Motivational MP3 Player

Adam Browning, Neil Jacildo, Brian Wirth

Dept. of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450

***Abstract* – Physical activity is the key to a healthy lifestyle. The human body needs a way to use up the energy it obtains from eating, that is, if one does not wish to become overweight. Thus, it was desirable to create a device which helps people get motivated to work out. It was decided from the beginning that music should be one of the main components in helping people achieve their fitness goals – as most everybody has a general love for music. The next step was bringing the luxuries of indoor exercise equipment *to* the user – aka, a portable device which can be taken anywhere, anytime, by anyone.**

***Index Terms* – Electrocardiograph, Health/Fitness, Microcontrollers, MP3, MSP430, SD Memory, ADC/DAC, Capacitive Touch, MP3,**

I. INTRODUCTION

The Motivational MP3 Player is an audio media playing device that is customized to promote a unique and effective exercising experience. The personalized exercise-enhancing experience of the player will be achieved by utilizing the user health information delivered to the device and customizing the music selection and playback based on that information.

The user data will consist of details about the individual and the current calculated heart rate of the user, which will be retrieved by a designed electrocardiograph module. The specialized playmodes utilized by the user data will establish the pace of the exercise by playing different songs with similar tempo. This player will enable uploading music libraries to the external flash memory of the device and executing the typical functions of a MP3 player. The MP3 player will include an external flash memory device for storing the audio files and user data, a capacitive touch control pad for navigating the device, a LCD to display the user interface, an EKG module to measure the user heart rate, one microcontroller dedicated for the touch control input and LEDs and another microcontroller dedicated for audio firmware, retrieving, decoding, and playmode algorithms.

The primary motivation for the design is to promote exercising activities with the inspiration of music, and also to allow people who do not prefer to work out on stationary machines to take an effective workout device to desired locations (e.g. running trails, neighborhoods, mountains, etc). The key element of applying personal user data to specialized music modes establishes a unique approach for MP3 players assisting in exercising. Enhancing the music's playback speed will engage the user and influence the exercise pace to work harder or to cool down. Personalizing a MP3 player device to a user will help motivate a person to exercise and build confidence for improving one's health. The user will be able to input their information and keep track of the progress made through each exercise session. This device is aimed towards the demographics who are interested in improving their health but lack the motivation to exercise.

To learn how to begin designing an MP3 player, other projects had to first be researched. Projects involving the decoding of MP3 files and DAC/ADC conversions were looked at, and various components studied. In this phase, many different microelectronic components were researched in detail, and a good idea of how to approach designing the MMP3P was resolved. In the final stages of design, a reference board (the MSP430 Launchpad) was used as a reference guide for laying out a suitable MP3 platform, for this reference board has all the features of MP3 decoding, USB communication, and microcontrollers complete with codecs and DAC/ADCs.

II. MOTIVATION

This project, the Motivational MP3 Player, is based on the motivation of building a portable device that can monitor bodily changes and communicates that information through the use of music. An indoor treadmill and other cardiovascular exercise equipment allow a person to change the pace of their exercise depending on their focus or goals. These equipments also have additional features that can help a runner keep vital data or keep them entertained by listening to a television or music. But the main disadvantage of these machines is the restriction of keeping a person stationary during their workout and not being able to cover actual distances while utilizing these applications. The motivation of this design is to bring the convenience of data features of an indoor treadmill to the freedom of outdoor use with hands-free technology simulated through music and activated by the dynamics of the human body.

The features of a treadmill can help a runner dictate the type of run they would like to have. Compared to running on a track or outside, it can measure and maintain crucial information (i.e. heart rate, distance, time) about the run. But in contrast, running on a treadmill has its difficulties of slowing down or increasing your pace since it is dependent on the machine. Treadmills can also cause runners to feel motion sickness or even vertigo. This project is hoped to create a crossover between the aid of treadmill technology and the portability of an MP3 player to promote the freedom of running wherever.

The Motivational MP3 Player will have the expected options and modes of a typical music player, but this device will also incorporate a more health-centered application that will allow it to stand out from other players. The MP3 player will have a unique feature which dynamically alters the tempo of the music in real-time to correspond it to the user's current heart rate. The user's heart rate will be measured by an electrocardiograph machine and the data will be interpreted by the device. The purpose of this feature is to keep a user's running session dynamic and interactive with the music rather than the music dictating the user's mood and run. This feature will make it easier to change the place of your run by choosing which specific heart rate you are aiming for and have the motivation to get the music up to its correct speed and keep up with it as well.

