Proposal

Disposable Mattress Cover That Detects When the Sheets Are Wet

ECE 4884/4007 Senior Design Project

Section L03, D.M.U. Team

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Executive Summary

The Disposable Mattress Cover is an efficient, cost-effective, and sustainable hospital accessory that can be used to cover hospital beds and to detect discharge of fluids through a patient's body.

Due to inadequate cleaning procedures in the hospitals, mattresses are often left unclean with blood stains, urine, and feces that lead to decubitus, ulcer, and skin infections [1]. A cost-effective disposable mattress cover, designed with monitoring functionalities, will provide an adequate solution to maintain clean and hygienic conditions for patients in hospitals.

The disposable mattress cover, which is made up of biodegradable polyethylene material and stitched with conductive threads, will detect the presence of fluids in the bed periodically and immediately transmit an alarm whenever a change of bed sheet is required. An alarm will be also transmitted for a broken circuit on the mattress cover. This disposable mattress cover will cost $2.00 and has an excellent growth potential in the market since hospital bed demand in U.S. will increase by as much as 43% in next 25 years due to demographic shifts [2].

Our project aims to build a working prototype of a disposable mattress sheet cover that can detect urine and blood on it. After rigorous testing, this prototype can be used to manufacture a sturdier commercial product that can be implemented in hospitals and private nursing homes around the world. The targeted manufacturing cost of this product is $ 2.00 per sheet with the detection unit being sold separately.

Introduction

Nasocomial infections are the number one cause of accidental deaths in the United States, overshadowing even HIV, breast cancer and automobile accidents combined [3]. About half of all nasocomial infections are caused by wet sheets. Our project aims to create a prototype for a low cost, disposable bed sheet cover that can reduce the risk of nasocomial infections in hospital patients by detecting wetness.

Objective

The objective of this project is to create a prototype for a disposable bed sheet cover that can detect wetness due to urination or bleeding. The design of the final prototype for the bed sheet cover will be used to create and manufacture a mass produced product that can be used on hospital beds to detect wetness. A mass produced bed sheet cover can not only be used in hospitals, but also at private nursing homes, and even for bed-ridden patients who cannot afford hospital care. The targeted manufacturing cost for the bed sheet cover is U.S.D. $2.00.

Motivation

Although the statistics for deaths due to nasocomial infections are not required to be released by hospitals, unofficial sources reveal this to be as high as two million per year [4]. The main cause of nasocomial infections are wet bed sheets. Wetness caused by urination or blood causes germs and bacteria to grow on the sheet and get into patients bodies through open wounds, contact or inhalation. In order to kill the bacteria, the sheets must be pressure washed at high temperatures. Although hospitals are required to wash and clean their sheets, the cleaning process is too expensive. A viable alternative to pressure washing is to create a disposable bed sheet cover that can detect wetness. Such a product has the potential to prevent nasocomial infections and thus save thousands of lives. The disposable mattress cover will also be bio-degradable and hence reduce pollution and be an environmentally friendly product.

Background

Nasocomial infections have been around since the mid-1800s [5] and with the development of the electronic industry there have been many products that claim to be able to detect wetness. The Malem Bedwetting Alarm by Bedwetting Stores has a detector in the underwear that is connected to an alarm [6]. The problem with this product is that it is invasive. Other similar products include a wet sheet detector that uses biological materials to detect wetness by measuring the change in resistance when the sheet is wet. Such products are not affordable by hospitals for every day use. A bio-degradable, disposable bed sheet cover that is cheap to manufacture and replace is the perfect solution to the problem of nasocomial infections.

Project Description and Goals

The design of the mattress cover will consist of conductive threads sewn onto a layer of absorbent paper manufactured by Georgia Pacific covered by a thin layer of biodegradable polyethylene. The conductive pattern stitched onto the mattress cover will serve as a wetness detection sensor. The polyethylene plastic layer prevents the leakage of electrolytic fluids reducing infections. The conductive threads will form a continuous loop and each loop will be checked for continuity periodically.

- Sew connective thread to paper using a sewing machine.
- Attach both paper and plastic together efficiently using adhesives.
- Discuss and design an automated assembly process to manufacture the mattress cover
- Detect changes in resistance due to leakage with a differential amplifier circuit
- Use LED to indicate wetness or broken circuit.

