Posture Perfect

J. Barr
J. Carlos
F. Lopera
F. Petersen

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Executive Summary

A majority of todays jobs consist of long hours spent sitting behind a desk. As a result, this job trend has correlated to an increase in back problems reported over the years. This has not gone unnoticed by the individuals who work these sedentary jobs. Due to this, there has also been an increase in demand for posture-correcting gadgets. Our product, Posture Perfect, was the result of a market without an acceptable solution to this ongoing demand. Posture Perfect will succeed where all other products failed. It will have a comprehensible analysis of the users spine as well as the distributed weight on the actual seat. This will show which side the user may be favoring while seated. Neck placement will also be analyzed to reassure the user is not leaning forward with their head. This device will strive to improve every aspect of the users seating routine and guide them to a healthy spine and more importantly healthy life.

In order to make an effective product we must properly research, design, and test this device. This report will give an extensive overview of how we developed our product. To begin, we made an outline of our goals for this device alongside a list of specific requirements it must accomplish in order to be effective. We then researched products that are already out in the market and compared it to the requirements we set out to accomplish. Features were added after we completed our research to reassure our product has the key features other products were missing. Once our research and system requirements were completed, we moved on to the design phase of the project. We researched several relevant technologies in order to compare and contrast what technologies would be best suited for our goals. Our main priority was power efficiency, so we set out to find the simplest sensors in the market and depended on our circuit designs to get the desired output. We also made a point to buy the simplest components and build everything ourselves. We did pervasive research in order to assure that the specific technologies selected were the most optimal for our project.

Afterwards, we started designing the algorithm that would best describe the users posture. There were many factors taken into consideration. The weight distribution, location of the lumbar region, distance of the upper back and neck placement were

the key contributors to figuring out the users posture. As well as monitoring the users posture. We set out to keep the user active so calculation of the time spent sitting was added into the algorithm. On top of that, we decided to do all the calculations in the cloud instead of on a separate side module. This was decided due to the increasing popularity in cloud service. The mobile application we develop would have to properly sync up to the calculations stored in the cloud and display the results to the user. To conclude, we analyzed that the components chosen for our hardware and software are fully compatible with each other. We made it a point to design our system with components that would lead to a power efficient system. This was possible by comparing related standards and constraints that are already set in place. These standards keep us accountable and remind us that the system chosen will have side effects on society.

With this in mind, we then developed a prototype to satisfy all conditions. Prototypes are a necessity when developing a successful product. The first created device is never market ready so the use of prototypes will assure the device is properly working and meets the essential goals set out by our team. The prototype will help us divide the project into different subsections so that debugging is made easier. For example, not only does our device need to analyze the users spine but it must also set out notifications to the user. It must accurately sense when a user is nearby and turn off after a long period of inactivity. This will in turn help the system save power which is an essential aspect in the prototype phase. We are trying to get the big kinks out during this phase and then later fine tune the most specific requirements.

In order to assure the device is fully functional we developed a list of specific requirements it must pass. The specific requirements will also be compartmentalized into different sub groups so that it is easier to debug these issues. The list has a variety of different situations that may occur alongside the acceptable response when each situation does occur. Every input must have the desired output during this phase in order to be considered fully functional. Whenever an undesirable output is obtained we will simple adjust the algorithm or hardware in order to achieve the correct output. This phase will be by far the most important and difficult part of our project. There is no gray area during this phase and we must get the correct response for every listed situation. Once we are done with this stage of the project the project will be considered complete.

Lastly, the administrative section will have the remaining strides taken to ensure the project was successfully researched, designed, and tested. On top of that, it will describe how we went about splitting up the project and what each individual completed during each phase. We will include the financial aspect of bringing our device to life and the amount of hours spent developing our device. Additionally, we will include the role of our mentors through the whole process and how they guided us through the development of our final device. This report will fully summarize and explain how this team brought the Posture Perfect into the world. We are excited to embark on this journey. The product we envisioned can help millions of people improve their posture and guide them to a longer, healthier life.

Chapter 2

Project Overview

This section will explain why we chose this as our project and the motivation behind bringing this device to the market. The motivation behind any project is what makes it special and different from any other product created. Its a requirement when creating a product that will have a long lasting effect on society. This report will also include all the goals and objectives set out by our team for this project. These goals are the main benefits we want to provide to the consumer and will guide us through the designing portion of the project. The most important part of this section is the specifications and requirements of our system. This will include everything the device must accomplish from a hardware and software perspective. These requirements will guide us in the design portion of our project.

2.1 Project Motivation

In this day and age, a majority of our time is spent sitting on a chair. The places where most of our society spends a large amount of time is at work, school, or at home. What do most people do in common at all these locations? They are typically working, studying, or just lounging around; usually seated on a comfortable chair. Due to the excessive hours spent on a chair, back problems have become an increasing issue all around the world. Many people seek out chiropractors and health physicians to find a solution to their poor posture while others look for gadgets that may improve their posture. Our device is intended for those people and for anyone who wants an economic solution to their posture. While many ergonomic chairs do exist in the market today, they only address the posture of someone with the approximate height the chair was designed for. The Posture Perfect will not be limited in this way and will provide more help than an ergonomic chair could ever provide. While not all posture problems can be avoided, it is still important to minimize the stress on our backs in any way possible. This project seeks to minimize the effects of sitting behind a desk for those people who sit for long hours. Simply reminding consumers of their slouching every so often will dramatically reduce back problems that may arise in the future.

The main motivation behind selecting the Posture Perfect is that it has never been done before by a senior design group and it still hasnt been perfected in the market either. Originality is something every engineer takes pride in, so we set out to accomplish something that no one has ever been able to do before. The market is full of smart gadgets such as smartphones, smart TVs, and smart cars. There is a demand for creating devices that are capable of doing more than one thing and we set out to fill that demand with our smart chair. On top of that, we firmly believe this project will have a long lasting effect in society. There is an obvious problem in seating posture so this device will help those who are worried on the effects of sitting for long hours with poor posture. As a matter of fact, there are others who are also worried about the effects on their health when sitting behind a desk for long hours or being inactive for a large period of the day. The Posture Perfect will help those concerned with the side of effects of inactivity as well as those concerned with their posture.

2.1.1 Life Expectancy Due to Excessive Sitting

There are many risks associated with sitting down for an extended period of time. For one, if you are constantly sitting down in front of a desk then you are less likely to be active. If you work 40 plus hours at a job that requires you to sit down in front of a desk that will obviously affect how much time you have in the day to be active. Not only that but youll likely become accustom to sitting down all day and not want to be active on your off days or when you have time to work out. Staying active on a daily basis is linked to a longer and healthier life so it is vital to stay active when having a sedentary work environment.

Studies show that men who are sedentary for more than 23 hours a week had a 64 percent higher risk of dying from heart disease than men who were sedentary for only 11 hours a week. Another study showed that those who used a computer for 11 hours a week or watched television for more than 21 hours a week have a higher risk of being obese than those who used a computer or television for a little more than 5 hours a week. On top of that, there is a study that states if you limit the time spent sitting every day to 3 hours you could increase your life expectancy by 2 years.

Sitting down for an extended period of time also has a correlation to metabolic slowdown. After sitting down for a little over an hour your body will slow down the production of enzymes that can burn fat by a whopping 90

2.1.2 Health Effects Caused by Excessive Sitting

Not only can sitting down too long effect your life expectancy but it can affect your overall health. Sitting down in front of a desk for an extended period of time can lead to organ damage, brain damage, posture problems, muscle degeneration, and leg disorders.

When discussing organ damage the biggest thing to worry about is your heart, pancreas, colon, and digestion. Sitting far too long can cause your blood circulation to slow down and your muscles tend to stop burning fat due to long periods of inactivity. As a result, you tend to have more fatty acids that can clog your heart. Another side effect of sitting too long is your bodys inability of responding to insulin. Sitting excessively long for even one day can cause your body to produce large amounts of insulin. This is why there have been studies that show a link between diabetes and sitting down excessively. On top of that, an increase in insulin production may increase your risk of getting endometrial, colon, and/or breast cancer. Staying stationary for a long time limits the antioxidants built by your body. This will increase your chance of getting lung cancer by 54 percent, uterine cancer by 66 percent, and colon cancer by 30 percent.

The next thing to worry about is possible brain damage when sitting for too long. Everything in the body slows down when you are inactive for long. Your body believes you are trying to rest so it slows down all activity so you can relax. This causes your brain to slow down as well and will not allow your brain to get the fresh blood that it needs. It will also limit the amount of fresh oxygen and this combination will affect your mood-enhancing chemicals which can lead to depression.

As stated earlier, staying inactive for long will take a toll on your back and affect your posture in the long run. On top of straining your lower back you can easily strain neck and shoulders when sitting stagnant. This is due to our tendency to hold our neck and head forward while working in front of a computer. Not only can this cause tension in the neck and shoulder but it can cause nagging headaches. It is important to remember that sitting down puts far more pressure on your spine than standing. This means that it must be a priority to keep proper posture while sitting down for a long stretch of time. Another side effect that has gone unmentioned thus far is herniated disks. Sitting down does not allow your disks to move freely. This is a problem because they are naturally meant to contract and expand several times a day.

In addition, sitting for too long can cause muscle degeneration or atrophy. One example of that is your abdominals. When you stand it forces you to constantly keep tension on your abdominal muscles. Whereas when you sit down all tension is gone and your body gets lazy in your abdominal region which means you end up having a weak core. Another body part that suffers is your hips. Staying stationary forces your hips to become tight and also limit its range of motion. This can become a problem as you age and could lead to bad hips. Your glutes can also suffer from muscle atrophy largely due to long periods of inactivity.

Lastly, staying stationary for too long can lead to leg disorders. The two things to worry about are varicose veins and weak bones. Poor circulation due to large periods of inactivity can cause varicose veins, swelling in your ankles, and of course blood clots. Being active reminds our body that we need denser and stronger bones. As a result, not putting any pressure or weight on your legs will lead to weaker bones and/or osteoporosis.

2.2 Objective and Goals

The main objectives for our project are to adequately analyze the users posture, notify the user after a prolonged period of inactivity, and to give helpful suggestions on how to improve their posture. The Posture Perfect will be different than any other gadget in the market intended to improve posture because it isnt attached to the chair or the person. We are creating a smart chair that will not only provide the support the user needs need but it will improve their posture as well. In order to do that, it must first understand what a correct posture is defined as for each user. This will be the most grueling task for us as the developers. The Posture Perfect will use all the sensors placed on the chair in order to decide what is deemed as a good posture for each user. There will be sensors on the back rest of the chair which no other device in the market has. These will be used to read the curvature of the spine. A distance sensor will be used alongside pressure sensors that will be placed on the lower part of the backrest. More specifically, the pressure sensors will be located near the lumbar region of the users spine. The neck placement will be one of the most important contributors. Distance sensors will be used in order to read the neck placement. This will help the chair determine if the user is slouching. If a users head is overly inward then it must be slouching especially if all other sensors point to the user being close to the back rest of the chair.

In addition, there will be pressure sensors placed on top of the chair seat. The sensors will be individually placed across the entire seat. These sensors are extremely important because they will show if a user is favoring one side over another. In other words, it will check if the user is putting more weight on either side; this will help in determining the users posture. If the user spends a prolonged period favoring a side we will notify them to straighten up with vibration motors. Similarly, if the user spends a prolonged period of inactivity we will notify them by vibrating the chair. We will develop a system in order to differentiate these different notifications. One way of doing this is by setting each notification to a different amount of vibrations. That way if the user feels multiple vibrations then they will know it means it might be time to get up and stretch or go for a brisk walk.

Subsequently, the sensors spread across the chair must come together to notify the user when their posture is incrementally becoming worse. Additionally, the algorithm must be well designed in order to accurately read and determine if the users posture is out-of-place. There will be a variety of flags set into place so that if any are triggered then the chair will alert the user to straighten up. The chair will have to communicate with the cloud in order to do most of its calculations. The mobile application will connect to the data stored in the cloud and present the information gathered neatly to the user. They will be able to see the amount of time spent sitting down, and other sitting tendencies. Alongside, a hotspot map of where pressure is being applied the most while the user is seated.

2.3 Project Specifications and Requirements

The engineering requirements specified here act as important guidelines and conditions that must be met in order to call our project a success. These engineering requirements are born from our project objective and goals. The requirements will be kept abstract and unambiguous in order to keep them understandable and not too specific. It is important they also be verifiable and traceable in order to prove that they can be satisfied. Through extensive research, intricate design and elaborate testing, the requirements will be successfully met.

2.3.1 Hardware Requirements

The physical constraints imposed by the chair will affect the requirements for the electronic components and sensors that will be embedded into the chair. With plenty of different hardware to choose from, we must make sure they satisfy all the requirements declared.

- The device must be a chair
- The chair must have a back support
- The chair must have armrest
- The device must have pressure sensors on seat and lower backrest
- The device must have distance sensors on the back rest
- The device must alert the user to get up and stretch
- The device must read neck placement
- The device must have vibration motors
- The device must have a proximity sensor
- The device must have a microcontroller
- The device must posses a wireless communication device

Sensors on the Chair

The role that the sensors on the chair will have in the project will be a crucial one. They will be the sources of all the data to be gathered from the user's activity to enable the system to monitor their posture. Therefore, having strict requirements for the sensors will allow us to acquire the type of information we need in order to properly monitor the users posture.

- Sense the presence of a user
- Sense the user sitting down
- Distinguish the user from an inanimate object
- Correctly measure the user's weight distribution
- Accurately ascertain the curvature of the users posture

Vibration Motors

The vibration motors will be the main source of notification. The chair will vibrate every time the user shows signs of poor posture. If the pressure sensors sense too much force is on either the left or right side of the seat for too long then the vibration motors will vibrate on the favored side. The chair will also vibrate whenever the user is stationary for a long period of time. Lastly, the chair will vibrate if any of the back sensors have noticed signs of poor posture for a prolonged period of time. For example, if the users lower back seems to be a lot closer to the chair then the rest of the spine or is the neck is identified as being overly inward. The chair would vibrate to alert the user that poor posture is being identified.

Microcontroller and Battery

The microcontroller on the chair will be the brain of our operation. Its function is to control every aspect of the system on the chair. Since the whole system will be powered with a battery, the microcontroller has to be energy efficient when performing its tasks. The battery will have to be selected carefully in order to fit the constraints of the chair and to supply power to the system for an adequate amount of time.

- Low power state and/or sleep mode
- Be able to handle the various sensor outputs as inputs
- Determine if the user is present
- Have wireless communications
- Battery must last at least a week

2.3.2 Software Requirements

The software of this chair is quintessential to the operation of the project, leveraging it appropriately to meet the requirements set out in this document need to have requirements that can be built to. Every piece of the software needs to have interfaces allowing for the communication between multiple platforms, they must interpret the hardware signals within an acceptable time, as such the software shall be able to react accordingly to the given input. The data collection and storage components need to be reactive to user input without the direct supervision of the user. The reporting software must be responsive enough to pass user acceptance, applications slow to respond or show signs of activity tend to be reviewed less favorably, and we anticipate that the success of this project will due to user satisfaction.

- The devices algorithm must analyze the distance between the user and chair
- The devices algorithm must analyze weight distribution
- The devices algorithm must calculate how long the user has been seated
- The devices algorithm must organize vibration notification
- The devices algorithm must incorporate all sensors specified in the hardware requirements

Signal Processing

Embedded system operation must operate with efficient code such that it can collect data that correlates to a single time snapshot of the user, or else the readings may be incorrect. The window of the aforementioned snapshot is determined to be 30 milliseconds.

- The system shall respond to activity in the chair within an accepted time frame.
- The transmission of updates to the data storage facility shall be on a regular interval while the chair is actively occupied.
- Incoming requests for updates to the storage shall be handled in less than 1 second.
- Data taken from the sensors in the chair shall be package organized and sent to the data store.

Posture Algorithm

The data collected from the chair has to be interpreted by some computing device to determine what kind of posture the user of the chair currently has, and how the reporting system can advise them in improving this posture. The algorithm has many facets to it, the current data fed from the chair, the historical data from the storage, and the interpretation of the data in a comparison to what is correct or non harmful posture.

- The algorithm shall take into consideration the history of the user.
- A baseline comparison for the algorithm to reference shall be modular enough to apply to people of different sizes, but within tolerable amounts.
- A typical report will update with a response of less than 5 minutes for the user to view.
- The program that runs the posture algorithm shall also manage memory and access to the respective database.
- The program that implements the algorithm shall generate the report and store it for access by the report display application.

Data Storage

The user data collected by this chair needs to be stored for the effectiveness of the coaching to be substantial enough to make an impact, as only some inferences about user posture can be made in real time. This storage of user data comes with a risk of security that must be taken seriously, as users of the internet age are sensitive about their personal data.

- The reporting application shall show the user data relating to their posture of time spent in the chair.
- The reporting application will be available to users connected to the internet.
- The data store shall be able to store backlogged data of greater than the past month of use.
- The data store shall be managed and organized with MySQL for compatibility with outside applications.
- Access to the databases will be restricted on a by-user basis, access shall only be granted to a user with the proper credentials.
- User accounts and their databases shall be managed by the phpMyAdmin service running on a server platform.

Chapter 3

Research Related to Project Definition

Once we have decided and listed all the required features for our project, we must research everything that encompasses our project in order to properly assemble what we set out to make. The research portion will be divided into three major subsections. The first subsection will provide important background information on the spine. It will include how to keep a healthy spine, the definition of proper sitting posture, how to properly align your spine, and the effects of static posture. The second subsection will provide information on existing solutions to the problem our product intends to solve. The third subsection will discuss the technologies that are relevant to our project and the specifications of these technologies. This section will help us determine which components will be the best suited for our projects purposes and which components will be most power efficient.

3.1 Anatomy of Spine

Our spine is composed of 33 bones, also known as vertebrae. These bones are individually stacked on top of each other and coated with muscles and ligaments. Only the top 24 of these bones have the capability of moving while the others are banded together. The tendons are what help connect our muscles to our bones whereas ligaments connect our bones to other bones. The tendons, muscle, and ligaments help unite all 33 bones together and also assure that the spine is aligned properly. The facet joints are a major facilitator to binding the vertebrae together. The 33 vertebrae alongside the facet joints is what gives the spine the flexibility needed to allow us to move around as freely as we do. The facet joints are similar to our knee or elbow, they allow for a wide range of mobility and flexibility. Each vertebra is similar to a washer and when merged together it forms a hollow tube that is used to store nerve tissues. These nerve tissues are used to help the brain communicate with our entire body.

The nerve tissues that go down the hollow tube formed by the 33 vertebrae is called the spinal cord. The length is approximately 18 inches long and its width varies from .25 to .5 inches depending on which region of the back is analyzed. After reaching the end of the spinal cord the nerve tissues split off, eventually passing through the tailbone. It then branches off to the legs and feet.

There are a total of 31 spinal nerves that branch off from the spinal cord. They are composed of two roots; the ventral and dorsal roots. The ventral has the job of sending messages from the brain to the spine whereas the dorsal sends messages from the spine to the brain. These two roots work together and are responsible for relaying messages between our body and spinal cord.

Naturally, the spine has an S-curvature when looking from the side. These curves are formed by the four different regions that work together to form the spinal column. These regions are the cervical spine, the thoracic spine, the lumbar spine, and the sacral region. These four regions come together to act similar to a coiled spring which absorbs shock, maintains balance, and allows even weight distribution.

The cervical spine is located at the very top of the spine and holds the weight of the head. It is composed of 7 vertebrae and has the shape of a backwards letter C which gives the spine the S-curvature mentioned earlier. The cervical spine is by far the most mobile of the four regions due to the needed mobility for the head. The main reason why we are capable of moving and rotating our head all around is because of the two, top most vertebrae. The first vertebra called atlas is directly connected to the skull whereas the second vertebra is named axis. The atlas allows us to nod our head in an up and down motion while the axis allows us to move our head to the left and right. These movements are crucial for daily tasks and could never be possible with the cervical spine. The cervical spine is at high risk for injury when it comes to strong sudden movements. This can typically happen during car accidents where whiplash is a preeminent injury.

The thoracic spine is located directly underneath the cervical spine and has the shape of the letter C. It holds the ribcage, protects the lungs and heart. It is also composed of 12 vertebrae with very limited movement.

The lowest part of the moveable spine is the lumbar spine. It also has the shape of a backwards letter C. It is typically made up of 5 vertebrae but on rare occasions it can include 6 vertebrae. The lumbar spines main responsibility is to carry most of the weight in the torso. It is also responsible for absorbing most of the stress when lifting heavy objects. As a result, it is the most frequently injured part of the back.

The sacral region is directly below the lumbar spine and is composed of the sacrum and coccyx. The sacrum is used to join the spine to the iliac or hip bones and is composed of 5 vertebrae. The coccyx, also known as the tailbone, is the lowest part of the spine and is located underneath the sacrum. The coccyx is entirely composed of 4 bones.

As you may know, the spine is extremely important to the human body because it is what allows us to move around properly and control every part of our body. That is why protecting the spinal column should be at a high priority. Always remember, without a healthy spine we are incapable of doing the things we take for granted on a daily basis. Keeping the spine healthy will also allow us to continue our life well until we are old without any significant back pain.

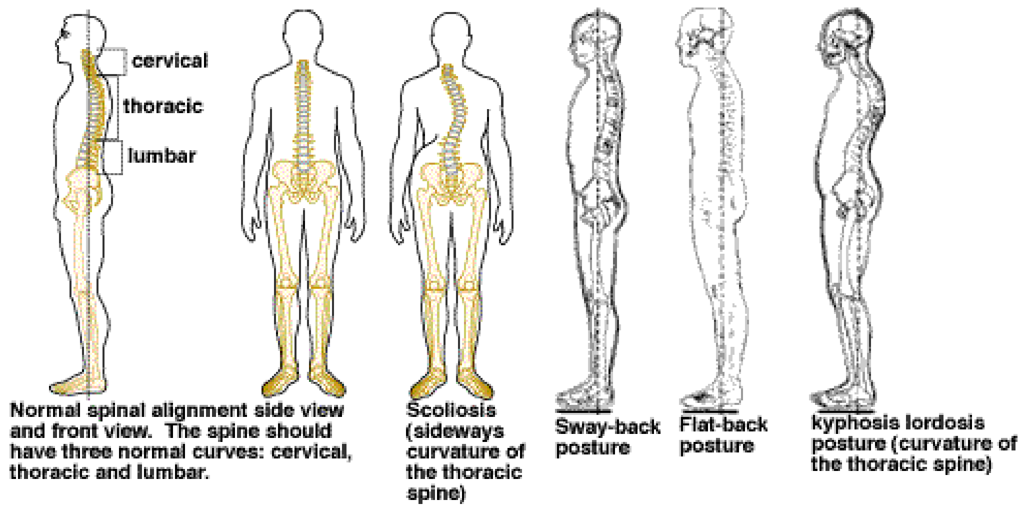


Figure 3.1: Spine Orientations

3.1.1 Proper Sitting Posture

We all have a tendency to slouch after sitting for a long period of time. A lot of times we are unaware to the poor tendencies we follow when sitting on a chair for long hours. As years go on the more bad habits we build and the worse our posture becomes. The first thing we need to realize is that we all have poor habits and we need to be held accountable for them. Keep your mind open to a solution and know there is always a way to improve.

Finding the chair with the correct dimensions for your body is the first step in improving your posture. There should be about 2 to 3 inches of legroom from your knees to the end of the chair. When you first sit down you should slide until your bottom has reached the back of the chair. Make sure you sit up and keep your shoulders back. This does not mean that your back needs to be perfectly straight. Your back has a natural curve to it so sitting up straight will do the trick. A good indicator of good sitting posture is if your arms are parallel to your spine. The height of the chair must be adjusted so that your feet are placed firmly on the ground. Your knees should then bend to form a 90 degree angle while your knees are also nearly level or a little bit above your hips. Try to avoid crossing your legs because this typically affects your weight distribution and the curvature of the spine. You should assure that your weight is evenly distributed on your hips to avoid discomfort and pain. It is heavily advised to slightly change your position after every 30 minutes of sitting down.

While at work you should sit as close as possible to your desk and rest your arms on the desk or chair. Your elbows should form a 90 degree angle while resting on desk or chair. It not you should adjust the height of chair so that it does form a 90 degree angle. Your arms and wrists should remain nearly perpendicular to the floor. While sitting down your work chair should have lumbar support for your lower back. This lumbar support is essential as it is the leading contributor to slumping. It also puts a lot of unwanted stress on your lower back that can cause severe back pain. Remember, the lumbar spine is responsible for holding most of the load of the upper body. If your foundation is not properly supported than the house will collapse. Your head and eyes should be directed straight toward the center of the computer screen while sitting on your chair. If you need to tilt your head up or down then you must rearrange the screen or the desk so that there is not stress on your upper spine. This stress can cause unwanted headaches and a lack of concentration. Lastly, the armrest should be slightly pushing up your shoulders so that youre not putting any strain of your upper back or shoulders. They should remain stress free and not slouching downward in order to reach the armrest.

Figure 3.2: Different Sitting Postures (Courtesy of Okamura)

3.1.2 Benefits of Proper Sitting Posture

Now that you know what entails in proper sitting posture lets talk about the overall benefits of using the procedure. Sitting up straight with proper posture will keep your bones and joints correctly aligned. That way your muscles will be used in the way they were intended which could ultimately limit stress on the ligaments, limit fatigue, and allow the body to use less energy. It would decrease the possible wear on your joints and help avoid arthritis. Keeping it properly aligned would also reassure that you are not fixing your back into an abnormal position that could cause other severe back problems. Most importantly of all, using proper posture while sitting would contribute to a healthy back and a good appearance.

3.1.3 Staying Active

Another thing to keep in mind is that staying active is just as important as proper sitting posture. That is why one of the previous recommended tips was to slightly alter your posture after 30 minutes or so. Having a static posture also contributes to back problems and muscle strains. Another way to cope with muscle strains is to get active after a prolonged time of sitting. Standing up and going for a quick walk to the bathroom or to get a sip of water will promote blood circulation throughout your back. This alongside stretching will significantly limit muscle strain.

Some of the symptoms you may encounter when sitting down for too long are eye-strain, lower back pain, soreness in the wrists, numbness in the elbows, pain in the shoulders and neck. These signs should be taken seriously and should be followed by a break. Take the time to get up and stretch so that you can get blood flowing through your entire body.

3.1.4 Realigning Your Back

Another recommendation to limit muscle pain would be to realign your back after an excessive amount of time sitting time. Every 2 or 3 hours it would be wise to follow these steps to get your back in the ideal alignment. This does multiple things for your back. It works as a stretch, gets blood flowing through your back, and puts your spine back to good form.

1. Stand up slowly with your feet pointing straight and forward.
2. Now, align the pelvis by squeezing your bottom and internally rotating the feet 15 degrees.
3. Then, roll feet to the side away from where your arch is located and gradually bring the legs back together without the heels moving. This step is used to make the butt and thigh muscles work together.
4. Slightly tighten your abdominals just enough to have a slight tension in your core.
5. Next, externally rotate your shoulder and arms as you keep your chest pointing up and your thumbs pointing away from the rest of your body.
6. Finally, while keeping your shoulders as they were, rotate your hands back to normal and make sure that your thumbs are facing your body.

A similar technique to improve posture is called foundation training. It not only helps to realign your back but it can also strengthen your back muscles. The movements are extremely similar to the ones mentioned earlier and were developed by Dr. Eric Goodman. He recommends the following procedure.

1. Stand up straight and slowly rotate your shoulders backwards.
2. Now, take two deep breaths and focus on getting long.
3. Using both hands, put your thumb on the lowest part of your ribcage and your pinky on the highest part of your pelvis. Both hands should be approximately 6 inches apart.
4. Then, take 3 more deep breaths slowly and focus on making the distance between your ribcage and pelvis larger and larger on each breath taken in. This will active your lower back and cause some lower back discomfort.
5. Keeping the length obtained between your ribcage and pelvis, pull your hips back and stick your bottom out.
6. You will now take another 3 deep breaths in and in the meantime you should feel more tension on your lower back.
7. Repeat step 1-6 one more time and your back will be aligned and stronger than before.

3.1.5 Weight Distribution

Weight distribution plays a vital role in determining poor posture for our system. As described earlier, an ideal posture requires the user to sit all the way back in the chair. In other words, their hips should be touching the back of the chair. The weight distribution for someone who is sitting without their hips touching the back of the chair is represented by the figure below. The right side of the figure shows how much pressure was applied to each portion of the chair. This representation was formed by using pressure sensor technology. When an individual doesnt follow this procedure, the body is only supported by their buttocks, thighs and upper back. As discussed earlier, the lower back is primarily responsible for supporting the body due to the strength located in the lumbar region. Using your upper back to support the body will cause all kinds of back problems. The pressure sensor reading shows that there is a lot of weight being applied to a specific location instead of the weight being evenly distributed. This figure will be much help for when we start designing, prototyping, and testing our project.

Now, let's analyze the weight distribution for when a user is using proper posture. As mentioned earlier, when a user has followed proper sitting protocol their hips will be firmly touching the back of the chair. The reason it is required to sit in this way is because there is a positive effect by placing the hips at the back of the chair. This causes the lumbar region to be firmly supported as well as the pelvic area. The lumbar support helps the body form a natural curve that evenly distributes the entire weight. The weight distribution for someone who is following the proper siting protocol is represented in the figure below. Once again, the right side of the figure

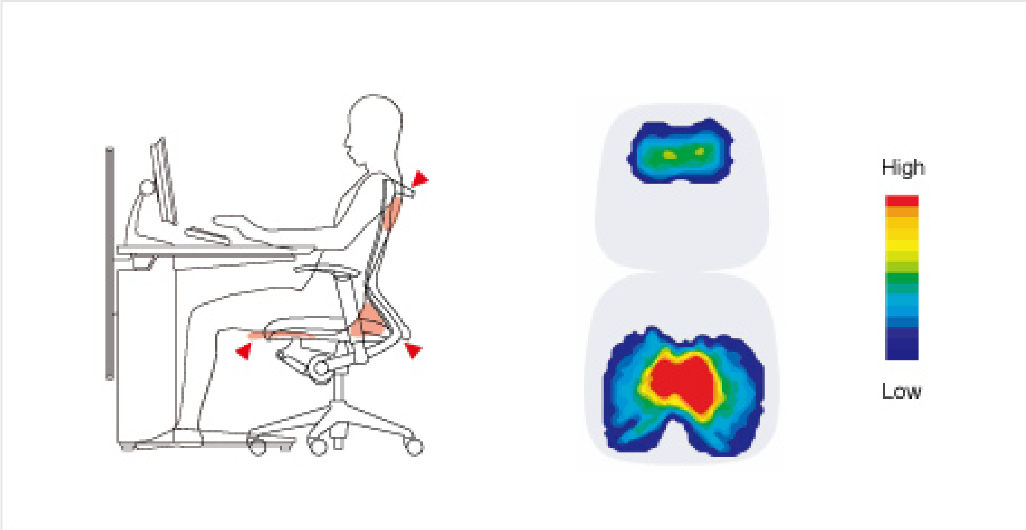


Figure 3.3: Pressure Distribution for Poor Posture (Courtesy of Okamura)

shows how much pressure was applied to each portion of the chair. If you analyze this pressure sensor reading you would notice how the weight is far more evenly distributed along the seat of the chair. There is far more surface area being used in this figure compared to the last figure. On top of that, there is also far less of the color in the seat mapping. This means that the users weight is not concentrated in any specific region and in turn there is less stress on the individual while seated. The fact that there is only pressure sensor reading on the lumbar region for this figure is also very promising because it means the lumbar is being used in the way it was intended. This will limit any back issues especially if the user is seated for a long period of time. This figure can help our algorithm determine, while using pressure sensor technology, if the user is seated with proper posture.

3.2 Existing Solutions

The market has introduced several solutions for improving back posture over the years. Before advanced technology, posture braces were the most economical solution to poor posture. Then ergonomic chairs were introduced into the market. While both of these solutions are indeed helpful, they are also extremely limited in the way they can help improve an individuals posture. In the last couple of years, there has been an increased interest for technology driven solutions to poor posture. These solutions will be discussed in full detail. Our product will include many features already in the market but more importantly it will include several key features overlooked by other products.

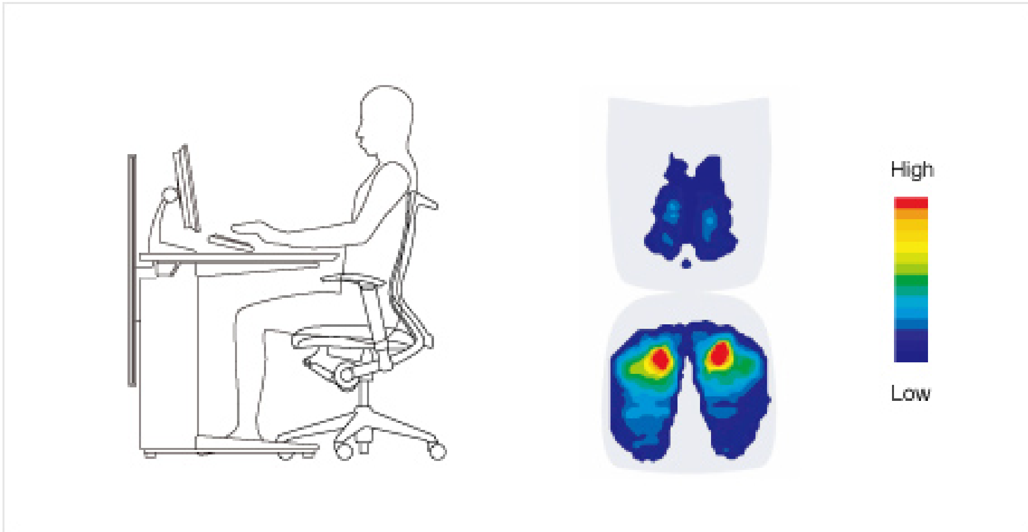


Figure 3.4: Pressure Distribution for Proper Posture (Courtesy of Okamura)

3.2.1 Lumo Lift

One of the simplest designs in the market for improving your posture is the Lumo Lift. Its a tiny square shaped device that is attached, with magnet, to your clothes about 1 inch below the collarbone. It comes in two pieces, the magnet and the actual tracking unit. The tracking unit must be laid directly on the users skin to work accurately. This tracking unit retails for $100.

