Motivational MP3 Player

Senior Design Documentation

Group 7

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1 Executive Summary

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 is 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 consists of details about the individual and the current calculated heart rate of the user, which is simulated by a pulse simulator (potentiometer) and fed into the analog pin of the PIC18 microcontroller. The specialized play modes utilize the user data and establish the pace of the exercise by playing different songs with similar tempo. This player enables uploading music libraries to the external flash memory of the device and executes the typical functions of a MP3 player. The MP3 player includes 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 play mode 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. Personalizing a MP3 player device to a user helps motivate a person to exercise and build confidence for improving one's health. The user is 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. Through the guidance of previous designs and a tangible reference board, the MMP3P was on its way to a workable design through the use of a multitude of microelectronic components.

2 Project Description
2.1 Project Motivation and Significance

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. This equipment also has 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 has the expected options and modes of a typical music player, but this device also incorporates a more health-centered application that allows it to stand out from other players. The user’s heart rate can be measured by an electrocardiograph machine and the data is interpreted by the device. The purpose of this feature is to keep a user’s playlist updated to their corresponding intensity of workout. This eliminates the need for the user to hand pick their playlist specifically for their workout.

The project includes an Electrocardiogram (ECK/EKG) simulator that acts as the analog input for the microcontroller, which can also be programmed to an actual EKG device. The reason for the simulator is because an actual EKG produces too much noise to effectively incorporate in the project, so the simulator provides proof of concept as an analog input. To test the concept of an analog read, an actual EKG device was used during the inception of the MMP3P. The EKG monitor adds a unique feature of connecting the user to the MMP3P by adding heart rate data and other personal information. Altogether, the features and components of the Motivational MP3 Player empower any user to exercise with a more personalized device, rather than just a preference of song choices.

2.2 Project Goals and Objectives

The Motivational MP3 player should first be able to fit the needs/fit the performance of an MP3 player. The player should have a reliable battery life of at least 3 hours. It has a flash memory card which is large enough to hold many songs. It also supports the typical music file types and be able to decode them properly. The player has an easy-to-read LCD screen to display the music details and volume levels and LED lights that serve as an indicator for Play Modes of the player and for other distinct functions. The interface also includes buttons for the functions of: play/pause, stop, next song, previous song, volume up/volume down, change Play Mode, and power on/power off.

The MP3 player has multiple Play Modes that fits the user's needs. A specified LED light to allow the user to easily see which mode they are using indicates all these modes. The first mode is Regular Play mode. The next mode is Power Saver mode, where the player uses the incoming data from the heart rate monitor to determine if the player is still being used. If the heart rate monitor is not being used, then the player powers down to conserve energy for more active sessions. The last mode is the Tempo-Changer mode.

The Tempo-Changer mode is indicated by all LEDs being lit and then uses each LED to specify which target heart rate zone the mode is using as a threshold. The four heart rate zones consist of Warm-up/Cool-down, Fat Burning, Target Heart Rate, and Anaerobic/High Intensity. These zones have a designated range of Beats per Minute, which compares the values measured by the EKG monitor and takes the difference and adjust the tempo of the music accordingly. The Tempo-Changer mode is able to slow the tempo down to a base speed and have an upper limit to which the tempo can reach above the normal speed of the song.

The MP3 player is able to communicate with the EKG monitor. The player should be able to receive the EKG data and to manipulate the data to display and use for the Tempo-Changer mode. The EKG monitor uses three measure points to determine the user's heart rate in terms of Beats per Minute. This data is displayed by an oscilloscope and is sent to the MP3 player's micro-controller wirelessly over a Bluetooth connection. The aim for this component is to accurately measure the heart rate at a maximum of 250hz so that it creates a reliable data output.

The connection between the EKG monitor to the microcontroller in the MP3 player and connection from the MP3 decoder to the output is established by Bluetooth connections.

2.3 Specifications and Requirements
2.3.1 Specifications

The Motivational MP3 Player was designed to following specifications and requirements of the standard MP3 player. Here is a compiled list of specifications for the MP3 player and EKG simulator. The following are guidelines that list the main aspects around which the project was designed.

2.3.1.1 Hardware Components

Mentioned first are the components for the EKG circuit which was used in testing. The majority of these components are integrated into the IC chip, such as the op amps that make up the filters and amplifiers for the heart-beat detection. However, there are some external components that were added to the circuit to complete the signal processing. These components are mentioned in Table #1 below.

Table 1 EKG Parts

Components:	**Quantity:**
AD8232 Heart-Rate Monitor Analog Front End	**1**
Resistors (Ohm)	
10M	5
1M	2
499k	1
200k	1
180k	2
100k	2
Capacitors (F)	
0.22u	2
10u	1
1n	1
22n	1
Leads:	
Premium Silver Tens Electrodes Pads	3
Alligator Clips:	3

Next to be mentioned are the components that make up the remaining parts for the Motivational MP3 Player. These include resistors, capacitors, and other various electrical components that are anticipated needing upon design of the player. Table #2 is a complete list of these items.

Table 2 MMP3P Parts

MP3 Player		
Battery	**Lithium ion**	1
Controls	Cap-Touch BoosterPack	1
Microcontroller	MSP430F1612	1
	MSP430G2452	1
	TUSB3410	1
Display	LCD	1
Audio Jack	PW3-012	1
EEPROM	511-M24LR64E-RDW6T2 64KB	1
USB Mini-B SMD Connector	PRT-00587	1
Slide Switch	V80212MS02Q	1
LED	RGB LED	1
	Green LED	1
Headers	10-pin Male	2
Resistors	100 (1)	170 (2)
100k (2)	270 (2)	3.3k (2)
47k (6)	1.5k (3)	10k (1)
33k (3)	15k (1)	
Capacitors	1uF (2)	10uF (1)
100nF (7)	12pF (2)	
	22pF	2
Diodes	1N4148D035-7	1

2.3.1.1.1 Electronic values - voltages

One of the key aspects decided upon was to have a battery that lasts longer than a few of the other competitors' products on the market today. In order to preserve the battery life, an operational voltage of 3.3V was chosen to be used. This voltage allows the device to be low-powered and allowing the battery to last longer. One reason why low-power devices are preferred is because they are safer and less current runs through them. The lithium ion battery is a relatively small battery that provides a voltage of 3.3V with a single cell, therefore, making a low-power device the ideal design.

2.3.1.2 Technical Specifications

For an effective design of an MP3 player and EKG, certain specifications had to be realized before the design process could truly begin. The MMP3P has the following technical specifications as mentioned in Table #3. These specifications are based on common MP3 player features in today's market.

Table 3 Specification

Battery Life	6 Hours
Dimensions	5.5 in x 2.75 in x 0.7 in
Weight	5 oz.
Flash Memory Size	16 GB
Supported Digital Audio Standards	MP3, WMA, WAV
ID3 Tag Support	Yes
Headphones	Wired
Sound Output Mode	Stereo
Connectivity	Wired
System Display	LCD
Display Diagonal Size	2.5 in

2.3.2 Requirements

Here is a list of requirements for the MP3 player and EKG monitor that ensures that they meet the adequate level of measurement and performance. These requirements not only outline the functionality of the MMP3P, but also lay the groundwork for design and implementation. These are the standards to which the final product shall be based upon.

2.3.2.1 MP3 Player Functions

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

- A visual display for navigation and music playing details.
- Read audio files from an external flash memory device that is inserted to the player console.
- A menu interface that allows the user to browse through the list of music files and allow the user to play the song.

2.3.2.2 MP3 Player Play modes

The MMP3P is a dual dynamic electronic device, which supports two different play modes. The following Table #4 includes a description of these modes and their basic features.

Table 4 Play modes

Basic Play Back	The player has the ability to play, pause, stop, move to the next song, move to the previous song, and adjust the volume.
Anaerobic Exercising	The Anaerobic mode requires an input value of the heart rate from the pulse detector and also for the user to select a starting song. As the workout progresses into the different areas the selection of songs is selected from same window as the workouts.

2.3.2.3 User Interface

The UI has accessibility through the capacitive touch boosterpack from TI. Some of the items that are able to be viewed are the track number being selected, the volume levels as they change, the current song playing, the play, pause, and stop commands, the BPM's being counted, the ten second sample timer, the current BPM, and the welcome message. These selections are programmed in the software, and stored in the memory of the ATMEGA328 microcontroller that is used in the circuit. The slave controller accesses the menus directly, using the Capacitive Touch Boosterpack from TI as the master controller. The controller must access the SD memory, which is the memory that contains the music information and user settings. The LCD displays these actions.

2.3.2.4 EKG

To test the analog read functionality of the project, an EKG from Analog Devices was used to implement a pulse detection. The EKG operates with three connected electrode leads – a non-inverted signal (left arm), an inverted signal (right arm), and a right-leg driver to help decrease the CMRR of the signal (right-leg). These electrodes enter an op amp inside their corresponding pins on the AD8232 chip. The signal proceeds to multiple internal stages of filtration and amplification to output a clean heart-beat. Figure #1 below shows the IC internal configuration and the external components needed to add ample processing. The image comes from the datasheet of the evaluation board for the chip from Analog Devices.

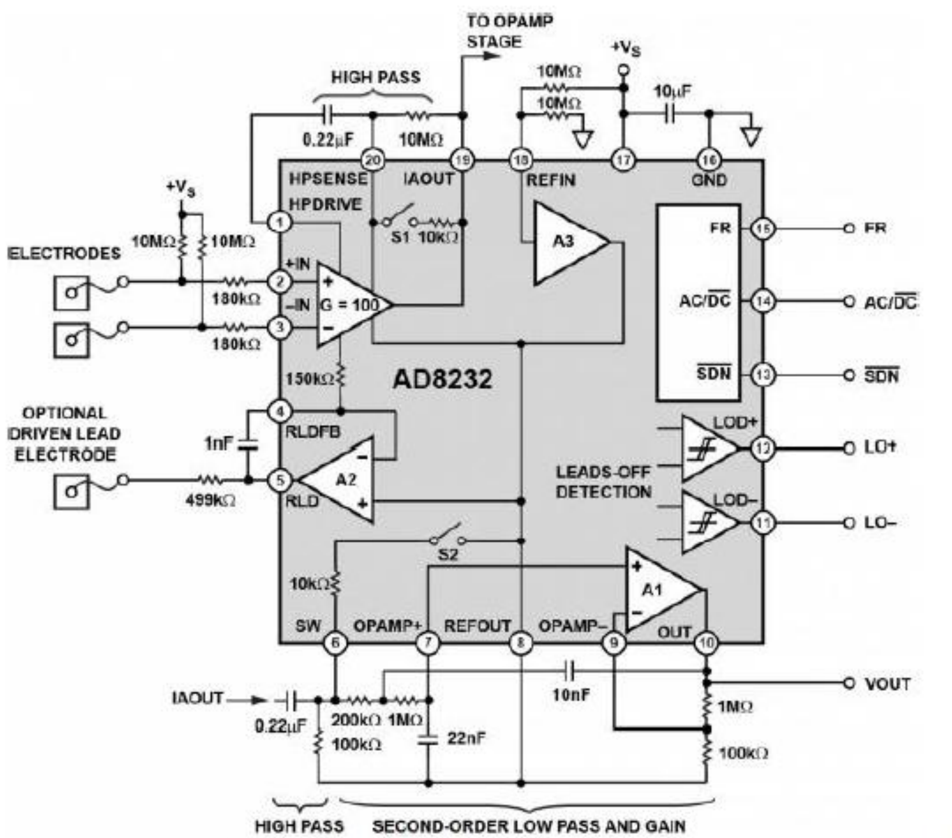


Figure 1 AD8232 Layout

As can be seen, there are three op amps and a buffer stage integrated inside the chip, which optimizes the desired small size of the chip and stabilizes the signal processing for an accurate reading. Shown below in Figure #2 is the schematic for the circuit which was initially to be used to the MMP3P circuit, before it was found to be too noisy on the PCB.

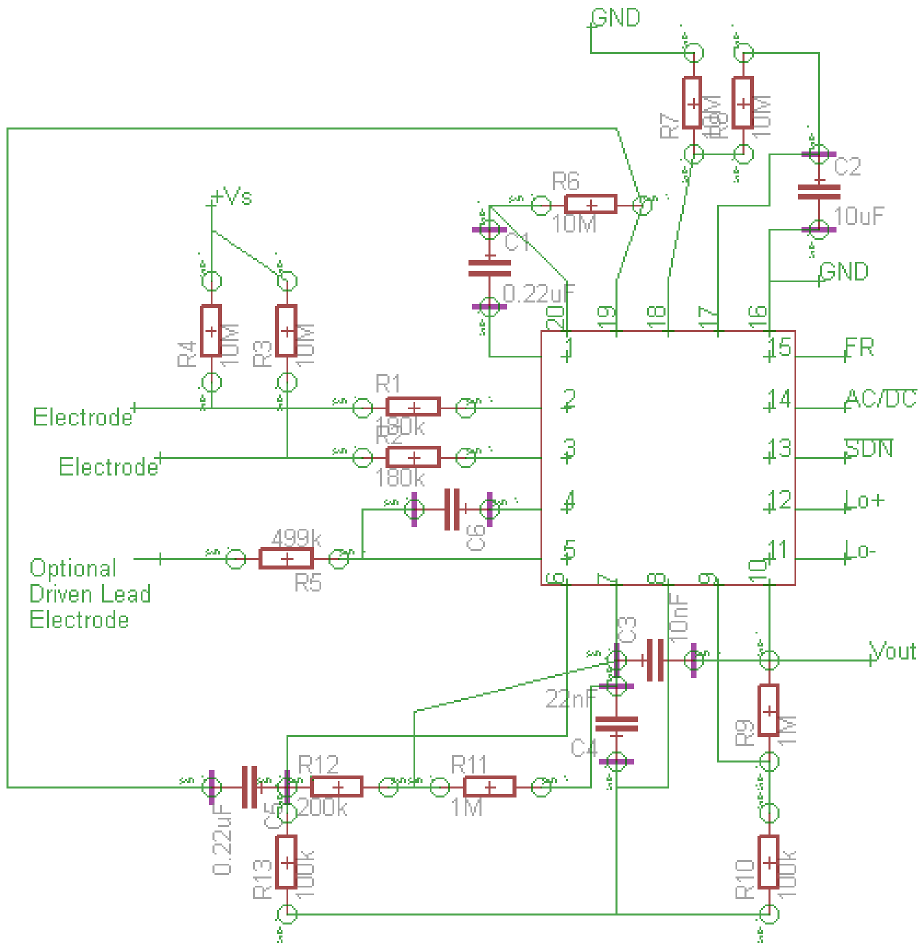


Figure 2 AD8232 Schematic

3 Related Research

3.1 Marketing Research

How will the Motivational MP3 Player be marketed to the public? This section is dedicated to the consumer marketing research that was done for the project. That is, why is this project a good idea? Why is it believed that the Motivational MP3 Player is a product that people would want to buy? Who would want to buy this product, and for what reasons? What are similar products and how did people react to them? These are all questions that an engineer or businessman should ask himself before trying to design a product, and here these questions are taken into consideration.

3.1.1 Obesity Statistics

According to the website *win.niddk.nih.gov* - a website for information on weight-control, obesity, physical activity and related nutritional issues - approximately 42% of adults 20 and over in the United States in 2009-2010 were considered obese or extremely obese. Another statistic reveals that 40% of males and 44% of females 20 and older were obese or extremely obese in the same time frame. Furthermore, 40% of the white population, 62.6% of the black population, and 44.1% of the Hispanic population of adults 20 and older were obese or extremely obese.

The graphs for these statistics are shown in Figure #3. It is these numbers that first and foremost make the idea for a device which encourages people to work out seem marketable to the general public. However, there are many reasons for obesity in this country. The following paragraphs discuss some of the causes for obesity in America.

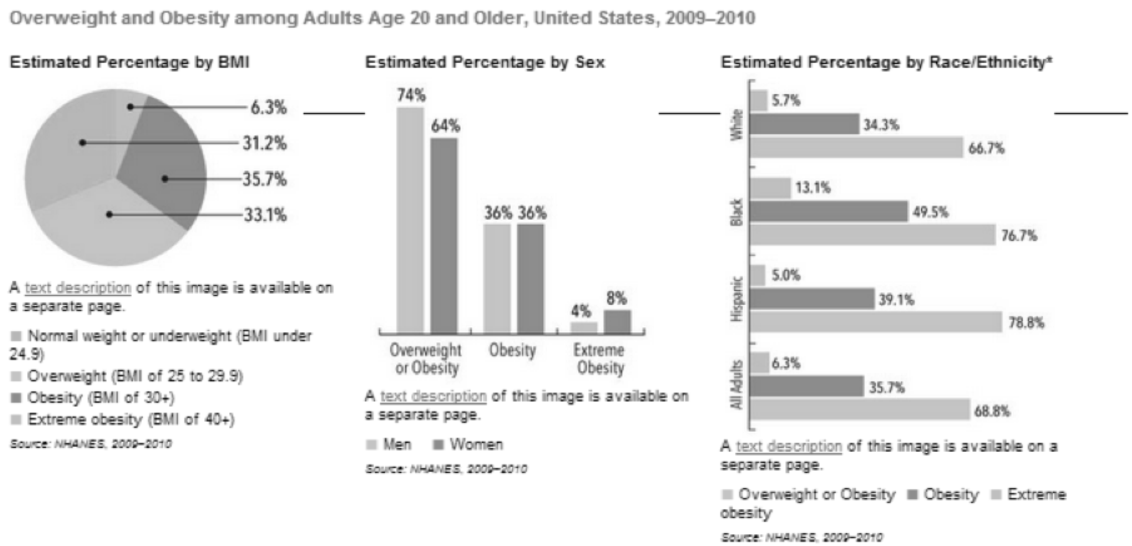


Figure 3 Obesity Statistics

3.1.2 How Much Should People Work Out?

A lack of physical activity may be the leading cause of obesity. The Weight-Control Information Network states that "Overweight and obesity result from an energy imbalance" (WCIN). Energy from food is counted by calories, and the body needs this energy to perform daily activities and functions. However, when more calories are being consumed by food or drink than are being used up as energy during daily activities, then the excess energy results in weight gain and obesity. Thus, calories are necessary, but too much can lead to unpleasant weight gain. For children who are growing, enough calories should be consumed such that normal growth and daily activities can be performed, but not to the extent of excessive weight gain. For adults, consuming the right amount of calories for daily functions will not result in weight gain, because the energy being taken in from food and drink is being used during daily activity.

The recommended amount of moderate intensity aerobic workout for adults is at least 150 minutes per week, or 75 minutes per week of vigorous intensity aerobic workout. The term “aerobic” means “living in air”. This type of exercise uses oxygen as the main energy supply during workouts, and generates an increased heart rate by working out leg, back, and other large muscle groups for prolonged periods of time. The lighter the workout, the longer a person can train. The more vigorous the workout, the less time a person can train at such intensity. According to the Weight-Control Information Network, “only about 3 to 5 percent of adults meet these recommendations’” (WCIN). This obviously means that adults need a motivational tool to encourage them to work out the recommended amount.

For young people ages 6 to 19, the recommended amount of daily physical activity is 60 minutes. Figure #4 shows a graphical display of this data. This amount of activity allows a young growing person to burn off the extra calories being consumed for the body to grow healthily and to not gain weight. However, studies show that young people are not getting the proper amount of physical activity needed to avoid weight-gain. A survey on children and adolescents aged 6 - 19 from 2004 shows that 42% of young people are gaining at least 60 minutes of physical activity per day. Also, 48.9% of young boys and 34.7% of young girls are receiving the recommended amount of daily physical activity.

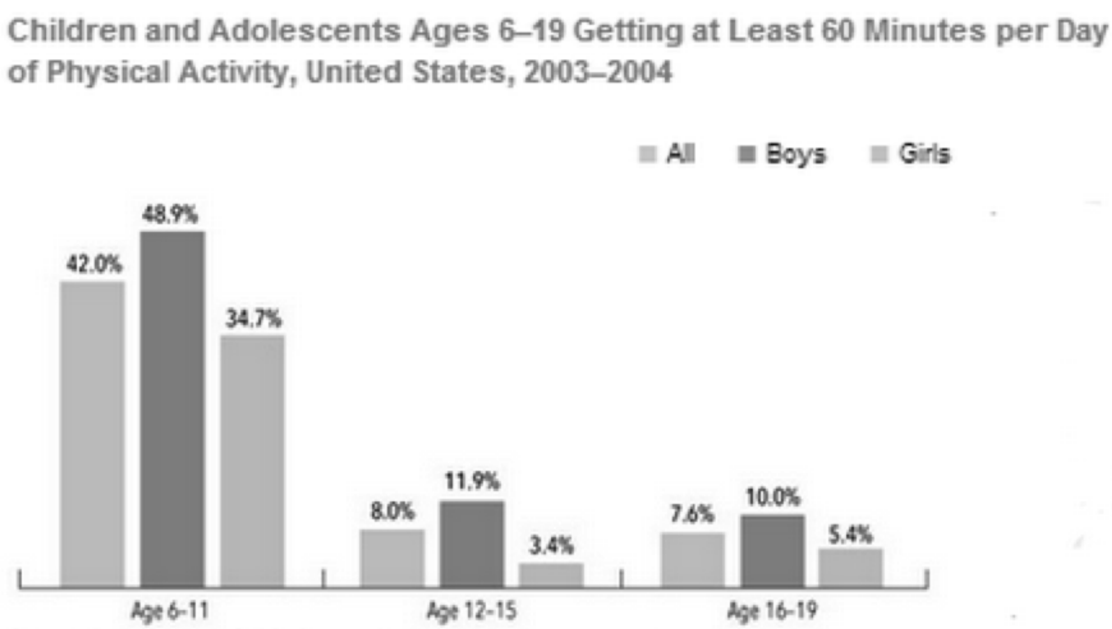


Figure 4 Physical Activity Statistics

3.1.3 Health Risks

Being overweight causes strain on the heart, and increases the risk of heart disease brought on by high blood pressure and cholesterol. By losing weight, heart health is increased. According to the website *livestrong.com*, “Type 2 diabetes and pre-diabetes are other reasons why many people want to lose weight” (livestrong/weightloss). Diabetes can also lead to other problems such as nerve damage, foot damage, or kidney damage. Along with these health problems, losing weight can help reduce “risks for stroke, hypertension, kidney disease, endocrine disorders, metabolic disorders, hormonal abnormalities, reproductive disorders, thyroid conditions and even some forms of cancer” (livestrong/weightloss). WebMD also states that losing weight can benefit in the form of decreased blood pressure, prevention of diabetes, and decreased sleep apnea. As can be seen, whether or not a person thinks he or she needs to lose weight or has a misperception of their weight, it is beneficial to stay in good shape and avoid obesity.

Now it has been shown that not getting enough physical activity in a day or a week is a primary cause for obesity. Also, about half the population of the United States is overweight or obese. Hence, a device which motivates people to work out seems like it would be marketable to just about half the population of people, or at least those who are unhappy with their sedentary lifestyles and wish to change their habits to lose weight It is also marketable to people who understand their risks of heart disease and other related health problems associated with being obese. However, do overweight people necessarily wish to get skinny/healthy?

3.1.4 Study One - “Does Perception Equal Reality?”

One instance of study on this topic was done by a group of doctors from Harvard School of Public Health. The title of the research was “Does perception equal reality? Weight misperception in relation to weight-related attitudes and behaviors among overweight and obese US adults”. In this study, the term “weight misperception” is a trait found in “those who reported themselves as ‘underweight’ or ‘about the right weight’” (ijbnpa.org).

The study showed that 71% of overweight/obese men who misperceived their weight do not think they should lose weight, and 60% of these men are therefore less likely to *try* and lose weight. The study also found that 65% of women who misperceived their weight do not believe they should lose weight because they think they are at a normal weight, and therefore 56% of these women have likely not tried losing weight in the past year. As these statistics show, there are some people who are classified as overweight or obese who have these misperceptions of their body image, and they do not consider themselves part of those classifications. These types of people likely will not be interested in buying a device to help motivate them to workout.

3.1.5 Study Two - "My Body Is OK"

Another study, done by Tiffany Powell, M.D, of University of Texas Southwestern Medical Center, shows that there are some obese people who actually perceive their body size as ok. This is slightly different from the previous study which was about people who didn't believe they were obese. In this case, Dr. Powell found that 8% of obese people who participated in the study do not believe their obesity is unusual, and that they do not want to lose weight. To these people, obesity has become the norm in American culture, and they do not think they need to lose weight. After all, the statistics shown above reveal the numbers, and there are more obese people than there are skinny people. So, who is to say what is the "normal"? For health reasons, obese people need to be aware of their risks by being overweight. For social reasons, apparently some obese people consider themselves to be normal with no reason to lose weight.

3.1.6 Workout Statistics

As mentioned before, statistics show that people, of all ages, are not exercising as much as they should for a healthy lifestyle. It is for this reason that "the prevalence for obesity for children ages two to five years-old increased from 5.0 percent to 12.4 percent" (lovetoknow). The same source states that "young people ages 12-19 showed an obesity prevalence increased from 5.0 percent to 17.6 percent" (lovetoknow). In order to increase the consumer market for the device which motivates people to work out, it is important to understand the trends in exercising today. It was found that people with a higher education is more likely to exercise more, and people 25 years or older with a college degree are twice as likely to participate in physical fitness activities and sports.

Of the popular forms of exercise, it has been learned that walking is among the most popular, while "about 30 percent of people aged 15 and older choose walking as a form of regular exercise" (lovetoknow). Men are more likely to participate in physical sports as a form of exercise, while the vast majority of women participate in yoga and aerobics exercise. Also, about twenty nine percent of people above 15 years of age will no more than an hour a day.

The fact that people with a college degree do more working out than others, it is a possibility to make a product that can sell for more money. If the design is good, and the consumer market is active, working class people, then a state-of-the-art device to help them engage in their physical activities is something that could sell for a decent price. Considering that the most popular time frame for working out is about 30-60 minutes, a portable device should last at least an hour, but preferably longer.

3.1.7 How Music Affects the Brain

According to the website *netdoctor.co.uk*, music can affect the brain in many ways. It has been shown that “music can help increase endurance by as much as 15 percent” (netdoctor). Listening to music while jogging can make the workout seem less intense, taking focus off of the effort of working out, and increases energy. Not only that, but music can improve focus in a person, and help a person maintain a regular routine. A long distance runner once said that she started out jogging listening to her favorite music, and every day she would try to run through more and more tracks until she could run through the entire album tirelessly. Thus, music is not only a good motivator for jogging and working out, but it is also a good way to track one’s workout duration.

With the research shown above, it is quite obvious that music plays a big part in a person’s motivation for working out. With the large portion of the population that does not work out, nor have any desire to work out, perhaps it is a motivator that is really needed. Whether people want to know it or not, being obese or overweight can be a threat to one’s life. If people had a tool available that could help them more easily achieve their goals for a good, effective workout, then perhaps the misperception of body weight will disappear and motivate more people to get up and get out. This is another point of concern.

Is the misperception of body weight a result of giving in to the belief that working out is useless and accepting that change is not necessary because it is unobtainable? As mentioned above, 8% of obese people who took part in a survey done by Dr. Tiffany Powell do not believe their obesity is unusual. Perhaps these people have tried working out in the past, did not achieve desirable results in their time frame, and gave up with the acceptance that they are the way they are and they’re not going to change. The following paragraphs will try to find insight into why some obese people do not work out.

3.1.8 Conscientious Contenders

From a new article on the MSNBC website, Jacqueline Stenson writes about why some people might be too embarrassed to exercise. A certain Debbie Holman is overweight, and she is too self-conscious to work out in public. Public exercise equipment poses as a threat to this woman because she is afraid of being looked at or possibly messing up the machines, or not using them correctly. As stated by writer Stenson in the article, “Lack of time, motivation and money are frequently cited reasons for not exercising. Embarrassment is another that seems to be increasingly common, especially as the nation’s waistline expands” (Stenson, MSNBC). According to the previous statement, people sometimes need that motivation to work out, and a way to do so that will not cause public humiliation.

3.1.9 The Perks of a Treadmill

A familiar trait in most modern gyms is the stationary treadmill. Most modern treadmills have a large display by the handles that behold a set of controls for the user to input information about him or her, such as weight and age. In most cases, there is even a heart-rate monitor that senses your heart rate and monitors your progress, your distance travelled and calories subsequently lost, your average speed over a specified distance, and often times there is an option to plug in headphones to enjoy your favorite music while jogging or working out on a similar stationary exercise machine. Shown below in Figure #5 is an example of a common treadmill headboard display with the controls and various other features shown.