Technical Specifications

Table 1. Technical Design Specifications

Design Aspect	Design Specifications
Voltage source	9V batteries
Threshold resistance	TBD
Output voltage levels	0V and 5V
Conductive thread	Silver Plated Nylon [7]
Adhesive to attach paper to plastic	3M Super 77 Spray Adhesive
External connection to circuit	4 conductive traces attached binder clip fastened by electric tape
Weight of Mattress Cover	TBD
Automated Process to mass produce mattress covers	TBD

Technical Details

The mattress cover will be composed of a paper sheet stitched with a pattern of conductive thread and placed onto a sheet of biodegradable polyethylene plastic. The plastic will keep the fluid in the absorbent paper and prevent it from being absorbed into the mattress. The conductive thread between the paper and plastic will be used to detect when the cover is wet.

The main constraint for this mattress cover is the cost since hospitals will be replacing the cover for every patient. Meanwhile, it also has to be flexible, disposable, and safe. Paper is the cheapest material for a cover that provides a reasonable level of comfort for the patient. Similarly, conductive thread and stitching are the most economic methods of installing a circuit into paper. The paper and thread are both slightly stretchable and can bend in any direction, so the cover will be flexible for the ranges of weights and contours of the patients. To prevent transference of pathogens between uses, the mattress cover will be discarded after each patient. Due to the cover's low price and the biodegradable materials, the hospital can provide a new mattress cover for every patient. The covers will also be safe for the user; the conductive thread will not have any contact with the

patient. Safety will also be improved through the use of the plastic undercoating. By preventing fluids from seeping into the mattress, many infections are prevented.

A wetness detection circuit will be attached to the mattress cover. By measuring the resistance across the two loops stitched into the cover, wetness can be determined. Since urine and blood have high concentration of electrolytes, the resistance of wet paper is significantly lower than that of dry paper. The circuit will have an output that indicates the current state of the mattress cover.

Conducting Thread Pattern

The conducting thread will be stitched into the paper in a pattern roughly like the one shown in Figure 1. There are two loops of different polarities. The two loops will be separated with a 6" gap. At the end of the loops, the four threads will be brought to the edge of the mattress cover to be attached to the detection circuit. This circuit will be measuring resistance across the two loops to determine the wetness of the mattress cover. The resistance of each loop will also be measured to ensure that no threads are broken.

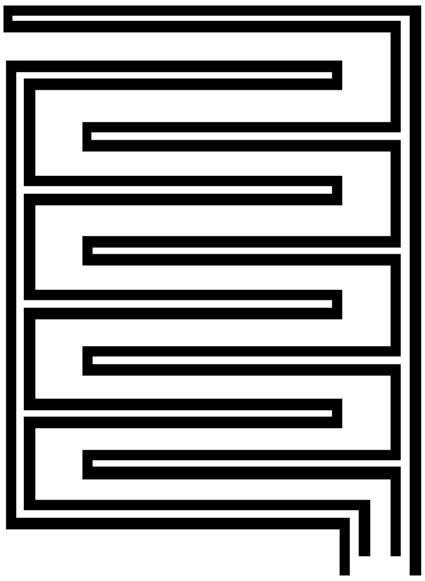

Figure 1. Wire layout on mattress sheet.

Stitching

The stitching will be done on the paper prior to the attachment to the plastic. A sewing machine will be used that attaches the conductive threads to the paper using cotton threads on top. This creates enough contact between the paper and the conductive threads to cause a connection when the paper is wet while separating the conductive components from the patient, reducing the likelihood of any electrical accidents.

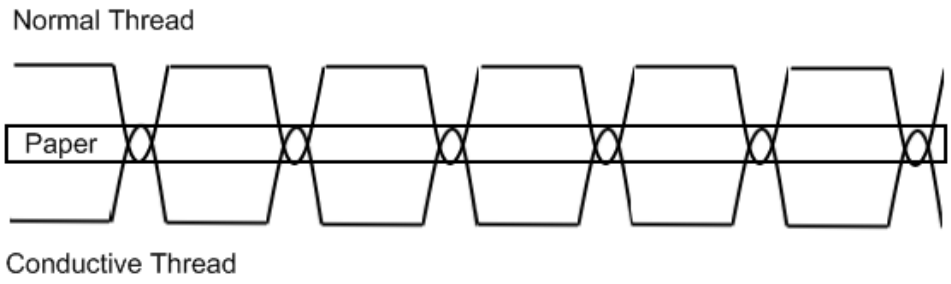

Figure 2. Stitching of the conductive thread on the mattress sheet paper.

