Accessible Weight Scale for Seated Users

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1. Alternative Design Project # 2

Introduction

The clients for the accessible weight scale for seated users all have mobility problems that make it difficult for them to use a standing scale. These clients may want to measure their weight several times a day in order to ensure that they are remaining healthy. The design for the accessible weight scale for seated users will integrate a weight scale into a shower chair allowing the user to easily and independently measure their weight. The shower chair scale will have several main components a shower chair, load cells, a microcontroller, a wireless transmitter, a hand held console, and foot support.

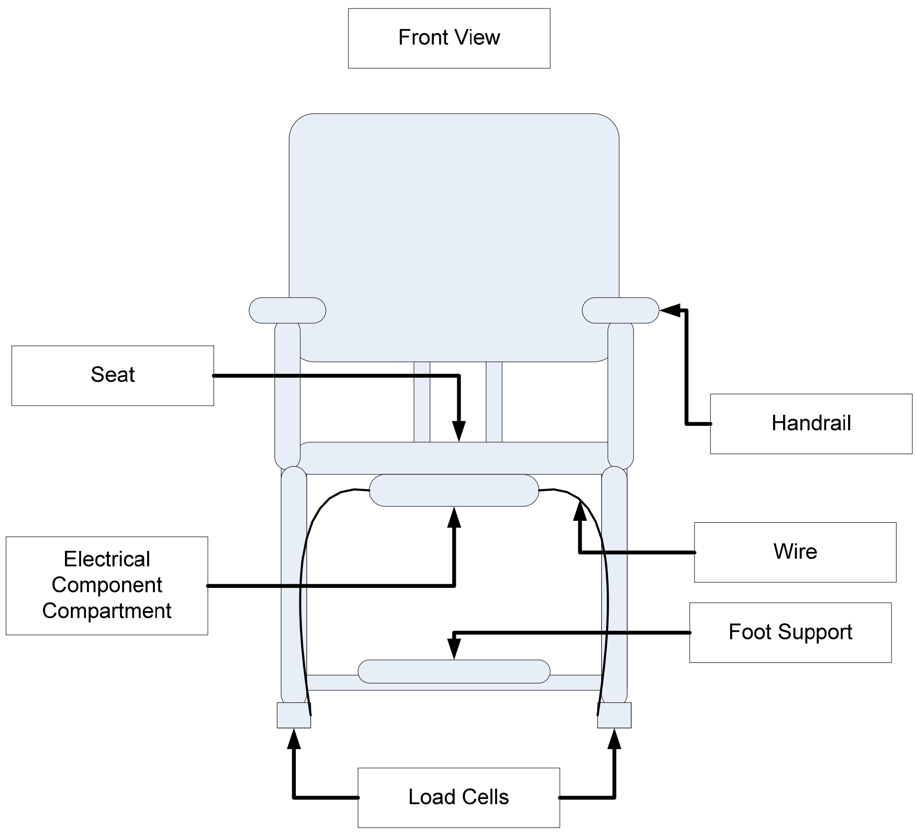


Figure 1 – Alternative Design 2 Shower Chair Scale

Figure 1 shows the overall appearance of the shower chair scale. The shower chair will be able to support at least 500 pounds. The height of the chair will be adjustable at each of the four legs.

The load cells will be put into the feet of the chair in order to incorporate all the weight of the user and the chair. The load cells will have to be made water proof in order to ensure that they operate in a shower setting. Wires connecting the load cells to the printed circuit board (PCB) will run along the legs and arms of the shower chair into a waterproof compartment housed underneath the shower chair. The wires will be surrounding by clear Polyvinyl Chloride

(PVC) tubing to aid with keeping the device waterproof and to protect the wires from damage. A waterproof adhesive sealant will be used in various places on the device to aid in waterproofing it as well.

Also incorporated into the waterproof compartment underneath the shower chair seat will be the microcontroller, which will be responsible for converting the signal from the load cells into a weight measurement that can be outputted in both kilograms and pounds. These outputs will be sent to the hand held console via a wireless transmitter, which will also be housed in the waterproof electrical component compartment.

The hand held console can be mounted anywhere inside the shower or on the shower chair since it will come with a suction cup attachment and Velcro if the user prefers to mount the hand held console on the arm of the chair. The handheld console will also be waterproof and provide two forms of output, visual and audio.

For posture support while using the device the shower chair will have hand rails incorporated into the chair and foot support will be added in the machine shop. An aluminum bar will be welded between the front two leg supports and a flat platform will be mounted on the bar.

Figure 2 shows a block diagram of the operation procedure for the accessible weight scale for seated users below. The user inputs are shown in rectangles with rounded edges and the actions completed by the accessible weight scale are shown in rectangular boxes with sharp edges.

Prior to using the device for the first time the user will have to turn the device on and press the “Tare” button on the handheld console. Pressing this button will cause the scale to take a measurement without the user on the device. This measurement will be stored in the microcontroller as the weight of the scale alone. This weight will be subtracted from the user’s weight when a measurement is taken so that the weight outputted by the device is the weight of the user alone. To provide the most accurate measurement the user could tare the device prior to every use, but it is not necessary if a small amount of error is allowable.

To operate the device the user will pick up the hand held console and switch the analog switch to the “ON” position. Next the liquid-crystal display (LCD) screen interface will display the message “Please be seated on the scale and press the measure button when ready.” This prompt will also be given in the form of audio output by the text to speech device housed within the handheld console. The user with impaired vision will receive the prompt as well. The user now has two choices. He or she can get on the scale and take a measurement or they can view past measurements by pressing the scroll up or down key. If it is more convenient for the user, the user can get on the device prior to turning it on as well.

To take a new measurement the user will get on the scale and press the “Measure” button. At this point the load cells at the base of each leg of the shower chair will send the reading to the microprocessor, which will subtract the current weight from the weight of the scale. This will be the measurement of the user’s weight, which will be converted into kilograms and pounds, stored in the memory, and displayed for the user on the LCD screen as well as the audio output through the speaker. The user now has the option of turning off the device or viewing past measurements.

The user can scroll through past measurements by pressing the up or down arrow on the user interface. These weights will be displayed in both kilograms and pounds on the LCD screen and the measurements will be outputted by the text to speech device as well. Figure 2 shows the block diagram of the process outlined above.

