Scale to Measure Nighttime Weight Change

Kyle Herzog – Team Leader
Joe Ferris – BWIG
Ben Engel – Communications
Eric Printz – BSAC

Advisor: Wally F. Block, Professor of Biomedical Engineering
Client: Timothy Juergens, M.D., Geriatric psychiatrist/sleep specialist

December 10, 2006

Table of Contents

Abstract

It has been proposed to design a weighing device that can measure weight change of a patient in a hospital bed over the course of a night. A patient's weight can fluctuate as much as 700 g in one night. Studies recently performed at Yale and the University of Japan have shown a direct connection between sleep and long term weight change. Our client believes that there is a connection between the pattern of this weight change and sleep stage changes. Due to the minute weight changes, the device would have to read at an accuracy of about 0.05 lbs, but the more accurate the device the more useful it will be. The weight of the patient should be recorded every ten to fifteen minutes throughout the night. The device would likely have to support a hospital bed supported by four legs. The device should be capable of being moved between beds with minimal difficulty and without any complex recalibration required. We considered three separate design alternatives: a weighing pad to be placed under the mattress, a load cell placed under each leg of the bed, and a tension meter design. After analyzing each option we decided to proceed with our load cell design. Our prototype consists of a load cell that sends its signal through an amplifier and then to an analog digital converter. This signal is then read by a computer and the weight readings are exported to an excel file using a program that we specially wrote.

Problem Statement

For most people, weight fluctuates throughout the day and night. As a result one can lose as much as 700 grams over the course of the night, even if they do not eat or go to the bathroom. Much of this is related to metabolism, as well as water loss. We would like to be able to measure this weight change accurately on people who are in hospital beds. This will require that our device record the patient's weight every fifteen minutes. The device would likely have to support a hospital bed, which sits on four legs, and read at an accuracy between 0.02- 0.05 lbs. Ideally the device could be moved to a different bed without too much difficulty (one to two hours time) and without complex recalibration.

Motivation

Tracking weight change over the course of a night may be important from a research perspective. There are a number of potential variables that may affect this weight change, such as medications and sleep stage changes. Another potential use would be to track and eventually predict those at higher risk of developing obesity, correlate with body fat measurements, activity, and assess for metabolic changes when we do things to improve or correct sleep problems. There is popular concern in recent sleep literature regarding various sleep stages, insomnia, and their impact on obesity.

Client Requirements

One of the device's important client requirements is that it output weight readings to a computer at chosen time intervals. The user should be able to choose the frequency of readings and have the data values imported to a program that is as universal as possible, such as Microsoft

Excel. This will allow for easy analysis and manipulation of the data. The more accurate the scale, the more useful the readings will be. An accuracy of 0.02 to 0.05 lbs is desired, but a slightly less precise scale would still be very useful. Achieving accuracy this high with materials that are of reasonable cost will be very difficult and a lower accuracy may be used in the prototype designed this semester. Another important client requirement is that the scale not be fixed to one bed. It should be capable of being moved from one bed to another without the need for many hours of labor or complex recalibration.

Background Information

Correlation between obesity and weight gain before bed

A recent study performed at Nakamura-Gauken University in Japan [4] proved that there is a direct correlation between the daily fluctuation in body weight immediately before going to bed, weight regain, and accompanying visceral fat accumulation in obese patients. The study consisted of a 16 month weight-reduction program with an initial four month education program. The 16 month weight-reduction program that the study focused on was completed by ninety-eight women in a charting group (recorded weights at four different times of day) and seventeen women in a noncharting group (no weight measurements). Consequently, ninety-eight obese women who ranged in age from 23 to 66 years who had no history of major diseases or medications known to influence the parameters examined in the study were assessed. Weight recordings were made using a standard hospital grade scale at four separate times during the day: immediately after waking up, after eating breakfast, after dinner, and before going to bed. Abdominal fat areas and blood samples were assessed at 0, 4, and 16 months. To ensure the comparability of the charts between days, adherence to the exact times and weighing instructions was critical. The study found that plotting the daily body weight measured at four critical times each day is effective in weight reduction, maintaining weight loss, and preventing subjects from dropping out of a weight loss program. Based on the rate of attrition, the performance of subjects in the charting group was clearly superior to that in the noncharting group, which confirms previous findings.

The results also revealed that the standard deviations of the difference in body weight between "after waking up" and "before going to bed" predicted the rebound increase in body weight. Patients who had an inconsistent weight before going to bed (higher than the weight after dinner) quickly regained their lost weight by the end of the 16 months study. Obese patients have the distinct characteristic of excessive snacking during the period before going to bed, which is called *night-eating syndrome*. Excessive energy intake during the night results in a rebound increase in fat accumulation. When compared, the study's charting results imply that an irregular weight pattern during the period before going to bed is a sign of excessive energy intake during the night [4].

