for users who enjoy listening to music and would also like to communicate to friends on a walkie-talkie system. The MusicMan provides the user the ability to simultaneously listen to an MP3 player and operate a communications device, such as a walkie-talkie. This product allows users to listen to music and use their walkie talkie.

II. Background:

The inspiration for this product came from witnessing many skiers and snowboarders listening to music while riding and being unable to communicate with their group. Myself, like many snowboarders and outdoorsmen, enjoy listening to music while riding. However, once group members put their headphones on to listen to music, all conversations stop and communication is limited. Combined with a walkie-talkie, this product allows communication to occur between people while listening to music.

III. Requirements:

The MusicMan Features:

- Two inputs: Walkie talkie in, MP3 in.
- One output: Outputs either walkie-talkie or MP3 audio signal. Must preserve left and right channels of both voice and MP3 signal.
- Analog signal processing on the MP3 signal: stereo equalizer that provides automated digital bass boost/cut, and an analog treble boost/cut.

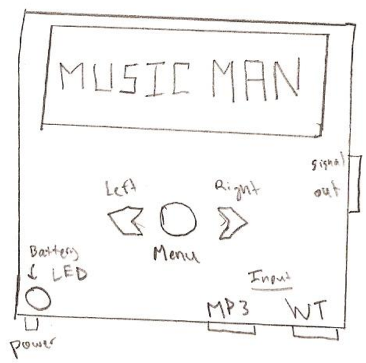
IV. Design

Proof of Concept:

The MusicMan, in its current incarnation, is too big to be used in the field. Ideally, it would be entirely integrated into a walkie-talkie. All that would be required is an extra audio port on the walkie-talkie to accept a MP3 player input. The walkie-talkie’s pre-existing headphone jack would then properly switch between music and conversation, as demonstrated by the

MusicMan. As is, the MusicMan is housed in a box far too large to ever practically be used. It has been built to demonstrate the functionality and performance of such a product.

Instead of integrating the functionality into a specific walkie-talkie, the MusicMan could be shrunk to far smaller proportions and allow any walkie-talkie to interface with it. A possible form-factor picture for a commercial product is shown in Figure 1.



Artist Rendition of Final Product
Figure 1

Design Overview:

The goal of this project was to create a working prototype that interfaces with walkie-talkie and MP3 players currently on the market. It was designed as a stand-alone product that any MP3 player and walkie-talkie could plug into it.

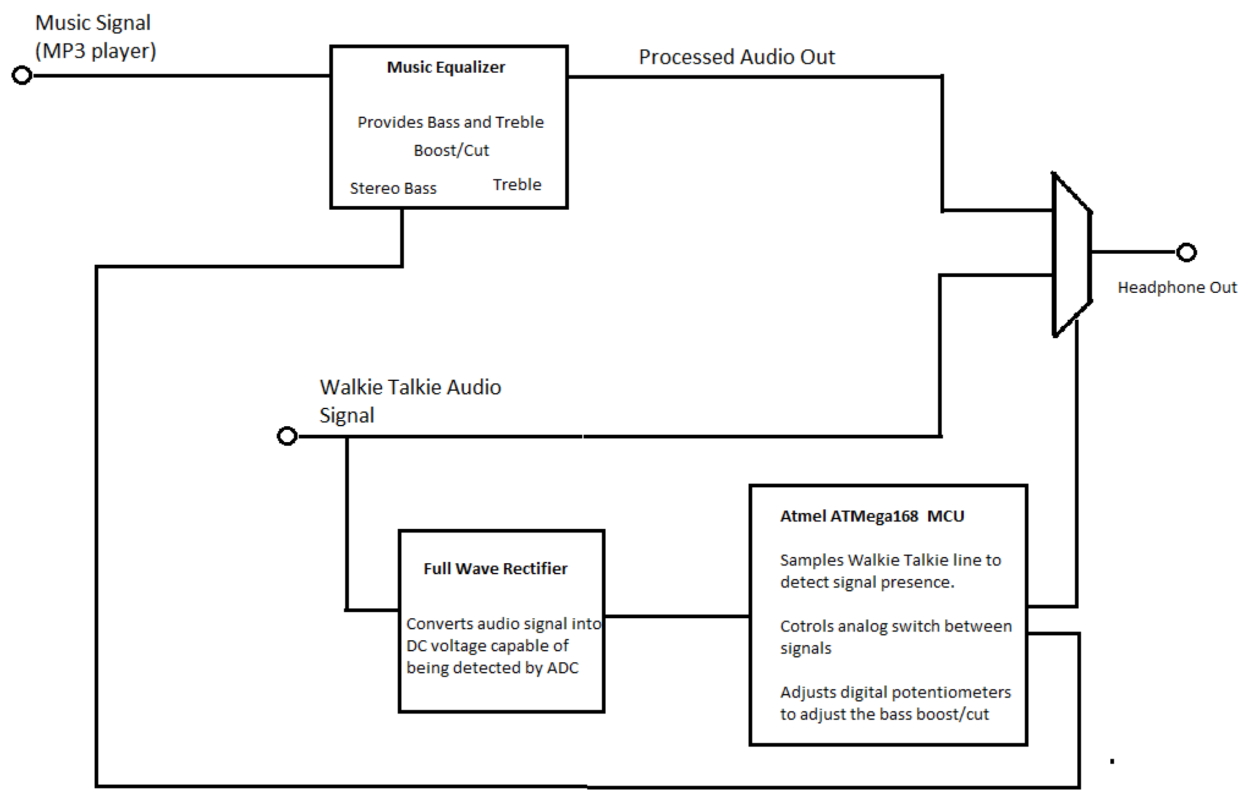
The walkie-talkie signal is fed into the MusicMan by connecting a 1/8'' chord into its headphone jack and connecting the other end to the MusicMan walkie-talkie input. Walkie-talkie's that don't have a headphone-out port are not compatible with the MusicMan. An 1/8'' chord also connects an MP3 player to the MusicMan, and headphones plug directly into the MusicMan headphone-out.

