PIEZOELECTRIC LED LIGHTING

A Thesis

Presented to the

College of Technology

Industrial Automation Department

Cebu Technological University

Main Campus R. Palma St. M.J. Cuenco Ave. Cebu City

In Partial Fulfillment

Of the Requirements for the **Degrees**

Bachelor of Science in Mechatronics & Bachelor of Science in Graphics and Design

By:
Jesse Angelo Maraat
Tim David Mayol
Andrea Marie Amistoso
Kevin Balansag
Janica Kate Ortigas
Matthew Seth Molero
Joevic Pitogo
Vincent Ruiz Colorito
Nash Ashley Duhaylungsod
Brosnan Nadal

2025

APPROVAL SHEET

This research entitled "**Piezoelectric LED Lighting"** prepared and submitted by **Jesse Angelo Maraat, Tim David Mayol, Andrea Marie Amistoso, Kevin Balansag, Janica Kate Ortigas, Matthew Seth Molero, Joevic Pitogo, Vincent Ruiz Colorito, Nash Ashley Duhaylungsod, Brosnan Nada**l **,** in partial fulfillment of the requirements for the Bachelor of Science in Graphics and Design and Bachelor of Science in Mechatronics has been examined and recommended for acceptance and approval for Oral Examination.

RESEARCH COMMITTEE

JANICE A. ALIVIO, Ph.D.
Dean, College of Technology

PAUL K. ZABALA, Ph.D.
Adviser

HARVEY O. ARCHES, MSIT
Panel Member

MARNIEL B. ALBINTO, MSIT
Panel Member

JOCELYN A. ABOJON, Ph.D.
Panel Member

PAUL K. ZABALA, Ph.D.
Chairman
Industrial Automation Department

JANET P. MONTECILLO, MBA
Chairman
Industrial Automation Department

PANEL EXAMINERS

Approved by the Committee on Oral Examination with a Grade of __PASSED__.

JANICE A. ALIVIO, Ph.D.
Dean, College of Technology

PAUL K. ZABALA, Ph.D.
Adviser

HARVEY O. ARCHES, MSIT
Panel Member

MARNIEL B. ALBINTO, MSIT
Panel Member

JOCELYN A. ABOJON, Ph.D.
Panel Member

PAUL K. ZABALA, Ph.D.
Chairman
Industrial Automation Department

JANET P. MONTECILLO, MBA
Chairman
Industrial Automation Department

ACCEPTED AND APPROVED in partial fulfillment of the requirements for the degree of **Bachelor of Science in Graphics and Design** (BSGD) and **Bachelor of Science in Mechatronics (BSMX).**

Date of Oral Examination: **May 6, 2025**

ABSTRACT

Title	:	**Piezoelectric LED Lighting**
Researcher	:	Jesse Angelo Maraat, Tim David Mayol, Andrea Marie Amistoso, Kevin Balansag, Janica Kate Ortigas, Matthew Seth Molero, Joevic Pitogo, Vincent Ruiz Colorito, Nash Ashley Duhaylungsod, Brosnan Nadal
Degree	:	Bachelor of Science in Graphics and Design Bachelor of Science in Mechatronics
Adviser	:	Paul K. Zabala, Ph.D.
Institution	:	Cebu Technological University Main Campus, R. Palma St. Cebu City
Year Completed	:	2025
No. of Pages	:	121

The main thrust of the study was to develop and assess the acceptability level of the Piezoelectric LED Lighting, which was designed to harness energy by turning mechanical stress into electrical energy. Despite the continuous generation of kinetic energy in high foot traffic public areas, there remains a significant gap in efficient, cost-effective technologies to harness this energy for practical uses such as LED lighting. The study uses a descriptive research method that utilizes a researcher-made questionnaire to assess the machine's acceptability level. The developed machine underwent a thorough demonstration at Cebu Technological University-Main Campus to evaluate its Performance, Features, Aesthetics, and Serviceability. The Piezoelectric Powered LED Lighting scored an overall average weighted mean of **4.52** which falls within the **Highly Acceptable** rating. The machine's main features meet the target respondents' expectations. This indicates that the Piezoelectric Powered LED Lighting was able to accomplish the desired charging and lighting of LEDs without experiencing any significant problems during the process.

ACKNOWLEDGEMENT

The researchers would like to express their profound appreciation to their friends and family for helping make this endeavor a success. Because the researcher has found strength in their love, support, and understanding throughout the difficulties and successes of this journey. Additionally, this would not have been feasible without the direction, assistance, and mentorship of the instructors. To all of the respondents who have helped make this initiative a success by being understanding and patient.

The researchers are also sincerely grateful to the panelists who generously shared their time, expertise, and valuable insights during the evaluation of this study. Your constructive feedback and critical suggestions have significantly contributed to the refinement and success of this research.

The Researchers would also like to thank Prof. Jay Lester Radam for assisting us in the functionality and wiring of the project.

The Researchers would also like to extend their deepest appreciation to their research adviser Dr. Paul K. Zabala for the unwavering guidance given to us throughout the project.

Above all, thanks to the all-powerful God for protecting and guiding the researchers on their mission.

The Researchers,

DEDICATION

Their cherished parents, who have been our inspiration and source of strength since the day we were born, are honored in this study article.

For his unwavering support, company, and encouragement along this journey, the researchers would like to sincerely thank their advisor, Dr. Paul K. Zabala.

As a tiny measure of thankfulness for your crucial assistance in its development, we humbly and joyfully dedicate this work to each and every one of you.

Over the course of our academic careers, we have encountered innumerable possibilities for collaboration, dialogue, and mutual learning. Your diverse perspectives, unending curiosity, and enthusiasm for learning have improved our classroom instruction and inspired us to seek the greatest caliber of research objectives.

Finally, we respectfully and gratefully dedicate this study undertaking to our Almighty God, the fount of all inspiration, guidance, and knowledge. We write these words to express our sincere gratitude and humility for your unwavering guidance and support during this study undertaking.

The Researchers,

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BIBLIOGRAPHY

1. Cady, W. G. (1946). Piezoelectricity: An introduction to the theory and applications of electromechanical phenomena in crystals. Dover Publications.

2. Chrysafides, M., & Souvatzis, P. (2017). Piezoelectric materials: Applications and challenges in energy harvesting. Materials Science and Engineering: B, 220, 56-62.

3. Fischer, E. M., et al. (2018). User acceptance and interaction with renewable energy systems in urban settings. Renewable Energy, 126, 326-337.

4. Heskett, J. (2005). Design: A Very Short Introduction. Oxford University Press.

   https://books.google.com.ph/books/about/Design_A_Very_Short_Introduction.html?id=5hxqRkf4znkC&redir_esc=y

5. Ghazanfarian, J., Mohammadi, M. M., & Uchino, K. (2021). Piezoelectric Energy Harvesting: A Systematic Review of Reviews. Actuators, 10(12), 312.

   https://www.mdpi.com/2076-0825/10/12/312?form=MG0AV3

6. Johnson, D. (2021). Energy consumption of consumer electronics in U.S. homes in 2020. *Journal of Consumer Electronics*, *21*(4), 123-135.

7. Koffka, K. (1935). Principles of Gestalt Psychology. Harcourt Brace and Company. https://archive.org/details/in.ernet.dli.2015.7888?form=MG0AV3

7. Kumar, D., & Chaturvedi, P. (2013). Piezoelectric energy harvesting from vibration induced deformation of floor tiles. In Sixth National Power Electronics Conference (NPEC).

8. Liu, H., Zhong, J., Lee, C., Lee, S.-W., & Lin, L. (2018). A Comprehensive Review on Piezoelectric Energy Harvesting Technology: Materials, Mechanisms, and Applications. Applied Physics Reviews, 5(4), 041306. https://www.cta.tech/resources/Articles/2021/Energy-Consumption-of-Consumer-Electronics-in-U-S

9. Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). "Overview of current development in electrical energy storage technologies and the application potential in power system operation." *Applied Energy*, 137, 511-536.

10. McGowan, K. J., & McGowan, S. J. K. (2020). User engagement with renewable energy technologies: Insights from case studies. Renewable Energy, 145, 1517-1525.

11. Priya, S., & Inman, D. J. (2009). Energy harvesting technologies. Springer.Roundy, S., & Wright, P. K. (2004). A piezoelect vibration-

based generator for wireless electronics. Smart Materials and Structures.

12. Rivera, J. P., Rosellon, M. A. D., & Maniego, M. E. (2021). Clean Energy Technology in the Philippines: Case of the Electric Vehicle Industry. Philippine Institute for Development Studies. https://pidswebs.pids.gov.ph/CDN/PUBLICATIONS/pidsdps2115.pdf?form=MG0AV3

13. Saghir, J., & Santillan, J. (2017). "Energy conservation and efficiency in the Philippines: Addressing cost and sustainability." *Philippine Journal of Energy Policy*, 15(2), 205-219.

14. Sarkar, A., & Singh, J. (2010). "Financing energy efficiency in developing countries—lessons learned and remaining challenges." *Energy Policy*, 38(10), 5560-5571.

15. Touloukian, Y. S. (1970). Thermophysical properties of matter: The TPRC data series, Vol. 12: Piezoelectric properties. IFI/Plenum.

16. Wang, S., Wen, L., Gong, X., Liang, J., Hou, X., & Hou, F. (2022). Piezoelectric-Based Energy Conversion and Storage Materials.

APPENDICES

Appendix A

LETTER REQUEST TO CONDUCT SURVEY

Republic of the Philippines
CEBU TECHNOLOGICAL UNIVERSITY
MAIN CAMPUS
M.J. Cuenco Ave. Cor R. Palma Street, 6000 Cebu
Website https://www.ctu.edu.ph/ E-mail thepresident@ctu.edu.ph
Phone +6332 402 4060 loc. 1137
COLLEGE OF TECHNOLOGY

BAGONG PILIPINAS

INDUSTRIAL AUTOMATION DEPARTMENT

February 28, 2025

DR. PAUL ZABALA
Chairman, Mechatronics Department
Cebu Technological Main Campus
R. Palma Street, Cebu City

Dear Dr. Zabala,

RE: Request for Permission to Conduct Survey

We, the undersigned research team, would like to request permission to conduct a survey within your institution, Cebu Technological University, as part of our ongoing research project which is "Piezoelectric Powered LED Lighting", as undergraduate 3rd-year students. Our research team has designed a survey questionnaire for our respondents to fill. We assure you that all responses will be kept confidential and used solely for research purposes. We kindly request your approval to administer this survey to BSGD faculty members, BSMX faculty members and to students under these two departments. We would greatly appreciate your cooperation and are available to address any questions or concerns you may have.

Thank you for considering this request.