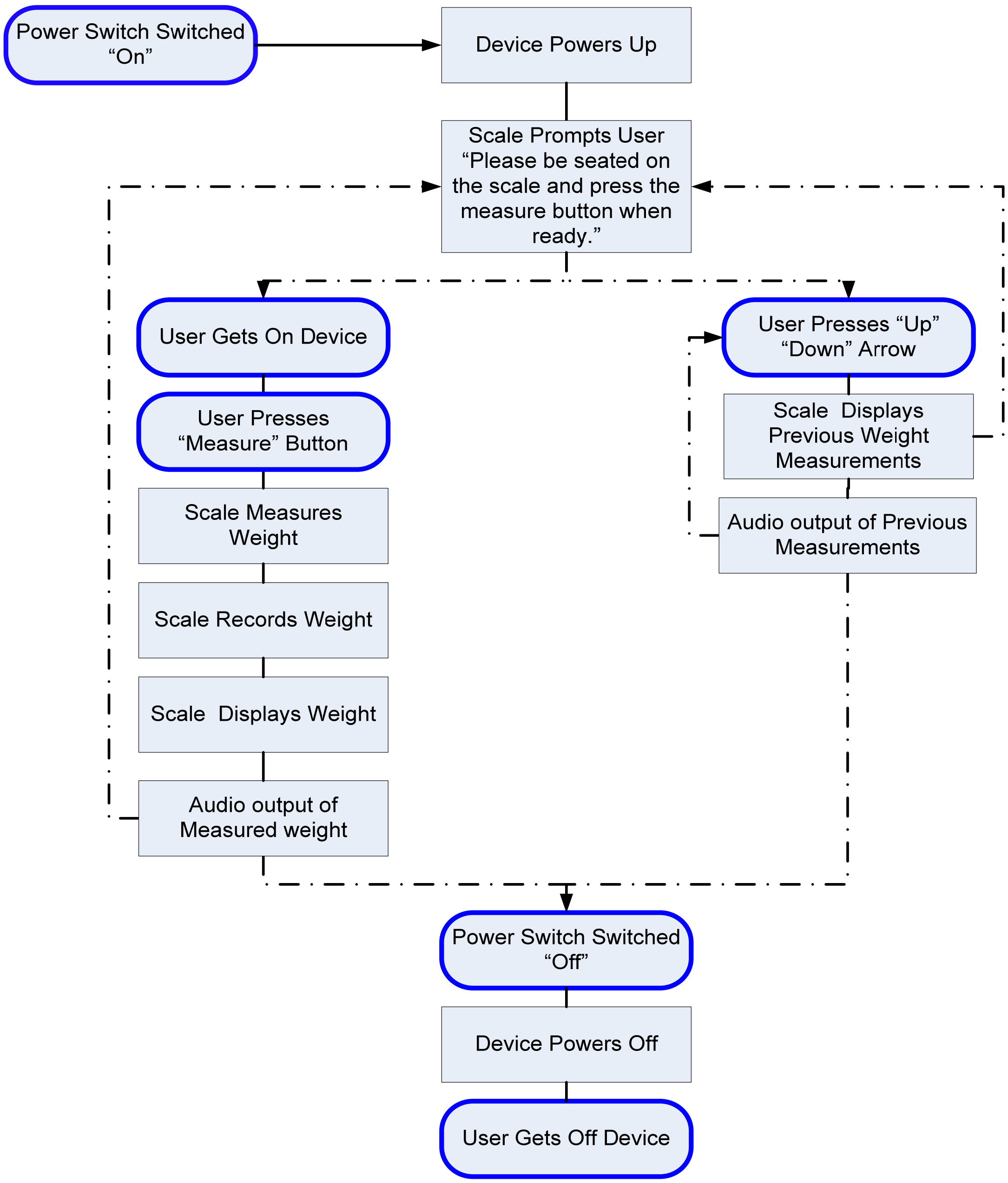


Figure 2 – Block Diagram of Operation Procedure

There are several differences between the first alternative design and the second alternative design. One major difference is that the first alternative design for the accessible weight scale for seated users was integrated into a toilet seat, while the second alternative design is a scale integrated into a shower chair. The shower chair will make use of four load cells rather than three. The scale will also make use of a wireless transmitter to communicate between the electrical component compartment and the handheld console.

1.2 Subunits

Shower Chair

There are several functions of the shower chair in this device. First it acts as a comfortable surface for the user to sit on while using the device. It also supports the user's weight while a measurement is being taken. Thirdly it acts as a mounting surface for the foot support, load cells and electrical component compartment.

Figure 3 – 1249 Heavy Duty Shower Chair with Arms

Above figure 3 shows the shower chair that will be purchased for this alternative design. It has a high strength rust-proof aluminum frame that can support up to 500 pounds. It also has handrails and adjustable height. Its maximum height is 20 inches and its minimum height is 16 inches. The seat is made of a blow-molded plastic with a textured finish. This shower chair also has suction cup rubber attachments at the bottom of each leg of the chair. These attachments will have to be removed to mount the load cells at the base of each leg, but they will be replaced underneath the load cells using a waterproof plastics adhesive. [1]

Below figure 4 shows how the other design components will be mounted on the shower chair.

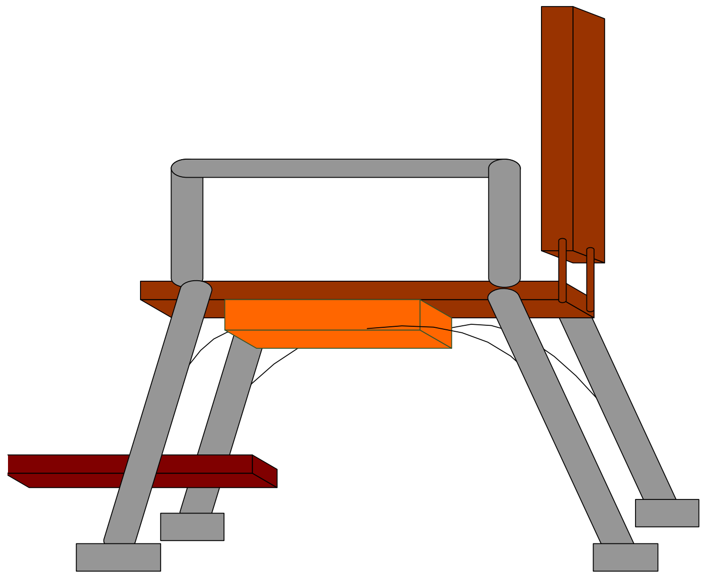


Figure – 4 Side View of Shower Chair

The load cells will be mounted in the rubber stops attached to the bottom of each leg of the shower chair. The wires that will connect the load cells to the electrical component compartment will also be enclosed within the supports of the chair. The device will be tested for 550, 200 and 100 lbs users the corresponding weights will be applied on the chair and the leg support to ensure that the shower chair is operational. After adding the suction cups back on beneath the load cells the chair will be tested on a wet surface to ensure that the chair will not slide and that the suction cups are properly attached to the bottom of the chairs feet and will not come off even when substantial forces are applied in the horizontal direction.

Foot Support

The function of the foot support is to keep the user's feet off the ground. The weight applied to the foot support is distributed to the support of the chair. This will ensures that all of the user's weight is distributed onto the chair support and incorporated into the measurement.

The foot support will be made of aluminum. It will consist of a circular bar, which will be welded to the two front legs of the shower chair. Mounted on the round cross bar will be a rectangular surface that will act as the foot support for the user. The surface of the foot support will be made of a flat aluminum sheet with rounded edges. On top of the surface three rubber strips will be attached using the waterproof plastic adhesive. These strips of rubber will prevent the user's feet from slipping off of the foot support during use. The foot support will have two resting positions a horizontal position and a vertical position. The horizontal position will allow the user to rest their feet while the scale is in use. The vertical position will keep the foot support out of the user's way if they wish to rest their feet on the floor of the tub while the scale is not in use.

The strength of the foot support will be tested by applying 550 lbs on the support. The device should be able to withstand a weight of up to 500 lbs. this test is essential to avoid any injury to the user and or damage to the device because the 500 lb user might stand on the foot support while getting on the device.

Load cells

The function of the load cells is to measure the compression force of the user sitting on the toilet seat. This compression force is changed into an electrical signal which is then sent to the electrical component compartment via wires, and input into the A/D conversion ports on the microprocessor for conversion of the analog signal to a digital signal. Most load cells are based off of traditional strain gauges, and utilize strain gauges to provide accurate measurements. The strain gauge has a thin metallic foil that is bonded to a dielectric layer, which transmits the electrical signal using induction. This involves the electrically charged film to create an additional electrical charge, which is sensed by the strain gauge. When a force is applied to the strain gauge, the foil is deformed causing a change in its electrical resistance. A Wheatstone Bridge then measures the changes in resistance, and relates this value to the gauge factor, where $GF = (\Delta R/R)/(\Delta L/L)$. A figure showing the related forces and dimensions of strain is shown on the following page:

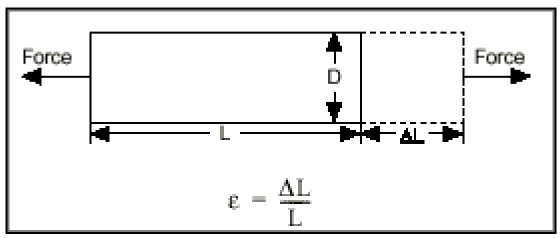


Figure 5 – Strain Specification

The Wheatstone Bridge consists of four resistive arms with a voltage excitation source. When the excitation voltage is applied across the bridge the output voltage will equal the following equation:

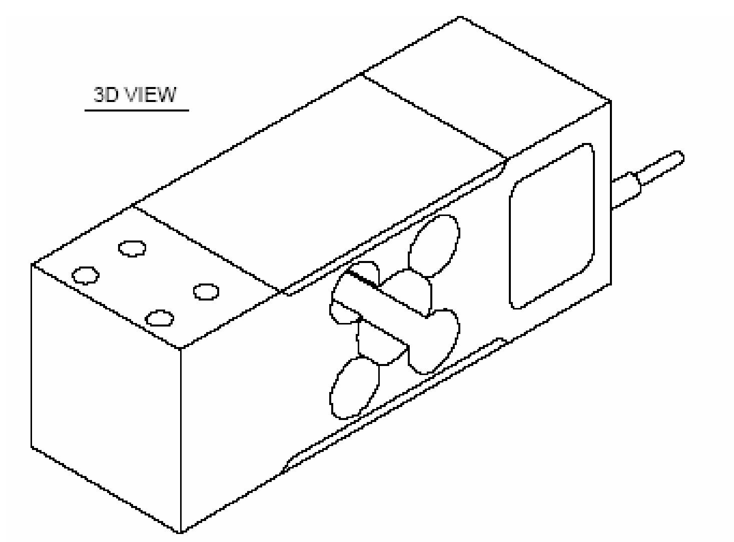
$$V_O = \left[\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2}\right] \bullet V_{EX}$$ [2]

The output voltage can then be used to calculate the applied force onto the strain gauge. The output voltages of strain gauges is usually quite small; therefore, the output signal will have to be amplified to boost the signal level for an increase of measurement resolution and improved signal to noise ratios. The amplification will also allow for the microprocessor to receive the appropriate minimum current for A/D conversion of the signal. Also, as with many electronics, there will be noise that can couple to the strain gauges. Therefore, a lowpass filter will have to be implemented to remove the high frequency noise associated with the electronics and environment.

In order to function correctly, the strain gauge must be mounted to a strain element using an adhesive due to the delicacy of the thin piece of wire within the gauge. The strain gauges that are intended for use in the project utilize a simple beam mounting configuration. This configuration, along with the proper adhesive, should allow for high accuracy and little error in the calculations. The strain gauge and element will have to be housed in either a laminate material or metal casing in order to prevent shock to the load cell, as well as adequate prevention of contact with liquids.