Connector

Since the mattress cover is to be inexpensive and easily disposable, the connection from the detection circuit to the four conductive thread leads should be simple and easy to attach by the nurses or attendants. To reduce costs, a physical connector on the mattress cover can be omitted if a connector is used on the detection circuit. To ensure a stable and secure connection with the mattress cover, the connector may be a tensioned clip with small teeth that sink into the paper. The clip will be insulated but will have four metallic pads attached to wires leading to the detection circuit. Since the cover will fold over the sides of the mattress, a slit will be cut near the ends of the conducting threads where the clip will clamp onto.

Wetness and Continuity Detection

The mattress cover will be attached by the connector to the detection circuit. The schematic of the circuit is shown in Figure 3. The conducting loops are used as inputs, shown as block rectangles, for detection. The two lines leaving the LM311 comparators are outputs that indicate wetness and continuity. The resistor values are given theoretical values but will be adjusted after experimentation to properly threshold the input. When the circuit functions normally, current flows from the voltage source through the two loops into a ground. The CompIN node should be at

about half the source's voltage. The node is compared with a relatively low voltage to determine wetness. When the mattress cover is wet, however, R2 is shorted and the voltage at CompIN is near ground, so the output would change values and indicate the sheet is wet. Continuity is similarly determined. The second opamp compares the CompIN node to a relatively high voltage. When a break in one of the loops occurs, the CompIN is pulled up above that threshold, so the output signals a break.