Figure 5 Orbit Cardio Strength

(http://www.orbitfitness.com.au/Treadmill-T940N.html / Permission Pending)

Other displays are more modern and advance, such as the one in Figure #6 which has touch-screen capabilities with all the same user interface controls and features.

Figure 6 My Heart Zone

(http://www.healthstylesexercise.com/shop/lifespan-tr4000i-treadmill.html / Permission Pending)

This particular headboard has a display for “Incline/Calories/Age”, “Time/Program?BodyFat”, “Speed/Sex”, “Pulse/Height”, “Distance/Weight”, “Incline/Time”, and “Calories/Program”. There are also buttons which control the many features to the display, and several options for choosing a particular workout type or intensity, or “profile”. As convenient as this headboard display may seem, it is the public equipment that makes some people insecure about working out.

3.1.10 Turning Stationary in to Portable

To some, it is embarrassing to be overweight and running clumsily on a workout machine that is on the verge of near-collapse, while other skinny people are running quickly and swiftly on the machine, the way it was designed for people to do. From the MSNBC article mentioned above, the overweight Debbie Holman was quoted saying, when she is in an aerobics class with mirrors on the walls, ‘I just want to be sick, especially when I am hiding in the back of the class and the skinny girls are up front, who are not afraid of the mirrors, look at me with disgust” (Stenson, MSNBC). Thus, merely being in the presence of others who are also working can be a cause for great insecurity and will cause someone to not want to work out or not get the full benefit of a workout.

The scenario just described may sound all too familiar to a lot of people. It is reasons like this that make an idea like a portable workout device that motivates the user by being able to go anywhere, anytime, and provide lasting entertainment and memory, a good idea for a project design. Imagine taking the above head-mount display from the treadmill, compacting it to a pocket size, and travelling with it. The device has all the capabilities as a treadmill, but without the nuisance of being surrounded by others while your use it.

3.2 Existing Products and Similar Projects

3.2.1 AndyMP3

The AndyMP3 is another music player that was looked at to gain insight on how to construct an MP3 player. This design decodes the MP3 format and is made using the VS1011e decoder chip from VLSI Solutions and uses a microcontroller as the CPU to the player. The components used in this player are discussed below. The AndyMP3 player consists of the following items:

- VS1011e decoder chip
- PIC18LF2550 microcontroller
- SD/MMC memory
- TC1262 voltage regulator
- Capacitors, Resistors, LEDs, Diodes, and various other components.

3.2.1.1 Decoder Chip

The VS1011e has a “reliable and high-quality MP3 and WAV decoding engine combined with a stereo D/A converter and earphone amplifier” (VLSI Solutions). Andres Olivares, creator of the AndyMP3, describes the codec as having “good sound quality”, and it was the codec of choice for this project because of its built-in digital-to-analog converter, and the stereo earphone driver simplifies the design. The current at any digital output is +/-50 mA. From the VLSI Solutions website and the VS1011e MP3 Audio Decoder Datasheet, other features are said to include:

- Decodes MP3 (MPEG 1.0 & 2.0 audio layer III (CBR, VBR, ABR)); MP1 & MP2 (MPEG 1.0 & 2.0 audio layers I & II) optional; WAV (PCM + IMA ADPCM)
- Full 320 kbit/s MP3 with 12.0 MHz external clock
- Streaming support for MP1/2/3 and WAV
- Bass and treble controls
- Operates with single 12-13 MHz or 24 - 26 MHz external clock
- Internal clock doubler
- Low-power operation
- High-quality stereo DAC with no phase error between channels
- Stereo earphone driver capable of driving a 30 ohm load
- Separate 2.5...3.6V operating voltages for analog and digital
- Serial control and data interfaces
- Can be used as a slave co-processor

- 5.5 KiB On-chip RAM for user code/data
- SPI flash boots for special applications
- New functions may be added with software and 4 GPIO pins.

It can be found for $19.95 on SparkFun Electronics, or for even cheaper on websites such as Ebay. Figure #7 shows the schematic from Andy's codec pinout.

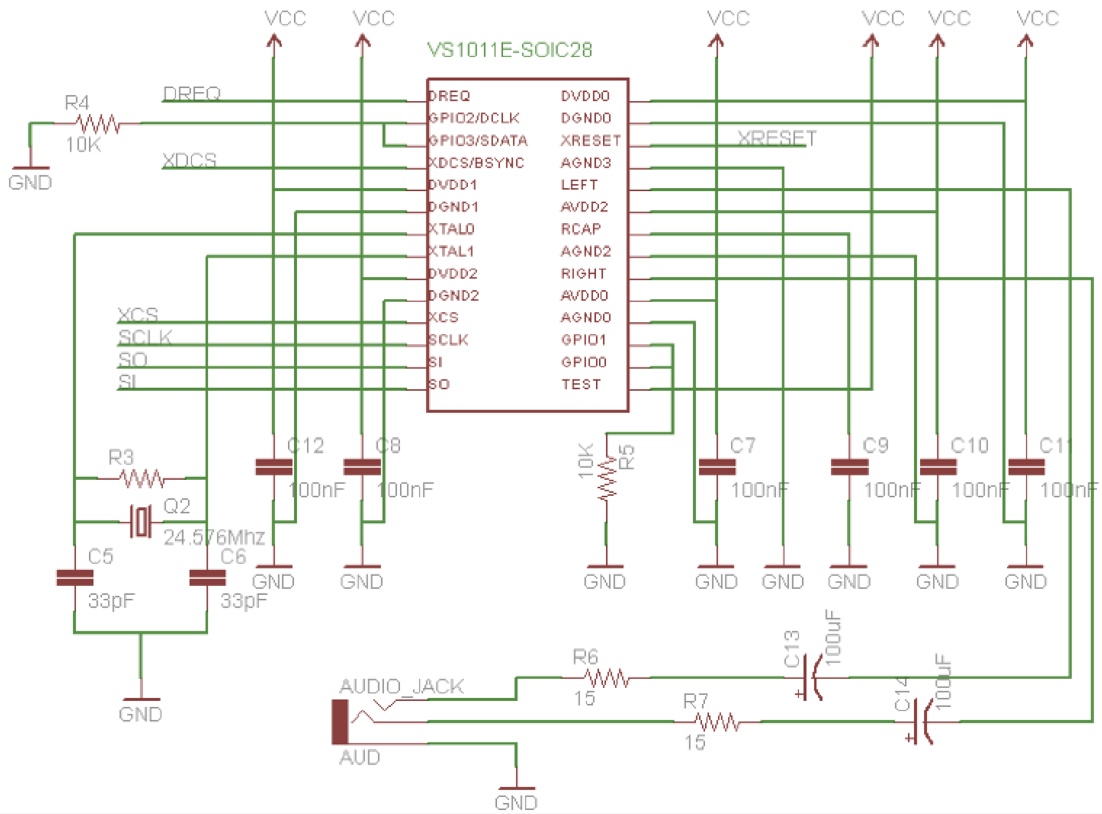


Figure 7 AndyMP3 Codec Schematic

3.2.1.2 Microcontroller

The PIC18LF2550 is a low-voltage version of the PIC18F2550. The circuit logic of the AndyMP3 works at 3.3V, making this microcontroller a good choice. It has high-performance and operates at speeds up to 20 MHz, and features a large program memory. There is a USB module on the chip, which is good for future implementation of a USB interface with the computer. From the PIC18F2550 Datasheet, other features are said to include:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports up to 32 Endpoints (16 bidirectional)
- 1-Mbyte Dual Access RAM for USB
- On-Chip USB Transceiver with On-Chip Voltage Regulator

- Interface for Off-Chip USB Transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)
- High-Current Sink/Source: 25 mA/25mA
- C Compiler Optimized Architecture with optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-Programmable under Software Control

The chip can be found for $4.51 on Microchip.

3.2.1.3 Flash Memory and Firmware

SD/MMC memories are cheaper than other memories compared to their high-capacity, and the SPI based protocol is easy to implement using microcontrollers, operating at 3.3V. This memory can be found at most electronics stores for approximately $15.00. The programming that was developed for the mp3 player firmware was based on the C language. It was not specified where the programming was stored, either in the microcontroller's and audio decoder's flash memory spaces or in the SD flash memory card itself. The mp3 player would access this firmware via the PIC18LF2550 in order to initialize all peripheral components using the SPI module that is included in the microcontroller. The firmware is based on 3 device drivers: the MMC driver, the FAT32 driver, and the VS1011 audio decoder driver.

The MMC driver is a firmware program that is based on SPI data communication between the PIC microcontroller and the MMC flash memory card. This driver selects the MMC and initializes the data for memory access. This is performed through the MMC chip select pin/SPI slave select from the microcontroller. The PIC then sends the initialize data and any following command data to the MMC through the SPI Master Output Slave Input (MOSI)/MMC's Data Input (DI). When the data command is acknowledged, the MMC sends the contained audio files through its Data Output (DO) to the PIC microcontroller which is later used for the decoder.

The FAT32 driver is the firmware that allows the organization and retrieval of the audio files from the MMC. After the flash memory card is initialized, the FAT driver is initialized and uses the file system library to interpret the MMC file table. The source code is quite large; it is composed of conversion equations for 8bit, 16bit, and 32bit integer units and calculations for cluster partitions and positions to obtain correct location values. The driver is based off the 32bit clusters that the audio files are divided into throughout the flash memory card. These clusters are chained together by an identifying number that completes the music file from beginning to end. The FAT driver locates the audio file's first cluster position and identifies all related clusters. This driver identifies the audio file's setup and information for the microcontroller to obtain for the audio decoder.

The VS1011 driver is the main component of the firmware that reinterprets the audio files into an analog signal for audio output. The decoder driver performs from two separate SPI buses. The XCS bus communicates from the PIC to initialize the decoder and send other commands dealing with audio data. The second SPI bus is the XDCS that handles the actual audio data that is transfer from the MMC, through the PIC, into the VS1011. These two buses alternatively enable and disable in order to send the VS1011 the commands and then transfer data. These buses are directed by the PIC's SPI module and by additional coding functions made that are stored in the flash memory.

The firmware utilizes these three drivers to initialize the MMC, decipher the audio files in the FAT format, and deliver the data to the VS1011 decoder. The last part of the firmware is the actual mp3 player programming. This coding is very large and incorporates the pins of the PIC and the VS1011 with the functions of both devices. The program directs the decoding of the retrieved audio files and directs the analog output to the audio output. The mp3 code also includes the mp3 interface functions, such as volume adjusting to the VS1011, playing or pausing the current song and running the next or previous song.

AndyMP3 made his source codes available for public use and to help understanding the process. It is unclear where the firmware and other software was store on the MP3 player design, but there is ample amount of memory space to store the code. The developer also included back up files (.bak) and many other alternative extensions of the drivers and mp3 player code to make it available to Windows OS, Apple OS, and Linux. The FAT format also helped understand the audio data framework which can be used to develop the Motivational MP3's tempo-changing algorithms dealing with raw audio data.

This source code is a good foundation to build the Motivational MP3 Player for the basic needs and performance of the design. It helped estimate the relative sizes of the firmware and software that is going to be programmed for the mp3 player and determine which memory spaces to allocate for these codes based on their function priorities. The source code for the VS1011 led the design in the right direction for audio decoding, but the other drivers are only references. Due to the fact that project's mp3 player control is very simplistic and it uses MMC flash memory and a PICLF2550 microcontroller, all of which were adjusted and improved for the dedicated design's specifications.

3.2.1.4 Voltage Regulators

The TC1262 allows the circuit to work with three 1.5V AAA batteries. It is a high-performance voltage regulator which has a specific functionality of working with low-voltage devices that use batteries. Using a voltage regulator simplifies the MP3 player design as much as possible, compared to using other approaches to supply 3.3V to the circuit, such as using a step-up converter. From the TC1262 Datasheet, the chip is said to include the following features:

- Very Low Dropout Voltage
- 500mA Output Current
- High Output Current
- Standard or Custom Output Voltages
- Over Current and Over Temperature Protection

This voltage regulator is very cheap and can be found for about $0.51 on Microchip.

3.2.2 DSPdap

The DSPdap player features the following hardware components:

- TMS320VC5507 dsp
- TLV320AIC23 codec
- 2 1.5V AA rechargeable batteries
- Full Speed USB 2.0 Connectivity
- Compact Flash card
- Stereo Line-in support for high-quality music recording

3.2.2.1 Digital Signal Processor

The TMS320VC5507 is a 16-bit fixed point DSP, which is cheaper, smaller, and runs faster than a DSP with floating point implementation. This IC contains 179 pins in a ball grid array. The Terminal assignments are shown in Figures #8 and #9.

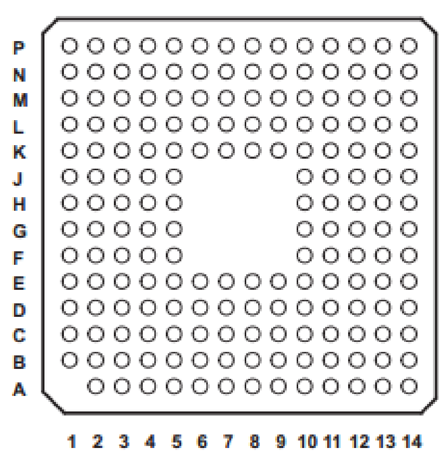


Figure 8 TMS320VC5507 Terminal (Bottom View)

(From Datasheet)

BALL #	SIGNAL NAME	BALL #	SIGNAL NAME	BALL #	SIGNAL NAME	BALL #	SIGNAL NAME
A2	V_{SS}	D5	GPIO5	H2	DV_{DD}	L13	D15
A3	GPIO4	D6	DR0	H3	A19	L14	CV_{DD}
A4	DV_{DD}	D7	CLKR1	H4	C4	M1	C10
A5	FSR0	D8	DR1	H5	C5	M2	C13
A6	CV_{DD}	D9	DV_{DD}	H10	DV_{DD}	M3	V_{SS}
A7	FSR1	D10	FSX2	H11	A'[0]	M4	CV_{DD}
A8	DV_{DD}	D11	V_{SS}	H12	$\overline{RESET}$	M5	V_{SS}
A9	CLKR2	D12	AIN2	H13	SDA	M6	A5
A10	DR2	D13	AIN1	H14	SCL	M7	A1
A11	DX2	D14	AIN0	J1	C6	M8	A15
A12	RTCINX1	E1	GPIO1	J2	DV_{DD}	M9	D3
A13	RDV_{DD}	E2	GPIO2	J3	C7	M10	D6
A14	RDV_{DD}	E3	DV_{DD}	J4	C8	M11	CV_{DD}
B1	V_{SS}	E4	V_{SS}	J5	CV_{DD}	M12	DV_{DD}
B2	CV_{DD}	E5	V_{SS}	J10	CV_{DD}	M13	V_{SS}
B3	GPIO3	E6	DV_{DD}	J11	CV_{DD}	M14	D12
B4	TIN/TOUT0	E7	DX0	J12	$\overline{TRST}$	N1	V_{SS}
B5	CLKR0	E8	FSX1	J13	TCK	N2	V_{SS}
B6	FSX0	E9	DX1	J14	TMS	N3	A13
B7	CV_{DD}	E10	NC	K1	A18	N4	A10
B8	CV_{DD}	E11	AIN3	K2	C9	N5	A7
B9	V_{SS}	E12	ADV_{SS}	K3	C11	N6	DV_{DD}
B10	CLKX2	E13	V_{SS}	K4	V_{SS}	N7	CV_{DD}
B11	V_{SS}	E14	XF	K5	V_{SS}	N8	CV_{DD}
B12	RTCINX2	F1	X1	K6	A3	N9	V_{SS}
B13	RDV_{DD}	F2	X2/CLKIN	K7	A2	N10	V_{SS}
B14	AV_{SS}	F3	GPIO0	K8	D1	N11	D8
C1	PU	F4	V_{SS}	K9	A14	N12	D11
C2	V_{SS}	F5	CLKOUT	K10	DV_{DD}	N13	DV_{DD}
C3	NC	F10	ADV_{DD}	K11	EMU0	N14	V_{SS}
C4	GPIO6	F11	V_{SS}	K12	EMU1/$\overline{OFF}$	P1	V_{SS}
C5	V_{SS}	F12	$\overline{INT4}$	K13	TDO	P2	V_{SS}
C6	CLKX0	F13	DV_{DD}	K14	TDI	P3	A12
C7	V_{SS}	F14	$\overline{INT3}$	L1	CV_{DD}	P4	A9
C8	CLKX1	G1	CV_{DD}	L2	C14	P5	A17
C9	FSR2	G2	C1	L3	C12	P6	A4
C10	CV_{DD}	G3	A20	L4	A11	P7	A16
C11	V_{SS}	G4	C2	L5	A8	P8	DV_{DD}
C12	RCV_{DD}	G5	C0	L6	A6	P9	D2
C13	AV_{SS}	G10	$\overline{INT2}$	L7	A0	P10	D5
C14	AV_{DD}	G11	$USBPLLV_{DD}$	L8	D0	P11	D7
D1	GPIO7	G12	$USBPLLV_{SS}$	L9	D4	P12	D10
D2	$USBV_{DD}$	G13	$\overline{INT1}$	L10	D9	P13	DV_{DD}
D3	DN	G14	$\overline{INT0}$	L11	D13	P14	DV_{DD}
D4	DP	H1	C3	L12	D14		

Figure 9 TMS320 Pin Assignment

(From Datasheet)

Since the MP3 player is a small device, the smallest DSP possible is ideal. The fact that the DSP is 16-bit and not 32-bit is a sign of the small size, cheap cost, and little power consumption of the processor, compared to 32-bit processors. Of course, the DSPdap project is a simple MP3 player with no other functions other than playing music, so a small processor may work well here but may not be suitable in a project that involves multiple other functions. Also, there is a chance that 179 terminals are too many for the MM3PM, which may do better with around 20 terminals.

The chip offers 128KB of on-chip data/program RAM. This amount of on-chip memory may be suitable for a processor to maintain full-speed operation if only a few functions are being performed, such as in a simple MP3 player. Adding functions to the project may require more on-chip memory to maintain full-speed operation of the processor. With a computing speed of about 108 MHz - 200 MHz (depending on which package chosen), a large program set may require a faster DSP. This digital signal processor is about $15 from Digikey.

3.2.2.2 Decoding Codec

The TLV320AIC23 is a codec with 24-bit resolution, 96 kHz sampling rate, and two channels. For music, 15 kHz - 20 kHz codecs are recommended, so the codec chosen for the DSPdap project seems to be acceptable. It is a 28 terminal DIP package, whose pinout and terminal descriptions are shown in Figures #10 and Table #5, respectively.

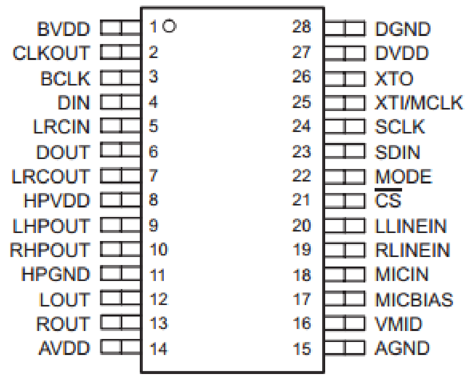


Figure 10 TLV320AIC23 Pinout

(From Datasheet)

Table 5 TLV320AIC23 Terminal Description

TERMINAL				
NAME	NO. GQE	NO. PW	I/O	DESCRIPTION
AGND	5	15		Analog supply return
AVDD	4	14		Analog supply input. Voltage level is 3.3 V nominal.
BCLK	23	3	I/O	I^2S serial-bit clock. In audio master mode, the AIC23 generates this signal and sends it to the DSP. In audio slave mode, the signal is generated by the DSP.
BVDD	21	1		Buffer supply input. Voltage range is from 2.7 V to 3.6 V.
CLKOUT	22	2	O	Clock output. This is a buffered version of the XTI input and is available in 1X or 1/2X frequencies of XTI. Bit 07 in the sample rate control register controls frequency selection.
$\overline{CS}$	12	21	I	Control port input latch/address select. For SPI control mode this input acts as the data latch control. For 2-wire control mode this input defines the seventh bit in the device address field. See Section 3.1 for details.
DIN	24	4	I	I^2S format serial data input to the sigma-delta stereo DAC
DGND	20	28		Digital supply return
DOUT	27	6	O	I^2S format serial data output from the sigma-delta stereo ADC
DVDD	19	27		Digital supply input. Voltage range is 1.4 V to 3.6 V.
HPGND	32	11		Analog headphone amplifier supply return
HPVDD	29	8		Analog headphone amplifier supply input. Voltage level is 3.3 V nominal.
LHPOUT	30	9	O	Left stereo mixer-channel amplified headphone output. Nominal 0-dB output level is 1 V_{RMS}. Gain of –73 dB to 6 dB is provided in 1-dB steps.
LLINEIN	11	20	I	Left stereo-line input channel. Nominal 0-dB input level is 1 V_{RMS}. Gain of –34.5 dB to 12 dB is provided in 1.5-dB steps.
LOUT	2	12	O	Left stereo mixer-channel line output. Nominal output level is 1.0 V_{RMS}.
LRCIN	26	5	I/O	I^2S DAC-word clock signal. In audio master mode, the AIC23 generates this framing signal and sends it to the DSP. In audio slave mode, the signal is generated by the DSP.
LRCOUT	28	7	I/O	I^2S ADC-word clock signal. In audio master mode, the AIC23 generates this framing signal and sends it to the DSP. In audio slave mode, the signal is generated by the DSP.
MICBIAS	7	17	O	Buffered low-noise-voltage output suitable for electret-microphone-capsule biasing. Voltage level is 3/4 AVDD nominal.
MICIN	8	18	I	Buffered amplifier input suitable for use with electret-microphone capsules. Without external resistors a default gain of 5 is provided. See Section 2.3.1.2 for details.
MODE	13	22	I	Serial-interface-mode input. See Section 3.1 for details.
NC	1, 9 17, 25			Not Used—No internal connection
RHPOUT	31	10	O	Right stereo mixer-channel amplified headphone output. Nominal 0-dB output level is 1 V_{RMS}. Gain of –73 dB to 6 dB is provided in 1-dB steps.
RLINEIN	10	19	I	Right stereo-line input channel. Nominal 0-dB input level is 1 V_{RMS}. Gain of –34.5 dB to 12 dB is provided in 1.5-dB steps.
ROUT	3	13	O	Right stereo mixer-channel line output. Nominal output level is 1.0 V_{RMS}.
SCLK	15	24	I	Control-port serial-data clock. For SPI and 2-wire control modes this is the serial-clock input. See Section 3.1 for details.
SDIN	14	23	I	Control-port serial-data input. For SPI and 2-wire control modes this is the serial-data input and also is used to select the control protocol after reset. See Section 3.1 for details.
VMID	6	16	I	Midrail voltage decoupling input. 10-μF and 0.1-μF capacitors should be connected in parallel to this terminal for noise filtering. Voltage level is 1/2 AVDD nominal.
XTI/MCLK	16	25	I	Crystal or external-clock input. Used for derivation of all internal clocks on the AIC23.
XTO	18	26	O	Crystal output. Connect to external crystal for applications where the AIC23 is the audio timing master. Not used in applications where external clock source is used.

(From Datasheet)

3.2.2.3 Power Supply

The fact that this project uses 2 1.5V AA rechargeable batteries is probably not the best route for designing an MP3 player for today's use. These batteries must be fully depleted of charge before being recharged, and they tend to be bulky. It will supply the needed 3.3V for the circuitry to work, but there are better options available, such as the lithium ion rechargeable battery which actually works betters if only partially depleted of charge before recharging.

3.2.3 MintyMP3

The MintyMP3 is an MP3 player built from cheap, accessible parts for a total cost of about $25.00. This design consists of a PIC18F452 microcontroller. This microcontroller reads and writes the compact flash card, reads button presses, and configures/runs the decoder chip. Also, this chip can be obtained for free by sampling it from *Microchip.* The PIC18F452 is a fully static design with a C compiler optimized architecture/instruction set, up to 10 MIPS operations (DC - 40 MHz osc./clock input, 4 MHz - 10 MHz osc./clock input with PLL active), 32 Kbyte on-chip FLASH memory, 1536 byte on-chip RAM, and 256 byte Data EEPROM. Some of the special features include:

- Self-programmable under software control - Allows PIC to write to its own program-memory (flash). Can be used for storing some application-parameters, which may change from time to time.
- Power-on Reset (POR) - Generates a reset signal when power is applied to the device to ensure that the device starts operating in a known state. It is incorporated into the integrated circuit that detects the power applied to the chip and generates a reset impulse that goes to the entire circuit, placing it into a known state.
- Power-up Timer (PWRT) - A special timer that delays the start of program execution after the PIC has been reset on power up. This delay gives the PIC oscillator time to start and stabilize.
- Oscillator Start-up Timer (OST) - A module used by some microcontrollers to keep the device reset until the crystal oscillator is stable. When a crystal oscillator starts up, its frequency is not constant, which causes the clock frequency to be non-constant. This would cause timing errors, leading to many problems. An OST ensures that the device only operates when the oscillator generates a stable clock frequency.
- Programmable code protection - Contents of memory are code protected by an EEPROM fuse, and are automatically erased if the code protects state of the EEPROM fuse is sought to be reset, and the EEPROM fuse is reset only after the erasure of the memory contents.
- Power saving SLEEP mode - Saves on electrical consumption compared to leaving a device fully on and, upon resume, allow the user to avoid having to reissue instructions or to wait for a machine to reboot.
- Single supply 5V In-Circuit Serial Programming via two pins (ICSP) - an enhanced ISP technique implemented in FLASH RISC microcontrollers (MCU). Use of only two I/O pins to serially input and output data makes ICSP easy to use and less intrusive on the normal operation of the MCU.
- In-Circuit Debug (ICD) via two pins - Allows you to run, halt, and single-step the program while the target microcontroller is embedded in the actual circuit. Once halted, the program variables, Special Functions Registers (SFRs), RAM and EEPROM locations can be examined and modified in real-time, thus assists the designer in debugging the firmware and hardware together. (http://embedded-lab.com/blog/?p=3289)

The Minty microcontroller sends data to the STA013 decoder chip, which is a fully integrated high-flexibility MPEG Layer III Audio Decoder, capable of decoding Layer III compressed elementary streams. Also decodes elementary streams compressed by using low sampling rates. The STA013 has a digital volume, bass, and treble control, serial bitstream input interface, serial PCM output interface, PLL for internal clock and for output PCK clock generation, low power consumption, and other features that make this a useful device. This component has a going rate of $12.00, making it a desirable choice. The chip is highly configurable (a good trait for our design), and thus has multiple modes of usage.

The digital-to-analog converter used in the MintyMP3 is the CS4340, which can be bought for a mere $2.50 with a high shipping fee, or can be replaced by the PCM1748 stereo audio DAC for $2.70. The CS4340 includes digital interpolation, fourth-order Delta-Sigma D/A conversion, digital de-emphasis, and switched capacitor analog filtering. MintyMP3 makers suggest modifying the values of the resistor/capacitor values to avoid signal attenuation with headphone usage.

This MintyMP3 player uses a 128M compact flash card. This option is acceptable, although we may want to include several options for various user preferences. The FM transmitter used is the MAX2606. This chip has very low power and can hook up a player to a car. A great thing about this chip is that it is very low power, only a few mA, thus it is not necessary to include a switch for it. Finally, there are two more chips - the USB to serial chip FTDI232BM, and the li-ion battery charger chip MAX1811. These allow the player to be plugged into USB and upload/download files and recharge the battery.

3.2.4 Electrocardiograph Research

Electrocardiographs have been around for many years going back as far as 1872 when Alexander Muirhead reported to have connected wires to a patent to study the heart. Ever since then the technology has been improving. In 1901 Willem Einthvoen had some major advance with the EKG machine and the responsiveness of the capillary electrometer. Einthoven was also responsible for the letter assignments of the different parts of the charts read out. As the heart beats it has the following pattern

1. Atrium begins to depolarize.
2. Atrium depolarizes.
3. Ventricles begin to depolarize at apex. Atrium re polarizes.
4. Ventricles depolarize.
5. Ventricles begin to re polarize at apex.
6. Ventricles re polarize.