There are numerous different load cells available on the market, but for the design project the SMD Sensors S290 Load Cell has been chosen in order to provide optimal functionality while being relatively cost-effective. An initial search for load cells resulted in many high capacity rated load cells that were very expensive. The S290 Load Cell, rated at a capacity of 250 pounds, has a cost of $190 per load cell. The group intends to implement four load cells for the design and manufacture of the device. Four of the load cells, all rated at 250 pounds capacity, will provide optimum weight measuring capacity and accuracy, as well as reducing the price of the prototype due to having a fairly low cost. Also, the S290 Load Cells are quite small and have a low-profile appearance, which will allow for the placement of the load cells on the underside of each of the shower chair legs; thereby, mimicking the actual stops or cushions on the underside of the legs, especially when used in conjunction with the rubber stops. As previously mentioned, proper adhesive will have to be used to mount the load cells to the undersides of the shower chair legs, and square or rectangular rubber stop will also have to be mounted to the load cells. This will result in unwanted slippage of the shower chair, and consequently the load cells, when the shower chair is in use and weighing is taking place. It will also provide accurate calibration of the load cells when the user tares the weight scale. A picture resembling the load cell, its dimensions, and its related specifications are shown below and on the following page:

Figure 6 – S250 Miniature Platform Load Cell (Same Design as S290, but smaller)



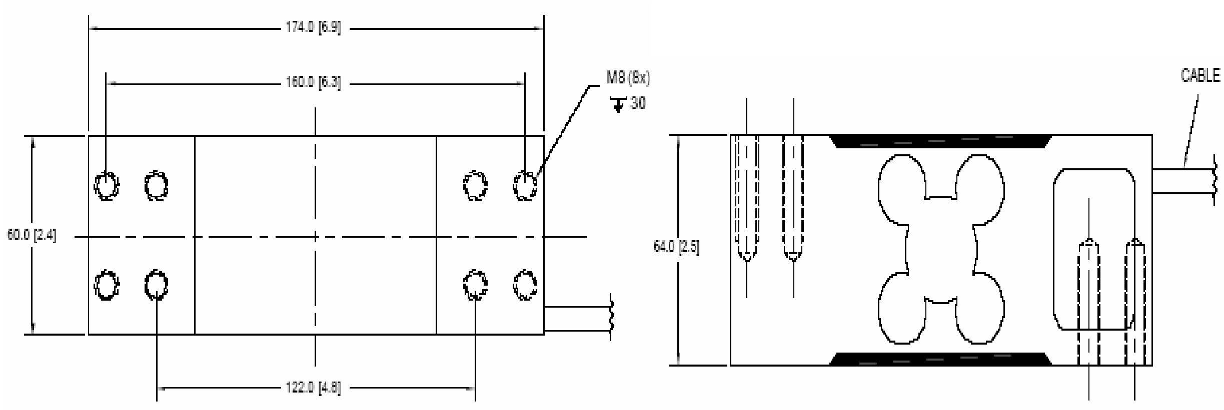


Figure 7 – S290 Load Cell 3D View and Dimensions

SPECIFICATIONS:

Rated Load:	50, 100, 150, 500kg
Rated Output:	2.0 mV/V ±5%
Zero Offset:	±5% Full Scale
Input Resistance:	402±10 Ω
Output Resistance:	350±10 Ω
Excitation Voltage:	5-12 Vdc
Nonlinearity:	0.02% Full Scale
Hysteresis:	0.02% Full Scale
Repeatability:	0.015% Full Scale
Creep (30 Min):	0.02% Full Scale
Use Temperature:	-10°C to +50°C
Temperature Effect on Zero	0.05% Full Scale/°C
Temperature Effect on Span	0.03% Full Scale/°C
Insulation Resistance:	5000MΩ(100V)
Overload Capacity, Ultimate:	150% Full Scale
Material:	2024 Aluminum Alloy

Table 1 – S290 Load Cell Specifications

A very significant part of the second design, especially concerning electronics and electrical components, is keeping the shower chair weight scale as waterproof as possible. This is quite necessary when considering the mounting and placements of the four load cells. A waterproof plastic covering will have to be bonded to the bottoms of each of the four legs to seal the openings so that no water will get through as this will keep the load cells protected. Additionally, small holes will have to be drilled into each of the four chair legs, right above the plastic covering, so that excess water can be drained out of the shower chair legs. It was previously mentioned that square or rectangular rubber stops will have to be mounted to the load cells, and they will need to fully cover the load cells while being bonded to the legs of the shower chair. The rubber will have to be bonded with an adhesive that fully resists water and condensation as the load cells cannot function in contact with water. A plastic covering will also have to be bonded to the bottom

In order to run the wires from each load cell to the electrical component compartment, the group decided it would be best to use PVC plastic tubing as conduits for each of the load cell wires. In implementing this design, it is necessary to drill a hole in each of the rubber stops on the side that the load cell wires protrude from. The hole will have to be big enough to allow the PVC tubing to snugly fit in, where it can be heated to bond with the rubber and have a waterproof sealant to fully seal the tubing into the rubber. Before the PVC tubing is sealed into the rubber, the load cell wires will have to be run through the tubing to a length that will allow for entry into the electrical component compartment, which will be situated under the shower chair. To run the conduit tubing up the legs will be a necessity, and will be done using twist ties around the chair legs and conduit tubing up the length of the legs and to the electrical component compartment. Two holes on each side of the electrical component compartment will be drilled to allow for entry of the PVC tubing conduit and subsequent load cell wires; the conduits from the right side of the chair will go into the right side of the electrical component compartment, and the conduits from the left side of the chair will go into the left side of the electrical component compartment. As with the rubber stops, the tubing will have to be snugly fit into the holes, and a waterproof sealant will be applied to each hole and tubing to fully seal the compartment from water. A picture of the type of PVC tubing that will be used is shown below, which is manufactured by NewAge Industries:

Figure 8 - CLEARFLO® PVC Clear Plastic Tubing

Electrical Component Compartment

The electrical component compartment will be stored under or next to the shower chair. It will contain the "guts" of the device, including the printed circuit board (PCB) and related electrical components, batteries, wires, and wireless transmitter that will communicate to the handheld console. One side of the device will be removable to allow for easy access to the circuit within; thereby, allowing for necessary modifications or repairs to the electrical circuit board or PCB. This part of the electrical component compartment will not be accessed by the user, but by an individual who is familiar with electronics and electrical components in the event that a modification or repair is needed. It will also need to be lined with a weather stripping in order to prevent water from entering into the electrical component compartment. There will also be another easily accessible compartment on the top of the device that will allow the user to change the batteries when necessary without opening the side compartment. This accessible battery compartment will also need to be lined with weather stripping in order to prevent liquid or condensation from entering the compartment and subsequently damaging the batteries. An example of the circuit schematic for the power supply to the microcontroller is shown and explained on the following page:

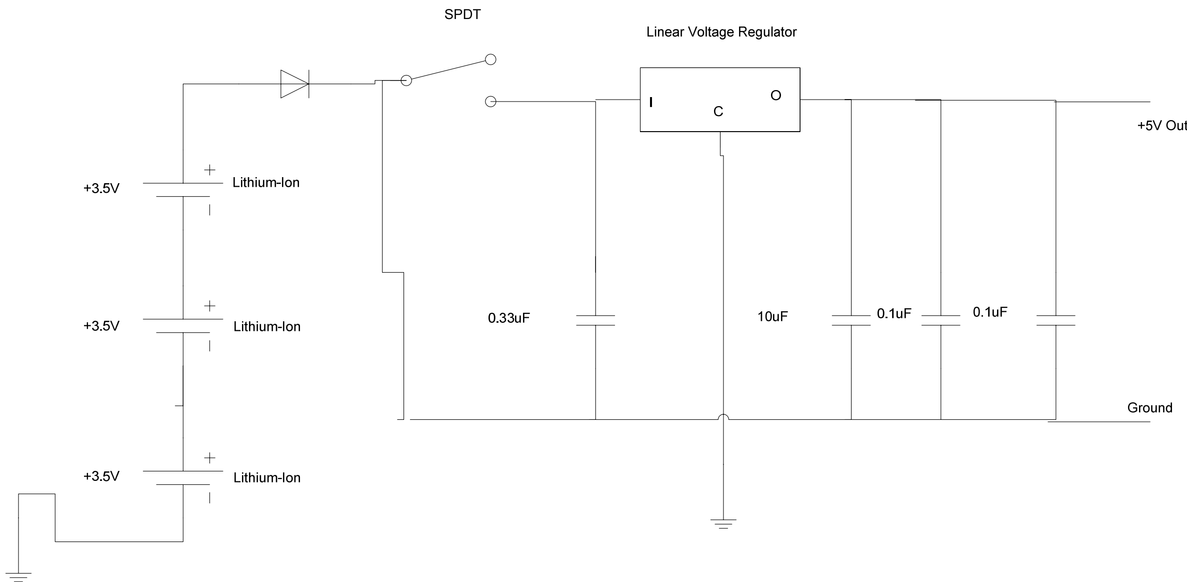


Figure 9 – Example of Power Supply to PIC Circuit

Three lithium-ion batteries will be wired in series and used as the power supply for the device. They are rated at approximately 3.5V a piece; therefore, a voltage of about 11.5V will be output from the three batteries mimicking a 12V DC power supply. A current limiting diode will be placed after the batteries and before the switch for prevention of electrical damage to the batteries. A single-pull-double-throw analog toggle switch will be placed after the diode in order to function as a disconnection of power to the linear regulator. For input into the voltage regulator, a 0.33uF capacitor will be necessary to filter out unwanted spikes or noise in the signal that could occur after the switching. After the linear voltage regulator will be a 10uF capacitor that will filter out any more unwanted voltage spikes that could occur after the switching and power up. Also, the input and output pins of the linear voltage regulator will have to be grounded to a common ground to provide the true functionality of the regulator, thereby supplying the desired 5V output. Finally, two 0.1uF capacitors will be placed after the 10uF and will be connected to the power and ground pins of the electrical components to filter out additional noise and voltage spikes. The circuit will be necessary and will work to down regulate the 11.5V from the lithium-ion batteries to provide the 5V output necessary for supply to the microcontroller and electrical components.

