Power to the People: New Student Union Building Energy Harvesting

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New SUB Energy Harvesting

Statement of the problem

The new Student Union Building for the University of British Columbia is being designed to be one of the most sustainable and energy efficient green buildings in the world. To achieve this, many different types of energy saving systems are being implemented in the new SUB.

The goal of this project was to design a *multi-function* energy harvesting system that was *creative*, *interactive*, and would *educate* the public about energy harvesting technologies and sustainable building design.

Background Information

Energy Harvesting

Due to growing concerns about global warming and resource depletion, finding methods of harvesting wasted energy is becoming an increasingly popular area of research. There are many different types of wasted energy that could potentially be scavenged for practical use. Some examples of possible untapped energy sources are body heat energy, human footstep energy and waste water energy.

Piezoelectric Effect

Piezoelectric ceramics are a special material that can create an electrical voltage when it is squished or stretched. This voltage can be used to power a variety of low input power devices, such as lights or speakers without any additional help from batteries.

Analysis

Many different methods of energy harvesting were initially investigated before finally deciding upon using stacks made from a piezoelectric material. There were several promising design applications using these special stacks that could be integrated into the new SUB. The top three designs were a piezoelectric floor tile, a piezoelectric stair case and a piezoelectric gaming unit where users could compete against one another to see who could generate the most power.

To promote student involvement, an online pole was posted on mynewsub.com and in-person surveys were conducted to see what current SUB users would most want to see in their new SUB. The piezoelectric floor tile was the most popular application because it was thought to be accessible to the widest audience.

Design

The floor tile consists of three major components, the system that allows the weight of the person on top of the tile to squish the piezoelectric stacks, the circuitry that connects the stacks to the lights and the supporting structure.

A user can step, walk across or dance on the tile and watch it light up with their movement.

CONCLUSIONS

The finished prototype is one tile that is able to light up several lights inside the tile when a user jumps or walks on and off the tile. The brightness of the lights is proportional to the weight and impact with which the user steps on the top of the tile.

The tile will bring people together while playing with the tile and also give visitors to the new SUB an idea of all of the potential sources of useable energy that we neglect every day. People will be able interact with the device and view their own personal energy being scavenged into something useful.

While other piezoelectric floor tiles do exist, it is still a very new and cutting edge form of technology. This application and specific method of harvesting energy from footsteps using this type of system is rare and has never before been done.

RECOMMENDATIONS

The design of the tile would have to be modified before it could be implemented in the new SUB. An ideal location for the tile would be somewhere dimly lit, but frequently accessed by the SUB patrons.

The components of the device could be made of more sustainable materials, but this was not feasible due to budgetary constraints for the prototype. If the tile were to be manufactured on a larger scale, it could be more economic to use more recycled parts, as their cost would be less in bulk.

Future improvements to the design could also potentially increase the output power of the device, allowing more lights to be lit up, or perhaps power something requiring even more energy.

THE UNIVERSITY OF BRITISH COLUMBIA

POWER TO THE PEOPLE

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1 Introduction

1.1 Purpose of Report

The purpose of this report is to summarize the results of our design project. Over the course of the past eight months, an energy harvesting floor tile was designed and built using piezoelectric stacks to generate a voltage that was used to power a series of LEDs in the device.

1.2 Format

The report is divided into four sections:

1. Objectives: the problem statement and interpretation of the problem
2. Design and Testing: the major components, how they work, testing and validation
3. Conclusion: how the final prototype performs and solves the problem
4. Recommendations: suggestions on improving the design and implementation of the device

This report is a compilation of a series of previous design phase reports. References to the previous reports will be made in footnotes.

2 Objectives

A new Student Union building is being designed and planned for the Vancouver UBC campus. The new SUB building is intended to be a world leader in sustainability and energy efficiency. The purpose of this project was to design and build some sort of energy harvesting device that could be installed in the new SUB. The clients for this project were the New SUB AMS.

Based on the needs that were identified by the clients, the purpose of this project was as follows:

Problem Statement

> *To design a multi-function energy harvesting system that is creative, interactive, and educates the public about energy harvesting technology and sustainable building design.*

There are many methods that can be used to scavenge wasted energy from our surroundings. Many different forms and applications of energy harvesting were researched and analyzed before determining that using piezoelectric technology would be most suitable for this application.

3 Background

The early concept generation phases of this project generated a number of different design types. Many things were considered, including a variety of energy harvesting ideas. Designs ranged from widely used technologies like wind turbines, to more obscure concepts such as energy harvesting trampolines. A series of winnowing stages ultimately narrowed the plausible concepts down to just three shown in Figure 1. They use piezoelectric elements to convert walking energy into useable electricity.