In order to get the most out of the Lumo Lift it is recommended that the user wear it on a daily basis in order to keep themselves accountable. After the user has put on their Lumo Lift correctly, the user must get into the posture they wish to keep the entire day. Afterwards, they should press the device twice in order to calibrate the device into align mode. The Lumo Lift will vibrate 3 times to indicate it has correctly captured the desired posture. The device will now monitor and compare your posture to the snapshot taken earlier. If it varies greatly to the captured posture then it will notify you by vibrating; it will do this every time you slouch. You can control how often it does this by changing the coach mode.

The Lumo Lift is very easy to use mostly due to its simplistic design. Ironically, it's major downfall is also in simplicity of the design. The Lumo Lift allows the user to determine what a proper posture is. This can be very worrisome because the user might know nothing about what a healthy posture looks or feels like. That means the user will be calibrating and maintaining an incorrect posture every single day. That on its own makes the Lumo Lift an ineffective device for improving posture. The Lumo Lift is incapable of promoting awareness with its simple posture snapshot and needs more than just an angle displacement to calculate proper posture. Another downfall of the Lumo Lift is the necessity to keep the device close to your skin in order to get accurate readings. This means youll need to adjust what type of clothes you wear and ignore those that are loose fitted. A device shouldnt dictate what you wear every day in order to be effective. The last major defect is that it has no LED display which means you have no way to check on your posture until after youve connected it to your computer. All in all, the Lumo Lift is far too costly for a device that cant even do the one thing you bought it for effectively. The Lumo Lift does provide other things like step count, calories burned, and distance traveled. Regardless, that is not where it prioritizes itself and a better algorithm needs to be developed to accomplish what it set out to do. Lastly, the Lumo Lift offers no data whatsoever on your back and isnt capable of tracking your sleep which is a normal feature for trackers nowadays.

3.2.2 Lumo Back

Another device made by Lumo is the Lumo Back. This device does everything the Lift does with a couple of added features. The Lumo back is capable of tracking your posture, sitting time, steps, movement, calories burned, and sleep. The big difference between the Lift and the Lumo Back is the sleeping and sitting time tracker. The design is also completely different for this tracker as it goes around your waist instead of clipping around your collarbone. Its essentially a glorified belt with Velcro so that you can buckle it up. Unlike the Lift, the Lumo Back can go under or over clothing without significantly effecting results. It should be placed a little bit above the hips. The Lumo Back retails for $150 due to the added features.

Understandably, it is also recommended that the user use the Lumo Back on a daily basis in order to get the most out of the device. The Lumo Back requires calibration in order to set up a general baseline for the activities the user will do throughout the day. The user once again should tell the device what proper posture is so that it can record or take a snapshot of their correct posture. Unlike the Lumo Lift, this device also has the user display what their back looks like when theyre slouching. Lastly, the device has the user take a few steps so that it knows how to calculate the steps the user has taken throughout the day. Once again, the device will monitor and compare the users posture to the baseline posture it recorded. Whenever their posture deviates from the baseline it will notify the user with a vibration. The strength of the vibration can be adjusted but it will vibrate every sing time the user slouches. As with the Lumo Lift, this device has capability with only the iOS which leaves all Android users without the ability to check on their progress. In contrast, the Lumo Back will notify the user when the battery is becoming low. When the user presses the button located on the belt it will light up with either a green or orange color. Green means that more than a days worth of charge is left while orange means there is less than a days worth of charge.

The Lumo Back very similarly to the Lumo Lift is far too simplistic when it comes to design. Once again the device is letting the user decide what proper posture is instead of telling the user how to sit, walk, and stand with proper posture. Like stated earlier, this can lead to the user building bad habits and having a worse posture. With that being said, the Lumo Back does have some bright sides. The Lumo Back makes the user calibrate 3 times versus just once. This can only improve their accuracy and consistency. And not only does the Lumo Back have the user calibrate a good posture but it also has them calibrate their slouching posture. As well as calibrating their step count which the Lumo Lift never bothers doing. On top of that, it has the added features of tracking sleep and sitting time. Sitting time, as discussed earlier, is also something to worry about when worrying about health so its an important measurement. The one negative of the sleep tracking is that the user must obviously wear the belt while sleeping. This could be extremely uncomfortable and provide an unpleasant sleeping experience. The user might forget to put it on while going to sleep as some people tend to shower after arriving home. Plus the unpleasantness of wearing it while sleeping might make most users disregard that feature all together. All in all, the Lumo back is an upgrade to the Lumo Lift, but there are still many concerns with the design and methodology it uses to correct your posture. Because of this it cannot be seriously considered for those who are in need of improving their posture.

3.2.3 Darma

A relatively new device called the Darma is an inactivity tracker developed to improve posture alongside other things. This product markets is not readily available as there is a wait time of about a month after ordering. The retail price as of now is $199 but prices are expected to rise once its more readily available to consumers. The Darma is essentially a smart cushion that is placed on your chair and attempts to track your posture by using patented sensors or pressure sensors. These sensors will allow the device to track posture, sitting time, and your stress levels. It seems to not require any calibration which makes it extremely user friendly. The device prides itself in being non-invasive in its tracking methodology.

The goal of the Darma is to passively watch your posture and give you suggestions on how to reduce strain. It doesnt simply vibrate to alert the user when it is slouching. Instead it allows the user to see how their posture is in real time on an application that also comes with the cushion. The application will show a variety of colors on the cushion and approximate the curvature of their back according to their current position. That way the user can correct their posture accordingly and sit up properly. Once they have found their ideal seated position for a proper posture they can minimize the window and focus on keeping it. The cushion will continue to track the users posture throughout the day so that they can check on how they did later in the day. If the users posture becomes increasingly worse as the day goes on the application will notify the user and give suggestions on how to improve their posture. The application can guide them with on-screen prompts and show how each movement affects the pressure on the seat. It will also display to the user what their current posture looks like as they move in their seat. This posture reading is approximated since there are no pressure sensors on the back of chair.

This device also puts a lot of stress on tracking the users sitting time which as stated earlier is just as important as posture position. The device will warn the user to get up and stretch after a prolonged time of inactivity. It will alert the user and also recommend certain stretches with a guide on how to them. The Darmas primary goal is to promote a healthy lifestyle so it does more than just focus on the users posture. This device does a good job of understanding that sitting long hours doesnt simply affect the users posture but it can also affect their overall health as well. Not only does it track the time spent sitting down by the user but it also monitors the users heartbeat and respiration levels. This allows the Darma to notify the user whenever their stress levels are above normal and suggests activities that they can do to improve their current state. The Darmas application connects through Bluetooth and is available for iOS or Android devices.

The Darma is far more developed when compared to the two Lumo products discussed earlier. The algorithms for this device are far more complex and are capable of calculating the curvature of the users spine. This is ideally what any user will want from a device bent on improving their posture. The device also provides feedback on how to improve the users current posture and doesnt just warn them when it seems to be off. There seems to be no guessing in this design whereas Lumos products were based off pure assumptions. This product is also dually compatible with iOS and android whereas Lumos products were not. As an added bonus the Darma also tracks respiration and heart rate which neither of the Lumo devices had such capability.

In conclusion, the Darma is a serviceable product with good intentions and decent performance. It is a step in the right direction and accomplishes a lot with the limitations of its design. The designs only flaw is that it uses only one measuring tool on the seat. The design from a marketing standpoint is understandable because it would be more of a hassle to have a two piece kit for the seat and back. Plus there might be complications when applying the back cushion depending on the seats material. Regardless, the accuracy is largely limited by only having the one measuring tool on the seat; especially if the main purpose is to analyze the users posture. Thankfully, the Darma doesnt only rely on its posture tracking abilities and comes with other features to promote the users overall health; this is what sets it apart from a lot of other trackers. Another design flaw is the inability of the cushion to provide much assistance without the application. If the user doesnt have their phone or a computer near them then the cushion will vibrate every 30 minutes to alert them to get up and moving. The cushion will also not work on a couch or car seat. It takes approximately 8 to 10 hours to charge the device and it cannot be used while being charged.

3.2.4 Zikto Arki

The Zikto Arki is an activity tracker similar to the Lumo Lift but is designed to go around the users wrist instead of their clothes. The Arki is also similar to Fitbit and is apart of the new wave of activity wearables. Its a tiny rectangular prism measuring 14 mm x 50 mm x 11 mm. It has a variety of interchangeable bands which sets it apart from any other activity tracker in the market. It currently retails for $149 on the current market.

The Zikto Arki is designed to be a replacement for a watch so it is suggested to use on a daily basis. What sets Arki apart from the rest of the activity wearables is the capability of analyzing the users posture and creating a biometric print with the users walk pattern. This means Arki will be capable of biometric authentication if coupled with any other device that requires you. For example, smart thermostats like the Nest would be able to be coupled with this device. In order to analyze the users posture, Arki does not require any calibration from the user. It can analyze the users posture with the algorithm and the sensors built into it. Similar to the Lumo Lift and Back, Zikto Arki uses haptic feedback in order to remind the user to fix their posture. The design is smart enough to know when the user has their hands in their pocket, are on their phone, or simply hunching their back. Arki will alert the user whenever they practice any of those bad habits. Not only will it vibrate to notify the user that they were practicing poor walking posture but it will also show on the LED screen which bad habit was perceived. All of this can be tracked on the mobile application.

Furthermore, Arki is capable of analyzing the overall balance in the users body while theyre walking. This will give the user a full analysis of their body balance and will identify their weak points. The Zikto Arki does this by comparing the swinging of your right and left arms. The algorithm is capable of telling the user what body part is lacking and recommend helpful exercises in order to strengthen those muscle groups. All of this information can be tracked on the mobile application. In addition, the Arki is capable of doing everything else a typical activity tracker does. This means tracking the users daily activity and monitoring their sleep. Arki calculates the steps taken, distance traveled, total calories burned in the day, and the amount of hours slept as well. Arki will also sync to your phone so that it vibrates whenever the user gets a phone call or text message.

In conclusion, the Zikto Arki is a better alternative to the other two activity wearables mentioned earlier. This activity tracker has better results and is very competitive in regards to price and features. In terms of hardware, it brings an accelerometer, gyroscope, proximity sensor, vibration motor, and LED display. There is not much too pick apart with the Arki since the algorithm seems more reliable than the algorithm used by the Lumo Lift and Lumo Back. It also has the capability of measuring weaknesses in the body which is a huge feature not discussed before. The fact that the Arki can distinguish between the users having their hands in their pocket, or when theyre using their phone is incredible and validates their software design. In my opinion, a major design flaw is the lack of a system to distinguish the purpose of each vibration. The Arki vibrates for about five different reasons. Even though the LED display explains the reason for it, I still think they could have made the device vibrate multiple times depending on the given situation. The only thing that is not mentioned in detail is how well it would help a user identify problems while theyre seated. The Arki also doesnt seem to be able to calculate how long the user has been inactive. It seems to only track activity time. However, suggesting workouts for improving body balance is a very nice added feature. The Arki is also a much more comfortable route in terms of an activity tracker. It goes comfortably around your wrist as opposed to around your lower back or on your shirt. The customizable band is also a huge plus for those serious of using an activity tracker on a daily basis. In the end, The Zikto Arki is a breath of fresh air and does a lot of good things for those trying to track walking posture. But, it might not be enough for those who work in an office and are more concern with sitting posture.

3.3 Relevant Technologies

For the purpose of making our project competitive with the extensively researched market, we will need to include the components necessary to impose our ideas into a revolutionary product. This section will include any and every type of technology we considered using for our project. Most importantly we examined pressure, proximity, and distance sensors. Along with several wireless communication technologies and vibration motors.

3.3.1 Pressure Sensors

In the seat of the chair a pressure mat will measure the weight distribution to help determine how the sensors will position themselves to read the spine position and also contribute to the data recorded to help with posture maintaining. The pressure mat will need to be able to not break under the weight of a person sitting on it, and will have to be able to read the data of an object placed on it. Many pressure sensors exist on the market today and provide a variety of functionality and interfaces. The pressure mat may be extensible to read the distribution of weight of a user, but there are complications that exist with the safety of such a device, such as the risk of puncture and heat to the device that may affect the user negatively. These pressure sensors will need to be able to detect the pressure caused by the physical objects placed in the chair and be able to support the weight of an object so that it will comply with the standards of a regular office chair. The sensors may not be able to read as high as the max supported weight of the chair, but as such the sensors should not become damaged if they are over loaded, and still be able to function normally after such an event has taken place.

Six main technologies exist for detecting pressure. Piezoresistive strain gauge, capacitive, electromagnetic, piezoelectric, optical, and potentiometric, but there are other types that use properties of matter to infer pressure like resonant, thermal, and ionization pressure sensors. While the application of these sensor technologies vary from simple altitude sensing to radiometric correction of transducer output, there is no one pressure sensor that excels in all fields. The selection of a pressure sensor that completes the task of the chair with the accuracy, the reliability, and the cost that is most effective in the environment created by the chair and its location will need to be selected.

Pressure sensors that use the properties of physical material to infer the pressure experienced by the supporting structure of the chair would rely heavily on there being a constant reference to refer back to, a zeroing point. The forces experienced by the chair may be easily read by the changes in resonance of the supporting structure, or by the changes in temperature of the cushion as it is stressed, but humans being natural heat sources throws these measurements off. Unfortunately these technologies, while very precise and having a wide scope, need precise calibration and continual support, and can be very costly. The force collector type sensors measure strain or deflection to accumulate data on pressure sources, as we will be using these sensors as sensors that detect pressure relative to a zero defined by us, it is useful to have a sensor that can be zeroed to a desired point. Optical inspection of an object may be used to infer pressure, as in the reflection of certain wavelengths due to stresses material, however the precision and cost of the optical units may be too great to use on this as such units as the fiber Bragg grating sensors are sensitive to strain, but are also sensitive to heat. Piezoelectric sensors rely on a piezoelectric material to react to a surrounding force and have many application in anything from automotive applications to acoustic measurement and detection, the are relatively cheap and can achieve an accuracy level acceptable to the requirements of our project. Another pressure sensor relies on electromagnetic inductance to measure the displacement of a diaphragm, these sensors are great at measuring changes in pressure, but do not measure static pressure well. Potentiometric sensors are simply a potentiometer connected to a physically resistive object (like a spring) that will change in resistance as the object becomes strained and actuates the potentiometer changing the resistance, a primitive solution that wont hold up to the constant pressure experienced by the sensors. Capacitive sensors have become more and more popular in modern times, capacitive touch screens have made their way into countless computer display systems, but the capacitive pressure sensors is more low-tech than you might have guessed. It simply measures the change in capacitance as one of the plates or dielectric is deformed, changing the distance between the plates, and overall changing the capacitance. Finally, piezoresistive strain gauges are by far the most common pressure sensors, as they are cheap to produce, and have a high accuracy when combined with a wheatstone bridge circuit, they work on the principle of measuring the change in resistance when mechanical strain is applied.

Given the higher reliability and availability of the piezoresistive sensor it is a better option for this project, but it is of note that the piezoelectric or capacitive pressure sensor may cost less and provide the accuracy needed for the scope of this project.

Table 3.1: Pressure Sensor Comaprison

Sensor Type	Price	Accuracy	Power Consumption	Integration Complexity	Availability	Score
Potentiometric	+	0	+	+	0	3
Piezoresistive	+	0	+	+	+	4
Captive	+	+	+	-	-	1
Piezoelectric	+	0	+	-	0	1
Electromagnetic	-	0	-	-	0	-3
Optical	-	-	-	–	-	-6
Resonant	-	+	0	–	-	-3
Thermal	-	0	0	–	-	-4

3.3.2 Proximity Sensors

The chair works for a person sitting in the chair, not for a person standing in front of the chair, not for a box sitting in the chair, and not for the air surrounding the chair. As such there needs to be a way of determining what is being measured and recorded is what we intended it measure. Detecting a user seems trivial to the adult human brain, but the concept of detecting a person in a particular position and orientation has proved difficult without an array of sensors placed on particular locations on the person. This chair seeks to be minimally invasive and wishes to not have the user need any additional hardware, like position sensors on their person, so the hardware provided on the chair and support module will be enough to detect and measure the user. In addition to the minimal invasive efforts of the chair, an effort to save on power consumption the device will attempt to limit its operation to times when the seat is occupied by a user. To detect the user there are several options available to do so, as such, it will be in our best interest to use the technology that can give us the highest accuracy with the lowest operating cost. To accomplish this several technologies will be considered to accomplish this, and a few may even be used in conjunction to improve the accuracy of a positive detection.

Passive Infrared

Mammals are usually pretty substantial heat sources, when considering the context of an office, that can easily be detected using an infrared (IR) sensor. The setup of this infrared sensor would be vital to the detection accuracy of the setup. As a place that may detect a false positive would result in increased power consumption, incorrect data being recorded, and false negatives would result in the device not performing its intended function, leading to an unhappy user. A passive IR sensor could easily detect a heat source, unfortunately is can be very sensitive to environment temperature changes, like the exhaust of a computer tower or an A/C vent heating and cooling the immediate surrounding area. A passive IR sensor works on the principal of two different sensors creating a different reading on each sensor to indictae that there is an object that is a source in the field of one of the sensors. To do this the two sensors need to have well defined detection regions, as if they overlap too much the difference in emission detected by each sensor will not vary enough to trigger a response from the sensor.

Active Infrared

An active IR sensor could detect motion using an IR light source and measuring when this source is disrupted using a single IR sensor, this technology is less susceptible to the false positive of the passive IR, however it requires an IR source to make a detection, a task that would require a power source to continually supply power to the device. It is of note that the combined use of the pressure sensor on the seat of the chair and the IR sensors can become redundant devices to help decrease the risk of a false positive. There is also the risk of the person emitting too much heat and washing out the sensor's field of view, depending on the sensitivity of the sensor, and the strength of the source.

Microwave and Radar

Similar to active IR sensors the microwave and radar sensors use a combination of transmitter and receiver to determine motion based on the reflection of electromagnetic waves off an object to determine if it has moved from its previous position, in particular the X-Band electromagnetic waves of 10.525 GHz. The principal system works similar to an ultrasonic sensor in that a pulse signal is generated and a response is detected, however the detection cannot determine distance due to the low energy of the output, and the speed at which electromagnetic waves travel. There are also a number of health concerns with using high frequency electromagnetic waves, especially when the user is continuously positioned in front of the transmitter at a relatively close distance.

Capacative

A major technology that has taken off in recent years, capacitive sensors can be used for a wide variety of sensing applications, including sensing an object within proximity. The capacitive sensors work on a simple principal of changing capacitance with different material present to act a dielectric, or to vary the distance between the two plates. With capacitive proximity sensors they work by having an electric field that extruders outwards to pass through a target that is close enough to affect the electric field generated from the capacitor. The presence or absence of the target changes the capacitance value affecting the response of the component to an oscillations. When capacitors go up in capacitive value they become less responsive to high frequency drivers, and as they go down in capacitive value they become more responsive to high frequency drivers, this principle allows for the sensor to detect an object that will change its capacitance. The composition of a person is of a much different electrical characteristic then the air, meaning that as a person comes close to the sensor it will change the value and trip the sensor, however this effect is only at very close ranges, usually only a few millimeters. Detection is not limited to just people, any object that can create a change in the electric field can trip the sensor, meaning a box of liquids, or a piece of metal could easily yield similar results.

3.3.3 Distance/Imaging Sensors

In order to measure the curvature of the spine to calculate the users posture, a pivotal part of this project, some type of distance sensing or imaging technology will need to be employed. The technology must be accurate at close proximities with longer ranges of no importance. The distance will be from the chairs backrest to the user if the user is sitting as close to the front of the chair that still allows for good posture. It should also be reliable under the proper or normal conditions and obviously be safe. The different technologies will be explored and compared below.

Optical

Optical sensors are light based sensors as the name implies, though the light that these sensors utilize is not of the visible kind but more of the infrared part of the light spectrum. For this reason, sometimes these sensors are called laser sensors. There are two types of infrared optical sensors, non-ranging or proximity sensors and ranging sensors. The non-ranging optical sensors only provide a binary output and are only good for detecting the proximity of an object or obstacle. For example, the sensor has a set threshold distance and once passed, the binary value goes from low to high. Therefore, this type wont be practical in our case since we need to measure the actual distance from the chair to the users back. The second type of optical infrared sensor is the ranging sensor. This type provides an analog output or a multiple bit digital output and can actually measure the object from the sensor. This type would be more suitable to our needs and isnt much more expensive than the proximity sensor type.

When it comes to measuring distance with optical sensors, there are various optical techniques that are each best suited for different types of applications and situations. The simplest technique is the time of flight method. The concept is based on shooting a pulse of light that reflects off the object of interest then the time it takes to come back to the sensor is measured in order to calculate the distance to the object. This technique takes advantage of the fact that lights velocity in air is constant no matter the conditions. Though the problem with the time of flight technique is that light is ridiculously fast. You would need extremely fast (and extremely expensive) electronic equipment to accurately measure the incredibly short round trip time of the light beam. The farther the object is away, the easier it is to pull off but the accuracy isnt as great. Though the problem becomes near impossible when dealing with close proximities because no electronic equipment is that fast.

The most common and widely used optical sensor technique is triangulation. The sensors shoots a laser at a certain angle so that when it hits the target of interest, the laser beam reflects back but not exactly at the same location. The laser beam hits an optical lens that is positioned slightly apart from the laser emitter. The reason this is called triangulation is because a triangle is formed between the laser emitter, the object and the optical lens. As a result of the triangular shape, we can use geometry to calculate the object's distance from the sensor. The major problem with triangulation is that if the object has holes or steep angles, the laser will not return into the optical lens for the measurement to take place. For instance, measuring the distance to a sphere will not work because the laser will never return to the sensor since the object isn't flat at all. A more complex technique called confocal sensing shoots the laser but the laser beam travels to and back from the object on the same path. Different variations of this technique exists by changing the color of the light that is used as the laser but this technique is usually used for 3D scanning or imaging.

In general, infrared optical sensors are not the most accurate technology since light does not reflect the same way off every surface. The values that the optical sensor obtains will be different for different colors, different shades and different surfaces (shiny and smooth or rough and dark) despite the actual distance never changing. This can pose a problem since the user could wear clothes of different colors and materials or fabrics. Another complication is when using the sensor in the outside in the sun. Since the sun shines visible light and light in the infrared part of the spectrum, the infrared optical sensor will hit interference and not work properly outside and to some extent inside as well (assuming there are windows). The one benefit to using this technology over the others is the price. Optical sensors are frequently cheaper than the alternative technologies such as ultrasonic or camera imaging.

Ultrasonic

Ultrasonic sensors (or sometimes called sonar) are used in many types of medical equipment for there noninvasive way of measure distance and shape. Unlike the optical sensors that use light as their mechanism of measuring distance, ultrasonic sensors use high frequency sound waves that are inaudible to humans to measure the distance between the target object and the sensor. This is done by having two openings on the sensor, one for emitting the ultrasonic waves and the other for receiving them. The ultrasonic sensor then measures the distance by timing how long it takes for the ultrasonic wave to reflect off the object and come back to the receiver. The aforementioned takes advantage of the fact that the speed of sound through air is known and by doing the simple calculation of multiplying the speed of sound with the time it took to make its way back and then finally dividing it by two, gives you the distance to the object. The ultrasonic emitter and receiver must be properly spaced apart because if not, they will experience interference known as crosstalk. This interference does not apply to the ultrasonic sensors that use one emitter that then changes its mode to receiver to receive the ultrasonic wave it sent out, there by being dual purpose.

The range on some ultrasonic sensors can be adjusted by using a potentiometer on the sensor or through software but they all have a minimum sensing distance which means if the object is too close, the sensor cannot accurately measure the distance. For reliable sensing the target object must have a minimum surface area which can differ from sensor to sensor. Therefore, if the object is too small or does not have enough surface area, then the sensor cannot sense the object there. The angle of the object is also of importance because if the ultrasonic wave bounces at a steep angle off the object, the sensors receiver will not pick up on the return wave as seen in Figure blank. This matters a little less if the target object is irregularly shaped with many different sound scattering surfaces and angles. Ultrasonic sensors can even sense liquid targets as well has solid targets. Smooth surfaces are generally more efficient at reflecting sound energy than rough surfaces but the angle is more restricted with smoother surfaces. Ultrasonic sensors are not thrown off by different colored surfaces but the material of the object does matter. Targets of low density such as foam, rubber, cotton, wool or very porous materials absorb sound energy making these materials difficult to sense especially at longer ranges. This could be a problem since the user could be wearing clothing of different types of materials or thick clothing such as jackets or coats that will absorb even more sound energy.

Changes in the environment such as humidity, pressure, humidity, temperature and airborne particles (like dust and smoke) may affect the ultrasonic sensors response. Even background noise may interfere with the sensors accuracy if the noise is really loud and powerful such as the hissing sounds produced from air hoses or motor engines. In general, ultrasonic sensors are more expensive than optical sensors but offer higher accuracy under more of a variety of conditions.

Camera Sensors

Having two camera sensors parallel to each other and on the same plane can also measure the distance to an object. One must know the specifications of the camera sensor such as sensor size and focal length in order to calculate the distance by comparing the offset of the image in the two pictures. The better the camera sensor (higher resolution = higher pixel count), the more accurate the distance measurement can be. Lighting conditions can decrease the accuracy though and dark lighting conditions make this option incapable of measuring distance. In our case, if the user is sitting in front of the computer without the lights on, this technology would fail to measure the users posture.

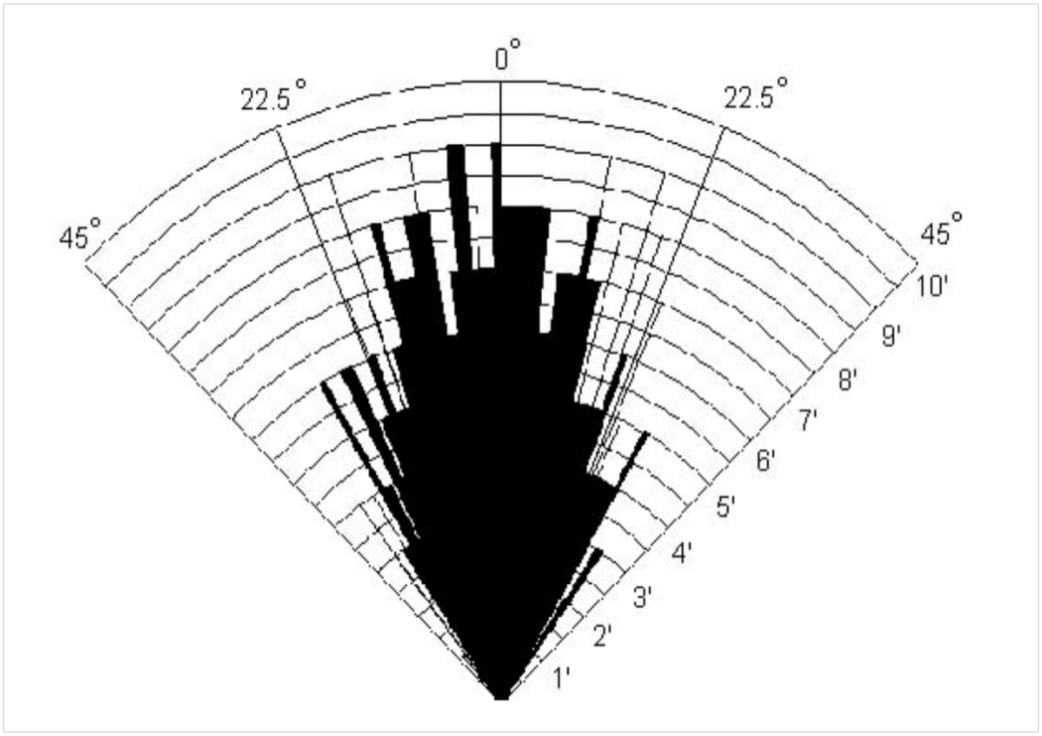


Figure 3.5: Typical Response of Ultrasonic Sensor at Varying Degrees (Labeled for Noncommercial Reuse)

Millimeter Wave Scanner

A millimeter wave scanner is a full body imaging device using a form of electromagnetic radiation. This technology can pass through clothing revealing concealed objects underneath. For this reason, airport security employ this technology to do full body scans of travelers. This technology would be ideal for our project since the users clothing remains an obstacle in measuring the curvature of the spine. The problem is this technology is very expensive and is enormous to be able to put it in a chair form. There are also safety concerns with this technology since it uses millimeter wavelength radiation which is subset of microwave radio frequency spectrum. Though it is still much safer to use than the alternative in airport security full body scanning known as backscatter x-ray. The energy that is emitted from the backscatter x-ray is a type of ionizing radiation that is capable of breaking chemical bonds and splitting DNA.

3.3.4 Block Diagram

3.3.5 Vibration Motors

The use of vibration motors is a must in order to notify the user. The chair needs to vibrate whenever the user has a long period of inactivity or whenever they are

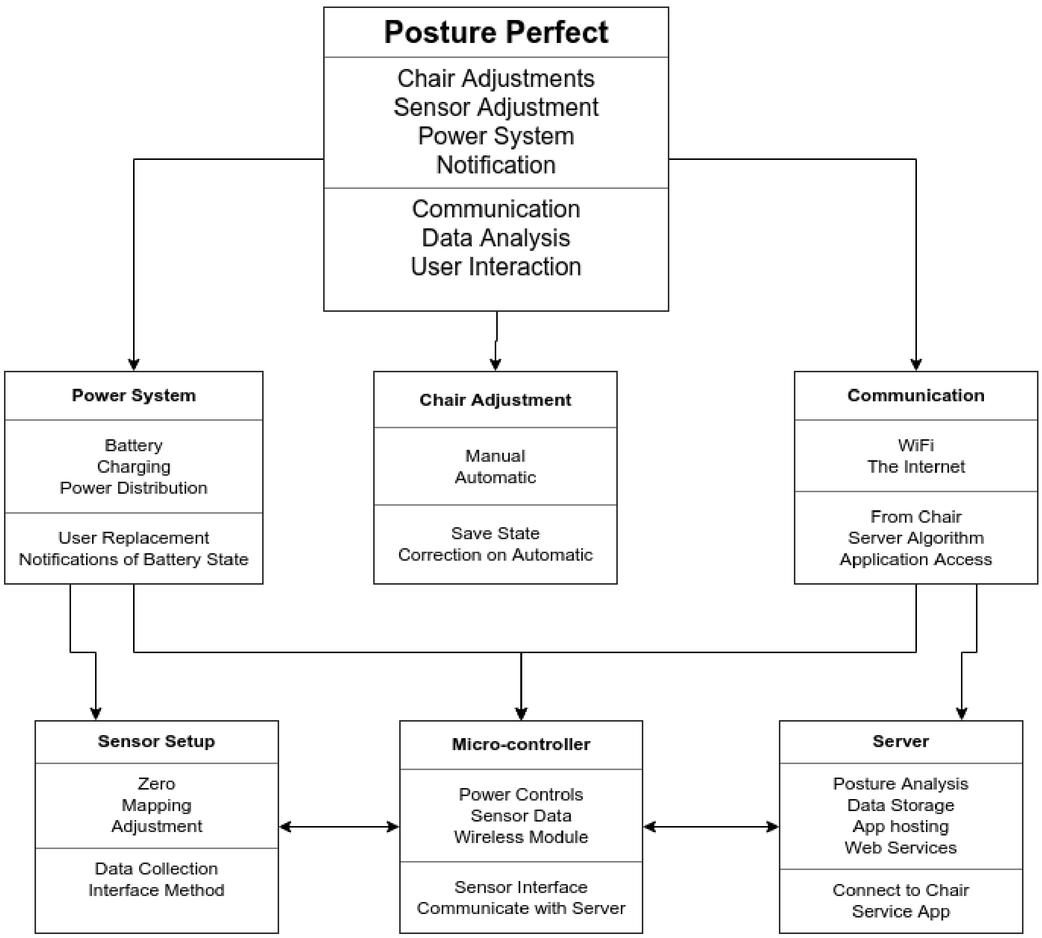


Figure 3.6: The Design Setup of the Project

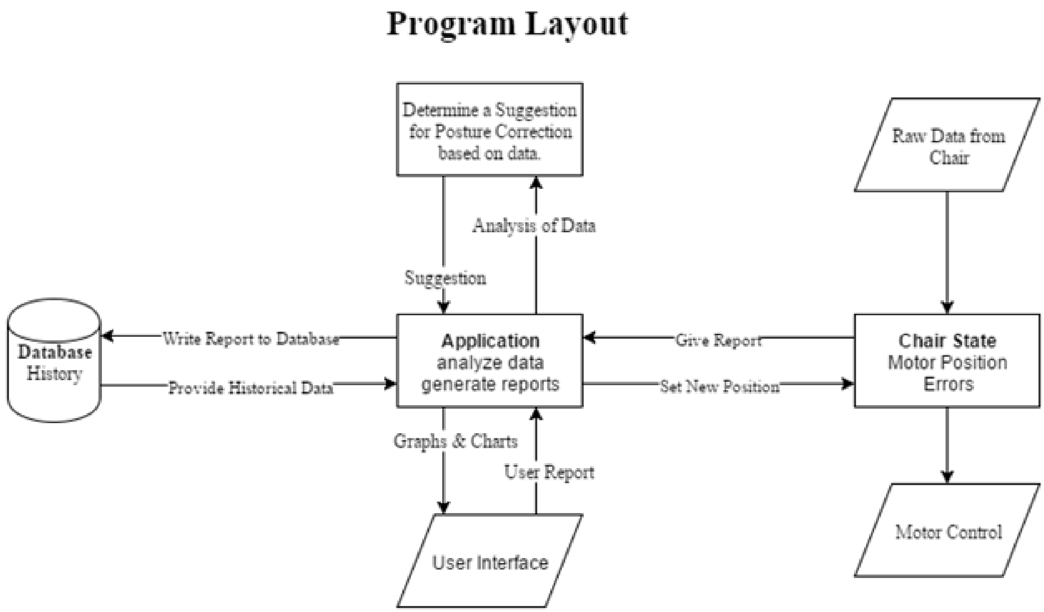


Figure 3.7: The High Level Design of the Application

favoring a specific side. The two major vibration motors in the market are the Eccentric Rotating Mass and the Linear Resonant Actuator. Each vibration motor has a specified purpose so investigating these will be essential in determining which is the best suited for our project.