The whole electrical component compartment will need to be tested on a protoboard prior to ordering the printed circuit board so that the group is ensured the correct PCB schematic is sent. A standard smoke test will have to be performed to make sure that all of the electrical components are functioning correctly and will function correctly when eventually connected to the PCB. A digital multi-meter will be used to check voltages, currents, and resistances throughout the protoboard to make sure that they meet the specifications of the various chips and linear voltage regulator, and so that there are no short circuits throughout the circuit. A diagram of the electrical component compartment is shown below:

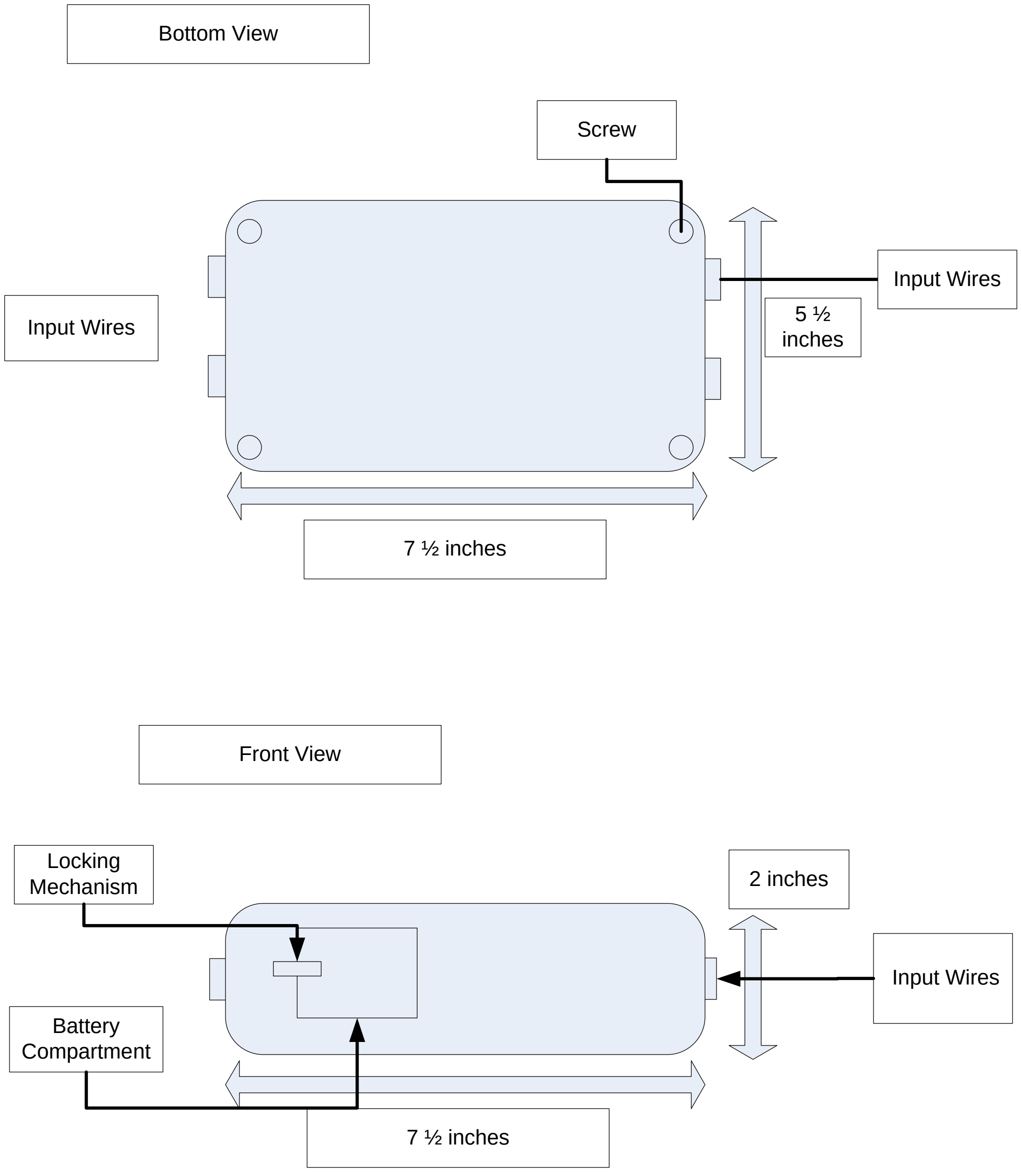


Figure 10 – Electrical Component Compartment Diagram

Microcontroller

The microcontroller is responsible for converting the electrical signal from the load cells into a weight measurement given in kilograms (Kg) and pounds (lbs). It is also responsible for storing the data of the collected weight measurements, and incorporating a wireless transmitter and receiver for communication between devices.

The PIC18F6723 microcontroller, made by the Microchip Corporation, will be used for the accessible weight scale for seated users project, and will be used in the electrical component compartment. The PIC18F6723 microcontroller was chosen for the project for numerous, various reasons. A main reason is that it has 128 kilobytes of program memory as well as 3936 bytes of data memory, which will be essential for storing multiple readings taken from numerous weight measurements. It also has twelve onboard, 12 bit analog-to-digital module inputs, which is an amount that is higher than what is needed for the project, the device only requiring four inputs for the load sensors; however, if more load sensors were later required for some reason, then the microcontroller would easily allow for the implementation of those sensors. A USART output pin will be used to transmit serial communications via a wireless transmitter to the microcontroller within the handheld console.

For the second design of the project, it was determined that a second microcontroller would need to be implemented in order to incorporate a wireless handheld console. Therefore, the PIC16F874A microcontroller was chosen due to a familiarity with programming, debugging, and utilization of this microcontroller in past projects. The LCD screen and buttons will be connected to the input I/O pins of the microcontroller, and the wireless receiver will be connected to one of the USART input pins for serial communication with the electrical component compartment.

As just mentioned, the PIC microcontroller employs USART serial communications, and it can allow for access to a computer through a serial port when a proper RS232 chip is used. The Microchip MPLAB Integrated Developer's Environment can also be used for the programming and debugging of the PIC microcontroller. It is also capable of parallel communications (PSP), thereby allowing for compatibility with peripheral devices and wireless applications. Furthermore, both the PIC18F6723 and PIC16F874A are stocked with Microchip's nanowatt technology, which limits power dissipation while increasing the electrical life when the PIC and device are operating on battery power; this will be useful for the group's device, which will be operating solely on battery power.