The device we are designing would open the door to a variety of studies similar to the one above. An obese patient's weight change over the course of a night could be correlated to his or her overall weight regain. For example, data obtained using such a scale may show that there is excessive weight regain during the REM stages of sleep. It may then be possible to prevent or minimize this weight gain by altering the sleep cycle through medication or some other type of intervention. The study performed at the Nakamura-Gakuen University implies that weight gain which occurs while the test subject is asleep definitely has a direct affect on the amount of weight a patient regains over a longer period of time. Studies using a scale similar to the one we are designing could help to further explain this correlation.

Correlation between Obesity and Insomnia

In a recent study performed by Yale School of Medicine [5] researchers showed that there is a possible link between insomnia (lack of sleep) and obesity. The link between the two has been traced to hypocretin/orexin cells in the hypothalamus region of the brain that are easily excited and sensitive to stress. The researchers found that if these cells are over-activated by environmental or mental stress in daily situations, they may support sustained arousal, triggering sleeplessness which leads to overeating. The more stress that a person undergoes the lower the excitation threshold of these hypocretin cells becomes. The study was performed by using electrophysiology and electron microscopy to observe hypocretin/orexin neurons in mice. Researchers found a previously undescribed organization of inputs on hypocretin neurons in which excitatory nerve junctions outnumber inhibitory contacts by almost ten fold. This unique wiring correlates well with their involvement in the control of arousal and alertness, but may also be an underlying cause of insomnia and associated metabolic disturbances, including obesity [5].

This study proves that there is in fact a direct correlation between obesity and certain sleep disorders. A functioning scale that tracks weight change over the course of the night could help Dr. Juergens and his colleagues to explain what it is about these sleep disorders that leads to a higher prevalence of obesity.

Design Alternatives

Load Cell

A load cell is a device that is used to measure the weight of an object based on the fact that the resistance of a material will change as the load applied to the material changes. When a load cell is subjected to a force, the change in resistance is related to the magnitude of the force applied to it. Ultimately the change in resistance is converted into a weight. In this design we would use four strain gauge load cells, each under one leg of the bed. Each load cell will be connected to an amplifier circuit which amplifies the signal before sending it to a computer for interpretation and logging (1).

The key component between the amplifying circuit and the computer will be an analog/digital converter. This device takes an analog electrical signal from the amplifier (which is connected to a load cell), and converts it into a serial signal which the computer can interpret. Therefore, our device will connect to the computer using the computer's serial jack. Since most computers have only one serial port, an additional PCI card may be needed to expand the computers serial port capacity to four (See Figure 1).

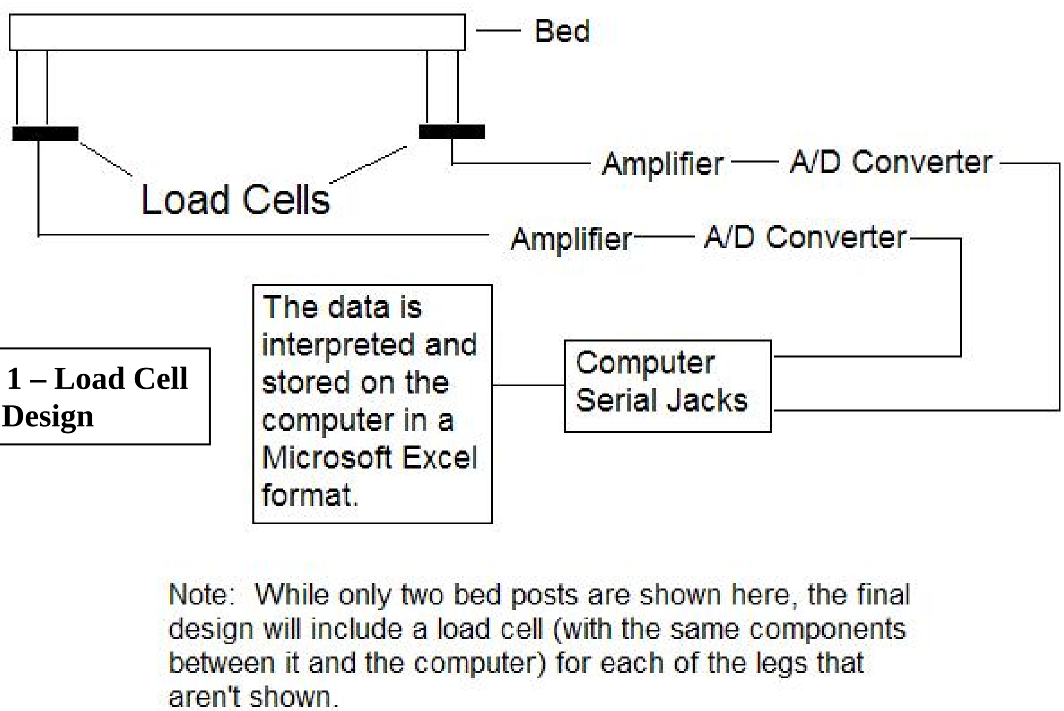


Figure 1 – Load Cell Design

The computer will interpret the signal and put the data into an excel spreadsheet, as our client has requested. Some analog/digital converters come with data recording software. If this software is able to record our weight data in fifteen minute intervals in a way such that the data is useful to our client, then we will use this software. If the included software does not have sufficient features then our second option is to write our own software using ActiveX controls.