Eccentric Rotating Mass

The Eccentric Rotating Mass motor is widely known as the pager motor. It is essentially a DC motor with an offset mass which is attached to the shaft. The Eccentric Rotating Mass motor creates its vibration by constantly displacing the motor. The offset mass causes a centripetal force that is asymmetric which in turn causes a displacement. Since the Eccentric Rotating Mass motor has many revolutions per minute, the motor causes a vibration with the repeated displacements. In order to successfully drive an Eccentric Rotating Mass motor, you must connect the terminals to a continual DC source at the desired voltage.

Some of the benefits of the Eccentric Rotating Mass motor are that they are mostly inexpensive, require little to no extra additional electronics, and are extremely easy to implement. They do have considerably more power consumption when compared to Linear Resonant Actuators, but feasibility depending on the project might be worthwhile. They also come in disk shaped package which might work best for this specific project since the user would barely feel them. The biggest disadvantage would be the power consumption since Linear Resonant Actuators waste only about half as much as the Eccentric Rotating motor.

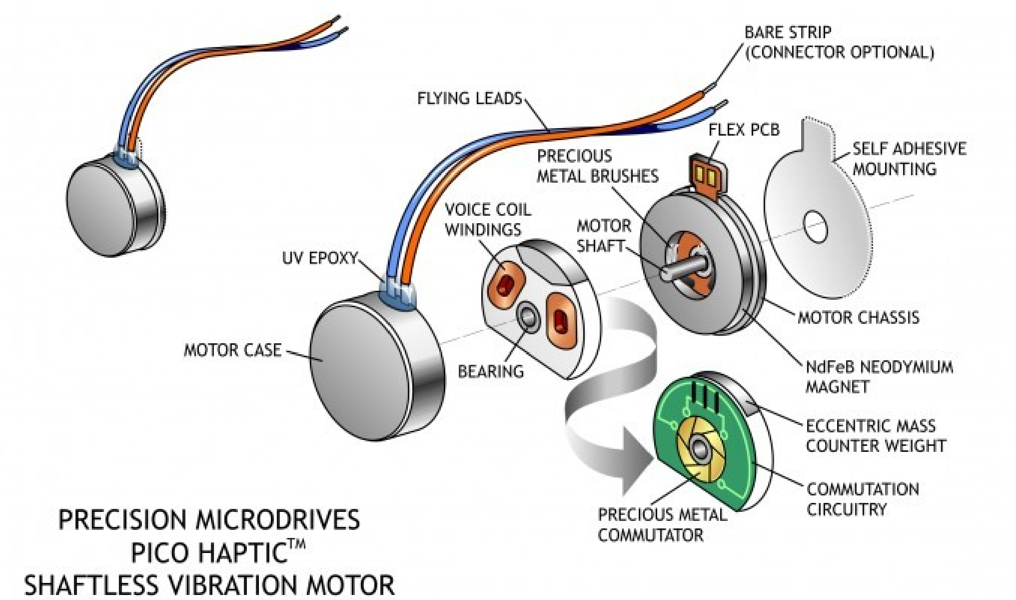


Figure 3.8: Inside an Eccentric Rotating Mass (Courtesy of Precision Microdrives)

Linear Resonant Actuator

Over the last several years, Linear Resonant Actuators have become increasingly popular. These motors make use of magnetic fields and electrical currents in order to create a force. A huge design difference is that the Linear Resonant Actuators voice coil stays stationary while the magnetic mass is the one that moves. This mass is returned to the center by a spring that is attached to the mass. Moving the magnetic mass up and back to the center constantly is what causes the vibration. The direction of the current in the voice coil must be constantly fluctuating due to the direction of the magnetic force constantly changing. In order to keep the voice coil completely stationary the Linear Resonant Actuator must use an AC drive in order to properly function.

The biggest benefits of the Linear Resonant Actuator are the performance and low power consumption that it brings to the table. Depending on how strong we need the vibrations to be we might need Linear Resonant Actuators. It would require less of these motors if we did decide to go that route. On top of that, Linear Resonant Actuators could save up to another 12

Table 3.2: Vibration Motors Parameters/Comparison

	Brushed ERM	**Brush-less Direct Current ERM**	**LRA**
Typical diameter	3.2mm to 45mm	10mm to 12mm	8mm to 10mm
Form Factor	Coin, Cylindrical	Coin, Cylindrical	Coin
Longevity (MTTF)	100 - 600 hours	1000+ hours	1000+ hours
Normalized Vibration Amplitude	0.25 150G	1 30G	0.75 2G
Rated Vibration Frequency	30 500Hz (1,800 30,000 RPM)	200 208Hz (12,000 12,500 RPM)	150 205Hz
Mounting Techniques	Spring pad, SMD/SMT, PCB Through-hole, adhesive, enclosure, bulkhead	Adhesive, enclosure, bulkhead	Adhesive backing
Rated Voltage	1.5 24V	3 5V	2V RMS
Driver Chip	Optional, recomended for haptics	Recomended, sometimes integrated in motor	Recomended, requires AC signal
Vibration Direction	Dual Axis (X and Z)	Dual Axis (X and Z)	Single Axis (Typically Y)
Priority (Cost vs Longevity)	Cost Effective	Long Life	Long Life

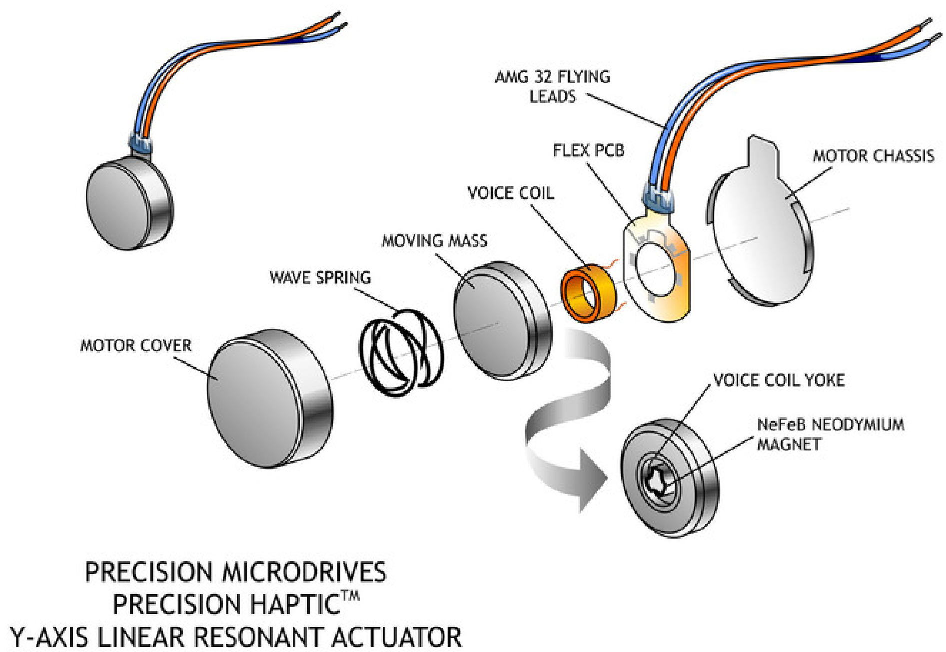


Figure 3.9: Inside a Linear Resonant Actuator (Courtesy of Precision Microdrives)

3.3.6 Microcontroller

The microcontroller is what connects the digital world to the real world. In our project it will act as the brain of our system in the chair. It will take all the data from the different sensors as input and decide on what to do and what to output. A microcontroller is, by its definition, a cpu, memory module and I/O all bundled in one small package. Microcontrollers are usually embedded inside another device so that they can control the actions or features of the product. They can be dedicated to one task or many tasks and run its program that is stored in read-only memory or ROM. They are usually implemented for low power operation and battery powered devices. It can also be argued that buying a microcontroller with all the components bundled inside is cheaper than buying each of the components separately and packaging it together.

The central processing unit for microcontrollers can vary in both speed and architecture. Frequency or the speed in which the clock cycles is a general reference to a CPUs performance. However, the clocks frequency can be changed by using a different timing crystal. This component is an important aspect to consider depending on how demanding the task will be for the microcontroller. The architecture defines the bit size or width that will be used throughout, whether that be for calculations or for storing/accessing in memory. For memory, a microcontroller can have ROM, RAM (random access memory) and nonvolatile memory like flash memory. Sometimes they can even have external memory in the form of SD cards or micro SD cards. Choosing the right memory capacity for our microcontroller will be important for knowing the maximum program code size we can upload onto the chip.

Peripherals are the name of the game when it comes to microcontrollers. They usually supply the input for the MCU but they can also act as outputs. For example, some inputs may be sensors, switches or even other microcontrollers with the input types being analog or digital. If the signal is analog an analog to digital converter or ADC will be needed since the microcontroller can only handle digital signals. Though a digital signal can behave like an analog signal through the pulse width modulation technique or PWM. If the output of the microcontroller must be analog, it must go through a digital to analog converter. Some examples of outputs are indicators such as LEDs or LCD screens or motor drives. There are different ways that these inputs and outputs interface with the microcontroller. The most common and cost effective method is serial communication since it only uses one pin on the MCU. There are many different types of serial communication such as UART, RS232, I2C and SMBus. It is crucial that the microcontroller we pick must have all the necessary input types and variations in order interference with our whole system.

3.3.7 Electrography

Electrography is a technique used mostly in medicine to analyze a patients emotional or physical health. It uses a high-voltage current that passes through the patient by direct skin contact and then outputs its reading as an image surrounded by incandescent radiation. This image is read by doctors and is used to determine certain attributes of the patient. We can use this technology on the user while they are seated on the chair to read how they are feeling as time goes on.

Electromyography (EMG)

Electromyography was the first type of procedure that came to mind when deciding if the product could benefit from an electrography reading. This procedure is capable of analyzing the health of the subjects muscles and the nerves that surround them. It can read when the muscles are being active and show how much of each muscle group is being used by the user. It may sound silly to add this to a posture correcting chair due to the long periods of inactivity but this procedure could help the chair read when a user has spent an unhealthy amount of time stationary. If the electromyography has not read anything after a long period of time then it could alert the user to get up and stretch. This would activate the users muscle groups and keep them from suffering of muscle atrophy.

More so, this procedure would show if the user is relying on their back muscle to sit up straight which is ideally what we want them to do. It would also show how much time was spent by the user to correct their posture. Since the electromyography would notice muscle activity every time they made an adjustment. If the chair is used long term, this procedure could help the user see how sitting down has affected their muscles and check on any nerve damage caused by prolonged periods of inactivity.

Lastly, this procedure could help evaluate muscle fatigue and identify which muscle groups are the users weakest. If it analyzes that theyre back muscles are the weakest muscle group, then the user could try to improve their back muscles by exercising or weight lifting. Afterwards, they could track their progress and check if their posture and muscle activity are improving accordingly. Realistically, it would be too difficult to incorporate an electromyography reading into our product. It would add another level of complexity and the benefits from the reading would not outweigh the time spent on incorporating this feature. On top of that, it would also require the user to place the probes directly on their skin which means either putting it under their shirt or sitting down shirtless; both of which are not ideal situations.

Electrocardiography (ECG)

On the other hand, an electrocardiography would be extremely beneficial for our project. Proof of that is the fact that one of the researched solutions used this procedure in order to read the heart activity of the user. An electrocardiography is a test that checks for any heart problems by analyzing the electrical activity of the subjects heart. It can read the amount of heart beats per minute and assure that it isnt beating too fast or slow. This can be useful for our product because if the user is having palpitations then they know they must change what theyre currently doing or alert someone. As discussed earlier, a majority of people who spend large periods of their time inactive typically suffer from heart problems so it would be wise to add this procedure to check up on their heart rate.

Lastly, electrocardiography could add another dimension to our project. Not only could it monitor the users heart rate but it could also notify the user when they are not getting enough blood and oxygen flowing to their heart. This would alert them to the side effects of poor posture and force them to stay more conscious of their posture while seated. Once again, even though this procedure would be beneficial to our project, it might add too much complexity to it. The Darma has an electrocardiography added into its seat matt but we feel that it is unnecessary in the long run. If our device accurately keeps track of the users posture and keeps them accountable, then it wont need to worry about its user suffering from a heart attack.

3.3.8 Wireless Communication and Wireless Networks

Wireless communication is form communication that a device uses to transmit and/or receive data without the need to physically be bound by a wire. This connection could come in the form of device to device, device to server, and more. There are a few ways for this form of communication to occur, but there are three that are most commonly by people today. Near Field Communication, Bluetooth, and WiFi.

Near Field Communication (NFC)

Near Field Communication or NFC for short is one of the forms of wireless communication that was looked into. This form of communication would require the user to have to pull out a smartphone that has this feature and get close enough to the that is connected to the microcontroller in order to transmit the data that the application needs. As one would image this is the shortest range of doing so and also the most inconvenient way to transmit the data. This communication has three different modes that transmits data.

- NFC card emulation
- NFC reader/writer
- NFC peer-to-peer

For the purpose of an application obtaining data from a microcontroller the NFC peer-to-peer would be best suited for achieve this goal. Card emulation is the device acts like a smart card in order for the user to make transactions and the reader/writer would read the information stored in NFC tags embedded in labels or smart posters. But the peer-to-peer lets two devices to communicate and exchange information in an ad hoc style. This would be the only way for the Posture Perfects application to interact with the microcontroller.

NFCs range is must be within a 10 cm or less range in order to transmit data. It would require the microcontrollers NFC module to constantly emit a radio frequency just for the user to obtain the data they require. Although the current consumption would be low, over time for a feature that could possibly not be used for a long time would be very inefficient to a low power consuming chair. The frequency that NFC would operate at 13.56 MHz on a unlicensed radio frequency. The data transfer rate would range from 106 kbits/s to 424 kbits/s. The NFC does not guarantee a secured form of communication even though the connection range is under 10 cm. The security of the data is important, the integrity of the data that the perfect posture application would receive could become compromised due to the lack of security.

Bluetooth

Bluetooth is another form of wireless communication that was considered for the transfer of data from the microcontroller to the Posture Perfect application. Bluetooth exchanges data over a greater distances than NFC, but is still consider a short range transmission distances. This form of communication would be more convenient than NFC, the smartphone could remain next to the user while obtaining the data that the user request from the application. Bluetooth uses personal area networks (PAN) to transmit the data. There are two types of bluetooth that widely used today .

- Low Energy (LE)
- Basic Rate/Enhanced Data Rate (BR/EDR) Bluetooth Basic Rate/Enhanced Data Rate is known for its faster data transfer.

The two types are similar in a few ways. The frequencies that they operate are between 2408 and 2480 MHz or 2400 and 2483.5 MHz this is over a unlicensed but not unregulated short-range band. The range that these signals would reach could range from 0.5 meters to 100 meters depending on the class of that it is under. The ranges varies due propagation conditions, material coverage, production sample variations, antenna configurations, and battery conditions. This would also lead to the power consumption varying as well. Class ones range is 100 meters with a power consumption of 100 milliwatts. Class twos range is 10 meters with a power consumption of 2.5 milliwatts. Class threes range is 1 meter with a power consumption of 1 milliwatt. Class fours range is 0.5 meters with a power consumption of 0.5 milliwatts. The most reasonable class of bluetooth that would be implemented in Posture Perfects microcontroller is class two. The user would confined to the area of their home, so 10 meters would be sufficient. Also most smartphones today use class two. Security like all forms of communication is also a concern although it is not as bad NFC not having a secure connection there are still problems. Bluetooth implements confidentiality, authentication and key derivation with custom algorithms based on the SAFER+ block cipher. This is normally based on a Bluetooth PIN that both devices must have in order to connect with each other. For the purposes of the microcontroller transmitting data to the user application this protection is sufficient.

WiFi

WiFi technology allows a device to connect to a wireless local area network (WLAN). WiFi is based on the IEEE 802.11 standards which is a set of media access control (MAC) and physical layer (PHY) specifications for implementing computer communication. Out of the three wireless communication that was talked about WiFi is the most widely used. WiFi is integrated into vast amount of devices for example video games, televisions, digital camera, etc. This form of communication would be implemented in a different way than both Bluetooth and NFC in are Posture Perfect project. It would allow the user application to access the data without even having to be near the chairs microcontroller. This would most likely involve the use of a cloud server. But by implementing WiFi the microcontroller would connect to a online server to store the information. Then the user application would access this information by connecting to the same server. Using this form of communication would optimize the convenience of using the application. Also this most likely produce the best results for power consumption because the microcontroller would only use WiFi when the controller is active. After sending the information to the cloud service the controller would go into a idle mode.

WiFi connected to internet uses 2.4 GHz ultra high frequency and 5 GHz of super high frequency. Due to the frequency that the standard 802.11b and 802.11g use interference from microwave ovens, wireless telephone, and Bluetooth devices could be a problem. But a simple change in channels that do not overlap could solve this potential problem. The standard 802.11a uses the 5 GHz radio band, but the 802.11b or g standard would be the more likely standard that would be used. Using 802.11b or g the range with a stock antenna of an access point reach is around 30 meters indoors. This range would not be any problem for the microcontroller, and the user application would be able to access the data from any WiFi hotspots. The rate that the data could transmit would be another concern. Although the data rate from a WiFi access point would greater than Bluetooth it is still susceptible to interference and bad connections which would decrease the data rate. The average data rate for WiFi is around 600 Mbps. Security for WiFi is the most security but also the most susceptible to a hackers. WiFi uses WEP and a more secure WPA2 to protect the user although not unhackable it is better than Bluetooth and NFC.

Table 3.3: Wireless Communication Compariosn

Aspect	NFC	Bluetooth LE	WiFi
Tag Requires Power	No	Yes	N/A
Network Standard	ISO 13157	IEEE 802.15.1	IEEE 802.11
Network Type	Point-to-Point	WPAN	WLAN
Security	Distance	PIN	WEP/WPA2
Range	¡20cm	10 meters	30 meters
Frequency	13.6 MHz	2.4 - 2.5 GHz	2.4 or 5 GHz
Bit Rate	424 kbps	1 Mbps	600 Mbps
Bandwidth	Low (200 Kbps)	Low (800 Kbps)	High (11 Mbps)
Current Consumption	15 mA (read)	15 mA (Read and Transmit)	20 mA
Ease of Use	Simplest to use with short range	Fairly simple, you can have multiple devices and easy to manage	Difficult, it requires configuration of software and hardware

3.3.9 Operating System Compatibility

In order for Posture Perfect to be of any use to a user it must have a way to interact with them. This is where a process or a mobile application comes into play. The sensors would obtain the raw data, then the microcontroller would process the raw data, and last it must be sent to a final stage where the user can make senses of the results. There are many operating systems that a program or application could be written for window, mac, linux, windows phone, android, ios.

Microsoft Windows OS

Windows operating system was developed by Microsoft Corporation for personal computers. This operating systems was the first to use a graphical user interface for IBM PCs. Windows is became the most used operating system round the world with around 90 percent of PCs using this OS. Windows was first released back in 1985 it was a GUI extension for MS-DOS. Window let DOS users navigate a virtual desktop, open windows that had folders and files with a mouse rather than using a command window. With future upgrades greater functionality integrated like Windows File Manager, Program Manager, Print Manager programs, and more dynamic interface. In 1990 with the release of Windows 3.0 its popularity grew because Windows software development kit this gave programmer more time to focus on program development over writing a device driver. Around 1992 Windows 3.1 was released with its improved icons, graphics with 16 colors, and better performance. At this time Microsoft Windows OS was had sold its most copies up to this point by selling 10 million copies. In 1995 Windows became even more popular with the release of Windows 95 because this was the era of the internet, email, fax, etc and way this operating system was upgraded gave the user more of an easy interface. They added a start menu, taskbar, the option to minimize, maximize, or close a window. Also this version of the operating system came with the first internet explorer giving people access to the world wide web. When the release of Windows 98 came around this was the first time that this operating system was targeted to the consumers. This version let the uses find information more easily on the computer and the internet. Windows 2000 Professional was designed to replace all the previous Windows operating systems with its greater upgrades.The upgrades added support for Plug and Play hardware, USB devices, IEEE 1394 devices, and infrared devices. Windows became more and more popular with the average consumer with the release XP and 7 with some setbacks from Windows Vista and 8. But the operating system still dominate the home and office computer industry.

This operating system could be great way to interact with the user for Posture Perfect. It is a operating system that almost every person that has computer experience has come access operating at one point or another. It is big for the vast amount of third party software that was developed for it and the easy to use interface. This would be very good to create a program for the user to obtain and evaluate their results. Since it is easier to use compared to the other PCs it the user would not have too much trouble accessing the application. This would make using this operating system in one aspect convenient. Although it would require the user to have access to a computer with an internet connection and the program installed on that computer, so looking at that aspect of convenience Windows would not be ideal. Another problem that a Windows application would encounter is security. Due to what makes Windows a programmer friendly operating system is also its biggest problem. The application would be vulnerable to all types of hackers which could lead to the information that is passed to the application to be invalid.

Mac OS

Mac OS is another operating system that is popular around the world. This is the competition of Microsofts Windows operating system and many people are familiar with the functionality of this OS. Mac OS is graphical user interface operating system that was developed by Apple Inc. for their Macintosh style of computers. But Apples Mac operating system was has two architectures that was implemented. The Mac OS major revision 9 from 1984 to 2000 used the classic Mac OS. Revision 10 that took place from 2001 to present time used an architecture called OS X. This could pose a potential problem user still uses this old with the Posture Perfect application if the user prefers to us the older architecture to run the application on. The operating system makes use of unique features that other operating system may not implement as good. Some of these features are mouse gestures and graphic controls, but if the user is not a native user of this operating system would have a difficult time taking advantage of this feature. This is another reason why making the application for this OS would not be the best choice. If we were to implement these features for the non native user would not have a friendly user interface. This operating system has one of the best security for their users. The way that this OS was designed did not let any third party software get installed on to it, this limits the possibility that any unwanted software could be installed on a mac computer. So the possibility that a hacker could intercept the data to alter it is slim to none. This fact that makes Mac operating system a good also provides a problem for creating an application of this OS. The tools to create it would most likely be difficult to use. So Mac OS is not really the most ideal operating system to create the Posture Perfect app.

Android

Android is a operation system that is based on the Linux kernel and is designed for touchscreen mobile devices. It was developed by Google with a user interface that revolved around using touch gestures to manipulate the screen. The Android operating system is not only limited to smartphones and tablets it is also expanded to cars, wristwatches, and even televisions. Android has the largest installed base of any operating system and is also the best selling OS for tablets and smartphones. This fact is a good indicator as to why we should make the application for android if it is the largest installed operating system and it is beating iOS out in sales than the odds that someone that is using the user application would know how to operate this OS is high. Also the gesture feature could be integrated into how the application is functions. Surveys on the operating system found that 71

iOS

This operating system, formal known as iPhone OS, was developed by Apple Inc. This is Apples mobile phone operating systems. It is the second most popular operating system after Android. The operating systems user interface is based on direct manipulation which is user multi-touch gestures. The interface the OS are gestures like swipe, tap, pinch, and reverse pinch. This is a good way for the user to manipulate the application on this operating system. It is simple and could be easy to integrate into the Posture Perfect app. The interface control elements are sliders, switches and buttons this would be a good way to terminate the application in an event that the application were to crash. The use of the accelerometers which allows the user to undo a command would be a good feature to integrate into the app. iOS shares with OS X framework like Core Foundation and Foundation Kit, unfortunately the user interface toolkit is not the same. This would not allow the Posture Perfect app to cross platforms. A feature that would have been useful if the user wanted to use their Macbook. A very useful feature that iOS has is Siri. This is a personal assistant that is controlled by voice commands. It would be a valuable feature to integrate into the app if we can support it. The user would not even have to pick up their phone to get their results. They would ask Siri and she would tell the user their values they want. This is conveniences that we want the user to experience when using the Posture Perfect app. The Language that application are natively created with for this OS is Swift and Objective-C. This limitation is not very convenient for the creation of the app. It would forced us to only have two options to create the app. The security of this OS is very reliable due to the Apple making app developers to tie their information to their app. The only clear for a user to experience problems with malware or viruses is if the user moves the operations system outside the protection of Apple. So knowing this almost promises us that are date is safe from a third party altering it or observing it.

3.4 Component Specifications

To meet the minimum requirements of the project out components need to be mapped out, and their selection must be able to keep within our scope and budget. To ensure component interoperability these specifications need to be compatible with each other, no conflicts of specifications that would cause the device to not be able to meet the project's requirements.

3.4.1 Communication Specifications

The three specifications that we would would like the different means of communication to follow are a good transmission speed, low power consumption, and convenience. There were two ways we wanted to implement how the data was going to be passed to the user application. First way is a two step process where the chair sensors raw data is sent to the side module and the side module values sent to the user application. The two steps call for two different forms of communication. The frequency must not overlap with each other and with the frequency of other devices that are around the chair, side module, and the smart phone. Data must be transmitted as fast as possible as well. The second implementation would cut out the side module and integrate cloud service. Where the raw data from the sensors are collected calculated and sent to the cloud service. From there the data would be accessible for the application in the cloud service. This implementation would only need one type of wireless communication.

Side Module Implementation

The wireless communication that would be chosen is bluetooth. Out of the various different forms of wireless communication we narrowed it down to two choices wifi and bluetooth. Bluetooth was the ideal form of communication when it involved the data that is obtained from the sensors being passed to the side module. Power usage, and convenience were all consider when choosing bluetooth over wifi for transferring the data to the side module.

When it came to power usage for are low power consuming chair bluetooth has the edge over wifi. The transmission of the data is always going to be very short range, so not a lot of power is required. Which is why bluetooth was picked over wifi from the power consumption perceptive. The convenience of have having the bluetooth over wifi is cutting out an unnecessary middle man. With wifi the data would have been pass to a router, then pass to the side module. This would not only be more difficult to implement, but also slower to perform compared to bluetooth. The chair is never going to be far from the side module. So it should directly be connected to the side module. The different types of bluetooths that was compared were Bluetooth Basic Rate/Enhanced Data Rate (2.0/2.1) and Bluetooth with low energy which is the newer standard (4.0/4.1/4.2). The best fit for transfer of data is the Bluetooth LE. With Bluetooth LE we get even lower power consumption and short burst of long-range radio connection. If we were constantly going to transfer data then Bluetooth BR/EDR would of been the better choice because it is made for continuous wireless connection. The chair's sensors are suppose to get points and seed to the side module but, the transfer the data points are only going to be transmits in intervals. Depending on the setting that the user chooses the intervals can vary but, it will never be a constant stream of data. Bluetooth LE would have a transmission/receiving data frequency of 2.4 GHz for the data points. The amount of channels the bluetooth module would have are not as much but the bandwidth would a lot broader compared to the Bluetooth BR/EDR. The way the two microcontrollers would implement bluetooth is by using USB port. When the raw data is gathered it is passed on to the bluetooth module, then the bluetooth module transmit the data to the microcontroller.

The form of wireless communication that was used for the side module to user application would be wifi. Wifi was chosen for this part of communication for one major reason convenience. The user application would receive the results after the side module calculates them. This application would be used on a smartphone or computer, so the user must be able to move around the house and still view their results.

Table 3.4: Bluetooth Parameters

Categories	Estimated Parameters
Frequncy	2.4 GHz
Power Consumption	1 mW
Distance	10 meters

Which is why wifi was pick over bluetooth for this connection. We consider Near Field Communication for the transmission on the results to the smartphone but, not every smartphone that is out on the market has this feature available to use. Also those who do would have to constantly bring their smartphone to the transmitting end of the near field communication module by the side module just to obtain their results this completely throws out convenience. Bluetooth was also considered, but the range would have been the problem in this case. So the best choice was wifi when comparing the three. The different types of wifi radios that we took into consideration 802.11b, 802.11g, and 802.11n. All of these have their pros and cons, but the wifi module that was mostly be chosen is compatible with all three radios. The frequency that the wifi module would use is 2.4GHz this is a standard for most wireless communication because it is what the public standard that anybody can use. So both the bluetooth and the wifi modules would have the same frequency but they would have a different channel to avoid interference.

Table 3.5: WiFi Parameters

Categories	Estimated Parameters
Frequncy	2.4 GHz
Power Consumption	Idle 12 micro A Active Varies
Distance	30 meters

The Cloud Service Implementation

The only way to implement this design is one of two ways wired connection or wifi connection. Both of these allows internet connection, but wifi would be inferior to a wired connection in the area of upload and download speed and also in reliability. Which is why wired connection was considered, but wifi would be the more ideal form of communication between the microcontroller and the cloud server that we use. The reason behind it is convenience for the user. Wired connection would fulfill two out of the three specifications low power consumption and transfer speed, but convenience takes the most priority out of the three specifications. Having a wired connection plugged in the into a chair when the user wants to use it would not only limit the users mobility but also the location that the chair could be set up at. This would make the other two specifications in the eyes of the user seem like nothing. So although wired connection has wifi beat out when it comes to power consumption and reliability it is not convenient at all. Wifi would cover all three specification the best. The parameters of wifi would also be the same as it we implemented the side module.

3.5 Power Specifications

3.5.1 Power Solution

Many different power solutions were taken into account to power the chairs onboard electronic components. One idea was to have all the sensors, microcontrollers, computers, and wireless communication attached to the bottom of the chair that would all draw power from a wire connected to a wall outlet. This can be seen as a major inconvenience to the user since a wire tethered to a rollable desk chair would cause tangling between the wheels and the wire. Thus, we opted in going for a battery solution.

Having a battery power the chairs electronics would allow the chair to be mobile and untethered to a power source. The next decision would be to decide if the battery would be rechargeable or nonrechargeable. Having a non-rechargeable solution would be cheaper to implement and last longer on a single charge. Though, given that our system is not a low-drain device, the obvious choice would be to go with the rechargeable solution. This allows for continuous use with the same battery which is cheaper in the long term rather than repeatedly buying disposable batteries.

3.5.2 Rechargeable Battery Requirements

The original requirements for the battery have changed to some extent because of the debate on whether to use the cloud or implement a side desk module. The desk module will perform the majority of the computations and also act as the server that will connect with the application that the user will utilize to observe their statistics and information. The desk module will act as a companion to the chair and will be powered by being connected to the wall outlet. Another role that the desk module have is being the charge station for the rechargeable battery.

There are two reasons why we considered implementing a charging station desk module. The first reason was to minimize the power draw on the battery by taking the heavy computations away from the chair and having it powered separately. The second reason was to eliminate any wires leading to the chair to connect to it in any shape or form. This can be done by making the rechargeable battery swappable.

In order to have the battery swappable, a requirement would be to have pinouts or terminals on the battery itself. Many rechargeable batteries or battery packs have leads coming straight out of the battery in order to be soldered where they need to go for permanent placement or to connect wires to it. But for our purposes, the battery cannot be mounted permanently and has to be easily swappable. For that reason, it is a requirement for the battery of have terminals or pinouts. For example, when putting in the rechargeable battery in a cell phone, the battery terminals come into contact with the pins in the phone to complete the connection. No wires needed. Of course this would mean we would need the correct mounting configuration to put the battery in the chair and in the charging station. Furthermore, including a second battery would mean one battery always remains charged in the charging station and the other battery discharges in the chair. Continuous operation can be achieved by never having to wait on a dead battery to charge.

Another requirement for the battery would be its size. Having a battery thats physically too large would make the charging station take up too much space and not be convenient to have on a desk anymore. It would also be too heavy to put on the chair. Finding the right size so that it could be easily swappable and fit into the battery compartment for the charging station and in the chair. The most obvious battery requirement to have would be the battery life. As there are four different monitoring modes each with different data gathering frequencies, the normal monitoring mode is the one that will be used to judge the battery life. The battery life requirement is to have the battery last roughly a week under normal monitoring mode and average sitting time.

3.5.3 Battery Types

There are many different rechargeable batteries that can meet the battery requirements. The three battery types that will be examined in greater detail all have high energy densities and dont house any toxic metals.

Nickle-metal Hydride (NiMH)

The Nickel-Metal Hydride battery has been around since the 1970s. It can be seen as the successor to the Nickel Cadmium (NiCd) battery since it can have a 2 to 3 times higher capacity and is environmentally friendly unlike the Nickel Cadmium battery. Compared to other battery types, Nickel-Metal Hydride batteries are better for high current drain applications. This is due to their lower internal resistance which allows them to perform better than other battery types without loss of capacity for heavy workloads. NiMH batteries have even been used in all electric vehicles and hybrids such as the Toyata Prius or Honda Insight.