The main difficulty of this project was to cheaply and effectively determine the presence of an audio signal on a walkie-talkie line.   Multiple approaches were analyzed.

Through the walkie-talkie's headphone-out jack, an audio signal above and below ground is outputted, with amplitudes of approximately 100mV for low volume signals to 1.4V for large signals. To detect the signal presence, it was realized that some type of AC-DC conversation would be needed. The final solution incorporated amplifying the WT signal and then using AC-DC conversion through full-wave rectification. The amplification allowed sensitive detection for both low and loud volumes of walkie-talkies.

To control the analog switch, a comparator or MCU could have been used. Utilizing a MCU to sample the processed the walkie-talkie signal allows flexibility in adjusting the threshold of detection, and this design option was chosen. The WT signal is split, sent both to the analog switch and the detection circuitry. This made it important to design the detection circuitry with high impedance so as not to draw too much current from the WT signal. This would attenuate the signal that reaches the output port.

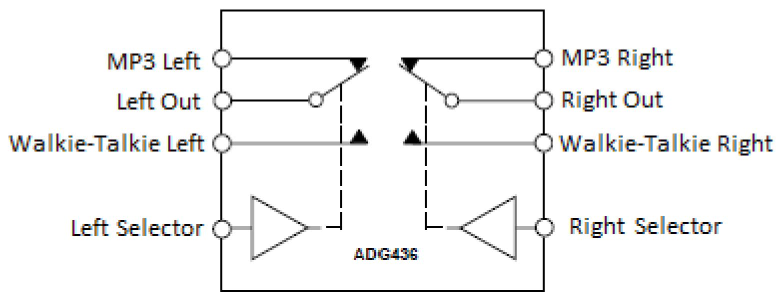
The MP3 signal travels through Bass and Treble processing before entering the analog switch. The switch is controlled by the MCU. The functional diagram is shown in Figure 2.



Functional Block Diagram
Figure 2

Analog Switch: ADG436B

The switch controlling the signal routing is a single pole double throw analog switch with a low on resistance (12 ohms) which provides the mechanism to switch between walkie-talkie and MP3 signals. The output signal is determined by the voltage applied to the selector signals. The microcontroller supplies the signal to the selector line to switch between the appropriate signals. It's functional layout is shown in Figure 3.