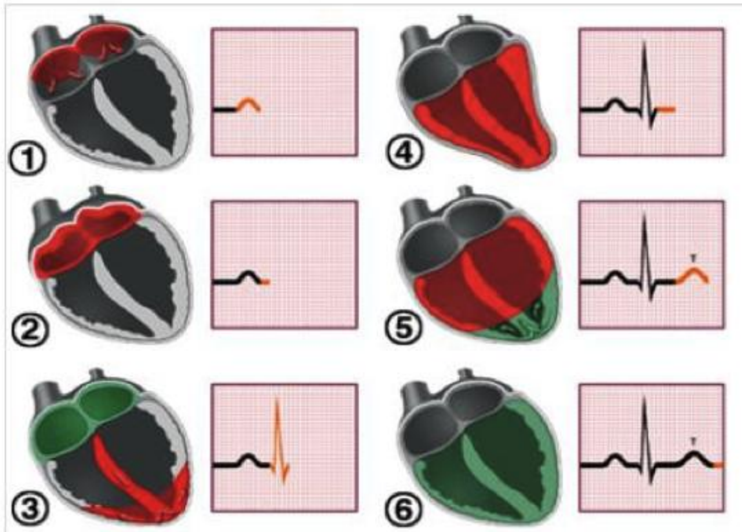


Figure 11 Heartbeat Patterns pending Permission

From this pattern the heartbeat is able to be represented and to be studied. In order to calculate the Beats Per Minute (BPM) the peak of the R waves are the important part to keep in mind. Figure #11 shows a visual representation of the heartbeat. As this peak hits, on most EKG machines, 1 mV the amount of time that it hits 1mV in sixty seconds is the rate. In order to speed up this process, technicians and doctors have found that the average heart repeats the pattern every six seconds allowing the time to calculate drop significantly. The average person's heartbeat is between 60 to 100 BPM.

3.2.5 Software Research

3.2.5.1 File Allocation Technology File System Format

File Allocation Table (FAT) is the file system architecture that is used for data memory. The latest version of this format is called FAT32, which is named after the amount of bits in a table element. A data file is composed of bytes which is broken down to a 32-bit format. The FAT32 still incorporates earlier versions of the file format, FAT16 and FAT12, which are still utilized to scale the bytes of data. The byte allocation of 32 increased the size of data that can be stored in a cluster and also improved the operation speed of the memory. The FAT32 format also has the capabilities of creating backups of the allocation tables automatically to the same memory to promote longevity of the files and reduce the need for repair or replacement.

The FAT32 format features a data unit called a Cluster, which holds the large amounts of data. Clusters are composed of Sectors (about 8units), and Sectors are composed of Bytes (512 bytes). Therefore, a cluster possesses the maximum data capacity of 8 x 512bytes, which is equivalent to 4096KB. The 32 bits that define the cluster has 4 bits reserved for file location in the memory. The first 4bits make up the first Sector, the Volume ID or Boot Sector, which carries vital information about the current partition, such as size of the FAT tables in the file, sectors per FAT or beginning address for the FAT.

Directory Entries in the FAT contain the file/folder name and other important information for finding the first cluster of a data. The directory entry is a 32 byte structure – 11bytes for the short filename, 2bytes for the first cluster low and first cluster hi each, 4bits for file size, and 1byte for the Attribute Byte. The attribute byte only uses 6bits for Volume ID, Directory/Subdirectory, and other attributes. The file name contains a short filename and a long filename, both having their advantages in organization of a group of files in a folder. The first cluster of the data is defined by the First Cluster High (DIR_FstClusHI) and the First Cluster Low (DIR_FstClusLO). By using the bit values in the first cluster and the file size, the chain of clusters connected to the first can be found and produce a complete, yet partitioned, data file.

3.2.5.2 SPI bus modes

3.2.5.2.1 SD Flash memory

Serial Peripheral Interface (SPI) bus mode is a synchronous serial data link standard that is a common data transfer option in many microcontrollers. It is also commonly used for MMC or SD flash memory card connection to retrieve data and for control devices, such as an audio codec or decoder. This serial link standard is based on a Master/Slave mode. There is one master to an SPI, such as a microcontroller, and there can be multiple slaves that the master commands to. Some slave peripherals can be real time clocks, sensors, amplifiers, LCD or USB controllers, converters (ADC/DAC), and data memories (flash or EEPROM). The master device communicates to the slave peripherals via the four logic signals: the serial clock (SCLK), the master output/slave input (MOSI), and slave select (SS). The master also receives input from the slave in the master input/slave output (MISO) signal. The master uses the SS and MOSI to select and initialize a peripheral when they need to send or read data.

SPI buses are easy to set up & understand and usually perform above a processing speed of 10Mbps. These two reasons make it the ideal data transfer mode for data streaming mp3 and other music files from a flash memory card to an audio file decoder with a reliable, real-time response.

3.2.5.2.2 Audio Decoder

The VS1011 audio decoder also responds to SPI bus data functions. The decoder has two separate SPI buses that regulate its functions, the XCS bus and the XDSC bus. VS1011 has two designated pins for each of these specific buses. The XCS is primarily used for serial control interfacing, such as initializing the VS1011 or sending the decoder commands for data. The XCS pin corresponds to the chip select/slave select pin from the SPI master. The XDCS bus is used for serial data interfacing, which is the main data input bus that the decoder uses to receive the audio data. The decoder also has a reset pin, XRESET, and a data request/data output, DREQ. The XRESET is an active low signal that clears out all control registers and sets them back to initial values. This is used for shutdown and power up purposes. The DREQ pin is an active high signal that determines whether the VS1011 FIFO can receive data. As long as the signal is on high, the master should send the decoder data. Once the DREQ signal goes low, the send must stop sending data. The signal can go high or low at any point, so the data transferring should be halted and not aborted. This signal is crucial for actively playing audio files in cases of play/pause controls or the functions of going to the next or previous track.

The VS1011 decoder uses the basic SPI standards as well, the SCLK, SS, MISO and MOSI. The four signals have their own unique pins on the decoder chip, separate from the XCS, XDCS, XRESET and DREQ. The standard SPI signals are still primarily used for audio and control data. Whereas, the first four signals discussed that are unique to the decoder are specifically for decoder functions, prompting for commands and serial data.

3.3 Relevant Technology

3.3.1 Batteries

Without batteries, an electronic device cannot be portable. For this reason, the main source of power for the Motivational MP3 Player project design is a battery. What kind of battery, though? It does not seem difficult to simply design the player to operate using 2 AA batteries at 1.5V each, as some past projects have done. However, for the sake of this project, it was important to discover the traits of different types of batteries available. Doing this helped achieve the overall goal: Learn which batteries are best for what appliances, and then choose one that optimizes performance for the project.

3.3.1.1 Primary Batteries

It is well-known that there are two main different types of batteries out there: batteries that can be recharged and batteries that cannot be recharged. The first are called “rechargeable batteries” and the others are “primary batteries”. In the paragraphs to follow, these two battery types are discussed in detail to try and decide what type of battery to incorporate into the Motivational MP3 Player based on battery life, cost, size, and power.

3.3.1.1.1 Carbon Zinc

First the primary batteries are discussed. One such battery is the Carbon Zinc, otherwise known as the “Heavy Duty” battery. These are the cheapest batteries on the market. The anode, or the negative terminal of the battery, is the outer shell of the battery, made out of zinc. The cathode, or positive terminal of the battery, is a cylindrical rod set in the middle of the shell casing with one end being used as the terminal and the other end being submerged in the carbon and manganese dioxide mixture of the battery. The cathode collects electrons which are coming from the negative terminal, or anode.

There is a separator which is usually paper or a fabric, and this separates the carbon and manganese dioxide mixture from touching the negative terminal. In order for electrons to flow in this battery, the mixture inside the battery must be able to react, and thus must not be used up. First, the outer zinc shell loses electrons, or oxidizes. A reacting between the electrolyte paste and the negative shell causes the anode to give electrons to the electrolytic paste, and a reaction between the positive cathode and the negative anode causes the cathode to takes electrons from the anode. Thus, electrons are moving from the negative shell to the positive inner workings of the battery, this charge flows through other appliances to make them operate.

Zinc Carbon batteries use Zinc because it has a stable structure yet electrons can easily be swept away from the outer shell to cause oxidization. Carbon rods are used in the center for the positive cathode because the "carbon rod collects electrons returning from the circuit and carbon powder is mixed in the manganese dioxide to make it more electrically conductive. The mixture of carbon powder and manganese dioxide improves conductivity. These batteries have an open circuit voltage of 1.5 V and have high volume of productivity.

3.3.1.1.2 Alkaline

Alkaline batteries are another type of primary battery. They have a 1.5V primary cell, and are the most popular general purpose battery. Similar to the carbon zinc, or Leclanche cell, the alkaline battery uses zinc and manganese. However, the electrolyte is Potassium hydroxide. Alkaline batteries have double the energy density of a Leclanche cell, last about 4 to 9 times longer, and are available mostly anywhere.

The battery looks like a Leclanche cell, but the electrolyte is different. Noticeably, there is an anode current collector in the shape of a rod in the middle of the anode mixture, and a cathode as the outer shell, surrounded by an outer sleeve. As can be imagined, the similar makeup of the two batteries means they operate in much the same manner. The main differences being in the electrolyte used which makes this battery a little more expensive, but work much better as was mentioned previously.

3.3.1.1.3 Lithium

Primary lithium cells have high energy, twice that of the alkaline battery. Lithium happens to be one of the most reactive metals, having the greatest electrochemical potential. These are disposable batteries, and use lithium as the anode, with manganese dioxide as the cathode, much like in previous batteries. The separator is a lithium salt in an organic solvent, and the current collector is made of carbon. They are long-living batteries and produce between 1.5 V and 3 V.

3.3.1.1.4 Silver Oxide

The silver oxide battery is a button-cell primary battery. With a small energy density, this lightweight battery is good for applications that involve a small battery with light weight. The battery has a different shape than the others, making it ideal for small appliances, but they are not powerful at the small scale. They are mainly good for large-scale applications, but are very expensive when the silver is made a significant part of the makeup.

A few of the primary batteries have been discussed here, and their chemistries and makeup have also been looked at. It is interesting to note that all the chemistry for each battery is somewhat similar; the main difference being in what material is used for the anode, which allows current into the current collector rod which then transmits the currents to the cathode terminal, travelling through any device which requires voltage to operate. There is another type of battery which is rechargeable or sometimes referred to as secondary and these are looked at next. For the sake of a portable device, many people prefer a rechargeable battery so they do not have to keep buying batteries to listen to music or take photos on a digital camera. It is for this reason that rechargeable batteries are seen everywhere in modern MP3 players. It is important to understand how they work, though, how they produce voltage and how long they last. This is discussed in the sections to follow.

3.3.1.2 Secondary Batteries

Secondary batteries are rechargeable. They cost more at first, but their recharge ability quickly makes them more cost-efficient in the long run. However, having a rechargeable battery means a less stable chemistry, which requires special care and handling. For instance, there are some secondary batteries which should not be thrown away in the trash, for they require a special sort of disposal. In the following sections, various types of secondary batteries are discussed, their advantages and their shortcomings.

3.3.1.2.1 Lead-Acid

One type of secondary battery is the lead-acid battery. In this battery, there are six cells: A white material that is pure spongy lead, and a silver material which is lead oxide. The lead oxide supplies the electrons which flow to the lead, leaving the lead oxide positive (cathode) and the lead negative (anode). In time, the plates convert to lead sulfate, and the battery stops charging. During recharge cycles (when an external charging source applies voltage to it), the water and lead sulfate react and form the material that originally made up the batter - namely, lead, lead oxide, and electrolytes. Although these batteries are large, they remain a good source of energy for cars because they quickly discharge their energy, whereas as some secondary batteries are not as quick to discharge their energy.

3.3.1.2.2 Rechargeable Lithium

The rechargeable lithium battery has high energy and is one of the most popular rechargeable batteries because of their price, power, and size. Their material is highly reactive. They behave generally like a primary lithium battery, however, the process can be reversed to supply lithium ions back to the cathode, and so upon power-up of the next use of the battery the process can be repeated. While electrons flow from the cathode through an external device to power it up, a positive lithium ion travels through the electrolytic material to the anode, carried by a mixture of carbon and manganese oxide.

According to the website *mpoweruk.com*, “Lithium batteries have now taken their place as the rechargeable battery of choice for portable consumer electronics equipment” (mpoweruk). This means the battery is very cost-effective and their cells have a high cell-voltage. A cell-voltage of 3.6 volts means that each battery needs fewer cells, reducing the overall size of the battery. Along with these advantages, they last a long time and they do not leak.

3.3.1.2.3 Nickel Cadmium

The nickel cadmium battery was once the popular choice for portable devices, but due to their cells only holding a mere 1.2V, other batteries have become more popular. However, these batteries have high energy and have a “high rate discharge capacity” (mpoweruk), making them useful for portable devices. The anode in this battery is the nickel hydroxide, and the cadmium is the cathode. Other than that, the basic principles of how all batteries work is how it operates. The equation for the chemical reaction in the battery is:

$$2NiO(OH) + Cd + 2H_2O \text{ --> } 2Ni(OH)_2 + Cd(OH)_2.$$

Missing from the equation is the electrolyte of the battery, the potassium hydroxide. This reaction is reversible, making the battery rechargeable and long-living.

3.3.2 Bluetooth

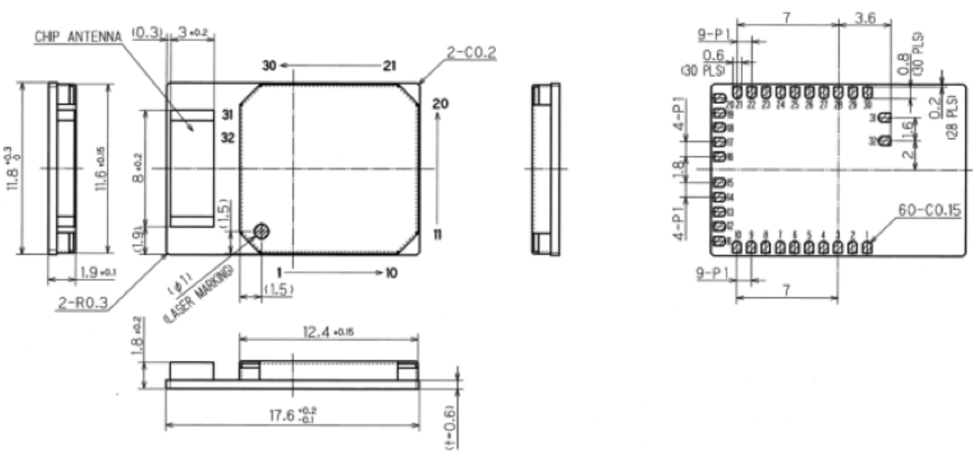
One of the features that would be good to incorporate in the design is to have the device wireless. In order to do this Bluetooth is a very good fit for the Motivational MP3 Player. With the major advances in Bluetooth the power consumptions have massively been reduced along with the types of devices that can be supported. Along with having low power consumption, the module needs to have dual-mode Bluetooth 4.0 capability. This allows the MP3 Player to receive the data from the heart rate monitor and send the audio signal at the same time.

One of the Bluetooth modules that can be used is the BT111 from Bluegiga. This module does not use a massive amount of power having an average range of

1.7V to 3.6V or 3.1V to 3.6V, which is in the range that is needed for the final design. This module is also very small allowing the overall size the of MP3 player not to increase. The BT111 uses on average 58 mA to transfer data, which has to be taken into consideration.

Another module that could be used is the BR-LE4.0-D2A from BlueRadios. It operates on 2.4V to 3.6V, which is right in the range that is needed. The nice thing about this module is that it has embedded "C" libraries making it extremely user friendly when it comes to coding. This module takes about 100msecs to start from a cold start.[1] The BR-LE uses at its worst case 24 mA making it more in the direction to look into.

BR-LE4.0-D2A (With 2 dBi TDK ANT8030-2R4-01 Antenna) – 11.8 x 17.6 x 1.9 mm



Units: mm

Figure 12 Bluetooth Dimensions From Datasheet

Table 6 Pinout for BR-LE4.0-D2A

Pin	Pin Name	Pin	Pin Name
1	GND	17	PIO_21
2	TEST / SBWTCK (Spy-Bi-Wire)	18	PIO_22
3	RESET (Active Low / Spy-Bi-Wire)	19	PIO_14
4	ADC_1	20	GND
5	SPI_MISO	21	ADC_0
6	SPI_CSB	22	PIO_9
7	SPI_CLK	23	PIO_2
8	SPI_MOSI	24	PIO_5
9	VDD (2.4-3.6V)	25	PIO_6
10	GND	26	PIO_3
11	UART_CTS	27	PIO_8
12	UART_RTS	28	PIO_4
13	UART_TX	29	PIO_7
14	UART_RX	30	GND
15	PIO_19	31	NC (RF Test Antenna)
16	PIO_20	32	NC (RF Test Ground)

The CC2540 needs a supply voltage of a maximum 3.3V allowing it to be powered off of a CR2032 battery, keeping this design really small. The CC2540 has a MCU on board with up to 256KB of flash memory, which would be more than enough room to have a small algorithm to calculate the BPM before sending the data. This could be one way to implement the design.

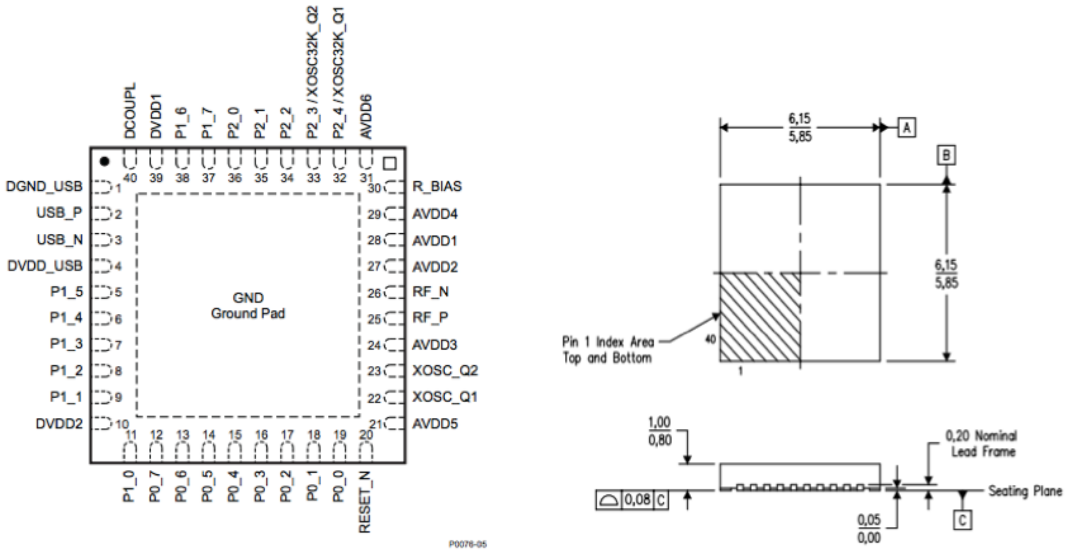


Figure 13 CC2450 Bluetooth Module

3.3.3 Codec

Since the Motivational MP3 player deals with an audio signal and MP3 files, a codec is needed to handle the function of decoding the digital file into an analog signal. The past projects looked at all had decoder chips, and they were all different. Discussed here are the features of those decoder chips and why they are suitable for an MP3 player project such as the Motivational MP3 Player, and also more decoder chips were looked at to find the best match for the project at hand.

The AndyMP3 Player uses the VS1011e decoder chip from VLSI Solutions. This chip is good for an MP3 player because it operates at 2.5V - 3.6V, a low-power solution to a key function of the player. The 5.5 KB of on-chip instruction RAM and 0.5 KB of data RAM give this chip the power to handle sufficiently large amounts of tasks, having even more instruction RAM than the microcontroller itself. It decodes MP3 files, which is of the main importance here, and also other file formats such as WAV, MP1 and MP2. This chip is simplifies design by including a variable sample-rate stereo DAC and an earphone amplifier. There is the option of adding application specific features, such as DSP effects, to the user RAM memory. This option sounds like a good way to alter the speed of the audio file for the Motivational MP3 Player. It operates quickly at 12-13 MHz or 24-

26 MHz external clock, so it can handle the speeds required for fast computation. At a price of $19.95, another solution is probably better at a cheaper cost. Figure #14 shows the SOIC-28 package pinout, and Table #7 is a table from the datasheet which describes the function of each pin.

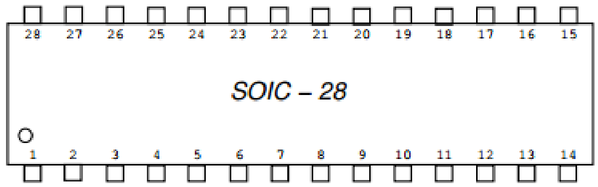


Figure 14 VS1011e Pinout

(From Datasheet)

Table 7 VS1011e Terminal Description

Pin Name	Pin	Pin Type	Function
DREQ	1	DO	data request, input bus
GPIO2[2] / DCLK[1]	2	DIO	serial input data bus clock
GPIO3[2] / SDATA[1]	3	DI	serial data input
XDCS[4] / BSYNC[1]	4	DI	byte synchronization signal
DVDD1	5	PWR	digital power supply
DGND1	6	PWR	digital ground
XTALO	7	CLK	crystal output
XTALI	8	CLK	crystal input
DVDD2	9	PWR	digital power supply
DGND2	10	PWR	digital ground
XCS[4]	11	DI	chip select input (active low)
SCLK[2]	12	DI	clock for serial bus
SI[2]	13	DI	serial input
SO	14	DO3	serial output, active when XCS=0, regardless of XRESET
TEST	15	DI	reserved for test, connect to DVDD
GPIO0/SPIBOOT[2,3]	16	DIO	general purpose IO 0, use 100 kΩ pull-down resistor
GPIO1[2]	17	DIO	general purpose IO 1
AGND0	18	PWR	analog ground
AVDD0	19	PWR	analog power supply
RIGHT	20	AO	right channel output
AGND2	21	PWR	analog ground
RCAP	22	AIO	filtering capacitance for reference
AVDD2	23	PWR	analog power supply
LEFT	24	AO	left channel output
AGND3	25	PWR	analog ground
XRESET	26	DI	active low asynchronous reset
DGND0	27	PWR	digital ground
DVDD0	28	PWR	digital power supply

(From Datasheet)

Table #7 displays the pinout for the VS1011E decoder chip which is used in the AndyMP3 player design. The DREQ pin is the input for digital signals from the microcontroller where the digital audio files are coming from. The GPIO2 is a general purpose I/O pin with serial input data bus clock. In the case of the AndyMP3 Player, there are no added features of for the design, such as DSP effects, and therefore these pins are connected directly to the ground. The XGCS/BSYNC pin is the data chip select, and in this case it is used to send MP3 data to the decoder IC to start the decoding process. There is another communication bus, the XCS, which is used to send commands to the decoder, like volume control, initialize decoder, etc. The DVDD1 pin on the decoder is the digital power supply pin, connected to the power supply. The next pin, DGND1, the digital ground, is connected to ground. The pins XTALO and XTALI are in crystal output and input, respectively, and are connected to the crystal 24 MHz crystal. There is also a pin for the serial bus clock, which clocks the serial input and output, SI and SO pins. Included in the chip is a Test pin, which is connected to the digital power supply.

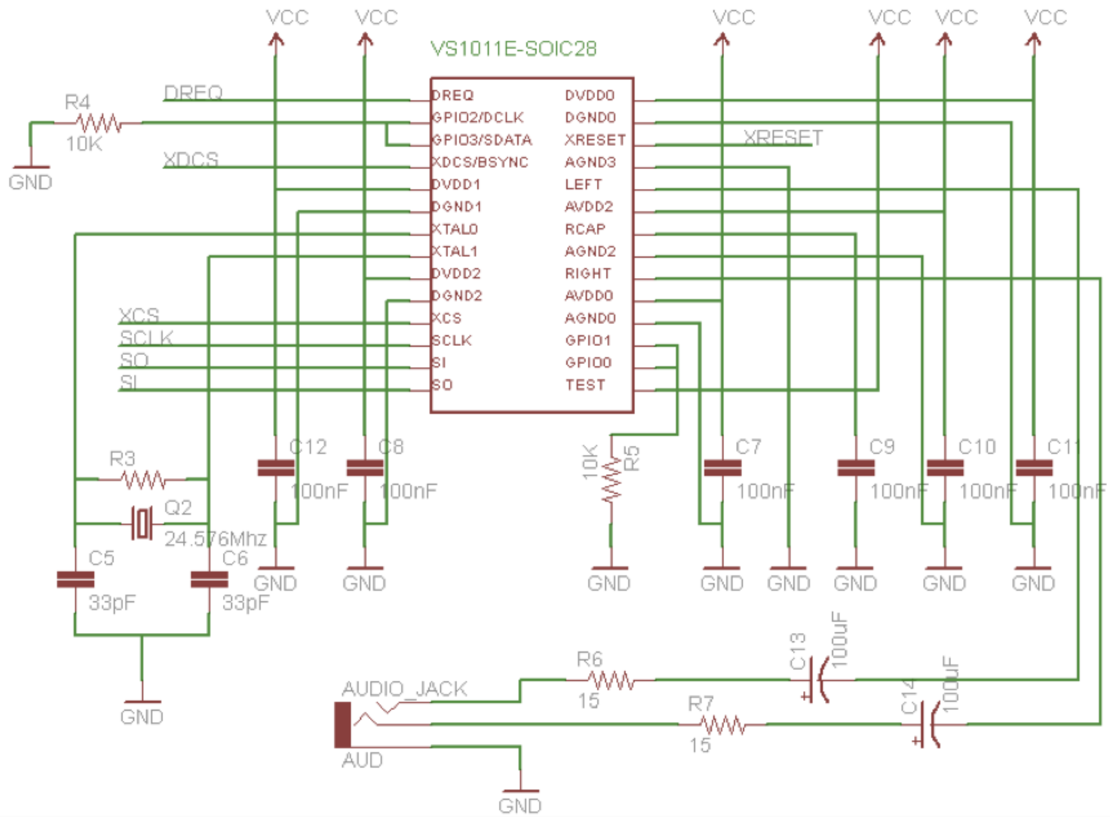


Figure 15 AndyMP3 Codec

The EchoMP3 Player uses the coded VS1002D. It has the capability of 2.5 KB data RAM, with 5 KB of instruction RAM, and operates at a speed similar to that of the VS1011e discussed above. It is also a low-power chip, and supports MPEG audio 1 and 2, and PCM input. This is the second VLSI chip that operates at the operating voltage desired at 2.5V to 3.6V, making it a good choice for the MP3 player design. This chip runs for about $4.00 on technology websites, so for pricing purposes it is a good candidate, and the memory is a good size for our purposes. It comes in 48 and 49-pin packages, both surface-mount and ball-grid array. Table #8 shows the pinout descriptions of each package.

Table 8 VS1002D Terminal Description

Pin Name	LQFP-48 Pin	BGA49 Ball	Pin Type	Function
MICP[2]	1	C3	AI	microphone input, use pull-down resistor if not used
MICN[2]	2	C2	AI	microphone input, use pull-down resistor if not used
XRESET	3	B1	DI	active low asynchronous reset
DGND0	4	D2	PWR	digital ground
DVDD0	6	D3	PWR	digital power supply
DREQ	8	E2	DO	data request output
GPIO2[2] / DCLK[1]	9	E1	DI	general purpose IO 2 / serial input data bus clock, use pull-down resistor if not used
GPIO3[2] / SDATA[1]	10	F2	DI	general purpose IO 3 / serial data input, use pull-down resistor if not used
XDCS / BSYNC[1]	13	E3	DI	data chip select / byte sync
DVDD1	14	F3	PWR	digital power supply
DGND1	16	F4	PWR	digital ground
XTALO	17	G3	AO	crystal output
XTALI	18	E4	AI	crystal input
DVDD2	19	F5	PWR	digital power supply
DGND2	20	F6	PWR	digital ground (in BGA-49, DGND2, 3, 4 conn. together)
DGND3	21	F6	PWR	digital ground
DGND4	22	F6	PWR	digital ground
XCS	23	G6	DI	chip select input (active low)
RX	26	E6	DI	UART receive, use pull-up resistor if not used
TX	27	F7	DO	UART transmit
SCLK	28	D6	DI	clock for serial bus
SI	29	E7	DI	serial input
SO	30	D5	DO3	serial output
TEST	32	C6	DI	reserved for test, connect to DVDD
SPIBOOT / GPIO0[3]	33	C7	DIO	general purpose IO 0, use 100 kΩ pull-down resistor
GPIO1[2]	34	B6	DIO	general purpose IO 1, use pull-down resistor if not used
AGND0	37	C5	PWR	analog ground, low-noise reference
AVDD0	38	B5	PWR	analog power supply
RIGHT	39	A6	AO	right channel output
AGND1	40	B4	PWR	analog ground
AGND2	41	A5	PWR	analog ground
GBUF	42	C4	AO	virtual ground for audio output, 1.23 V nominal
AVDD1	43	A4	PWR	analog power supply
RCAP	44	B3	AIO	filtering capacitance for reference
AVDD2	45	A3	PWR	analog power supply
LEFT	46	B2	AO	left channel output
AGND3	47	A2	PWR	analog ground

(From Datasheet)

The MintyMP3 Player used the STA013 decoder chip. Comparing it to the VS1011e, this chip operates at a low-voltage, with low-power 3.3V CMOS technology. There are controls for digital volume, bass, and treble, making this chip unique and versatile for people who enjoy controlling the music they listen to. It computes at a speed of 10 - 14.7 MHz, and decodes MPEG2 Layer 3 stereo channels, dual channel, and single channel (mono). There is no on-chip RAM in this chip, so an outside source is required to hold the memory necessary for this chip to operate. It is found that this chip operates at a slower CPU speed than the VS1011e, but it costs less at just $10.28. The fact that there is no on-chip memory may not matter if the microcontroller can handle all the programming for the design of the Motivational MP3 player. Thus, so far it is a cheaper alternative for the low-power solution currently being sought after. It comes in 28, 44, and 63-pin packages, which are described by terminal function in Table #9 below.