Overall the load cell design option has many advantages. Load cells are currently the "state of the art" way to weigh objects of a wide variety of sizes. Through our research we have found that a fairly standard accuracy for a load cell is 0.02% of its full load. We feel that this is a sufficient accuracy because our load will be spread out among four load cells. Spreading out the load will help to increase accuracy by allowing for use of load cells with lower maximum weight capacities. Furthermore, this design will be versatile. As new load cell technology is developed it will be fairly easy to purchase a new load cell and hook it up to the amplifying circuit. Also, from a data logging standpoint, we will be able to record and interpret the data in just about any way because of the ability to write our own programs that interface with the analog/digital converter.

The main disadvantage of this design is cost. The average price of a load cell with the required accuracy is around $300. We will need four of these. The amplifying circuit and analog/digital converter will cost less than $40 so those aren't as much of a concern. To remedy this problem we would purchase only one low capacity load cell for under $40. If we are able to record data from this load cell on a computer, then we feel that we would be confident enough to purchase four higher capacity load cells. Another disadvantage is portability. Since there are four load cells with multiple components between each of them and the computer, the device may be difficult to move for someone who isn't familiar with the device.

Pad Design

Weighing pads are a type of scale that are very thin and have a large surface area. They are generally made out of stainless steal and come with a rubber mat for comfort. Weighing pads utilize a digital LCD readout and are most often powered by either AC adapters or a variety of different batteries. They are commonly used by veterinarians to weigh animals. In our weighing pad design we would place one of these pads under the mattress of the bed. Data is transferred to LCD readouts via a parallel connection. We would need to reroute the wiring on this parallel connection and input the data into a computer system through a parallel port. The computer

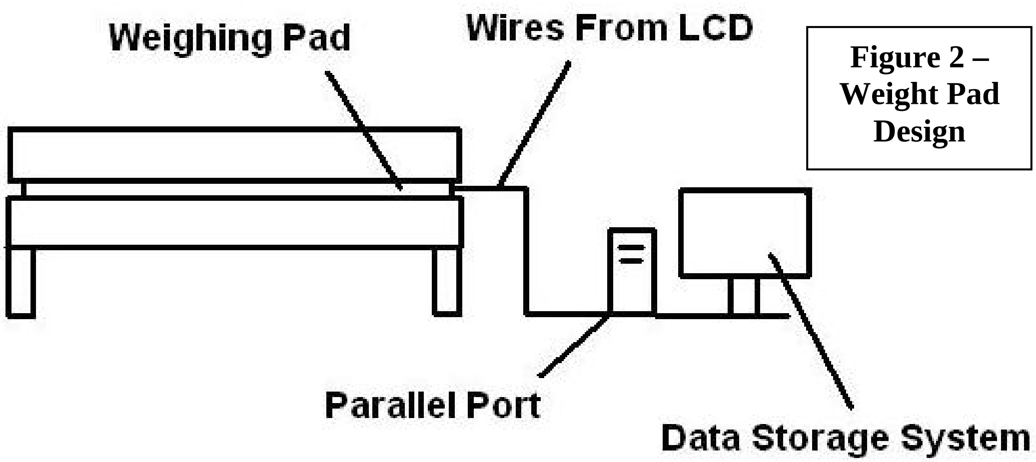


Figure 2 – Weight Pad Design

system would be designed to take readings at a designated interval, recording throughout the course of the night, preferably using an Excel spreadsheet (See Figure 2).

The weighing pad design offers a number of advantages. Because the weighing pad is a single unit, and would likely be wired to the computer through a single cord, transfer of the product from bed to bed would be quite simple. The ability to place the pad directly under the mattress substantially decreases the overall load. Since accuracy is dependent on the size of the load, this could aid in achieving the accuracy requested by the client. Also these weighing pads are designed for large loads, often up to 400 pounds, meaning the client could use the device with virtually any patient.

The weighing pad design also has a number of disadvantages. In our research to date we have been unable to find a weighing pad that is capable of obtaining the accuracy requested by the client. Many of these pads on the market are only accurate to .1 of a pound, whereas the client has requested accuracy to .02 to .05 pounds. Also many of the weighing pads are not large enough to cover the entire area of the hospital bed. With the pad being placed under the mattress, there is the chance that the patient's movement would throw off the instantaneous readings. The placement of the pad under the mattress could lead to patient discomfort which, by the client's request, is unacceptable. Weighing pads are also quite expensive to replace if anything were to go wrong with the design.