As previously stated, the analog-to-digital conversion ports will be used for the output signals of the load sensors, in order to convert the electrical signals into actual values of weight, in pounds and kilograms, for display on the LCD screen. There are in-circuit-debugger (ICD) ports which will be used for the programming and debugging of the microcontroller. The programming and debugging can be done using the MPLAB IDE in conjunction with the Microchip ICD 2 or PICSTART Plus. Programming will either be done in the assembly language (ASL) or C++ language. It is much easier to program in C++, mainly due to the simpler use of loops in C++ in comparison to the numerous bundles of programming in ASL. However, each programming language can be converted to the other for greater ease of programming. Testing the microcontroller will be done by setting up a protoboard circuit that has a power supply and telephone type data connect, which will plug into the Microchip ICD 2 for debugging and eventual programming. Showing that the microcontroller is actually functioning will require the use of an oscilloscope and probe, which should show a 5V peak to peak sinusoidal wave assuming that the protoboard is wired correctly. The following figures show the PIC18F6723 microcontroller and the PIC16F874A microcontroller, and their various pins:

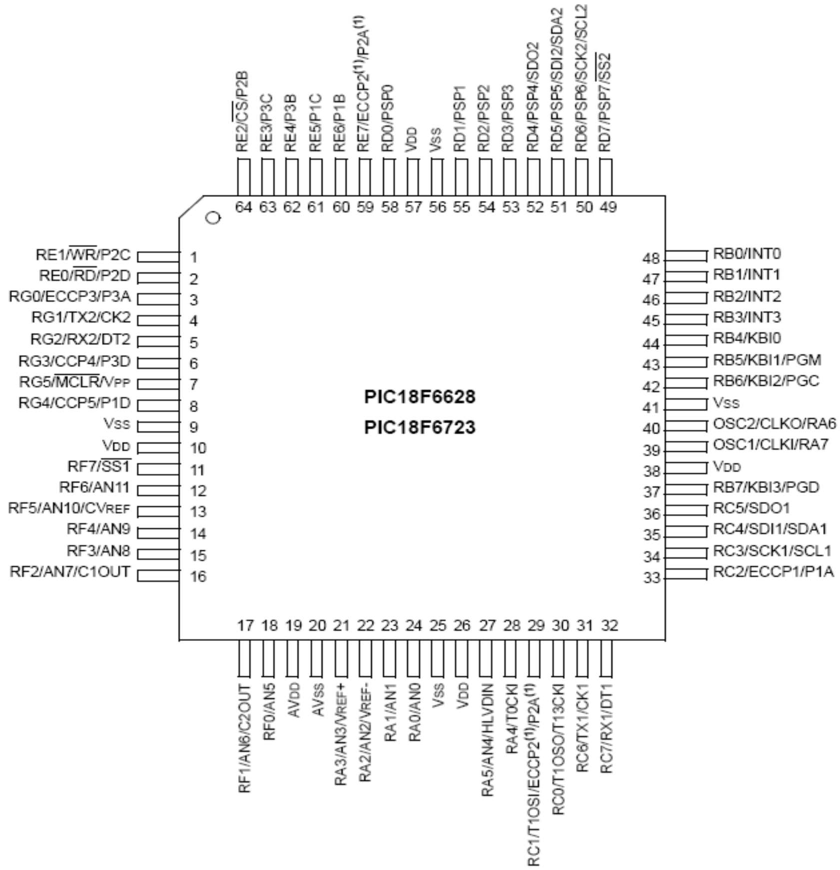


Figure 11 – PIC18F6723

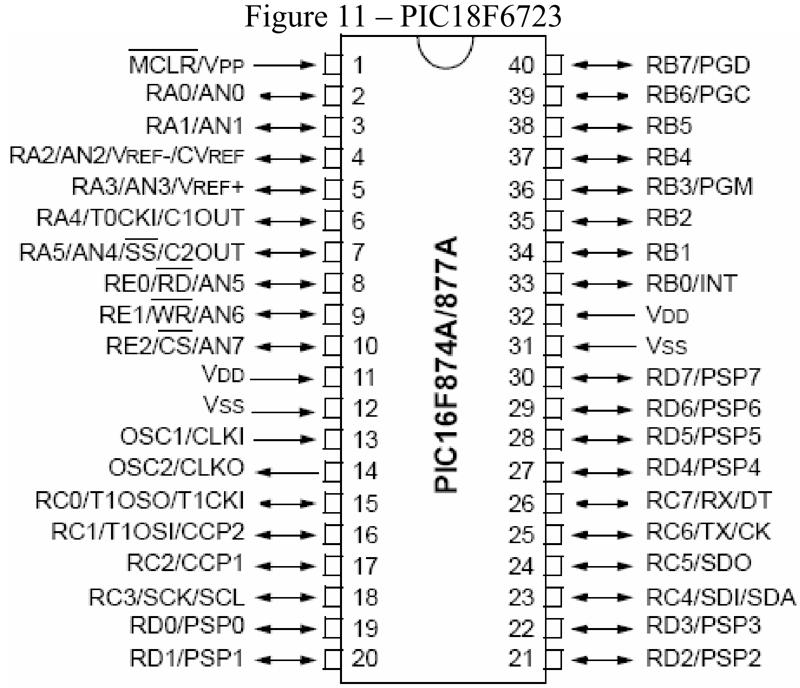


Figure 12 – PIC16F874A

Handheld console

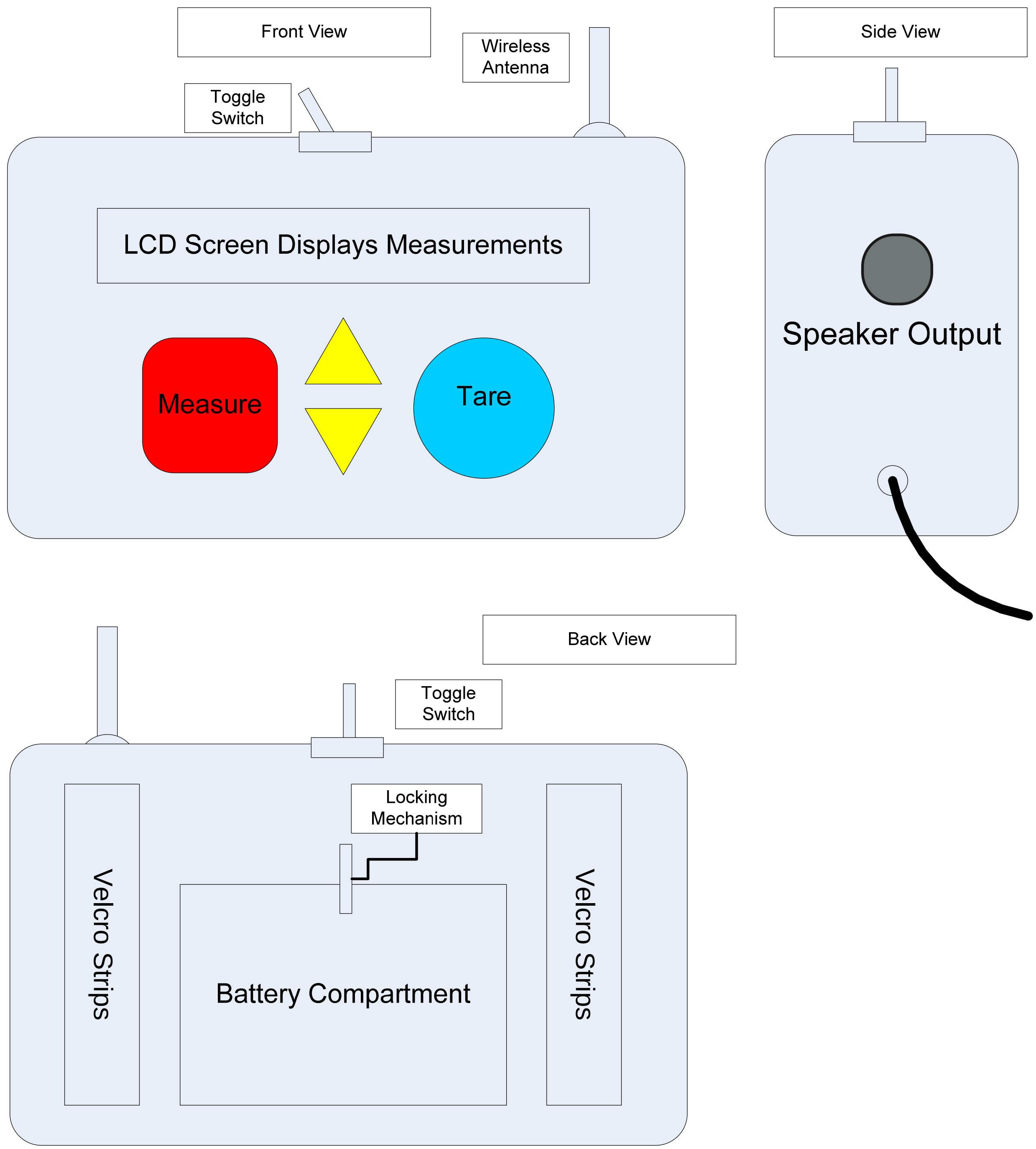


Figure 13 – Handheld Console Diagrams

The handheld console functions as the user interface for the device. It contains a toggle switch on the top of the console to allow the user to easily turn the device on and off. It will also contain a "Tare" button that will allow the user to tare the device prior to getting onto the scale. It will contain a "Measure" button that will allow the user to easily take a measurement once seated on the scale. There will be a scroll up and down button that will allow the user to scroll through previous readings. There will be a liquid crystal display (LCD) screen that will have characters about half of an inch in height. The handheld console will be connected to the electrical component compartment via wireless transmission and serial communication. The handheld console will take 9 V batteries that will be easily accessible from the back of the console. A linear voltage regulator circuit will have to be implemented in order to down regulate the 9 V battery output to a 5 V LCD input. The LM317L linear voltage regulator manufactured by ON Semiconductor Corporation will be used as the linear voltage regulator for 5V input into the LCD screen. These voltage regulators have a variable voltage output of 1.2V to 37V, which will incorporate the needed 5V output and input into the LCD, and will work well considering the use of 9V battery power supply. The current output for the LM317L is in excess of 100mA, which is not too high of a current, but will still make it necessary to put a current limiting diode in series with the 9V battery in order to prevent backflow of current, which could damage the battery and possibly other electrical components (shown in Figure 15). A circuit diagram of the external components wired to the LM317L is shown below, and will be wired as so for the design of the device:

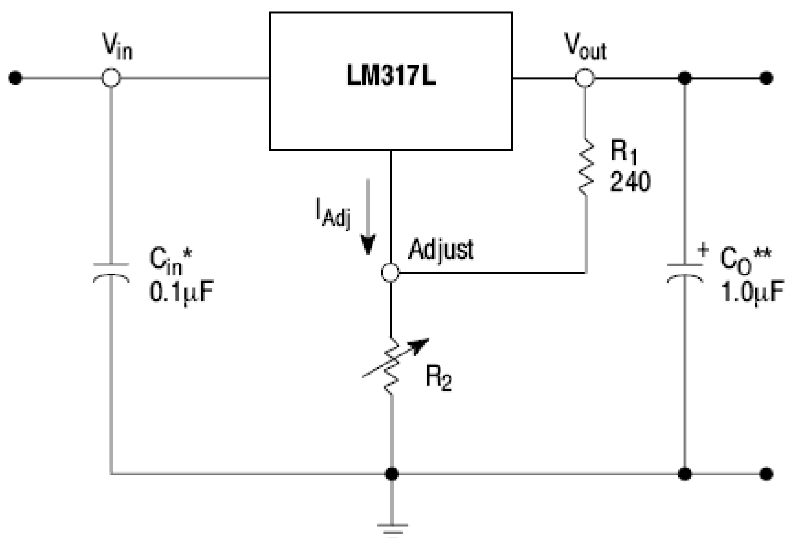


Figure 14 – LM317L Linear Regulator Circuit Setup [4]

The LCD that the design group intends to use is the LCM-S01602DSR/D manufactured by Lumex Inc., and a picture of the LCD screen is shown below:

Figure 15 – LCM-S01602DSR/D [5]

The LCM-S01602DSR/D screen, shown on the following page, is ideal for the group's design for a few reasons. The first reason is that it has sixteen characters X two lines, which will be useful when sending messages to the users from the microcontroller, as well as when displaying the weight measurement readings. Another reason is that is has a large viewing area with a dimension of 99 X 24 mm, providing a fairly big view to the users. The LCD also has a character size of 4.84 X 9.63 mm, which will make it easier for any user with vision impairments to read the screen. It has a wide viewing angle, which will easily compensate for viewing if a user is holding the handheld console at an angle. The backlight on the LCD will make it easier to read in dimly lit settings. Lumex states that the LCD has low power consumption with long operational life and that will be vital to the accessible weight scale, as batteries will be used and replacing them often is not desired. It must also have a voltage input of 5V and a 12mA current. A schematic for the power supply to the LCD screen is shown below:

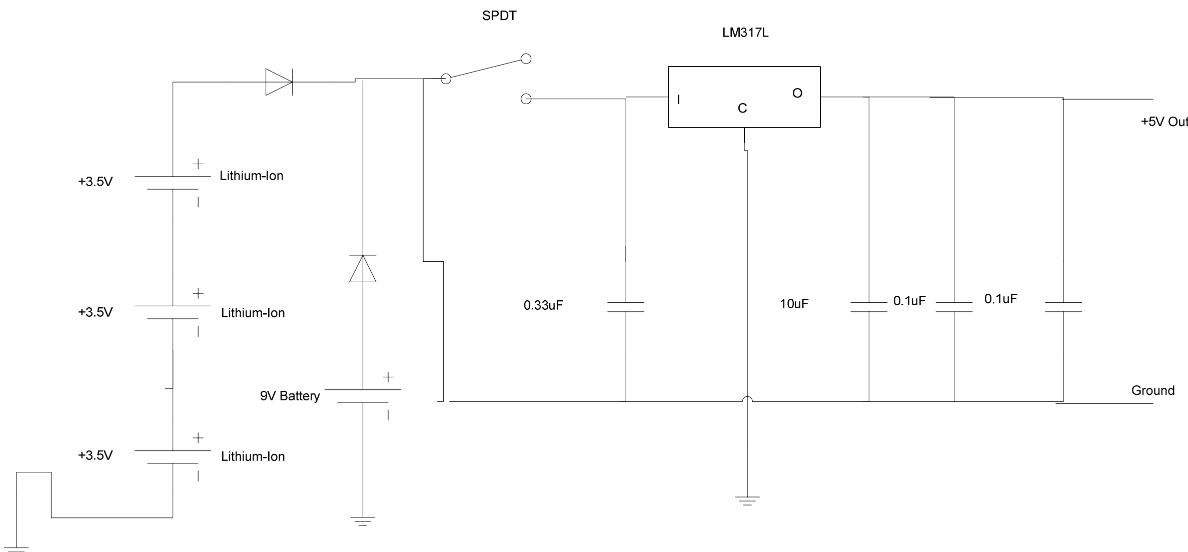


Figure 16 – Example of Power Supply to LCD Circuit

The power supply to the LCD screen should resemble the schematic shown above in order to meet the voltage and current requirements for input into the LCD. However, due to the incorporation of a backlight on the LCD, there may need to be another 9V battery added to the initial battery to meet the power requirements of the backlight. If need be, the 9V batteries could be put in parallel to ramp up the current to meet all of the current specifications.

Another important component of the handheld console will be the text-to-speech device. This device's incorporation into the design is vital to the user(s) that has extreme vision impairment or possible blindness. The group will be implementing the RC8650 Voice Synthesizer® Chipset made by RC Systems in order to accommodate the text-to-speech functionality. The RC8650 can store up to 3.5MB of memory and includes playback of fifteen minutes of pre-recorded messages. This is more than enough memory to include the speech output that is necessary for the device. The chip is available in 3.3V and 5V operating voltage packages, and the 5V operating voltage chip will most likely be chosen for the voltage specifications of the device. The RC8650 will connect to three ports on the microcontroller for input, output, and clear functionality. The RXD port of the chip will receive data (text) and commands from the microcontroller. The TXD port will be used to read information out of the RC8650, and CTS# port will acknowledge each byte received on the RXD pin by going high (it is initially low) and allowing the data. The $A0_0$ and TS_0 pins will transmit the analog output and talk status output from the RC8650 to a low-pass filter operational amplifier circuit, which will then output to an 8 ohm speaker for audible speech output of the weight measurement to the user. Testing of the chipset will be done using a protoboard setup to connect a set of inputs to make sure that the outputs match the data and commands of the inputs. This can be done by setting up the RC8650 chipset testing circuit (given in the datasheet) on a protoboard to see if the DC characteristics match up to those provided in the datasheet. A figure showing a picture of the RC8650 chipset is shown below:

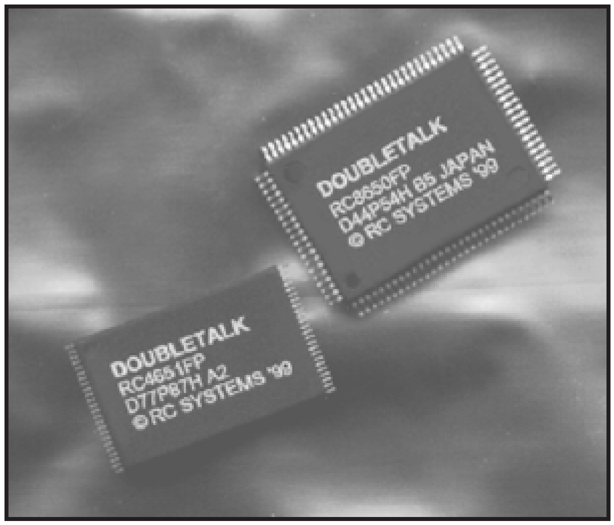


Figure 17 – RC8650 Chipset [6]

The outer casing of the console will be made of the same hard plastic as the electrical component compartment. It will need to be big enough in size to safely fit the LCD, push buttons, batteries, and electrical components. Yet, it also must not be bulky in order to make it comfortable to the user. All of the buttons will be clearly labeled, either directly on the buttons or directly above or below the buttons. They will be labeled in English text as well as Braille for users with vision impairment. The “Measure” and “Tare” buttons will preferably be of the same size, but of different shapes and colors, making it even easier to distinguish between the two. The two arrow buttons will be the same size and color, but will be distinguished by the direction that they face (up/down, north/south). A number of push buttons were found that could be used in the design of the device; however, not many of the push buttons had an option to be bought with Braille incorporated into them. Grayhill Inc. is one manufacturer of push buttons that has an option for Braille on the push buttons, and an inquiry has been issued with them to see whether or not a word, such as “Measure”, can be put onto the push button. Innovation Industries Inc. is another company that actually manufactures push buttons with Braille already on them; however, these buttons are used for more commercial settings, like an elevator, and do not have Braille words on the push buttons that would be pertinent to the group’s device.