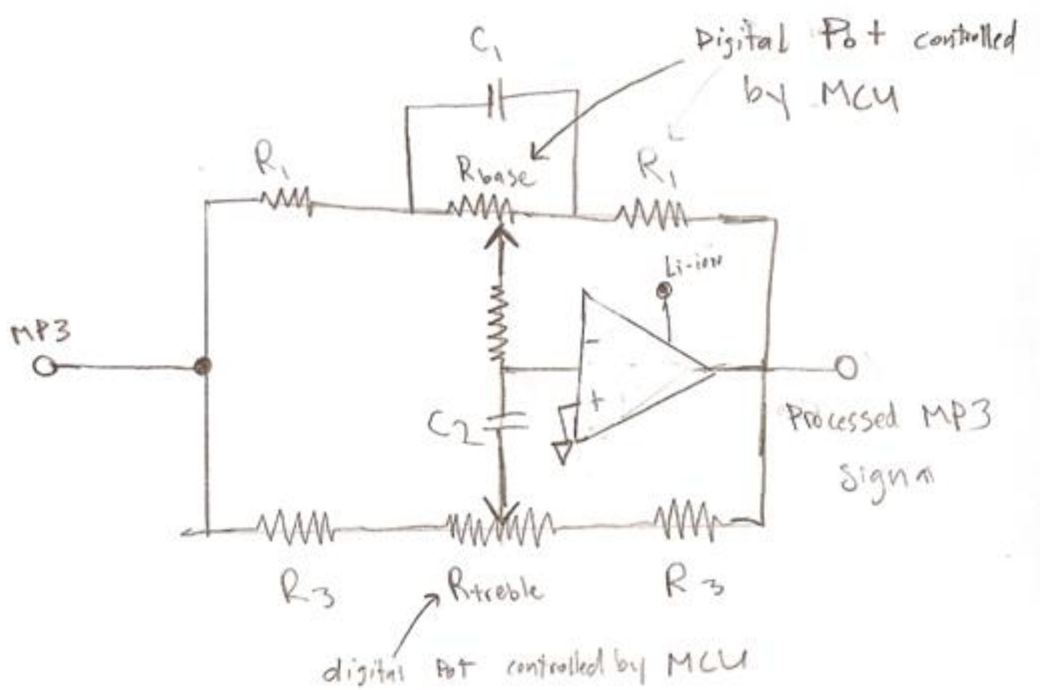
ADG436B
Analog Switch
Figure 3

MP3 Equalizer Circuit:

The MP3 audio equalizer circuit features an active filter that boosts and cuts bass and treble frequencies, and is shown in Figure 4. A digital potentiometer controlled by the MCU, adjusts the gain of the bass. A normal potentiometer adjusts the treble, and is controlled by manually turning the treble knob on the case. The original design and its derivation is found in Design with Operatinal Amplifiers and Analog Integrated Circuits by Franco. The circuit was designed to amplify and attenuate frequencies below 30Hz and above 10 KHz by 20dB. This circuit does not provide midrange frequency modification. Its frequency response can be seen in Figure 5. The MusicMan features two of these circuits, one for left and right audio.

R1 = 11k R2 = 100k pot (digital) R3 = 3.6K R4 = 500K pot R5 = 11K C1 = 47nF
C2 = 5.1nF TL-081 Op-amp