The project will include an Electrocardiogram (ECK/EKG) machine that will help measure and monitor a user's heart rate. It will also be built because it is cheaper and more adventurous to make a heart rate monitor that is specifically designed to correspond with the MP3 player. The EKG monitor will add a unique feature of connecting the user to the MMP3P by adding heart rate data and other personal information. This additional element will be the main component that will drive the tempo-changing feature of the MMP3P. Altogether, the features and components of the Motivational MP3 Player will empower any user to exercise with a more personalized device, rather than just a preference of song choices.

III. OVERVIEW

The flow of the system begins with the user and the capacitive touchpad (Captouch Boosterpack by TI). The user "wakes" the system up by turning it on or enabling the proximity sensor, then selects the desired playmode. The control signal from the corresponding microcontroller sends data to the LCD screen, and more signals are sent to another microcontroller, which handles the SD card accessing and audio decoding. As the audio files are selected and decoded by this controller, the information of the current MP3 file are sent back to the first controller, which sends the MP3 information (Title, Artist, Track Time) to be displayed on the LCD.

The system is powered by a 3.7V lithium polymer battery that feeds the power through the two microcontrollers, which extend the voltage to the peripheral devices that are connected to each controller. The system has added features to observe low-power consumption and to disable certain peripherals to reduce consumption and conserve voltage in the battery.

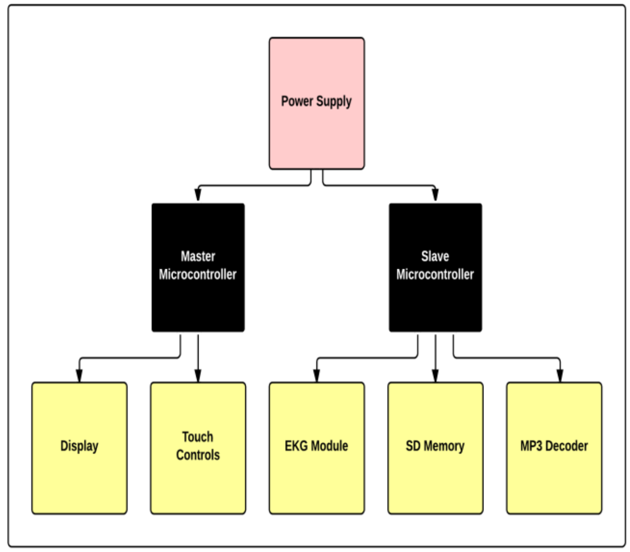


Fig 1: System Block Diagram

The anaerobic playback mode has another feature included. It enables the use of a built-in EKG, or electrocardiograph. This EKG is a three-lead electrode configuration, which detects the potential difference of the user from different parts of the body (arms and leg), then passes this voltage through a series of op-amps and filters to produce a legible heartbeat. The heartbeat is read by the audio-decoding microcontroller, which activates an LED with every pulse detected, and also can have the BPM displayed on the LCD by sending the information to another microcontroller.

In anaerobic mode, the BPM which is calculated using the EKG will be used to determine which song is played next. This feature allows the user to enjoy a comfortable workout, simply at the pace which is desirable to each and every individual by keeping a consistent beat pattern which is preferred at the time of workout.

IV. SPECIFICATIONS

The Motivational MP3 Player should meet the specifications and requirements of the standard MP3 player. Here is a compiled list of specifications for the MP3 player and EKG monitor. The following are guidelines that list the main aspects of the design that will have to be achieved.

The MMP3P will have the technical specifications listed below in Table I. These specifications are based on common MP3 player features in today's market and from desired components.

TABLE I

LCD Electrical Characteristics

Battery Life (hr.)	6
Dimensions (mm)	58.54 x 152.17 x 24
Weight (oz.)	5
Flash Memory Size	8 GB
Supported Audio Standards	MP3, WMA, WAV
ID3 Tag Support	Yes
Headphones	Wired
Sound Output Mode	Stereo
Connectivity	Wired, Bluetooth
System Display	LCD
Display Diagonal Size (mm)	75

V. REQUIREMENTS

The design will meet the following list of requirements for the MP3 player and EKG monitor that ensures that they meet the adequate level of measurement and performance.