Table 9 STA013 Terminal Description

SO28	TQFP44	LFBGA64	Pin Name	Type	Function	PAD Description
1	29	B5	VDD_1		Supply Voltage	
2	30	B4	VSS_1		Ground	
3	31	A4	SDA	I/O	I²C Serial Data + Acknowledge	CMOS Input Pad Buffer CMOS 4mA Output Drive
4	32	B3	SCL	I	I²C Serial Clock	CMOS Input Pad Buffer
5	34	A1	SDI	I	Receiver Serial Data	CMOS Input Pad Buffer
6	36	B2	SCKR	I	Receiver Serial Clock	CMOS Input Pad Buffer
7	38	D4	BIT_EN	I	Bit Enable	CMOS Input Pad Buffer with pull up
8	40	D1	SRC_INT	I	Interrupt Line For S.R. Control	CMOS Input Pad Buffer
9	42	E2	SDO	O	Transmitter Serial Data (PCM Data)	CMOS 4mA Output Drive
10	44	F2	SCKT	O	Transmitter Serial Clock	CMOS 4mA Output Drive
11	2	H1	LRCKT	O	Transmitter Left/Right Clock	CMOS 4mA Output Drive
12	3	H3	OCLK	I/O	Oversampling Clock for DAC	CMOS Input Pad Buffer CMOS 4mA Output Drive
13	5	F3	VSS_2		Ground	
14	6	E4	VDD_2		Supply Voltage	
15	7	G4	VSS_3		Ground	
16	8	G5	VDD_3		Supply Voltage	
17	10	F5	PVDD		PLL Power	
18	11	G6	PVSS		PLL Ground	
19	12	G7	FILT	O	PLL Filter Ext. Capacitor Conn.	
20	13	G8	XTO	O	Crystal Output	CMOS 4mA Output Drive
21	15	F7	XTI	I	Crystal Input (Clock Input)	Specific Level Input Pad (see paragraph 2.1)
22	19	E7	VSS_4		Ground	
23	21	C8	VDD_4		Supply Voltage	
24	22	D7	TESTEN	I	Test Enable	CMOS Input Pad Buffer with pull up
25	24	A7	SCANEN	I	Scan Enable	CMOS Input Pad Buffer
26	25	B6	RESET	I	System Reset	CMOS Input Pad Buffer with pull up
27	26	A5	VSS_5		Ground	
28	27	C5	OUT_CLK/ DATA_REQ	O	Buffered Output Clock/ Data Request Signal	CMOS 4mA Output Drive

(From Datasheet)

The DSPdap project uses the TLV320AIC23 decoder chip. Sample rates of 8 kHz to 96kHz for word lengths of 16, 20, 24, and 32 bits are supported, and it is a low-power chip, consuming less than 23 mW during playback. It features a 90-dB SNR ADC at 48 kHz, and operates at 2.7V - 3.6V. The chip includes a stereo headphone amplifier which is capable of delivering 30 mW per channel into 32 ohms, analog volume control and mute. This codec is great for battery life in portable devices, allowing for selective shutdown of codec functions with the power management option and low power consumption. There is no on-chip RAM, so anything the microcontroller cannot handle on its own takes the program longer to compute. This may cause problems when programming the GPS compatibility and other add-ons, because more computational power and speed are desired.

Searching Mouser Electronics website for comparable codecs, it is desired to find a low-power, high-speed, low-cost codec chip that potentially has some on-chip instruction and data RAM for adding applications. The TLV320AIC326 is one such chip. Featuring 101dB SNR with stereo DAC, and a CPU speed of 48 kHz, this chip consumes 2.7 mW during playback. Complete with a 30 mW headphone driver and a Power Tune feature which adjusts power vs. SNR, this chip is ultra lower power and perfect for applications such as portable media players and gaming systems. It operates at 2.7V to 5.5V, perfect for a 3.3V circuitry, and it includes two miniDSP engines. This chip costs $11.27, making it a cheap solution.

Another codec from the same VLSI manufacturers, the VS1001k. Featuring a clock speed of 12-13 MHz or 24-26 MHz, low-power operation at 2.5V - 3.6V operating voltages, it has similarities to the VS1011e. The chip is versatile with the ability to add new functions such as DSP effects, and it is capable to driving a 30 ohm load, and supports MPEG 1 and 2 and all their sample rates in mono and stereo. The main difference between this chip and its similar one mentioned above is that the on-chip working memory is only 4 KB compared to 5.5 KB, with 0.5 KB of data RAM. Noting this, it is worthy to mention that this chip is cheaper $4.95.

Another decoder chip was found that is good for applications such as mobile and smart phones, mp3 players, and handheld devices. The TWL6041 is a high-quality, low-power audio codec for portable applications. It operates at 2.3V - 5.5V, has a low-power playback mode at 12-38.4 MHz, and includes an accessory plug and accessory button press detection. There are 4 DAC's, and plenty of special features on this chip to make it a good candidate for the Motivational MP3 Player design. The cost is only $4.27, making it the cheapest solution so far.

Another decoder chip was looked at, and that was the TLV320. This chip operates at 2.7V - 3.6V, is a low-power stereo audio codec for portable audio. This chip supports sample rates from 8kHz to 96kHz, supports 16-bit to 32-bit data, and has flexible power saving modes to enhance performance. There are six audio output drivers for high-quality playback at 14 mW with a 3.3V analog supply, and features a flexible clock generation and programmable input/output analog gains. This chip costs $5.06, and seems to be a perfect chip to be used in the Motivational MP3 player.

Thus far, most of the codecs looked at all seem to have similar qualities: high speeds, low-power consumption, and multiple special features to enhance to overall functionality of the decoder chip. One thing that stands out on the first codec, the VS1011e, is the large on-chip RAM available. This RAM could be very important in dealing with the high computational requirements needed for the Motivational MP3 Player, and that is why it is the chip being considered for the design right now. Although it is about four times more expensive than the other chips, it may just be that extra feature that allows the project to run with full speed functionality at low-power consumption.

3.3.4 Heart Rate Monitor

In order for the Motivational MP3 Player to determine the tempo of the song a heart rate monitor, or pulse detector, is needed. As the heart increases the speed of which it pumps, more blood is able to circulate faster throughout the body. Doctors have different ways of testing the heart rate of the patient. One of the ways that they are able to put a sensor on the fingertip and the other way is to attach small feeds to the body and measure the difference in current across the body. This device is called an electrocardiogram (EKG). A good majority of companies like Garmin and Nike have started to develop heart rate monitors that are more focused for the simple user that has no medical experience.

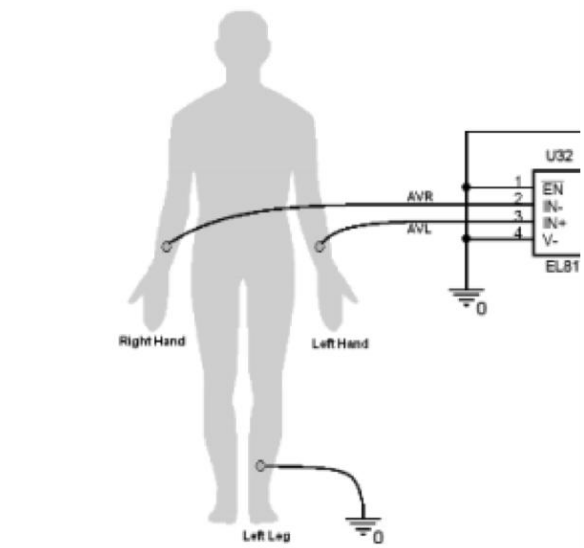


Figure 16 EKG Hook Up

Once the input is given from the body it needs to be passed into an op-amp to increase the signal. After the initial op-amp, it needs to go through a low pass filter to remove a good portion of the noise that is in the signal. Once at this stage the signal might have some noise but for the intent of the project it is fine. At this point, the Bluetooth module takes effect with the microcontroller that is onboard. It calculates the hearts beats per minute (BPM) and transfer that data to the MP3 device.

All of the parts that would be needed to create the basic EKG could be purchased for a really cheap amount, keeping the overall budget in sight for the MP3 Player. Prebuilt heart rate monitors can range from as low as twenty dollars all the way up in the hundred-dollar range, which is why building one is the path that was taken. The parts that were used for this basic EKG are the AD8232 that has an operation voltage of 3.6V and the evaluation board on which it is mounted.

The AD8232 Evaluation Board allows for simple implementation to increase the voltage coming off the person’s body. With having that increase it is only natural to have to filter the signal. According to Chia-Hung Chen, Shi-Gun Pan and Peter Kinget, they suggest from the study that they conducted that when designing an EKG that after the initial op-amp that it is passed through a band-pass filter that ranges from .04 Hz to 150 Hz. Once going past the filter, the signal is a nice and clean EKG signal.

3.3.5 Microcontrollers

In the Motivational MP3 player design, a DSP was considered to take on the role of processing the audio signal and converting it to an analog form and sent through to the headphones. It was found, however, that in today’s market there is a fine line between microcontrollers and digital signal processors. Nowadays, there are processors that can take on the role of both controller and processor. Since the Motivational MP3 player takes on other functions such as pulse detector, a microcontroller was chosen, because the purpose is not simply to stream audio and processes it. There are buttons being pressed and other ICs being controlled which are processing things, so the microcontroller can handle these tasks as well as deal with the DSP operations. It was found that pure DSP’s are not used much anymore except in specific industries, such as high end audio, radar processing, etc.

That being said, a low-voltage microcontroller was sought after to perform the desired tasks of the project. As discussed in the ‘past projects’ section of this paper, the AndyMP3 player project used the PIC18LF2550 microcontroller. It is low-power, and the supply voltage is the same as the operating voltage at 2V to 5.5V, a speed of 48 MHz, and has a 2 KB data RAM with 32 KB program memory, at just $5.43/unit. Also, this chip features an on-chip voltage regulator and an on-chip USB transceiver, on-chip DAC, and an SPP for USB streaming transfers. This could come in handy for including a USB interface on the player. Was there a better option? Alternatives were looked for to try and find a bigger program memory, faster, cheaper, yet still operates at 3.3V.

A microcontroller used in the EchoMP3 Project researched is the PIC18LF458. This chip can be found on Mouser Electronics’ website for $6.90. It operates at 2 V to 5.5V operating voltage, at a CPU speed of 20 MHz. The program memory on this device is 32 KB, so there is plenty of space for holding the code needed to implement the functions of the Motivational MP3 player. With 1.536 KB SRAM, that leaves less room for user applications. However, in the EchoMP3 Player project design, this microcontroller is obviously powerful enough to handle such functions as real time display, micro joysticks, LCD contrast adjustability, and serial interface control. With a built in ADC, this chip is perfect for MP3 player functions, and has the ability to handle other tasks needed to make the Motivational MP3 Player execute properly. However, it is more expensive with a smaller memory than the previous microcontroller mentioned. The IC comes in various packages, the most appealing being the 28-terminal DIP, whose package is shown below in Figure #17.

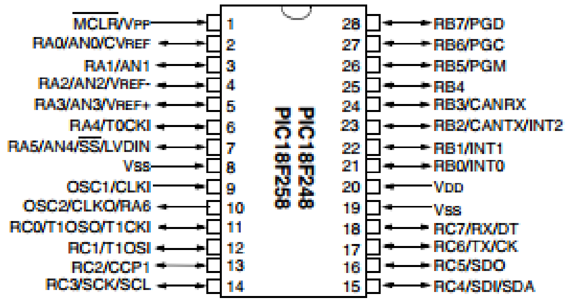


Figure 17 PIC18LF2550

(From Datasheet)

As can be seen, many pins are assigned multiple functions, between analog/digital read/writes, oscillatory inputs/outputs, and access to the different ports. An IC such as this can be utilized to accomplish a multitude of functions and applications.

On the website for Mouser Electronics, it is possible to search for similar products, so the PIC18LF2550 was typed in as the product number and other similar products were able to be found quite easily. One such chip is the PIC18LF8722. It is low-power as well, operating at 2V - 5.5V with a speed of 40 MHz. This chip has a 128 KB program memory and 3.936 KB of data RAM. It is more expensive at $11.46/unit. It includes an on-chip DAC as well, for the purpose of processing the digital signal into an analog one. So, it is slower with a bigger program memory, and twice the cost. More alternatives were searched for. This is an advanced microcontroller with 64 terminals in surface mount orientation. Figure #18 shows the pinout as shown from the datasheet.

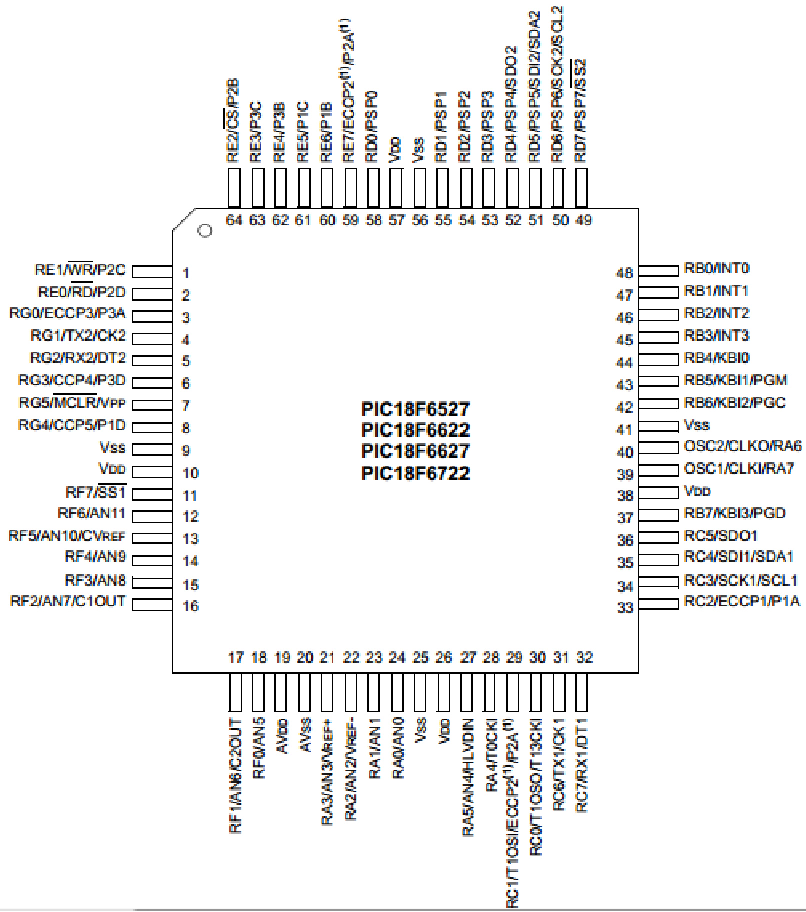


Figure 18 PIC18LF8722 Pinout

(From Datasheet)

The PIC18F2520 is a microcontroller which operates at 2V - 5.5V, low-power at a speed of 40 MHZ. The 32 KB of program memory and 1.536 KB data RAM make it comparable to the PIC18LF2550, and costs less at $4.98/unit. It includes an on-chip DAC, but no USB interface. Although they cost about the same, this microcontroller is slightly slower than the first one. In the Motivational MP3 project, speed is a factor. Various applications are working at once, and the GPS navigation system works in real-time, so speed is of vital importance. Figure #19 shows the pinout for this 28-terminal IC.

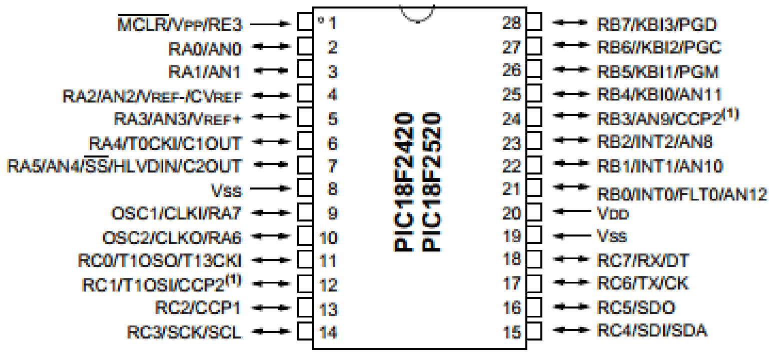


Figure 19 PIC18F2520 Pinout

(**From Datasheet**)

The microcontroller PIC18F4550 is very similar to the first one looked at, if not better. At just $5.48/unit, this microcontroller operates at 2V - 5.5V with a speed of 48 MHz, has a 32 KB program memory with 2.048 KB of data RAM. They appear to be almost identical. However, the supply voltages for this microcontroller may be of concern. The aim for the Motivational MP3 Player design is to have all the circuitry operate at 3.3V supply voltage. The Supply voltage for this microcontroller is 4.2V min and 5.5V max. This is something to consider when making the final choice for the microcontroller.

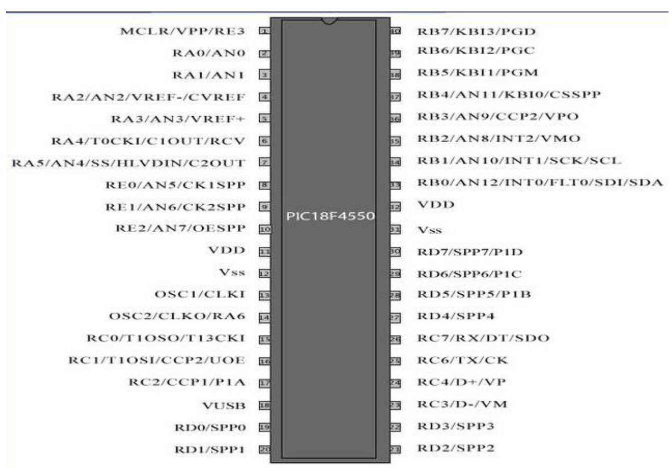


Figure 20 PIC18F4550

(From Datasheet)

For the time being, the PIC18LF2550 appears to be a suitable microcontroller for the purposes of the project. The 32 KB program memory should be sufficient for the overall functions of the player, and so far it is the chip that operates at the fastest speed. It is low-power which saves battery life during operation, which is a key attribute looked for in today's market for music players/portable technology.

3.3.6 Flash Memory

Data memory can be managed in two different types of format: Flash memory or Hard disk memory. Hard disk memory devices, or HDD, are motorized storage devices with physical disks, which are magnetically coated, that are scanned to store and read data. Flash memory devices, or solid-state drive (SDD), are more compact and durable than Physical Disk memory. Flash memory storage is purely based on logical storage of data on flash memory chips. Both types of data storage save system data when the system is powered down. They store application and personal data and files which can be accessed and utilized the same way by a processing unit.

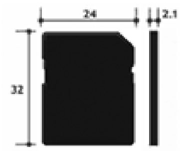
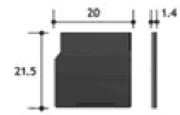
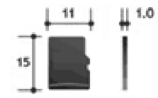
Hard disk memory and solid-state/flash memory differ in the aspects of pricing, capacity, performance quality, performance speed, fragmentation, and aesthetics. Hard disks are known for having larger memory capacities, up to 2 Terabytes now, and are relatively cheaper compared to SSD memory with similar memory sizes. However, SSD memory is advantageous in general performance, where data retrieval and prevent any fragmentation of data. The flash memory chips help decrease the sizes of SSD memory and increase the processing speed of the memory. The physical disks are sensitive to motion and can create noise during data scanning; therefore, the flash memory drives are more durable and completely eliminate noise. SSD memory is the preferred type of memory for any devices involved with physical activities, i.e. MP3 Players. The stability and performance speeds make it possible for mp3 players to be shaken around while running and to maintain consistent responsiveness to play music.

Flash memory cards were produced primarily in two different types: MultiMediaCards (MMC) and Secure Digital (SD) Cards. MMC is a flash memory card standard. Typically, an MMC is used as storage media for a portable device, one of the first standards of flash memory produced. SD is a flash (non-volatile) memory card format and is also used for storage. Both MMC and SD cards are made to be easily removable from one device to the other and accessible for PC connection. Both flash memory standards are relatively a small, portable size with similar uses. However, some MMC can be used in SD card slots, but more SD cards cannot fit in MMC-specified slots.

The primary difference between MMC and SD memory storage cards is that MMC are an open storage format and SD has added security and protection to the memory. Both brands of memory cards were relatively the same physical size in their standard product. But SD extended their production towards smaller physical sizes and larger memory sizes. The SD cards later produced miniSD and microSD cards which allowed accessibility to more devices, such as mobile phones and smaller camera models. SD cards are known to be more “up-to-date” with technology standards and are the preferred brand for portable flash memory storage due to the higher memory capacities, SD’s 1GB~8GB against MMC’s 128MB~512MB, and process speeds.

Table 10 SD Card Standards

For more details on the physical standards of SD standards, please find the following matrixes.

		Full size SD	miniSD	microSD
	Size			
	Card Type	SD, SDHC, SDXC	SD, SDHC	SD, SDHC, SDXC
Physical	Area	768 mm^2 (100)	430 mm^2	165 mm^2
	Card Volume	1,613 mm^3 (100)	602 mm^3	165 mm^3
	Thickness	2.1 mm	1.4 mm	1.0 mm
	Weight	Approx. 2g	Approx. 1g	Approx. 0.5g
	Number of pins	9 pins	11 pins	8 pins
	File System	FAT16/32	FAT16/32	FAT16/32
	Operating Voltage	2.7V - 3.6V	2.7V - 3.6V	2.7V - 3.6V
	Write-protect Switch	YES	NO	NO
	Copyright protection	CPRM (mandatory)	CPRM (mandatory)	CPRM (mandatory)

SD has produced in three standards for capacity. The SD standard has a maximum memory size of 2GB and utilizes the FAT 12 and 16 file systems. The SDHC, SD High Capacity, have a memory capacity range of 2GB to 32GB using the FAT32 file system. The standard model with the most memory capacity is the SDXC with 32GB to 2TB memory and using exFAT file system. All three models can be purchased in the three physical size categories of full, miniSD or microSD. The three standards also have a Normal Speed (NS) and High Speed (HS) for bus speed.

3.3.7 Voltage Regulators

One of the most key features for the circuitry of the Motivational MP3 Player project is keeping the operating voltage at a level that results in low power consumption and making sure that none of the hardware components get destroyed by too much voltage or do not get enough voltage to operate properly. For this reason, specs such as operating voltage supply and input voltage supply are being looked at for all the components. For some purposes, though, the voltage may need to be regulated to reach the ideal level for a certain component.

In the AndyMP3 Player, for instance, the operating voltage of 3.3V must be maintained for the microcontroller, decoder, and the memory to work. Using three 1.5V AA batteries, this operating voltage is reached by using the voltage regulator to keep the steady 3.3V operating voltage. This voltage regulator is the TC1262. This chip takes a minimum voltage of 2.7V and a max voltage of 6V and supplies an output voltage of 3.3V with a max input bias current of 0.08 mA and an output current of 500 mA, making it low-power, and is designed specifically for battery-operated systems. This regulator includes ultra low noise operation, low dropout voltage, and fast response to step changes in load. It is extremely cheap at just $0.56/unit.

The DSPdap project uses the low-dropout regulator TPS73601. This chip has an input voltage range of 1.7V to 5.5V, making it perfect for the battery supply used in their project which was 5V. The output voltage ranges from 1.2V to 5.5V, and the dropout voltage is at 0.2V for 400 mA. This is an adjustable output type which can be adjusted to the desired 3.3V operating voltage. Adjusting the output voltage seems to make this regulator a little more difficult to work with, as opposed to a chip that has a standard fixed output voltage. This chip costs $1.68/unit.

More voltage regulators were searched for in order to find the best possible selection for the Motivational MP3 Player design. One such chip was the MCP1700. It has an input voltage range from 2.3V to 6V, with a fixed output voltage of 3V, and a dropout voltage of 350 mV and producing 250 mA output current. The voltage regulation accuracy is 3%, making it suitable for the 3.3V desired voltage for the circuitry. Over current limit and Over Temperature shutdown are featured in this chip, making it a stable regulator that can be confidently placed in any circuit for a reliable solution to most any application. The cost of this chip is $0.40/unit, making it very cheap indeed.

The MCP1804 is another voltage regulator looked at that has suitable characteristics for what the Motivational MP3 Player needs. The input voltage range is from 2V to 28V, producing an output voltage of 3.3V (or 1.8V to 18V in 0.1V increments available upon request). Output voltage accuracy of 2% is nice, with a low dropout voltage of 260 mV at 20 mA, and an output current of 150 mA. The versatility of this particular component makes it attractive for various applications such as use in car audio and navigation systems, digital cameras, and home appliances.

The MCP1702 voltage regulator has an input voltage range from 2.7V to 13.2V, an output voltage of 1.2V to 5.5V in 0.1V increments, output current of 250 mA, and dropout voltage of 625 mV, with a secure 0.4% output voltage tolerance. Depending on how much voltage is needed for the navigation system and other features of the Motivational MP3 Player design, this looks like a suitable voltage regulator for the job, with a low cost of just $0.52/unit.

As was found, there are plenty of different voltage regulators available that can all be chosen for a low-dropout voltage, fixed voltage, low output current voltage regulator for the design purposes. The one parameter that is most important is the supply voltage of the circuit with all the key functions added to it.

3.3.8 Step-Up Converters

In some cases there is a desire to have a circuit operate on a smaller voltage supply, but the components need to operate at a higher voltage supply. In cases like these, a step-up converter may be used as opposed to the different case where the regulator needs to bring the operating voltage down to a specific voltage. The step-up converter takes a small voltage and brings it up to the desired level in order for microelectronic components to work with a smaller power supply. This method eliminates bulkiness from any design, because the circuit can be designed with fewer batteries and therefore an overall more compact design. However, in some instances the battery may be drained if overused and some users may not be satisfied with a small battery life, especially in today's world with portable electronic devices and a desire for long-lasting components. In any case, step-up converters are discussed here for the sake of potentially including one in the Motivational MP3 Player project design.

In the DSPdap MP3 Player project design, there are instances where the voltage needs to be regulated down, and then also stepped up. The step-up converted TPS61103 is used to generate a fixed 3.3V from 1V to 3V battery input. This is an example of a fixed-output voltage converter, with an adjustable output voltage up to 5.5V and a minimum voltage input of 0.8V to 3.3V. This chip actually has a battery supervision option, and battery supervision to help control wasting battery life. This is a low-power device with an output current of 270 mA, and has a switching frequency of 320 KHz to 800 KHz, making it an efficient product that works quickly with 95% efficiency. The TPS61103 features Over Temperature protection, although this is unlikely in such a low-power device being operated at just 3.3V, such as the Motivational MP3 Player. The specifications of this chip make it ideal for use in applications such as single or dual cell battery operated products, DSP applications, and audio players and cameras. At a price of $4.05, this chip does the opposite of a regulator, and may be needed in the circuit of the project design.

Like everything in the technology world, there are many other alternatives for the same function. This purpose of looking at different products is to find one that meets the criteria of our design the closest for the cheapest cost. Another step-up converter that could potentially be used in the Motivational MP3 Player design is the LMR1428. This step-up converter accepts a voltage input range of 1.2V to 14V, making it a possibility for a design that includes GPS navigation and other higher-powered functions. With a component such as this, a small device can be designed but still have high-powered features that require a larger supply voltage, which can be supplied from a small battery pack of simply 3.3V or so. This chip has an output current of 0.1 mA, meaning that it maintains the low-power operation after the voltage is stepped up. The switching frequency is 2 MHz, a very fast operation. This chip seems like a great value, for just $1.46/unit, it definitely outweighs the pros of the chip described above.