This battery type usually takes the form of cylindrically shaped batteries. They come in all the standardized sizes ranging from AAA to D sized cylindrical batteries that are rated 1.5 volts each. They also come in the standard 9-volt battery size with its signature rectangular shape. With these standardize sizes, many different charging solutions already exist for these batteries that can be easily implemented in our design.

The problem with these nickel-based technologies is that the batteries have something known as battery memory. Battery memory causes the battery to hold less charge than its initial capacity. This is because if the battery is constantly recharged with only being partially discharged, it remembers its smaller capacity it has been using and only uses that percentage of its total capacity. Though this problem is less prominent in NiMH batteries and is a more serious problem in NiCd batteries.

Another problem that arises from this technology is over-discharge. This happens when the battery is completely discharged and one or more of the cells reverses polarity. The good cells in the battery then have to work against the reserved cells which causes damage. Though this problem can easily be avoided by connecting the cells in parallel or by making sure the battery isnt completely discharged. In our design, we are going to have a battery indicator that will warn the user when the battery is running low so that the user will swap batteries with the one thats fully charged in the charge station.

The only safety mechanism that this battery type uses it a resettable fuse that is in series with the cell. This fuse prevents too much current to flow through the battery and also opens when the temperature gets too high.

Lithium-ion (Li-ion)

The lithium-ion batteries first became commercially available in the early 1990s and is now the most popular and widely used battery technology in the world. Lithium-ion batteries have a higher energy density than NiMH batteries. They are also lighter which lets them have superior energy to weight ratio due to the fact that lithium is a lighter metal than nickel. With Li-ion, the battery consists of only one cell because of the high cell voltage. Therefore, the over-discharging problem with the nickel batteries is nonexistent with li-ion batteries. There is also no memory problem which makes li-ion batteries low maintenance with no scheduled cycling to prolong the batterys life.

Compared to NiMH, Li-ion batteries are more costly to manufacture. However, the price of these batteries has gone down considerably over the years due to popularity and advancements in the technology. To meet the requirements and still be an affordable solution, lithium-ion batteries made for phones is an ideal choice. They come in compact sizes but still offer plenty of milliamp hours and can be easily swappable because of the built-in battery terminals. On the plus side, phone batteries can be found for cheap online.

This battery type does have a couple problems though. One problem is that it is fragile. It requires a protection circuit built into the battery, usually next to the terminals, that limits the peak voltage during charging and prevents the voltage from dropping too low when discharging. Furthermore, it limits the maximum charging and discharging current as well as monitors temperature to make sure it never gets too hot.

Lithium-ion Polymer

Lithium-Ion Polymer batteries are very similar to Li-ion batteries in terms of pricing and energy densities. The major difference between the two is that Li-ion polymer allows for unique form factors. As a result of how the batteries are made, they can be as thin as a credit card and flexible unlike the rigid structure of Li-ion batteries.

The only problem is that they are harder to come by. Li-ion Polymer batteries are built for the application they are going to be used for such as smartwatches where the flexibility becomes a real advantage over Li-ion.

3.5.4 Charging System

As with any battery operated system the charge of the batteries does not last forever and thus needs to be recharged to continue operation. The battery embedded in the chair will need to be charged on a regular basis for the device to operate normally. There are a few solutions that are regularly used to charge batteries in our daily lives, but for the power and safety requirements of the project there is no clear solution to the charging problem. For the purposes of selecting a solution that comes at a reasonable cost of time and money several charging solution have been selected for the purpose of discussion in finding one that conflicts with the fewest requirements of the project. The methods discussed for this project include conductive wired charging, near field inductive coupling, near field capacitive coupling, radiative lasers, and old fashioned swappable batteries.

The classic charging methods involve using a conductive connection method in which power in the form of voltage and amperage is fed into the storage device. The efficiency of this method is why it is widely used by in todays technology, however that does not mean it is without loss of power, in fact the best case for wire charging a battery from an AC source is only around 65.4

Near field inductive charging is probably the most well known form of wireless charging at this time, it is seen in everything from smart devices like smartphones and smartwatches to simple electric toothbrushes. The efficiency of this method is directly based on the distance between the transmitter and receiver. In the best case scenario for wireless charging about 51.6

A similar technology to the inductive coupling technology of the paragraph above is capacitive coupling. While the intermediary devices and medium are similar in

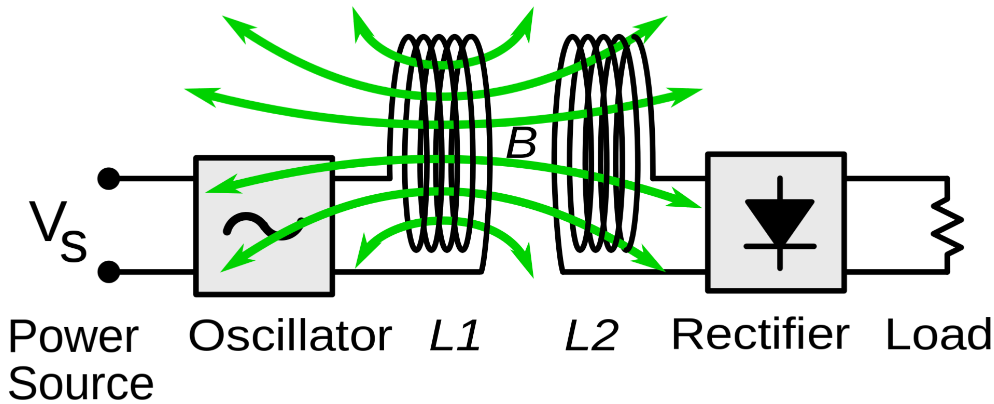


Figure 3.10: Inductive Power Transfer Principle (Labeled for non commercial reuse)

nature the capacitive inductance can be used with less possibility of interference from outside magnetic sources and relies more on high potential voltage than current to achieve the same results as the inductive charging. This method holds all the same advantage as the wireless inductive charging, but due to the rapid dropoff of air as a dielectric of the capacitors it is affected by distance more so than the inductive charger.

A fantasy that only sci-fi novelist would think up, transferring power with lasers. It is not as far fetched as it may seem, in fact a prototype aircraft developed by NASA proved that it could keep an aircraft aloft with regular recharging of the systems using directed lasers from a ground unit, and a set of photovoltaics on the aircraft. This technology still has a long way to come, with lasers having electrical efficiency below 60

The complexity and hazards of all the previous charging methods are a tradeoff for not having the user interact with the charging system. It is not the ideal solution but its simplicity, ease of implementation, supportability, and safety make for strong arguments for a swappable battery pack. There is no strong electromagnetic field to worry about, no lasers that can burn your retina, and if properly placed, no cord in a position to receive or cause damage. The longevity of a battery pack must still be able to support the device, but if a battery pack has become damaged or is losing its ability to hold a charge, applying its replacement is simple. The major drawbacks of the system include the user's necessity in changing battery packs out on a regular basis, and the system can only be supplied with power from the pack while in operation, this means when the battery needs to be charged the chair will not operate, and while the battery is charging unless there are multiple batteries, which implies you have to buy at least two batteries, a costly solution.

3.6 Application Specifications

The application would designed to interact with the user. After obtain the results the application would then recommend different ways of helping the user improve their posture and also health tips for example stretches and times when the user needs to get up and take a break. The application would be capable of obtaining the user's result at any given time regardless if the user is in the same location as the side module. The application would be written in programming language java to make a friendly interface.

Table 3.6: Classes for Application

The Name of Each Class	**Intended Function**
Interface	Support the User Interface
Results	Hold and Display the Results
GetUp	Timer to tell users when to get up and move around
Exercise	Instructs the user on a proper exercise to perform.

The would be broken up into three sections Results, Exercises, Settings. Each of these sections would be selectable through the user interface. There would also be a timer that would start when user sits in the chair that keeps track of how long the user has been sitting in the chair. That time would then go off as a notification on the user's smart phone reminding them to get up and move around.

The Result tab would bring up the most current results of the condition that the user has had their posture in for an interval of time. This tab would also allow the user to see the past conditions they had their posture. It would also tell the user if they have been improving or making their posture worst over a set interval time for example a week the user has been sitting in the chair.

The Exercises tab would do two features the first would be a recommender and the second would tell the user all the different exercises. The recommender feature would just take the date results from the user's posture and pick to the best suited exercise the user should perform. Then the 2nd feature would just tell the user all the different exercises that the application has available. The exercise that is selected by user would give the user instructions on how to perform the exercise also include a picture of the exercise.

The Setting tab would be there to turn features on or off.

- It would allow the user to turn the notification on or off
- Set the application to synchronize

- Set recommend exercises
- Set the Get Up features

3.7 Platform Specifications

In order for the application to be convenient there are a few specification that must met.

- Processing of the results must be fast
- The data must be easily accessible
- Creating, maintaining, and troubleshooting must be easy

With these specification the usage of the application for both the user and the programmers would allow for the best experience.

3.7.1 Processing Results at Reasonable Speeds

The application is not going to be doing any real heavy calculation the applications job is to take the data and give the user exercise recommendations. So without a doubt the processing of the results is not going to take that long to execute. In order for the application to process the results it must obtain the data from a cloud service after the side module has ran the raw data through the algorithm. This data is then compared with the preset data to indicate the best choice for the recommend exercise.

3.7.2 Accessibility of the data

The accessibility of the data must be quick and easy. The user should be able to start up the application select the past data results and obtain them in no time, no matter the locations of where the user is trying to receive that data. Which is why we turn to the Internet of Things for the application to obtain the data. The Internet of Things as one would know is the integration of physical objects whether it be a house, car, even toaster into network by embedding software, sensors, and network connectivity with lets the object send and receive data. The Internet of things lets the objects be controlled over the network infrastructure with allows more improved efficiency, accuracy and economic benefits. With concept the data would be accessible using a Cloud service to obtain the best results. Also it adds are posture perfect chair to that list of smart objects preparing it for the future. So the cloud service that we chose for the data to be placed will depended on the compatibility of the application and microcontroller. But it has to be able to access the data fast and reliably.

3.7.3 Create and Maintain Application

The application after it is said and done is the face of our Posture Perfect chair. Without it the user would have no way of making use of the information that the microcontroller provides, so the maintenance of the application is high priority. In order for us to take care of the application we must have a reliable application development tool. The ideal development tool would be one that has a simple code editors to full-featured tool families with support to writing code, be able to test code, deployment of code, and ect. With these features if a problem occurs we should be able to pinpoint what went wrong.

Chapter 4

STANDARDS AND CONSTRAINTS

4.1 Standards Relevant to Project

Standards exist to aid in the ease of development and the compatibility of many systems together, to ensure the ease of use and safety of our project. Several standards exist for code and make the code more easily readable for those aware of the standards used in the project. For the mobile app development we will use the java coding standard set by Google, as it should comply closely with the expected code for their operating system, Android. In designing the embedded code for the chair controller and the base station we will, again, use the coding standard set forth by Google, this time for the C++11 language. If we require low level programming we may have to use C or assembly, in which case we will use the NASA coding standard. Hosted by the base station may exist a web page for the user to access this data from their computer, this will require a combination of php, html, and javascript. The php code will follow the Wordpress.org standard, the html will follow Googles standard, and JavaScript will follow the Google JavaScript standard. There exists a standard for chair design to ensure safety of the users, to ensure our project is safe in this respect we will conform to the standards set by the American National Standards Institute and Business and Industrial Furniture Manufacturing Association for office chair safety and requirements. We will utilize several communication standards including WiFi, Bluetooth, and the USB 2.0 standard. For determining the standard for posture and positioning of the spine for minimal impact while in the sitting position we will refer to the NASA paper on neutral body position.

The project will need to communicate to other devices to make use of the data collected by the chair, this can be done by creating an entirely new system of transmitting and receiving bits with a new version of flow control, error correction, and data encoding. If creating a new method is too costly in terms of time and knowledge required there are several standards that can be used in place of creating a new one.

Table 4.1: Code Standards

Standard Name	Language	Description
Google C++ style guide	C++, C++11	The Google style for writing C++ code for easy reading and support of code base.
NASA C style guide	C99	The low level C guide by NASA is one of the only C guides that focuses on data crunching on an embedded processor.
WordPress PHP coding standard	PHP5	The php code will be used for generating websites from a database and controlling login credentials, thus wordpress standard works well.
Google Javascript style guide	Javascript	The Javascript code that will be used for web-app will follow Google standard for the ease of support.
PEP 8	Python	The code generated for the python language will follow this standard.

There are several standards that exits to be utilized for several purposes, they are outlined in the table below.

For the application to reach an acceptable level of usability it need to operate on multiple platforms, to be able to operate on multiple devices the data must be stored on a central repository, and the devices that access this central storage must have a method to interpret that data to be able to display the data in a similar method. To be able to display the data using a common data base and a common aesthetic, knowledge of the operating systems and hosting systems is required, as outlined in the table below there are standards as how different styles of operating systems have their own standard for handling the hardware/software interface where some work better with native built applications, others can utilize web based applications with little concern for platform dependencies. The hosting services that will accept the data from the chair will also have its own method of handling this interaction, there are not any set standards yet, but there is currently an Interface Control Working Group (ICWG) working on standardizing these cloud service interfaces, those documents are referenced in the table below.

As part of our safety we need to not only confirm the interfaces of the sensors meet safety standards, but also that they are safe to sense the organic material that is a person without harming them. There are several standards for sensors we are using, including their interface requirements and their performance requirements.

Table 4.2: Physical Communication Standards

Standard Name	Type	Standard Designation	Description
WiFi	Wireless	IEEE 802.11	The wireless fidelity standard allows for a standard method of communicating with an access point so that our device can connect to the internet easily.
Bluetooth	Wireless	IEEE 802.15.1	Another wireless connectivity method, like WI-Fi, that will be used for data transfer, but this time for direct communication to the user's phone.
Near Field Communication	Wireless	ISO/IEC 14443	The near field technology can be used as something similar to an RFID tag used to identify individual users by the signature of their phones in their pockets.
USB	Wired	IEEE 1667	The universal serial bus technology that is known for high speed data transfer as well as small power transfer is an essential technology compatibility.
BTLE	Wireless	IEEE 802.14.4k	Bluetooth Low Energy is a wireless bluetooth standard that does not require a license to print an antenna making it ideal for hobbyists and students.

Table 4.3: Application Platfrom Standards

Standard Name	**Type**	**Standard Designation**	**Description**
Andriod	OS Standard	IEEE 1003.1	The app developed for this project will run natively on android OS.
iOS	OS Standard	IEEE 1003.1	The app will need to run on iOS devices nately for major market shares.
Windows Phone	OS Standard	IEEE 1003.1	The application will be accessible on Windows Phone through.
Windows OS	OS Standard	IEEE 1680.1	The data will be accessible through a server that will be hosting a version of the app.
Mac	OS Standard	IEEE 1680.1	The data will be accessible through a server that will be hosting a version of the app.
Linux/Debian	OS Standard	IEEE 1680.1	The data will be accessible through a server that will be hosting a version of the app.
Google Cloud	Cloud Standard	ICWG/2302	Remote servers used for processing the data will be hosted by a cloud service.
Amazon Web Services	Cloud Standard	ICWG/2302	Remote servers used for processing the data will be hosted by a cloud service.
Microsoft Azure	Cloud Standard	ICWG/2302	Remote servers used for processing the data will be hosted by a cloud service.

Table 4.4: Application Platfrom Standards

Standard Name	**Type**	**Standard Designation**	**Description**
Infrared	Occupancy	IEEE 2700	To determine the safety and communication standards for infrared sensors so that the design can be simplified.
Piezoelectric pressure	Pressure	IEEE 176	To determine the safety and communication standards for piezoelectric sensors, for the safety of the user, and design constraints.
Piezoresistive pressure	Pressure	IEEE 2700	The limited standard provides a baseline for creating the array of sensors we require.
Ultrasonic	Depth	IEEE C62.41.1	Interfaces and orientation for design and safety concerns of the ultrasonic sensors.

4.2 Constraints Based on Requirements

Due to the nature of this project the requirements must be made specific enough to remove ambiguity that would cause lengthy setbacks, and remain under a very low budget ceiling, but most importantly of all, the device needs to be safe, not just for one time uses, not for once a week, but in fact multiple hours per day that one might be spending in this chair. Constraints help narrow the scope of the requirements in an effort to make the project more manageable, this is essential for development, less we spend endless time researching the latest and greatest technology, only to discover it would cost a small fortune to implement, would become obsolete within a few years, and like all things the general populous dont understand, would be accused as possible source of cancer. The constraints we will focus on primarily revolve around time, accuracy, and health, things like sustainability and cost are considered secondary constraints, and will only be dismissed if it conflicts with a primary constraint.

The most obvious constraint of the project is time, it literally has a due date set by an outside body, of which the overall judgment of the device/project/chair will be at their discretion. As such the project relies heavily on supplies and materials that can be procured in a timely manner, and will require extra safety precautions when handling said materials, as obtaining replacements may be costly to our timetable, affecting the critical path of development. To help alleviate some pressure on material procurement, some pieces may be ordered in batches so that spare parts will be readily available. The development of the software is especially sensitive to time, as some programmers have a way of trying to improve their software to no end, the always in beta, never released kind of development. To limit this there will be definite end conditions set up in the testing portion of this document to help prevent that endless cycle of development.

Measuring the spinal position of a person is no easy task, and when they wear clothing this task becomes even harder, as such there needs to be a balance between functionality and accuracy. The sensors we use will need to be accurate enough to detect when a person is in the correct position, compared to when they are in a poor position, this can be a very small difference in posture and will need to be treated with the proper response, it would be a shame if the user is sitting in the correct position and the chair was adamant about them having poor posture due to inaccuracy.

The main concept behind the project is health, helping people improve the health of their bodies by minimizing impacts of extended sitting sessions. Having someone using the device for long periods of time is a major concern when it comes to selecting components, everything from padding on the seat itself to the base station off to the side need to not increase any stresses on the user beyond a regulars day activity, as this would be counteractive to our original goal. The sensors will need to be tested extensively to prove they are safe enough to use over long periods of time, the electronics will need to be isolated well enough that any malfunction is contained and poses no threat to the user. The app might not seem like a candidate for health concerns, but it communicates all the data collected to help improve the user experience, and if that data is wrong or miscommunicated it could lead to problems with adjustments on the chair.

Sustainability and cost are minor pieces of the constraint puzzle, they only offer vague areas of acceptability and dont have as great an impact as time and health. The project's sustainability will stem from its primary use as a chair, as a chair it can remain functional as long as it still supports a person, but the measurement and data collection side will need to last just as long, as such the components will interface with each other using standardized connectors. With standardized connectors on all the components it becomes easy to sustain operation through the replacement of components as they lose their functionality. The software for this project is easily supportable through a simple update system that will be integrated to the chair, base station, and mobile application.

Chapter 5

DESIGN PHASE

5.1 Hardware Design

The first step in designing the hardware of this project is to decide on which technology to use for each part of the system. Why this technology was chosen will be explained and how it will can implemented in our project. The desired values of the component will be specified and described. Different manufacturers for the electronic components will be explored and compared with each other. Once a part is chosen, it will be explained why it was chosen and how it will be utilized in our design.

5.1.1 Measuring Weight Distribution

The use of pressure sensors is one of the most important aspects of our project. These sensors will be used a great deal when designing an algorithm to determine proper posture. The concentration of the users weight will be mapped by these sensors and give us an idea of the users posture. The pressure sensors can also be used to determine if too much weight is being applied to a specific side of the of seat by the user. This would cause the user to have their spine curved either to the right or left which would result in backache after a prolonged period of time. Pressure sensors located on the backrest can also provide a mapping of the users lumbar region. If this region showed a low amount of pressure, then it can be used to determine that the users lumbar support was not ideal.

In addition, the pressure sensors can be used to determine how long a user has been seated. This can be used to alert the user to get up after a long period of inactivity has been calculated. As was previously stated, the most important attribute of the pressure sensors is to measure the weight distribution of the user. Studies have already shown the correlation between the mapping of an individuals weight distribution to a healthy looking posture. This mapping used alongside distance sensors would give us a great plot of the users calculated posture.

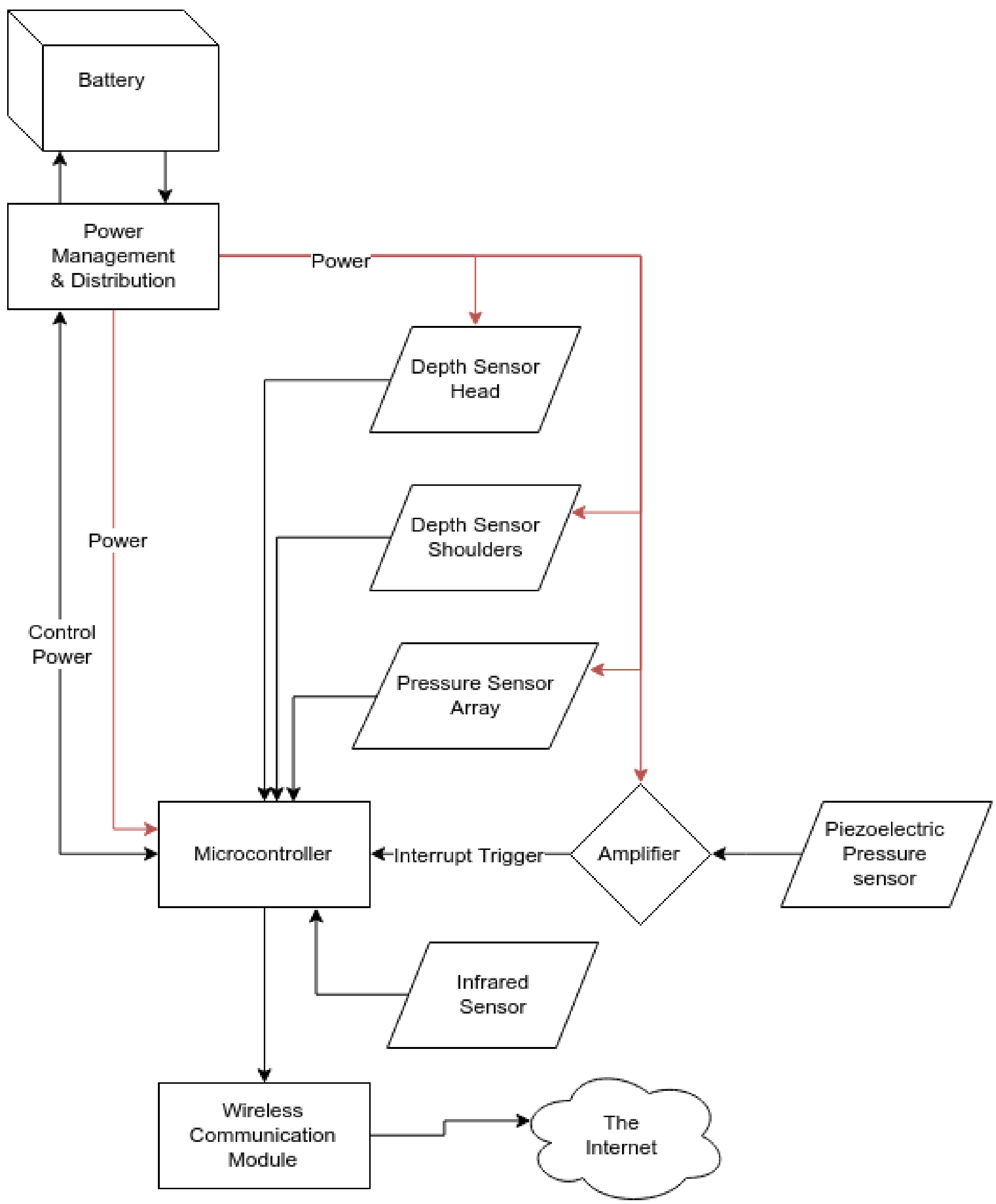


Figure 5.1: Hardware Block Diagram

Table 5.1: Desired Characteristics for the Piezoresistive Force Sensor

Specifications	**Desired Value**
Operating Temerature	30 - 70 °C
Loat Range	At least 50 psi
Actuations	At least 100,000
Voltage Drive	5V or less
Sensing Area	At Least 10 mm diameter
Device Rise Time	Less than 3 micro seconds
Output	Voltage

As discussed earlier, there are several pressure sensors that could be applied to our project. In the end, Piezoresistive force sensors were selected due to the cost effectiveness and high accuracy that they provide. The features mentioned earlier will be used as guidelines to help determine the desired characteristics for the Piezoresistive force sensor. The sought out characteristics in a pressure sensor for this project are described below.

In order to properly analyze and measure weight distribution from the user we must select the right piezoresistive force sensor. Each piezoresistive force sensor has a different force range so we must select a sensor that can hold the appropriate weight for our project. Thankfully, the weight of the user will be distributed throughout the entire seat so we wouldnt need the pressure sensor to measure much more than 5 pounds per square inch. To be on the safe side we will be comparing pressure sensors that are capable of holding up to 20 pounds. The chosen force sensor should have high accuracy and a large sensing area. The surface area of the force sensor must be large in order to properly measure the weight distribution of the user. A small surface area will negatively influence the calculations and give misleading data. There is a large variety of force sensitive resistors to choose from. The requirements discussed earlier were used in order to limit the available options for a Piezoresistive force sensor.

The three Piezoresistive force sensors compared above all fit the desired characteristics mentioned previously. As stated earlier, our design requires a sensor with the highest possible accuracy, and surface area so the the sensor chosen for our final design is FSR Model 406 by Interlink Electronics. This model has the largest width and surface area. It also has the best accuracy and response time. On top of that, it is a very affordable option so we can use it for our prototyping phase as well. The layout of the chosen Piezoresistive force sensors mechanical data is shown in the figure below.

The chosen Piezoresistive force sensor requires the simple voltage divider circuit shown below. The measuring resistor, Rm, determines the force sensitivity for the system. A lower resistance will allow the pressure sensor to be sensitive to weight change. This can be seen in the figure below as well. The output voltage has a larger rate of change which will help when trying to identify and analyze weight change applied by

Table 5.2: Comparison of Pressure Sensors

Manufacturer	**Tekscan**	**Interlink Electronics**	**Interlink Electronics**
Part Number	FlexiForce A401	FRS 406	FRS 402
Voltage Supply	3.3 to 5V	3.3 to 5V	3.3 to 5V
Maximum Current	2.5 mA	1 mA/cm^2 applied force	1 mA/cm^2 applied force
Response Time	<5 micro seconds	<3 micro seconds	<3 micro seconds
Temperature Range	-40 °C to 60 °C	-30 °C to 70 °C	-30 °C to 70 °C
Long Term Drift	<5% log(time)	<5% log(time)	<5% log(time)
Output Type	Voltage	Voltage	Voltage
Repeatability	<2.5%	<2 %	<2 %
Positional Accuracy	<3 %	<2 %	<2 %
Hysteresis	< 4.5% full scale	< 10% full scale	< 10% full scale
Load Range	0-7000 pounds	Up to 150 psi	Up to 150 psi
Actuations	At least 1,000,000	At least 1,000,000	At least 1,000,000
Sensing Area	Circleo of 31.8 mm diameter	Square shape with a side lenth of 39.6 mm	Circle with a diameter of 13 mm
Connector	2-pin male	2-pin female	2-pin female
Price	$19.50	$7.95	$6.95

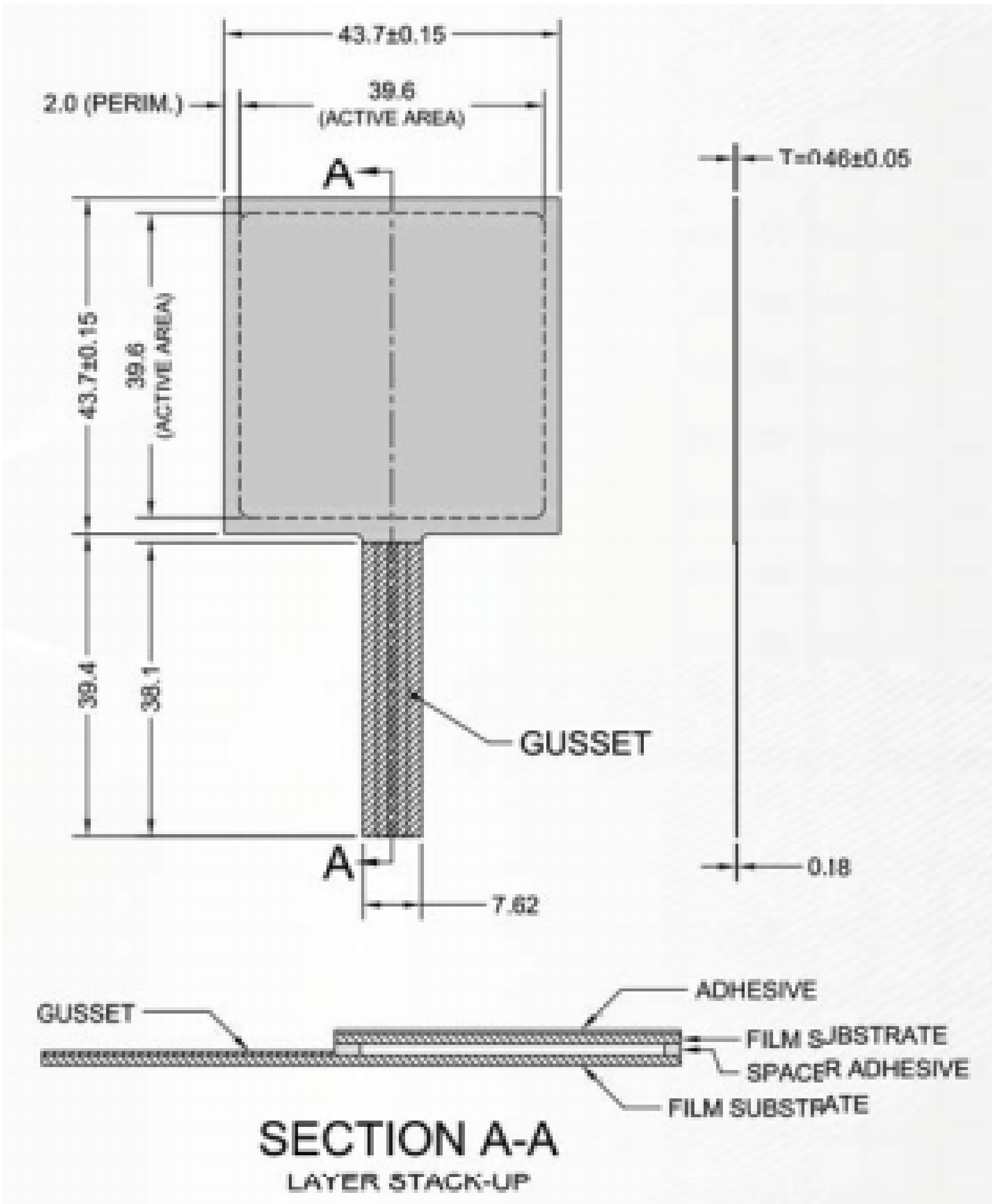


Figure 5.2: FSR Model 406 Mechanical Data (Courtesy of Interlink Electronics)

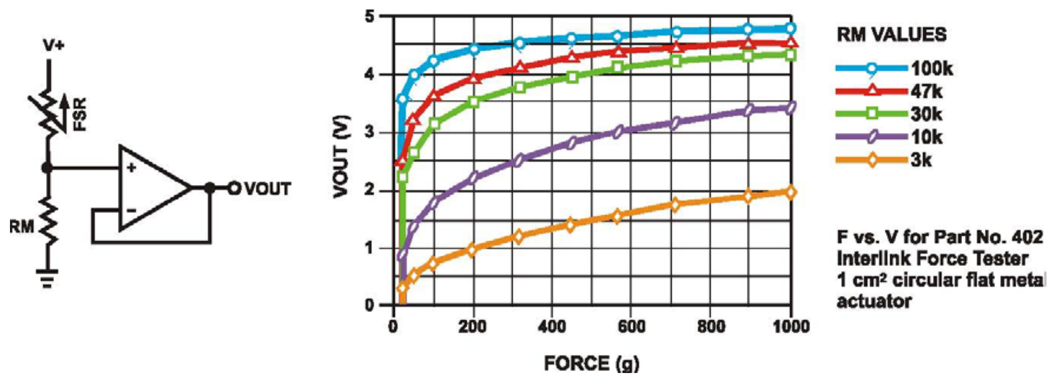


Figure 5.3: Voltage Divider for FSR 406 or 402 (Courtesy of Interlink Electronics)

the user.

The figure below shows how we could incorporate sampling cycle into our design in order to use a discrete signal instead of a continuous signal. In order to do this, the microcontroller switches to a specific FSR channel and toggles it high while toggling all other channels low. Afterwards, the RESET channel is toggled high which then triggers a timer. At the same time a capacitor (C1) is charged. Depending on which FSR is toggled high indicates the rate that the capacitor is charged. When the capacitor hits the threshold of the INPUT channel the timer is stopped RESET is toggled low, and the capacitor is discharged.

The count which is proportional to the FSR resistance is the time it takes in between the RESET toggles high to when the INPUT toggles high. This range that the count falls in is set by a RMIN and RMAX resistor values. RMIN and RMAX can be used to re-calibrate the range that the count fall into. By running a cycle on RMIN the count obtained is set to the new zero and vice versa with the RMAX. The continued counts values of the FSR are changed to reflect the new zero value. The full range is zoned by dividing the max count by the number of desired zones. This would outline the width of each zone. Constant sampling is record to measure the changes due to the change in force.