Sincerely,

Jesse Angelo Maraat   Tim David Mayol   Andrea Marie Amistoso   Kevin Balansag
Janica Kate Ortigas   Matthew Seth Molero   Joevic Pitogo   Vincent Ruiz Colorito
Nash Ashley Duhaylungsod   Brosnan Nadal

Noted by:

Dr. Paul Zabala
Research Adviser
Mechatronics Department

Approved By:

Dr. Paul Zabala
Chairman
Mechatronics Department

Republic of the Philippines
CEBU TECHNOLOGICAL UNIVERSITY
MAIN CAMPUS
M.J. Cuenco Ave, Cor R. Palma Street, 6000 Cebu
Website: https://www.ctu.edu.ph/ E-mail: thepresident@ctu.edu.ph
Phone: +6332 402 4060 loc. 1137
COLLEGE OF TECHNOLOGY

BAGONG PILIPINAS

INDUSTRIAL AUTOMATION DEPARTMENT

February 28, 2025

PROF. JANET MONTECILLO
Chairman, Graphics and Design Department
Cebu Technological Main Campus
R. Palma Street, Cebu City

Dear Prof. Montecillo ,

RE: Request for Permission to Conduct Survey

We, the undersigned research team, would like to request permission to conduct a survey within your institution, Cebu Technological University, as part of our ongoing research project which is "Piezoelectric Powered LED Lighting", as undergraduate 3rd-year students. Our research team has designed a survey questionnaire for our respondents to fill. We assure you that all responses will be kept confidential and used solely for research purposes. We kindly request your approval to administer this survey to BSGD faculty members, BSMX faculty members and to students under these two departments. We would greatly appreciate your cooperation and are available to address any questions or concerns you may have.

Thank you for considering this request.

Sincerely,

Jesse Angelo Maraat   Tim David Mayol   Andrea Marie Amistoso   Kevin Balansag
Janica Kate Ortigas   Matthew Seth Molero   Joevic Pitogo   Vincent Ruiz Colorito
Nash Ashley Duhaylungsod   Broshan Nadal

Noted by:

Dr. Paul Zabala
Research Adviser
Mechatronics Department

Approved By:

Prof. Janet Montecillo
Chairman
Graphic and Design Department

WURI

Appendix B

COVER LETTER OF THE QUESTIONNAIRE

Republic of the Philippines
CEBU TECHNOLOGICAL UNIVERSITY
MAIN CAMPUS
M.J. Cuenco Avenue Cor. R. Palma Street, Cebu City, Philippines
Website: http://ctu.edu.ph

GRAPHICS AND DESIGN DEPARTMENT
MECHATRONICS DEPARTMENT

INDUSTRIAL AUTOMATION DEPARTMENT

February 12, 2025

Dear Respondents,

We are currently conducting a research study entitled ***Piezoelectric Powered LED Lighting*** This study aims to assess and evaluate the feasibility of the project.

In regard to this, we respectfully ask for your assistance in accurately and truthfully filling out the following questionnaire. Rest assured that every piece of information gathered will be kept private and utilized only for scholarly research.

Your valuable participation in this study is greatly appreciated.

Sincerely yours,

Jesse Angelo Maraat　Tim David Mayol　Andrea Marie Amistoso　Kevin Balansag

Janica Kate Ortigas　Matthew Seth Molero　Joevic Pitogo　Vincent Ruiz Colorito

Nash Ashley Duhaylungsod　Brosnan Nadal

Noted by:

Dr. Paul Zabala
Research Adviser
Mechatronics Department

Appendix C

THE QUESTIONNAIRE

ACCEPTABILITY LEVEL OF THE PIEZOELECTRIC POWERED LED LIGHTING

Name:___________________________________ Date:_________

Instructions: Answer the following questions by putting a check (✓) mark that corresponds to the number of your ratings. Use the following scale in rating the product. You may write comments/suggestions on the j space provided below for the development of the product.

SCORING WEIGHT

Scoring	Categorical Response	Verbal Description
5	Highly Acceptable (HA)	When the machine is 90% - 100%, it is deemed highly acceptable.
4	Moderately Acceptable (MA)	When the machine is 71% - 89%, it is deemed to be moderately acceptable.
3	Fairly Acceptable (FA)	When a machine is 51% - 70%, it is deemed to be reasonably acceptable.
2	Least Acceptable (LA)	When the machine is 31% - 50%, it is deemed least acceptable.
1	Not Acceptable (NA)	When the machine is 0% - 30%, it is deemed completely unacceptable.

Performance	HA (5)	MA (4)	FA (3)	LA (2)	NA (1)
1. The Piezoelectric Powered LED Lighting is able to light the LED.					
2. The Piezoelectric Powered LED Lighting stays in place while being stepped on.					
3. The Piezoelectric Powered LED Lighting operates effectively under different weights and pressures.					
4. The Piezoelectric Powered LED Lighting operates effectively with no observed malfunction.					
5. The Piezoelectric Powered LED Lighting operates silently or minimal noise during energy generation.					
Others Specify:					

Features	HA (5)	MA (4)	FA (3)	LA (2)	NA (1)
1. The Piezoelectric Powered LED Lighting is a user-friendly.					
2. The Piezoelectric Powered LED Lighting support fast charging of capacitor.					

3. The Piezoelectric Powered LED Lighting charging capabilities are reliable and efficient for daily use.					
4. The Piezoelectric Powered LED Lighting storage capacity is sufficient for multiple charges.					
5. The Piezoelectric Powered LED Lighting charging process is smooth with no interruptions.					
Others Specify:					

Serviceability	**HA (5)**	**MA (4)**	**FA (3)**	**LA (2)**	**NA (1)**
1. The Piezoelectric Powered LED Lighting is easy to install and set up.					
2. The Piezoelectric Powered LED Lighting design is allow easy troubleshooting.					
3. The Piezoelectric Powered LED Lighting is easy attach and detach.					
4. The Piezoelectric Powered LED Lighting energy storage system is easy to access and manage.					
5. The Piezoelectric Powered LED Lighting components are accessible in the market.					
Others Specify:					

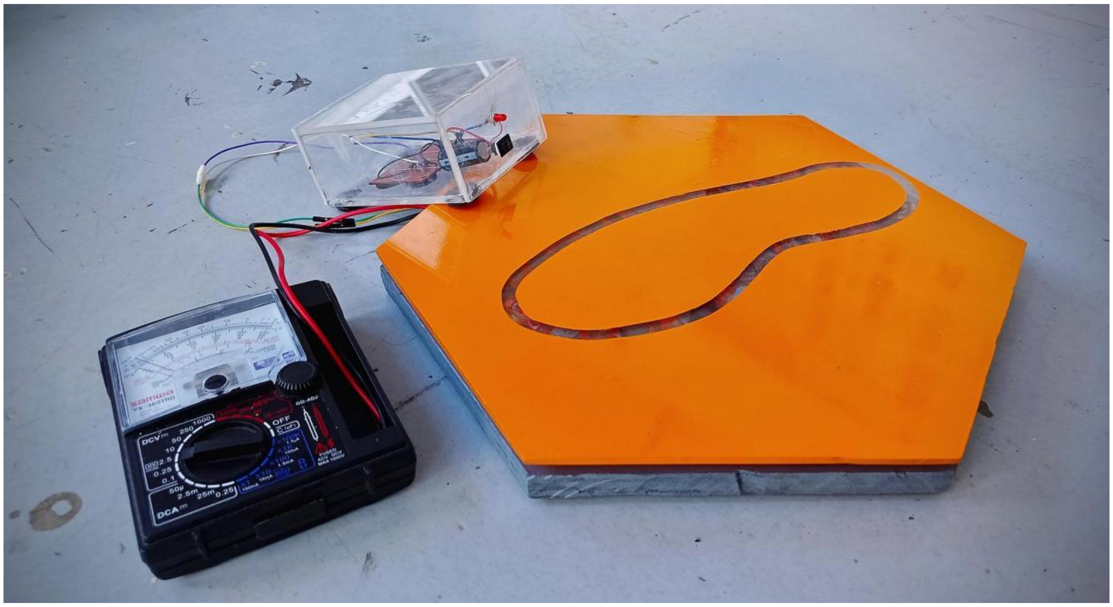
Aesthetics	HA (5)	MA (4)	FA (3)	LA (2)	NA (1)
1. The Piezoelectric Powered LED Lighting design polished and leveled edges.					
2. The Piezoelectric Powered LED Lighting appearance is sleek and unobtrusive.					
3. The Piezoelectric Powered LED Lighting's compact size and has aesthetic appeal.					
4. The Piezoelectric Powered LED Lighting components are well-arranged.					
5. How does the choice of materials enhance the overall functionality and performance of the Piezoelectric Powered LED Lighting?					
Others Specify:					

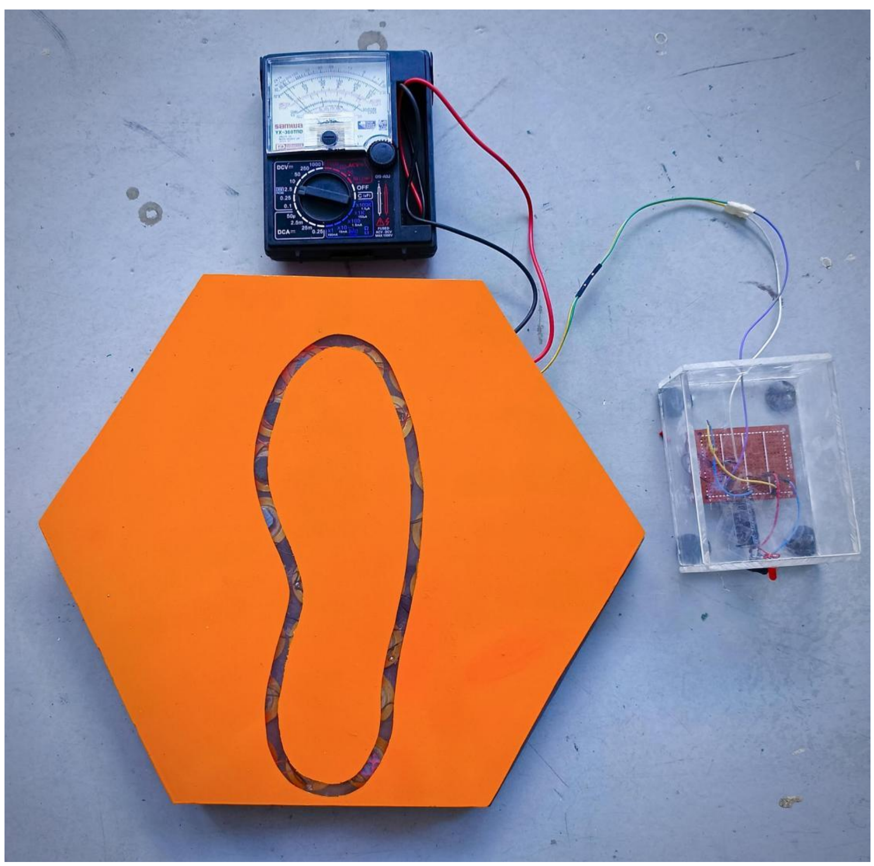
____

Respondent's Signature

Appendix D

PICTORIAL VIEW OF THE PIEZOELECTRIC POWERED LED LIGHTING





Appendix E

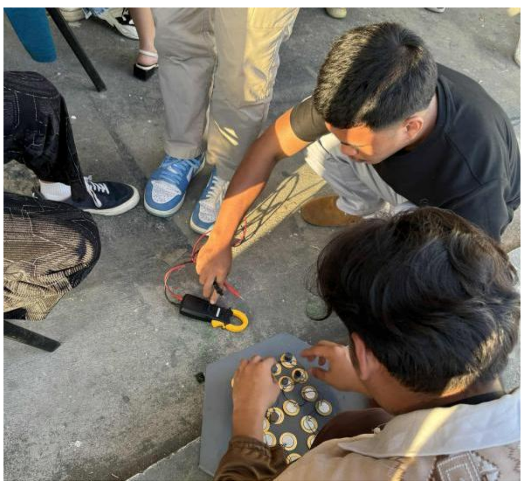
PICTORIAL DURING THE CONSTRUCTION OF THE PROJECT


Carefully cut the acrylic with the grinder.