A. MP3 PLAYER FUNCTIONS

The MP3 player will be required to perform the basic function of any ideal music player, which includes the following:

- The player will need a visual display for navigation and music playing details.
- The player will need to be able to read audio files from an external flash memory device that will be inserted to the player console.
- The player will need a menu interface that allows the user to browse through the list of music files and allow the user to play the song.

B. MP3 PLAYMODES

1) Basic Play Back

- The player will need to be able to play, pause, stop, move to the next song, move to the previous song, and adjust the volume.

2) Anaerobic Exercising

- The Anaerobic mode will require an input value of the heart rate from the EKG sensor and also for the user to select a starting song. As the workout progresses into the different areas the selection of songs will be selected from same window as the workout.

3) User Interface

- The UI will be required to have menus for the music library, the featured playmodes, the user information, the settings, and a shortcut to the display for the current song playing.

4) EKG

- The EKG will need three electrodes, a positive, negative and ground, that will connect to the user in order to record an accurate heart rate.
- The EKG will have to transfer this recorded heart rate value and send the data to the MP3 player to be manipulated.

VI. ELECTRICAL HARDWARE

The electrical power-grid and connections are shown in the block diagram of Figure 1. The portable device is powered by a single-cell, 3.7V lithium polymer cell, which is rechargeable. Of course, the majority of components in the design are meant to operate at 3.3V, so the use of a voltage regulator is needed to bring the voltage down to that level.

Initially, the system is powered on by a switch, and the master MCU takes in user data via the capacitive touchpad. That information is processed and some information is sent to the LCD to be displayed, while some data is sent to the audio MCU. The two controllers work together to synchronize data transmission and file selection.

A. EKG

The EKG design is based around the AD8232 chip from Analog Devices. This IC offers the convenience of only being 4mm x 4mm in size, and provides complete processing of the heart beat for detection. The pinout for the AD8232 is shown in Figure 2 below. With a few added external components for custom amplification and filtration, a clean pulse is sent to an analog-read pin on the MCU, which is then converted to a digital value for further processing. Figure 3 shows the heart beat detected using the AD8232 as shown from an oscilloscope in a lab setting.

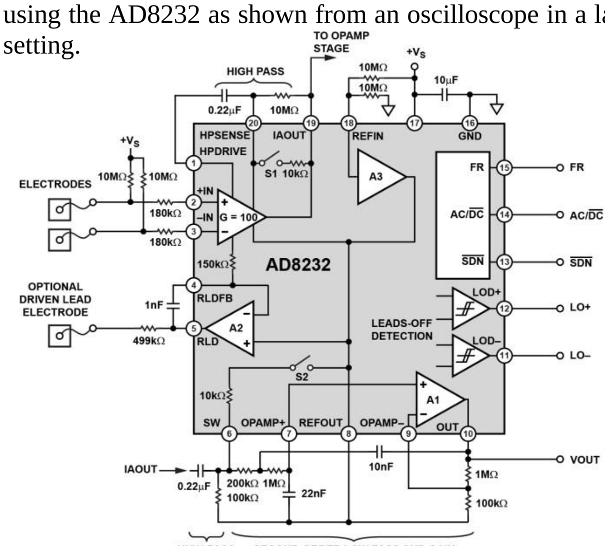


Fig 2: AD8232 Pinout

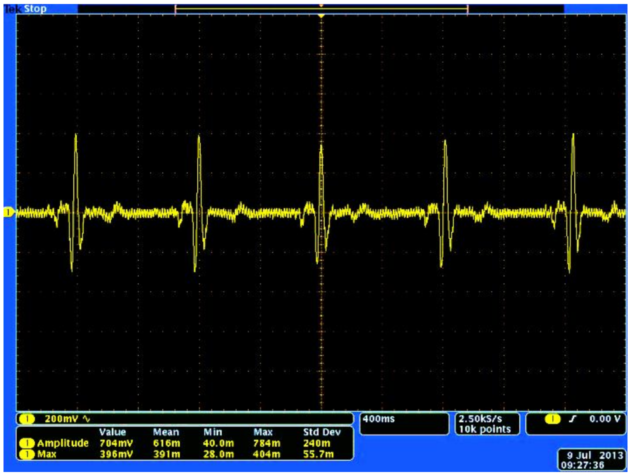


Fig 3: Heartbeat Detected from EKG

B. Microcontroller

The processing of signals in the system is controlled by the MSP430g2553, by Texas Instruments. These controllers come in 28-pin SOIC packages which have all the required pins for the project's applications, and they deliver a compact, reliable solution to the overall design.