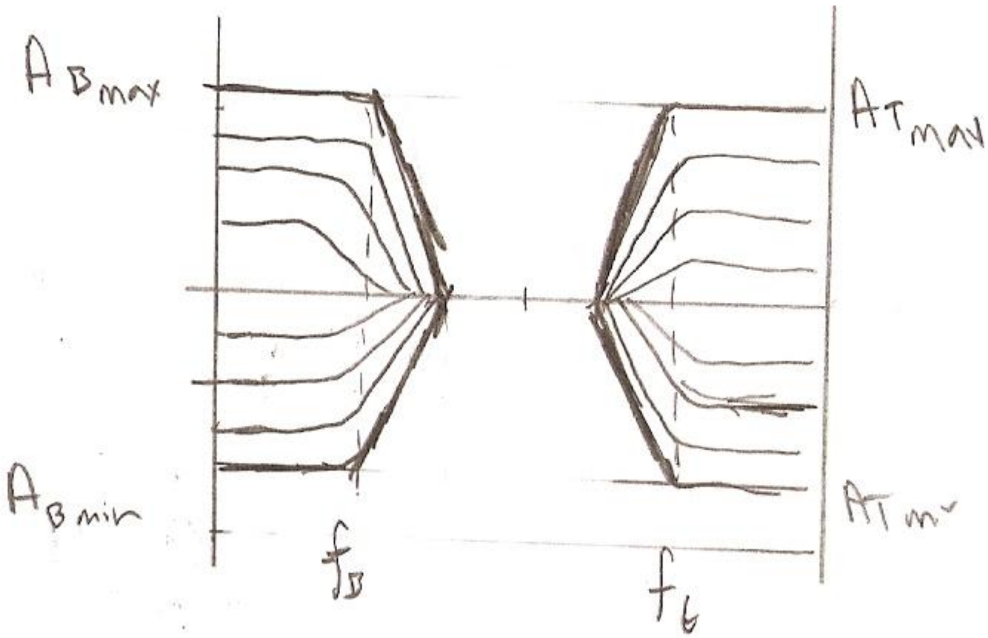
Max Attenuation/Amplification = 20dB



$$\frac{R_1}{R_1+R_2} \le A_B \le \frac{R_1+R_2}{R_1}$$

$$\frac{R_3}{R_1+R_3+2R_5} \le A_T \le \frac{R_1+R_3+2R_5}{R_3}$$

MP3 Equalizer circuit
Design by Franco
Figure 4

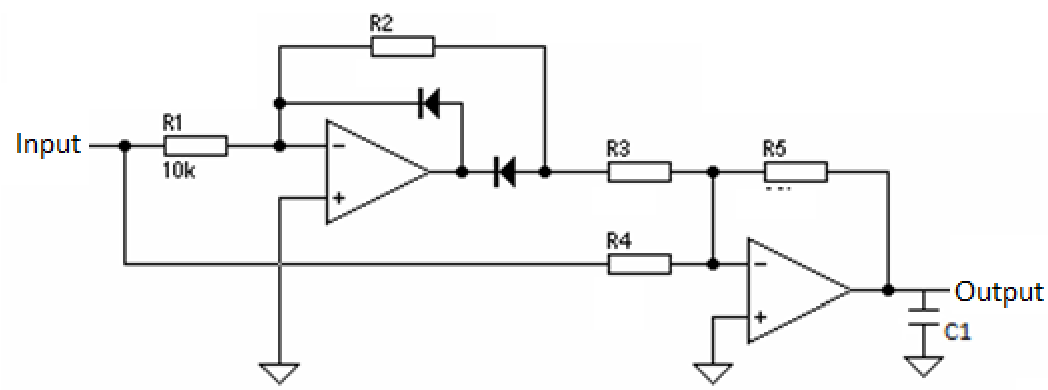


Frequency response of equalizer (Franco)
Figure 5

<u>Full Wave Rectifier:</u>

Prior to being analyzed by the microcontroller's analog to digital converter, the walkie-talkie signal is fed through a full-wave rectifier. This circuit also amplifies the signal with a gain of 10. This amplification allows small signals present on the walkie-talkie line to be detected. Original design from Franco, shown in Figure 6.

R1 = R2 = 10K R3 = .5 (R4) = 10K R4 = 20K R5 = 200K
Gain = R5/R4 = 10 TL-081 Op-Amp



Full Wave Rectifier
Figure 6

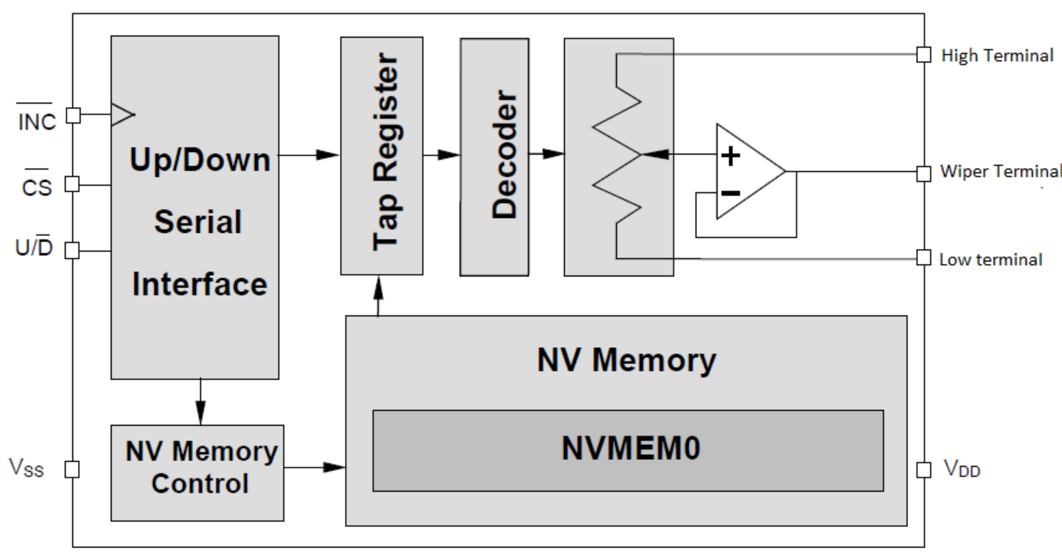
100KΩ Digital Potentiometer: WMS7170

The WMS7170 is a potentiometer controlled by three digital signals: chip select, increment, and increment direction pins. When CS' is held low, the digital pot is enabled. A high voltage applied to U/D' forces the wiper terminal to move one increment towards high terminal. When a clock signal is applied to INC', the wiper terminal moves one increment towards the terminal dictated by U/D' (if U/D' is high, the wiper moves towards the high terminal, and when U/D' is low, moves towards the low terminal). This occurs on the falling edge of the clock signal, and the clock signal is provided from the microcontroller. The WMS7170 is non-volatile so that it the wiper will retain its position when not receiving power. The MCU is in charge of providing the appropriate signals to increment and decrement the digital pot. It's functional diagram is shown in Figure 7.