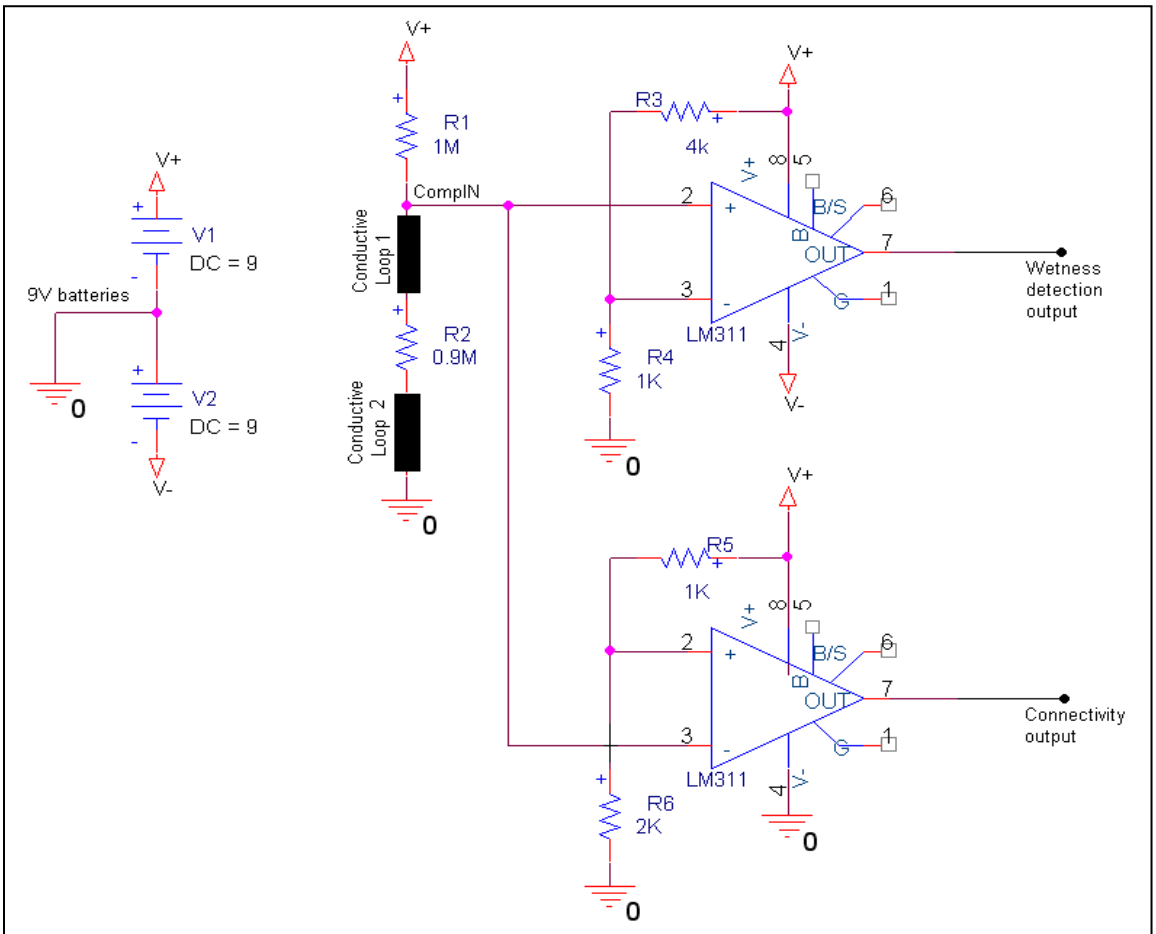

Figure 3. Wetness and broken lead detection circuit.

Schedule, Tasks, and Milestone

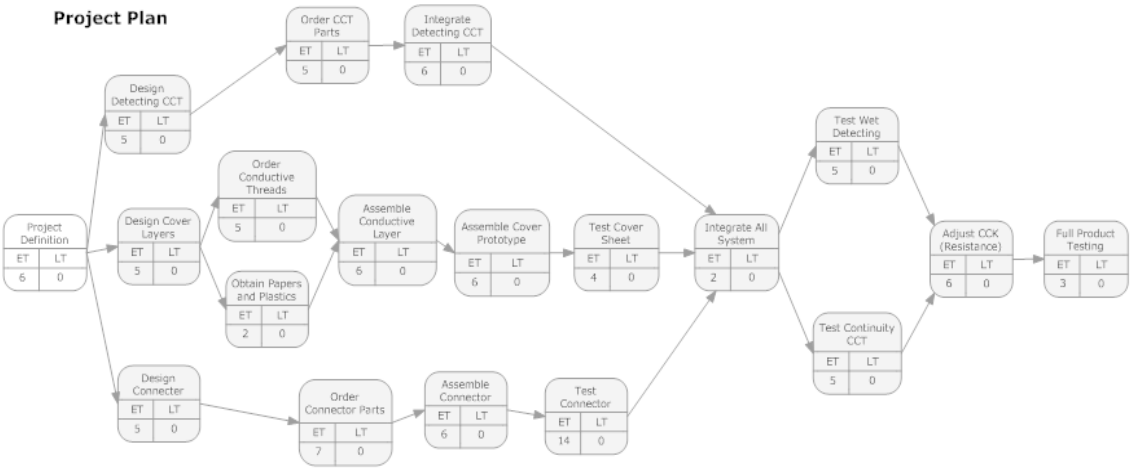

Figure 4. PERT Chart of Project Schedule.