The LMZ10501 is a step-up converter with a minimum input voltage of 2.7V and maximum input voltage of 5.5V. This chip seems suitable for a circuit operating at a low-power level of 3.3V, for it has an output voltage of 0.6V to 3.6 V. This chip could operate on 2 1.5V batteries, and the output current is 1 A. This current is higher than other components looked at, but it might come in handy when designing the Motivational MP3 Player and adding its extra features. For a simple MP3 player design, this output current may be too high if trying to avoid high-power functionality. Remembering that Power = Voltage X Current, the higher the current the more power is consumed, and this is to be avoided in low-power devices that operate on rechargeable batteries. This chip costs $3.48/unit.

An alternative to the chip just described above is the LMZ10500, which costs only $2.92/unit. The specifications are generally the same, with an input range of 2.7V to 5.5V, and an output range of 0.6V to 2.6V. However, the output current is 650 mA, making it more suitable for low-power devices to maintain the battery life, which is the main goal whenever using a component that steps up the voltage and increase power during operation. Sometimes the relationship in designing a product is give-take, meaning something has to be sacrificed. If more voltage is being supplied to increase power consumption, the next thing to look at is the output current to be sure the circuit can be re-stabilized to a low-power state. This chip does that better than the one mentioned above, and is cheaper.

4 Project Hardware and Software Design

4.1 Hardware Design

The hardware of the project is made up of mp3 player components and the pulse simulator. With having these components talk with each other, it is able to make the design work. The following sections discuss in more detail how each of the subsystems work with one another.

4.1.1 First Subsystem – Master Controller

The first hardware component that was considered in the design of the Motivational MP3 Player was the Master microcontroller. This is the MSP430g2553 microcontroller from Texas Instruments, and has the necessary programs loaded onto it to controller touchpad selections and to transmit UART transmissions to the slave controller to control player functionality. This is a 28 pin SOIC surface mount controller, very small, and is mounted on the PCB underneath the touch pad wheel. Featured in this device is Enhanced UART supporting auto Baudrate detection, synchronous SPI, and i2c. The memory features are as follows:

- 512 B RAM for internal data
- 16 kB Flash
- LF, DCO, VLO Clocks
- 2x TA3 Timer_A

Operating from 1.8V to 3.6V, this device has ultra-low power consumption, and operates at 1MHz in active mode, at 230 uA, with a 62.5-ns Instruction Cycle time. Featured also are 24 capacitive-touch enabled i/o pins. This chip is specifically designed to be used with the capacitive touch boosterpack, and is able to transmit data via UART line, and that is why it was chosen at the master controller. The pinout of the MSP430g2553 as used in the Motivations MP3 Player is shown in Figure #21.

Pin	MSP430 Port	BoosterPack Signal	Description
1	VCC	NC	Supply voltage, not connected to BoosterPack
2	P1.0	LED9	The white center LED
3	P1.1/TXD	NC	Backchannel UART transmit data output, not connected to BoosterPack
4	P1.2/RXD	NC	Backchannel UART receive data input, not connected to BoosterPack
5	P1.3	LEDx	LED base to drive the eight multiplexed LEDs
6	P1.4	LED1	LED1 positive and LED5 negative drive
7	P1.5	LED2	LED2 positive and LED6 negative drive
8	P2.0	SENS0	Capacitive-touch proximity sensor
9	P2.1	SENS1	Capacitive-touch wheel sensor left
10	P2.2	SENS2	Capacitive-touch wheel sensor down
11	P2.3	SENS3	Capacitive-touch wheel sensor right
12	P2.4	SENS4	Capacitive-touch wheel sensor up
13	P2.5	SENS5	Capacitive-touch center button sensor
14	P1.6	LED3	LED3 positive and LED7 negative drive
15	P1.7	LED4	LED4 positive and LED8 negative drive
16	RST/SBWTDIO	NC	Reset line for SBW JTAG data, not connected to BoosterPack
17	TEST/SBWTCK	NC	Test line for SBW JTAG clock, not connected to BoosterPack
18	P2.6/XOUT	NC	Oscillator output, not connected to BoosterPack
19	P2.7/XIN	NC	Oscillator input, not connected to BoosterPack
20	GND	GND	Supply ground

Figure 21 Capacitive Touch Boosterpack Interfaces

Each pin is shown to connect to its corresponding capacitive touch input. The g2553 master controller simply takes in inputs from the control wheel, and sends the corresponding commands via the RX pin (pin 4) to the slave controller. UART plays a vital role in the transmission of data to the controller.

4.1.2 Second Subsystem – Slave Controller

The slave controller is the Atmega328P and is the controller used to make everything else on the board operate correctly. All of the commands from the master controller are processed in this controller and the peripherals are connected to its pins. When operations are sent to the RX pin of the ATmega, then the programs jump into various functions to control another feature, such as displaying text or reading and playing an MP3 file, or reading a pulse. The pinout of the Atmega328P controller is shown below in Figure #22.

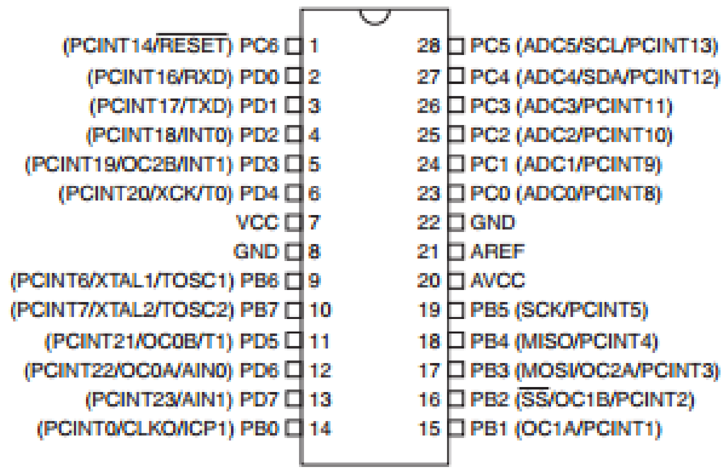


Figure 22 Atmega328P Pinout

The various functions are dictated by the proper pinout. Have 28 pins leaves room for the necessary functions needed, and are described in the following paragraphs.

The reset pin is tied to power through a 10k pull-up resistor. Pin 2 is used to receive UART commands from master controller. Pin 3 is unused. Pins 4, 5, 6, 11, 12, 13, and 14 are digital i/o pins used to initialize i2c protocol with the sd card.

Pins 15 and 16 are unused. Pins 17, 18, and 19 are used to initialize serial communication with the codec. Pins 23, 24, 25, and 26 connect to the LCD data lines to send characters to be displayed. This pinout allowed the MMP3P to run without any problems and no lack of space or available pins.

Features of this chip consist of a 10-bit analog to digital converter, programmable serial USART, a frequency up to 20MHz, and adequate memory for writing memory to the device. The memory features 1Kb EEPROM, 2Kb of SRAM, and can perform 10,000 Flash write/erase cycles and 100,000 EEPROM write/erase cycles. This way, there is not a realistic probability of the chip burning out if being used properly.

4.1.3 Third Subsystem – Pulse Simulator

The pulse simulator was designed to prove the concept of the EKG analog input. This simulator transmits a direct, exact, analog signal at varying voltages that are able to be controlled with a turn wheel potentiometer. The voltage is able to be increased above an analog threshold value. When the threshold value is reached, then the beat is counted. Another beat is counted when the voltage is dropped below the threshold and then raised again. This cycle simulates a pulse reading, and the signal is fed into pin 28 of the ATmega controller.

Also on the board containing the pulse simulator is an on/off button. This way, the device can be removed from the power source to save power consumption. The pulse simulator which was b built is shown below in Figure 23.

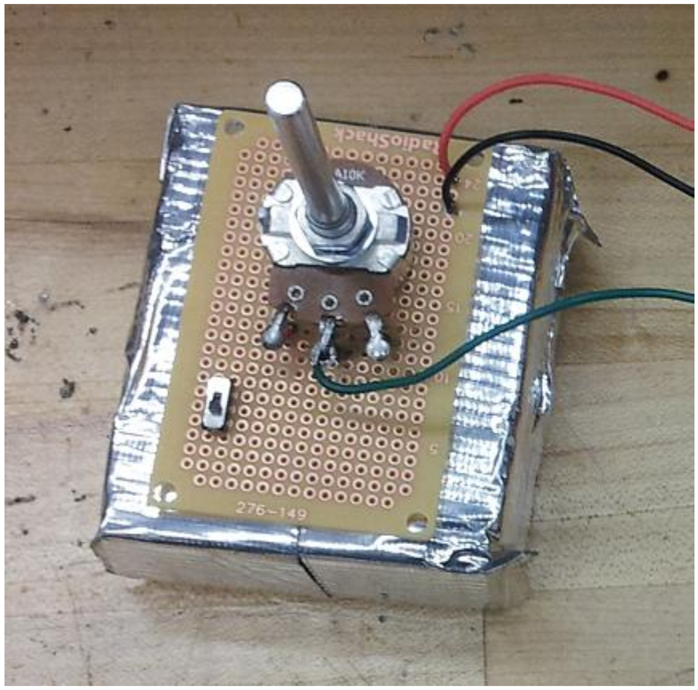


Figure 23 Pulse Simulator

Turning the knob to the right decreases the voltage level with a varying resistance. The resistance varies from 0k to 10k. Turning the knob to the left increases the voltage. This exact voltage changer acts as a pulse simulator, rising and falling above and below the threshold value which is programmed into the slave controller. The ADC value which is coded in the project is 250, about a quarter turn of the dial.

4.1.4 Fourth Subsystem – LCD Display

The width of the player is aimed at 69.85 mm (2.75 inches). Thus, ideally a screen that is within that width is desired. There are many LCD displays on the market, so it is a goal to find one within the specifications. The following paragraphs explore some of the displays available to the public and hopefully choose one that is a good fit for the MMP3P.

The image in Figure #24 is an LCD display for displaying information for user interaction. This is the LCF-09066 and allows a parallel based LCD to be controlled over a single-wire interface. The serial backpack, which comes connected to the 16x2 black on green LCD, features a PIC16LF88 which maintains operation of the device, takes a TTL serial input information from the MSP430F1612 and sends the data to the screen.

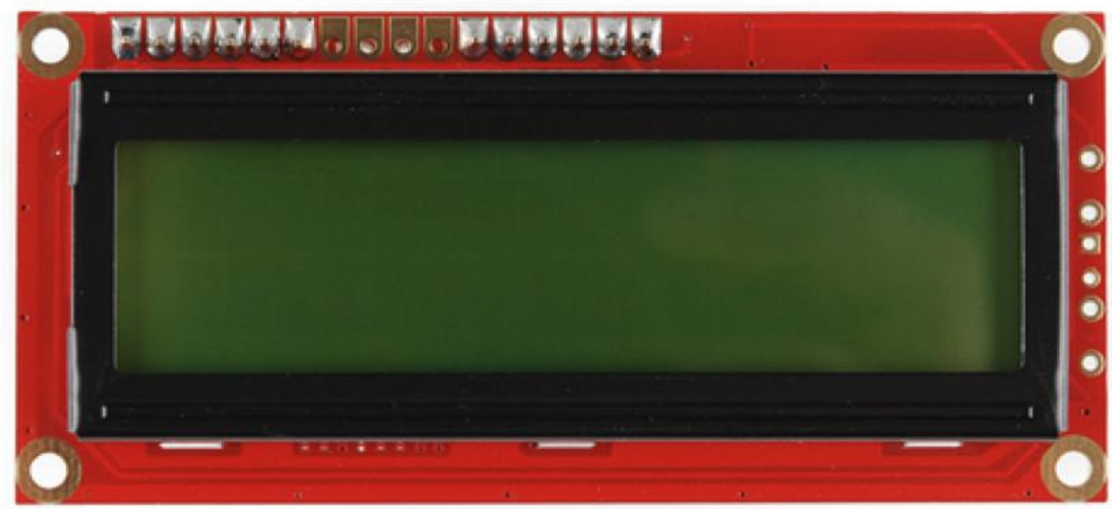


Figure 24 16x2 LCD

Some more features of this display are onboard UART for greater communication accuracy, greater processing speed at 10MHz, an incoming buffer which stores up to 80 characters, a 1A backlight transistor, adjustable backlight brightness and current consumption, faster boot-up time, and it is small. Operating at 3.3V, this LCD display is simple to use because of its single-wire interface, and comes with a number of pre-programmed modes for various operations. This display allows the user to view his or her input upon startup, and view information about the workout in progress. The pinout of the device is shown in Table #11.

Table 11 Pinout for LCF-09066

1	VSS	GND
2	VDD	+5V
3	V0	Contrast adjustment
4	RS	H/L Register select signal
5	R/W	H/L Read/Write signal
6	E	H/L Enable signal
7	DB0	H/L Data bus line
8	DB1	H/L Data bus line
9	DB2	H/L Data bus line
10	DB3	H/L Data bus line
11	DB4	H/L Data bus line
12	DB5	H/L Data bus line
13	DB6	H/L Data bus line
14	DB7	H/L Data bus line
15	A	+4.2V for LED
16	K	Power supply for BKL(0V)

As mentioned previously, these pins are connected to the serial backpack which comes with the package. The package only needs three connections to operate: +3.3V, GND, and signal. The schematic of the LCD is shown in Figure #25.

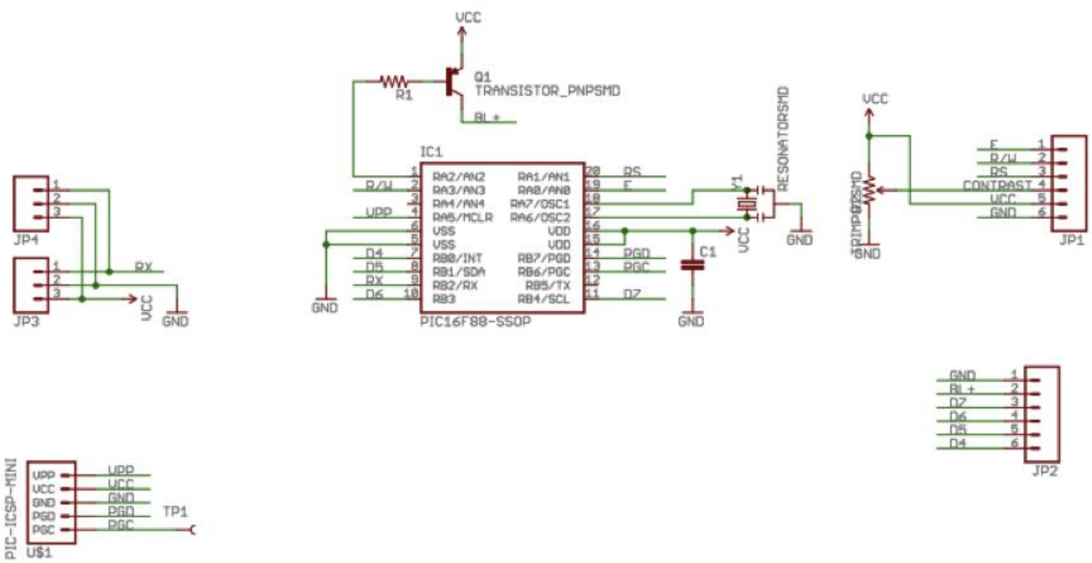


Figure 25 Schematic for LCD Backpack

The PIC-ICSP allows for serial in-circuit programming from the backpack to the display, a single-wire interface labeled TP1. The fact that this connection comes with all the schematics and connections already pre-assigned helps simplify the design of the Motivational MP3 Player.

Figure 26 Backside of Backpack LCD

The silkscreen on the image of Figure #26 shows a 5V connection, but it must be made clear that the connection is actually for 3.3V, and the silkscreen is misprinted. The Rx pin in the blue box located on the backpack must been connected to the MSP430F1612 to allow data to flow from the microprocessor to the display. The schematic part for the LCD display is shown in the schematic above for the MSP430F1612 microcontroller and as can be seen only has three pins. This situation makes the design aspect involving the display very simply, as it becomes a problem of programming the microcontroller to handle the proper functions.

One of the main downfalls of this component is its limited display area. The user wants a full account of his or her progress, and for a small display, the information is limited to about 2 to 3 pieces of information per screen. For a complete account, multiple screen changes are required, further complicating the controller interface and limiting the amount per screen display. For some cases, a larger screen may be desired. As is known, in popular devices such as the iPod or smartphone displays, most if not all of the information can be displayed in one look of the screen. This may be an approach desired for the Motivational MP3 Player design. For this case, more displays shall be reviewed.

Another LCD screen display that is considered is the Displaytech Ltd. LCD Module. This display is larger and a better choice for a portable device.

Figure 27 Displaytech, LTD Image

This display's specifications are listed in the table #12:

Table 12 Displaytech Ltd. LCD Module Specifications

Item	Contents
Display Format	240 x 128 DOTS
Dot Size (W x H)	0.325 x 0.325
View Area (W x H)	92.0 mm x 53.0mm
Module Size (W x H x T)	98.7 mm x67.7mm x 9.5 mm
LCD Type	FSTN
Polarizer Mode	Transflective
View Angle	6 / 12 O'clock
Backlight	LED
Backlight Driver Type	External Power
Backlight Color	White
Controller & LCD Driver	ST7529-G
Driving Method	1/144 Duty, 1/12 Bias

This screen has 240 x 128 dots on the display, making for a more interactive formatting area, allowing more information at one time to be viewed on the screen. As can be seen, the module size alone is 98.7 mm wide, 67.7 mm high, and 9.5 mm thick. If this module is chosen in the design of the Motivational MP3 Player, this makes for a large viewing area, and probably larger than desired. A screen that is 98.7 mm wide compare to a touch wheel that is only 50 mm probably makes the device off-centered and undesirable. It runs at 3.3V typical operating voltage, and draws 2.0 mA of current, so the display is low-power and operates at a voltage with the power supply.

Table 13 LCD Maximum Power Ratings

ITEM	SYMBOL	MIN.	TYP.	MAX.	UNIT
Power Supply for Logic	VDD-VSS	-0.5	---	4.0	V
Power Supply for LCD	VLCD-VSS	-0.5	---	20.0	V
Input Voltage	VIN	-0.5	---	VDD+0.5	V
Supply Voltage for LED Backlight	V_{LED}	---	3.2	---	V
Normal Operating Temperature	Top	0	---	50	°C
Normal Storage Temperature	Tst	-10	---	60	°C
Wide Operating Temperature	Top	-20	---	70	°C
Wide Storage Temperature	Tst	-30	---	80	°C

The display in Figure #28 is larger than the design for the MMP3P, and so another option must be explored.

Another LCD screen was found which more closely meets the specifications for the player. This screen is the Graphic LCD 84x48 - Nokia 5110 and is 84 x 48 mm in size, and costs only $9.95. This is slightly wider than would have been preferred, but overall would make for a good display considering its large display area and many lines for coding to show up on. It operates off 2.7 to 3.3V operating voltage and is low-power. The functions for the displays are all controlled via one chip, making for a simple-to-use device while consuming low power, and allowing the display to operate at the supply voltage of 3.3V because the voltage generation for the display is located on this chip. The display is shown in Figure #28, along with voltage specifications and ratings in table #14.

Figure 28 LCD 84x48 - Nokia 5110 Display

Table 14 LCD 84x48 - Nokia 5110 Limiting Values

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{DD}	supply voltage	note 3	−0.5	+7	V
V_{LCD}	supply voltage LCD	note 4	−0.5	+10	V
V_i	all input voltages		−0.5	V_{DD} + 0.5	V
I_{SS}	ground supply current		−50	+50	mA
I_I, I_O	DC input or output current		−10	+10	mA
P_{tot}	total power dissipation		−	300	mW
P_O	power dissipation per output		−	30	mW
T_{amb}	operating ambient temperature		−25	+70	°C
T_j	operating junction temperature		−65	+150	°C
T_{stg}	storage temperature		−65	+150	°C

4.1.5 User Control Design

For the user to interact with the device, a system for controlling signals was to be incorporated into the design of the Motivational MP3 Player. Similar to an iPod, there are touch-screen controlling devices available for incorporating into the design, but the goal here is to find a controlling system which would be efficient, affordable, and effective. For instance, the interface could be completely touch-screen, or it can be external buttons which control the data entered into the program. Below is a discussion on different options for a controlling system.

4.1.5.1 PIC18F2520

If the design for the Motivational MP3 Player was to use buttons for controlling the input signals, then what different options are available? First and foremost, the microcontroller should have pins available for I/O devices, and that's what a button is - an I/O data entry controller. So, it is very possible to simply program user buttons into the microcontroller and be on one's way. The PIC18F2520 microcontroller has many digital I/O ports for these purposes.

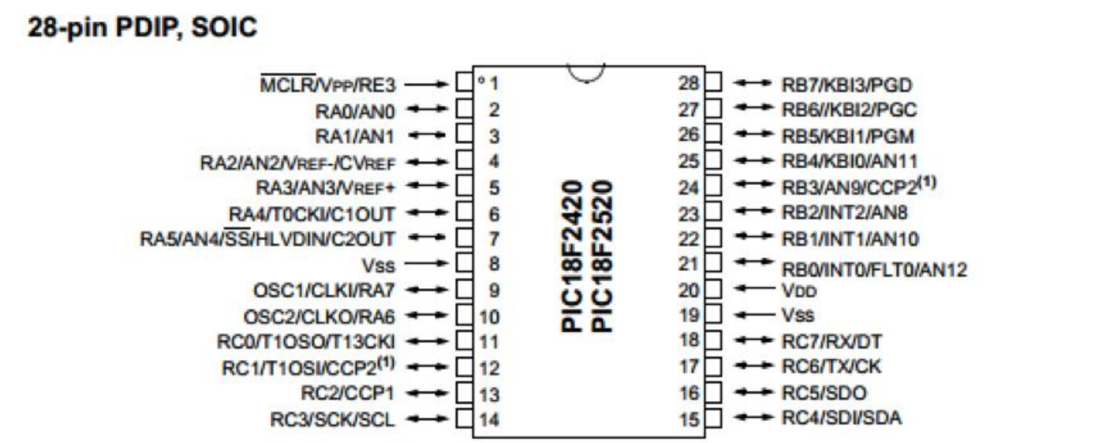


Figure 29 Pinout for PIC18F2420

Figure #29 above shows the pinout for the PIC18F2520, 28-pin PDIP, SOIC. The ports 2, 3, 4, 5, 6, 7, 21, 22, 23, 24, 25, 26, 27 and 28 are all digital I/O ports which can be configured in a number of different ways.

Pin 2 is a digital I/O but also acts as an analog input 0, hence the name RA0/AN0. Pin 3 is digital I/O and doubles as analog input 1, hence the name RA1/AN1. Pin 4 is RA2/AN2/Vref-/CVref, which means that, in addition to the digital I/O and analog input, it serves as the A/D reference voltage (low) input, and a comparator reference voltage input. Pin 5 is named RA3/AN3/Vref+, which means it serves the function of A/D reference voltage (high) input. Pin 6 is RA4/T0CKI/C1OUT. The name TOCKI mean it is an external clock input for Timer0, and C1OUT represents Comparator 1 output. For all the other digital I/O pins, there are different features included in each port so each port can be either a digital I/O and/or serve as another function as well.

To program a PIC controller, C language is typically, or sometimes assembly language. There are many techniques that can be used to program the pins, but essentially the programmer assigns functions to each of the pins to control what they do. This is how a button is programmed to a pin on a microcontroller, and it is a straightforward approach.

4.1.5.1 MSP430 Family

The idea for the Motivational MP3 Player is to have a user interface that is simple yet effective. The Texas Instruments MSP-EXP430G2 LaunchPad Experimenter Board was used as a reference board for the initial design of the Motivational MP3 player. The launchpad is shown in Figure #30.

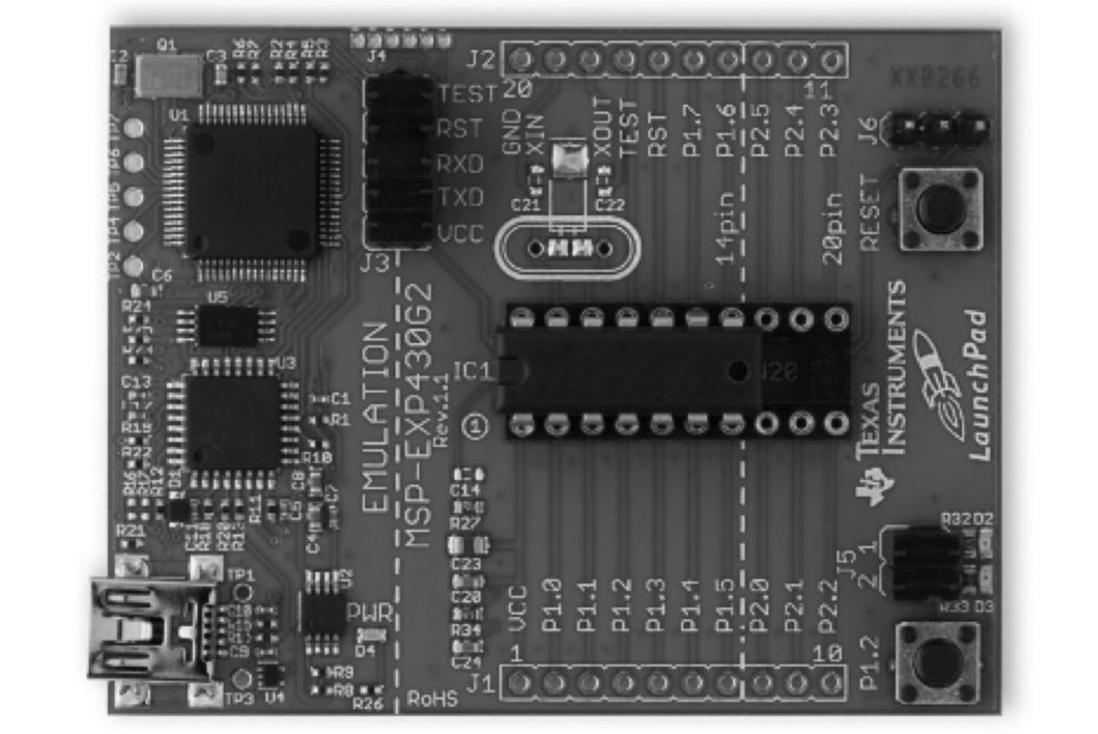


Figure 30 MSP430 Launchpad

(http://importgeek.wordpress.com/2012/06/26/how-to-setup-msp430-launchpad-in-ubuntu/ / Permission Pending)

This board was a good reference design because it includes many features pre-installed in its memory components, and many projects have been implemented on this popular device. Although there are more features on this development kit than is needed for the design at hand, tinkering with this board served as a good reference to how the design of the Motivational MP3 Player would pan out.

The key features of the MSP-EXP430 are the memory space allocated for writing programs and communicating with the computer via mini-USB hub. As can be seen in the image above, there are three microcontrollers included on the PCB. The one on the top right of the image (labeled U1), is the MSP430F1612 Mixed Signal Microcontroller from Texas Instruments. This microcontroller operates at a low supply-voltage range from 1.8V to 3.6V, and operates in ultralow power consumption mode, with an active mode current of only 330 micro amps, and a standby mode current of only 1.1 micro amps. There is a 12-bit analog-to-digital converter and a 12-bit digital-to-analog converter, an on-chip comparator, and a supply voltage supervisor. In this chip, there is 55KB+256B of Flash Memory and 5KB of RAM for writing programs.

The version of the MSP430F1612 used in the MSP-EXP430 is the PM, RTD Package as shown in Figure #31.