The g2553 has the pins necessary to achieve UART and I^2C protocols, analog to digital conversion, and a multitude of general purpose I/O's for various other functions. Needless to say, these ICs had everything that was needed and more, and with just two of them the design could be implemented.

C. CAPACITIVE TOUCH BOOSTERPACK

The MSP430 family of microcontrollers came with a great feature that complemented the MMP3P very well – the Captouch Boosterpack, shown in Figure 4

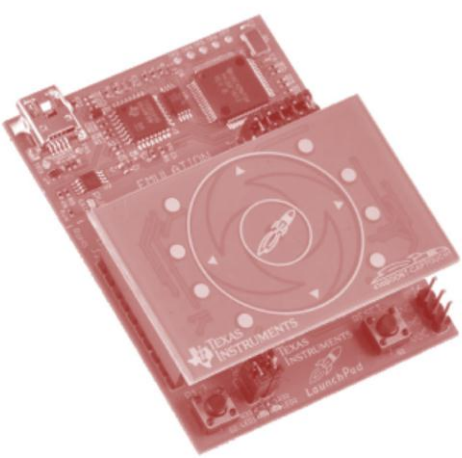


Fig 4: Captouch Boosterpack for MSP430 MCU's.

The touch screen allows the user to input information to the microcontrollers without the use of buttons. This functionality gives a more modern feel to the project, and mimics the ever-popular scroll wheel of the iPod. With appropriate software written to the controllers, the generated signals from the touch screen act as a user-controlled interface to communicate with the project. Thus, the user can engage directly with his or her workout experience.

D. SD CARD MEMORY

The SD card will be the memory storage for the audio files, user information, and any other data files that need to be kept. The flash memory will incorporate the FAT32 file system and will make use of the High Speed bus speed for data access. There will be a program that will act as the Driver to initialize the SD card memory and access the MP3 files from the FAT32 system. This will enable the microcontroller to read the large amounts of MP3 files and decode them using the DAC.

The Flash memory will be large enough to hold music files, up to 500 songs, and will also hold the Users' saved information, up to three users and preferred settings. The types of music files that will be primarily focused on are the MPEG3 (.mp3), Wave Sound (.wav), and the Windows Media Audio (.wma).

The music files on the memory will be organized by the ID3 tags, which all music files have. The ID3 tags will be edited to follow the correct file format for Artists and Song titles to optimized library organization. The music files will also content the file's song length, genre, beats-per-minute (BPM), and file protection setting. The song length should be established by the file and the file protection should be set to false to allow dynamic editing to the file's ID3 tag. The artist, song title, music genre and BPM will be adjusted manually to ensure there are no errors that will affect the memory organization. The MP3 player will also include a feature that can listen to an active song and decipher the music's BPM and edit the file for future reference, if the value is not already recorded. .WAV files and .WMA files do not have the BPM description under their tagging format, but these two file types still support ID3 tags so the BPM will be embedded as an attribute.

The user data will be saved on the flash memory, as well. The data will include the user's Name, Age, Weight, and how frequently they work out (rating from 1 to 5). This information will be develop a foundation for the user's workout routine by computing their Target Heart-rate and recommending appropriate playmodes to cater to their current health. There will also be some memory management features on the MP3 player where you can modify user details, delete a user profile and check the current amount of memory space that is occupied and the amount that is still available.

Both of these data types will be accessed by firmware programming that will be embedded in the MSP430 microcontroller memory space. The music files will be retrieved for reading to the microcontroller and processed to the audio output via headphone jack or through the Bluetooth headset module. The user data files will be both read and write and stored back in the primary SD flash data card. This data will be readily present for the microcontroller to manipulate and extract the correct user information to execute the appropriate music and playmode settings for the selected user. This user information will set the starting point for the exercises which the user will perform to make it comfortable for them and it will also establish a threshold which will determine the user's exercise limitations.