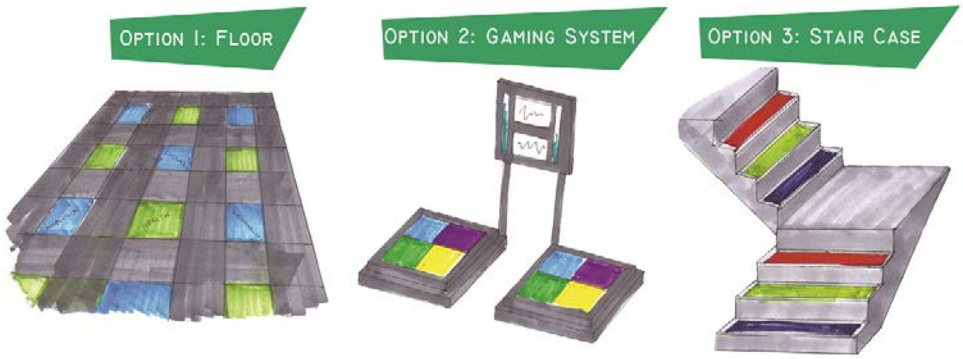

Figure 1 - Piezoelectric design choices considered

In order to decide between these options, the choice was taken to the public for feedback, and the general consensus was that the piezoelectric floor option was the most popular. The basic concept of operation can be seen below in Figure 2. A user interacts by walking on the clear top of the tile. The force of walking is transferred to the piezoelectric stack, which powers LED's through a signal processing circuit. The user experiences the tile lighting beneath their feet with every step.

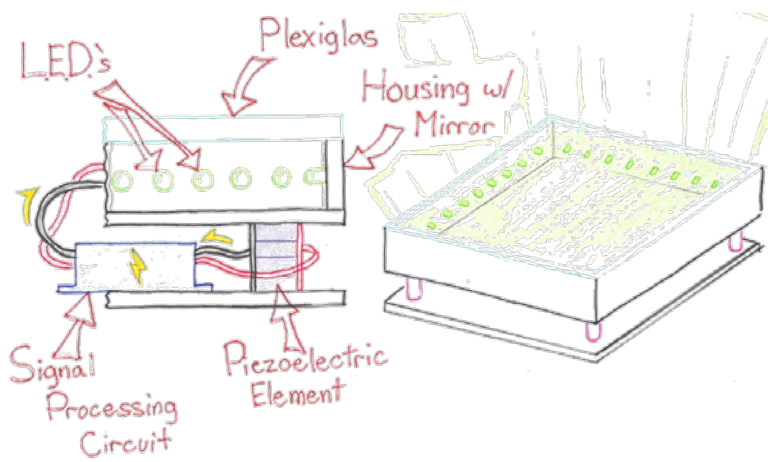

Figure 2 - Conceptual function of a piezoelectric floor tile

4 Design and Testing

4.1 Major Components

The upper section of our design consists of a clear Lexan sheet, a steel frame, and basic circuitry. The bottom part consists of a mechanical leverage system, a base and piezoelectric ceramic stacks. Users will only interact with the Lexan sheet, which will be flush with the surrounding floor, and supports will be press fit into the Lexan to allow room for LED lighting effects. The leverage system provides fourteen times force amplification. In the final circuit design as shown in the ciruit diagram in Figure 3, there are two capacitors, a bridge rectifier, and a number of LEDs.

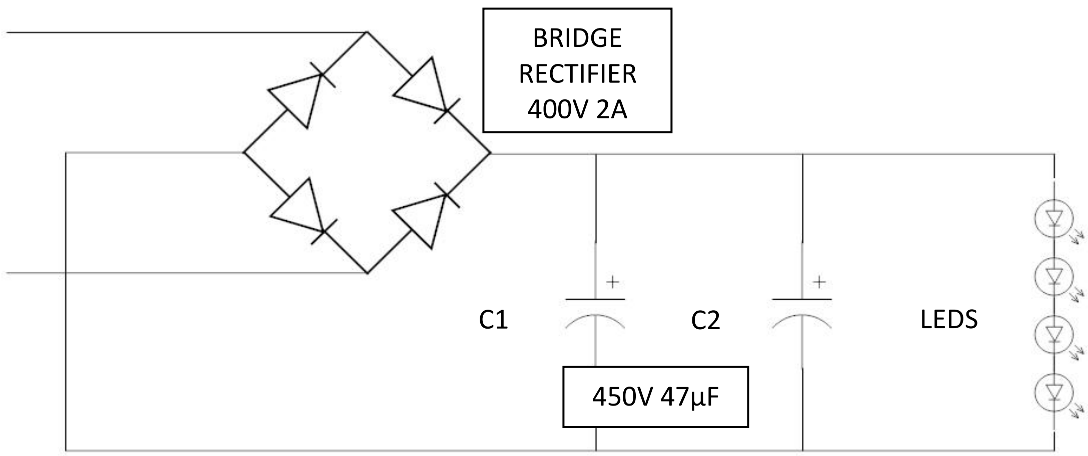

Figure 3: Electrical Circuit Diagram

4.2 How It Works

The vertical force of the user is applied to four identical lever arms. Figure 4 shows a side view of the system. When the vertical force is applied, the lever arms pull the two metal blocks, tensioning the attached bolts.