As with the testing of the electrical component compartment circuitry, the whole handheld console circuitry will need to be tested on a protoboard. A standard smoke test will have to be performed to make sure that all of the electrical components are functioning correctly and will function correctly when eventually connected to the PCB. A digital multi-meter will be used to check voltages, currents, and resistances throughout the protoboard to make sure that they meet the specifications of the various chip, LM317L, LCD, and buttons. This will also make sure that there are no short circuits throughout the circuit.

A very important addition and upgrade to the second design of the accessible weight scale for seated users is the implementation of wireless/RF technology. The wireless/RF technology is necessary for the second design because of a need to minimize the amount of exposed wires. A large wire from the electrical component compartment to the handheld console, containing power and input/output wires, would be quite exposed and subject to contact with water, which is a danger to the user and cannot exist in the design. Therefore, the LR Series Long Range Wireless Communication Modules, made by Linx Technologies, were chosen to meet the wireless/RF technology demands. The 418MHz transmitter and receiver modules were chosen, which will hopefully reduce the amount of interference during transmission and provide accurate transmission of data between the two PIC microprocessors. They can incorporate a supply voltage of 5V, which is good for the power systems of the design since 5V supplies will be used. The modules have a direct serial interface and that will allow for accurate communications between USART pins of the PIC microprocessors. The 10,000 bits per second data rate of the LS modules is more than enough for the transmission of the data needed for the project; yet this will result in quicker communication between the handheld console and electrical component compartment, thereby resulting in quicker visual and audible weight readings. No external components are needed for the wireless modules, except for an antenna; therefore, the 418Mhz CW Series antenna was chosen for receiving of the data in the 418MHz frequency. These antennas are fully weatherized, which is optimal due to the environment in which the antenna will be used.

2 Realistic Constraints

The realistic constraints of the accessible weight scale for seated users include engineering standards put forth by the Americans with Disabilities Act (ADA), the economic, health and safety, social, sustainability, and manufacturability constraints. All of these constraints were determined by the team and addressed in designing this alternative design.

The most important engineering standard that should be met in the design of this project is the Americans with Disabilities Act (ADA) design standards for accessible design of shower chairs. The ADA is enforced by the Department of Justice of the United States. ADA was developed to protect the rights of Americans with disabilities. One ADA standard is that the handrails that will be used for this device have to have a diameter of 1-1/4 inches to 1-1/2 inches at the gripping site. The handrails have to be kept at least 1-1/2 inches from the wall. The handrail must not deform when a 250 pound bending stress or shear stress is applied to the handrail. Also the fastener or mounting device should be able to support a 250 pound lateral load or direct tension force. There are no other ADA standards that must be met by this design. [7]

The economic constraints associated with this project will be the expense of the accessible weight scale for seated users. Our prototype costs cannot exceed $2000. Our projected cost for this alternative design prototype will be roughly $1700. This leaves only $300 cushion in the event one of the components is damaged during construction of the device. The future cost of the device is usually estimated as being 35% of the prototype costs making the device cost approximately $600. The market price of the device will be higher in order to make a profit, but the price of the device should still be significantly lower than current products on the market. Many of the currently available products that meet our specifications of accuracy within one fifth of a pound and total capacity of 600 pounds cost between $1,500 and $2000. These designs are not incorporated into a shower chair and are less convenient for the user, but they set the standard for the price range of this device. In order to compete with these products, the accessible weight scale for seated users should be less expensive than the currently available products. Many public hospitals and would appreciate a less expensive accessible weight scale for seated users given their tight budgets. Also it may be more beneficial for hospitals or private owners to have the scale incorporated into a shower chair because it is one less device to purchase and cheaper than purchasing two separate devices.

There are some definite constraints to the device in regards to health and safety. Similar to any electronic device there is an inherent risk of electric shock to the user. Because the device will be housed in a bathroom setting, this risk is even greater due to regular contact with water. This means that all electrical components will have to be safely housed to prevent electrical shock to the user when the device comes into contact with water.

Also the device will have to be easy to sanitize in order to prevent the user from coming into contact with harmful bacteria. In building the device it will be important to make sure that there are no crevices or hard to clean regions that bacteria could grow. This should not be difficult for this particular design since the user will interact only with the shower chair, which will be purchased and already is easy to sanitize.

Another health and safety constraint is making sure there are no sharp edges on the device that could potentially injure the user. Cuts sustained from sharp edges could be painful and if the surface is not clean they could also result in infection of the wound. Any sharp edges will have to be filed down until they are smooth. This is especially important with the foot support since the foot support will be created by the group members.

Another health and safety constraint is ensuring the stability of the shower chair in the shower. The greatest number of injuries to the mobility challenged occurs in the bathroom. The greatest number of these accidents occurs when the person tries to get in or out of the tub. Most shower chairs including the one that will be purchased for this project come with rubber suction cups on the foot of each leg of the chair. This aids in the stability of the chair on a wet floor ensuring that the chair will not slide as easily. A problem with this design is that the suction cups will have to be removed from the bottom of the chair legs in order to install the load cells. To keep the stability of the shower chair a plastics adhesive that is waterproof will be used to attach the suction cups to the bottom of the rubber stoppers that will protect the load cells.

A definite social constraint of this project is ensuring that the device will increase the quality of life for the clients. The main objective of biomedical engineering is to engineer solutions that will increase the quality of life. This means that the user should be able to independently use the device without the help of another person. By making the device easy to use for a mobility impaired individual, the device will better the quality of life for the individual, allowing them to have control of monitoring their weight themselves without feeling embarrassed by a loved one seeing their weight or helping them use the device. Also it is important to make sure that the accessible weight scale does not prevent the user from using the shower chair without the help of another person. This would significantly lower the quality of life of the user if they had to rely on another person to shower if they did not previously have to do so.

Sustainability of the device is another constraint for this project. Most of the users are old and cannot be expected to repair the weight scale. The weight scale should require very little maintenance beyond sanitizing the device. The electrical and mechanical components should not in any way be subject to failure. This could be difficult because some of the users are obese and the scale will be exposed to substantial forces. Another concern for this device is that it should be capable of operating for a long period of time. The device should have a long battery life so that the user will not have to change the battery often and it should be easy for the user to change the battery when necessary. If the user has to dig through complicated wires in order to remove and replace the battery they will not replace the battery and the device will not work.

In the event that the accessible weight scale does need to be repaired, the device should be relatively easy to repair. The device should remain light weight so that it would not be too difficult for the users loved one to remove the device and bring it in for repairs. Also the circuitry should be readily available. The electrical component compartment will have a removable panel to allow for easy access to the electrical components. The panel will be removed with a screwdriver to prevent the user from tampering with the electrical equipment.

One manufacturability constraint on this project is that the machine shop is not equipped with the machines required for working with plastics. This will drastically limit the choices of materials to be used for the accessible weight scale for seated users. Some of the materials might sacrifice aesthetics for functionality and manufacturability. When the actual device is manufactured there will be a greater number of machines available and the device may be produced with more aesthetically pleasing components.

It is important to keep in mind how these designs might be manufactured in the future. If one design would be more difficult to manufacture and require a large number of man hours to complete then it is possible a different alternative design would be a better choice in order to keep the cost of manufacturing down for the product.

3 Safety Issues

While designing this device it was important that the safety issues that are associated with the device were thought of, discussed and addressed within the design of the product. Many devices, especially electronic devices, have safety issues. These safety issues are not a problem for the user as long as they are properly addressed and accounted for in the design of the device. The different types of safety issues that have been determined for the accessible weight scale for seated users include electrical, biological and mechanical safety issues.

Any electronic device has an inherent possibility of causing electric shock to the user if constructed improperly. Electric shock is very dangerous and could cause pain, burns and even cardiac arrest. For this reason the accessible weight scale for seated users will be made completely waterproof in this design. The shower chair design will come in constant contact with water and cannot endanger the safety of the user while in contact with water. In truth the scale should not be used while the shower is running since the running water could add pressure to the scale and slightly affect the reading of the scale. However, for safety reasons the device the design will be treated as though the scale will be immersed in water during operation. The accessible weight scale will keep the wires and load cells from contact with water at all times. The wires connecting the load cells will run through plastic tubing from the load cells to the electric component compartment underneath the shower chair seat and sealed on either end with waterproof sealant. The load cells will be protected using rubber stoppers and the electrical component compartment will communicate with the display using a wireless transmitter.

Another potential safety issue associated with the accessible weight scale for seated users is sanitizing the device. The scale will be integrated into a shower chair. Especially in a clinical setting the shower chair may be used by multiple users and will come into contact with germs and bacteria that could be spread from user to user. It is important that the weight scale be easy to clean and sanitize in order to limit the amount of risk to the users. This means that the device should not have a large number of crevices and hard to clean areas that could house bacteria and increase the risk of the user coming into contact with harmful bacteria. As stated previously this should not be difficult because the shower chair is being purchased and is already easy to sanitize.

One of the mechanical safety issues associated with the accessible weight scale for seated users is the stability of the shower chair in the tub. The shower chair would normally have suction cups at the base of each leg of the chair to prevent it from slipping on a wet surface. These suction cups will have to be removed in order to install the load cells, but will be replaced by using the adhesive sealant to attach the rubber stoppers that protect the load cells to the rubber suction cups that will allow for stability of the device.