A considerable limitation to using the digital pot is its predicted 100,000 write cycle lifetime. With the application used in the MusicMan, the wiper position is being changed 10 times a second. After 3 hours, the write limit will have been exceeded.

10 writes/second x 60 seconds = 600 writes/min x 60min = 36,000 writes per hour. 100,000 / 36,000 = **2.78 hours**/100,000 writes.

Few practical applications would require constant changing of the digital potentiometer as frequent as done in the MusicMan, but this limitation should be considered. After running the MusicMan for over 4 hours, the digital potentiometer seems to still be working fine.



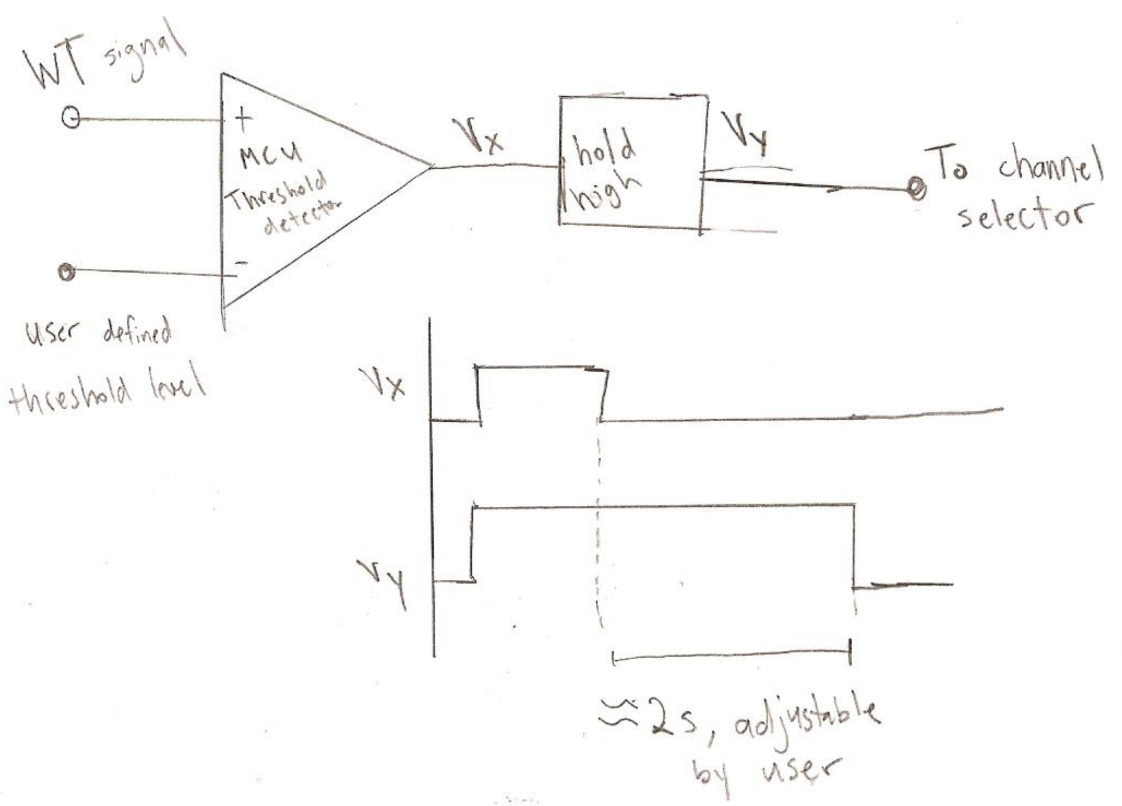
WMS7170
Digital Potentiometer
Modified from WMS7170 datasheet
Figure 7

Microcontroller Functionality and Requirements: ATMega168

Atmel's ATMega 168 microcontroller was selected due to its economical price, ease of use, performance and assortment of input and output pins. Future prototypes will utilize a smaller microcontroller to conserve space and cost.

Within the MusicMan, the ATMega168 constantly polls the walkie-talkie line to determine if the signal present is above a programmed threshold. When the signal is above this threshold, it signifies that the walkie-talkie signal is present and that someone is talking. An analog to digital converter pin on the ATMega168 is used to sample the signal line, after it has been full-wave rectified and converted into a roughly DC signal.