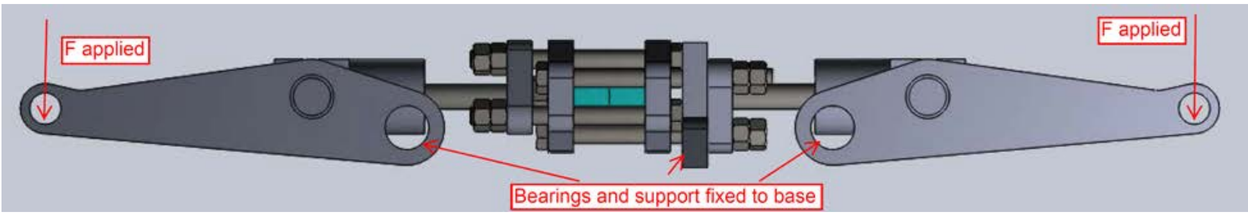

Figure 4: Leverage system

The middle section of the leverage system converts the tension created from the lever arms to compression around the piezostack.

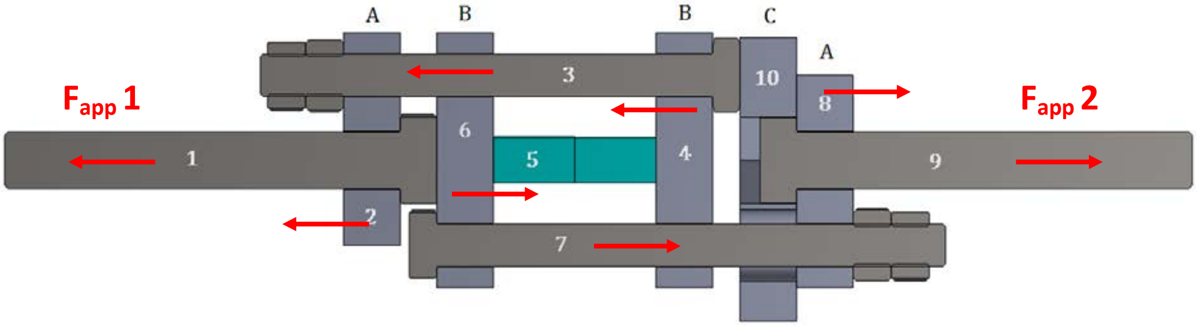

Figure 5: Section view of piezostack system

Force 1 applied, on the left of Figure 5, creates a tension force in bolt 1 and transfers it to block 2. Then block 2 pulls on bolt 3 which pulls on block 4. Block 4 squishes the piezostacks (5) against block 6. Block 6 pulls on bolt 7 which pushes on block 8, which in turn pushes on base 10, assuming bolt 9 is unloaded.

Similarly, when force 2 is applied to the right of the figure, a tension force is applied to bolt 9, pulling on block 8. Block 8 pulls on bolt 7, which pulls on block 6. Block 6 squishes the piezostack (5) against block 4 which pushes the head of bolt 3 against the base (10).

A solid model representation of the system is shown in Figure 6.