E. VISUAL DISPLAY

In order for the user to engage with the device, there needed to be a way to view the information that is being processed inside the machine. The visual display that was chosen is a 16 character x 2 row LCD, by Sparkfun Electronics. It includes a black adjustable back light, and white characters with adjustable contrast. The LCD chosen for the MMP3P is shown in Figure 5.

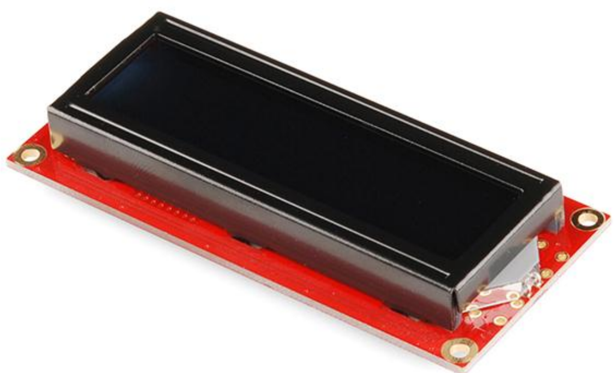


Fig 5: 16 x 2 White on Black LCD

This LCD, like every component in the circuit, requires special considerations when adding to the project. The electrical characteristics for this display are shown in Table II below.

TABLE II
LCD Electrical Characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply voltage for LCD	V_{DD}-V_0	Ta =25℃	-	3.0	-	V
Input voltage	V_{DD}		3.1	3.3	3.5	
Supply current	I_{DD}	Ta=25℃, V_{DD}=3.3V	-	1.5	2.5	mA
Input leakage current	I_{LKG}		-	-	1.0	uA
"H" level input voltage	V_{IH}		2.2	-	V_{DD}	
"L" level input voltage	V_{IL}	Twice initial value or less	0	-	0.6	
"H" level output voltage	V_{OH}	LOH=-0.25mA	2.4	-	-	V
"L" level output voltage	V_{OL}	LOH=1.6mA	-	-	0.4	
Backlight supply voltage	V_F		-	3.0		
Backlight supply current	I_{LED}	V_{LED}=3.3 V R=25 Ω			16	mA

As seen on Table II, the input voltage of 3.3V draws about 1.5mA of current. This does not take into consideration the voltage and current required to power to backlight alone, which are 3V and 16mA, respectively. The reason for incorporating these values here is because upon connecting the power source to the circuit for the first time, it was discovered that not enough power was being delivered to the LCD when all other components were also connected. This realization called for a bigger battery, with more capacity.

F. AUDIO DECODER/ADC

The audio decoder chosen for the project is the STA013 MPEG 2.5 Layer III Audio Decoder from ST Microelectronic. This is the same IC that is used in various other MP3 players that were researched at the beginning of the design process, and it was soon discovered that this chip is a great selection because it automatically decodes MP3 files upon initialization of the I^2C protocol with another microcontroller. The connection for the STA013 is not very complicated, has a fixed setup for every circuit, and is shown in Figure 6.

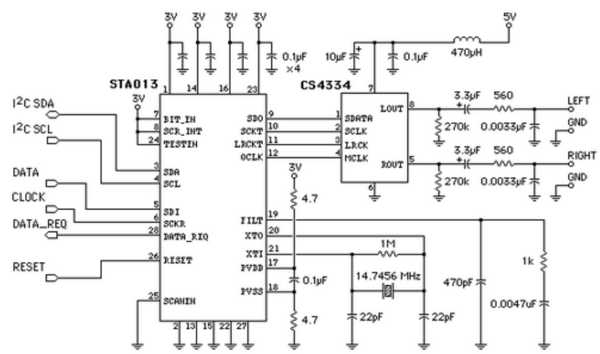


Fig 6: Connection for STA013

Included in the above connection diagram is the CS4334. This is the digital to analog converter which transmits an analog waveform to the audio jack. This particular chip would work well for the design, however, it operates at 5V. A different chip in the same family, the CS4340, would be selected as an alternative, for it contains the same features but operates at 3.3V.

G. BATTERY

In considering the battery to be used in the project, the total current draw had to be determined so as to determine the capacity of the battery. The total current draw from all the circuit components is approximately 800mA at maximum operation. Since the portable device should operate for an extended period of time without the need for recharging, a battery of 1000mAh was initially selected, but would only run at full power for about an hour. Therefore, a 2000mAh, 3.7V lithium polymer rechargeable battery was chosen to replace it, for it would run longer as the device will not be operating at full operating power at all times, and is expected to last several hours before the need to recharge.