5.1.2 Vibration Motors

A form of communication must exist between the system and the user in order to properly modify the users activities. That makes alerting the user of poor posture a necessity in our project. As well as reminding them to stand up every so often. The form of communication chosen for this project will be a vibration. As discussed earlier, there are two main types of vibration motors; Linear Resonant Actuators, and Eccentric Rotating Mass motors. We chose the Eccentric Rotating Mass motors because of the cost per unit and simplistic design. Subsequently, we must now decide on which Eccentric Rotating Mass motor we would like for our project. When further analyzing these motors, we found that there are two types; a brushed or brushless

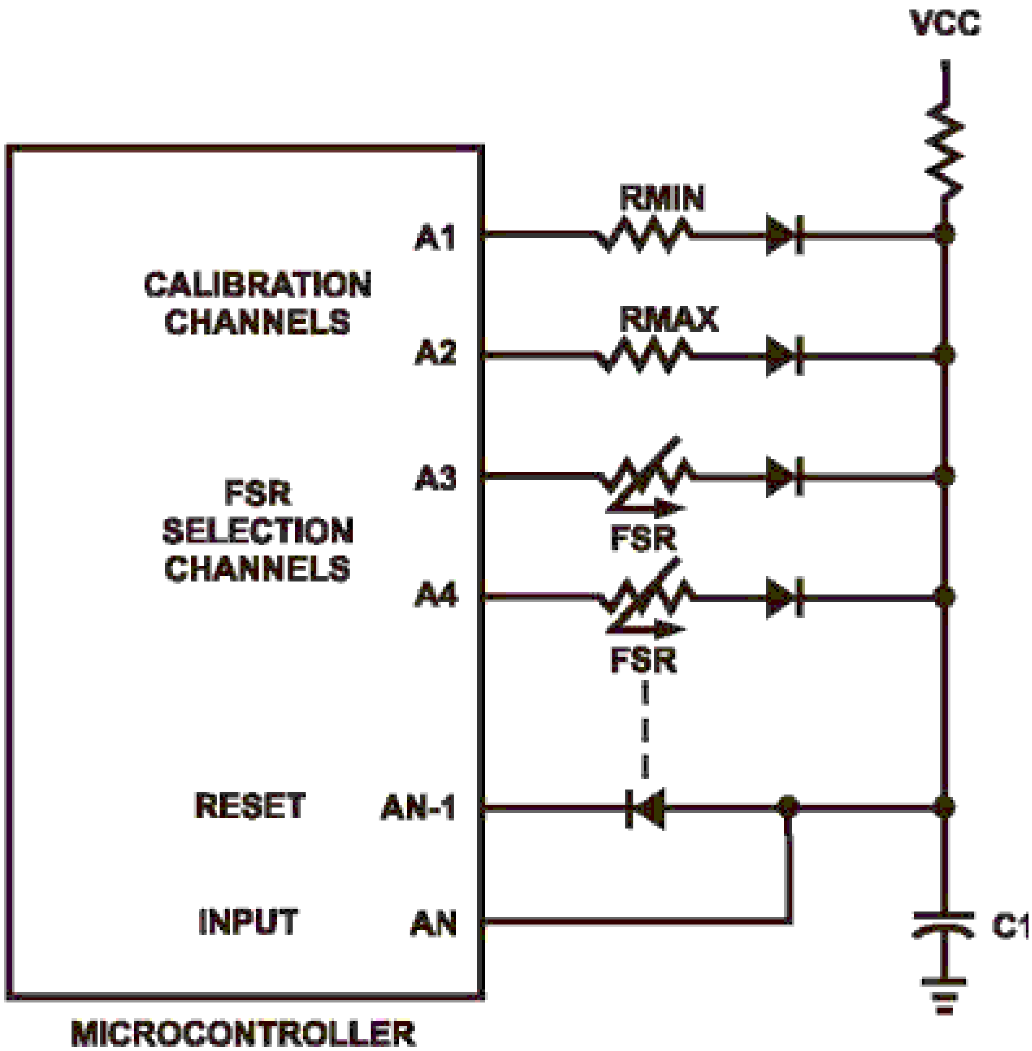


Figure 5.4: Multi-Channel FSR-to-Digital Interface (Courtesy of Interlink Electronics)

motor. There are pros and cons to each of these options, so comparing all their features is important.

The key difference between the brushed and brushless motor is the life expectancy of each one. The brushed has a very limited life expectancy and would not be ideal for our project, whereas the brushless could last over 1000 hours. This significant variance was a determining factor when selecting a vibration motor; largely due to the specifications of the project. A user will be using this chair for several hours in the day and we cannot afford to use cheap motors that will not even last them up to a year. However, due to its cost effectiveness, the use of brushed vibration motors will be used in the designing and prototyping phase. This will lower the budget and help us determine the ideal location and amount of motors. This way we don't overbuy vibration motors, and determine how many are necessary to get the users attention.

To reiterate, the main reason for introducing these vibration motors is to have a form of communication between the user and the system. The chair will be worthless if it cannot convey its readings and measurements to the user. This motor will alert them whenever the user favors a side on the seat, apply more pressure on upper back than on lower back on the backrest, have a concentrated pressure on a large region of the seat, or after a long period of inactivity has been calculated. Many flags will be built into the algorithm to determine any signs of poor posture and the user will receive notification whenever they need to modify their current posture. There will be a system in place so that the user knows what each vibration means. For example, if the user feels the right or left side of their seat vibrating, then it means they are favoring that specific side for far too long. If the seat vibrates for 5 seconds, then its time to get up and moving. There will also be vibration motors on the backrest, so the user knows when they are using their upper back more than their lower back or if their neck is overly inward. The seat will also vibrate twice if combinations of things are wrong with their posture which will notify them to straighten up and improve their current posture. The chair will then analyze their posture for the next minute and check to see if the users new position is ideal. If the algorithm finds something wrong then it will once again vibrate twice and if not then it will not bother the user again.

Now that we have designed the way the vibration motors will be used, we must list the desired characteristics for the Eccentric Rotating Mass motors. The three major factors are vibration speed, load power consumption, and sensing area. The vibration speed must be fast enough so that the vibration is noticeable by the user. The sensing area is almost as important because if the surface area is far too small then the user will not be alerted by the vibration. On the other hand, the load power consumption must be analyzed so that the system designed is as power efficient as possible.

Next, we must select a brushed and brushless vibration motor that fits our design requirements.

The three Eccentric Rotating mass motors compared above all fit the desired characteristics mentioned earlier. As stated earlier, brushless is the ideal choice for our

Table 5.3: Desired Characteristics for Eccentric Rotating Mass Motors

Specifications	**Desired Value**
Operating Temperature	Around -30 to 80 C
Operating Current	At most 75 mA
Operating Voltage	3V
Vibration Speed	At least 12,000 rpm
Load Power Consumption	At most 225 mW
Sensing Area	At least 10 mm in diameter
Communication	Brushed or Brushless

Table 5.4: Comparison of Eccentric Rotating Mass Motors

Manufacturer	**Precision Microdrives**	textbfPercision **Microdrives**	textbfPercision **Microdrives**
Part Number	910-101	310-118	312-108
Operating Voltage	3V		
Maximum Start Voltage	2.5V	2.3V	2V
Rated Operating Current	90 mA		100 mA
Max Start Current	100 mA	130 mA	170 mA
Vibration Speed	12,500 rpm	14,000 rpm	12,500 rpm
Load Power Consumption	195 mW	180 mW	225 mW
Vibration Amplitude	1.4G	1.1G	2.6G
Vibration Efficency	7.2 G/W	6.1 G/W	11.8 G/W
Rise Time	140 msec	96 msec	132 msec
Stop Time	280 msec	128 msec	285 msec
Temerature Range	-30 to 70 °C	-20 to 60°C	-10 to 60°C
Life Expectancy	At least 1,000 hours	100-600 hours	
Sensing Area	Circular with a diameter of 10 mm		circular with a diameter of 12 mm
Motor Construction	Flat Coreless		
Communication	Brushless	multicolumn2—c— Brushed	
Price	$10.37	$5.97	$5.97

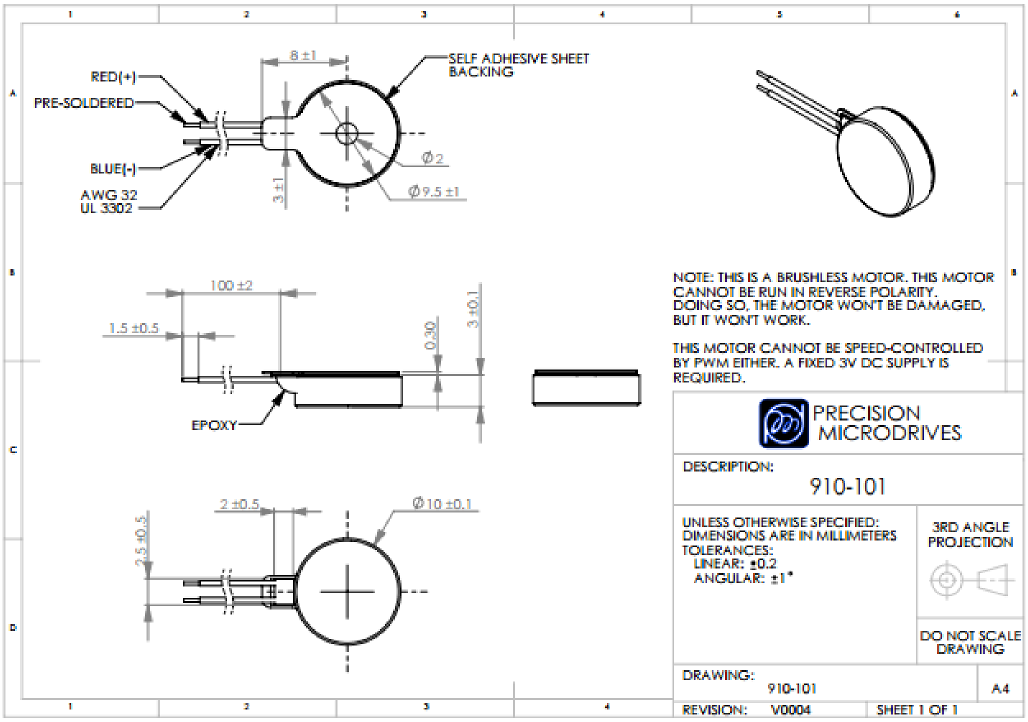


Figure 5.5: Model: 910-101 Dimensional Specification (Courtesy of Precision Microdrives)

final design because of the long life expectancy so the brushless motor chosen for our final design is Model: 910-101. This model has a diameter of 10 mm which was the biggest diameter available by Precision Microdrives. This model also had the strongest vibration speed for a brushless motor so it was the optimal choice for our brushless motor. On the other hand, the best option for our prototype brushed motor is Model: 310-118 because it closest resembles our final design motor. It has the same diameter and close to the same vibration speed. Its operating specifications are also very similar which will help when implementing our final design.

The figure below provides the pin layout which will be used to incorporate it with the microcontroller.

The figure below shows the expected performance of our selected vibration motor. This will help us modify the voltage to get the desired vibration performance for our project.

5.1.3 Sensing the User

To be able to sense the user is an important task for our system. In doing this we can make sure that when the data from the sensors is recorded, the user is sitting in the chair and avoid the recording of incorrect data that can through off the users

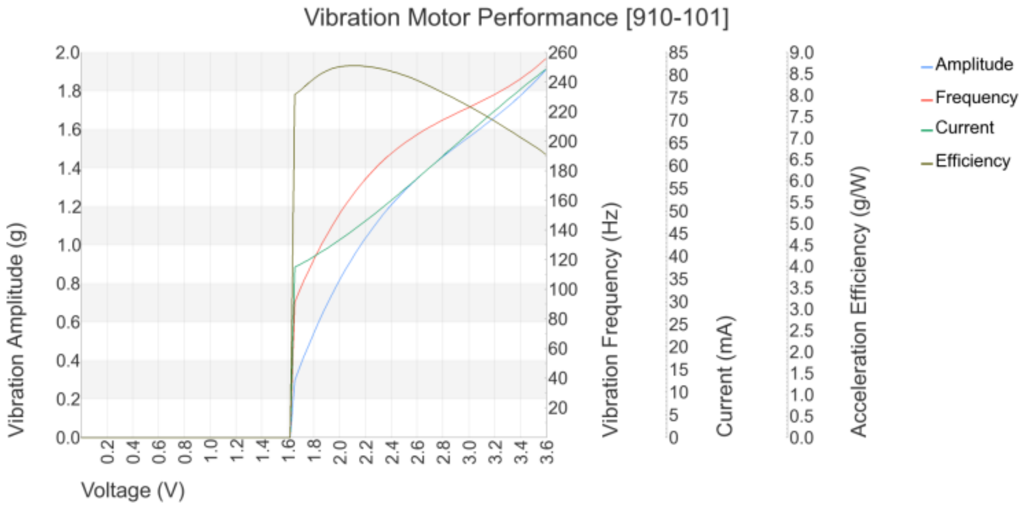


Figure 5.6: Brushless Vibration Motor Performance Characteristics (Courtesy of Precision Microdrives)

posture statistics. This can be achieved with the pressure sensors that are used to measure the distribution of weight of the user. When the user sits down in the chair, the values from the sensors would change and once they pass a certain threshold that we propose, it would be known that a user is sitting in the chair. Though this method is efficient because we reuse the pressure sensors that are already implemented in our design to take on this second role, there is one significant flaw with this method. This method only senses weight and the weight it senses might or might not be the users weight. For example, if a box or any other object was to be placed on the chair that passes the threshold weight, a false positive would occur and the system would think the user is sitting down in the chair. As can be seen, the pressure or force sensors alone will not suffice in accurately determining if the user is sitting in the chair.

In order to sense the user, a special type of sensor will need to be employed to accomplish this. Since human beings are radiating sources of heat, a sensor that measures temperature would be the most efficient and straightforward way of seeing if the user is sitting in the chair. The added benefit of using a thermal sensor is that inanimate objects wont be determined as a false positive. Thermal sensors come in many shapes and forms but for our purposes, we need a contactless sensor that can measure temperature at a distance. With our investigations of the different technologies available, IR or Infrared sensors fit the bill.

IR sensors would be able to accurately measure the temperature without contact in a zone in front the sensors placement. The placement of the IR sensor is important because there are areas on the chair that would have a better line of sight or view point of the user. By placing the IR sensor in the most optimal position, we can minimize the chance of the sensor picking up another heat source in the room resulting in the system recording data when the user is not seated. So far, the most optimal positioning for the IR sensor would presumably be the lower half of the chairs back

Table 5.5: Desired Characteristics for the IR Sensor

Specifications	**Desired Value**
Temperature Range	Include 25-37°C
Accuracy	At least 1°C
Voltage	5V or less
Output Type	Digital

support. This way the sensor is always pointed directly at the user who is sitting in the chair. If the sensor were to be placed higher up along the back rest, there is a chance it could miss the user if the user is leaning to the left or to the right. Having it placed or embedded along the lower half of the back support cushion guarantees the temperature being measured is of the users.

For added assurance, the pressure sensor system could be used to improve the certainty that the user is sitting in the chair. For instance, if the user is standing in front of the chair, the IR sensor will measure the users temperature. This results in the system determining that the user is sitting down in the chair and proceeds to record the posture data. To avoid this dilemma, the system has to first check if the temperature being measured passes the set threshold. If it does then it checks to see if there is weight being applied to the seat. If both turn out to be positive then the system can accurately determine that the user is indeed sitting in the chair.

The reason why our system needs to sense the user or know when the user is sitting down in the chair is to save power since our system will be running on battery power. Yet, how does the system determine that the temperature being measured is of the users? For that, we need to denote a threshold temperature. This would result in a simple computation that checks if the current temperature that the IR sensor is measuring is higher or lower than our threshold temperature. Then depending on that computation, they system would record the data values for all the other sensors and send them over the wireless communications. When selecting our threshold temperature, we would need to use a value close to the average temperature of a human being. We would choose a value a little less than that to account for the difficulties of measure temperature through clothing.

Now that we know we are going to use IR sensors, the next decision to pick a sensor to implement in our project. There are certain specifications and characteristics that the sensor should have that are desired. For example, the sensor needs to at least have the average temperature for a room and the average temperature of the human body in its range. Organized below in Table Blank are the desired characteristic for the IR sensor.

With the desired characteristics in mind, the next step would be to find sensors from different manufactures and compare them so see which sensor would best satisfy our requirements for the project. One specification that was left out of the research for

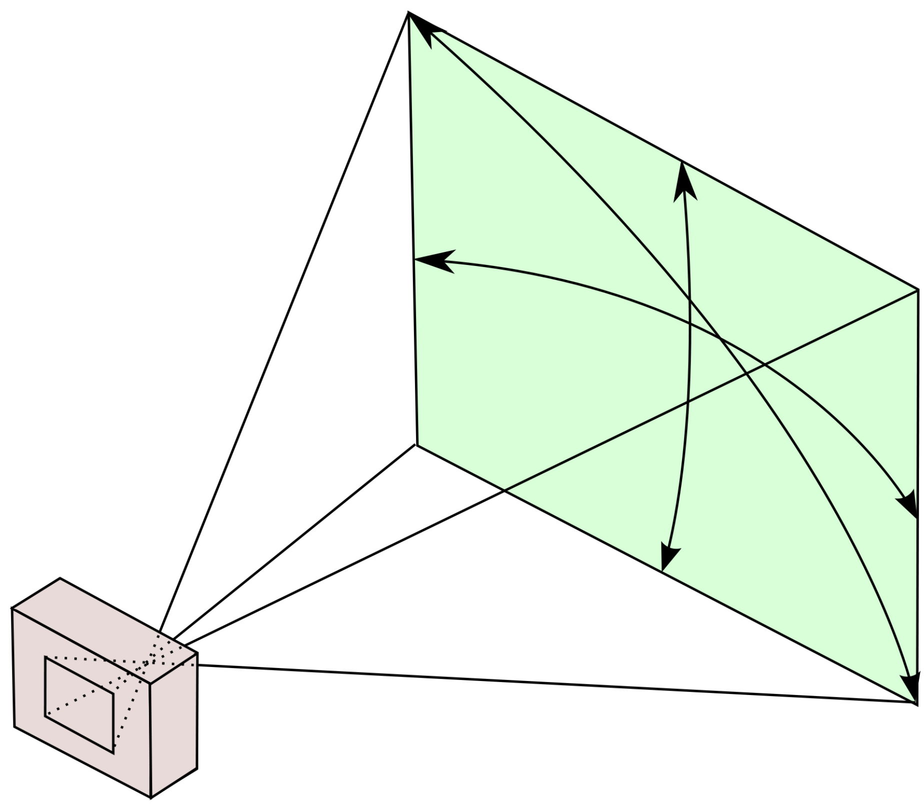


Figure 5.7: Depiction of field of view concept (Labeled free to reuse for non commercial use)

picking a sensor was the FOV or field of view. Figure blank is representation of the field a view portrayed from the sensors point of view.

The field of view of the infra red sensor depicts the area of observation that the sensor measures the temperature. The farther away the object of interest is, the wider the sensors field of view is. This can become a problem if the field of view is too wide. If the field of view is too wide, the sensor may pick up infrared radiation from sources other than the user or object that is placed in the chair. For example, if an object with modest weight is resting on the seat of the chair and a person is standing beside the chair, the sensor may read the infrared radiation coming from the person standing beside the chair and think that the user is currently sitting in the chair. If this happens, the system would record the data from all the other sensors, thus resulting in inaccurate posture data. Though this problem can be solved.

A simple fix to this problem would be to limit the IR sensors field of view. This can be done in a view ways. One way would be to move the subject of interest closer so that it envelopes the whole field of view leaving no room for other objects to be detected by the sensor. Though the users size (width) and distance from the chairs backrest can vary from person to person so this solution would not be a guaranteed

Table 5.6: Comparison of IR Sensors

Manufacturer	Texas Instruments	Melexis	TE Conectivity Measurments Specialities
Part Number	TMP007AIYZFR	MLX90614ESF-BAA-000-TU	G-TPMO-022 (TSEV01S01C90)
Voltage Supply	2.5 to 5.5V	2.6 to 3.6V	3.3 to 16V
Active Current	270 microA (max)	1.3 mA	2 mA
Sleep Mode	2 microA	2.5 microA (typical) 5 microA (max)	N/A
Temerature Range	-40 to 125°C	-70 to 380°C	0 to 100°C
Temerature Accuracy	1°C (typical)	0.5°C	1°C
Output Type	Digital		
Interface	I^2C and SMBus	PWM and SMBus	SPI
FOV	110°	70°	90°
Price	$6.40	$14.08	$33.24

fix. The most effective way to fix this problem would be to obstruct the sensors view with a cover. A metal cover with a slit or hole could be placed on top of the sensor to limit its field of view to a specific area. This can be done to any IR thermopile sensor in order to tweak the measured area to our liking. Therefore, even though its shows up in Table blank, it does not play a factor in deciding which sensor to choose.

The three sensors that were compared above were chosen because they best matched the desired specifications. The TE IR sensor is the priciest out of the three and it does not have a sleep mode function making it the least favorable option out of the three choices. The Melexis IR sensor has the best temperature range and highest accuracy out of the three and its price sits in between the two other prices making seem like a more suitable option. The Texas Instruments IR sensor has a decent temperature range and manageable temperature accuracy but what makes this sensor stand out is its price. Priced at $6.40 makes this pick the most appealing especially since we do not have any sponsors.

After much consideration, our thermal sensor selection is the Texas Instruments TMP007AIYZFR. For our purposes, we do not need the highest temperature range available. All we really need in our temperature range is the values for room temperature and the average human body temperature to be included. The temperature accuracy is sufficient for our measurements and the low current demand and voltage supply of the sensor is a plus since our system is running on a battery. The field of view is the widest of the three sensors but this can be easily adjusted by applying a cover over the sensor.

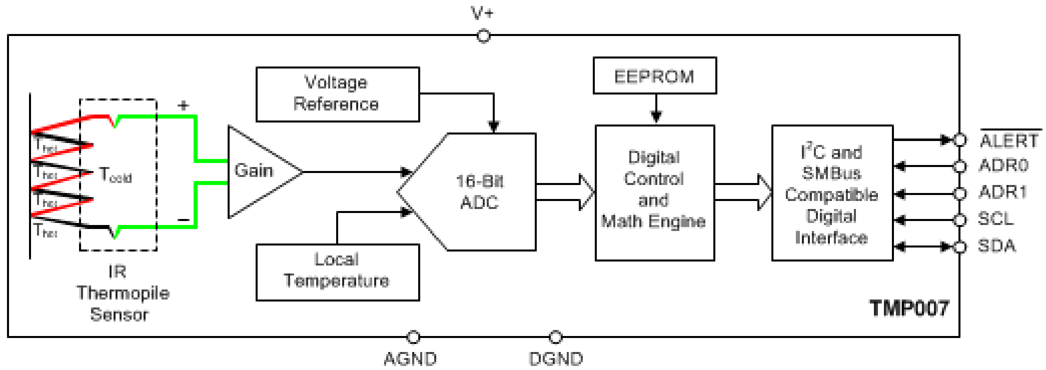


Figure 5.8: Function Block Diagram of the TMP007 (Courtesy of Texas Instruments)

Since the Texas Instruments IR sensor and the others sensors compared have digital outputs, then paired with the sensors for be an analog to digital converter. This can be seen in Figure blank and all the other functions of the TMP007AIYZFR. As can be seen, the TI IR sensor also has a math engine. This is very important because without this, we are just left with the output of the analog to digital converter which is just the voltage change across the thermopile expressed digitally. The math engine calculates the target object temperature by combining the voltage change across the thermopile with the internal cold-junction reference temperature sensor. This allows the IR sensor to output the exact data we need without the microcontroller having to do extra calculations

The TMP007 will interface with the microcontroller through Inter-Integrated Circuit protocol or I^2C for short. I^2C is a serial computer communications bus that is widely used in connecting generally low speed integrated circuits to either processors or microcontrollers. The TMP007 has nonvolatile memory in the form of registers. This is advantageous because if the IR sensor where to suddenly lose power, the values in the registers would remain and not be reset. The values that are stored in the registers are the configuration and calibration information, temperature limits, local temperature, the temperature of the die, measurement results and the thermopile voltage measurement result. These measurement values stored in the registers are used by the math engine to calculate the object temperature. Thus when the microcontroller gets the output of the TMP007, its retrieving the data from the IR sensors register. The microcontroller access the TMP007s registers using the address pins show in Figure blank .

Texas Instruments IR sensor comes in a small package and has a total of 8 pins. This will allow it to easily fit on the system within the restricted space constraints. The pin layout and descriptions are important to know for when designing the PCB. Table blank presents the individual pin names and their respective descriptions.

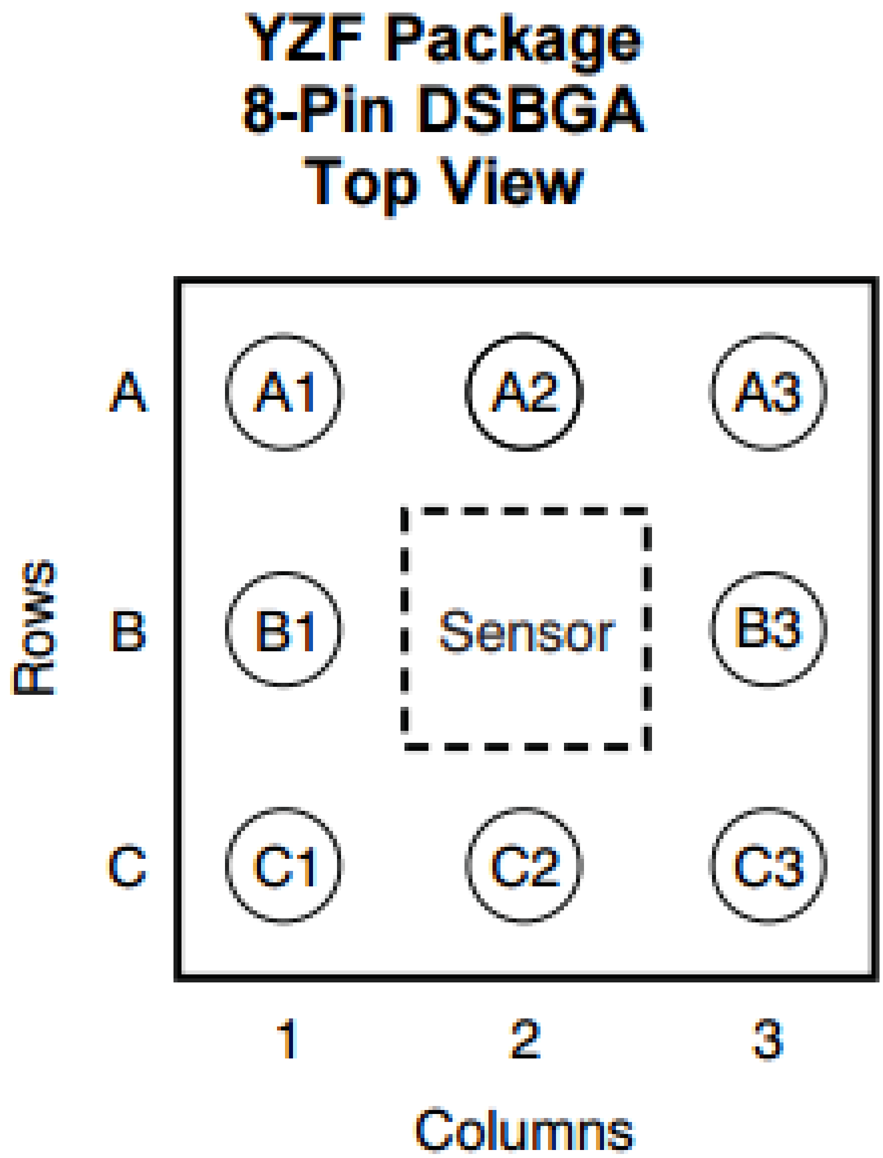


Figure 5.9: TMP007 Package and 8-pin Top View (Courtesy of Texas Instruments)

Table 5.7:

Pin Name	Pin Number	Description
ADR0	C1	Input address 0 selection pin
ADR1	B1	Input address 1 selection pin
AGND	A2	Analog ground
ALERT	C2	Alert output pin; active low, open drain. Requires a pull-up resistor to (1.6 V to 5.5 V) supply.
DGND	A1	Digital Ground
SCL	B3	Input clock pin
SDA	C3	Input/output data pin; open-drain; requires pull-up resistor to (1.6 V to 5.5 V) supply
V+	A3	Supply voltage (2.5V to 5.5V)

5.1.4 Determining Curvature of the Spine

A great deal of posture information can be obtained from the weight distribution part of our project. For instance, seeing if the user is leaning forward or backward or slouching to one side. However, measuring the curvature of the users spine is essential in determining the overall posture. The technologies explored in the research section of this report have shown that the two most potential types of sensors that can achieve the projects requirements are optical IR sensors and ultrasonic sensors. They allow for a noncontact and reliable method of measure the distance from the chairs backrest to the users back.

The power draw from these sensors was estimated to be the highest but it would still be ideal to have to supply voltage equal to or less than the batterys max voltage output and have the current draw be minimum. The range can vary depending on how the user is sitting in the chair. The most extreme case would be if the user is leaning forward considerably. The accuracy is even more important here than it was for the thermal sensors. There is not much flexibility in what is considered good posture and bad posture. So the more accurate the sensor is the better because of the lower chance for error. Laid out below in Table blank are the desired characteristics for the distance measuring sensor.

With the desired characteristics defined, the next step would be to find sensors from different manufactures and compare them so see which sensor would best satisfy our requirements for the project. Even within the same technology divisions, there are different types of sensor configurations and setups to choose from that offer different advantages and disadvantages. Both technologies will be looked at when comparing sensors but the best or most potential candidates of each technology will be compared in Table blank.

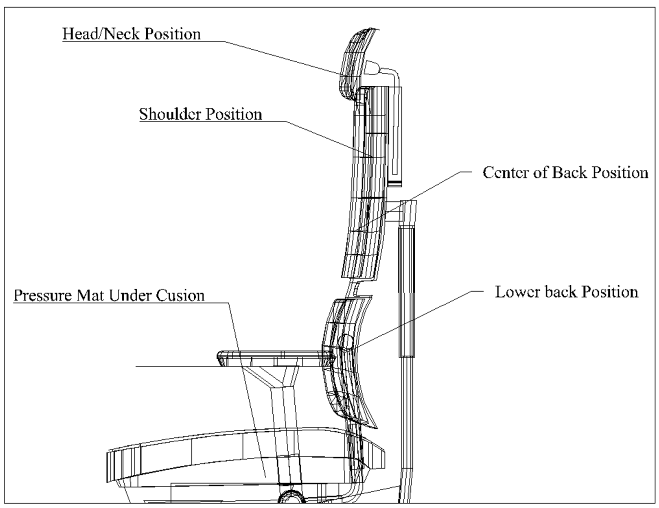


Figure 5.10: Sensor Layout in Chair (Waiting for permission to reprint from Steelcase)

Table 5.8: Desired Characteristics for the Distance Measuring Sensor

Specification	**Desired Values**
Distance Measureing Range	0 to 18 inches
Accuracy	at least 1 inch
Voltage	5V or less
Output Type	Digital

Table 5.9: Comparison of Distance Measuring Sensors

Manufacturer	MaxBotix	Paralax	Sharp
Part Number	LV-MaxSonar-EZ MB1040	Ping)))	GP2Y0E02B
Voltage Supply	2.5 to 5.5V	5V	2.3 to 3.3V
Active Current	2 mA	30mA	26 mA (typical) 36 mA (max)
Sleep Mode			40 microA
Distance Measuring Range	15 to 622 cm	2 to 300 cm	4 to 50 cm
Output Type	Analog	Digital	Digital
Interface	PWM, analog voltage and RS232 serial output	Positive TTL pulse or CMOS	I2C
Price1	$28.75	$29.99	$10.34

The first sensor is ultrasonic sensor by Maxbotix. This is a single element ultrasonic sensor where the ultrasonic wave emitter also acts as the wave receiver. The model MB1040 was chosen because it offers the most narrowest beam width that is also the least sensitive to side objects. It has the lowest amperage out of the three but it's less than stellar distance measuring range and accuracy makes this the least favorable option. Paralaxs Ping))) sensor is an ultrasonic sensor as the name implies. Ping))) is the dual element ultrasonic sensor where the ultrasonic wave emitter is separate from the receiver. This is maybe why it has superior accuracy over the single element ultrasonic sensor. However, with the highest supply voltage and current, this option is the most power hungry out of the three not to mention it is also the most expensive. The last sensor in the comparison is an optical infrared sensor with the manufacturer being sharp. This is the cheapest solution and the sensor is the only one that offers a sleep mode or standby function. The distance measuring range and accuracy are the second best out of the three and the output is strictly I2C.

After much consideration, we chose Ping))) to be our distance measuring sensor for our project. For evaluating the curvature of the users spine, accuracy is of the utmost importance. With an accuracy of 0.5 cm or 0.20 inches, Paralaxs ultrasonic sensor allows us to be confident that the possible error in measurement wont lead to false positives in posture readings. The drawback though is that it demands the highest voltage requirement and active current. We must ensure that the battery supplying power to the chairs onboard electronics can power this sensor as well as everything else.