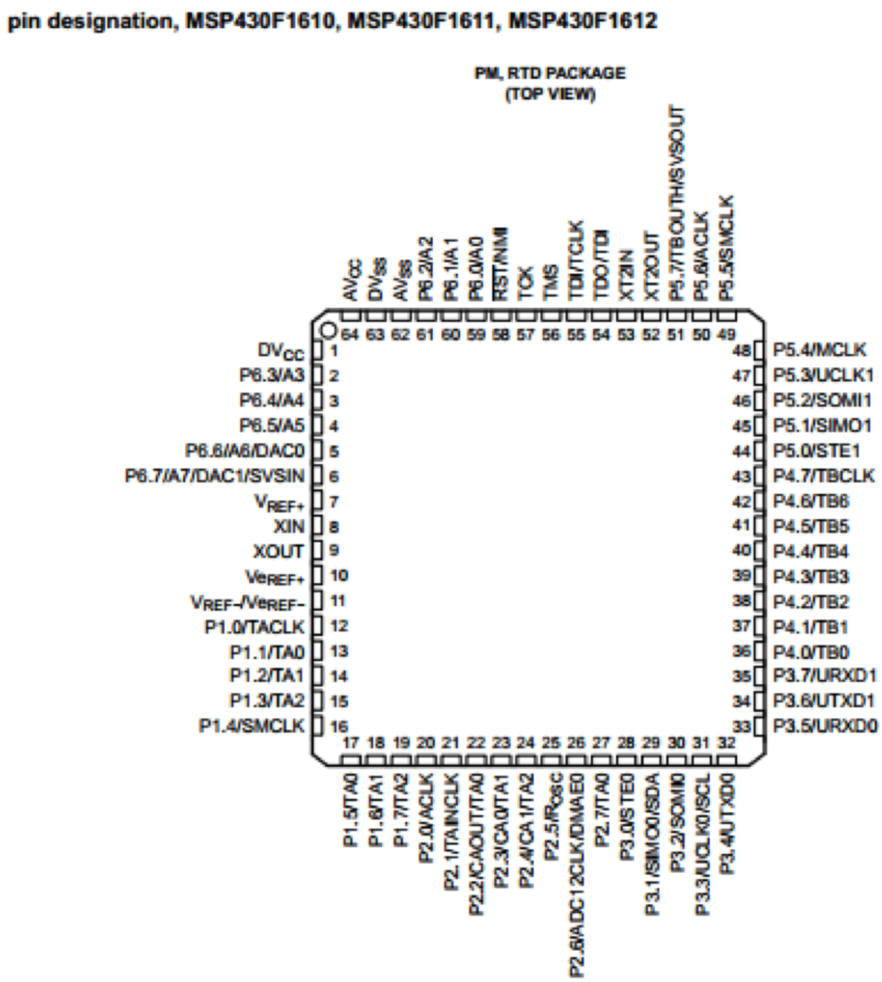


Figure 31 Pinout of the MSP430 Family

Pin 1 is connected to the voltage supply, VCC. Pins 2 through 14 are actually not used in the MSP-EXP430 LaunchPad board, although they serve as digital I/O and analog inputs, voltage references, crystal oscillator inputs/outputs, and the likes. Pin 15 and 16 are connected to the USB controller RTS and DTR, respectively. RTS is a request to send signal, and DTR is a data terminal ready signal. Pin 17 and 18 are connected to the USB DSR and CTS pins, respectively. These pins are the data set ready and clear to send signals. These pins must be programmed in the microcontrollers in order for the two chips to communicate to each other. One of the chips is reading data from the computer via USB cord, and the other chip is sending and receiving data to/from that chip. Since the Motivational MP3 Player is able to communicate with a USB device, this feature is something that stood out. This particular chip includes a multitude of general-purpose digital I/O pins which also can be programmed to perform other features as well. It is features such as this that make this chip ideal for including in the Motivational MP3 Player as a main source of program memory and pinouts, seeing as how there are so many pins to make this a versatile chip. This part can be found for about $9.50 from Texas Instruments website.

4.1.5.3 TUSB2410

Another microcontroller that is included in the MSP-EXP430 Launchpad is the TUSB2410 USB to Serial Port Controller from Texas Instruments. This chip is selected for inclusion in the Motivational MP3 Player because it is a way for the USB data to be transferred from computer to chip, and this chip controls those functions. Included in this chip is an 8052 microcontroller unit with 16K bytes of RAM that can either be loaded from the hose or the external on-board memory. There is also 10K bytes of ROM, allowing the microcontroller unit to configure the USB port at boot time.

This chip requires 3.3V to operate, but has an internal operating voltage of 1.8V provided by a voltage regulator. The MCU includes the following memory components: 256 x 8 RAM for internal data, 10K x 8 ROM (with USB and I2C boot loader), 16K x 8 RAM for code space loadable from host or I2C port, 2K x 8 shared RAM used for data buffers and endpoint descriptor blocks. The chip features software selectable baud rate from 50 to 921.6k baud. Included on the MSP-EXP430 Launchpad is the VF Package as seen in Figure #32.

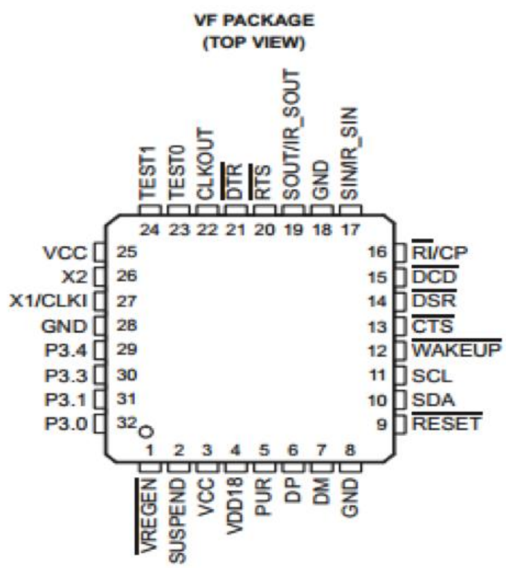


Figure 32 Pinout for TUSB3410

This is the chip that communicates to the MSP430F1612 as mentioned previously. A voltage of 1.8V must be externally supplied to pin 4, so a voltage divider circuit must be built. As can be seen, there are several general purpose I/O pins, and the memory space available in this chip means it is suitable for the Motivational MP3 Player project design. This part can be bought from Texas Instruments for about $2.95.

Finally, the third microcontroller on the MSP-EXP430 LaunchPad Experimental Board is a 14-pin microcontroller, but in the Motivational MP3 Player, the MSP430G2452 Mixed Signal microcontroller is used, which is 20-pins. Much like the previous chip described, the MSP430G2452 operates at 1.8V to 3.6V, with only 220 micro amps of current flow in active mode, making this an ultra-low power consuming product. This chip features an internal very-low-power low frequency oscillator, so a crystal is not needed to maintain a clock input. This chip has up to 16 touch-sense enabled I/O pins. The chip is shown in Figure #33.

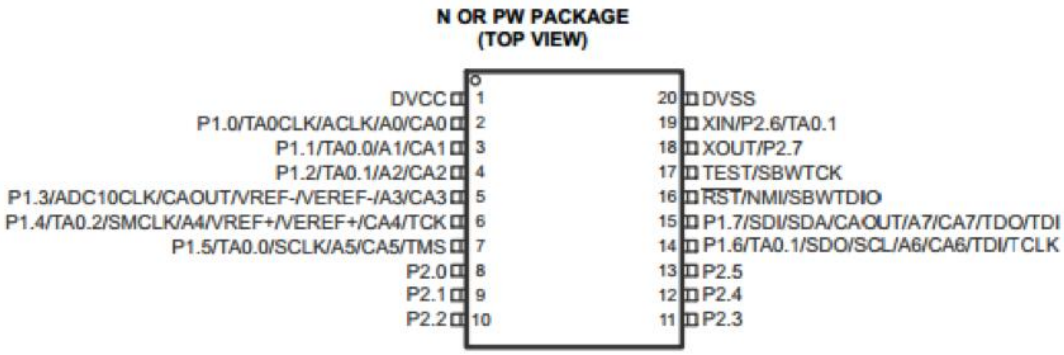


Figure 33 Pinout for the MSP430G2454

The main function of this chip is to communicate via a set of male headers to the capacitive Touch BoosterPack. The touch-sense enabled I/O pins make this chip ideal or communication with the cap touch boosterpack, and this acts as the main control unit for the Motivational MP3 player. While the other microcontrollers are communicating with the computer, the heart rate monitor, and other added features of the Motivational MP3 Player, this chip takes on the role of controlling the user input data for a portable experience and data entry.

The chip communicates also with other memory devices, which is where most of the data is read and written. The point of this microcontroller is to hold the information needed to read the cap-touch boosterpack instructions. The reason for giving this function its own microcontroller is because the additional features of the project needs to allocate as much memory as possible, and therefore there is no need to waste memory space on a set of instructions to handle the control pad’s usage.

4.1.5.4 Capacitive Touch

Which brings up another feature of the Motivational MP3 Player - the Capacitive Touch Boosterpack from Texas Instruments, shown in Figure #34 below attached to male headers on the MSP-EXP430 Launchpad.

Figure 34 Capacitive Touch Boosterpack

(http://store.43oh.com/image/cache/data/LaunchPad_Capacitive_BoosterPack-500x500.jpg /Permission Pending)

This device was created specifically to give touch sense capabilities to any MSP430 microcontroller, and since MSP430 microcontrollers are being used in the Motivational MP3 Player, it is included as the main control source for user data entry. The pinout for the above device is given in table #15.

Table 15 Pinout for Boosterpack

Pin	MSP430 Port	BoosterPack Signal	Description
1	VCC	NC	Supply voltage, not connected to BoosterPack
2	P1.0	LED9	The white center LED
3	P1.1/TXD	NC	Backchannel UART transmit data output, not connected to BoosterPack
4	P1.2/RXD	NC	Backchannel UART receive data input, not connected to BoosterPack
5	P1.3	LEDx	LED base to drive the eight multiplexed LEDs
6	P1.4	LED1	LED1 positive and LED5 negative drive
7	P1.5	LED2	LED2 positive and LED6 negative drive
8	P2.0	SENS0	Touch-sense proximity sensor
9	P2.1	SENS1	Touch-sense wheel sensor left
10	P2.2	SENS2	Touch-sense wheel sensor down
11	P2.3	SENS3	Touch-sense wheel sensor right
12	P2.4	SENS4	Touch-sense wheel sensor up
13	P2.5	SENS5	Touch-sense center button sensor
14	P1.6	LED3	LED3 positive and LED7 negative drive
15	P1.7	LED4	LED4 positive and LED8 negative drive
16	RST/SBWTDIO	NC	Reset line for SBW JTAG data, not connected to BoosterPack
17	TEST/SBWTCK	NC	Test line for SBW JTAG clock, not connected to BoosterPack
18	P2.6/XOUT	NC	Oscillator output, not connected to BoosterPack
19	P2.7/XIN	NC	Oscillator input, not connected to BoosterPack
20	GND	GND	Supply ground

As can be seen, the pinout of this boosterpack is ideal for routing signals to the MSP430 microcontroller, and hence, that is why it is included in the project. The cap-touch boosterpack includes eight multiplexed LEDs to light up the display during activity. They have the following setup in Figure #35:

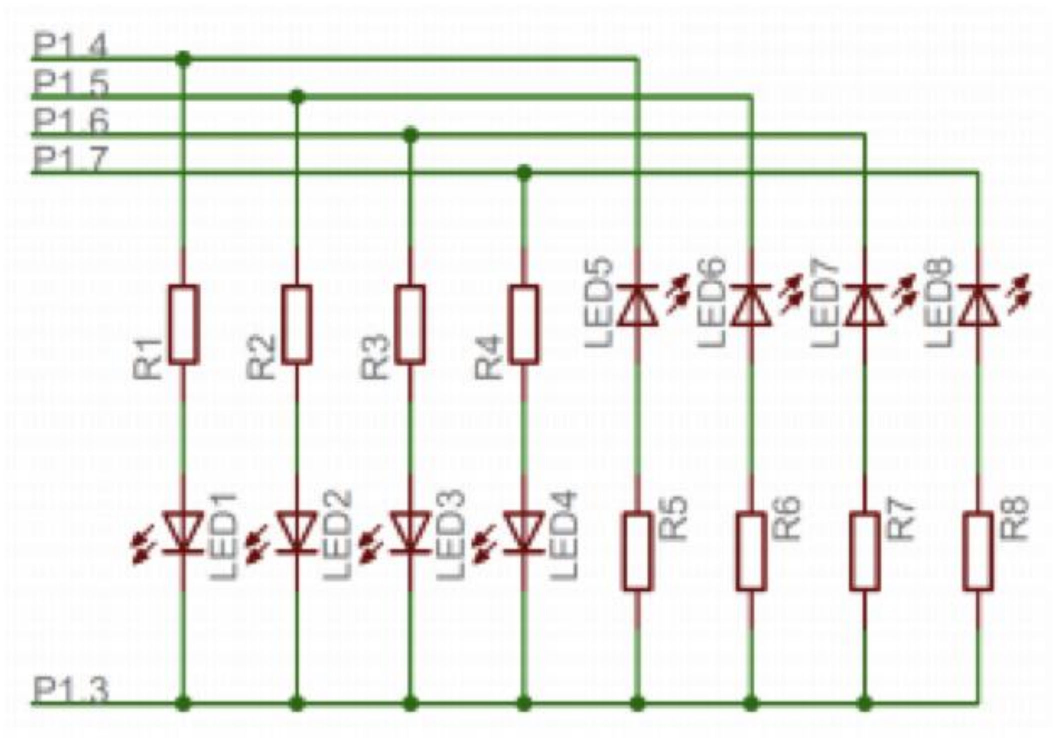


Figure 35 LEDs in the Cap-Touch Boosterpack

There are two modes in which each set of four LEDs operates, and switching between modes at a speed no less than 100 times per second gives the illusion of a constant light pattern. The LEDs are laid out on the PCB in the following fashion, in Figure #36:

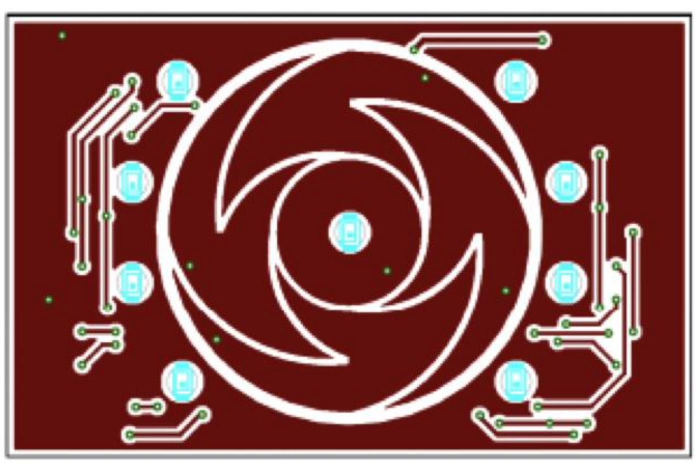


Figure 36 LED Organization in the Cap-Touch Boosterpack

As can be seen, there are four LEDs on either side of the rotational wheel. Upon user activation (either by touching or hovering above in close proximity), the LED's light up, but the modes of activation must be no less than 100 times a second in order for the LEDs to give off a constant illumination pattern such as the example as shown in Figure #37:

Figure 37 Cap-Touch Illumination Pattern

A great feature about these chips is the fast wakeup time from their standby modes. Standby mode is important in portable devices - or, electronic devices in general - because the device consumes and potentially wastes power if it is running in active mode all the time, even when not being active. In standby mode, less current flows through the device (in the MSP430G2452, 0.5 micro amps in standby).

4.1.6 SD Flash Memory

The PCB has a component which reads in an SD flash memory card. The standard that is used for Motivational MP3 is the miniSD. The SD card is the memory storage for the audio files, user information, and any other data files that need to be kept. The SD has a memory capacity of 16GB and is of the standard size of 20 x 21.5 x 1.4 mm. The flash memory incorporates the FAT32 file system and makes use of the High Speed bus speed for data access. There is a program that acts as the Driver to initialize the SD card memory and access the MP3 files from the FAT32 system. This enables the microcontroller to read the large amounts of MP3 files and decode them using the DAC.

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

The music files on the memory are organized by the ID3 tags, which all music files have. The ID3 tags are edited to follow the correct file format for Artists and Song titles to optimized library organization. The music files also contents 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 are adjusted manually to ensure there are no errors that affect the memory organization. The MP3 player also includes 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 is embedded as an attribute.

The user data is saved on the flash memory, as well. The data includes the user's Name, Age, Weight, and how frequently they work out (rating from 1 to 5). This information develops 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 also is 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 are accessed by firmware programming that is embedded in the MSP430 microcontroller memory space. The music files are retrieved for reading to the microcontroller and processed to the audio output via headphone jack or through the Bluetooth headset module. The user's data files are both read and write and stored back in the primary SD flash data card. This data is 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 sets the starting point for the exercises which the user performs to make it comfortable for them and it also establishes a threshold which determines the user's exercise limitations.

The data on the SD flash card is managed via USB extension to the user's PC. The files are accessed through the traditional Apple or Windows explorer where they are able to drag and drop the music files of their choice into a music folder. A separate folder also is designated for the user health and exercise information which can be edited or deleted without the MP3 player being on. The MP3 player and microcontroller are able to recognize when a user has edited the music or the user information. There are safeguards made to detect and prevent music file corruption or user information corruption and does not alter the music player's performance. There also are precautions if a user modifies any information in an incorrect format or if the user removes a user's information from its slot or adds too many users than the UI can handle. These precautions lead to a prompt the current user on the next MP3 player power on that there are issues with the user settings and request the user to reconnect the MP3 player to a PC/Mac to resolve this issue. Any corrupted data or mismatched files are quarantined and are taken note of for the next future USB/PC connection.

Accessing the memory is performed by the SD driver firmware. This firmware is able to calculate the Logical Block Address, LBA, of the specified audio files and then use that address to open and read the designated memory block. The block is read through the SPI bus and sends the audio data in a sequential order. The audio data may not be in contiguous in the memory, therefore, the FAT driver is able to decipher the memory and file format and deliver the correct data to the MSP430 for it to be converted and played.

The SD card also incorporates a password to access the memory when connected to a PC/Mac. This is a default setting that has a default password of a simple combination, abc123 or 1234, and the user can change the password if they wish too. This default setting can also be disabled to allow easy access and sharing of the data memory and device. The aim of this is to keep the device private and more personal for each user. The added security allows a user their privacy from other users, which should offer more confidence and relief during their exercise and use of this device.

The miniSD memory requires pull up converters to prevent inputs to the data lines, command lines, and clock from the microcontroller when it is not actively driven. This is done with internal pull up resistors which can be applied with some software to manage these registers. An alternative to the software is using external resistors that connect to these data lines and the Vcc. The input pins that are used from the F1612 microcontroller are pin 1 for chip select/slave select, pin 5 for SCLK, pin 2 for MOSI/SD command input, and pin 7 for MISO/SD data output.

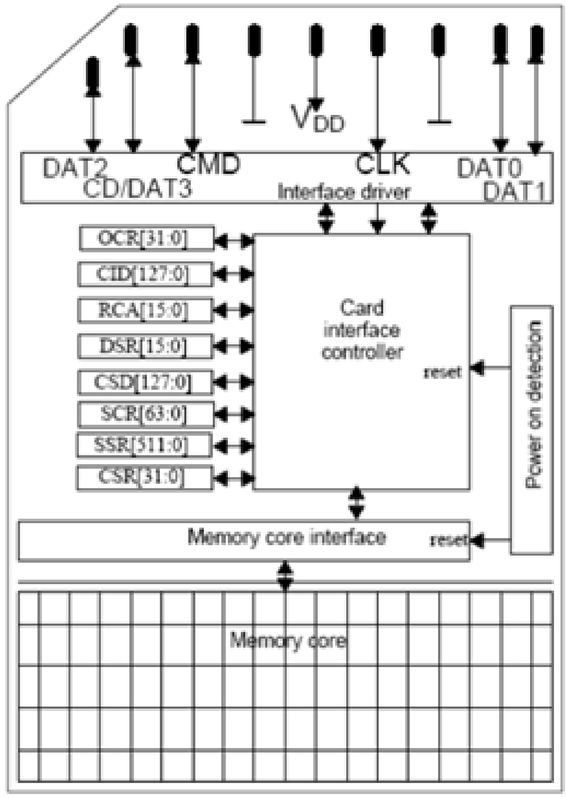


Figure 38 Memory Card Layout

Table 16 Memory Card Pinout

Pin No.	Name	Type	Description
1	CD/DAT3	I/O/PP[3]	Card Detect/Data Line [Bit3]
2	CMD	PP	Command/Response
3	V_{SS1}	S	Supply voltage ground
4	V_{DD}	S	Supply voltage
5	CLK	I	Clock
6	V_{SS2}	S	Supply voltage ground
7	DAT0	I/O/PP	Data Line [Bit0]
8	DAT1	I/O/PP	Data Line [Bit1]
9	DAT2	I/O/PP	Data Line [Bit2]
10	NC[4]	I/O/PP	For Future Use
11	NC[4]	I/O/PP	For Future Use

Pin Definition

4.1.7 Audio Jack Socket

The audio output of the MMP3P is sent via audio jack to any attached headphones. The audio socket consists of 5 pins, one for ground, two for left and right output, and two for left and right signal. The socket is wired to Vcc and ground to power the component. And the left and right signal pins are connected together to connect to one I/O pin of the MSP430F1612 microcontroller for audio output.

Figure 39 Socket

4.1.8 Mini USB Connector

To allow the microcontroller to power up and communicate to the computer, a miniature USB connector is added to the circuit board. This connector controls the voltage supply to the device and allows the player to communicate serially with the computer strictly when the plug is being used. This is a source for charging the battery via computer power, and also for loading new information into the device. This component costs $1.50 from Sparkfun Electronics, and is compatible with miniature USB plugs found in most major electronics stores.

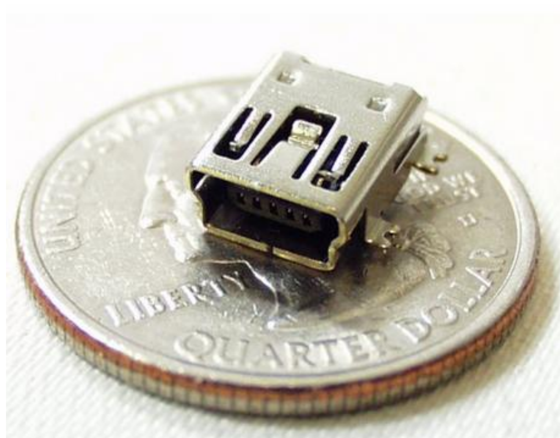


Figure 40 Mini USB Connector

4.1.9 Case Design

One of the major factors that comes into play with designing the Motivational MP3 Player is ease of use while the user is running. With keeping this in mind a adjustable strap that can be used to hold the EKG sensor on the user in combination of a lightweight case is ideal to have.

With respect to the MP3 Module, the housing needs to be compact and lightweight as well. Similarly the case for this module is made out of some type material as the EKG sensor to keep the two items

The hardware and software for the Motivational MP3 Player have been discussed, considered, selected, and designed for the project. The main challenge that still remains is how to lay the components out on the completed circuit board and designing the finished product with proper dimensions suitable for a standard portable device. To do this, it is wise to look at other similar products to gain insight on what sort of designs are already popular. After doing this, a good decision can be made for how to lay out the final product of the Motivational MP3 Player.

4.1.9.1 iPod Nano

The iPod Nano is an mp3 player that is popular on the market. Similar to the Motivational MP3 Player, the Nano has a touchscreen interface, with a capacitive touch wheel, so naturally this is a product that can be referenced for designing product dimensions. There are currently seven generations of the iPod Nano.

The version of the Nano, which most resembles the project being designed is the fourth generation, shown in image #41.

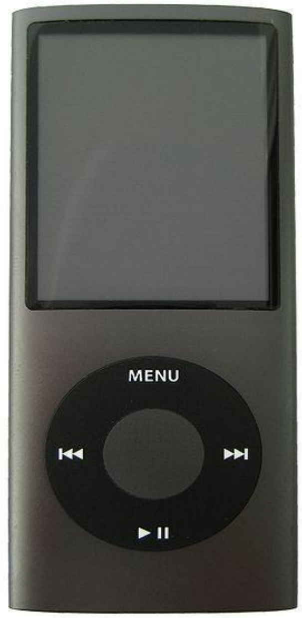


Figure 41 4th Generation iPod Nano

(http://en.wikipedia.org/wiki/File:IPod_Nano_4G_black_crop.jpg / Permission Pending)

As can be seen from the image, the wheel is very similar to the Texas Instruments capacitive touch boosterpack. The dimensions of this product are given in table #17.

4.1.9.2 Size and Weight

The size of the MMP3P should be portable, therefore easily transported via hand or pocket, or bag. A reference for the portable size of the player is the iPod portable MP3 player. This player has small features and is easily transported by the user. Table #17 shows the dimensions of the iPod.

Table 17 iPod Nano Dimensions

Height	3.6 in.	90.7 mm
Width	1.5 in.	38.7 mm
Depth	0.24 in.	6.2 mm
Weight	1.3 ounces	36.8 grams

This iPod can easily be fit in a pants pocket, and there are plenty of accessories available to attach the device to a person's arm or other body part to assist in running and working out while listening to music. The 4th generation iPod nano allows listeners to hear many of the names of menus, song titles, and artists without viewing the screen, change fonts to make them easier to read, contains a high-resolution 2-inch (diagonal) LCD display with adjustable brightness settings. It does not contain a Bluetooth receiver or heart-rate monitor. It would be ideal to have a design that is small in size like the iPod nano, but the TI cap-touch boosterpack is already 31.5 mm tall, 10.5 mm thick, and 50 mm wide

The project being designed is going to be larger than the iPod nano already, because the touchscreen wheel is wider and thicker than the iPod, but it can still be made to a size that is suitable for portability.

4.2 Software Design

The MP3 player system software is comprised of multiple software components that work collaboratively to carry out the expected functionality of the design. The each subsystem of the player have specialized software that is explained in a later section.

4.2.1 Audio Playing Software

The audio playing firmware incorporates the SD flash memory, the FAT file format and the built-in 12bit DAC module in the MSP430F1612 microcontroller. The coding is embedded in the MSP430F1612 flash memory space. It utilizes the SPI bus modes of the microcontroller to communicate with the SD card to access the data, and the FAT formatting allows data retrieval from the SD to the F1612 microcontroller. The microcontroller manipulates this partitioned data with the DAC operations to produce an analog, audio output which is driven to the audio jack provided.

The process begins with enabling the SD flash memory and initializing the memory via SPI bus outputs from the microcontroller. The memory receives commands from the F1612 for reading specific data from the flash memory. This data is sent to the microcontroller through the SPI SD output data bus. This procedure then activates the FAT format firmware in order to locate the starting location of the specified audio data and partition the data into 512MB sectors for the SD to send as blocks to the microcontroller. The FAT32 format utilizes the 32bit addressing and 512MB partitions to break down the data transfer process.

The audio data partitions are received by the F1612 microcontroller via SPI bus and are manipulated by the DAC module. The data is decoded into an analog signal which is outputted through the dedicated I/O data pins to the audio jack outlet. This decoding coding is interrupt-driven and incorporated with the touch control software to allow real-time music control. The audio playing software is also incorporating the playmode setting software depending on which one is chosen. The aim of this software is to execute general music playback with response to control inputs. The playmode software furthers this programming dynamically.

4.2.2 Touch Control Software

The capacitive touch controls has programming designated for decoding touch input and corresponding functions for each specific touch control. The touch control is based off interrupt-waiting functions in relation to the audio playing controls and the display controls. All the firmware is stored in the MSP430G2542 microcontroller's flash memory storage. The electronic input data is deciphered from the designated pins of the capacitive touch sensor to the G2542 microcontroller, which then translates the input into output data which interacts with the main MP3 player microcontroller, the MSP430F1612.

The touch control output data affects the audio file playback, primarily with the left, right, down, and clockwise & counter-clockwise touch buttons. The up button is dedicated for going up menu or back to previous menu. The middle button is dedicated for selecting a menu open or going into the next highlighted menu. These controls work along with the UI flow diagrams and are displayed by the LCD display to allow accurate navigation through the MP3 player. The control layout of the capacitive touch can be seen in Figure #42.