H. ADDITIONAL COMPONENTS

Along with the aforementioned circuit components, there are several low-power consuming components which help complete the overall design.

These components are the audio jack, which is fed an analog signal from the DAC; the potentiometer, which controls the LCD character contrast; USB battery charger, which chargers the LiPoly battery by USB connection; Voltage regulator, which regulates the system voltage from 3.7V to 3.3V.

The voltage regulator used is the ADP1111-3.3. This is a fixed, 3.3V switching regulator, which operates using a Schottky diode and a 4.2uH inductor. The ADP1111 IC chip has another feature which was appealing – the low-power indicator. When the power level reaches a certain point (i.e. 2.7V in this case), the pin goes high and tells the microcontroller that the battery power is reaching a critical value. Liner regulators normally do not have this function. The low-power level can be adjusted by the engineer. The EKG also has a role in the low-power operation. Upon receiving a signal from the regulator that the battery power is going low, the microcontroller has the ability to send a signal to the EKG which commands the EKG device to shut down. This also helps to reduce power and battery life.

The Triple 2-channel analog multiplexer is another crucial component that connects to the slave microcontroller to allow the separation of the SPI and I2C lines, which are both necessary for SD memory access and for communicating to the STA013 decoder chip.

VII. PCB

In order for the MMP3P to be a “portable” device, it needs to adhere to a size which is small enough for most people to easily transport via hand or hand bag. As a reference for size, a Samsung Galaxy S2 was used to determine a suitable size. The S2 has dimensions which are shown in Table III below.

TABLE III
Samsung Galaxy S2 Dimensions (mm)

Height	Width	Thickness
125.3	66.1	8.5

The S2 has a weight of 116 g, and can easily be carried by hand, pocket, or purse.

With having a reference to a portable size, the PCB was designed to have the smallest size possible, while also being able to fit all the necessary components. The PCB dimensions for the MMP3P are given in Table IV below.

TABLE IV
MMP3P PCB Dimensions (mm)

Height	Width
58.54	152.17

As can be noticed from the dimensions, the MMP3P will be wider than it is tall. This size PCB will fit nicely inside a small casing, which will be approximately 24 mm thick, and this is only because the touch screen pad alone is 13 mm, and there are some larger capacitors on the back side of the PCB which need to have space. All together, the MMP3P will have a small, yet sturdy design which will be light-weight and handy to transport. The PCB layout as designed on Pad2Pad software is shown in Figure 7.