Tension Meter

Another alternative design that would be able to record the weight of a patient during the course of the night is the use of a digital tension meter. A digital tension meter measures the precise tension in a cable. The cable is run through prongs which sense the deformation in the cable. The tension meter then transforms this deformation into a digital reading which is then

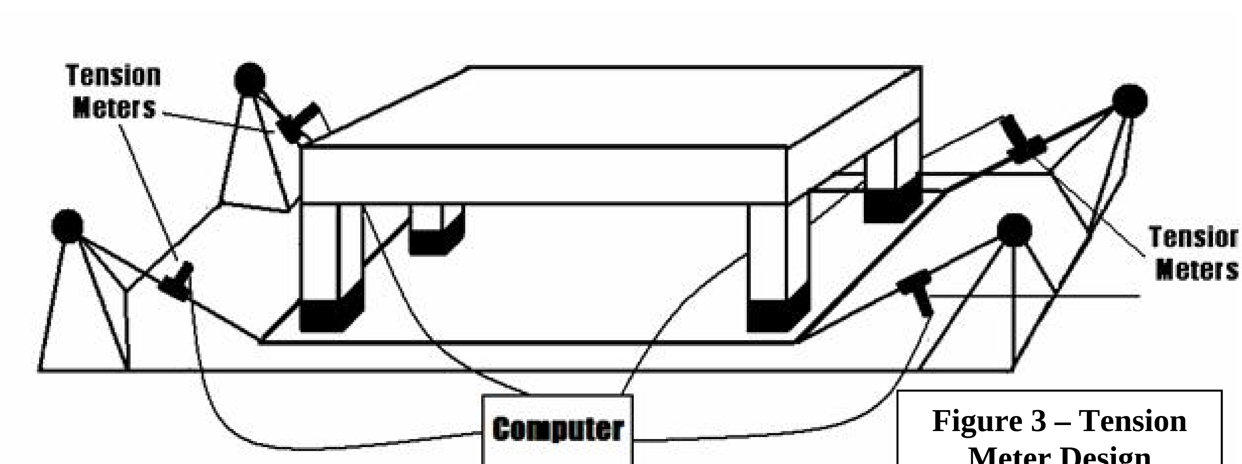


Figure 3 – Tension Meter Design

displayed. Our third design incorporates two digital tension meters, steel cable, and a platform upon which the bed rests.

In our design, we would se four digital tension meters (see figure 3) to record the change in weight of the patient. The use of multiple tension meters would distribute the weight of the person and bed between four separate meters, giving us a more accurate reading. The tension meters that we would like to use would accurately measure the tension in the cable to .01 lbs of force. Digital calibration will be necessary to ensure that only the weight of the patient will be taken. Instead of having the digital tension meter display the readings on the meter screen, many digital tension meters are readily able to interface to computers with the use of a USB port. The digital serial data produced by the digital tension meter will then be directed into the computer with the use of WinWedge Pro. WinWedge captures serial data, custom tailors it, then transfers the data to a PC application such as Excel. Using this specific type of meter, we would be able to manipulate the data-taking interval with WinWedge Pro and observe the data with the use of Excel. This type of digital meter will be allowed to record continuously while connected to a power supply. In our design, we will make use of four of these digital tension meters which will both be separately interfaced to a computer. With the use of Excel, we will be able to take the four different readings and combine them to produce the desired reading.

These tension meters will be attached to steel cables. The steel cable we will use in our design is 3.18 millimeters thick with a max breaking force of 920 pounds, sufficient for the load placed on these cables. These cables will first attach to a platform underneath the bed (refer to figure 3) and then to respective rods which will be anchored to a second platform. The bed will be firmly attached to the platform to avoid any sort of movement.

There are reasonable advantages to this design. All the parts to the design are readily made and obtainable to assemble. We would not need to create an amplifier or A/D converter to manipulate the signal. The tension meter already converts this signal for us. Also, the digital tension meter has a setting for automatic calibration when the size of the wire is known. This would save us time trying to calibrate our design for the patient. Finally, this design has no irregular discomfort associated with it. Since the device is used under the bed, the patient will experience the same comfort he or she would experience without this device.

There are, however, some disadvantages to this design. One of the difficult obstacles to overcome is the price of this design. Accurate tension meters needed for this design are very expensive. The cost of a single digital tension meter can run anywhere from $750 to $1100. We would need to purchase four of these digital tension meters for this design. Another problem associated with this design is the accuracy. If a person moves around significantly at night, the readings from the digital tension meter will show this tension fluctuation. This fluctuation could make analyzing the data very difficult. Finally, the portability and availability of space is a concern. Our client recommended that the device be portable in a window of one to two hours time. This may be possible with design. However, the design is bulky compared to the other two which would make movement difficult with only one person. Also, storage and usage of this design would require more space in the hospital room then the other two designs.

Design Evaluations

Our group analyzed each of the three designs and ranked them according to several categories that we and our client feel are most important to the success of the device. Each design was ranked in its fulfillment of five categories. Rankings between 1 and 5 were given out in each category with 1 being poor and 5 being good. The values given in each category represent a comparison among the three designs. They do not have a quantitative value, as this would require more specific experimental data. Table 1 shows a design matrix and provided each design and the ranking it received in each category. After each design had been ranked in every category, the total ranking of all five categories was found. Each category was ranked equally because no single aspect of the design is more important than the others.