Attaching the wires to the piezo disc.

Cleaning the piezo disc to remove adhesive residue after incorrect tape placement.


Positioning and attaching the piezo in the base.

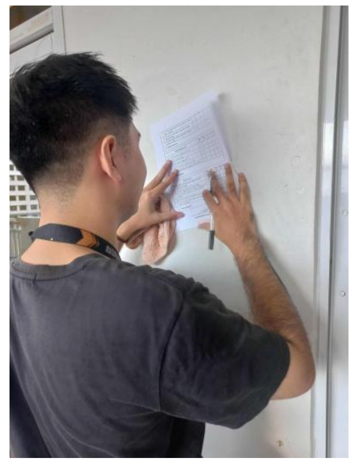



Testing the piezo disc for proper functionality.

APPENDIX F

PROJECT SURVEY/ IMPLEMENTATION





Student Survey/ Implementation



Faculty Survey

APPENDIX G

SURVEY ATTENDANCE SHEET

Republic of the Philippines
CEBU TECHNOLOGICAL UNIVERSITY
MAIN CAMPUS
M.J. Cuenco Ave, Cor R. Palma Street, 6000 Cebu
Website: https://www.ctu.edu.ph/ E-mail: thepresident@ctu.edu.ph
Phone: +6332 402 4060 loc. 1137
COLLEGE OF TECHNOLOGY

BAGONG PILIPINAS

INDUSTRIAL AUTOMATION DEPARTMENT

PIEZOELECTRIC POWERED LED LIGHTING

DATE: ____________________

Respondents #	Name		Signature
1.	TAN ADRIAN DUNN	BSMX 3-A	
2.	Abing, Jhaue	BSMX 3-A	
3	Charl Catamco	BSMX 3-A	
4.	Ugsang, Edz	BSMX 3A	
5.	Archival, Daniel Clement C.	BSMX 3-A	
6.	Enriquez Winge	BSMX 3-A	
7.	CASIANO, KURT VINCENT	BSMX 3-A	
8.	Viñalon, James Jhairey	BSMX 3-A	
9.	DEPI, JOHN FEDERIO N.	BSMX 3-A	
10.	ESMERO, CYRVAN JAY H.	BSMX 3-A	
11.	Calzado, Reneboy A.	BSGD 3-B	
12.	Bamon, Fren Chei	BSGD 3-A	
13.	Jane Claudine T. Celestial	BSGD 3-A	
14.	Remedio Francis Nick R.	BSGD 3-1	
15.	Mark Andrie E. Estrella	BSGD 2-B	
16.	Olsen Rey A. Jonog	BSGD 2-B	
17.	Izabelle Margaret B. Ottanes	BSGD 2-B	
18.	Dexter C. Larita	BSGD 2-B	
19.	Bohol, Barron Jay J.	BSMX 3-B	
20.	Pardo, Mark Angelo L.	BSMX 3-B	
21.	LAMOSTE, BRIAN G.	BSMX 3-B	
22.	Tenio, James M.	BSMX 3-B	
23.	Socobos, Jaythen S.	BSMX 3-B	
24.	Jenny Tacbobo	BSMX 3-B	
25.	Yap, Kattyrene. B.	BSGD	
26.	JOHN MATTHEW VINCENT ANGELO	BSGD 3-C	
27.	Grpulan, Reymark	BSMX 3-B	
28.	Odilao, Luke	BSMX 3-B	
29.	Cabarrubias, Adnan Love D	BSMX 3-B	
30.	Selima, Jose Daniel R.	BSMX 3-B	

Republic of the Philippines
CEBU TECHNOLOGICAL UNIVERSITY
MAIN CAMPUS
M.J. Cuenco Ave, Cor R. Palma Street, 6000 Cebu
Website: https://www.ctu.edu.ph/ E-mail: thepresident@ctu.edu.ph
Phone: +6332 402 4060 loc. 1137
COLLEGE OF TECHNOLOGY

BAGONG PILIPINAS

INDUSTRIAL AUTOMATION DEPARTMENT

PIEZOELECTRIC POWERED LED LIGHTING

DATE: ________________

Respondents #	Name		Signature
31.	LA ARLE SETH B. TUMOY	BSGD 3-C	
32.	Andres, Rainvelle	BSGD 3-A	
33.	Balatucan, Donnabelle P.	BSGD 3-A	
34.	Arganan, Angel	BSGD 3-A	
35.	Nepomuceno, James Clyde O.	BSGD 3-A	
36.	Arong, Luke Ivan	BSGD 3-A	
37.	Christian Basaf	BSGD 3-A	
38.	Blessy Simonel Bove	BSGD 3-A	
39.	Kurt Christopher R. Dano	BSGD 3-A	
40.	Arches, Harvy Arches	faculty	
41.	Villatima, Jhennath	BSGD 3-B	
42.	Baylasis, kristine Mae	~~BSGD~~ Faculty	
43.	Abaja, Jecelyn	Faculty	
44.	ANDRIE SINDA	FACULTY	
45.	Marriel Albino	Faculty	
46.	Ravat Rodson P. Malayana	Faculty	
47.	Paul Jaiden Sumaling	Faculty	
48.	Rudina Pore Gimenez	Faculty	
49.	KHENSA C. TANUS	FACULTY	
50.	HORTEL, CLARK KENNETH	FACULTY	

Appendix H

COMPONENTS DATA SHEET

Capacitor

Specifications:

Capacitance: 10,000 microfarad

Voltage Rating: 16V DC

ESR (Equivalent Series Resistance): Varies by manufacturer, typically 12-60 mΩ

Tolerance: ±20%

Operating Temperature: -40°C to 105°C

Lifetime: 1,000 to 10,000 hours at rated conditions

Lead Spacing: 5mm to 15mm (depending on package type)

Size: Diameter ranges from 16mm to 35mm, length varies from 25mm to 66mm

Termination Style: Radial, Snap-in, Screw Terminal

Red LED

Specifications:

Forward Voltage: 1.8V - 2.2V

Forward Current: 10mA - 20mA (max)

Peak Emission Wavelength: ~640nm

Dominant Wavelength: ~635nm

Luminous Intensity: 40mcd - 200mcd (varies by type)

Viewing Angle: 25° - 60°

Operating Temperature: -25°C to +80°C

Storage Temperature: -40°C to +100°C

Switch

Specifications:

Voltage Rating: 120V, 240V, or higher

Current Rating: 5A, 10A, 15A, etc.

Contact Type: SPST, SPDT, DPDT, etc.

Actuation Type: Toggle, Push Button, Rocker, Rotary

Material: Plastic, Metal

Mounting Type: Panel, PCB, Surface

Durability: Rated for thousands to millions of cycles

Rectifier Diode

Specifications:

Voltage Rating: 1700N

Continuous Forward Current: 115A per leg / 230A per device

Peak Forward Surge Current: 750A (non-repetitive)

Reverse Leakage Current: 2μA at 25°C

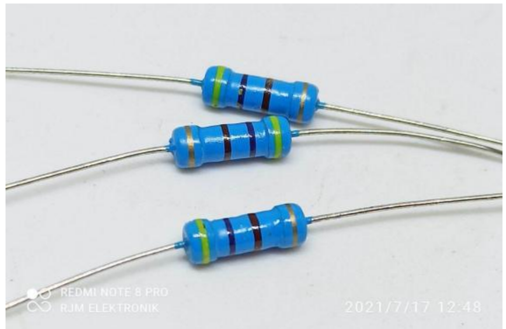
Forward Voltage Drop: 1.6V (typical), 1.8V (max)

Total Capacitive Charge: 358nC at 600V

Operating Temperature: -55°C to 175°C

Thermal Resistance (Junction to Case): 0.27°C/W

Resistor



Specifications:

Resistance: 470Ω (Ohms)

Tolerance: ±5% (carbon film), ±1% (metal film)

Power Rating: 0.25W (¼W), 0.5W (½W), or higher

Temperature Coefficient: ±100ppm/°C (varies by type)

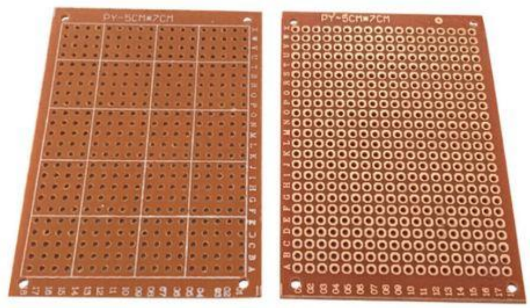
Operating Temperature: -55°C to +155°C

Color Code: Yellow-Violet-Brown-Gold (±5%) or Yellow-Violet-Black-Black-Brown (±1%)

Material Types: Carbon Film, Metal Film, Wirewound

Mounting Type: Through-hole or Surface Mount (SMD)

PVC Breadboard



Specifications:

Material: PVC (Polyvinyl Chloride) or ABS plastic

Tie Points: Typically 400 to 1660 points

Distribution Strips: 2 to 4 for power rails

Hole Pitch: 2.54mm (standard spacing)

Wire Compatibility: 21 to 26 AWG

Voltage Rating: 300V

Current Rating: 3A to 5A

Insulation Resistance: 500MΩ / DC500V

Withstanding Voltage: 1,000V AC / 1 minute

Dimensions: Varies by model, common sizes include 6.5 x 4.4 x 0.3 inches

Heat Distortion Temperature: 84°C (183°F)

Piezoelectric Transducer

Specifications:

Impedance: ≤500Ω

Voltage Rating: ≤30Vp-p

Operating Temperature: -20°C to +60°C

Storage Temperature: -30°C to +70°C

Strain Sensitivity: 5V/µƐ

Material: Quartz (most commonly used)

CURRICULUM VITAE

JESSE ANGELO MARAAT

Maghaway, Talisay City, Cebu

jessemaraat@gmail.com

09609295374

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	October 31, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2022- Present)

SENIOR HIGH SCHOOL:

Talisay City National High School (2022)

JUNIOR HIGH SCHOOL:

Talisay City Science High School (2020)

PRIMARY:

Lawaan Elementary School (2016)

JANICA KATE ORTIGAS

Mabolo, Cebu City

Janicaortigas40@gmail.com

09692815140

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	September 29, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2022- Present)

SENIOR HIGH SCHOOL:

Mabolo National High School (2022)

JUNIOR HIGH SCHOOL:

Mabolo National High School (2020)

PRIMARY:

Mabolo Elementary School (2016)

TIM DAVID MAYOL

Consolacion, Cebu City

timmayol0@gmail.com

09058042309

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	June 19, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2022- Present)

SENIOR HIGH SCHOOL:

Cabancalan National High School (2022)

JUNIOR HIGH SCHOOL:

Mandaue City School For the Arts (2020)

PRIMARY:

Mandaue City School For the Arts (2016)

ANDREA MARIE AMISTOSO

Consolacion, Cebu

amistosoandrea0@gmail.com

09605157131

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	November 14, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2022- Present)

SENIOR HIGH SCHOOL:

San Roque College De Cebu (2022)

JUNIOR HIGH SCHOOL:

La Consolacion College, Liloan Cebu (2020)

PRIMARY:

Consolacion Central School (2016)

KEVIN BALANSAG

Lorrega, Cebu City

kevinkevs0808@gmail.com

09208083650

PERSONAL INFORMATION:

AGE:	22
DATE OF BIRTH:	April 28, 2002
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2022- Present)

SENIOR HIGH SCHOOL:

University of Cebu Private (2021)

JUNIOR HIGH SCHOOL:

Zapatera National High School (2020)

PRIMARY:

Zapatera Elementary School (2016)

BROSNAN NADAL

San Roque, Talisay City, Cebu

broskie.nadal@gmail.com

09936014020

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	April 30, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2021- Present)

SENIOR HIGH SCHOOL:

San Roque Senior High School (2021)

JUNIOR HIGH SCHOOL:

San Roque National High School (2020)

PRIMARY:

San Roque Elementary School (2016)

JOEVIC PITOGO

San Roque, Talisay City, Cebu

joevicoypitogo@gmail.com

09164432076

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	July 23, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2021- Present)

SENIOR HIGH SCHOOL:

San Roque Senior High School (2021)

JUNIOR HIGH SCHOOL:

San Roque National High School (2020)

PRIMARY:

San Roque Elementary School (2016)

VINCENT COLORITO

Anonang Sur, Bogo City, Cebu

vincentruiz012@gmail.com

09623099891

PERSONAL INFORMATION:

AGE:	22
DATE OF BIRTH:	February 14, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2021- Present)

SENIOR HIGH SCHOOL:

City of Bogo Science and Arts Academy (2021)

JUNIOR HIGH SCHOOL:

Anonang Sur Tabaco Frasco National High School (2020)

PRIMARY:

Anonang Sur Elementary (2016)

NASH ASHLEY DUHAYLUNGSOD

San Roque, Talisay City, Cebu

nashoyyy@gmail.com

09934008591

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	May 17, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Roman Catholic

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2021- Present)

SENIOR HIGH SCHOOL:

Laray San Roque National High School (2021)

JUNIOR HIGH SCHOOL:

Laray San Roque National High School (2020)

PRIMARY:

San Roque Elementary School (2016)

MATTHEW SETH MOLERO

Purok Pink Rose, Yati, Liloan, Cebu

matthewsethmolero0710@gmail.com

09569855735

PERSONAL INFORMATION:

AGE:	21
DATE OF BIRTH:	July 10, 2003
CIVIL STATUS:	Single
NATIONALITY:	Filipino
RELIGION:	Iglesia Ni Cristo

EDUCATIONAL ATTAINMENT:

TERTIARY:

Cebu Technological University – Main Campus

M.J Cuenco Ave. Cor. R. Palma St., Cebu City (2021- Present)

SENIOR HIGH SCHOOL:

Liloan National High School (2021)

JUNIOR HIGH SCHOOL:

Liloan National High School (2020)

PRIMARY:

ACADEMIA del Christifidelis Elementary School (2016)

INTRODUCTION

Rationale of the study

The shift to sustainable energy solutions has become essential as the globe struggles with the urgent issues of climate change, energy security, and economic development. One major issue is reliance on nonrenewable resources. These sources are being reduced daily, and they might eventually run out entirely. People consume energy at a large rate, which contributes to the depletion of non-renewable resources. According to Johnson (2021), In 2020, almost 3.3 billion electronic devices used about 176 TWh, which is about 12% of all domestic electricity use and 4.5% of all electricity used in the US.Even at the product level, though, the average yearly electricity cost to run consumer electronics is a relative steal: roughly $3 for a smart speaker, $24 for a TV, and $9 for a laptop computer. As such, finding alternatives for energy sources and proper energy usage is a critical strategy for reducing energy consumption and minimizing environmental impact.

Increasing demand for sustainable energy solutions has driven new techniques in harnessing energy from routine activities. Although there are numerous studies that have analyzed piezoelectric materials, there still remains a lack of research focused on their practical applications in urban settings, particularly concerning energy conservation and user interaction. Studies indicate that improving energy efficiency in buildings can reduce energy consumption by

20%-30%, which contributes significantly to both economic and environmental benefits (Sarkar & Singh, 2010).

In the Philippines, energy conservation studies emphasize enhancing energy efficiency to address both the high cost of electricity and environmental concerns. As per the study by Saghir and Santillan (2017), electricity rate in the Philippines is among the highest in Asia, driving the need for energy conservation initiatives to reduce financial burden on consumers and advance sustainability.

The need for improved energy storage systems to support intermittent renewable energy sources is one critical gap; existing storage solutions are either costly or have limited capacity, making it difficult to consistently meet large-scale demand (Luo et al., 2015). A 2021 study by the Philippine Institute for Development Studies points out that expanding renewable energy not only addresses energy security concerns but also contributes significantly to climate mitigation goals (Rivera et al., 2021).

Part of our daily routine is moving from one place to the other. We use force to walk on roads, stairs and railways. This provides mechanical force which produces energy into the ground. This muscular force on the ground gets wasted. However, with the aid of piezoelectric transducers, this mechanical energy can be transformed into electrical pulses. According to Chaturvedi & Kumar (2013), it is possible to use these alternating electrical pulses directly or to store them for later use by a storage device.

This study aims to develop and assess the acceptability level of Piezoelectric LED Lighting that can collect, store, and utilize energy from the force applied to it. This includes repetitive movements such as walking, jumping, stepping, and other physical activities that apply force towards the tile. This provides a solution for collecting the wasted muscular force produced by people and an efficient method of storing it. By integrating this, it will greatly benefit communities and facilities that suffer from the lack of energy sources and by providing them with energy efficient solutions.

Theoretical Background

The integration of piezoelectric LED lighting systems has gained a significant attention in the past few years due to its potential to enhance energy conservation and sustainability. The involvement of the conversion of mechanical energy, such as vibrations, into electrical energy using the piezoelectric materials had been the fundamental concept of piezoelectric energy harvesting. This harvested energy can then be stored and used to power various applications, including LED lighting. In Priya and Inman's (2009) "Energy Harvesting Technologies" presents a detailed examination of the fundamental principles and contemporary advancements in energy harvesting system. Elucidating their distinct mechanisms for converting ambient energy into usable electrical power including piezoelectric.

Wang, S., Wen, L., Gong, X., Liang, J., Hou, X., & Hou, F. (2022). The authors of the literature review paper "Piezoelectric-Based Energy Conversion and Storage Materials," discussed about the recent developments in piezoelectric-based catalysts and electrochemical energy storage. Providing a thorough understanding of the mechanism involved in energy conversion and storage by highlighting the qualities of various piezoelectric materials and their uses. Ghazanfarian, J., Mohammadi, M. M., & Uchino, K. (2021), in their systematic review titled "Piezoelectric Energy Harvesting: A Systematic Review of Reviews," the authors provide a thorough analysis of piezoelectric energy harvesting technology. They address a variety of topics, including piezo-materials, modeling methodologies, and design points for various applications. This review emphasizes the need of improving piezoelectric materials and designs in order to enhance energy harvesting efficiency.

Liu, H., Zhong, J., Lee, C., Lee, S.-W., & Lin, L. (2018). In their paper titled "A Comprehensive Review on Piezoelectric Energy Harvesting Technology," the authors present a detailed overview of the state-of-the-art piezoelectric energy harvesting technology. As the authors emphasize the potential of integrating piezoelectric energy harvesting with LED lighting systems to create self-sustaining and energy-efficient lighting solutions. They discuss the materials, mechanisms, and applications of piezoelectric energy harvesting, highlighting the development and challenges in the field.

Fischer et al. (2018) explore the dynamics of user acceptance and interaction with renewable energy systems, particularly within urban settings. Their research, published in Renewable Energy, highlights the critical role that user engagement plays in the successful integration of renewable technologies. By analyzing various factors influencing user behaviors, the authors demonstrate that effective communication and understanding user preferences are essential for fostering acceptance of innovative energy solutions. This foundational knowledge is particularly relevant for the implementation of piezoelectric technologies, which harness energy from everyday activities in densely populated areas. Supplementing this, McGowan and McGowan (2020) analyze user engagement with renewable energy technologies through multiple case studies, revealing that user participation significantly affects the effectiveness of these systems. Their findings emphasize that effective education about the benefits and functionalities of renewable technologies can enhance user involvement and satisfaction. This insight is crucial for piezoelectric applications, as the success of these energy-harvesting systems largely depends on user acceptance and their willingness to engage with the technology.