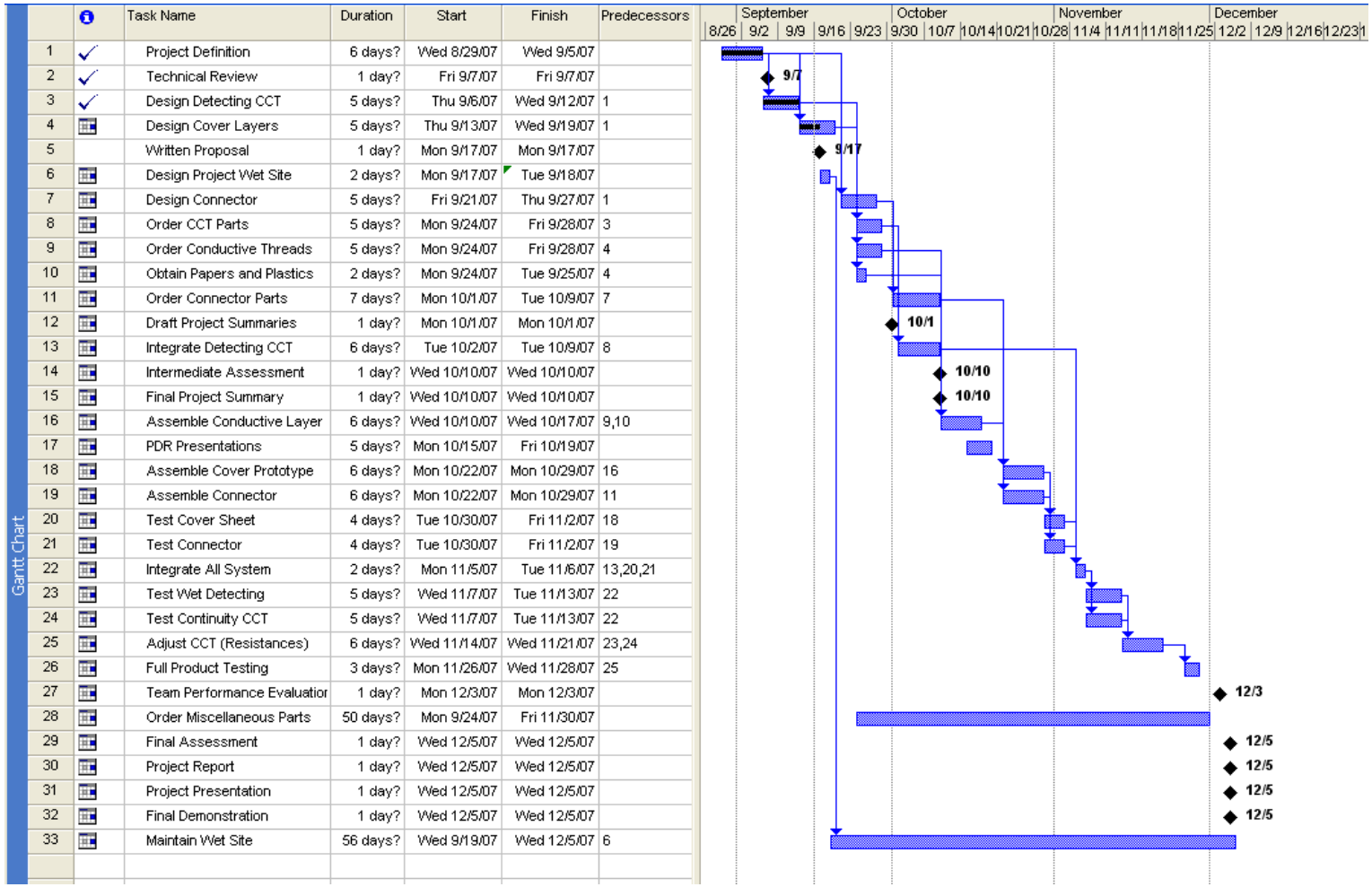

Figure 5. Gantt Chart of Project Schedule.

Project Demonstration

The final prototype for the mattress sheet cover will be placed on a hospital mattress for demonstration purposes. A volunteer from the group will lie on the mattress to show that the sheet will not set off false alarms and that the conductive threads are not so fragile as to break due to patient movement. A glass of salty water (with a concentration of 1g/L of common salt in water) will be used to simulate the effects of urine or blood on the sheet. A dropper will be used to drop the salty water on the sheet so that the sensitivity of the circuit in detecting blood and urine can be demonstrated. A LED lighting up will simulate an alarm signal to show that the sheet is capable of sending an alarm to any monitoring station.

After the blood and urine detection demonstration, one of the wires on the sheet will be cut at an arbitrary point to demonstrate that the sheet can detect tears. The alarm signal for a tear will be a second LED lighting up.

Marketing Analysis

Today many of the infections occurring in hospitals are caused by body fluids left undetected on the beds. More than 80,000 deaths happen because of these kinds of infections [8]. Using disposable mattress covers that can detect these kinds of fluids, it will be possible to reduce the number of deaths by a significant number. These numbers support the development of the product for hospitals. In addition, if the product succeeds in hospitals, it would be possible to expand to nursing homes and home usage.

As of today, there is no other disposable product that has the capability of effectively detecting body fluids. Some products that are used to detect urine of people at the age of 3-16 already exist, but while the disposable mattress cover will cost approximately $2.00 (detailed cost breakdown will be discussed in more details in the next section), these other products cost about

$70-$100. For instance, the Bedwetting Store offers Malem Bedwetting Alarm, which has a detector in the underwear that is connected to an alarm [6]. This product is offered for $79.95-$84.95. In addition, The Bedwetting Store offers alternative products that are used to detect bed wetting by an external device that is laid under the bed covers. The Wet Call Bed-side Bedwetting Alarm with Pad is an example of these kinds of devices. The device is a mattress that can detect fluids and is connected to an external alarm [9]. This product costs $84.95.