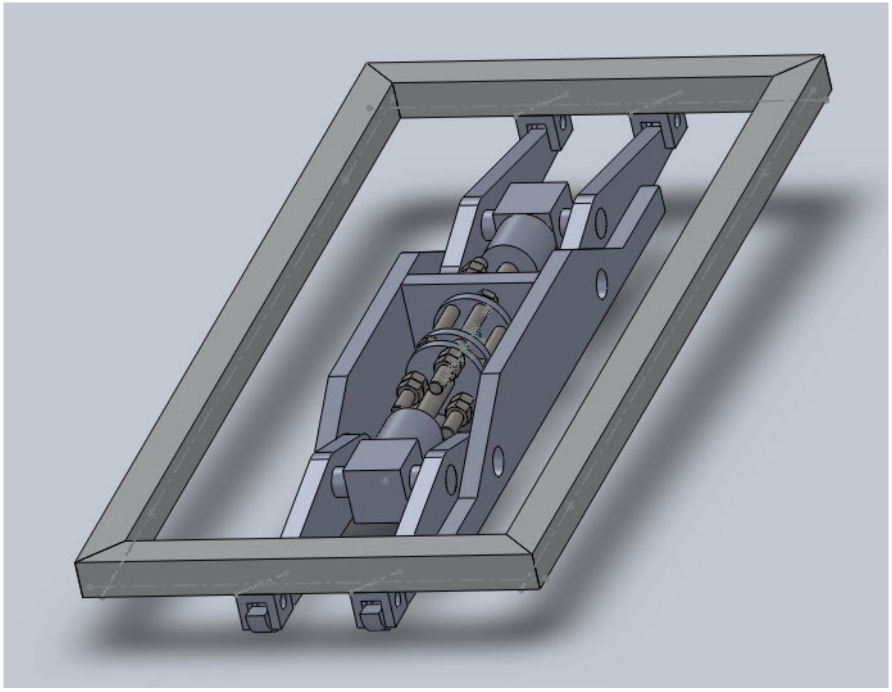

Figure 6: A solid model of the leverage system

When subjected to compression, the piezostacks output a positive voltage and will also produce a negative voltage once the compression is released to return to the steady state. A full wave bridge rectifier is used to ensure the current flows in one direction. The current is smoothed through two capacitors, which are used to power LEDs. The accumulated charge is able to dissipate over time, resulting in the LEDs being lit up for a longer period of time.

4.3 Testing and Results

The main objective of the prototype is to harvest sufficient energy to power LEDs or equivalent. Research was done thoroughly to specify the piezoelectric stacks needed, tests were performed using a compressive rig on one piezoelectric stack connected to an initial electric circuit with four LEDs[1]. The tests verified that a series of four LEDs can be lit by applying force onto the compressive rig, thereby validating the piezoceramic material.

A physical wood prototype of the proposed leverage design to excite the piezoelectric stacks was also built. It identified major areas that required additional support and constraints and potential flaws in the leverage design[2]. Upon modifications of the leverage design, the final design was finalized after extensive calculations[3] and computer analysis in SolidWorks.

Final testing on the entire assembled device included strength tests[4] and trials of a combination of activities performed on the floor tile and varying weights of typical adult users[5]. From these tests, it was concluded that while the device has sufficient strength and structure support for supporting a user's weight, the tile was not entirely stable at the outer edges. In addition, the optimal number of LEDs is determined from the limiting voltage that the piezoelectric stacks are capable of generating in the case when a light user performs a stepping motion onto the floor tile. The optimal number of LEDs is configured in three strings of two LEDs in parallel with each other. Additional surveys were conducted towards users to question them about their experience after interacting with the device[6]. These results will aid in generating recommendations regarding the structure of the device and how the device can improve on the user's experience.

[1] See Phase 10+11 Section 3.1
[2] See Phase 10+11 Section 3.3
[3] See Phase 10+11 Appendix
[4] See Phase 12 Section 2.3.1
[5] See Phase 12 Table 2
[6] See Phase 12 Section 2.3.3

5 Conclusions

The prototype was successful in the fact that it fulfilled its design requirements. It educates users that even something as small as footsteps, if used correctly, can be put towards doing useful work. The aim wasn't to educate about piezoelectrics in particular, but educating about sustainability as a whole. We believe the design, if presented correctly, can help inject ideas of sustainability into the mindset of the user. It is innovative due to the fact that piezoelectric harvesting is a cutting edge technology, and it is creative due to the fact that illuminating floors are seldom seen. It promotes exercise because it beckons users to jump on it, it is directly interactive with the user, and it acts as a conversation piece, helping to bring people together and share their ideas of sustainability. If recycled materials could be implemented for the final design, it would promote the 3 R's, and give it an overall "greener" footprint.

In terms of measurable performance wise, the prototype withstood a variety of operating conditions we put it through, and it produced a significant light output for even the lightest of individuals tested. By our criteria, the prototype was a success.

6 Recommendations

Through testing of the final prototype, several issues became evident that need remedy before the production unit. They are listed below:

1. It should be fixed to the floor. It would improve stability as well as reduce the tendency for the tile to tilt.
2. Cotter pins should be incorporated into the shafts. Otherwise, the shafts will be pushed out over time.
3. Having thinner or no bushings would be beneficial in the fact that the tile would displace less when it is stepped upon. Ideally, if no plastic bushings are present, the displacement of the tile would be negligible.
4. A proposed lighting effect would be to laser etched the underside of the Lexan with a message or a picture, like "Powered by You", a picture of a leaf, or the UBC logo. It would illuminate the same matter as an LED edge lit sign.
5. Investigation into the use of more sustainable or recycled materials should be considered if possible. Availability may be an issue, but it is more feasible at large scale.
6. Though white LEDs are the brightest variety, coloured tints can be used to change the colour while still keeping a high light output efficiency for variety or emphasis
7. Seals between tiles may be necessary to prevent debris or water from entering.
8. Doubling the height of the piezoelectric stack will double the performance of the tile, so maximizing the amount of piezoelectric material per unit cost is critical during the final sourcing of components. The lower the cost, the more feasible it is to implement more per tile.