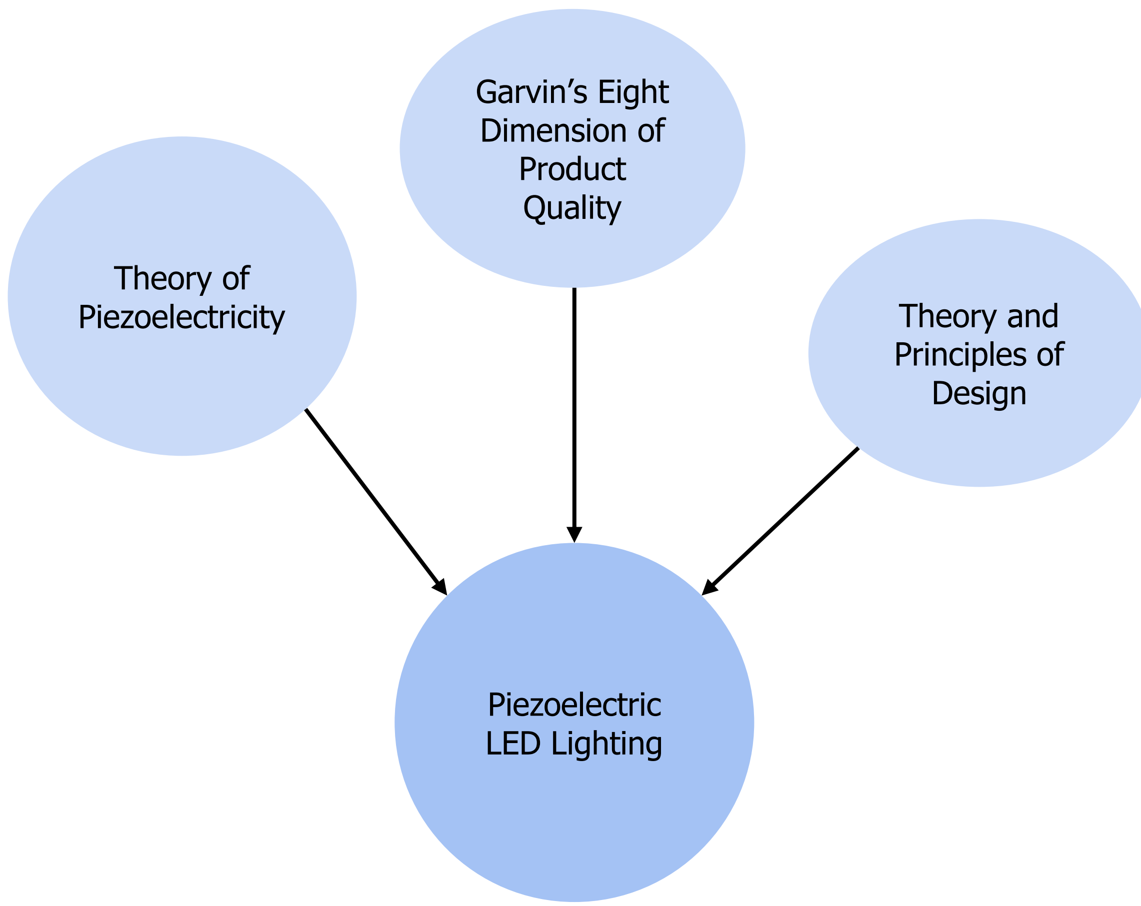


Figure 1
Theoretical/Conceptual Framework of the Study

Theory of Piezoelectricity. The piezoelectricity theory describes how certain materials develop an electric charge when subjected to mechanical stress.This effect arises because these materials lack a center of symmetry in their crystal structure, resulting in a redistribution of electrical charge when deformed (Curie & Curie, 1880). The direct piezoelectric effect is the development of an electric charge in response to mechanical stress, whereas the converse piezoelectric effect is the mechanical deformation of a material in the presence of an electric field (Cady, 1946). Piezoelectric constants, which are material-specific coefficients that regulate the effect's efficiency, explain the relationship between applied stress and generated electric charge (Touloukian, 1970).

In mathematical terms, the piezoelectric effect can be expressed using tensor notation, where the electric displacement is related to the applied mechanical stress through the piezoelectric coefficient tensor (Chrysafides & Souvatzis, 2017). This theory has widespread applications in various fields, including sensors, actuators, and energy harvesting devices, where piezoelectric materials are used to convert mechanical energy into electrical energy or vice versa (Chrysafides & Souvatzis, 2017).

Garvin's Eight Dimension of Product Quality

The application of Garvin's eight dimensions of quality to the research on piezoelectric generating tiles and their integration with lithium battery storage reveals several relevant dimensions, particularly focusing on:

Performance: A critical dimension for assessing the efficiency of piezoelectric tiles in converting mechanical stress into electrical energy. This study will evaluate how well the tiles perform under various conditions, ensuring that they generate adequate electrical power for practical applications. The overall effectiveness of the energy generation process will determine the viability of these tiles as a sustainable energy solution.

Features: The additional characteristics or attributes that enhance the product's appeal or functionality beyond its basic performance.

Reliability: Essential in evaluating the durability and consistency of the energy generated by piezoelectric tiles. The research should include assessments of how often the tiles produce energy without failures and their longevity under typical usage conditions. Reliability directly impacts user confidence in utilizing piezoelectric systems for energy needs, making it a crucial aspect of the study.

Conformance: Refers to how closely a product's design and operating characteristics match pre-established standards or specifications.

Durability: The product's ability to withstand wear, pressure, or damage and continue to perform over an extended period.

Serviceability: Refers to how easily the energy generation system can be maintained and repaired. Evaluating the design for user-friendliness in maintenance procedures. This dimension is particularly relevant for ensuring that the system meets user expectations in real-world applications.

Aesthetics: Concern the sensory characteristics of the product that appeal to the consumer's taste or aesthetic preferences, such as appearance, feel, sound, or smell.

Perceived Quality: Encompasses the user's perception of the product's value, which can be influenced by design elements such as the choice of a wooden base. This study's focus on aesthetic appeal and sustainability aims to enhance perceived quality, impacting user acceptance and adoption of the technology in various environments.

Garvin's model are particularly suitable for evaluating the proposed research on piezoelectric generating tiles. These dimensions will help assess the overall functionality, user interaction, and acceptance of the technology within the context of sustainable energy solutions. Each dimension provides a framework for ensuring that the technology meets user needs while contributing to broader sustainability goals.

Theory and Principles of Design. Design is an intricate field that encompasses various disciplines, including graphic design, architecture, and industrial design. At its core, design theory seeks to understand the fundamental principles that guide the creation and evaluation of visual and functional experiences. One of the foundational theories in design is the Gestalt Theory, which emphasizes the human tendency to perceive patterns and wholes rather than just individual components. This theory suggests that elements arranged in a certain way can create a more cohesive and meaningful experience, highlighting the importance of organization and layout in design (Koffka, 1935).

The idea of balance is another fundamental design principle. The distribution of visual weight in a composition is referred to as balance, and it can be accomplished by either symmetrical or asymmetrical arrangements. While asymmetrical balance can generate a sense of movement and vitality, symmetrical balance offers solidity and formality. This approach is essential for establishing visual harmony and directing the viewer's eye through the design (Heskett, 2005).

THE PROBLEM

Statement of the Problem

This research aims to develop and assess the acceptability level of Piezoelectric LED Lighting. This study will be conducted in Cebu Technological University – Main Campus located at M.J. Cuenco Ave., corner Palma Street, Cebu City, Cebu, Philippines, for academic year 2024-2025.

Specifically, it seeks to answer the following questions:

1. What are the technical requirements in developing the Piezoelectric LED Lighting in terms of:

   1.1 Operational Flow;

   1.2 Schematic Diagram;

   1.3 Materials and Equipment; and

   1.4 Design Model?

2. What is the acceptability level of the Piezoelectric LED Lighting in terms of:

   2.1 Performance;

   2.2 Reliability;

   2.3 Serviceability; and

   2.4 Aesthetic?

3. Based on the findings, what can be developed for the Piezoelectric LED Lighting?

Significance of the Study

The study is significant to the following:

Cebu Technological University - The value of a piezoelectric LED lighting to Cebu Technological University (CTU) stems from its ability to harness renewable energy. It contributes to CTU's sustainability activities by turning mechanical stress, such as footsteps, to electrical energy. This novel strategy not only minimizes dependency on traditional power sources, but also promotes university-wide research and development of renewable energy technologies.

CTU Administration - By improving energy management and encouraging sustainability in educational facilities, this research offers advantages for school administration. Additionally, by encouraging an eco-friendly attitude among employees and students, it supports educational objectives and provides a real-world example of renewable energy concepts in action. Installing a piezoelectric power bank improves the school's standing as a progressive, environmentally conscious organization in addition to helping with budget management.

Students – This research will help students especially Graphics and Design and Mechatronics takers by expanding their product design knowledge, which will aid them in their future jobs. Additionally, this study encourages students to interact with and comprehend the concepts of energy generation, conservation, and environmental responsibility in addition to highlighting the possibility for large financial savings.

Faculty - The purpose of this study is to identify the precise variables that affect faculty motivation, well-being, and performance. The goal of the research is to enable faculty to enhance their professional experiences and, in turn, their effectiveness as teachers and job satisfaction by identifying areas that need attention and best practices.

Houses and Facilities - Installing a piezoelectric LED lighting in residences and businesses offers a revolutionary way to improve sustainability and energy efficiency. Over time, this contributes to significant cost savings by lowering utility costs and reducing reliance on traditional energy sources. Additionally, by encouraging citizens to use renewable energy sources, the incorporation of piezoelectric technology promotes an environmentally conscious culture. According to research, this technology has the ability to completely transform energy management in both residential and commercial settings, opening the door to a more sustainable future and enabling communities and individuals to take an active role in energy conservation.

Department of Science and Technology – Numerous obstacles to innovation and progress in energy harvesting and sustainable energy technology will be addressed by this study. This will boost the study's credibility and encourage advancements in technology in this area.

Local Communities - This research reduces energy costs for consumers and encourages environmental stewardship by absorbing and transforming ambient energy from nearby communities into usable power. Communities will benefit from increased resilience and energy independence as a result of implementing these creative solutions, which will promote economic growth and aid in the shift to a greener future.

People in the Provinces – This research will benefit the communities that are far from the City's center where there is limited access to electricity. This will provide power, and add energy efficient and conservation techniques by supporting sustainable energy practices.

Future Researchers – Future research will be guided and referenced by the results of this study. It will assist student researchers in learning about and being conscious of the fish farm cleaning procedure.

Scope and Limitations

The study focused on developing a piezoelectric LED lighting designed to harness mechanical energy from various activities within a school environment. The power bank utilizes piezoelectric materials to convert kinetic energy - generated from footsteps, movement of furniture, and other vibrations into usable electrical energy. It is specifically designed for installation in high-traffic areas such as hallways and classrooms, where it can effectively capture energy from daily activities. This study is primarily implemented in educational institutions within the region, allowing for real-time monitoring of energy output and utilization.

However, due to time constraints, budget limitations, and voltage drop detected from smaller piezoelectric discs caused by the brittleness of its ceramic material, the researchers were restricted to using a specific type of piezoelectric material, which may limit the overall energy efficiency of the device. Additionally, the piezoelectric energy storage output may only be sufficient for low-power watts in powering LED lights. The device's effectiveness is also dependent on the frequency and intensity of foot traffic; thus, areas with low activity may not generate adequate energy. Overall, while the piezoelectric LED lighting shows promise, its practical applications are currently constrained by these factors.