The products that are offered in the market are for home usage and are meant to be used more than one time. Since it is assumed that people with bed wetting problem are going to experience repetitive bed wetting, the products offer a device that is reusable. The product proposed, on the other hand, is meant for one time use only. Once body fluids are detected, the mattress needs to be replaced and a new sheet is to be put on the bed. The advantage is that the product being developed will cost approximately 3% of the products that are currently on the market. This will be particularly useful in hospitals, where there is a high need for cleanliness and where patients change their bed cover sheets all the time. It will be possible to keep a high level of hygiene at a low cost.

Cost Analysis

This cost analysis assumes income of $52,200 per year for Electrical Engineering students from Georgia Institute of Technology [10]. This yields $25 per hour of work.

Determination of Selling Price:

Based on twelve billion units sold in the first five years assuming 10% market share [11]. Assembly labor is very low since the sheets are going to be produced in an automated line in the factory. Each sheet will be tested by eye sight only. Marking cost are used only to advertise the new product. The company that is manufacturing the product has already market share and does not need to market the product as a new one. Prices for parts are taken from company quotes.

Development Costs:

Fringe Benefits

Item	Percentage
Health Insurance	5%
Fuel & Other Transportation Costs	5%
Cell Phones	1%
401k	1%
Total	12%

Parts	Price	
10 Covers + shipment	$21.70	
Conductive Thread	$76.95	[12]
20 LN741CN Op Amps + shipment	$19.80	[13]
Other electric parts: batteries, board, and box	$40.00	
Total	$158.45	

Labor	Hours	Price
Yuval Rooz	161	$4,025.00
Meetings	64	$1,600.00
Classes	32	$800.00
Writing Reports	25	$625.00
Product Development	30	$750.00
Web Development	10	$250.00
Jacob Huang	156	$3,900.00
Meetings	64	$1,600.00
Classes	32	$800.00
Writing Reports	30	$750.00
Product Development	30	$750.00
Gopinath Jayaprakash	156	$3,900.00
Meetings	64	$1,600.00
Classes	32	$800.00
Writing Reports	25	$625.00
Product Development	30	$750.00
Grroup discussion page maintenance	5	$125.00
Ankit Hemani	151	$3,775.00
Meetings	64	$1,600.00
Classes	32	$800.00
Writing Reports	25	$625.00
Product Development	30	$750.00
Heonwoo Song	151	$3,775.00
Meetings	64	$1,600.00
Classes	32	$800.00
Writing Reports	25	$625.00
Product Development	30	$750.00
Serju Vasavada	151	$3,775.00

Meetings	64	$1,600.00
Classes	32	$800.00
Writing Reports	25	$625.00
Product Development	30	$750.00
Total	926	$23,150.00

Cost and Price Calculations

Fringe Benefits	***12%***	of labor
Overhead	***20%***	of materials, labor & fringe
Sales & Marketing Expense	***15%***	of selling price
Warranty & Support Expense	***5%***	of selling price

Development Cost (Non-recurring Cost)

What it costs the company to develop the product

Parts	***$155.45***
Labor	***$23,150.00***
Fringe Benefits, % of Labor	$2,778.00
Subtotal	$26,083.45
Overhead, % of Matl, Labor & Fringe	$5,216.69
Total	$31,300.14

Determination of Selling Price

What the customer pays the company for the finished product

Based on: ***12,000,000,000*** units

Parts Cost	***$1.00***
Assembly Labor	***$0.05***
Testing Labor	***$0.10***
Total Labor	$0.15
Fringe Benefits, % of Labor	$0.02
Subtotal	$1.17
Overhead, % of Matl, Labor & Fringe	$0.23
Subtotal, Input Costs	$1.40
Sales & Marketing Expense	$0.30
Warranty & Support Expense	$0.10
Amortized Development Costs	$0.00