At the onset of signal detection, the ATMega168 asserts the switch control lines to route the walkie-talkie through the output jack. After the signal is no longer present, the microcontroller momentarily delays switching back to the MP3 to ensure that the user is done talking. After a roughly 1.5 second duration of an absence of the walkie-talkie signal, the microcontroller de-asserts the switch control lines to allow the MP3 signal to pass through the output. This functionality can be visualized in Figure 8.



Conceptual functionality of microcontroller comparator
Figure 8

The microcontroller also interfaces with the audio EQ circuitry to dynamically change the bass response of the MP3 signal. Every 100ms the microcontroller provides a signal to increment a digital potentiometer 1kilo-ohm, which increases the gain of low frequency signals. Proper interfacing with the digital potentiometer requires the microcontroller to provide an appropriate clock signal and control lines to the potentiometer as stated in the potentiometer's specifications.

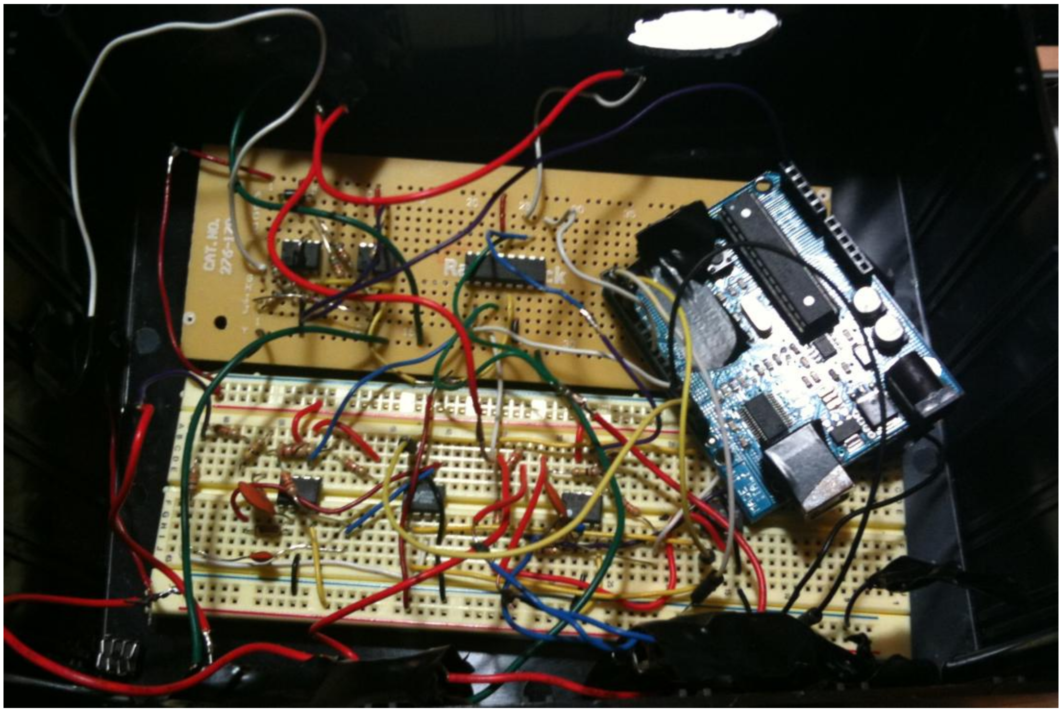
After 10 seconds, the microcontroller then decrements the potentiometer every 100ms. This produces an effect of the bass response dynamically changing with time. It should be noted that this feature is implemented merely for novelty and for the sake of learning. Few consumer's would think this feature to be of value. However, having digital control over the MP3's frequency response demonstrates that a digital interface to change the EQ would be easily implemented. For example, the press of a button would cause full bass cut or boost, or a flat response.

V. Construction:

The switching circuitry that routes the MP3 and walkie-talkie signal to the output pin was soldered onto a PCB, with wires attached to the microcontroller and the active equalizer. The equalizer was built using a soldered breadboard due to time constraints. Also, 1/8'' headphone stereo connecter's are used to separate the left, right, and ground signals from all audio signals.

The MusicMan is enclosed in a plastic case with three ports for the 1/8" headphone connecters to fit into, as well as holes for the treble know and power supply wires. Pictures of the final construction can be seen in Figures 9 and 10.