	Load Cell	Bed Pad	Tension Meter
Cost	3	3	1
Portability	3	5	1
Accuracy	5	1	3
Complexity	3	5	1
Sleep Hindrance	5	1	5
Total	19	15	11

Table 1 – Design Matrix

After observing the results of these rankings, our group has decided to move forward with the load cell design. It has the most advantages of any of the designs and our group feels as though it is the design that has the most probability of someday producing a functional device. This design's high accuracy and versatility are what most influenced our decision to proceed with it. As previously stated, load cells are the most current and efficient way to obtain weight readings. As load cell technology changes we would be able to easily incorporate a new load cell into our design, whereas other scales may just become obsolete. Load cells would be the most probable way for us to achieve the accuracy we need. Accuracy goes down as the size of the load goes up, but our load will be distributed over four separate load cells. This will limit the amount of weight on each individual cell, allowing for a much higher level of accuracy.

Final Design Components

Analog-Digital Converter

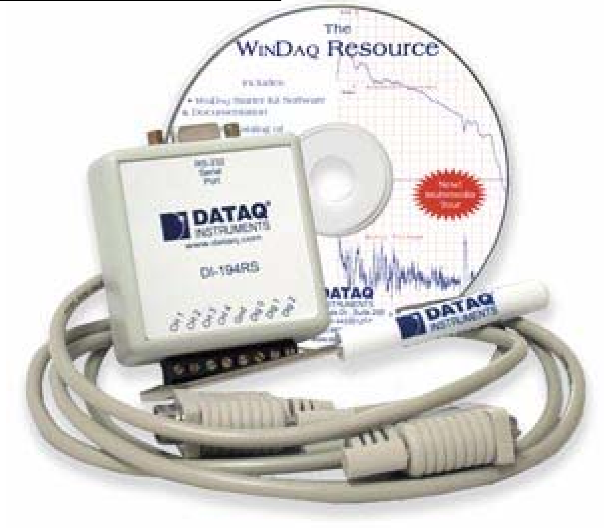
An analog digital converter will be needed to convert the voltage being produced by the measuring device to a discrete number. Traditionally an analog digital converter, or ADC, receives a continuous signal output and produces discrete values that can be output digitally. There are many factors to consider when choosing the correct ADC for your task.

The resolution of the converter indicates the number of discrete values it can produce over the range of voltage values. The voltage resolution of an ADC is equal to its overall voltage measurement range divided by the number of discrete values. The resolution required would vary depending on the voltage range of the measuring device used. The resolution is limited by the signal-to-noise ratio of the signal being input. If there is too much noise in the incoming analog signal, it will be impossible to resolve the signal beyond a certain number of bits of resolution. The number of bits that are capable of being resolved is known as the "effective number of bits" (ENOB). While the ADC will produce a result even if the signal-to-noise ratio is very low, the result is not accurate, since its lower bits are simply measuring noise. The ratio should be around 6 dB per bit of resolution required.

Non-linearity may also be a problem. All ADCs suffer from some non-linearity as a result of their physical imperfections. This can cause incorrect readings that can skew data. This can be minimized by properly calibrating the ADC before it is put into use, or by testing to discover an approximate value of this non-linearity and then compensate for it accordingly [3].

In our prototype we used a 4-channel, 10-bit, data acquisition starter kit. This 10-bit resolution would not be high enough for a functioning design but will allow us to prove the concept in our prototype. The amplified signal will run through the ADC and be read continuously by the WinDaq software that comes as part of the starter kit package (see Figure 4).

Figure 4 - ADC



Amplifiers

An amplifier will be required to amplify the signal being produced by the measuring device to a level that can be recognized by the ADC. An amplifier simply uses a small amount of energy to control a larger amount of energy. Most amplifiers can be characterized by several parameters. The extent to which a signal is amplified is called gain and is usually measured in decibels (dB). It is defined very simply as the output level divided by the input level. Noise is frequently introduced in the amplification process and must be taken into account. It is also measured in decibels and is an undesired but inevitable effect of the electrical set up and components [2].