RESEARCH METHODOLOGY

The study will utilize a descriptive research method to gather data. The goal is to conduct a survey and gather data through the researcher-made questionnaire. This method will evaluate the acceptability and effectiveness of the energy harvesting

Flow of the Study

The study shows the three components of the study flow for the development of the study: the input, the process, and the output. These components are depicted in a paradigm in Figure 1.

The **INPUT**, evaluating the acceptability of technical requirements for developing a piezoelectric LED lighting include defining the operational flow, creating a schematic diagram, listing materials and equipment, and designing a model based on four key criteria: Performance , Reliability , Serviceability , and Aesthetic.

The **PROCESS** of the research contains the transmittal letter, conducting of survey, data gathering and tabulation, data treatment and analysis of research of the study.

The **OUTPUT** of the study is the proposed "Piezoelectric LED Lighting ".

Input

1. What are the technical requirements in developing the Piezoelectric LED Lighting in terms of:

1.1 Operational Flow;

1.2 Schematic Diagram;

1.3 Materials and Equipment; and

1.4 Design Model?

2. What is the acceptability level of Piezoelectric LED Lighting in terms of:

2.1 Performance;

2.2 Reliability;

2.3 Serviceability; and

2.4 Perceived Quality?

Process

A. Transmittal Letter

B. Survey

C. Data Gathering and Tabulation

D. Data Treatment and Analysis

Output

"Piezoelectric LED Lighting"

Figure 2

Flow of the Study

Figure 3

Locale of the Study

Research Environment

This study will be conducted at Cebu Technological University (CTU), located at M.J. Cuenco Ave., Cor R. Palma Street, 6000 Cebu City, Philippines as shown in Figure 3. CTU provides an ideal community for this study, where they enable local engagement, cultivating a practical demonstration of these sustainable technologies within the university environment. These factors create an atmosphere conducive to developing innovative solutions that address real-world energy challenges.

Research Instrument

This study will be done through researcher-made questionnaire made based by Garvin's Eight Dimension of Product Quality to identify the acceptability of the product that would answer the problem stated at the beginning of the study. A Likert scale-based questionnaire is a type of survey instrument used in research to measure or rate the performance, reliability, serviceability, and aesthetics of energy harvesting Piezoelectric LED Lighting. These questions are designed to evaluate the ease of use and its functionality. Likert scale data provides clear indicators of its usability, guiding potential improvements.

Research Respondents

The respondent that will be involved in this study are ten (10) different Faculty Members, twenty (20) BSGD Students, twenty (20) BSMX Students.

Therefore, in total there are fifty (50) target respondents of this study as shown in Table 1.

Table 1

Respondents of the Study

N= 50

Respondents	No. of Respondents	Taken as Respondents	% of Distribution
CTU Faculty	10	10	20%
BSGD Students	20	20	40%
BSMX Students	20	20	40%
TOTAL	**50**	**50**	**100%**

Procedure for Data Gathering

The researchers will seek for an approval from the Department Chairman and administer the questionnaire through an face to face set up. The researcher will search for fifty (50) respondents among faculty, students, and staff, which aim to assess participants' knowledge, perceptions, or experiences regarding energy harvesting Piezoelectric LED Lighting. The researcher will explain the objective of conducting the study and ensure the respondents' privacy. The respondents' responses will help the researchers conduct a thorough study for improvements.

Data Treatment

Data analysis will be used in this study to evaluate the performance, reliability, serviceability, perceived quality of the Piezoelectric LED Lighting.

Responses will be carefully organized, tallied, and tabulated by using specific statistical methods.

Weighted Mean. To evaluate in terms of survey replies, the effectiveness of the corresponding to LED Lighting Piezoelectric Energy Storage features.

$$\boldsymbol{x} = (\sum fw)/n$$

Where: $\boldsymbol{x}$ = weighted mean of the machine features' respective efficacy

$\boldsymbol{f}$ = frequency of responses for the respective machine features

$\boldsymbol{w}$ = weight given for responses on the respective machine features

$\boldsymbol{n}$ = number of respondents

Percentage. It will make use of the percentage distribution of the corresponding machine factors as well as the frequency of specific features.

$$\boldsymbol{P = \left(\frac{f}{n}\right) x\ 100\%}$$

Where: $\boldsymbol{P}$ = percentage (%) of respondents

$\boldsymbol{f}$ = frequency of response

$\boldsymbol{n}$ = number of respondents

Scoring Procedure

This process allows us to give numerical values and ranks to pertinent factors, allowing for a thorough study and interpretation of our findings. It also provides a solid foundation for the analysis of the collected data. Every response to the questionnaire was first scaled, and each scale was given a value based on the distribution of the normal curve, which is

Table 2

Scoring Procedure of Performance, Reliability, Serviceability, and Perceived Quality

Weight	Verbal Interpretation	Range	Categorical Response
5	Highly Acceptable (HA)	4.21-5.00	When the machine is 90%-100%, it is deemed highly acceptable.
4	Moderately Acceptable (MA)	3.41-4.20	When the machine is 71%-89%, it is deemed to be moderately acceptable.
3	Fairly Acceptable (FA)	2.61-3.40	When a machine is 51%-70%, it is deemed to be reasonably acceptable.
2	Least Acceptable (LA)	1.81-2.60	When the machine is 31%-50%, it is deemed least acceptable.
1	Not Acceptable (NA)	1.00-1.80	When the machine is 0%-30%, it is deemed completely unacceptable.

Definition of Terms

To assist you understand the concepts used in the study, below are some definitions.

Piezoelectric: It refers to the ability of certain materials to generate an electric charge in response to applied mechanical stress or pressure. Piezoelectric materials are commonly used in applications such as sensors, actuators, microphones, and energy harvesting devices because of their ability to convert mechanical energy into electrical energy (and vice versa).

LED: LED stands for **Light Emitting Diode**. It is a semiconductor device that emits light when an electric current passes through it.

Lighting: Refers to the illumination produced by light-emitting diodes (LEDs) powered by the electrical energy harvested from piezoelectric plates. It serves as the visible output that indicates the effectiveness of the energy conversion and storage process within the system.

Energy Storage: refers to the capture of energy produced at one time for use at a later time.

Charging: refers to the process of storing electrical energy generated by the piezoelectric plates−components that convert mechanical stress from foot traffic into electrical energy–into an energy storage device.

Chapter 2

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This chapter presents, analyzes, and interprets the data gathered based on the survey questionnaires on the identified respondents. This includes the technical requirements and acceptability of the developed product.

1. TECHNICAL REQUIREMENTS IN THE DEVELOPMENT OF THE " PIEZOELECTRIC LED LIGHTING"

The development of the Piezoelectric LED Lighting followed a clear process. First, researchers planned the functionalities of the piezoelectric powered led lighting and built a functional model to test those functionalities. This initial planning stage likely involved creating sketches or diagrams. Then, during project preparation, a prototype was created. This included designing the machine in 3D software, gathering materials, and testing the equipment to ensure the design translated well into a physical form. Finally, after the physical prototype was finalized, the piezoelectric powered led lighting's electrical system was built and tested. Any necessary adjustments were made to the hardware before the final stage of testing the software that would control the piezoelectric powered led lighting's operation.

1.1 OPERATIONAL FLOW

The operational flow of the Piezoelectric LED Lighting contains process connections that exemplify steps in an operation, and relation lines that signify the order of series steps.

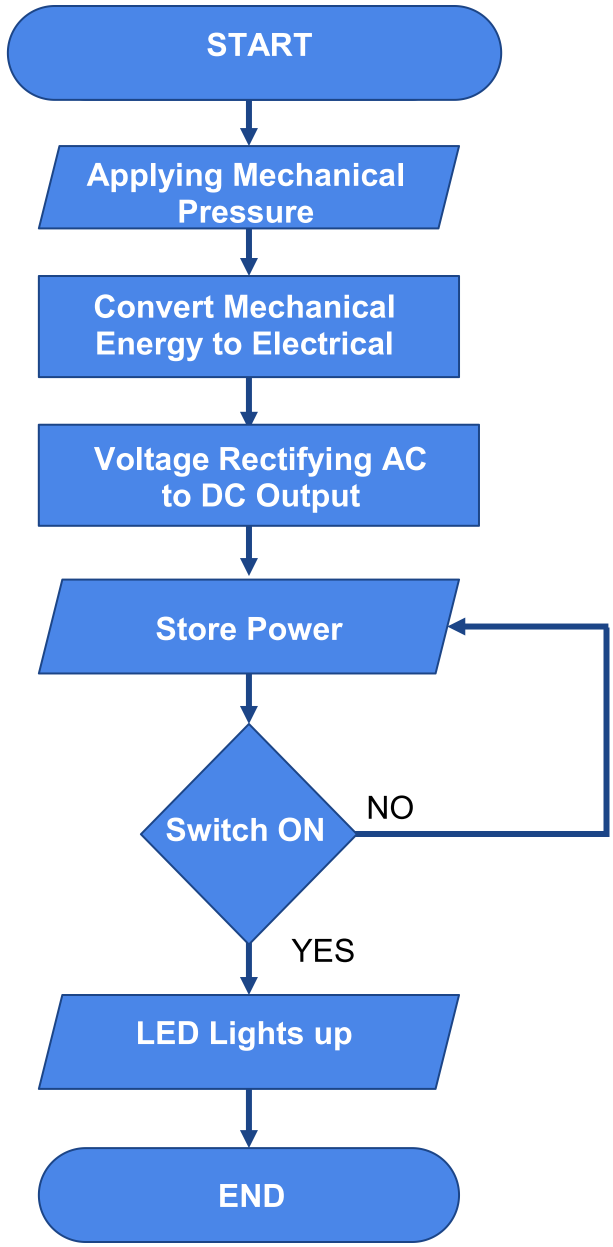


Figure 4

Operational Flowchart of the Piezoelectric LED Lighting

The operational flow of the Piezoelectric LED Lighting explains the (4) four essential phases: Mechanical Pressure, Rectification, Store, Output.

Phase I. Mechanical Pressure - Sets the step by turning footsteps or any mechanical stress into electricity. It remains in this state until mechanical stress is absent.

Phase II. Rectification - The electric current is converted from Alternating Current to Direct Current by the circuit and making the electricity usable for LED Lighting.

Phase III. Store - Collects the converted electrical current and stores it. It remains at this state until the user decides to activate the next phase.

Phase IV. Output - Is the result of the process which was produced when the electric current goes through all the phases. When the switch is turned ON it lights up the Red LED.

Following this, the machine is wired to operate in a continuous cycle. When the piezoelectric transducers receive stress, the circuit turns that stress into usable electricity and stored. This ensures efficient energy harvesting by eliminating unnecessary pauses and stopping only when mechanical stress is absent.