Front of case
Figure 9



Innards of Case
Figure 10

VI. Testing

The switching circuitry was built first onto a breadboard. Prior to amplifiying the WT signal, it was difficult to detect it's presence. After designing the full-wave rectifier to provide large gain to the signal, the microcontroller was easily able to detect its presence. The microcontroller simply adjusts the analog switch selector line appropriately to route the correct signal through the output.

Also, the walkie-talkies used for this project produce an odd voltage spike after a transmission is over. After approximately 400ms after a transmission is finished, the walkie-talkie produces a voltage on the line that does not represent an audio signal. Through software, this problem was overcome by ignoring the voltage spike after transmission occurs.

The microcontroller constantly sends data to a computer through its USB port to facilitate troubleshooting. I have programmed the MCU to send the current ADC sensor reading, the highest sensor reading that has occurred in the last 200ms, and various programming variables to ensure that the hardware and software are functioning properly.

VII. Conclusions and Recommendations:

The MusicMan effectively switches between walkie-talkie and MP3 signals. The effect sounds smooth and coherent, and all user's that have tested out it's functionality were impressed by it's functionality. In this regard, the project is a success as a proof of concept.

The audio circuitry also performs admirably well. The bass responds well to the EQ filtering, providing a powerful bass signal when at max boost and almost unnoticeable signal at maximum bass cut. Two separate op-amps were purchased and tested for the EQ state, which included a standard TL-081 and a specially designed audio Op-amp, the LM833. The TL-081 sounded identical to the LM833 but was far less expensive. The final product exclusively uses TL-081 op-amps. Also, it was quite enjoyable to hear the microcontroller dynamically altering the frequency respose by controlling the digtal potentiometer. I would like to conduct further experiements using a 7band equalizer stange controlled exclusively by a microcontroller with random adjustments of all the settings.

The next stage of the project involves shrinking the MusicMan as much as possible so that it could actually be used in the field. It will require a small microcontroller with as minimal input and output pins as possible to preserve space. Ideally, a custom PCB will be made to support surface mount chips. The success of this product in the market heavily depends on its size and obtrusiveness for connecting MP3 and walkie-talkie devices to it.

Methods of cordlessly powering the device will also need to be investigated. After the appropriate legal steps are determined, this product will either be shopped around to walkie-talkie makers or I will attempt to make a small-business out of it. This should occur in the coming year.

VIII. Bibliography

Fraco, Sergio. Design with Operational Amplifiers and Analog Integrated Circuits. 3rd edition. McGraw-Hill, New Delhi. 2002

Appendix A:

Bill of Materials

Part	Type	Quantity	Total Cost ($)
TL-081	Op-Amp	4	2.72
ATMega168	Microcontroller	1	4.90
ATMega Interface Board	Development Board	1	30.00
ADG436B	Analog Switch	1	4.44
WMS7170	Digital Potentiometer	2	7.60
100k Potentiometer	Potentiometer	1	4.99
Radioshack Breadboard	Breadboard	1	11.99
Radioshack Protoboard	Protoboard	1	8.00
1/8’’ Stereo Connecters	Audio Connector	3	6.35
1N4001	Diode	2	1.80
Ceramic Capacitors	Capacitor	5	2.80
Plastic Case	Case	1	6.00
Insulated wire	Wire	1	7.99
Resistors	Resistor		
		Total Cost:	**$99.61**