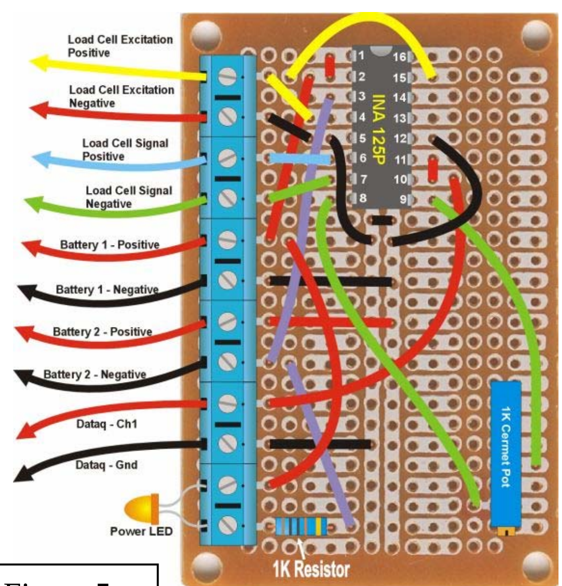


Figure 5

We first attempted to build the amplifier circuit seen in Figure 5. When we attempted to test it we found that it was a completed circuit (the LED lit up), but the signal was not being amplified at all. The source of this malfunction could have come from any of several sources, but was most likely a problem with soldering. This circuit is the one we would ideally use with a functioning design, but for the purpose of our prototype we built the secondary circuit seen in Figure 6. We used a bread board for this circuit to avoid any soldering problems. When we tested this circuit we saw significant amplification of the signal. We adjusted the potentiometer so that the voltages observed would be within the range of the ADC (-10V to 10V).

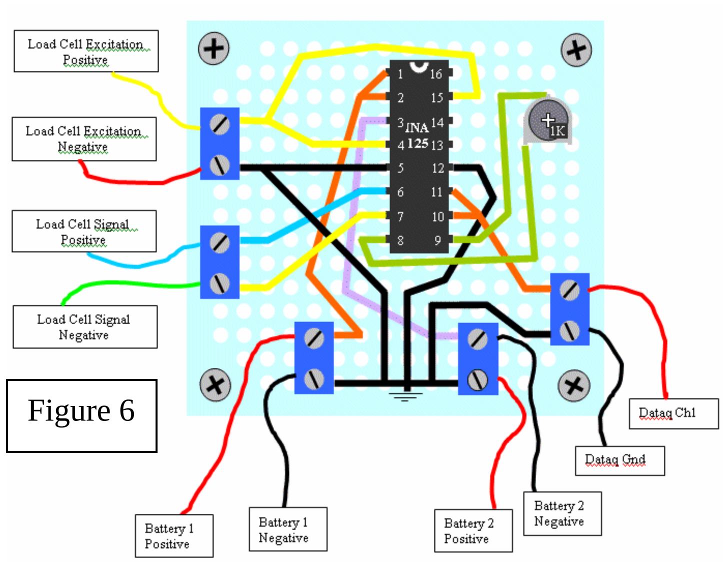


Figure 6

Load Cell

As mentioned before, a load cell is a device that transforms mechanical energy into an electrical signal. This transformation takes place as a result of a change in resistance in the device which allows for the conversion of a force into a variable electrical signal. The final design prototype employs a load cell with a forty-four pound maximum load purchased from Aerocon Systems. This load cell is a cantilever style load cell, also known as a single-point load cell. One end of the load cell is to be firmly secured to test stand, while the other end is designed for the placement of the load. Figure 7 is an image of an unmounted single-point load cell.


Figure 7

The load cell used in the final design prototype was powered using two 9-volt batteries connected in series. These batteries were not directly connected to the load cell, but were connected indirectly through the amplifier circuit. The load cell was designed to produce variable electrical signals on the range of -2 to 2 mV. For this reason, amplification was necessary to transform these small signals into data that would be useful, and more easily manipulated. The wiring scheme for the load cell consisted of four wires. Two were for the excitation of the load cell, one was to carry data to a data acquisition source, and the last was grounded.

Test Stand

In order for the load cell to function properly, it needed to be securely mounted to a test stand. The design for the test stand was simple, and consisted of just two major components; a hollow steel beam, and an aluminum shim. The hollow steel beam provided a sturdy base for the load cell to be mounted on, while the aluminum shim provided ample elevation of the one end of the load cell where the load was to be placed. The maximum physical deflection of the load cell was rated at less than 1 mm therefore the thickness of the shim was chosen accordingly. Figure 8 contains pictures of the load cell mounted on the test stand.

Figure 8

Holes were drilled in both the steel beam and the aluminum shim that matched the two holes on the top of the load cell, and the parts were fastened together using 6 mm. screws with matching nuts. The screws were fastened securely enough so that under a large load, the cell would not deflect enough to come in contact with the steel mount.

Data Interpretation

To interpret the data that is sent to the computer by the load cell we wrote our own computer program. This was the best way to collect our data because it allowed us to completely customize our data logging process to make it a perfect fit for our project. The program was written using Microsoft Visual Basic.Net and it uses an ActiveX control that was created by Dataq instruments (the company that made the Analog/Digital converter that we used in this project). There are three main options for the user to select in this program. The first of these options is what time interval data should be recorded in. The user can select anywhere from five to thirty minutes. The second option is at what time of day data recording should stop. Lastly, data is outputted into a Microsoft Excel Spreadsheet; thus, the user must select where the spreadsheet should be saved to. Once the user has chosen something for each of the options, the last step is to click the “Start” button to begin the data recording process.