1.2 SCHEMATIC DIAGRAM

The schematic circuit diagram of the Piezoelectric LED Lighting offers a detailed draft for the flow of electric current and how it is converted into usable electricity.

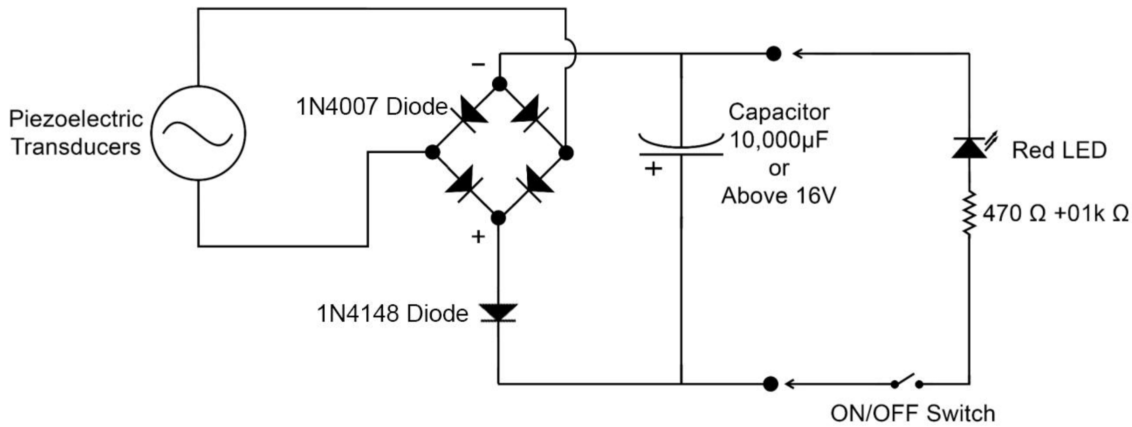


Figure 5

Schematic Diagram of the Piezoelectric LED Lighting

This circuit uses Piezoelectric Transducers in a series-parallel connection as the component that converts mechanical stress into electrical energy. The electrical energy passes through a full-bridge rectifier, sometimes referred to as a bridge rectifier, converts AC to DC by arranging four diodes in a bridge configuration. The 10,000µF 16V capacitor acts as the main power storage for this circuit and serves as a buffer to absorb voltage spikes and smooth out variations, serving as a "local energy reservoir" to help stabilize voltage. The switch serves as the main gateway, before the electrical current passes through the resistor and effectively powering the Red LED. This would help conserve and accumulate the harvest. The configuration makes it an efficient circuit for power storage and distributes electricity efficiently.

1.3 DESIGN MODEL

The design model of the Piezoelectric LED Lighting shows an exquisite design concept, giving the user/operator/troubleshooter enough efficiency for troubleshooting processes. The visual aesthetics of the Piezoelectric LED Lighting quite resembles an actual industrial device that can be both functional and visually appealing. The design model is also an important part in terms of the Piezoelectric LED Lighting's functionality, securing its wide area that avoids unwanted short circuits.

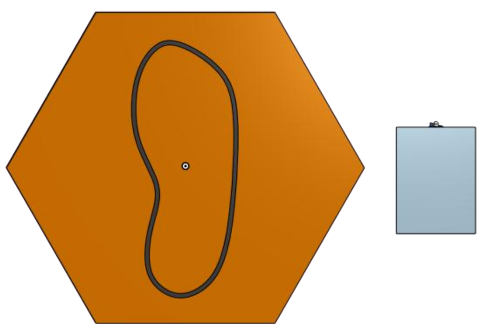


Figure 6.A
Top View

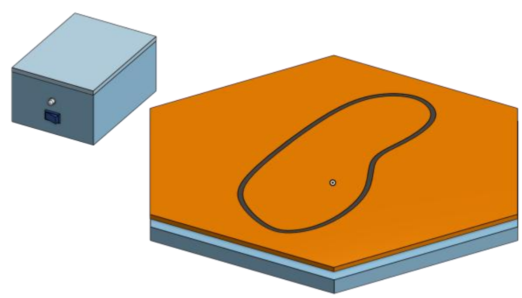


Figure 6.B
Isometric View

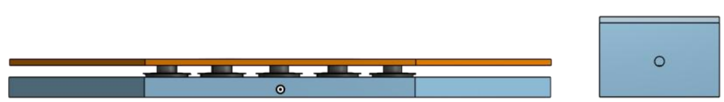


Figure 6.C
Front View

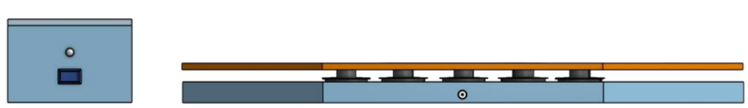


Figure 6.D
Back View

Figure 6

Design Model of the Piezoelectric LED Lighting

Figure 6 illustrates the structural design of the Piezoelectric LED Lighting system, consisting of two main components: the power storage unit and the footstep plate. The piezoelectric transducers, located between the acrylic footstep plate and the wooden base, absorb the impact from footsteps and convert mechanical energy into electrical energy.

The power storage unit, housed in an acrylic exterior, contains the circuitry for energy collection. This includes a rectifier diode that converts the generated alternating current (AC) into direct current (DC), and a 10,000 μF, 16V capacitor for energy storage. The stored energy is then used to power the LED, which serves as the light source.

1.4 MATERIALS AND EQUIPMENT

The Piezoelectric LED Lighting uses locally available materials and carefully selected, low-cost components to ensure quality. These materials are chosen based on factors like mechanical properties, corrosion resistance, and environmental considerations, ensuring the Piezoelectric LED Lighting durability and long-term performance.

Materials

To guarantee effective operation and longevity, the piezoelectric led lighting is built from a variety of components, carefully selected for their cost and accessibility, ensuring consistent performance and minimal maintenance requirements over its operational lifespan as shown in Table 3.

Table 3

Materials of Piezoelectric LED Lighting

NO.	MATERIALS	QUANTITY	USES
1	Wooden base	**1 pc (0.5m x 1m x 1.5cm)**	Provides structural support for the piezoelectric system and other components.
2	Acrylic sheet	**1 pc (2ft x 4ft x 4.5mm)**	Serves as a protective cover and platform for footsteps. This is where mechanical stress is prominent.
3	Small rubbers	**100 pcs**	Used for vibration isolation or cushioning to optimize piezoelectric energy conversion.
4	Spray paint (grey)	**1 pc**	Provides a neutral color, protective coating for surfaces.
5	Spray Paint (Yellow Orange)	**1 pc**	Used for aesthetic purposes, enhancing visibility and design. The main color for the design.
6	Piezoelectric transducers	**100 pcs**	Convert mechanical vibrations into electrical energy to power the LED.
7	LED (red)	**1 pc**	Light source powered by the piezoelectric transducers.
8	Small wires	**2pcs (3m)**	Facilitate electrical connections between components.
9	Switch	**1pc**	Allows for the control of the LED circuit.
10	Capacitor	**1pc**	Stores energy generated by the piezoelectric transducers for efficient LED operation.
11	Rectifier diode	**4pcs**	Converts alternating current (AC) generated by piezoelectric transducers to direct current (DC).
12	Resistor	**1pc**	Regulates current flow in the circuit, protecting the LED and other components.
13	Soldering Lead	**4pcs (1m)**	Used to connect electrical components by melting it..
14	Glue Stick	**12pcs**	Used as an adhesive and sticks rubbers on top of the Piezoelectric Transducers.

Equipments

The Piezoelectric LED Lighting is constructed with a variety of equipment to guarantee accuracy & effectiveness as shown in Table 4.

Table 4

Equipment of Piezoelectric LED Lighting

NO.	EQUIPMENT	USES
1	Grinder	Used to cut the wood base and acrylic sheets for their designated shape.
2	Saw blade	Used to manually cut the wood base according to their shape.
3	Glue gun	Used to melt the glue sticks for adhesive on the rubbers.
5	Soldering iron	Used to melt the soldering lead for connecting electrical wirings and components.
7	Multimeter (tester)	Used to measure the voltage output of the Piezoelectric transducers and the amount of power stored in the capacitor.
8	Cutters	Used to cut the rubbers into correct sized pieces for the Piezoelectric transducers.

2.0 ACCEPTABILITY OF THE "PIEZOELECTRIC LED LIGHTING"

The acceptability of the "Piezoelectric LED Lighting" as perceived by the chosen faculty and students was based on its **Performance**, **Features**, **Aesthetics**, and **Serviceability**. To evaluate the technology, they examined how well it met key criteria such as energy conversion efficiency, long-term functionality, ease of installation, and environmental impact. An ideal lighting system would excel in these areas, ensuring consistent and sustainable performance. By meeting these standards, the piezoelectric LED lighting would become a practical, eco-friendly solution, offering reliable and efficient lighting while contributing to energy conservation.

2.1 PERFORMANCE

The first aspect evaluated in the survey was the performance of the Piezoelectric LED Lighting. Performance focused on the system's efficiency in converting mechanical energy into electricity, the consistency of its light output, and its overall effectiveness in providing continuous illumination as shown in table 5.

Table 5
Acceptability as to Performance
(n=50)

2.1 PERFORMANCE	HA 5	MA 4	FA 3	LA 2	NA 1	$\bar{X}$	VD
2.1.1 The Piezoelectric LED Lighting is able to light the LED.	30	17	3	0	0	4.54	HA
2.1.2 The Piezoelectric LED Lighting stays in place while being stepped on.	30	19	1	0	0	4.58	HA
2.1.3 The Piezoelectric LED Lighting operates effectively under different weights and pressures.	23	25	2	0	0	4.42	HA
2.1.4 The Piezoelectric LED Lighting operates effectively with no observed malfunction.	25	20	5	0	0	4.4	HA
2.1.5 The Piezoelectric LED Lighting operates silently or with minimal noise during energy generation.	34	15	1	0	0	4.66	HA
Average Weighted Mean						4.52	HA

Legend: HA – Highly Acceptable; MA – Moderately Acceptable; FA – Fairly Acceptable; LA – Least Acceptable; NA – Not Acceptable; VD – Verbal Description; $\bar{X}$–Weighted Mean

In terms of performance, the piezoelectric LED lighting system was rated on five key parameters. First, its ability to illuminate the LED received a weighted mean of 4.54, suggesting that the device effectively harnesses the energy generated from stepping. Next, its stability when stepped on was rated at 4.58, indicating that respondents consider the device to remain securely in place during repeated use. Furthermore, its effectiveness under varying weights and pressures received a weighted mean of 4.42, demonstrating that the system performs consistently under different mechanical loads. Additionally, the device's reliable operation—with no observed malfunctions—earned a weighted mean of 4.40, reflecting its dependable performance. Lastly, its silent or minimal noise generation during energy production achieved a weighted mean of 4.66, highlighting the system's quiet operation.