To determine the curvature of the users spine, we must have at least two sensors placed along the chairs backrest. By comparing the distances that are measured by

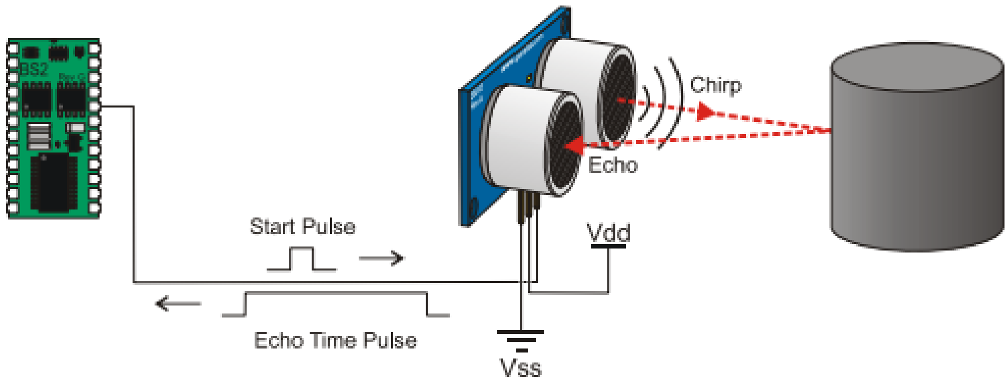


Figure 5.11: Ping))) Measuring Distance and Interfacing with Microcontroller (Reprinted with permission from Parallax)

the sensors, one can determine if the upper back or lower back is closer or farther from the chairs backrest. Then using their relative distances it can be determined if the user is slouching forward or leaning backwards. For extra assurance, we can use the data from the weight distribution system and see if the distribution of weight matches the effects of leaning forward or backwards. As a result of our method, sensor placement is crucial. The position for the lower sensor has to be in a spot that, no matter the users height, will get an accurate reading on the users lower back curvature. Once the position for the lower sensor has been established, the position for the upper back sensor must be resolved.

The optimal location for the upper ultrasonic sensor would be to measure the distance from the chair to the users upper back, between the shoulder blades. The problem with finding the perfect position for the upper sensor is that it varies from person to person. For example, we can set the position for the sensor at a height that matches a specific user but once a taller or shorter user sits in the chair, the positioning for the upper sensor would be off. This would force the chair to be of use for only one user. It is not our intention to set such limitations on the use of Posture Perfect. To fix this problem, we would have to make the upper sensor adjustable along y-axis. There are many ways that can be thought of to achieve this but the most straightforward way would be to have the top sensor on some sort of rail. This way you can slide the sensor up or down and once you find the right spot, you lock it in place. Indeed this would require manual set up before being able to use Posture Perfect but this would only have to be done when switching users. Therefore, if Posture Perfect only has one user, you would only need to set it up once and leave it there permanently.

The PING))) ultrasonic sensors would interface with the microcontroller through TTL pulse or serial communications. This done for input which would be telling the sensor to take a measurement and for output which would be receiving the determined distance measurement. Figure blank demonstrates the sensor in action and interfacing with the microcontroller.

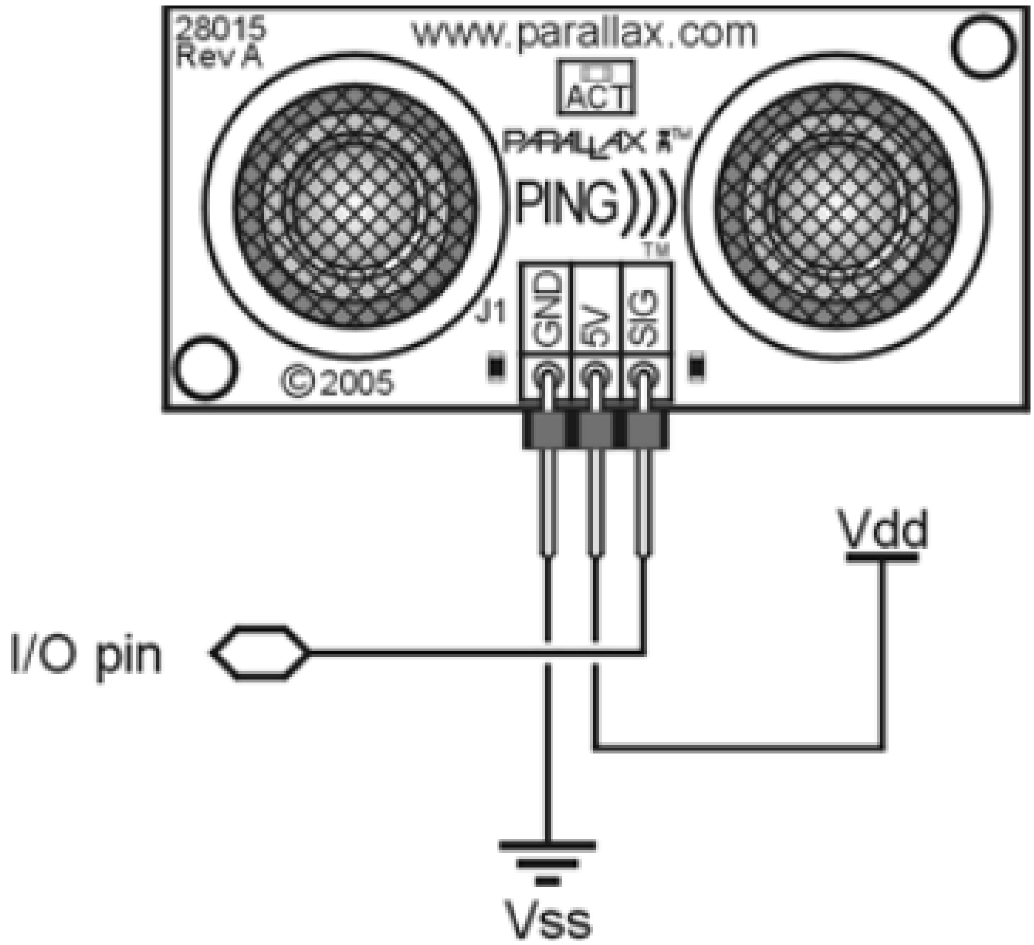


Figure 5.12: Schematic of Ping))) (Reprinted with permission from Parallax)

When designing the printed circuit board or pcb, adding the two (or more) ultrasonic sensors would be relatively simple. Each sensor only has 3 pins. One pin is for the signal that connects to one of the microcontrollers I/O pins. The second is for power which is 5 V and the last pin is ground. This can all be seen in Figure blank.

5.1.5 Microcontroller

The chair needs to have a method to manage all the data it is collecting, in this sense there needs to be a device that can make the decisions of turning on and off, what to send, to where, how, and with what interval. There are many methods of integrating a so called smart device into objects of our everyday lives, a popular method involves attaching an entire system-on-chip that can run an embedded version of a full operating system, however the complexity of this device does not warrant an entire operating system. With a full blown operating system not needed there exist two major systems for creating the logic for an embedded device, a field programmable gate array, and a microcontroller, with the gate array there is great difficulty in formatting the data collected for efficient transmission across a network, thus a microcontroller is the simplest, cheapest, and most reliable method of managing the onboard device of the chair. On the chair there needs to be a controller to manage several aspects of the devices operation, including managing power distribution, data collection intervals, sending data to the user, and determining when to begin and end the data collection.

Power of the device will need to be closely managed for the device to be able to operate for the one week required on a limited power source. The microcontroller can pump out a good amount of current and power the devices directly from the microcontroller, however this ties up several ports on the controller itself, so the controller will need enough pins to support the output to all sensors. The power of all the combined sensors may exceed the power sinking capabilities of the microcontroller, in which case an external controller may be needed. In addition to sinking power to the sensors to make measurements the microcontroller will also need to manage its own power, as such it should support a variety of low power states to aid in the power management system.

The chief responsibility of the microcontroller is to collect data from the user, to do so there are several features that are required to achieve the performance and accuracy requirements. First will be the analog input transformed into digital data, many microcontrollers have analog to digital converters (ADC) built into them. These are essential to achieving the performance requirements, as attempting to convert an analog signal into a digital signal without hardware support requires additional code and external hardware designs that if designed and constructed by us will not be able to read as accurately. With accuracy in mind the bit depth of the ADC can have an impact how precise we can take into account the measurements gathered from analog sources, with most microcontrollers supporting at minimum 8-bit ADCs with many microcontrollers supporting an accuracy of 12-bits.

With the system of collecting data and power management outlined it becomes necessary to note the timers and interrupts required for the system. The system will check for a variety of variables at regular intervals, like power state, occupancy sensor readings, and data connection status. To achieve this a set of timers will need to be active even when the device is in a low power state attempting to conserve power. Even when the chair is actively taking measurements from the user the timers should still be triggering the check for the data link, and power availability. When timers are set to go off at a particular time they should be able to activate the device for the purpose of taking measurements, this means the microcontroller should support interrupts caused by timers. As a supplementary cause of checking for occupancy measurements there should be an external switch connected to a pin that can cause an interrupt in the controller to wake it and begin taking measurements.

The final major requirement of the microcontroller is its ability to encapsulate and send this data it has collected to the user. To send data to the user it has to be able to interface with a communication device, this means that it must support serial

Table 5.10: Desired Characteristics for the Microcontroller

Specifications	Desired Value
Voltage	5V or less
Power Save Mode	Multiple modes
ADCs	At least 8
Trigger availability	At least 1
Communiocation	Serial, I2C or SMBus, and TTL pulse or CMOS
USB	For power and debugging

or parallel communication, where serial is preferred for compatibility and interface complexity. There are a few technologies that will be implemented to facilitate wireless communication as noted in later sections of this document. To support these communication methods an adapter will need to be added to the connections of the microcontroller and in doing so the microcontroller must support the additions of such modules and preferably have pre-built functionality for interfacing with such a module. In addition to sending data through this device it should be possible to receive data from this module as well. With these prerequisites in mind, Table blank was constructed.

There is a plethora of microcontrollers and manufacturers to choose from. It is tempting to select TIs MSP430 series to work with because of the low power solutions they offer and our familiarity with the MSP430. Nevertheless, we opted in choosing Atmel for our microcontroller due to their software flexibility and available open source libraries to take advantage of. By using the desired specifications to narrow down the many options available, our final microcontroller pick is the ATMEGA32U4. The ATMEGA32U4 is an 8-bit microcontroller with 8K of EEPROM, 20K of RAM and 32K of flash memory for the program code. This should be sufficient for our program size and complexity. The MCU is clocked at 16MHz with an internal oscillator and runs on 2.7 to 5.5 supply voltage. Having the microcontroller's supply voltage match that of the other sensors simplifies the power management aspect of the system. It has twelve 10-bit ACDs on its I/O pins. A multiplexer will need to be used if the weight distribution system outputs analog signals with more than twelve sensors. The total number of I/O is 26 which is plenty for our purposes. The ATMEGA32U4 has all the necessary interfacing protocols such as I2C, SPI and UART to communicate with the projects various sensors and components. Finally, the microcontroller costs 6.32 dollars which is perfect given our lack of sponsors and finite budget. Figure blank shows all the microcontrollers functions and components togeather in the microcontroller.

With the most pins and complexity, knowing the pin layout is crucial when designing pcb. Figure blank will help identify the pins and their function in order to wire all the other components.

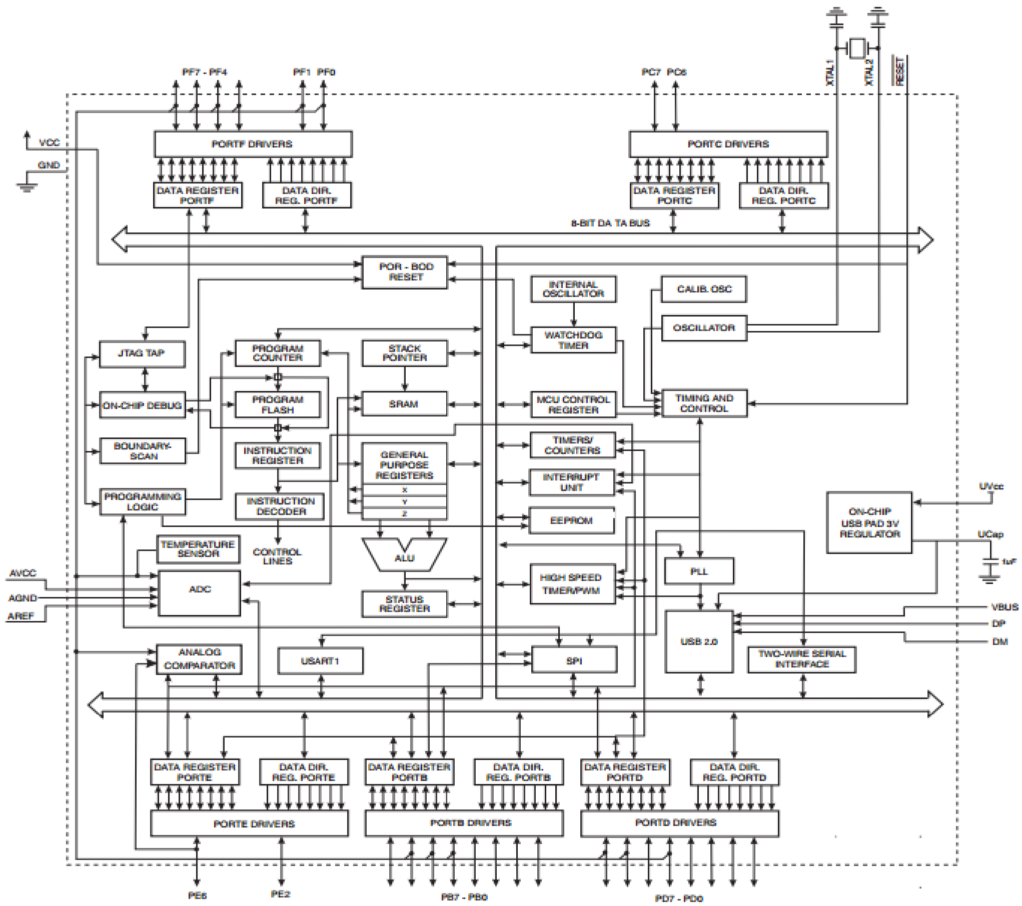


Figure 5.13: Function Block Diagram of ATMEGA32U4 (permission pending)

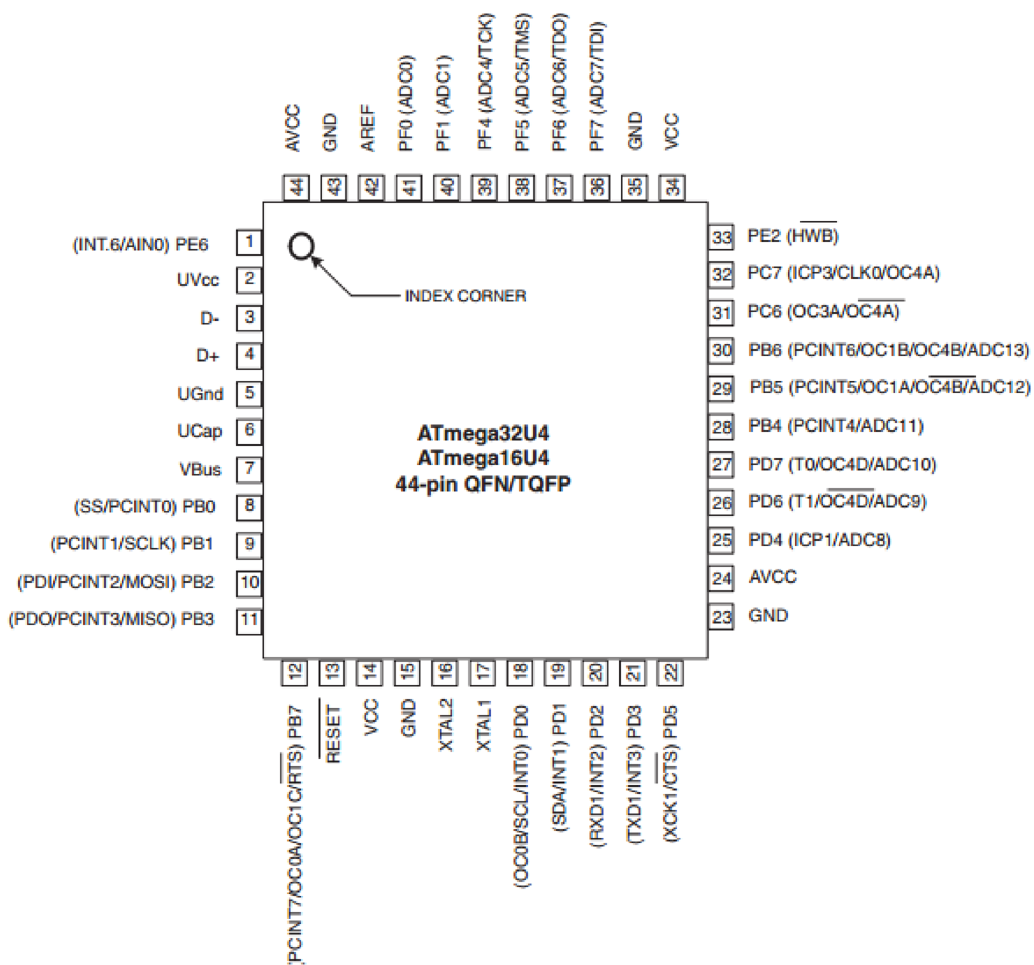


Figure 5.14: Pin Layout of ATMEGA32U4 (permission pending)

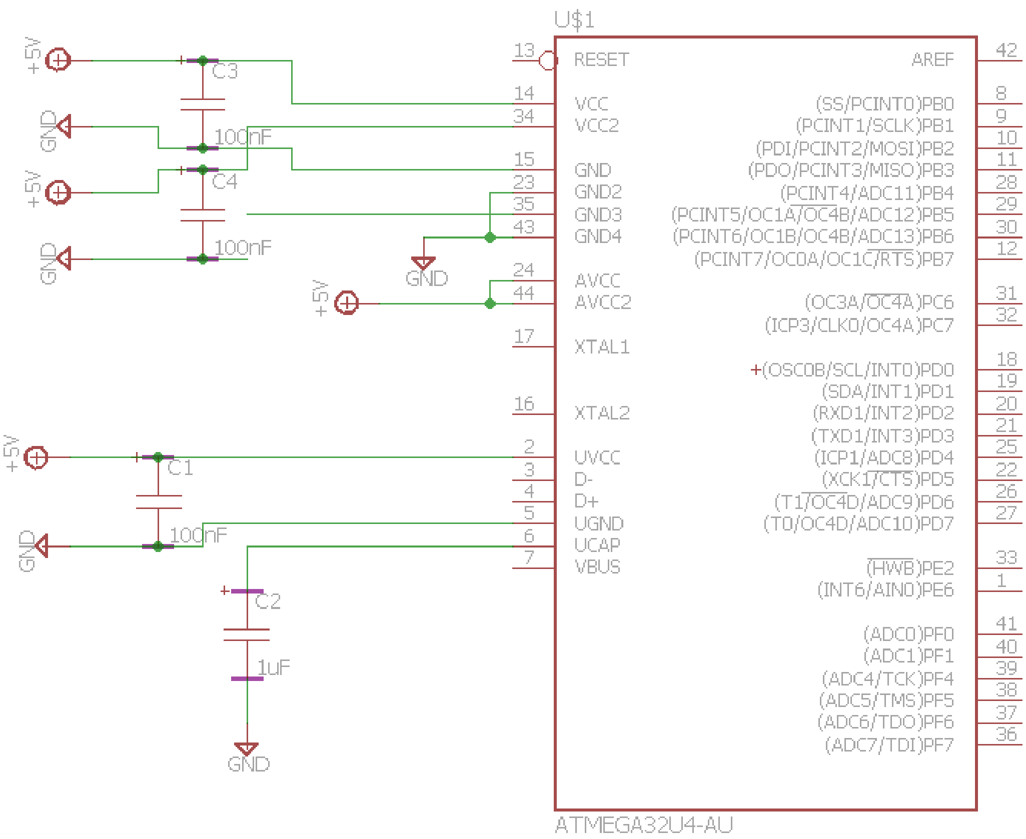


Figure 5.15: Schematic of Microcontroller on PCB in Eagle

5.1.6 PCB Design

In order to design and construct the printed circuit board, the program EAGLE V7.5 is used. This software from CadSoft specializes in the making of schematic and board designs. They offer many resources such as documentation, tutorials and examples for beginners. As can be seen in Figure blank, you can make a schematic and place the individual components to wire them up. This would then reflect the connections made in the board file. After this you could tweak the layout to make it more organized and efficient.

5.1.7 Power Management

Power management would be designed so the the microcontroller would not have to deal with the stress of powering all the sensor that are attached to it. We would create a side circuit that would optimize the amount of power that would be distribute to all the sensors. This would not pose a problem due to the fact that the majority of the sensors that are being used need 5V to be powered. Also the only components this circuit would be responsible for are the sensors. The circuit would be connected to a battery. The microcontroller and the sit vibator would be powered by connecting directly to the battery. This would help distribute the power the most efficient way.

5.2 Software Design

5.2.1 Embedded

The microcontroller on the device needs to be responsive and consume small amounts of power, a system that can take full advantage of the available resources, such as I/O buffers and independent system caches. The software on this embedded system must be able to take advantage of the microcontroller resources as well, lending itself to performing fewer operations and consuming less power when active. As the system must also support a low power state for extended operation and for when the user is not occupying the system, the software must be able to interface with the microcontroller's interrupt system, usually vector interrupts, and react to them within the time specified in the Requirements section of this document.

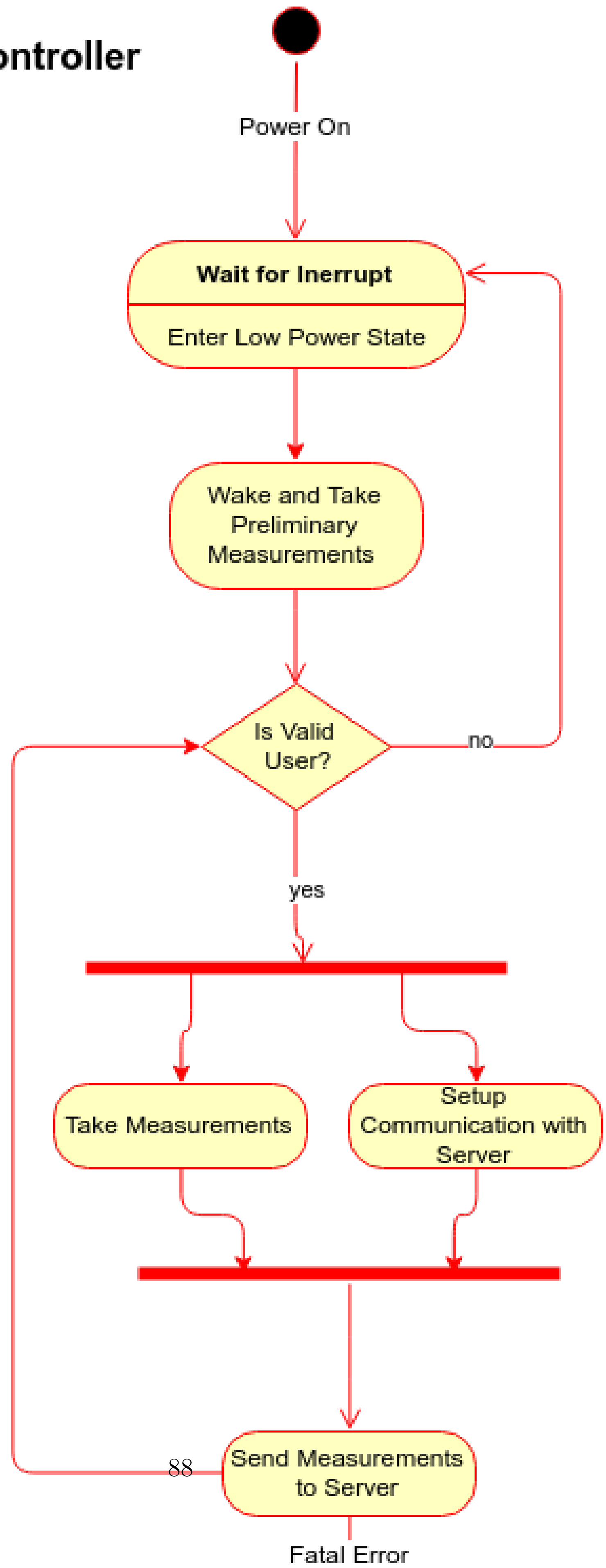
Language

There are few languages that support embedded programming, and even fewer that support the functionality we need for this project. The need for communication that can regularly update the storage mechanism is one of the most challenging portions of the embedded devices responsibility, a language that can easily interface with a network interface for regular communication is important.The primary options explored in this project point towards one of the following options, C, assembly, and C++, as they will be further discussed in this section.

The classic C style code is one of the most well known embedded languages in the world, and is supported by many platforms. The C language supports all the functionality we need to make our program run successfully on almost any microcontroller on the market, in addition it has libraries for handling interfaces of many microcontrollers. For the microcontroller we choose the C language will support all the functionality of any possible inputs and outputs we will need, however there limit to how detailed this program can be, given the time constraint there is not the time to write entirely new functions for sending and receiving signals over WiFi or Bluetooth. Having pre-built libraries and functions for the standardized communication portion of the project can greatly accelerate development, and there is wide support for many microcontrollers to use the C language.

Closest to machine language is the assembly language, it varies based on the architecture and instruction set of the chip, but it is the most customizable in terms of hardware optimization. Any microcontroller we choose will support its own version of an assembly language. Like the C language this is a very basic language, even

Chair Microcontroller Flow



more so than C, and as such will have very little support for external modules using pre-built functions and libraries. The lack of support leaves this language as a very much a learning tool and not very useful for this project.

Last in the queue is C++, the descendant of C it has many similar characteristics, but with its expanded functionality it provides many common interfaces to supported devices. The object oriented support and target based compilation methods offer greater flexibility of code and greater performance on the target device. Due to its many similarities with C much of the code developed in C can be easily used in C++ projects, lending the wide support of C to the object oriented functionality of C++. The complexity of C++ may make support and functionality easy to come by, but the size of the projects tend to be much greater than that of C or assembly programs, and without proper management can easily take up a large amounts of memory. In reviewing the languages and their applications it is most likely that the C++ language will be used due to its support of embedded systems, sustainability for future users, and built in functionality to allow for rapid development.

5.2.2 Mobile App

Platform Choice

The mobile platform is the platform best suited for the Posture Perfect application. It was chosen over desktop operating system due to conveniences. Out of the multiple different mobile operating systems two showed the most promise. iOS and Android was the final two operating systems that was compared. These two were picked over Microsofts Windows phone solely because those two operating systems are what is dominating the mobile market at this point in time. Android was chosen over the two because of a few key reasons, the user database, customizability, and building of applications.

Software Development Kit and Languages

There are a few programming languages that can be used to create the user application. All of them has their pros and cons. The three that was consider when it came to choosing a language is Java, LUA, and HTML5/Javascript. Java is a language that is used more often when creating an Android application, whereas the other two languages are more of a substitute for if you do not like programming in Java. The SDK that uses LUA is called Corona. This high level software development kit uses programming language LUA because it is much simpler than Java. It also is designed to take away the stress of making a Android app. Corona also allows you to run the program without having to compile it. But the reason why we did not go with this SDK is because it is designed for more advance Android apps. You would use this if you were trying to create a gaming application due to its extensive libraries for devel-

Table 5.11: Platform Comparison Matrix

Categories	**Android**	**iOS**
Customizability	Vast amount of customizable features	Limited customaziable options
Manufactures	HTC, LG, Motorola, Samsung, Sony, etc	Apple
Quantity of apps	Google Play ∼600,000	Apple app store ∼700,000
Open Source	Kernel, UI, and most applications	Kernel is not open source but is based off open source Darwin OS
Widgets	Yes	No
Market Share	81.5% of smartphones globally	14.8% of smartphones globally
Crash rate	2.0 % (Lolipop)	2.2% (iOS 8)
Security	Less due to app permissions	More, due to apple's review of all apps
Privacy	User cannot select permissions, not good.	Better, user installs app, then grants permissions.
Building and Publishing	Painless, and can be created in C, C++, Java, and for free.	Created only in Object-C or Swift and $99 developer license.

oping a game. Phonegap is based on Apaches Cordova project. It uses programming languages HTML5, Javascript, and CSS to create the app. This is done by creating a webview which can then be manipulated by using Javascript. The web app interacts with different device features just like a normal Android app. The reason behind not using this to create the application is because a web like application could cause problems if we are not familiar with HTML5 and we have to troubleshoot it. This is why Java was chosen to create the application. The majority of the programmers working on this project knows Java to some degree, so the libraries that would be needed we would know. Also Java is the official language for Android development so troubleshooting the program would be easier than with the other languages.

As for the software that we are going to write the java based app it is going to be Android Studio. It offers us valuable features that other app developing softwares do not. Some of the features that available are code templates that help build app features, a layout editor that supports drag and drop theme editing, built-in support for Google Cloud Platform. There are other software that has these features and more, but they are pay software this is a free program that is also the official IDE of Android app development.

Design and Logic

The design of the application is going to have three parts it will have three classes along with a main class that brings it all together. The three classes would be created is a class for recommended exercises, view results, and the settings of the app. These would be linked together with the use of a graphical user interface. The classes would have access to the server that we select in order for it obtain the data that it needs. It would also have a notification icon to notify the user of the recommended exercises to perform that moment.

5.2.3 Cloud

The cloud software will be a wide combination of languages and systems that work together to provide the user with the functionality of data storage, data analysis, web app access, and chair configuration utility. There are several cloud services that will be used through the prototype process until one is selected. The standardization for cloud systems is not yet a concern, so there may yet be one that releases some functionality that improves our project.

The data collected from the user will be stored in the cloud using an SQL managed database, this will be split into several categories of data for further organization. First sub division will be time, as the cloud is not limitless in its storage capacity there will be compression of data as time goes on, creating generalized functions that represent historical data and storing them in tables that will store compressed versions of data that has resided in the database for lengthy amounts of time. More recent data is in a table that will be optimized for greater ease of access, as this data is most relevant to the users needs, and the algorithm will place more weight on recent events and less on past events. Second division of data will be by difference in measurement results, like a change in posture while sitting, this will signify when and how your posture changed which is useful for mapping your activity and change in posture throughout the use of the chair. The third subset of data is an attempt at correlating the posture of the user to different times of the day, or based on how long theyve been sitting in the chair. This can be used to find out if the user has some habit that tends to cause them to slouch after an hour of sitting, or if every day at around 2:00 PM they start hunching over. By splitting the data into these sections and using relational databases, the level of analysis required by the algorithm to process this data incurs much less overhead.