The data recording process will stop at the time specified by the user, or the user can click the “Stop” button to stop recording before the specified time. In either case, the data that was collected is outputted into a Microsoft Excel file and saved to the location specified by the user. Each row of the excel file contains a weight reading in pounds as well as a time stamp which indicates at exactly what time that reading was taken.

In order to convert the voltage value that the load cell sent to the computer to pounds, we needed to perform some experiments to come up with a good mathematical conversion formula. To do this, we applied a known weight to the load cell and recorded the voltage that the load cell sent to the computer. We did this four times for weights ranging from zero to four thousand grams. Once we had recorded the data, we averaged the voltage values for each of the known weights and created a linear best fit curve with the data that we had. The data used to create the linear best fit curve is shown below along with the equation of the curve (Table 2 and Figure 9).

Mass (g)	Voltage (V)
0	-0.098
500	-0.166
1000	-0.244
1500	-0.313
2000	-0.391
2500	-0.469
3000	-0.547
3500	-0.615
4000	-0.6935

Table 2

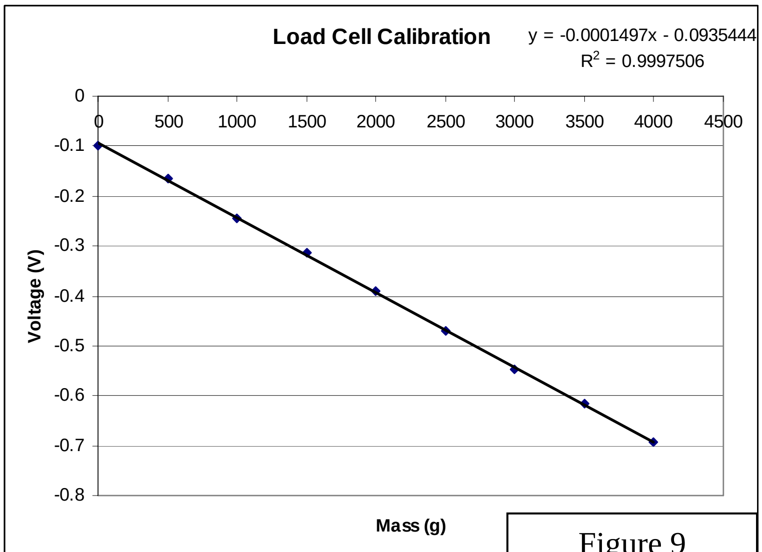


Figure 9

Cost Analysis

• Aerocon 44 lbf load cell	$25.00
• DATAQ data acquisition starter kit	$25.00
• (2) 9V batteries	$8.00
• Grid-style PC board	$1.79
• (2) 9V Heavy-duty battery snap connectors	$2.59
• 1k cermet potentiometer, 15 turn	$1.29
• 16-pin IC Socket	$1.29
• (6) 2-position PC board terminals	$4.58
• Solid core hookup wire, 22 ga	$6.29
• 1000 ohm fixed resistor, ¼ watt	$0.99
• LED – 1.8V	$2.59
• General purpose dual PC board	$1.79
• 1k micro potentiometer	$1.29
• Red LED w/ holder	$1.99
• 16-pin amplifier	$5.00
• **TOTAL**	**$89.48**

Future Work

The prototype that was designed this semester was a proof of concept for our client. The device that was built proved to our client that it was possible to create a prototype that met all his requirements. Due to time and money constraints, the actual device that will be used in the hospital setting is still being improved. There are several components to this design that will be upgraded.

The first part of the device that will be upgraded will be the load cell. Right now, the prototype operates with a load cell capable of weights up to 44 lbs. One of our client's parameters requires the device to measure patients up to 300 lbs so it will be necessary to purchase a load cell with this kind of weight capacity. These types of load cells are currently available and typically cost about $300 each.

In order to accurately measure the weight change in a patient during the course of the night, we will need to purchase four of these high load capacity load cells, placing a load cell under each leg of the bed. The four signals from the load cells will then need to be combined into one readable signal. With correct wiring, the wires leading from the load cell will be joined together to produce this signal. Another idea would be to build an amplifier for each of the four load cells and run the four signals separately into the computer. The signals would then be added in the computer to achieve the final signal.

Once we successfully have our signal from the combined load cells, it will be necessary to calibrate the device. With the current prototype, calibration was not fully accurate. Since our load cell had a max weight of 44 lbs, we extrapolated our calibration curve to weights that were not tested. With the higher load capacity load cells, we will be able to test weights that accurately reflect the range of actual loads that will be placed on the device. An accurate curve that reflects the points will then be used to interpret the change in voltage signal.

Testing the device is the final step in creating a working device that can be used by our client. Testing the error in each component of our design will give us an idea of the overall error in our calculations. Using an oscilloscope, we could test overall accuracy of our load cell and compare this to the reading transmitted through our device. We could then find the error due to our amplifier and our analog digital converter. We could then look to reduce these errors by changing up our circuit or ultimately buying more precise components. Once we are confident in the readings from the device, we will then be able to test the device in a hospital setting with human patients.