Subtotal, All Costs	$1.80	
Profit	$0.20	9.9%
Selling Price	***$2.00***	

Total Revenue	$24,000,000,000
Total Profit	$2,380,768,700

Summary

The project is currently in its design phase wherein a team of group members are deciding on most economical and sustainable stitching process of the conductive threads on the sheet. A discussion is underway with various companies both in U.S. and outside U.S. The manufacturing of the biodegradable, polyethylene-treated, disposable paper is being discussed with Georgia Pacific. Another project group is currently working on the design of the amplifier circuit, which can transmit the output signal to the microcontroller. The microcontroller will further correlate these changes with the ideal conditions and trigger appropriate signals on LEDs. Consultation is also sought from Dr. Leech at Georgia Tech to design the correct gain for the amplifier. A prototype of the mattress cover will be built as soon as an optimal circuit is realized. The working methodologies of the entire project are currently discussed on a group page, wherein all the relevant information regarding circuit architecture and design, daily progress reports, and suggestions by professors is maintained and distributed to the members of the group. Since the project is expected to be implemented for mass production, a comprehensive cost-benefit analysis was performed by a group member to analyze the feasibility of its implementation on a mass scale. Also, the project is realized in different stages, and the group is divided into a sub groups wherein each member of the subgroup will contribute to one of the aspects of the project related to his specialization. Gantt charts will be effectively used in the process. The group intends to open a website dedicated to the progress of the project after successfully designing and implementing the prototype mattress.

References

[1] A. Koblasz, "Project AK6: Disposable Mattress Cover that Detects When the sheets Are Wet. Koblasz Projects for ECE 4007 fall 2007." [Online Document] (Aug. 2007), Available: http://www.ece.gatech.edu/academic/courses/ece4884.

[2] Y. Yonezawa, Y. Miyamoto, H. Maki, H. Ogawa, I. Ninomiya, K. Sada, S. Hamada, and W. Caldwell, "A new intelligent bed care system for hospital and home patients", Biomedical Instrumentation & Technology, vol.39, 313-384, July- Aug 2005.

[3] A. Koblasz, "Re: [Ece4884a] More about the Tech Review Paper", Personal E-mail (Sep. 4, 2007).

[4] Q. Nguyen, MD. "Hospital-Acquired Infections." Internet: http://www.emedicine.com/ped/topic1619.htm, Aug. 21, 2007 [Sep. 16, 2007].

[5] J. Heritage. "Killing Microorganisms." Internet: http://www.bmb.leeds.ac.uk/mbiology/ug/ugteach/dental/tutorials/xinfect/history.html, Apr. 2007 [Sep. 16, 2007]

[6] Bedwetting Store, "Malem bedwetting alarm," [online document], 2007 Sep 05, [cited 2007 Sep 16], Available HTTP: http://www.bedwettingstore.com/Bedwetting_Alarms/malem_bedwetting_alarm.htm.

[7] The EMF Safty Superstore, "EMF shielding & conductive fabrics," [online document], 2007 Sep 04, [cited 2007 Sep 07], Available HTTP: http://www.lessemf.com/fabric.html.

[8] B. Starfield, “Is US health really the best in the world,” The Journal of the American Medical Association, Vol. 284, no. 4, pp.483-485, 2000.

[9] Bedwetting Store, “Wet Call Bed-side Bedwetting Alarm with Pad,” [online document], 2007 Jun 20, [cited 2007 Sep 16], Available HTTP: http://www.bedwettingstore.com/Bedwetting_Alarms/wetcall_bedwetting_alarm.htm.

[10] Career Services – Georgia Institute of Technology, “Salary survey,” [online document], 2007 Sep 16, [cited 2007 Sep 16], Available HTTP: http://career.gatech.edu/students/bachelor.pdf.

[11] MSEC, “Hospital bed sheets,” [online document], 2007 Sep 16, [cited 2007 Sep 16], Available HTTP: http://home-health-care.medical-supplies-equipment-company.com/PPF/page_ID/230/article.asp

[12] RadioShack, “Slim Line 2" alligator clips,” [online document], 2007 Sep 15, [cited 2007 Sep 16], Available HTTP: http://www.radioshack.com/product/index.jsp?productId=2062224&cp=2032058.2032235.2032304&parentPage=family.

[13] RadioShack, “LM741CN Operational amplifier (8-Pin Dip),” [online document], 2007 Sep 16, [cited 2007 Sep 16], Available HTTP: https://www.google.com/accounts/ServiceLogin?service=mail&passive=true&rm=false&continue=http%3A%2F%2Fmail.google.com%2Fmail%3Fui%3Dhtml%26zy%3Dl&ltmpl=default&ltmplcache=2&hl=en.