The analysis of this data that will provide the user with advice on posture control is handled by an algorithm on the cloud based computing platform. There are many services for data crunching provided by cloud computing service providers, in these data crunching methods there are a range of sizes for data sets from big data to small scale crunching. Given the data set of this project the small scale data processing will work with more than enough power to compute the results needed by the application

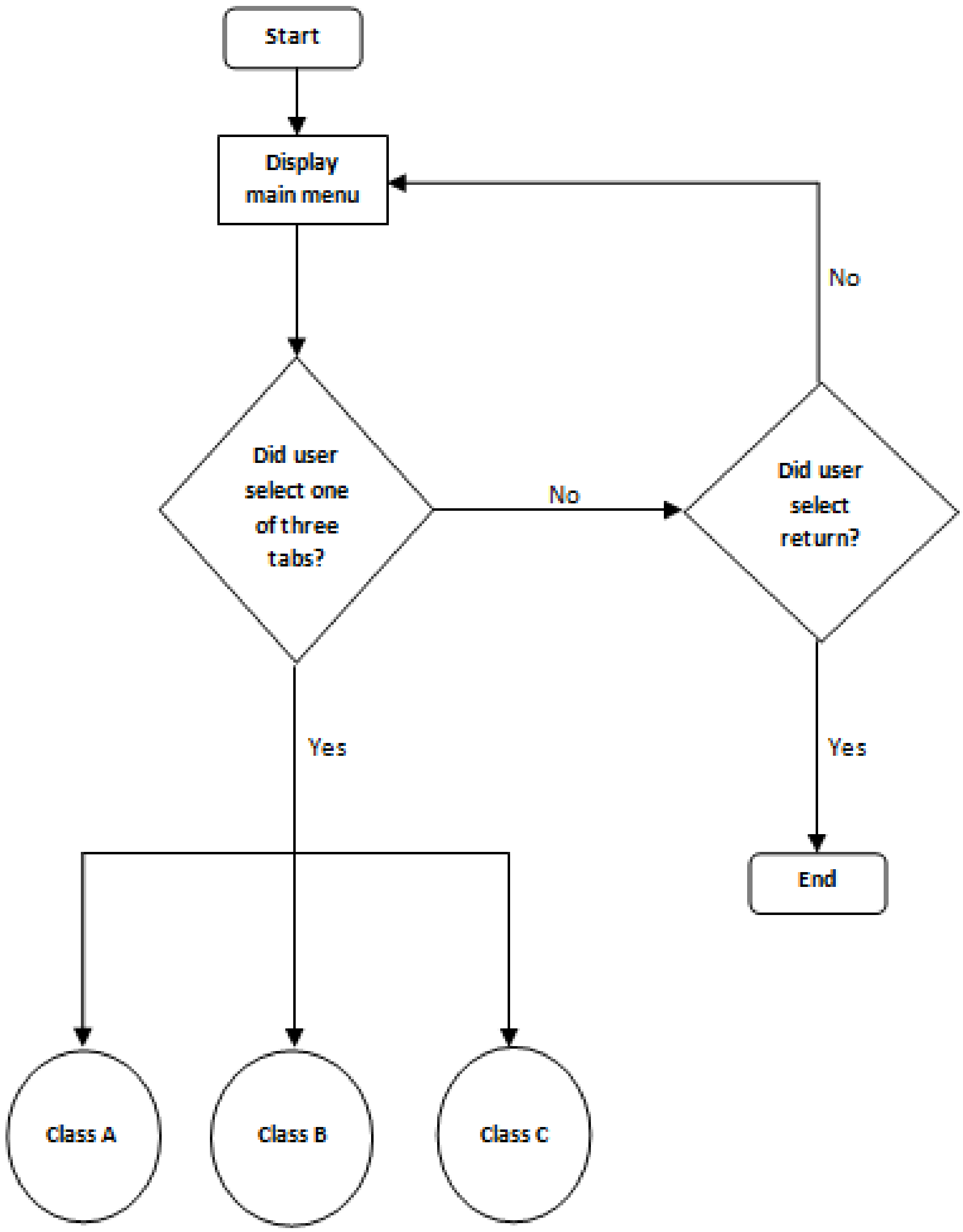


Figure 5.17: Home method logic

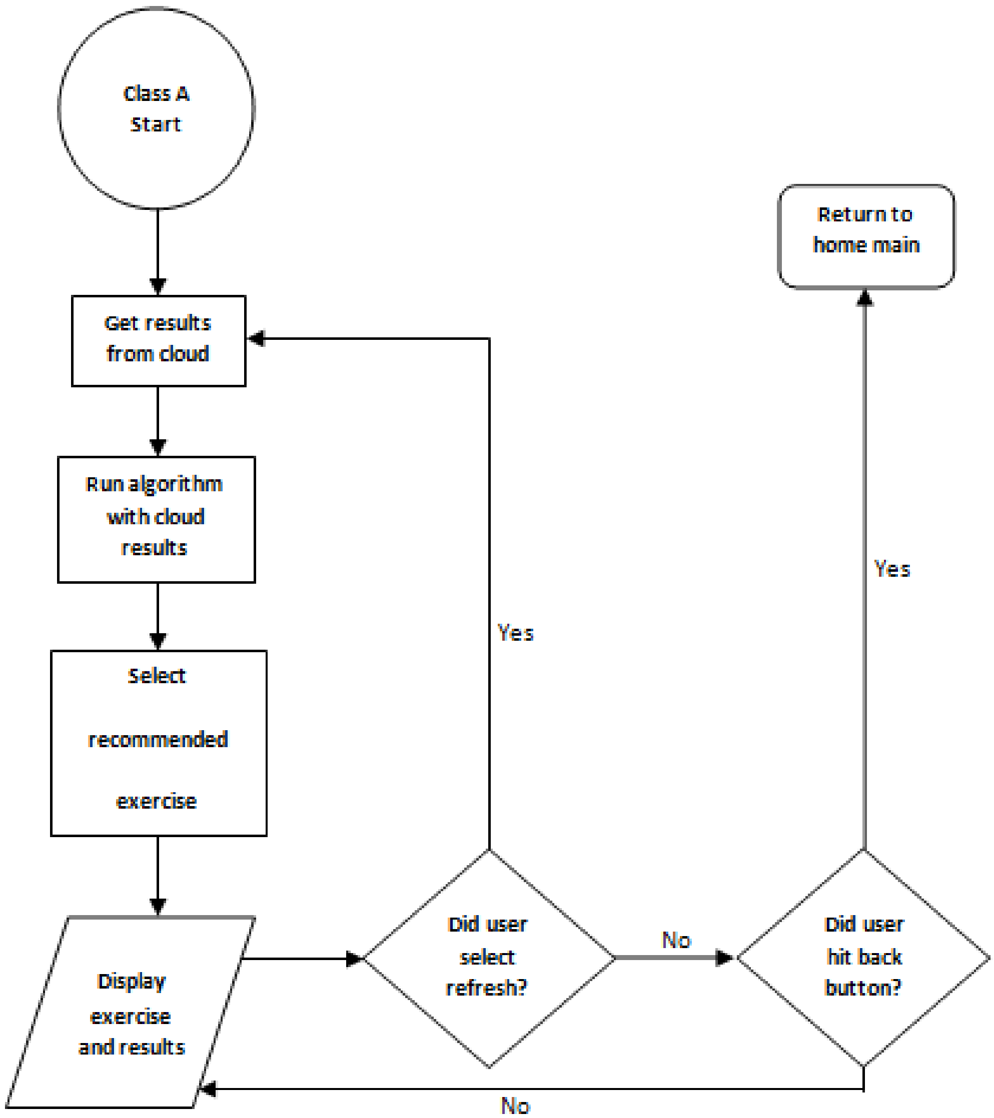


Figure 5.18: Recommended exercises method logic

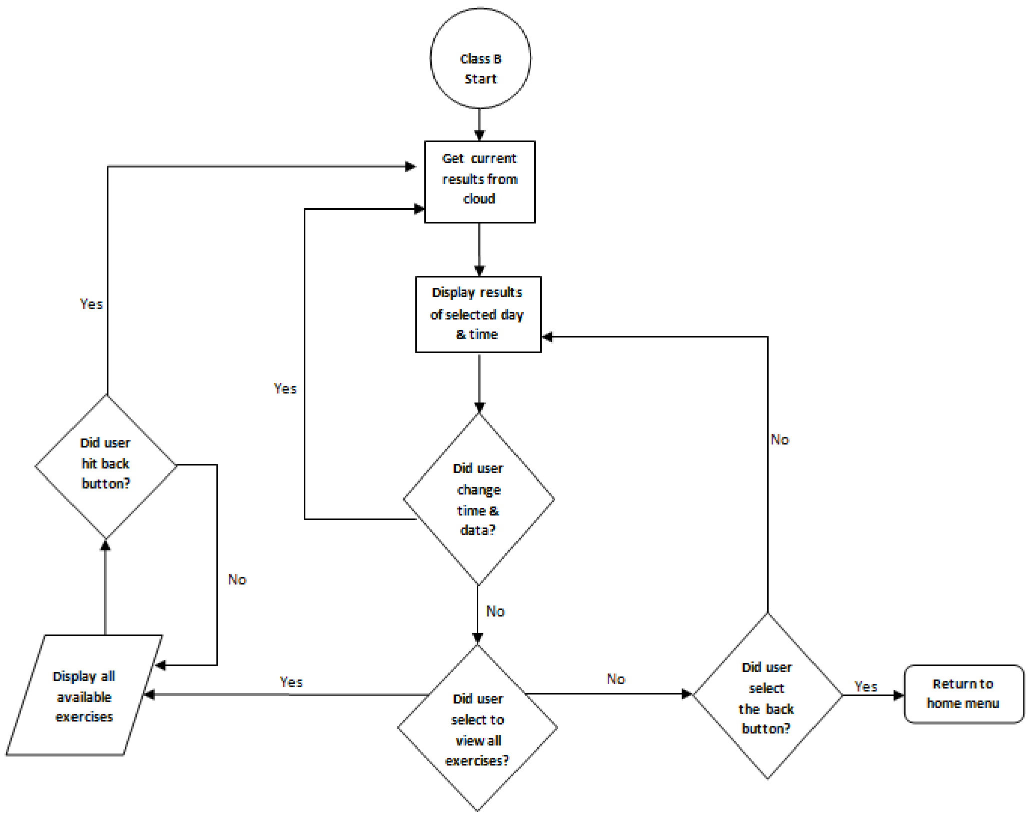


Figure 5.19: Result method logic

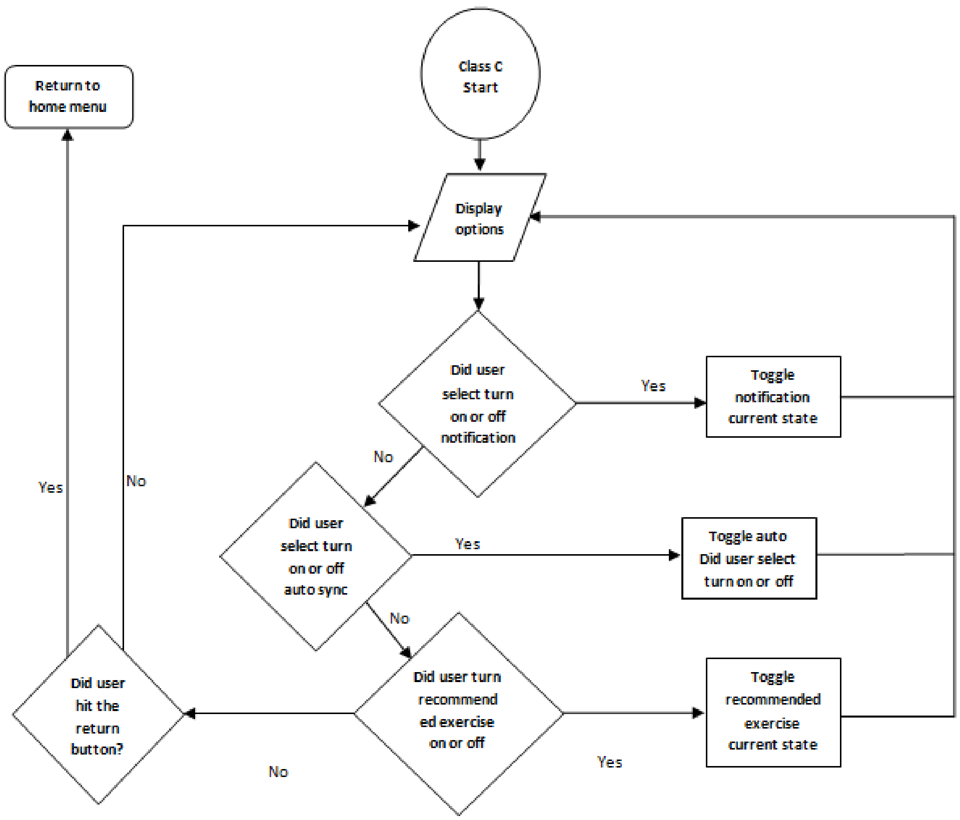


Figure 5.20: Settings method logic

of the user.

The application used to display data will be able to run on natively on most mobile platforms, however the desktop platform is much less restricted when it comes to user input and resource management. Taking advantage of this input mobility the application for desktop computers will be a web portal to a hosted app on a cloud server. The access of data from the web app will be a much simpler task than requiring a build for each desktop operating system, making support for future desktop OSs a simple task, and access to your data from any of your devices. The mobile app will pull the same data from the same server, but will run its own display formatting system to make use of its hardware, providing a more polished experience to the user.

5.3 Aesthetic Design

The chair that will be used for Posture Perfect will look like a regular leather desk chair with modifications. All wires and electronics will be hidden out of sight within the chairs upholstery. The pressure sensors may or may not be visible depending if they are placed below the chairs seat cushion or above. If they are placed above, the sensors will be flush with the curvature of the seats cushion and not cause any disturbance or discomfort when sitting of them. However, the other sensors such as the thermal sensor and the distance measuring sensors will be visible. This is due to the fact that the sensors cannot be covered up since they need line of sight in order to function properly. Given this, we will still try to make the sensor placements as unobtrusive as possible. The battery or battery compartment may be visible in order to make the battery accessible. It could simply be covered by the chairs leather or be in a plastic 3D printed compartment with a color matching the chairs color. Most likely the chair will be taken apart in order to modify its structure in order to accommodate the sensors. As a result, the armrests could possibly be removed from the final design.

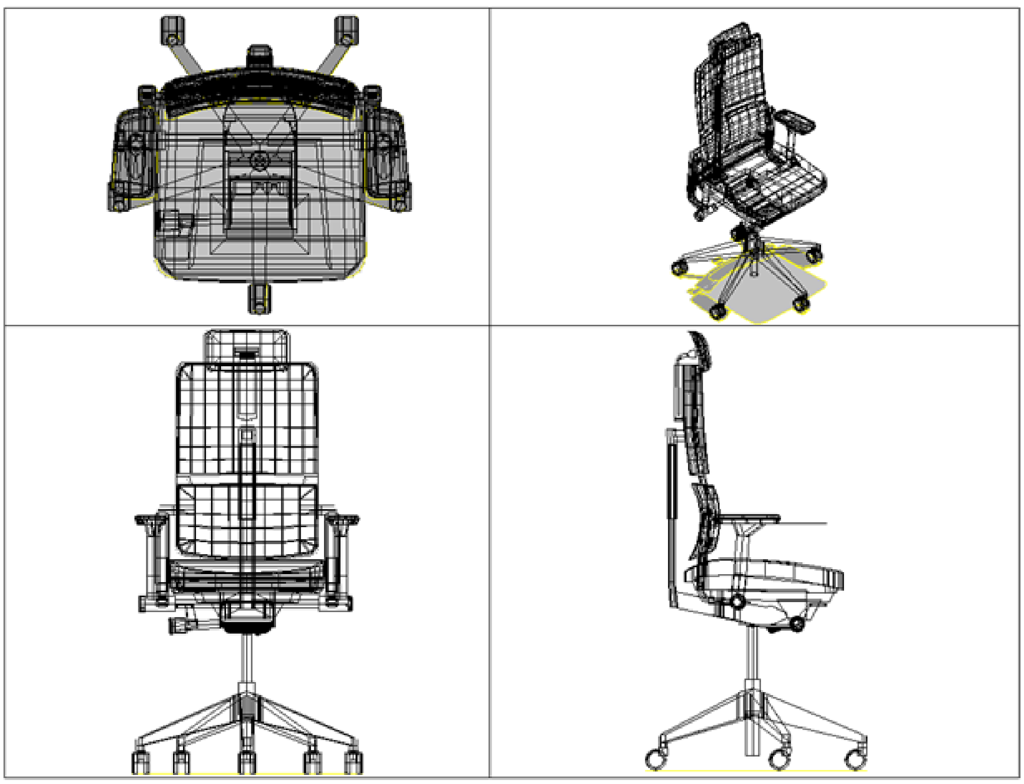


Figure 5.21: Physical Layout of Chair (Waiting for permission to reprint from Steelcase)

Chapter 6

PROTOTYPE CONSTRUCTION AND CODING

6.1 Hardware

The University of Central Florida offers many convenient resources and services for its students such as 3D printing, electric machinery for mechanical construction or modifications, laser cutters, soldering stations with microscopes, electronic test equipment and pcb ordering. We will take advantage of these resources in constructing the pcb and soldering any components or wires. The 3D printing services will be used to print a plastic housing for the printed circuit board and any other sensitive electronics. The electric machinery can be used to construct the metal adjustable railing for the ultrasonic sensor and any other modifications to the chair that will need the cutting of metal or wood.

The printed circuit board of our final design will be order with all the elements and components mounted on it. However, for prototyping, the sensors will be all purchased individually and an exact or similar atmel microcontroller will be obtained in the DIP package. An alternative to this would be to buy an already made arduino since they are excellent for prototyping because of their open source hardware and software. Whatever these purchases may be, they will be at digikey.com since they offer everything in one place and have quick shipping options. This will allow us to set up the system and see if it works. We could test different size vibrating motors to see if one is more noticeable than the others and experiment with different sensor placements. Having it be usb connectible would be a plus because it would allow for debugging and powering the MCU without having to rely on the battery for prototyping. The advantage is choosing to work with a similar atmel MCU is so that when we write the program code for it, there won't have to be many changes to it when we switch to the real deal.

As for the chair, we have two used leather desk chairs that one of us will provide for the project. The two chairs are about the size of a regular executive desk chair. The structure of both chairs solid and in good condition to serve as a reliable foundation. The leather on the chairs though is not in the best shape. On one of them the leather has peeled off in many areas around the chair, while the other chair has deep indentations on the seat and the arm rests. The reason why we have two chairs to use is in case we damage or mess one up while we are gutting the upholstery and cushions out to be left with just the frame. When the chairs are taken apart we might interchange parts or completely replace them with new cushions or upholstery. When we are just left with the chairs frame, the positions for the sensors will be determined and modifications will be made to make the system adjustable for any user. This will also be the time when we decide on how and where the pcb and battery will be attached to the chair.

6.2 Embedded Software

The embedded device will need to be initialized on a critical failure or power loss, this means that proper initializing operation must be run at startup. The basics of the microcontroller that need to be configured are a series of timers, interrupts, interrupt enables, data caches, input and output pins. Without theses configurations there will be no way for the microcontroller to perform its functions. The sensors will also have to be zerod on startup to ensure that correct measurements can be taken reliably, that means powering on and taking measurements from the ultrasonic sensors, determining if there is something blocking the sensor or interfering with operation, like a loose connection. The same zero process needs to be taken from the pressure sensors, the piezoelectric sensor needs to be read as zero to properly trigger the interrupt for taking measurements. The piezoresistive elements dont require as sensitive zeroing due to the nature of their operation being based on the power provided by the management unit.

6.2.1 Sensor Data

The data collected from the sensor must be interpreted into numbers that must make sense to the algorithm to be implemented on the remoter system for data analysis. Each sensor sends its own form of signal to the controller, these signal need to be interpreted to be used properly. The signal from each set of sensors need to be handled as seen below.

The pressure sensors will be read in and transformed into a digital signal using an Analog to Digital Converter (ADC) that will be matched to a range of data that correlates to a particular pressure on that point of the chair. These pressure sensors will be in an array and if the proper number of input ports that support ADC conversion cannot be acquired, then it may be possible to link a second microcontroller with the express purpose of collecting data from the grid of pressure sensors.

The ultrasonic sensor is less straightforward than the pressure, it relies on the timing and reflection of a transductive sound wave that must be timed properly to generate an accurate signal. The signal replied to the board will have to be interpreted as a continuous failure of reply until the sensor changes state, this will rely on the speed the microcontroller can react at, and thus should be handled in a separate function from the main looping structure.

6.2.2 Power Management

The use of low power states will be used extensively in conjunction with interrupts to make the most of onboard battery power provided. As the chosen microcontroller supports a variety of low power states, these will be implemented to conserve power with the highest regard for minimal power consumption. When there is no user detected in the chair it will enter LPM4, disabling all clock signals and waiting for the interrupt from occupancy sensors to begin taking measurements. The measurements will only need to be taken at intervals, so between those intervals the device will drop into LPM0, disabling the CPU, but leaving all the clocks active to raise interrupts when new data is needed.

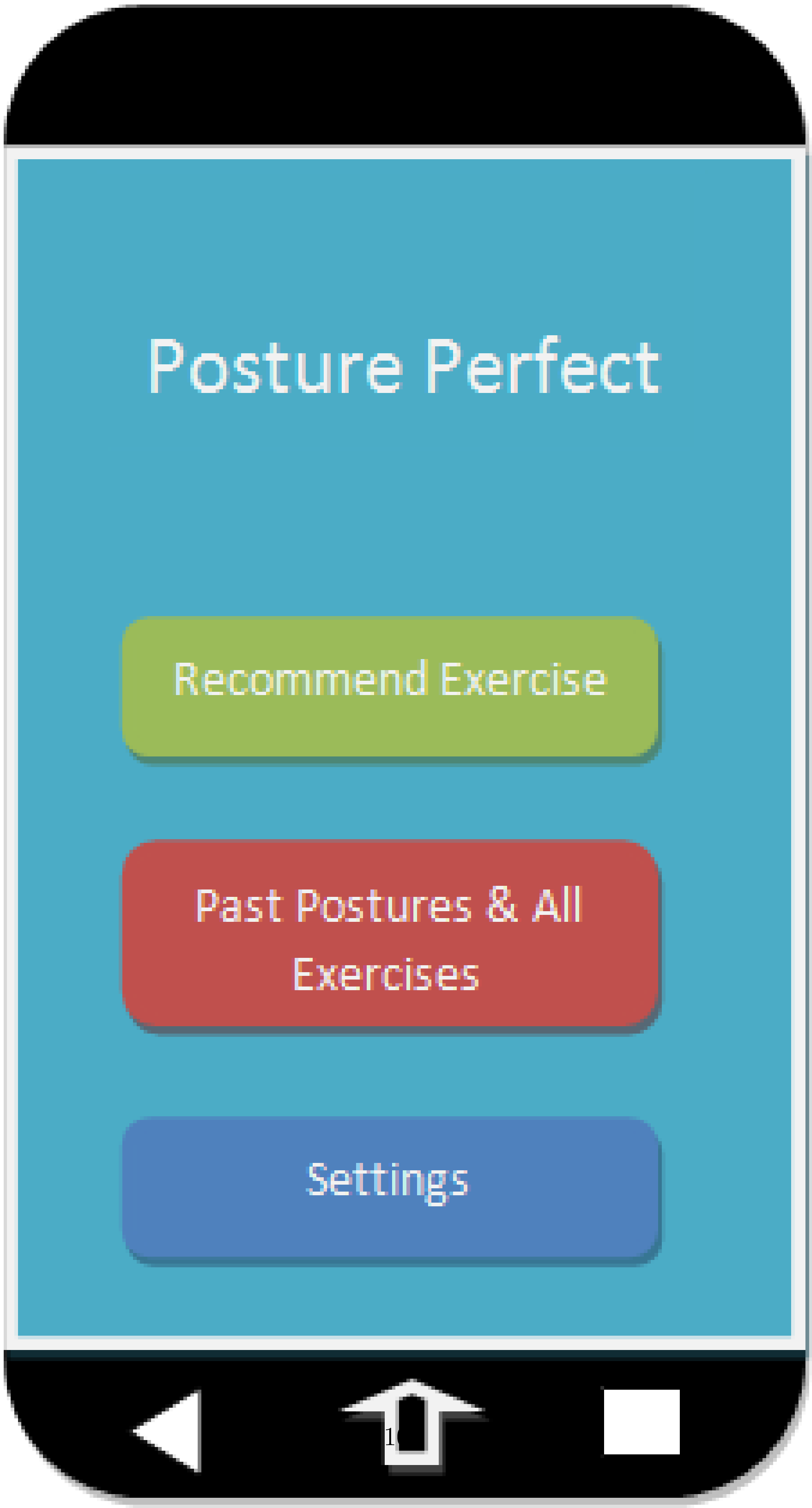
6.3 Application Software

6.3.1 Application Prototype

The application prototype displays the four major screens that we want the user to interact with. We want the application to follow a exact if not similar design as what we display in the figures below. The design was created with the objective to create a user friendly interface in mind. That is if a user has never used an Android OS or never used the app before could access the main features of the app. We also wanted the application to be visually appealing to the user.

6.3.2 Home Screen

The home screen would be the simplest of the four screens. It shows the three options that user has to pick from. It would be have different colors from each button selected to help distinguish the different option from each other better that way. It also has the title of the project just in case the user forgets what app they are using. Figure X shows what this menu would look like.


Posture Perfect
Recommend Exercise
Past Postures & All Exercises
Settings

6.3.3 Recommended Exercise Prototype

The recommended exercise screen only option are the details to the exercise and the back button. This screen would display the results of how the users posture been on the top half of the screen. Showing a percentage of how good the users posture is using a range of 0 to 100 percent. There would be 2 to 3 number for the lower back, maybe the mid back, and the upper back. The number would be one of three color green (good posture), yellow(average posture), and red(bad posture). It will be label in a way for the user to understand easily. The bottom half displays the recommended exercise displayed in figure X. If the user selects the exercise it would display how to do the exercise.

6.3.4 Results Prototype

The results screen has two options beside the back button. The first button displays the past posture results and another button to view all of the exercises that was put into the application. The past results would be formated in a chart with the dates at the bottom and posture percent on the left. This would be simple for anybody to understand, the higher the number the better and vice versa the lower the worse. Then the view all exercise button would just show the list of exercises like in figure X. If the user wants more information on the exercise all they have to do is select the one they want and it would show them how to perform it.

6.3.5 Setting Prototype

The setting screen has three buttons excluding the back button again. It has option to toggle the notification that the application displays when it wants the user to do an exercise on or off. Then next option is to turn the auto synchronization on or off. The last option let the user pick what exercises gets to show up in the recommended and the notification exercises as displayed in figure X. We only keep it at these options so any user would know what setting they could alter.

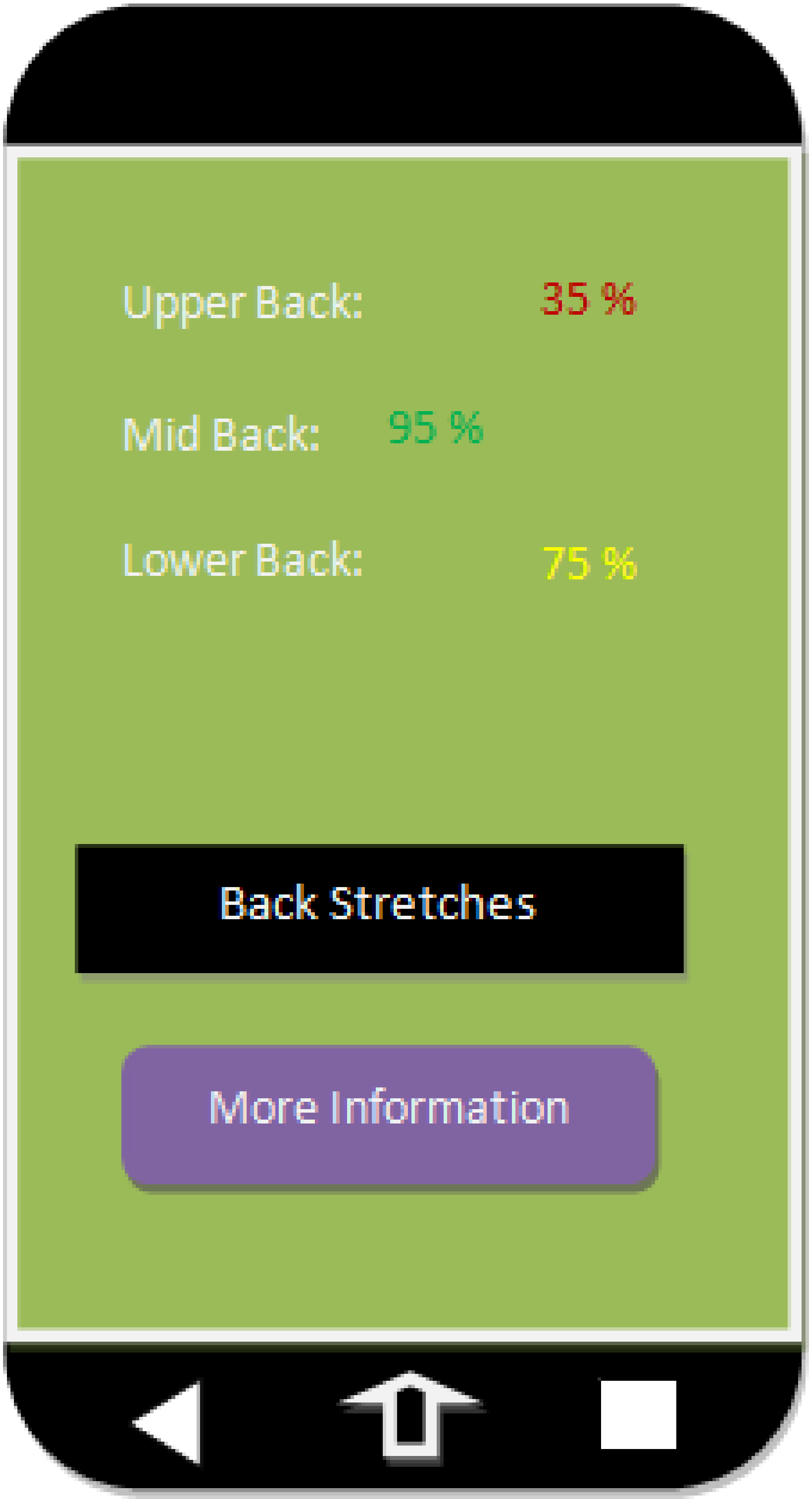


Figure 6.2: Recommend screen of app

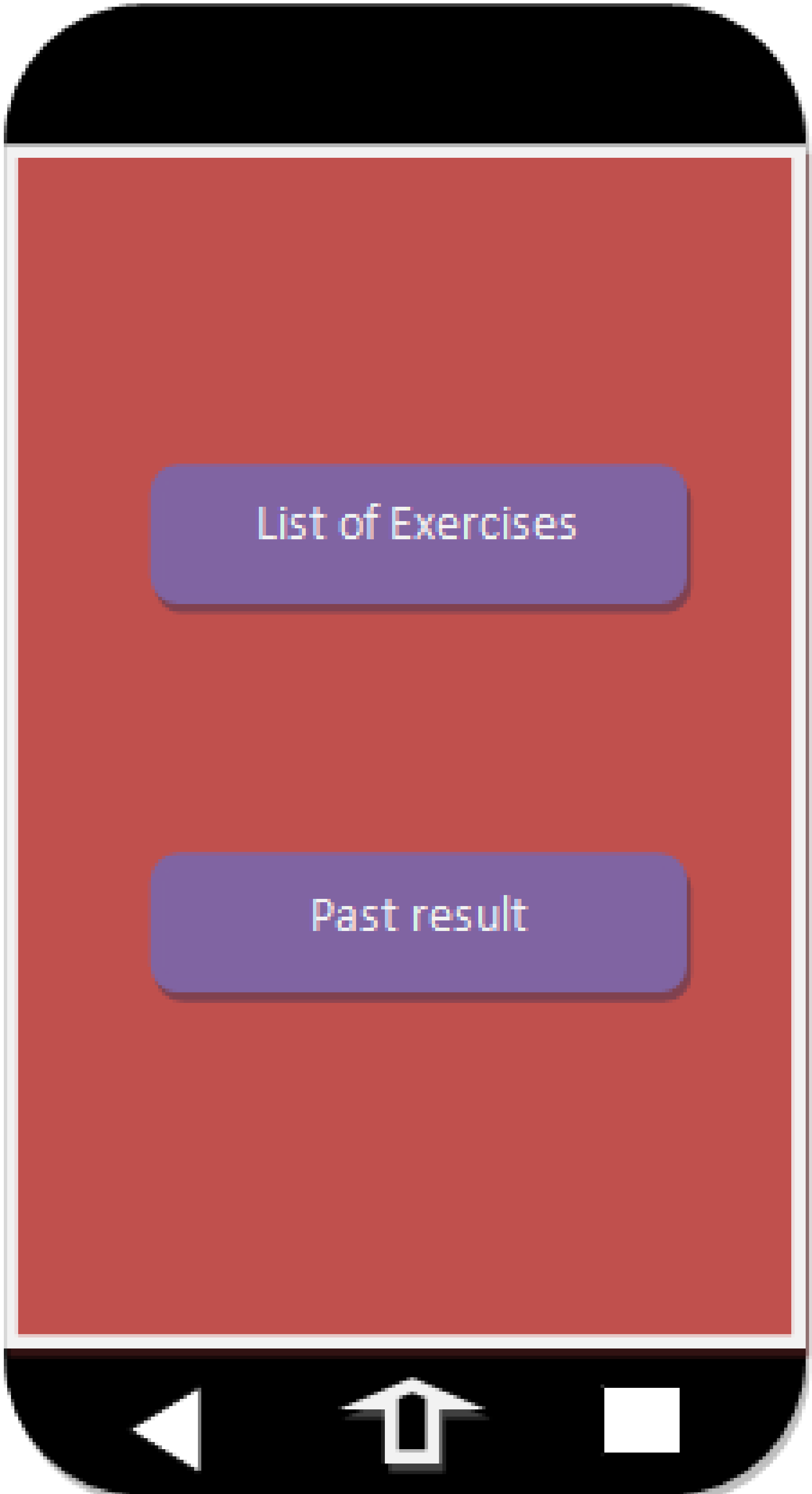


Figure 6.3: Past results screen of app

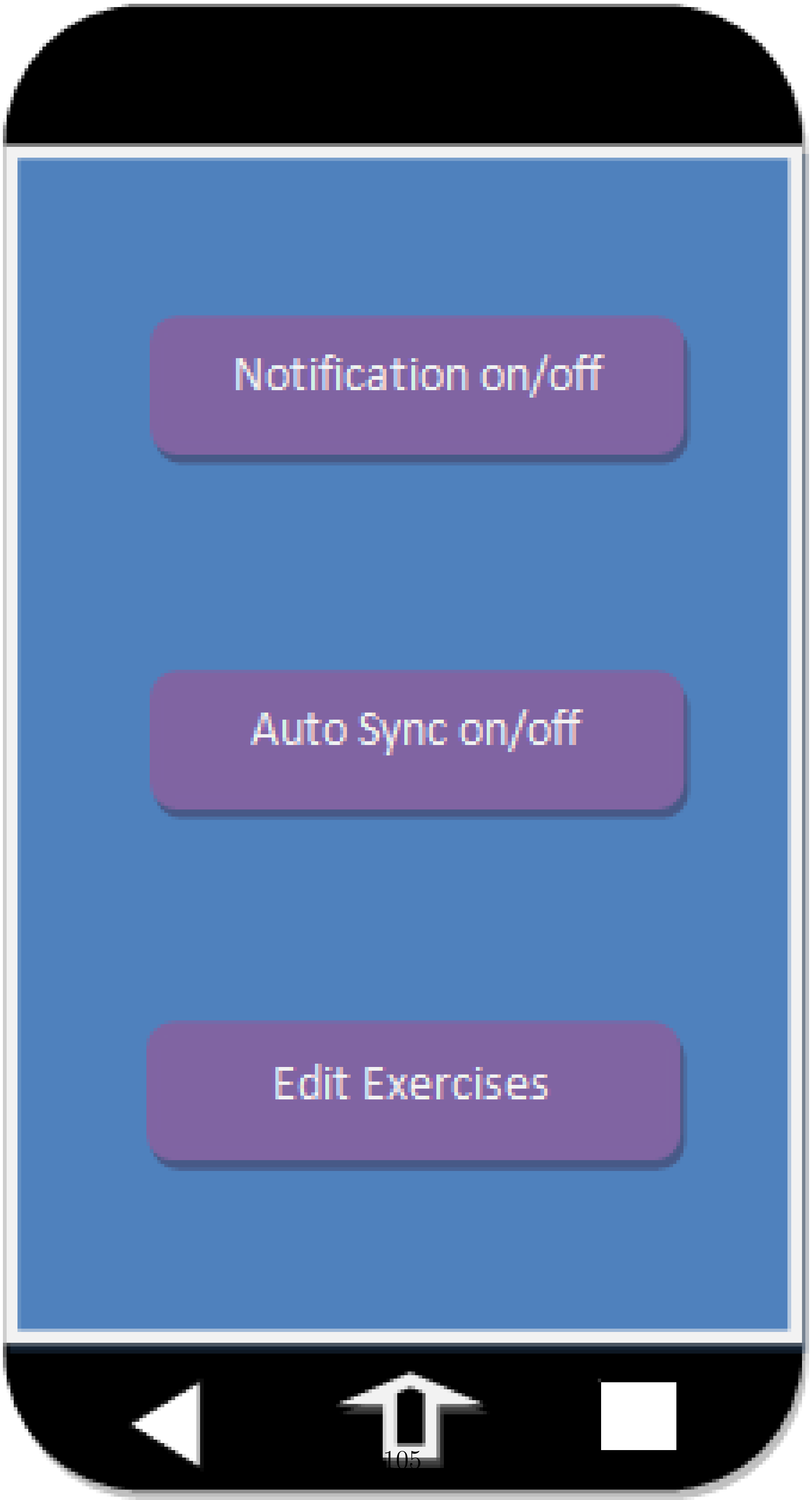


Figure 6.4: Settings screen of app

Chapter 7

TESTING

Testing will be compartmentalized with several subsystems being tested individually and then integrated one at a time to attempt to isolate errors and fix them with as little effort as possible.