Ethical Concerns

When designing our device, we researched previous products that are currently on the market. Although we did not hire professional help, we are relatively certain that we did not violate any copyright laws. The prototype that was created was a product of documented research and our own ingenuity. In the primary testing of our prototype, no animals or humans were harmed. When we decide to test our final device in the hospital setting, certification from the Institutional Review Board (IRB) for human testing may be necessary. Our device, however, should not harm a patient in any way because there is no direct contact between the human and the device.

References

[1] "Introduction to Load Cells". Omega Engineering Technical Reference. 10 October 2006 < http://www.omega.com/prodinfo/loadcells.html>

[2] Harris, Tom. "How Amplifiers Work." How Stuff Works. 12 October 2006 < http://electronics.howstuffworks.com/amplifier.htm>

[3] Staller, Len. "Understanding analog to digital converter specifications". Embedded Systems Design. 13 October 2006 < http://www.embedded.com/showArticle.jhtml?articleID=60403334>

[4] Tanaka M, Itoh K, Abe S, Imai K, Masuda T, Koga R, Itoh H, Konomi Y, Kinukawa N, Sakata T. "Irregular patterns in the daily weight chart at night predict body weight regain." Experimental Biology and Medicine. 229:940-945, 2004.

[5] Horvath, Tamas. "Obesity and Insomnia Linked by Excitability of Brain Cells." Cell Metabolism. Vol. 1, Issue 4 (April 2005).

Product Design Specification
Periodic measurement of nighttime weight change while asleep
Updated: October 15, 2006

Team Members:
• Ben Engel: Communications
• Joe Ferris: BWIG
• Kyle Herzog: Leader
• Eric Printz: BSAC

Problem Statement:
Dr. Juergens would like to be able to measure this weight change accurately on people who are in hospital beds, and be able to view and record the weight changes over various intervals through the night (such as weighing a person who agrees to lay in bed all night at intervals of every 10-15 minutes). These weight readings should be sent to some digital storage software such Microsoft Excel. This is important from a research perspective on numerous potential variables that may affect this weight change, such as medications as well as sleep stage changes. He would also use this to potentially track and eventually predict those at higher risk of developing obesity, correlate this with body fat measurements, activity, and assess for metabolic changes when he does things to improve/correct sleep problems. There is popular concern in the most recent sleep literature about various sleep stages, insomnia, and their impact on obesity. This scale would likely have to support a hospital bed, which sits on 4 legs, and read at an accuracy ideally around 0.02- 0.05 lbs (many scales on the market record to such accuracy, the more accurate the better). Ideally it would be a device which could be moved to a different bed without too much difficulty (such as in 1-2 hours time), and without too complex recalibration.

Client Requirements:
- Accurate to 0.05 lbs
- No discomfort to patient
- Quick (1-2 hours) transfer time between beds
- 300 lb maximum weight
- Price range of $300 - $500
- Provide digital readout of data to computer software, preferably Microsoft Excel

Design Requirements:

1. Physical and Operational Characteristics

a. Performance Requirement: The device must be operational for up to 12 consecutive hours. The maximum usage would be 12 hours in a 24 hours period.

b. Safety: The device should not provide any discomfort to the patient. It should be stable, meaning it should not be possible for it to malfunction and cause the patient any injury.

c. Accuracy and Reliability: The device must be accurate to 0.05 lbs. It should be able to obtain readings for a 200 to 300 lb patient, also taking into account the weight of the bed. Readings should be taken at least every 10-15 minutes.

d. Life in Service: The device must be operational for 12 hours. It must also be capable of repeated use on consecutive day. The life expectancy will depend upon the durability of the parts being used in the device but it should not need replacement within the next 10 years.

e. Operating Environment: The device will be used in a bedroom type setting in the VA hospital (Department of Veterans Affairs). There should be no harmful conditions it undergoes.

f. Ergonomics: The device must be comfortable for the patient. The programming aspect should be simple enough training of no more than several minutes is required. It should also be capable of being moved within 1 to 2 hours.

g. Size and Shape: The device must be of minimal size. No part of it should protrude from either the top or bottom of the bed. Its interaction with the bed must minimize any sleeping distractions.

h. Weight: The device must be a minimal weight so that transfer is not difficult (maximum 20 kg).

i. Materials: Materials should minimize cost, discomfort, noise, and visibility.

j. Aesthetics, Appearance, and Finish: The device should be appropriate for a hospital setting. It should not interfere with the patients ability to sleep comfortably.

2. Product Characteristics:

a. Quantity: One device is required.

b. Target Product Cost: The prototype should cost less than $500 to build.

3. Miscellaneous:

a. Standards and Specifications: The device should comply with all regulations established by the FDA for medical instruments. More information can be found on the FDA website.

b. Customer: The typical customer would be doctors researching sleep. We are designing it more for this specific study, as opposed to producing it for mass production.

c. Patient-related concerns: The patient must feel comfortable, and the device must not prevent sleep in any way.

d. Competition: No similar device currently exists.