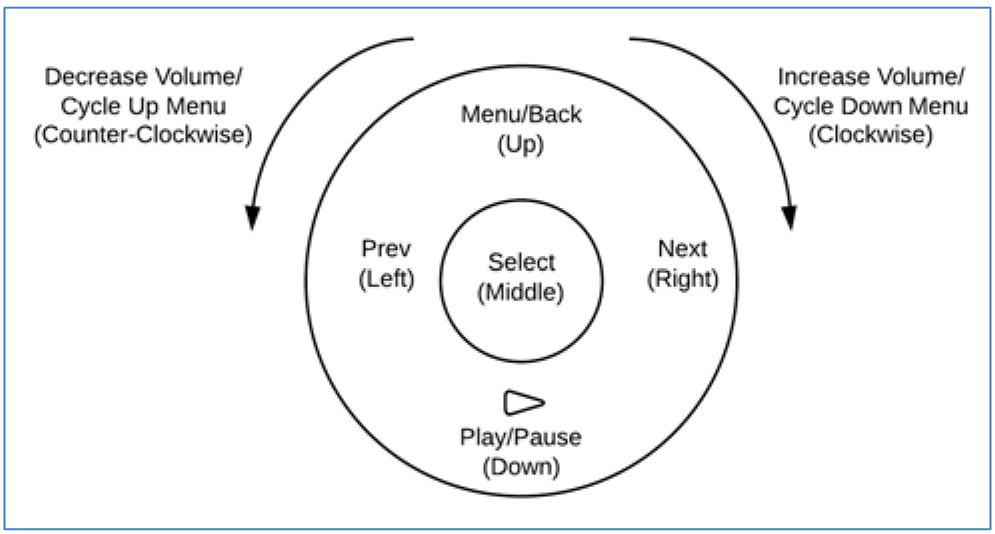


Figure 42 Designated Control Layout

The programming is written in C++ with basic C structuring. The firmware performs as a driver to Wait for a control response from the capacitive device and operates in collaboratively with the audio decoding/output firmware that is in the MSP430F1612 microcontroller. All control programming interprets input data which produces outputs to the second microcontroller or directly affect the menu or other MP3 settings. The controls maintain a receptive voltage state until an allotted amount of time before entering an idle mode, which can be exited when new voltage input is delivered to the controls. The control microcontroller is an interrupt-based controller which relays these interrupts to the main microcontroller and produced the corresponding results.

4.2.3 LCD Display Software

The LCD display is the face of the MP3 player. It conveys current audio and control information for user reference. The display also supports the user interface display to allow easy navigation of the mp3 player functions. The visual display is executed by C/C++ software that is embedded on the MSP430F1612 microcontroller and EEPROM. The programming incorporates the UI layout for side-scrolling menu display, the music information details for track time, artist, song title in the Now Playing display, and the EKG heart rate data that is utilized for the Playmode settings and for the user notifications.

The display also is real-time responsive, in relation to the master system clock in the microcontroller, with the control component of the MP3 player so that the ease of use is to its best capacity. The software has an approximate 1-second refresh rate to keep the user up to speed with the MP3 player.

4.2.4 User Interface Software

In order to make the Motivational MP3 Player really desirably to users, it must have a very easy to use and understand User Interface. For having a very basic and clean looking UI the device can be targeted to all aged markets. One of way to make the UI easy to have a really intuitive way to control the device, and that is through the capacitive touch sensor from Texas Instrument. With the touch sensor the user is able to control the device as if they are using a laptop or any other device with their thumbs, like people have done for years.

Another key aspect of making the user interface is the layout of the display screen. With having a screen that is the proper size, it allows for more information to be displayed at one time so that the user is able to process what possible menus and make a smart decision on what it is that needs to be done. Some devices have a small screen that limits the amount of possible options that can be performed within that section. When this happens, the user feels that if the task that they would like to perform is not on the screen that they are in the wrong spot or tend to lose track of the full menu list of the subsection. For this fact the Motivational MP3 Player has a simple menu scheme that does not have hundred of levels so that the users are able to not have to think about where they need to access in order to use the device.

For instance, if the device had a display of a 16 by 2 LCD and the device had a top-level menu of five options. Within each of the menus there are another set of five choices. The user has to be able to remember not only where the subfolders are but also the position of each of the folders so they are able to access the information that is need.

4.2.4.1 Menu Overview

When taking at look at the menu structure for the Motivational MP3 Player the users are going to be given a lot freedom right out of the gate. The user is able to use the capacitive touch sensor to select which menu item they would like to select. As the user starts up the Motivational MP3, they see a menu layout that they are able to scroll to and select. The different options that they are able to select are Music, User accounts, Play Modes, Settings and Now Playing.

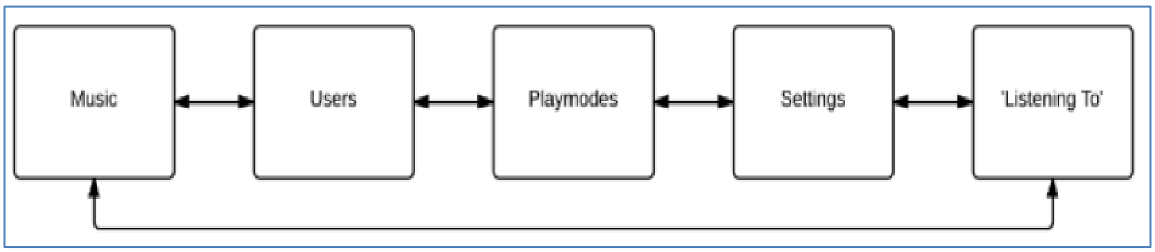


Figure 43 Top Menu Flow Diagram

4.2.4.2 Music

Looking into the Music part of the menu is where most of the database features are going to take over. Upon entering the music menu, the user is greeted by another set of options. From here the user is able organize the music in alphabetical order depending on the artist name, song titles, and also genre's. Another feature that is added to the Motivational MP3 Player is for the user to be able to create a playlist while importing the data so that the song selection has the music that they would like to limit versus pulling choices from the whole SD card.

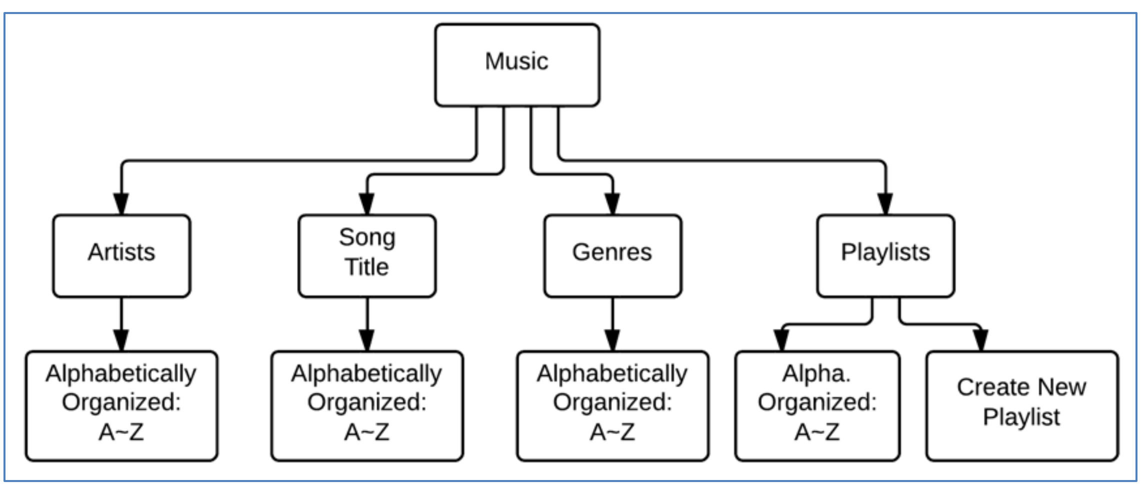


Figure 44 Selection Diagram

4.2.4.3 User Accounts

The next area of the top-level menu that is accessible is the User Accounts. In this menu the user profiles are handled. The user is able to select out of the three memory slots which profile is there so that the age, weight and gender is not needed to be entered each time that the device is going to be used. If the memory slot is empty the user is asked to select using the capacitive touch sensor to scroll to the age of that user, weight to the nearest 5 pounds and also male or female. After importing the data, the device asks if the user would like to proceed to do a workout and if so to select the type of work that would like to be selected either the dynamic style, anaerobic or just use the device as a standard audio player. From here if the user wishes to back out they are able to drop back to the top-level menu. Another aspect of the User Accounts menu is the profile manager. Similar to adding the user information by selecting an empty slot, the user also is able to add, edit and remove profiles from within this section.

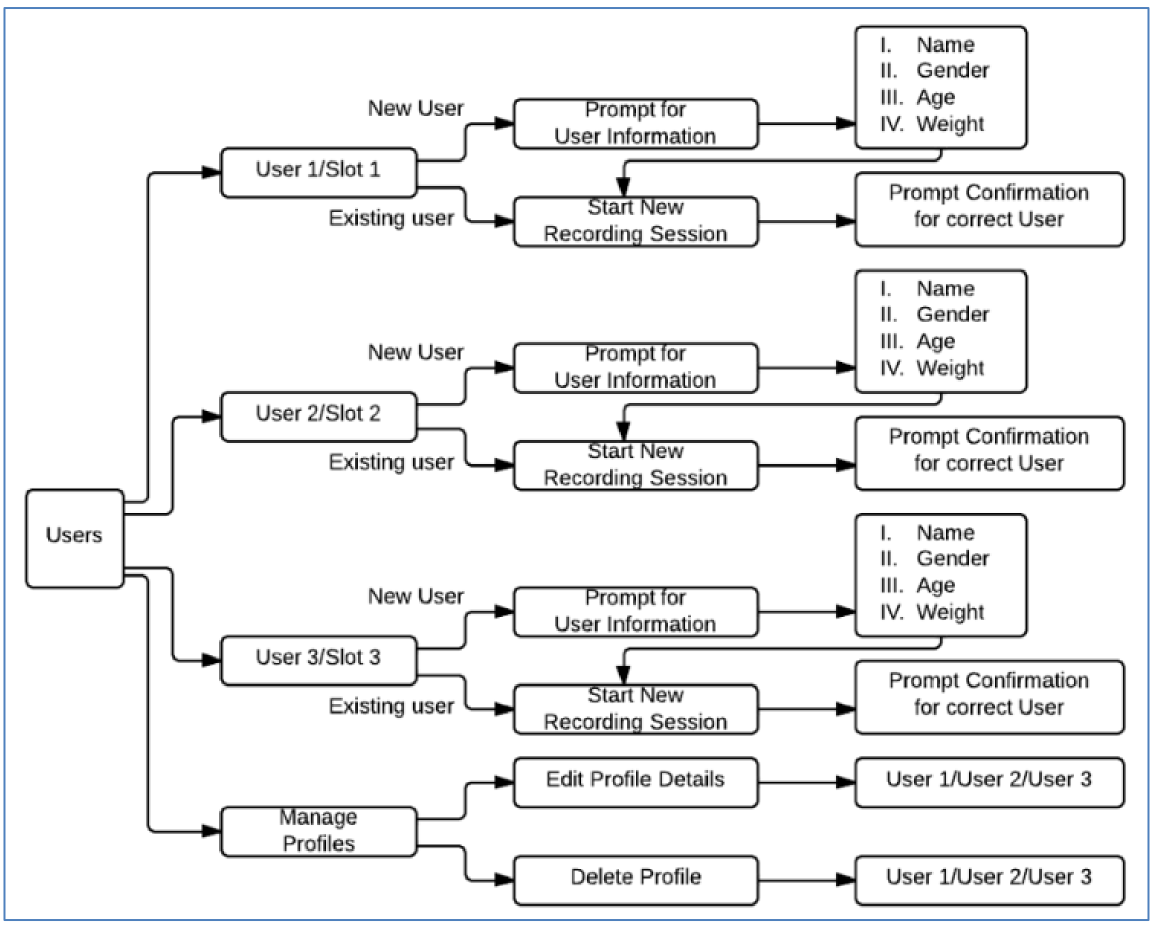


Figure 45 User Menu Flow Diagram

4.2.4.4 Playmodes

The menu item that is going to be used the most is the Playmode section. By default when starting the device it prompts onto this menu. Upon entering this menu the user has the option to select which type of change in music that they would like to experience for that workout. The first mode that is able to be selected is the dynamic play mode followed by anaerobic and finally has a basic that can either be selected by going through this menu or by directly selecting the song that the user would like to listen to.

4.2.4.4.1 Basic

The last play mode that the Motivational MP3 player has is a basic play mode. In here, the user is able to listen to the music that they love without having to use the EKG sensor or limiting the song selection to keep up with a workout plan, which is always a good thing to allow the user to have a relaxing way to listen to music. This is the mode that is used by default, so if the user selects a song without going through the Playmode menu they don't have worry about having the music being changed or needing to have the EKG sensor hooked up.

4.2.4.4.2 Dynamic

In order to do the tempo change a really good audio library is need that can has the features to make the unit work. One of the good libraries to use is the FMOD, which is supported with C++. Within the FMOD API audio playback becomes a lot simpler from all of the function calls. With this being fully functional with C++, it is a given that the User Interface will also be written in C++.

Included in the FMOD API are ways altering the existing files to interact differently than the standard method for playing an audio file. With finding the frequency of the song and comparing it to a known value of the ideal heart rate for the age of the user, or by taking the starting heart rate from the EKG sensor as the starting point and be able to scale from there. As the user starts to become more and more active the heart rate increases, as the heart rate increases by the percentage, either the song can be speed up with the same scale rate or the next song that is played has a scaled starting BPM rating from the starting point given from the user.

FMOD is a really interesting with all of the functionality that can be used with not a lot of changing in the code. Some of the basic calls and functions of the FMOD allow for the audio to be filtered and pan from left to right speakers. From having these basic features, changing the tempo of the song should be doable.

4.2.4.4.3 Anaerobic

In this mode, the user selects a starting song that they would like to begin with. As the user continues in the workout, they enter the different workout zones. Each zone has BPM rating that the user's heart rate should be within if the user wants to see the best results. As the user progresses to a new zone the songs that can be shuffled are songs that are in the same BPM rate. This is a good way to make sure that the workout stays at a good pace as long as you keep to the music.

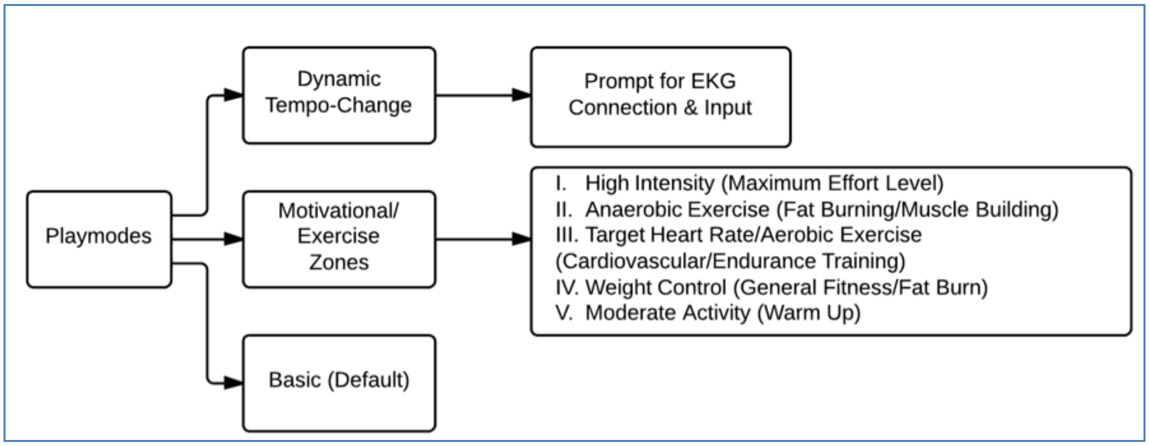


Figure 46 Playmodes Flow Diagram

4.2.4.5 Settings

The next menu that is able to access is the Settings. In Settings, all of the different options are able to be selected that the user would like to use. Options for the time include repeat, shuffle and also more information on the unit. These are standard choices that you can find on any type of music player on the market to date. By giving the user these choices they have a feeling that they have more control of the selection than the microcontroller for the taste in music. It is always a good idea to have the same type of visual of the amount of memory that is left on the device. With showing the user the amount of memory is remaining they are better able to manage the songs on with either new music or see what songs are not needed to stay on the unit taking up space. Also included in this menu is the option to see the firmware version.

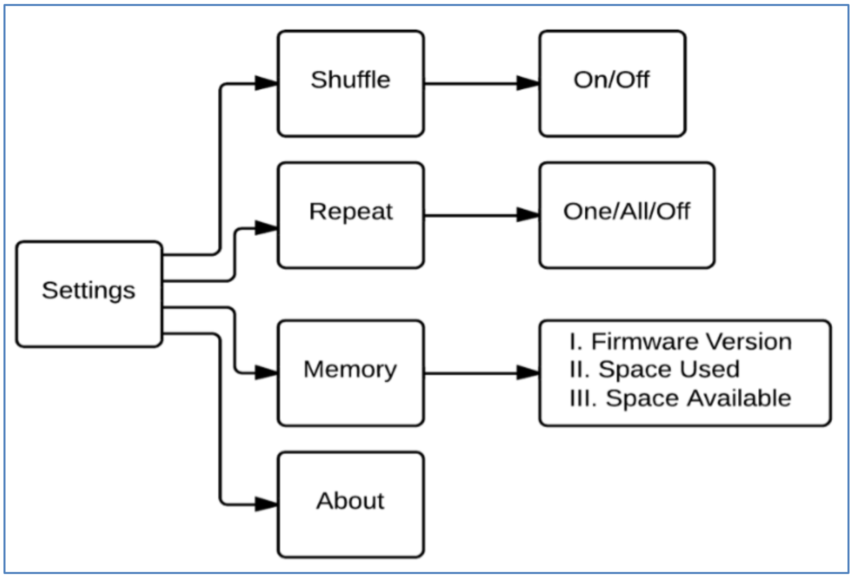


Figure 47 Settings Flow Diagram

4.2.4.6 Now Playing

The last top-level menu is the Now Playing section. In here, the user is able to see the song that is currently playing with all the info. Along with displaying the song title, the screen also shows the heart rate of the user and also the BPM of the song. From this information that is displayed the user is able to gather more data about their workout and could also keep an eye on their heart rate.

4.2.5 EKG Software

EKG has a simple algorithm that deciphers the analog input of the heart rate as a digital output for the mp3 player playmode.

5 Design Summary

This is the backbone of the design for what eventually is called the Motivational MP3 Player. This device has many of the same key features as a treadmill, such as age, weight, profile, gender, and controls to input all the information. It also displays to the user all the key factors of their workout, such as calories burned, distance travelled, time, average speed, and heart rate, all while being in the form of a convenient and entertaining MP3 player.

Exercise experts on the website *getfitguy.quickanddirtytips.com* answer questions about how to enjoy your workout better, and they also conduct studies on what some of the best ways to work out are. One such question was "Do workout songs and music make you exercise harder/" Exercise expert Ben Greenfield of the website answered, and here's some of the details of his study.

In Britain, researchers studied 12 male cyclists while they listened to music, and then adjusted the music tempo during 25 minute riding intervals.

By increasing the tempo of a cyclist's music by 10%, the cyclist's increased their distance travelled, and they also pedaled faster. Conversely, slowing down the music by 10% decreased the distance travelled and they pedaled slower. The music was also reportedly enjoyed more when played at faster tempo. While music may increase performance, especially if played at faster tempos, "once you get up to very high intensities, studies have shown that music doesn't provide any additional benefit" (getfitguy). This interesting study is important for a key role in the Motivational MP3 Player.

The Motivational MP3 Player is a device that is used to help people workout more efficiently, happily, and comfortably. However, since it is a music player, and according to the study described above, it should make for a much more effective device if the tempo of the songs was made to increase or decrease relative to the user's heart rate which is already being monitored for the device controls. It is common knowledge that the heart rate is an important component for getting a good workout. It is for this reason that many exercise machines are able to detect your heart rate, and display it on a board. There are many charts available for what range of heart rate is recommended for different workouts. One such chart is Figure #48.

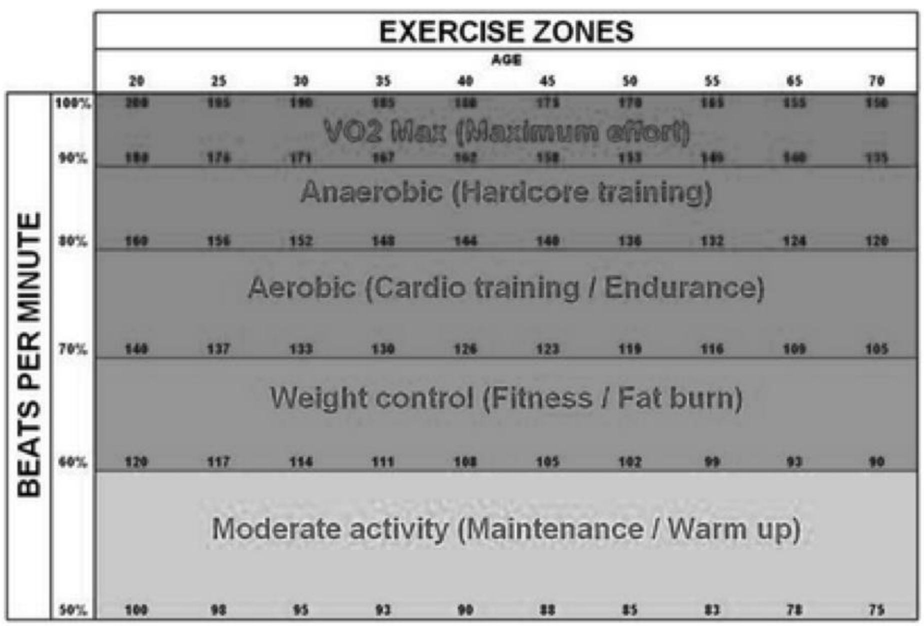


Figure 48 Exercise Zones

(http://www.notyouraveragefitnesstips.com/beginners-workouts/aerobic-vs-anaerobic-exercise-low-intensity-vs-high-intensity Permission Pending)

It is clear from this chart what range a person's heart rate should be in if, for instance, an aerobic workout was desired. Since the heart rate is being monitored, by the workout device, and the music tempo should change according to the heart rate, the user controls and device, working together, should identify which range the user is in, along with controlling the tempo of the music with respect to the corresponding changes in training zones. For instance, a 5% increase in tempo may be desired as the trainer increases his or her exercise zone from aerobic to anaerobic. Or, the 5% decrease in tempo may occur when the aerobic zone drops down to the lighter “weight-control” zone. The aerobic zone is used as a reference because it is in the middle, and most people aim for an aerobic workout.

There are some downsides to this development idea, though. According to the study on the effects of music tempo affecting biking distance and speed, a device which increases the tempo of music without bound may pose as a threat to a user who aims for the highest possible intensity level. There is no aim to harm anybody with a device which is meant to help people workout, so there should be some caution in designing such a device. For example, a feature may be added which ceases the increasing tempo after a certain level, or cautions the user that his or her heart rate is reaching and/or has surpassed a level that may be dangerous to their health.

There may also be a default setting which shuts the player off if the heart rate keeps increasing. Along with these features, perhaps some visual displays, such as LEDs, to indicate levels of exercise or rate of heartbeat may be included. It is with features such as these and the initial design concept of the device which makes the Motivational MP3 Player something that many people in the exercise/health market want to buy and experience.

5.1 Initial Design Summary

This initial design composed of two microcontrollers (MSP430F1612 and MSP430g2452), Capacitive Touch Controls, LCD Display, SD Flash memory card, Batteries (one for EKG and one for MP3 player), USB port module and controller (TUSB3410) and a separate EKG unit.

The high level diagram, Figure #50, shows the general flow of information between the user, the EKG module, and the MP3 player. The nodes of the EKG detect electrons from the human body, and transmit this data (heartbeat) via Bluetooth to the MP3 Player. The player then takes the information it receives, processes it, and sends it back to the user. As Figure #49 shows, there is no back-and-forth transmission, but just one-way communications per module. The EKG is responding to the user, the MP3 player controllers are responding to the EKG, and the user receives the analog signals sent to them from the mp3 player.

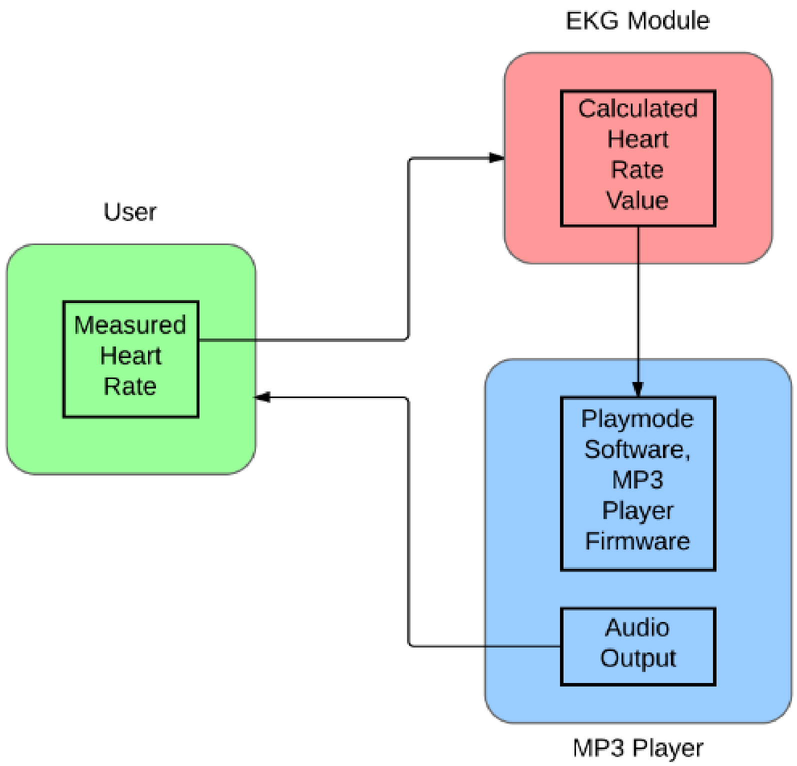


Figure 49 High Level Flow Diagram of MMP3P

The EKG module consists of a specialized circuit to measure the heart rate value from the user. Figure #50 shows the high-level diagram of the EKG. The input data is the user's heart rate, and it is detected by electron detection nodes, as can be seen in the first block. This current data is then deciphered by the module and converted into an analog data signal. This analog signal is received by the Bluetooth module, which analyzes the data with a time frame reference to calculate a sampled heart rate. The Bluetooth module transmits this sampled heart rate data to the MMP3P Bluetooth receiver module for this data.

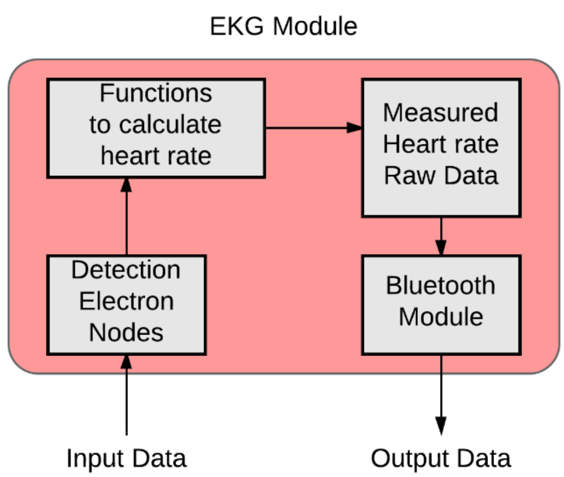


Figure 50 High Level Flow Diagram of EKG

The Bluetooth module in the EKG and MP3 player must establish a connection before data transmission occurs. Once connection is confirmed, the MP3 player uses the sampled heart rate as the based heart rate that is the reference point for the tempo changing.

In regards with the capacitive touch controls, the user is able to interact with the environment of the MMP3P by scrolling back and forth to select the different menus. Depending on which exercise playmode is chosen, the data from the Bluetooth interacts differently with the songs. In one case, the song sees an increase to the song's original BPM similarly to the increase of the user's heart rate. This mode also applies a lower-limit and upper-limit for the range of the BPM. In the other mode, the song selections that are made for the next track to play are within range equal to the percentage increase of the heart rate. These playmodes are contained in the main MP3 microcontroller, MSP430F1612.

The MP3 player audio output firmware is governed by the MSP430F1612 microcontroller. This firmware incorporates the control inputs from the MSP430G2542 microcontroller, the menu and 'Listening To' UI for the LCD display output, functions to handle and apply the user heart rate data, the basic audio output where the F1612 utilizes the DAC12 module and execute as a codec, and the additional software that is required to alter the song playback or selection to meet the playmode requirements.