Another mechanical issue associated with this design is that it will have components built in the machine shop. It will be important to ensure that these components do not have any sharp metal edges that could injure the user. Any sharp edges will have to be filed down so that they are no longer sharp and no longer a danger to the user.

For each of the safety issues that have been determined for this project a solution has been made in order to ensure that the device is safe for the user. It will be important to keep these design solutions in mind while building the device if it becomes apparent that one of the safety solutions is not adequate to keep the user safe. At that time a new solution will have to be developed or the old solution will have to be improved. The safety of the user is paramount to the success of the accessible weight scale for seated users.

4 Impact of Engineering Solutions

As engineers it is important to consider the impact of our engineering solutions prior to starting a project. It is the engineer's responsibility to ensure that their engineering solutions are ethical and beneficial to society. The impacts of the accessible weight scale for seated users include economic, societal, environmental, and global impact.

There are two types of economic impact that the accessible weight scale for seated users would have. One type of economic impact would be the impact on the consumer, which would come in the form of a cheaper device. The second type of economic impact would be on the competing companies, which would come in the form of a competing device taking some of their market share.

By producing an accessible weight scale for seated users that is inexpensive, there will be an economic impact on the individual consumer. The individual consumer may have a fixed income, many expenses and limited savings. This consumer would save money by purchasing the accessible weight scale for seated users rather than purchasing other products that have the same capabilities, but are more expensive. The device would not only be cheaper, but it is a shower chair and weight scale combined. The consumer then only has to purchase this one device instead of spending more money by buying both a weight scale and a shower chair.

For competitors to the accessible weight scale for seated users the economic impact of the device will not be a good one. Competitors will have some of their market share taken by a less expensive and more convenient device. This means that competitors will lose money and be forced to drop prices in order to maintain their market share. They will also be forced to pour more money into research and development in order to design an accessible weight scale that is even better than their new competition. The companies' new products could be even cheaper and more convenient than the accessible weight scale for seated users, which will benefit the consumers. This benefit does not come to the consumers, however, unless new products are developed and introduced to the market.

The accessible weight scale for seated users could have a significant societal impact on people with limited mobility. It is currently quite difficult for seated users to monitor their weight. They often require another person's aid sometimes even having to travel to the hospital in order to measure their weight. This dependence on other people is sometimes very detrimental the psyche of a mobility challenged person. They can often feel that they are a burden on their loved ones. This depression can be especially detrimental to obese patients with limited mobility because their depression could cause them to eat more and monitor their weight less. By developing a weight scale that is convenient and easy to use without the help of another person, it will be possible to increase the seated user's independence from their loved one. This will allow them to feel less of a burden and to let them focus on monitoring their weight and ensuring their continued health.

In order to ensure that this product is environmentally friendly the accessible weight scale for seated users will not use lead based materials to operate. Restriction of Hazardous Substances (RoHS) came into force on July 1 2006. This directive restricts the amount of lead, cadmium, mercury and other hazardous substances that can be contained in an electronic device and sold within the European Union. In order to ensure that our device follows these standards, the electronic components for the accessible weight scale for seated users will only be purchased from RoHS compliant suppliers. In the event that the weight scale is thrown out it will not have as significant an impact on the environment as other electronic devices sometimes do. [8]

The design of the accessible weight scale for seated users can be easily adapted for a global market. It uses battery power and will not require power adaptors or power cords to work in different nations. Also the weight of the user is given in both pounds and kilograms. Allowing users everywhere to clearly understand how much it is they way. Also this design will be RoHS compliant, meaning no lead based materials, which will allow the product to be sold in the European Union.

There are several factors that will impede the global impact of the accessible weight scale for seated users. One reason for this is that selling a product in an international market takes more time than selling the product in the United States. An international patent should be applied for in order to protect the device from being adopted and sold by other companies. Also international distribution channels would need to be fostered and grown. Before entering a market a significant amount of market research should be conducted. There may be products sold in foreign nations that have not yet made it to the United States. These products may already have a sizable piece of the market and depending on their design it may be difficult to take some of that market share with a new product. Also determining pricing strategies in foreign nations could take time given fluctuating values of foreign currency and a lower standard of healthcare and living in other nations. In the future these impedances may fall away in the future, but for the time being the global impact of the accessible weight scale for seated users will be slow in coming.

Taking all of these impacts of engineering solutions for the accessible weight scale for seated users into account, there are many reasons to build this device and few reasons not to. The device will have negligible impact on the environment when compared with other devices and the economic impact is a positive one. The societal impact is the driving force for this project and is the main reason for developing this device. The users will benefit from being able to independently monitor their weight.

5 Life-Long Learning

Life-long learning is a concept that is present in educational institutions all over the world. The Australian department of education has defined life-long learning as "the process of acquiring knowledge or skills throughout life via education, training, work and general life experiences." [9] The concept of life-long learning has made a large impact at the University of Connecticut. One of the program outcomes for the biomedical engineering program is, "a recognition of the need for, and an ability to engage in life-long learning." [10] Our senior design project is a principle component of our education to meet this program outcome. In this project a number of skills have been developed through life-long learning that would not have been achieved through normal educational means. Among these skills are working on a multidisciplinary team, applying education in a real world application, learning market research concepts, and machine shop training.

In our educational experiences at the University of Connecticut each of the three team members have worked on several engineering projects. None of these projects have been as challenging and none of these projects have required that our teammates be from different tracks within the biomedical engineering program. The three tracks that are represented in our team are chemical engineering, bioinstrumentation and biomechanics.

The most important skill that is developed when working on a multidisciplinary team is delegating tasks. These projects are so large and time consuming that in order to complete them, tasks have to be delegated to the various team members in such a way that plays to their strengths based on previous experiences. Each team member could probably complete any of the given tasks, but some are better than others because of their individual experiences at UConn. Determining which skills each person has and how best to implement those skills was probably the first challenge in this project and a skill that will be of great use in our careers.

The average engineering student has amassed a wealth of knowledge by their senior year of college, but may not have had many chances to apply that knowledge to real world problems. This is a skill that needs to be developed if the student is to succeed in his or her career. It is also a skill that is being developed in this senior design project. All of the seniors have to complete their senior design project in order to graduate with a degree in biomedical engineering from the University of Connecticut. Each team is asked to design a product that is needed in the world in order to increase the quality of life for their clients. In order to produce a successful project each team member has to apply the knowledge they have gained at UConn. Being able to apply that knowledge and skill is a lesson in and of itself.

These projects are all real world applications and that means that if it is going to be made for the real world it has to be able to be sold in the real world. This means that as engineers it is not acceptable to only develop a product that solves a problem. They must also develop a product that can compete in the market today. In order to do this it is necessary for the team to learn how to use market research in order to determine if there would be a market for their design project. The market research for these projects is limited to secondary research for the most part with the exception of the students who work on NSF projects and have a client with specific needs. For the rest it is imperative that they are able to see what other products are available and to design the project in a way that it can compete with the available products. This skill will inevitably be useful in future careers because it ensures that the product being engineered not only solves the problem, but can be sold as well.

Each senior design student is required to complete machine shop training. This training is necessary in order to ensure that the team can build the device in the second semester of senior design. This hands-on training is a skill that would not necessarily be learned at any other time in the student's life, but could be of definite benefit when working on future prototype designs at companies.

All of these additional skills that the student learns while completing their senior design project are important in meeting the program outcomes that the biomedical engineering program has developed. These program outcomes prepare the students for their future careers in the field of biotechnology and prepare them to continue their education through life-long learning.

6 References

[1] The Medical Club.com 1249 Heavy Duty Shower Chair With Arms http://www.themedicalclub.com/Heavy_Duty_Shower_Chair_p/ehs-32661.htm

[2] National Instruments. http://zone.ni.com/devzone/cda/tut/p/id/3642

[3] SMD Sensors. http://smdsensors.com/detail_pgs/s290.htm

[4] ON Semiconductor Corp. http://www.onsemi.com/pub/Collateral/LM317L-D.PDF

[5] Allied Electronics. http://www.alliedelec.com/Search/ProductDetail.asp?SKU=670-1137&SEARCH=&ID=&DESC=LCM%2DS01602DSR%2FD&R=670%2D1137&sid=471550806480E17F#

[6] RC Systems. http://www.rcsys.com/Downloads/rc8650.pdf

[7] "ADA Standards for Accessible Design," Department of Justice, United States of America, available at, http://www.usdoj.gov/crt/ada/adastd94.pdf

[8] RoHS "Home" http://www.rohs.gov.uk/

[9] "Glossary of terms F to L" Department of Education, Science and Training Australian Government, available www.dest.gov.au/sectors/training_skills/policy_issues_reviews/key_issues/nts/glo/ftol.htm

[10] "Program Outcomes," Department of Biomedical Engineering, University of Connecticut, Storrs, CT, available at, http://www.bme.uconn.edu/ugrad/bmeprgoc.htm