Appendix B:
Functional Code

```
#include "WProgram.h"
void setup();
void loop();

//*********Initialize Variables************************************
int sensorValue = 0;  //stores current sensor reading from the ADC
int wtLevel = 0;     //Stores highest level signal has achieved in the last 200ms

int IncrementPin = 4;  // Defines location of output pin on MCU (digital pot interface)
int CountUpPin = 2;  //  Defines location of output pin on MCU (digital pot interface)

 int FirstTime =1;   //flags that deal with voltage spike glitch after a transmission has ended
int FirstPass=1;

int LOW = 0;   //used to facilitate code readability
int HIGH = 1;

int w =0;     //variables used for looping and delays
int x = 2;
int y =0;
int k;
int d = 0;
long t;
int count3 = 0;
int AdjustPots;

//*************************************************************
void setup()
 {
  AdjustPots = 1;
//Sets up general purpose in/out pins to output or input
   pinMode(12, OUTPUT);
   digitalWrite(12, LOW);

   pinMode(8, OUTPUT);
   digitalWrite(8, LOW);

   pinMode(IncrementPin, OUTPUT);
   digitalWrite(IncrementPin, LOW);
```

```
  pinMode(CountUpPin, OUTPUT);
  digitalWrite(CountUpPin, LOW);

  pinMode(8, OUTPUT);
  digitalWrite(8, LOW);

}



void loop()
{

if (AdjustPots == 1)  //turns both potentiometers to right-most position so they both equally
                         //increment. Otherwise, the pots could be out of phase with each other and
                          // user would hear different bass response in each headphone
 {
  AdjustPots = 1;

        for (k=0; k<120; k++);
              {
                pinMode(IncrementPin, HIGH);
                  for (t=0; t<200; t++);
                 digitalWrite(IncrementPin, LOW);
                 for (t=0; t<200; t++);
              }


        }

  x = x+1;
  sensorValue = analogRead(2);      //reads voltage present on pin 2

              //Sends data through serial port to computer:
               Serial.print(sensorValue);
                Serial.print("    ");
                Serial.print(wtLevel);
                Serial.print("    ");
                Serial.print("   Count: ");
                 Serial.print(count3);
                Serial.print("   //  ");
                Serial.println(x);
```

```
 if (sensorValue > wtLevel)
             { wtLevel = sensorValue;
             }




 w++;

//Produces necessary clock pulse to increment digtal pot
if (w>5)
            {
                        w =0;
                      count3 = count3+1;

                       if (count3 == 100)
                         {
                                 digitalWrite(CountUpPin, HIGH);
                         }
                      else if (count3 == 200)
                            {
                              count3 = 0;
                              digitalWrite(CountUpPin, LOW);
                            }

      digitalWrite(IncrementPin, HIGH);

             for (t =0; t<20000; t++);
                  digitalWrite(IncrementPin, LOW);


 }




 if (x>2)
           {
            x = 0;
             }

   if (x==0)
```

```
{


if (wtLevel >=800)  // Threshold that determines if a signal is present.
    {

      FirstPass = 1;


        digitalWrite(12, LOW);    //Route walkie-talkie signal to output
        digitalWrite(8, LOW);
        wtLevel=0;
        y++;
        d=0;

    }
    else
    {

      if (FirstPass == 1)              //route audio-signal through, deal with voltage glitch
      {
       FirstPass = 0;
        for (t =0; t<600000; t++);
         digitalWrite(12, HIGH);
           digitalWrite(8, HIGH);
           wtLevel = 0;
      }

          // for (t =0; t<200000; t++);
          // if (d ==2)
          // {
             y=0;

          FirstTime = 1;


          //  }

    }
  }
}
```

Appendix C: ABET Accreditation

Analysis of Senior Project Design

Project Title: MusicMan Communication System
Students Name: Dan Strengier
Student's Signature:

Advisor's Name: Dennis Derickson
Advisor's initials:

Student's Name: Dan Strengier

Summary of Functional Requirements:
Accepts MP3 and walkie-talkie input signal, provides one headphone output. When no one is talking on the walkie-talkies, the MusicMan outputs the MP3 signal. When communication is occurring over the walkie-talkie, the MusicMan outputs the walkie-talkie signal.

Primary Constraints:
Effectively interfacing with audio signals.

Economic Costs:
Estimated cost of component parts: $50
Actual cost ofcomponent parts: $99.17

Equipment required to design, test and build:
Multimeter, oscilloscope, power supply.
Original estimated development time: 100 hours
Actual development time: 70 hours

Bill of materials:

Part	Type	Quantity	Total Cost ($)
TL-081	Op-Amp	4	2.72
ATMega168	Microcontroller	1	4.90
ATMega Interface Board	Development Board	1	30.00
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Insulated wire	Wire	1	7.99
Resistors	Resistor		
		Total Cost:	**$99.61**

Environmental and Sustainability:
The MusicMan was soldered entirely using lead-free solder, and all electronic components used were ROHS compliant. The PCB and plastic case are unlikely to be easily recycled.

Ethical, Social, Political, Health, and Safety:
The MusicMan provides stereo output would realistically be used to drive a pair of headphones for the user. The active user who enjoys riding bikes or skiing must check with local law enforcement to see if it is legal to ride with two headphones. Oftentimes it is legal to ride bikes with two pairs of headphones. The user could be putting themselves and others in danger by using the MusicMan with both ears. If it is legal, and they choose to, caution should be taken to ensure safety of surrounding people and themselves.

Currently, music players are frequently seen on ski resorts and accidents have occurred because people become unaware to their environment when using two headphones. While this will unlikely become illegal in the near future, especially since ski resorts are private property, allowing people to use two headphones is of questionable ethical grounds. Certainly it would be unethical to wear two headphones in all of the cases of physical activity, but responsible users can ascertain when it is appropriate and safe to wear two headphones.