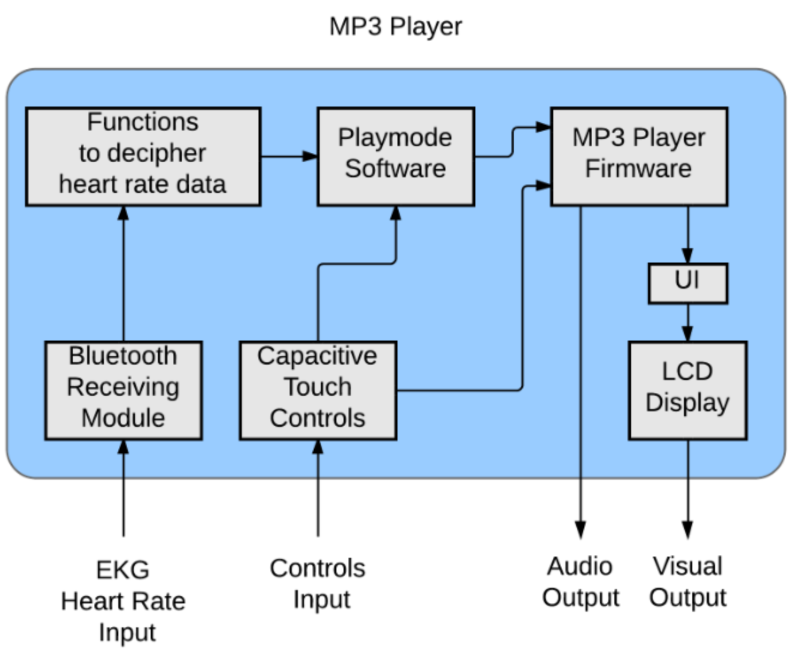


Figure 51 High level flow diagram of MP3 Player

6 Testing and Evaluation

The testing for the Motivational MP3 Player involves both hardware and software features. By doing the testing on the hardware and software, it helps identify areas in where improvements can be made.

6.1 Hardware

The hardware components of the design are tested individually, as separate components, and together, as a whole unit. The hardware is divided respectively between the EKG module and the MP3 player module. The following explains the details of testing each module

6.1.1 EKG Module

To make sure that the Motivational MP3 Player is getting the proper heart rate from the EKG sensor, it has to be connected to an oscilloscope to track the output signal before it hits the Bluetooth module. By doing this, it not only confirms that the circuit design is correct, but it also allows for a better understanding of creating the algorithm to calculate the heart rate.

6.1.2 MP3 Module

In order to make sure that all of the components in the Motivational MP3 work together, said device needs to be subject to testing under different type of instances. To insure that the capacitive touch works while the user is working out, looking at the difference of the finger surface as a workout progresses and adding in either some type of compensation for it might be necessary.

Testing on the user interface also shows the areas of improvement to make the overall experience easy for a novice to pick up the device and start using the Motivational MP3 Player. This also leads into evaluating the LCD display, making sure that the text is a proper size and overall easy to read.

In regards with the memory it allows for a better evaluation to check if any areas are able to be reduced in memory size allowing for lower power consumption in hopes to improve the battery life.

6.2 Software

The software components of the Motivational MP3 Player are tested for basic functions and include many debugging conditions and prints. There is a defined list of errors that is made solely for debugging purposes to ensure accuracy of testing and allow a pinpoint approach for areas with errors in the code. For the firmware and basic mp3 playing function, the three main components contain tests throughout the playing process.

The basic audio decoding and output need to be tested. This is done with a simple software function, Sine Test, which sends a beeping sound periodically through the output. This has to be done manually to ensure sound quality. The next component is the software corresponding to the controls. This testing should measure the responsive time in relation to the music and volume controls. It can be done with unit tests and manual testing. LCD display software. The navigation from menu to menu and the visual depiction of these lists must be well-organized so allow optimal ease of use for the device and correspond the correct data to visual details.

Also included under software testing, abundant testing for the user interface needs to be done as well to ensure that it is intuitive for the most novice user. Testing for the navigation through the main menus, down to the sub-level menus, and back up to the main menu is done manually and is simulated with the UI software with prints of current menu states.

After the basic MP3 player meets the correct functional requirements, the remainder of software testing is dedicated to the specialized playmodes. There is extensive testing on modifying the actual audio file data or the playback speed in relation to the tempo. There also is testing on whether to adjust the tempo to the heart rate value proportionally related or inversely related. This is done with experimentation with the F1612 microcontroller and DAC12 module. The playmode also depends on file organization and retrieval from the flash memory. There has to be additional organization algorithms in order to sort the audio library based on the ID3 tag information for tempo, which is not include in all kinds of audio files. These test the requirement of the dynamic features of the MMP3P.

7 Administrative Content

In any project there needs to be some context for the budget and a guideline to make sure that the project stays on track and completed on time. This is accomplished by setting milestones that need to be put in place that to encourage the group to work as efficiently as possible since time is of the essence in a shortened semester.

7.1 Budget and Financial Details

Every project and design requires a specification for the amount of money to be spent for development. The budget and finances discussed by the group are kept in mind when building this affordable MP3 Player.

7.1.1 Group Budget

The Motivational MP3 Player is aimed to be affordable while still being cost-efficient in terms of quality components. The maximum budget that the project is based on is $500.00, approximately $166.67 per project member. This budget is roughly within the same price range as current-market MP3 players with touch controls and other similar features. The budget is largely affected by the Bluetooth modules for the MMP3P and the EKG module. The budget range allows minimization of components to make it more appealing for the overall cost and consumer interests.

7.1.2 Component Costs

When forming the group, it was discussed that the overall budget of the project should not surpass a total of three hundred and fifty dollars. Since all of the members of the group are at a financial disadvantage this seems at an ideal figure to work with.

The parts that are going to be used in the Motivational MP3 Player are for the most part basic with a few exceptions.

Table 18 Price List for MMP3P

Parts Need	For MP3 Player			
Type	Name	Qty.	Price	Tot
EKG Dev Board	AD8232 Dev	1	$50.00	$50.00
SOIC to DIP Adapters	8, 16, 20, and 28	6	$3.99	$25.00
Battery	Lithium ion	1	$8.95	$8.95
Controls	Cap-Touch BP	1	Free	Free
Microcontroller	MSP430F1612	1	Free	Free
	MSP430G2452	1	Free	Free
	TUSB3410	1	Free	Free
Display	LCD	1	Free	Free
Audio Jack	PW3-012	1	$0.25	$0.25
USB Mini-B SMD	PRT-00587	1	$1.50	$1.50
Pushbutton Switch	D6C00 F2 LFS			
Slide Switch	V80212MS02Q	1	$4.17	$4.17
EEPROM	511-M24LR64E	1	$2.02	$2.02
LED	RGB LED	1	$1.03	$1.03
	Green LED	1	$1.03	$1.03
Headers	10-pin Male	2	$.50	$1.00
Resistors	Assorted (500)	1		$10.00
Diodes	1N4148D035-7	1		
				$338.06

From the parts listed above creating the MMP3P, it is within the budget that the group had set from the beginning of the project. Even with building the EKG sensor, it does not exceed the budget that was projected.

Table 19 Price List For Electrocardiograph

EKG		
Dev Board	AD8232 Dev	$50.00
Front End Analog	AD8232	$8.00
Leads	Premium Silver Tens	$7.00
Total		$65.00

Even though Bluetooth is used within the EKG sensor, the CC2540DK includes two modules with separate development boards which is one of the factors of having such a high price tag.

7.2 Milestones

The milestones of the design helped marked progress with the limited amount of days through the summer semester and uphold morale and efficiency for the project. The following contains details for the duration of the design building.

7.2.1 Senior Design One

With two semesters to complete the total project, it is important to budget time to complete different tasks at a time. This way, progress can easily be tracked and completion can be obtained. The table #20 below shows the time that has been budgeted from beginning to completion of the research stage of the MMP3P, for the time in Senior Design One.

Table 20 Dates For Senior Design One

Project	Chosen on	2/12/2013
Research	Completed on	3/5/2013
Initial Design	Completed	4/11/2013
Documentation	Completed by	4/25/2013

7.2.2 Senior Design Two

The following Table #21 is a similar graph to the one above, however, it shows the time allotted for completing specific tasks in senior design two in order to develop the prototype of the MMP3P and have a working design.

Table 21 Completion Dates for MMP3P

Order Parts	Complete by	5/3/2013
LCD	Displaying	5/17/2013
Capacitive touch	scrolling and buttons	5/17/2013
SD card	Read From	5/24/2013
Music	Basic Play Back	5/31/2013
Bluetooth	Receive Data	6/14/2013
Tempo Change	Tempo Change /	6/21/2013
Prototype	Completed	7/5/2013
Order Parts	Completed By	5/3/2013
Generate Signal	Completed By	5/17/2013
Transmit Signal	Send Signal	5/24/2013

7.2.3 MP3 Player Built And Functioning

The first thing that the Motivational MP3 Player should do is store, read, and convert music data. Thus, it sets the player up for MP3 functionality. These functions utilize the flash memory, EEPROM, microcontroller, and USB features. The SD card holds data and information to be read, approximately 8 GB or however much the user chooses. The MSP430F1612 microcontroller has a built-in ADC and DAC with low-power, high-speed operation, allowing for quick conversion to and from analog/digital signals to be sent to the headphones.

The second thing that the MMP3P does is take the analog converted music signal and send it to the headphones to be heard. This function requires the use of the audio jack on the circuit board. The music is converted in the previous step, and then this step completes the MP3 playing functionality. Thus, after this step, the project should act as a complete player.

The third requirement for the MMP3P is the user interface, aka basic menu, setting, ‘Now Playing’. This requires use of the LCD display connected to the MSP430F161, which in turn is connected to the EEPROM and MSP430G2452 controller. The cap-touch wheel is used to select and input different user settings, and multiple users can store information on the nonvolatile memory. This is a requirement because the user wants to know what music is being listened to as opposed to hearing a random selection of songs.

The Bluetooth input is from the ECG/EKG and allows the heart rate pulses to be sent wirelessly to the player. This way the user can attach the heart rate to any part of the body without a wire restricting movement. This part of the project also allows for utilization of new technology to be handled and further understood.

7.2.2 ECG/EKG Built, Functioning, Connection

As far as the ECG/EKG is concerned, a requirement for this feature is to have the proper data reading when in use. Thus, the heart rate pulses should be correct and accurate, and sent/received at the proper times, and functionality should be user-controlled at the correct moments. Thus, proper data reading should happen with the Bluetooth module. Also, the correct data should be sent to the output of the player. This is a requirement because the correct music should be played when selected, and this is a function of the microcontroller and audio output.

7.2.3 Exercise/Workout Features

For this requirement, the player should be able to retain information on its nonvolatile memory, aka EEPROM, and display the correct information on the LCD screen corresponding to user inputs. Also, proper information such as accurate heart-rate readings should be read and displayed. The user interface should be able to store and retrieve the correct data upon command, and the proper motivations should activate when the data readings are selected (LEDs, Visual Warnings, etc).

Another requirement for the exercise/workout is the dynamic tempo mode. This mode motivates the user to work out by receiving input BPM (from ECG/EKG), and alters the music BPM/tempo with real-time responsiveness. This feature is one of the main motivational aspects of the Motivational MP3 Player. This feature allows correlation between ECG input BPM to music tempo’s BPM and adjust it correspondingly.

7.3 Final Product

The final product of the design is the integration of all components into one complete unit. There are three main divisions: The EKG, MP3 Player, and the User. As seen in Figure #52, the MMP3P has a stable flow of data from the user to the entire device and the user receives the adequate visual and audio output of a completed MP3 player.

From the beginning of the design process, many aspects of the project have been altered. For instance, the controllers used have changed, the functions of the controllers have changed, and the EKG is being simulated by a pulse simulator. The following paragraphs explain the major changes that have taken place. Following that section will be explanations of how the testing and procedures were carried out for the project.

7.3.1 Component Changes

The following contains explanations for design changes made throughout the duration of creating the MMP3P. This includes additions to the project for the heart rate monitoring and pulse reading, addition of an Arduino microcontroller for the slave microcontroller, and the changes of decoding component for better compatibility.

7.3.1.1 MSP40G2553

In the initial design of the MMP3P, the master controller was going to be the MSP430F1612 mixed signal microcontroller. This chip was changed to the G2553 mixed-signal microcontroller because it has less pins, but enough to handle the tasks of master controller. There are adequate pins for capacitive touch boosterpack, and a UART transmitter to send commands to the slave controller. This chip, as stated previously in the research and development section of the paper, comes in various packages, but we chose the 28-pin SOIC chip. This is a surface mount component and fits compactly on the PCB.

7.3.1.2 ATMEGA328P

The ATMEGA328P controller, a 28-pin DIP chip, now takes on the role of the slave controller on the PCB. The original design planned for use of the PIC18 chip because of its pin availability and memory usage. However, the ATmega controller turned out to be easier to program, and allowed for the programs to be effectively uploaded via the Arduino Uno. This chip’s pin selections allow for control over all of the peripherals on the MMP3P.

7.3.1.3 VS1053B Codec Breakout/SD

One of the most major changes that occurred in the final prototype of the MMP3P is the inclusion of the VS1053B breakout board. This board contains breakout pins for communication with a DSP used for MP3 decoding, and an on-board micro SD socket. This board was chosen as a last-minute change because of its ease of use, small size, and functionality with the ATmega controller. It requires a 16MHz crystal oscillator (load capacitance of 22pF). Figure #52 shows an image of this breakout board. The massive support for this product made it simple to include in the design of the MMP3P.

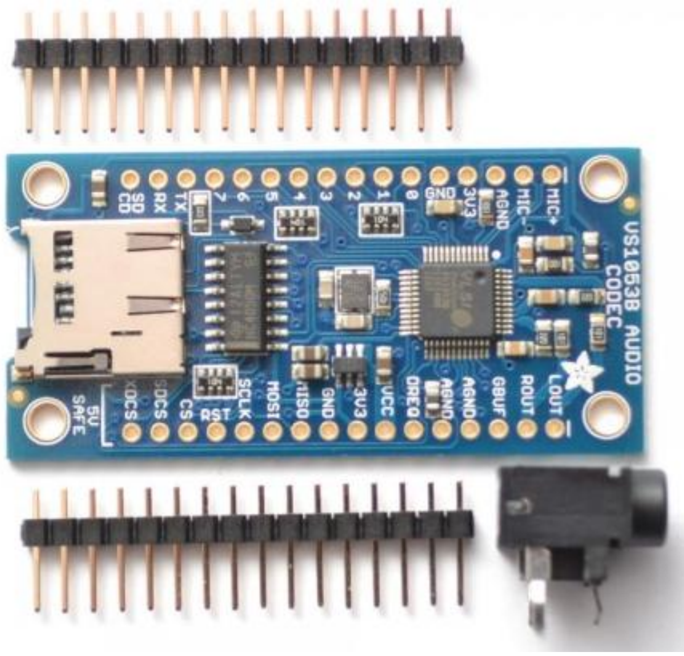


Figure 52 VS1053B Breakout

7.3.2 Testing Final Product

Testing the components was a major part of the final prototype. Many components were initially selected to be part of the MMP3P, but were found to not be suitable for inclusion after testing results turned up erroneous. The following paragraphs explain how testing was carried out and how that led to the inclusion of various components.

7.3.2.1 Microcontrollers

To test the microcontrollers, the respective development boards were utilized. For MSP430 family components, the Energia environment was used because of its ease of programming and various example codes for testing the on-board features of the chips. The development boards allow for the basic functionality of the controllers to be explored before the body of the code is actually written. These capabilities include flashing an LED to become familiar with the call functions and the computer organization.

The MSP430 Launchpad was a great environment for testing the MSP430 family microcontrollers. It includes an interactive environment with on-board LEDs for test programming, parallel rows of headers for adding boosterpack components, and emulation with USB support. Also supported by the chip is analog to digital conversion, which was tested using the function generator. A sine wave was fed into the sensor pin, and on the serial port screen attached to Energia, the digital values of the converted signal were able to be viewed and further processing and design was able to be done.

The Arduino Uno environment was used to test the Atmega328P controller. This development board, much like the TI Launchpad, contains placement holders for various controllers, testing features, and breakout headers. Much like Energia, the Arduino environment contains many example codes for blinking LEDs to get used to pinout and I/O control, and massive support networks are available for coding on this environment. This made it very convenient for including this pin in the project design.

Once the I/O pins were understood, it was easier to design control systems to peripherals. The LCD contains eight data lines which control the ASCII symbols and characters displayed. These lines are connected in parallel and binary combinations are sent as digital pulses from each I/O line.

7.3.2.2 Pulse Simulator

Initially, an EKG was in the design phase to be included in the MMP3P. The AD8232 Evaluation board from Analog Devices was purchased as a test board. This included the surface-mount component and various headers broken out for testing purposes. A clean waveform of an EKG signal was captured and ready to be fed into a threshold-reading analog sensor pin to count pulses. Figure #53 shows the waveform captured by the EKG.

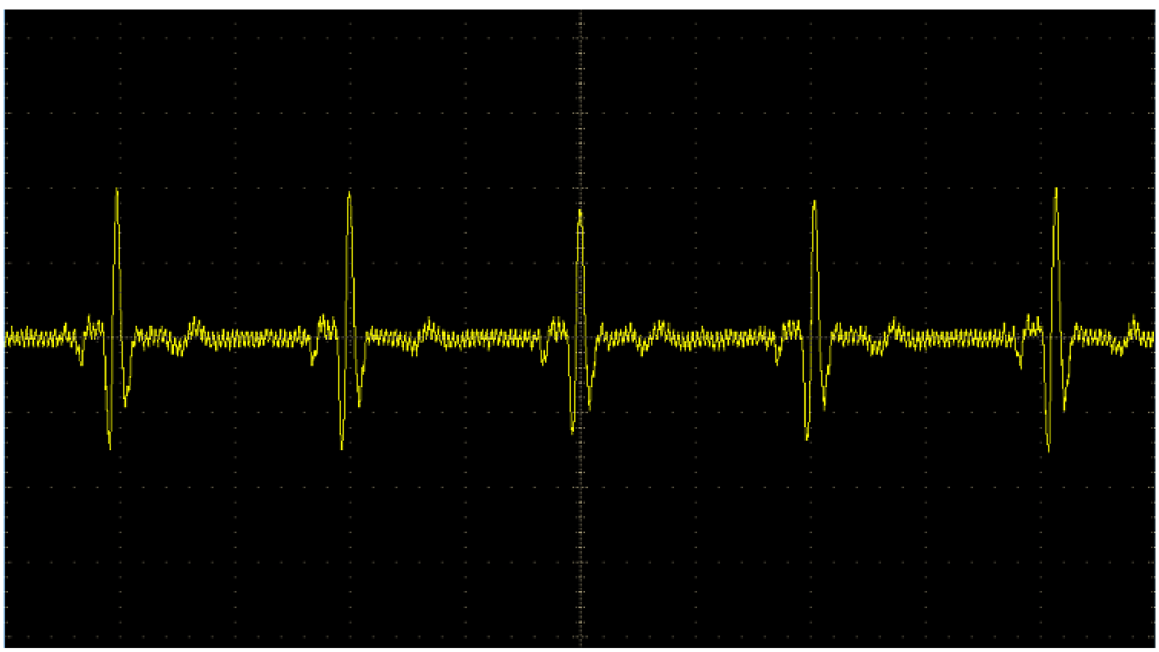


Figure 53 EKG Waveform

The development board for the EKG chip was the platform for designing the EKG circuit on the PCB. However, once the PCB arrived and components were mounted, it was found that the EKG signal was not producing such a clean signal as tested from the development board. To prove the concept of analog reads of a simulated heart beat, the pulse simulator was conceived and developed.

The testing of the ADC values was the basis for the inclusion of a pulse simulator. When testing threshold levels for the ADC input from the EKG, a DC power source was used, and the value of the voltage was manually fluctuated to test the threshold level in the software. When the EKG signal became too noisy in the testing process, the pulse simulator idea was conceived from the way the threshold was tested. The pulse simulator allows for adequate proof of concept for an analog input from an EKG device.

7.3.2.3 Battery/Charger

The battery that was chosen for use in the project was a 1000mAh lithium polymer rechargeable battery. However, this was realized to be not sufficient for battery lifetime, seeing as how at any given time the circuit could draw up to 800mA of current, thus making for a short lifespan before another recharge was needed. Thus, a 2000mAh battery was used instead, making for longer life. Also, after the exclusion of the EKG circuit, the circuit consumed significantly less power than previously expected, thus making the 2000mAh battery an ideal choice for extended battery life.

Along with the battery, a breakout board from Sparkfun was included with a micro USB battery charger included on-board. This board is convenient for the addition of a battery charger for a rechargeable battery. It allows the circuit to be used with a depleted battery if the USB port is plugged in.

7.3.2.4 PCB

The printed circuit board was designed using Pad2Pad free software. This software allows for an easy design of a double-sided PCB with available components for selection. Figure #54 shows the design of the PCB, and Figure #55 shows the board itself.

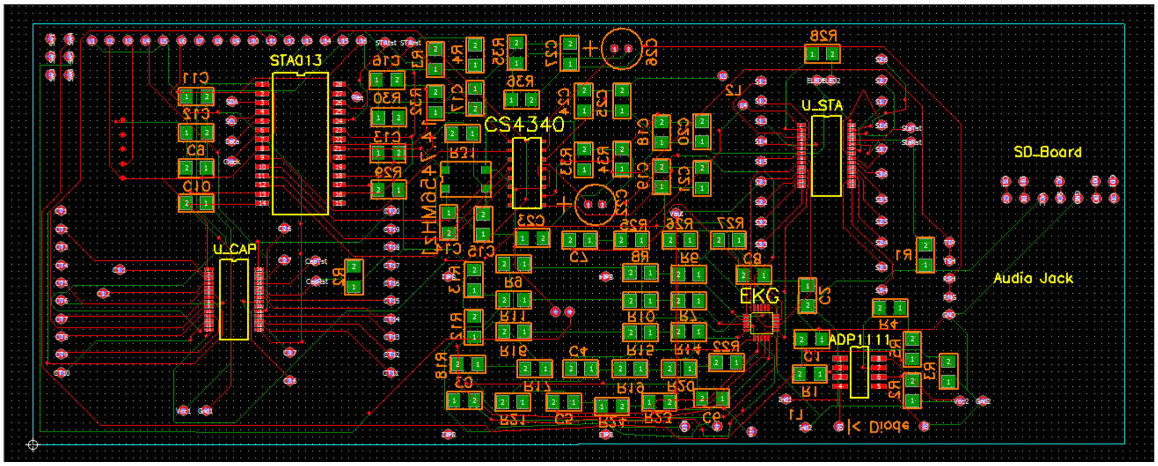


Figure 54 Printed Circuit Board Layout

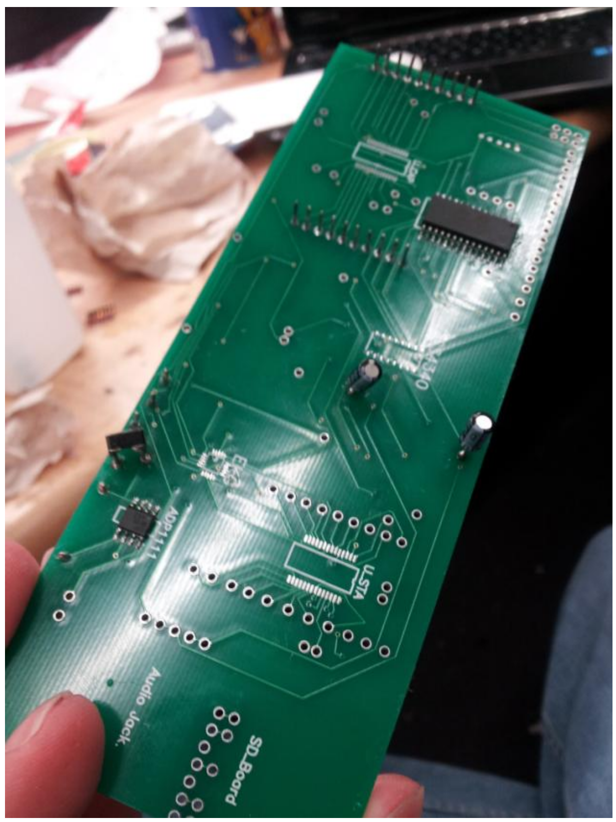


Figure 55 Printed Circuit Board

7.3.2.5 Case

The final product of the project is encased in non-glare plastic box. Openings are cut in the plastic to allow the LCD to be seen more clearly and the capacitive touch wheel to be used. An additional printed circuit board section protrudes from the case, as this was a last minute addition, but for the most part the circuit is contained inside the plastic box. The casing is a little bit wider than originally designed, however, it is close to the specifications of the project description. The final product of the player is shown in Figure #56.

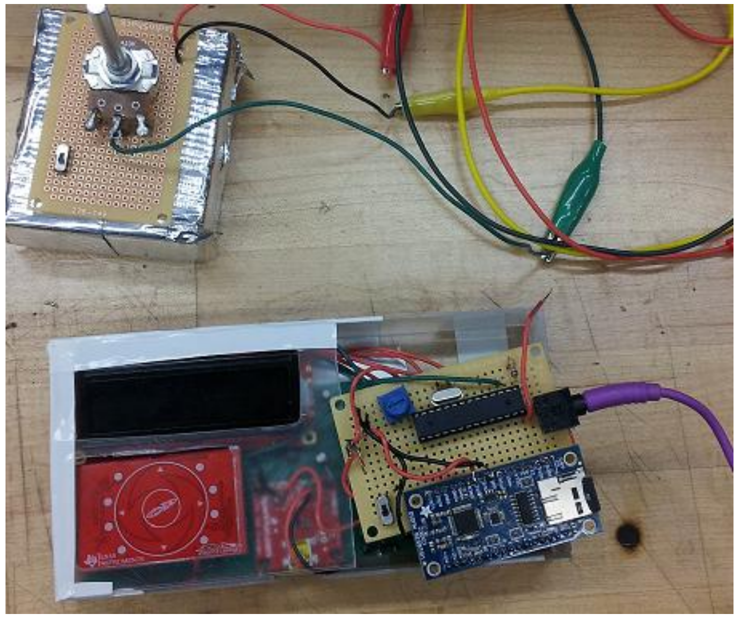


Figure 57 Final Product

8 Project Summary
8.1 Summary

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. Not only this, but the fun feature of dynamic tempo change 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. On the other hand, though, many people have a hard to sticking with their memberships, or buy a membership but never visit the gym. Sometimes, memberships can be as expensive as $30.00/month, with a $100.00 initiation fee. That is a lot of money for only occasionally visiting the gym.

If one stops to think about it, is $30.00/month plus gas money a fair price to only experience a mediocre workout on a machine that has been used by many people before, in an environment that can make someone feel insecure and reduce their workout experience? That is why the Motivational MP3 Player is a device worth building. This device can be taken anywhere, anytime, anyplace, for a one-time payment, and an experience that is 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 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 are 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!

9 Appendices

A. Copyright Permissions

AndyMP3:

Hi Adam:

You have my permission to refer my MP3 player design in your paper and I'm happy to know it served someone else. Hope to read the finished paper soon if possible.

Regards,

Andy

...

2013/4/18 Adam Browning <mannaman86@gmail.com>

> Hi Andy, I am sending this message to ask for a formal permission to refer to your mp3 design in our paper. We simply used yours and other similar projects to get our project off our feet as far as using certain components. Thanks for your contributions to the technological world!
>
> "Hi Andy, we are writing a research paper for senior design at UCF and were wondering if we could have permission to cite your MP3 project in our paper. Thanks.

SD Card Matrix:

University of Central Florida Student - Senior Design Image Permission

NEIL JACILDO <neil.jacildo@gmail.com> Apr 17 (7 days ago)

to helpdesk

To whom it may concern

I am Neil Jacildo, currently a Senior-level student at the University of Central Florida. I am currently enrolled in the Engineering Capstone course, Senior Design, where we are using the SD card product.

We would like to ask for the permission to reuse the images displaying the physical standards matrix of the SD standards from the webpage - https://www.sdcard.org/developers/overview/capacity/

Please let us know as soon as possible.

Thank you,
Neil Jacildo

B. References

Weight-Control Information Network (Figures 3, 4):

National Diabetes Education Program
http://www.yourdiabetesinfo.org

National Diabetes Information Clearinghouse
http://diabetes.niddk.nih.gov

National Health and Nutrition Examination Survey (NHANES)
http://www.cdc.gov/nchs/nhanes.htm

National Health Interview Survey (NHIS)
http://www.cdc.gov/nchs/nhis.htm

Online BMI Calculators
Adults: http://www.cdc.gov/healthyweight/assessing/bmi/adult_BMI/english_bmi_calculator/bmi_calculator.html
Children and teens: http://apps.nccd.cdc.gov/dnpabmi/Calculator.aspx

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http://pdf1.alldatasheet.com/datasheet-pdf/view/330205/TRANSCEND/TS4GSDMHC.html