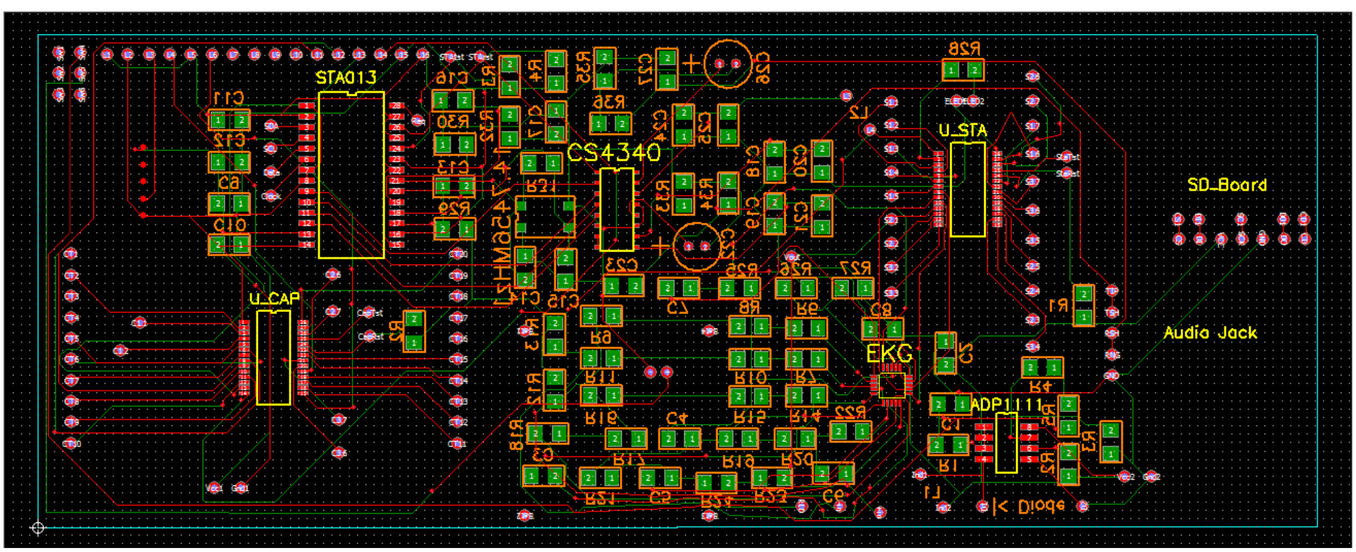


Fig 7: PCB Layout

VIII. SOFTWARE

The functions of this system are written in C-language to allow communication between microcontrollers in order to perform specific tasks. Each peripheral has specified coding held in their respective master controllers which dictate the timing of their functions.

The system holds the firmware within the two microcontrollers, the master and slave MSP430G2553's. The master microcontroller will execute the main functions of the MP3 player, directly including the touch controls and the visual display. The slave microcontroller will house the EKG analog-to-digital conversion, SD memory access, and MP3 decoding codes. The master and slave microcontrollers will communicate via UART Tx/Rx pins through serial communication.

A. CAPACITIVE TOUCH CONTROLS

The coding for the capacitive touch controls will be held within the 28pin MSP430G2553 microcontroller. This microcontroller is the master controller of the system and communicates directly with the Capacitive Touchpad module with the Port2 pins, which will register user input actions via the capacitive sensors tied to these pins, as seen in Figure 8.

The Capacitive Touch functions categorize the user input into actions which then are utilized to update the state of the system, navigate the menus, select menu choices, and control music playback. The functions of the controls change as the state of the system traverses through the menus and modules.

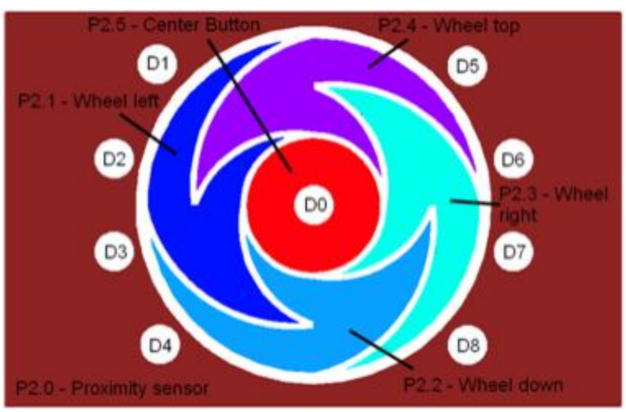


Fig 8: CapTouch Sensor Pins

B. VISUAL DISPLAY

The LCD device is initialized and driven by the master microcontroller. The data input lines for the display are connected to the Port3 pins of the microcontroller. The screen supports prints of all ASCII characters over the 16x2 display lines. The power, ground, and wiper lines are also initialized and connected to their corresponding positions. The functions of the display run in parallel with the state of the system, whether in menu or in-playing, and will output the appropriate strings to maintain internal consistency and assist in user navigation.

C. SD MEMORY

The SD card is access via breakout board and is a peripheral of the slave microcontroller. The pins for SD communication are connected to the microcontroller's USCI SPI pins. The Chip Select and Clock pins enable SD access, and the Data In and Data Out pins on both SD card and microcontroller allow writing and reading of files on the SD card.

The SD memory also uses a two channel 2-input multiplexer to alleviate the conflict of the SPI and I2C pins overlap. The I2C pins are required for MP3 Decoding, therefore, the multiplexer creates new outputs for the I2C pins and still maintains the SPI pin connection to allow communication with the SD memory.

D. MP3 DECODING

The MP3 decoding functions of the system are handled by the STA013 decoder and the CS4340 DAC component. The STA013 is a peripheral component that is connected under the slave microcontroller and is parallel with the SD Memory. The slave microcontroller will initialize the MP3 decoder with a simple write and read function via I2C, and then, the decoder will receive MP3 data from the microcontroller when prompting for it. The STA013 then sends the decoded data to the DAC chip which will produce the analog signals which will output to the audio jack.