These first set of test are focused around the basic safety requirements of the chair so that it can comply with the ANSI/BIFMA standard for the purposes of a basic office chair.

Testing the measurements of each sensor setup will be a challenge to overcome several obstacles we have been fretting, like the influences of clothing to the accuracy of the sensors, or the ability of certain clothing to absorb ultrasonic signals. The following tests will help us make this project more accurate and help answer the decisions on what kind of sensors we need to use.

Table 7.1: Chair Test 1

TestName	Testing the Chair to conform to the ANSI/BIFMA standard by using weights of various sizes and densities.
Objective	Have chair support weight of at least 250 lb distributed on the seat.
Description	Using several weights, from a weight set, add,weight to the seat of the chair in increments of 5 pounds starting,at 180 lb and increasing all the way to 255 lb.
Condition	The chair will be on solid ground with no lateral movement during the test, the chair will also be subjected to standard gravity of Earth, as well as standard temperature and pressure.
Expected Results	The chair will hold the full weight of 250 pounds without breaking or showing signs of breakage.

Table 7.2: Chair Test 2

Test Name	Confirm compliance with BIFMA standard
Objective	Have the chair not topple over when a weight of 25 lb is attached to the back of the chair.
Description	A weight of 25 pounds is affixed to the back of the chair using rope or chain.
Condition	The chair will be on solid ground with no lateral movement, during the test, the chair will also be subjected to standard, gravity of Earth, as well as standard temperature and pressure.
Expected Results	The chair will not topple over even with 30 pounds on the back of the chair.

Table 7.3: Chair Test 3

Test Name	Compliance With BIFMA standards
Objective	Have chair be adjustable by user for height of seat, headrest, and armrests by user for adaptations for motor adjustments.
Description	The chair will be adjustable in the height of the seat, as such it should be adjustable from a 16 to 21 inches high as is standard for most office chairs. The height will be measured from the supporting surface of the chair to the bottom of the seat, as the variable height of the top of seat would cause complications. The adjustments of the armrests will adjust between 7 to 9 inches above the seat, the headrest will support an adjustment of 18 to 24 inches above the seat.
Condition	The chair will be on solid ground with no lateral movement during the test, the chair will also be subjected to standard gravity of Earth, as well as standard temperature and pressure.
Expected Results	The chair should be able to support the heights listed in the standard and test description.

Table 7.4: Sensor Test 1

Test Name	Pressure Accuracy
Objective	Determine the accuracy and resistance of the different types of pressure sensors selected.
Description	Several pressure sensors will be tested for several categories including, cost, accuracy, capacity to resist being crushed, power consumption, and availability.
Condition	The Tests will be conducted in a controlled,environment, most likely the senior design lab, with weights of,varying size and weights.
Expected Results	The data collects will hopefully point to a sensor that meets all the requirements of the project and that sensor will be selected for use.

Table 7.5: Sensor Test 2

Test Name	Ultrasonic Vs Cloth
Objective	Determine the effects of different clothing material effects on ultrasonic sensors.
Description	An ultrasonic sensor will be setup with a solid,block at a predetermined distance from the sensor and several accuracy points will be taken to determine sensor overall,accuracy, then a piece of several types of fabric will be tested individually by placing them halfway between the solid surface and sensor, blocking the solid surface from the view of the sensor. Several data points will be taken with the clothing material in that position and a comment will be made about the accuracy of the sensor when blocked by a particular cloth in the test report.
Condition	This test will occur in a controlled environment,where the block used to set the control distance is a substance, known to work well with ultrasonic sensors, like as smooth metallic surface perpendicular to the detector signal.
Expected Results	The sensor will read the smooth metallic target,successfully and will be able to read the cloth targets with,acceptable accuracy.

Table 7.6: Sensor Test 3

Test Name	IR false positive test
Objective	Determine the accuracy of the passive IR sensor used for person detection.
Description	A passive IR sensor will be set up in a control environment where a heat source of varying temperature and distance from sensor will be placed,within the view of the sensor and data points will be recorded based on the output of the sensor.
Condition	A controlled environment where the ambient temperature doesnt fall outside the operating temperature of the sensor, and the control device is tested in increments of 3 degrees Celsius until the sensor cannot tell the difference between the background and the control object. Within that range of the last successful detection and the first failure a more precise pass with temperature increments of only 0.25 degrees Celsius difference between passes.
Expected Results	The detection range of the device will be able to identify a heat source of a person even if they are in clothing and have a large enough temperature difference in environment temperature of an office space.

Table 7.7: Sensor Test 4

Test Name	Actuator position sensing test
Objective	For detecting the position of chair arrangements there may be a set of sensors attached to the various adjustable mechanisms of the chair, determine what caliber of sensors to use.
Description	With the actuating mechanisms of the chair being mostly linear motion, the sensors best fit to measure this wide linear motion will need to be employed, test several types of liner sensors and compare them in terms of cost, accuracy, availability, and power consumption.
Condition	A test object will be moved along a linear path, the longest of which will be the maximum distance a piece of the chair travels in another test.
Expected Results	The linear sensor will be able to determine the position of the device to within half an inch of actual position.

Table 7.8: App Test 1

Test Name	App performance
Objective	Verify mobile application performance test.
Description	This test will determine the performance of the mobile application on several mobileplatforms running the android operating system. First the app will be installed on the system, and then launched, and the app must remain responsive to user input throughout a rigorous 15 second test involving opening and closing menus, killing and re-opening the app, and opening the server connection settings.
Condition	The app will be installed on several android phones, including high performance flagship phones like the HTC M8, and Samsung Galaxy S5, and low-end phones as well, like the Jiake G910, with devices running at least android version 4.6 or higher.
Expected Results	The app will perform acceptably on all devices tested, and will not cause any device to become inoperable for any period of time.

Table 7.9: Unit Test 1

Test Name	Pressure Maximum
Objective	Pressure sensors provide accurate reading at the required pressure
Description	Each individual pressure sensor will be tested for threshold and, accuracy using an ohmmeter in combination with a set of weights that will range in weight with small enough variation to achieve 0.2 N weight up to 20 N of force.
Condition	Assuming normal gravity of earth 9.81 m/s2 with,the weight maximum should only reach 4.4 pounds.
Expected Results	The sensors should give a variation in resistance through the full range of 0 N to 20 N in 0.2 N increments.

Table 7.10: Unit Test 2

Test Name	Microcontroller Network Test
Objective	Confirm link of microcontroller to internet through ICMP use.
Description	Using the internet control messaging protocol to make a reply request from a device on another network that will respond to the device.
Condition	A controlled WiFi network that will have been confirmed to possess an internet connection, and another network device that correctly responds to an ICMP.
Expected Results	The device will respond within 10 milliseconds without any problem.

7.1 Unit Testing

Even in the individual pieces of the project, the chair, the remoter server, and the application, there are subsections of those parts that must be tested to verify requirements. For each test case in the unit test portion there are likely external sources of output being utilized for test verification purposes.

7.2 Integration Testing

Once all the portions of the project have been confirmed to work independently of each other, it becomes necessary to make sure they work together. These integrations are simple portions that rely heavily on interface standardizations, and protocol compliances, a major portion of the standards relevant to project section of this document.

Table 7.11: Unit Test 3

Test Name	Height adjustment test
Objective	Confirm depth sensor placement on chair correlates to user height, with correct proportions.
Description	The chair will be adjusted for several people of different sizes, and then with sensors in their positions we measure depth and pressure and correlate the data with proper posture, and see if the sensor matches close enough.
Condition	The depth sensors will be mounted to a test bed for power and data collection that will be constructed independent of the chair, and only used for testing purposes.
Expected Results	The sensors position should correctly align to the user's anatomy within tolerances.

Table 7.12: Unit Test 4

Test Name	Algorithm Test
Objective	Test the algorithm to confirm it is making correct analysis of data available.
Description	Feed the algorithm a set of artificially created data that will simulate several situations including, but not limited to, current correct posture, current incorrect posture, historically incorrect posture with current correct posture, historically correct posture with current incorrect posture.
Condition	The feedback will in a controlled environment, most likely a development machine running either a Windows or Linux OS.
Expected Results	The return from the algorithm will inform the user of the proper course of action to improving their posture.

Table 7.13: Integration Test 1

Test Name	Phone and Server
Objective	To confirm communication between the applications and the remote server.
Description	With the server active and the application running on one or all of the platforms specified a request will be made by the applications for data, and upon data reception the application,will display the corresponding data.
Condition	The server will be online and accessible, the application will have internet connectivity.
Expected Results	The data should successfully be sent and received.

Table 7.14: Integration Test 2

Test Name	Controller to server
Objective	Push updates from chair to remote server.
Description	The chair will have to send updates to the server at regular intervals to make sure the data displayed to the user will be up to date, sending artificially generated data through the microcontroller to the server and confirm data integrity.
Condition	The server will be internet accessible and the microcontroller will have internet access through the attached wifi module.
Expected Results	The data received by the server will be exactly the same as that sent from the microcontroller.

Table 7.15: Integration Test 3

Test Name	Sensor to Microcontroller
Objective	Confirm the sensors are connected to the microcontroller correctly and the controller is receiving measurements correctly.
Description	Each set of sensors will be connected one at a time and a simple output test compared to the output of the controller will take place to confirm that the voltage, or signal is properly transmitted and received.
Condition	The sensors will exit in a controlled setting as to minimize possible errors, and the controller will be connected to a test bench output device to confirm it is receiving properly.
Expected Results	The controller should output the correct readings from the sensors.

Table 7.16: Integration Test 4

Test Name	Combination
Objective	Assemble all the components together and do a system check.
Description	Put the sensors in the chair, put the microcontroller and wifi module in the chair, confirm server operation, confirm app operation. Create several sets of data by actually sitting in the chair and using it. Confirm the posture recording on the application
Condition	All sensors in chair, microcontroller connected to sensors and wifi, server running, app running and connected to server.
Expected Results	The system will display a feat of continuous data collection and processing, and celebration soon to follow.

Table 7.17: Acceptance Test 1

Test Name	Application Usability
Objective	Measure user satisfaction with application performance and layout.
Description	Have several users follow a set of vague instructions on installing, launching, and navigating the application.
Condition	The app will be used on the platform at the user's discretion.
Expected Results	Data relating to user experience.

Table 7.18: Acceptance Test 2

Test Name	Minimal User Interaction
Objective	Determine chair impact on users everyday experience
Description	Test the chairs impact on a user's everyday life by placing it in place of an existing office chair and seeing how often our chair proves to be more troublesome than the standard office chair.
Condition	Home office of development team.
Expected Results	The chair should only impact the use by a user with respect to charging the battery on a regular basis.

7.3 Acceptance Testing

To have the system work on an engineering level is fulfilling of some of our requirements, but there are a few sets that specify that the system should meet expectations of users in terms of performance and reliability. The acceptance testing phase is strongly based in the experience of users outside the development team, as such these test will not have definite results and only plan to create a baseline for improvements to the system.

Chapter 8

ADMINISTRATIVE SOLUTION

There are those who plan to fail and those who fail to plan, following neither of these philosophies we set out with a plan to make this project possible within the time limitations we face. It is important to have clear goals and limitations understood by all group members for a project to successfully move forward. When different group members design to different specifications they have have to rebuild to allow for one of the pieces to work with the other, and hopefully the rest of the project. This section will go into detail on the topic of many different facets used to organize this project.

Several sections hold greater importance than others for the intent of organization by importance these section will be presented first in this document, they will follow the structure of this paragraph. The milestones and timeline of the project are our greatest limiting factor, as it dictates how far we can take the characterization and testing before the project becomes due. No project can be completed without funding of appropriate size, in both time and actual money, for the budget to balance we cannot have expensive devices that can compensate for other failures, as such the budget is more than tight, it is absolute. The division of work is important for the group portion of a group project, and for each member to contribute to the portion that they best know helps build teamwork and experience. With the major administrative hurdles out of the way the simple task of explaining our members ambition and practices as they pertain to this project.

8.1 Timeline and Milestones

To keep a schedule on target there needs to be measurements of progress towards an end goal, with engineering this becomes challenging, as quantitative measurements sometimes show no correlation to actual progress. In order to better manage the tasks and progress of the development team a set of milestones were established. These tasks were broken down into major development areas with the first being the completion of this design paper as outlined in the table below. Beyond the creation of this paper there is the creation of the device of itself, those milestones are outlined in the Table X: Prototype Tasks seen below the table Table X: Milestones and Tasks. Keeping to this schedule is an absolute necessity as the completion of the tasks provided are directly related to the requirements of the class.

After the spring semsester comes to a close and the final paper becomes due, there is no cause for rest, as other portions of the project need to be actively worked on to improve out outlook for the fall semester. To begin this arduous journy a sencondary set of tasks that revolve arounf the actual prototype and final construction of the device has been layed out, though the tasks have yet to find their true nature, they will be delt with in time.

8.2 Budget

To create a proper presentation of technology and its application in a chair to help correct posture, a sum of money will be required. Before any of us can think of contributing to the project we must find pieces of the project that will fit our needs for as little as possible. Selecting components and vendors that can provide quality components capable of meeting our performance specifications and for as little cost as possible is essential for keeping a project within budget.

Acquiring funding for the project proved difficult, as many of us have no experience with many of the companies that we sought for funding. The final contribution of the project has come from the group members themselves, and working jobs to pay for this project is no easy task. Balancing personal budgets to allow for contribution to the project is difficult on a college student wages.

8.3 Roles and Responsibilities

In order to complete this project with all its requirements under the set time constraints, parts of the project have been divided and designated to each of the group members. This will make efficient use of our time. A description of the group member and their respective role will be detailed below.

Freddie Lopera is an Electrical Engineer Major at the University of Central Florida. As the pure electrical engineer in the group, he will be responsible for finding a power solution for the system. Another main role that Freddie has is PCB design and hardware interfacing. During the prototyping phase, he will make sure all the hardware is functioning properly.

Johnny Claros is an Electrical/Computer Engineer Major at the University of Central Florida. As the second electrical engineer in the group, his main job will be to assist

Table 8.1: Tasks for Paper

Task Name (Paper)	Task Owner	Comment
Component Specification-Communication	Floyd	
Application Specification	Floyd	
Application Spec-Platform Specs	Floyd	
Application Spec-OS	Floyd	
Software Design	Floyd	
Prototype Construction & Coding	Floyd	
Relevant Technologies	Floyd	
Table of content users	Floyd	
Comp Spec-Sensors-Spine	Fred	
Component Specification	Fred	Broken down int subsections.
Comp Spec-Controller	Fred	
Comp Spec-Sensors	Fred	
Comp Spec-Power	Fred	
Desktop Unit VS Cloud	Fred	This comparison will be a joint effort.
Circuit Board Design	Fred	
Aesthetic Design	Fred	
Relv Tech-Sensors	Jacob	Broken down into subsections.
Relv Tech-Sensors-Sense User	Jacob	
Block Diagram	Jacob	
Standards Relevant To Project	Jacob	No more than 10 pages.
Constraints based on health	Jacob	
Testing	Jacob	
Administrative	Jacob	
Appendix	Jacob	
Executive Summary	Johnny	
Project Motivation	Johnny	
Objective and Goals	Johnny	
Project		

Table 8.2: Prototype and Construction Table

Task Name (Construction)	Due Date	Task Owner	Comments
Server Bseline	Beginning of Fall	Jacob	
Server Communication setup	End of Fall 2016		
Proper Posture Algorithm	Beginning or Fall	Johnny	
Sensor Assembly	Mid Fall 2016	Johnny	
Microcontroller Program	Mid Fall 2016		
Microcontroller	Mid Fall 2016	Fred	
App Baseline	End of Fall 2016	Floyd	
Physical Chair Adjustments			Overhead
Power Controller Assembly	Mid Fall 2016		
App Port to Multiple Platforms			
Microcontroller Board Creation	Beginning of Fall		
Sensor Connection	Mid Fall 2016		
Microcontroller Communication Creation			

Table 8.3: Budget

Predicted Budget	
Chair	$200
Sensors	$300
On-board Device	$80
Wireless communication device	$40
Motors and Actuators	$120
App Development License	$50
Funding	$-0
Planned Out of Pocket	$790
Unforeseen Expense	$210
Likely Total	$1000

with hardware interfacing; specifically with the pressure sensors and vibration motors selected, He will also have a hand in designing the algorithm, app development, and assuring the product is user friendly.

Floyd Petersen is a Computer Engineer Major at the University of Central Florida. One out of the three computer engineers in the group, he will be tasked with the development of the Posture Perfect user application. Developing, troubleshooting, and testing of the application is his primary task. Secondary task is co-development of the code for the microcontroller and/or server.

Jacob Barr, a computer engineering student at the University of Central Florida, is looking for ways to improve the everyday lives of people, and as such he was strongly supportive of creating a chair to help not fall into the habits of bad posture. As yet another computer engineer on the team the positions with hardware have been filled by the most qualified members, leaving the one topic no-one on this team is familiar with, the cloud. A combination of database management and active computation of received data the position is more akin to an IT position but ready to tackle any problems ahead he forges forward in his learning.

Chapter 9

Project Summary and Conclusion

The dream of having perfect posture is difficult, but not impossible. Our reason as to why the Posture Perfect project was chosen by are our group is to help make that dream of a perfect posture come true. We as a group understand firsthand the turmoil that the average human being faces when at a desk using their computer hours on end without a break in between. This was a good incentive for a group of engineers to take advantage of and help correct. In order for us to help solve a universally problematic issue we had to be ambitious. What better way to approach this project then to start researching everything we could. We had to understand everything about the human posture from what good posture is to how a person could develop bad posture when sitting in a chair. This extensive research gave us ideas as to how we would go about helping a person that is sitting in a chair the improper way and is in the chair for too long. After we came to an agreement we started to brainstorm as to what components were required for use to create the chair, so we did more research. The key part of this project was the type of sensors that would give use the most accurate reading in order to assess state of the persons back. We had to put more time into this aspect of the project because if the sensors can not do their job then the project would be a failure. When we obtained a rough idea of what sensors we wanted to integrate into the chair. We did a more detailed search into them and moved on to the microprocessor. The microprocessor was another important component this is the brains behind the project, so a massive amount of time went into pick this part. After we decided on what would be the most appropriate board all we had left was how we would display the results to the user. The group came to the conclusion to create an application to take care of this job. The data would be sent to a cloud service and is retrieved by the application that the person is using. This was the rundown on how design the Posture Perfect chair. The chair components was specifically chosen for optimization of convenience and power consumption. So one of the agreement that we all had from the beginning of this project was the chair being powered by a battery and so all the components had to be low powered in order to avoid having the user to recharge the battery constantly. This design was then prototyped and test were created for use to see if it works.

Posture Perfect is going to change the way that people think about maintaining their back. The chair is going to bring us as humans into the future of a healthy lifestyle. With its constant reminder of limiting the time that one should sit in chair. Also its available anytime, anywhere access to the users data with online server. This not only helps the user remember to watch their posture when not using the chair, but also paves the way for the chair to join the growing number of objects that are in the internet of things which is the future. Posture Perfect is PERFECT!

Chapter 10

APPENDICES

10.1 Copyright Permissions

10.1.1 Permission from TI

10.1.2 Permission from Okamura

10.1.3 Permission from Precision Microdrives

10.1.4 Permission from Tekscan

10.1.5 Permission from Interlink Electronics

10.1.6 Permission from Parallax Inc.

10.1.7 Permission from Cleveland Clinic

10.1.8 Permission from Atmel

10.2 Refrences

FL Freddie Lopera

To: univ@ti.com;

Reply all

Thu 4:43 PM

Sent Items

Hello,

I'm an electrical engineering student at the University of Central Florida and I am working on my Senor Design group project. I am emailing you today to request permission to use some of the diagrams and/or figures found on TI's webpages and/or datasheets in our Senior Design report.

We will provide all necessary citations and references in the Final Report including the credit line "Courtesy of Texas Instruments", and it will only used for academic purposes.

Thank you in advance!

Freddie Lopera

Figure 10.1: Requested Permission from TI

univ@ti.com
To: Freddie Lopera;
11:41 AM

Hello Freddie,

You have permission to you any information found on TI's webpages as long as you include the "Courtesy of Texas Instruments" citation. Best of luck on your Senior Design project and report!

Regards,

John Gracia
Program Coordinator
North America University Program
Texas Instruments
www.ti.com/university
Email: univ@ti.com

==

Figure 10.2: The Response from TI

Permission to use photos on senior design project

Johnny Claros
To: sales@okamura.com.sg;
Reply all
12:31 PM

Greetings,

I am an electrical/computer engineering student at the University of Central Florida and I am currently working on my senior design project. I am emailing you to request permission to use some photos found on your website. We will provide all necessary citations and reference in the Final Report. It will only be used for academic purpose.

Thank you in advance for your consideration.

Figure 10.3: The request sent to Okamaru

Permission to use datasheets, diagrams, and tables on website

Johnny Claros

To: enquiries@precisionmicrodrives.com;

Reply all

12:41

I am an electrical/computer engineering student at the University of Central Florida and I am currently working on my senior design project. I am emailing you to request permission to use some of the diagrams and/or figures and/or datasheets found on Precision Microdrives' website in our senior design report.

We will provide all necessary citations and reference in the Final Report including credit line "Courtesy of Precision Microdrives". It will only be used for academic purpose.

Thank you in advance for your consideration.

Johnny Claros

Figure 10.4: Request Sent to Microdrives

Doug Roberts (Precision Microdrives) <enquiries@precisionmicrodrives.com>

Reply all

To: Johnny Claros;

Mon 6:51 AM

=== Please reply ONLY ABOVE THIS LINE when responding ===

From: Doug Roberts

Dear Johnny,

Thank you for requesting permission, you are welcome to use the content from our datasheets in your report with the appropriate reference. If the article or any elements of it are published online, I would ask that you include a hyperlink and / or a reference of our website www.precisionmicrodrives.com.

I wish you luck with your design project and degree.

Kind regards,

Doug

Doug Roberts, BEng MSc MIET

Figure 10.5: The Response from Microdrives

Permission to use datasheets, diagrams, and tables on website

Johnny Claros

To: info@tekscan.com;

Reply all

10:31

I am an electrical/computer engineering student at the University of Central Florida and I am currently working on my senior design project. I am emailing you to request permission to use some of the diagrams and/or figures and/or datasheets found on Tekscan's website in our senior design report.

We will provide all necessary citations and reference in the Final Report including credit line "Courtesy of Tekscan". It will only be used for academic purpose.

Thank you in advance for your consideration.

Johnny Claros

Figure 10.6: Request sent to Tekscan

LM Laura McCann <LMcCann@Tekscan.com>

To: Johnny Claros;

Reply all

Mon 5:00

Action Items

Hi Johnny,

I'd be happy to help you. What exactly are you looking for and what is the project? I can provide you with higher resolution photos. We just need you to reference Tekscan, Inc. and the names of whatever products you show along with the trademark or registered symbol.

Thanks!
Laura

Figure 10.7: The Response from Tekscan

JC Johnny Claros

To: americas@interlinkelectronics.com;

Reply all

10:34

I am an electrical/computer engineering student at the University of Central Florida and I am currently working on my senior design project. I am emailing you to request permission to use some of the diagrams and/or figures and/or datasheets found on Interlink Electronics' website in our senior design report.

We will provide all necessary citations and reference in the Final Report including credit line "Courtesy of Interlink Electronics". It will only be used for academic purpose.

Thank you in advance for your consideration.

Johnny Claros

Figure 10.8: The request sent to Interlink

KA Ken Altman <kaltman@iefsr.com>

To: Johnny Claros; Cc: Lajoy, Jaynie <jlajoy@iefsr.com>;

Johnny,

You are welcome to include our documentation in your senior design project. Good luck with the project -

Regards,

Ken

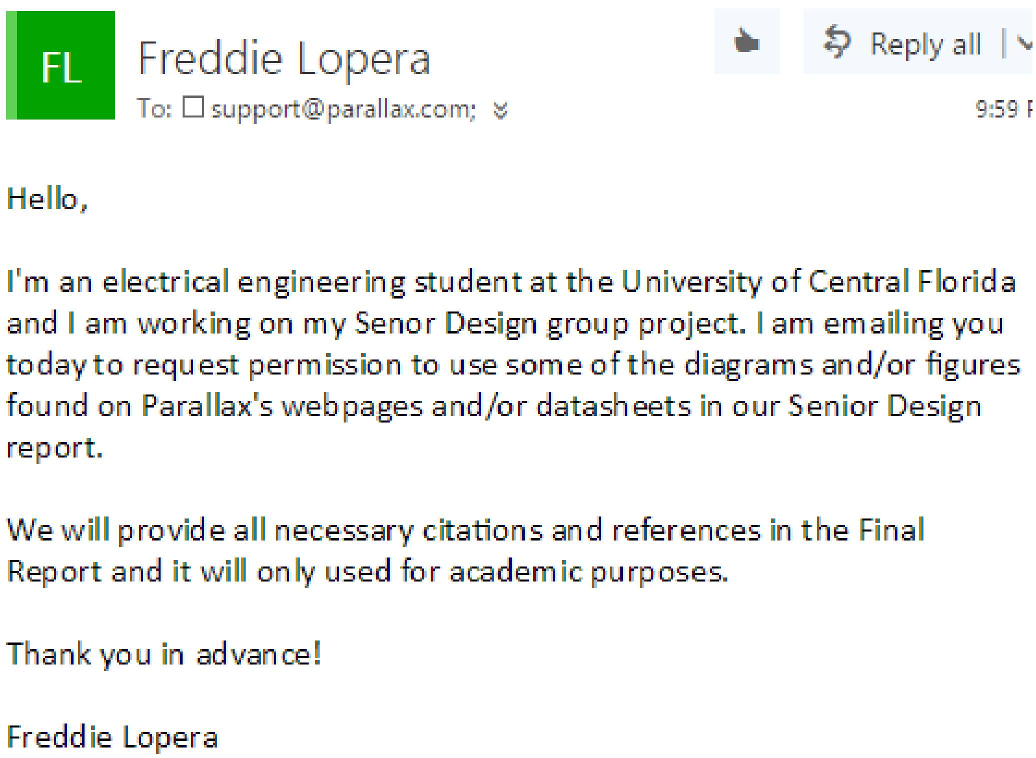
KEN ALTMAN
REGIONAL SALES & BUSINESS DEVELOPMENT MANAGER

INTERLINK ELECTRONICS®

www.interlinkelectronics.com

Phone: +1 919.210.0418
Skype: ken.altman5
Email: kaltman@iefsr.com

Figure 10.9: The Response from Interlink



FL Freddie Lopera

To: support@parallax.com;

Reply all

9:59 F

Hello,

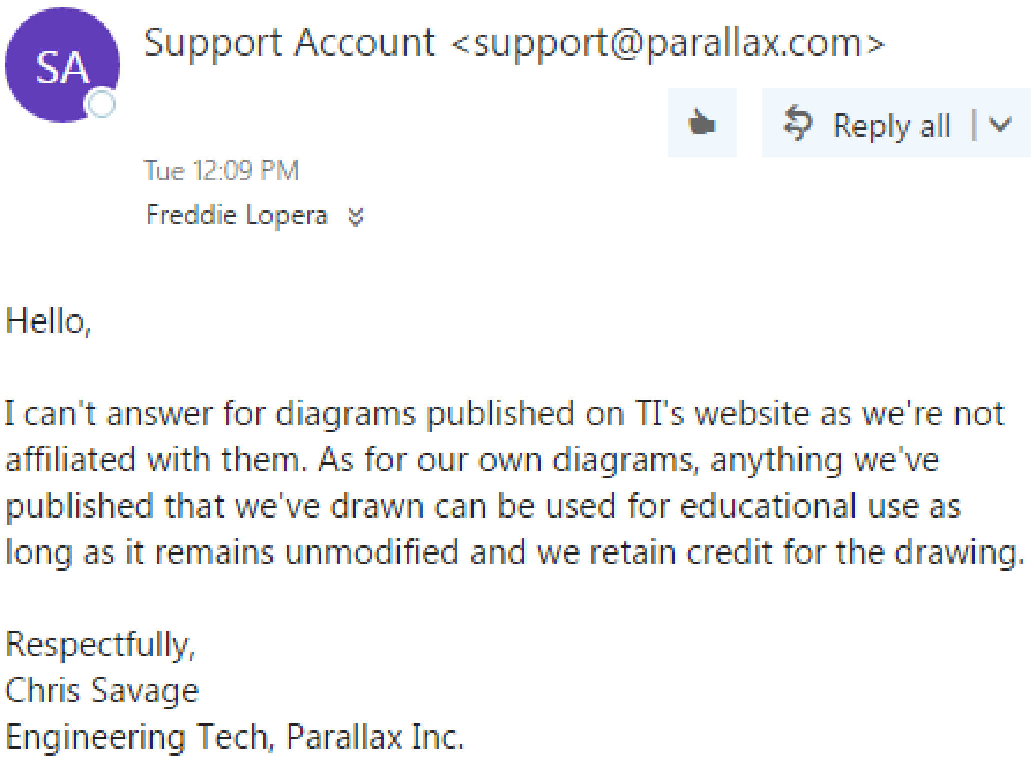
I'm an electrical engineering student at the University of Central Florida and I am working on my Senor Design group project. I am emailing you today to request permission to use some of the diagrams and/or figures found on Parallax's webpages and/or datasheets in our Senior Design report.

We will provide all necessary citations and references in the Final Report and it will only used for academic purposes.

Thank you in advance!

Freddie Lopera

Figure 10.10: The request sent to Parallax



SA

Support Account <support@parallax.com>

Reply all

Tue 12:09 PM

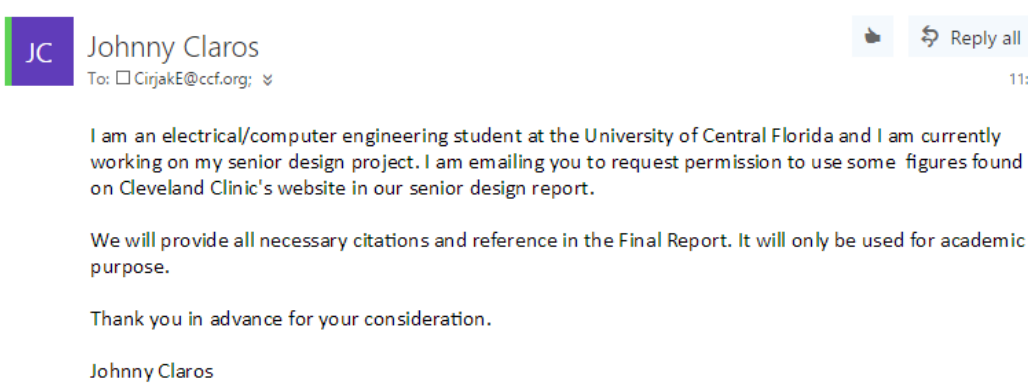
Freddie Lopera

Hello,

I can't answer for diagrams published on TI's website as we're not affiliated with them. As for our own diagrams, anything we've published that we've drawn can be used for educational use as long as it remains unmodified and we retain credit for the drawing.

Respectfully,
Chris Savage
Engineering Tech, Parallax Inc.

Figure 10.11: The Response from Parallax



JC

Johnny Claros

To: CirjakE@ccf.org;

Reply all

11:

I am an electrical/computer engineering student at the University of Central Florida and I am currently working on my senior design project. I am emailing you to request permission to use some figures found on Cleveland Clinic's website in our senior design report.

We will provide all necessary citations and reference in the Final Report. It will only be used for academic purpose.

Thank you in advance for your consideration.

Johnny Claros

Figure 10.12: The request sent to Celveland Clinic

FL Freddie Lopera
6:24 PM
customerservice@atmel.com

Reply all

Hello,

I'm an electrical engineering student at the University of Central Florida and I am working on my Senor Design group project. I am emailing you today to request permission to use some of the diagrams and/or figures found on Atmel's webpages and/or datasheets in our Senior Design report.

We will provide all necessary citations and references in the Final Report and it will only used for academic purposes.

Thank you in advance!

Freddie Lopera

Figure 10.13: The request sent to Atmel

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