E. EKG

The EKG input and power functions are managed by the slave microcontroller. The EKG pulse input is read by an ADC pin which deciphers the analog signals into readable pulses. This is done by setting a voltage threshold which registers a pulse and prevents any double-counting or misread pulses.

The EKG also has functions for lead-detection to ensure that there is a complete circuit from the system to the user through the leads. And the module also has a function for low-power detection, which measures its incoming voltage power, sends a signal to the microcontroller and disables the module from taking any more power.

IX. CONCLUSION

The overall goal of the Motivational MP3 Player is to allow a person to workout at their own pace, with a device that can engage with the user in a unique way, and to allow a person with low workout confidence to experience an effective workout to the "beat of their own heart". Studies showed that there are people who avoid working out because they are too embarrassed to step on stationary machines with a fear of being looked at. With the ability to bring all the perks of a stationary machine (such as heart rate, motivations, music, etc) to any desired location, any person is able to enjoy their own personalized, effective workout in a more confident manner. Along with, the fun feature of tempo-based song selection can help boost spirits, which studies also have shown can increase one's workout.

Nowadays, state-of-the-art gyms are being built across the country, and they become overcrowded with people who wish to work out. It is a competitive field, and many people buy memberships to gyms. This device can be taken anywhere, anytime, anyplace, for a one-time payment, and an experience that will be like none other found at a gym. The user can become immersed in a virtual workout in one's own backyard, or, to take things even further, can even bring it to the gym with them to escape the pressure of being surrounded by others and feeling the urge to keep up with others.

With the Motivational MP3 Player, the user knows exactly what he or she should be doing while working out. The heart rate monitor/dynamic tempo changer tells it all. No longer will the desire to run as fast, as swiftly, or with as much ease as the person to the right or to the left of left on the neighboring treadmill. It is important for a person to know what his or her target heart range is, and the MMP3P is the device that can do it all - travel, entertain, and motivate. The great thing about the MMP3P is that multiple users can share it at different times, and each individual's personal information, statistics, and data will be saved in the nonvolatile memory. This makes the MMP3P a device that can benefit an entire family, or a household of roommates in college.

The MMP3P features a variety of colored LEDs to display specific signals and alerts, which make for yet another method for detecting performance. This easy-to-use, portable, user-friendly device is perfect for anyone trying to get the maximum workout at their own, unique pace - because everyone is unique!

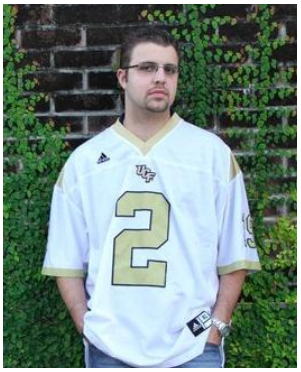
ACKNOWNLEDGMENT

We would like to acknowledge Texas Instruments' MSP430 and other resources for datasheets our microcontrollers and capacitive touch controls. We would like to thank Andy Olivares with his AndyMP3 project which helped us start a foundation on our design. We appreciate all the other reference designs that we found over the course of our project development, such as MintyMP3, PetitFS Filesystem, LCD Serial Display. We would like thank Mr. Douglas for the rental lab equipment and various circuit components we needed, and we would like to thank Dr. Richie for being a great source of guidance, and Dr. Flitsiyan and Dr. Leavens for serving in our Design Review Committee. We appreciate our families and friends for their support and motivation to complete our design.

BIOGRAPHY

Adam Browning is a senior at the University of Central Florida. He will be graduating with a Bachelor's degree in Electrical Engineering. He has interned in the Fall semester of 2012 at Atlantis Cyberspace Inc. in Winter Park. He aspires to move to New York City and to pursue an electrical engineering position in the field of satellite communications or microwave engineering.

Neil Jacildo is a senior at the University of Central Florida. He will be graduating with a Bachelor's degree in Computer Engineering. He has worked as an intern at Lockheed Martin with the College Work Experience Program for a year and is hoping to obtain a full-time position as a Systems Engineer. He is planning to pursue a graduate degree in Industrial Engineering.



Brian Wirth is a senior at the University of Central Florida. He will be graduating with a Bachelor's degree in Computer Engineering. His interests include videos games, tinkering with electronics and solving problems. He is currently interning at the New York Stock Exchange. He plans to join the workforce immediately after graduation.