Overall, the Piezoelectric LED Lighting system's performance was evaluated using a number of significant factors, and the results consistently show strong performance across all metrics, gaining a high overall rating with an average weighted mean of 4.52, classified as "Highly Acceptable."

The results indicate that the Piezoelectric LED Lighting system effectively converts everyday physical activity into usable electrical energy. Its consistent performance in generating and maintaining light output from common actions like walking or stepping highlights its potential as a reliable, eco-friendly lighting option. This makes it particularly relevant for areas with limited access to traditional energy sources.

2.2 FEATURES

The next factor assessed was the features of the Piezoelectric Lighting. Features considered in the survey included the ease of installation, additional functionalities, and versatility of the system in adapting to different environments and user needs as shown in table 6.

Table 6
Acceptability as to Features
(n=50)

2.2 FEATURES	HA 5	MA 4	FA 3	LA 2	NA 1	$\bar{X}$	VD
2.2.1 The Piezoelectric LED Lighting is user-friendly.	31	19	0	0	0	4.62	HA
2.2.2 The Piezoelectric LED Lighting supports fast charging of capacitor.	25	12	12	0	0	4.18	HA
2.2.3 The Piezoelectric LED Lighting charging capabilities are reliable and efficient for daily use.	20	22	8	1	0	4.18	HA
2.2.4 The Piezoelectric LED Lighting storage capacity is sufficient for multiple charges.	19	26	4	0	1	4.24	HA
2.2.5 The Piezoelectric LED Lighting charging process is smooth with no interruptions.	27	18	4	1	0	4.42	HA
Average Weighted Mean						4.33	HA

In terms of features, the piezoelectric LED lighting system was assessed on five key attributes. First, its user-friendly design received a weighted mean of 4.62, indicating that users find the interface and operation intuitive. Next, the system's support for fast charging of the capacitor was rated at 4.18, reflecting efficient energy transfer capabilities. Similarly, its overall charging performance ensuring reliability and efficiency for daily use also earned a weighted mean of

4.18, which underscores consistent performance in routine operations. Additionally, the storage capacity for multiple charges achieved a weighted mean of 4.24, demonstrating that the device can retain sufficient energy for extended use. Lastly, the smoothness of the charging process, with no interruptions, was rated at 4.42, highlighting a seamless and effective feature integration.

In summary, The Features of the Piezoelectric LED Lighting was evaluated using several key criteria, achieving a high overall rating with an average weighted mean of 4.33, classified as “Highly Acceptable.” Each aspect of the system was carefully assessed, and the results consistently indicate strong performance across all metrics. The high ratings for the system’s features highlight its practicality and user-centered design. With intuitive operation, efficient charging, and dependable performance, the system shows strong potential for everyday use while reducing reliance on conventional electricity. Its adaptability to different environments further emphasizes its role in promoting sustainable, decentralized energy use.

2.3 SERVICEABILITY

Serviceability was another key criterion evaluated by the survey respondents. This aspect focused on the ease of maintenance, accessibility for repairs, and the availability of replacement parts, ensuring the system’s longevity and minimizing service interruptions as shown in table 7.

Table 7
Acceptability as to Serviceability
(n=50)

2.3 SERVICEABILITY	HA 5	MA 4	FA 3	LA 2	NA 1	$\bar{X}$	VD
2.3.1 The Piezoelectric LED Lighting is easy to install and set up.	32	17	1	0	0	4.62	HA
2.3.2 The Piezoelectric LED Lighting design allows easy troubleshooting.	31	16	2	1	0	4.54	HA
2.3.3 The Piezoelectric LED Lighting is easy to attach and detach.	35	13	2	0	0	4.66	HA
2.3.4 The Piezoelectric LED Lighting energy storage system is easy to access and manage.	33	13	3	1	0	4.56	HA
2.3.5 The Piezoelectric LED Lighting components are accessible in the market.	29	16	5	0	0	4.48	HA
Average Weighted Mean						4.57	HA

In terms of serviceability, the piezoelectric LED lighting system was evaluated on five key attributes. First, its ease of installation and setup received a weighted mean of 4.62, suggesting that users find the initial setup straightforward. Next, the design that facilitates easy troubleshooting was rated at 4.54, indicating that potential issues can be resolved with minimal difficulty. Furthermore, the device's ability to be attached and detached effortlessly was awarded a weighted mean of 4.66. Additionally, the energy storage system’s ease of access and management achieved a weighted mean of 4.56, while the market accessibility of its components was rated at 4.48.

As a result of evaluating the responses gathered, the device's overall serviceability rating provided an average weighted mean of 4.57, which is equivalent to the verbal description of Highly Acceptable. These findings demonstrate the device's exceptional serviceability in a number of areas, such as the materials and component availability and minimal maintenance costs. These results highlight the device’s practicality for long-term use, especially in low-maintenance or resource-limited settings. With users finding it easy to install, repair, and access replacement parts, the system stands out as a viable candidate for widespread implementation. The high serviceability score underscores the importance of visually appealing and functional design in advancing clean energy solutions that are not only functional but also economically and logistically feasible for the public.

2.4 AESTHETICS

Lastly, the aesthetics of the Piezoelectric LED Lighting were evaluated. This involved assessing the visual appeal of the system, how well it integrated into various environments, and the design’s impact on user acceptance and overall appeal as shown in table 8.

Table 8
Acceptability as to Aesthetics
(n=50)

2.4 AESTHETICS	HA 5	MA 4	FA 3	LA 2	NA 1	$\bar{X}$	VD
2.4.1 The Piezoelectric LED Lighting design polished and beveled edges.	35	14	1	0	0	4.68	HA
2.4.2 The Piezoelectric LED Lighting appearance is sleek and unobtrusive.	35	13	2	0	0	4.66	HA
2.4.3 The Piezoelectric LED Lighting's compact size and aesthetic appeal.	36	11	1	0	0	4.72	HA
2.4.4 The Piezoelectric LED Lighting components are well-arranged.	35	14	1	2	0	4.72	HA
2.4.5 How does the choice of materials enhance the overall functionality and performance of the Piezoelectric LED Lighting	31	15	3	0	1	4.5	HA
Average Weighted Mean						4.66	HA

In terms of aesthetics, the piezoelectric LED lighting system was evaluated on five design-focused parameters. First, the polished and beveled edges of the design received a score of 4.68, reflecting a refined and visually appealing finish. Next, its sleek and unobtrusive appearance was rated at 4.66, suggesting that the system blends well with various environments. Furthermore, the combination of compact size and aesthetic appeal earned a weighted mean of 4.72, indicating an efficient and attractive design. Additionally, the well-arranged components were also rated at 4.72, underscoring a thoughtfully organized layout. Lastly, the selection of materials, which enhances both functionality and performance, achieved a weighted mean of 4.50, highlighting the importance of material quality in the overall design.e of the Piezoelectric LED Lighting?” with a weighted mean of 4.5.

To sum up, the device's overall attractiveness was evaluated by analyzing the collected responses. In conclusion, the collected responses were analyzed to determine the device's overall appeal. A weighted average system was used to translate these answers into a score. The average weighted mean of the evaluation was **4.66**. This score corresponds to a verbal assessment of 'Highly Acceptable.' In other words, the device's features were widely regarded as visually pleasing. The high aesthetic ratings indicate that the system’s visual appeal and quality of materials play a key role in encouraging user acceptance. When a product combines functionality with an attractive design, it becomes easier to integrate into various environments without disruption. This blend of form and function enhances the system’s potential for broader adoption, as its design naturally fits into both public and private spaces. A visually pleasing appearance can also help build a more positive perception of energy-saving technologies, making users more open to embracing new sustainability solutions.

SUMMARY ON THE ACCEPTABILITY IN THE DEVELOPMENT OF THE PIEZOELECTRIC LED LIGHTING

Table 9 provides the summary of the responses on the acceptability of Piezoelectric LED Lighting.

Table 9

Overall Summary of Acceptability

Summary	Weighted Mean	Verbal Description
Performance	4.52	Highly Acceptable
Features	4.33	Highly Acceptable
Serviceability	4.57	Highly Acceptable
Aesthetics	4.66	Highly Acceptable
Average Weighted Mean	4.52	Highly Acceptable

Based on Table 9, the overall evaluation of the system is "Highly Acceptable" across all categories, with an average weighted mean of 4.52. This indicates that the system performs exceptionally well in terms of its performance, features, serviceability, and aesthetics.

Specifically, "Performance" received a weighted mean of 4.52, indicating that the device effectively harnesses and utilizes the energy generated, resulting in consistent operation. "Features" was rated at 4.33, reflecting that its functional aspects, such as energy conversion and operational mechanisms, are appreciated. Meanwhile, "Serviceability" achieved a weighted mean of 4.57, demonstrating ease of maintenance, accessibility of components, and a user-friendly design for repairs. Notably, "Aesthetics" received the highest rating at 4.66, underscoring the device's visually appealing design and seamless integration into its environment. Overall, the high ratings across these dimensions affirm the strong acceptability of the system.

The consistently high ratings across these factors suggest that the system is well-received and meets the expectations of users in terms of both functionality and design. Therefore, the overall judgment of the Piezoelectric LED Lighting regarding its Performance, Features, Serviceability, and Aesthetics is highly positive and widely accepted.

Chapter 3

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter provides a general summary of the study's problem and the methodical process used, as well as the research's findings, conclusion, and the researchers' recommendations.

SUMMARY

The researchers assess the developed Piezoelectric LED Lighting, which was designed to generate energy through mechanical pressure to power an LED without traditional electrical issues.

Technical specifications for the piezoelectric LED lighting were outlined, including an operational chart, schematic diagram, design model, and a list of necessary materials and equipment. Using a descriptive approach, the study employed a survey questionnaire to assess the acceptance of the developed Piezoelectric LED Lighting, focusing on factors such as performance, feature, serviceability, and aesthetics. The device was constructed and tested at Cebu Technological University-Main Campus and approved for a survey utilizing the standard deviation method to analyze and interpret the collected data from the fifty (50) targeted respondents.

The results indicated excellent acceptability across all evaluation dimensions with the overall weighted mean of **4.52**, which implied that the Piezoelectric LED Lighting is classified as **"Highly Acceptable"** confirming the device's effectiveness and its liability to meet or exceed established standards.

Findings

The study evaluated the respondents opinion of the Piezoelectric LED Lighting prototype, which was largely rated as highly acceptable. Most respondents praised its ability to power an LED using mechanical pressure, however several proposed enhancements for faster charging and greater energy efficiency. The prototype was complimented for its user-friendly design, aesthetic appeal, and ease of assembly, as well as the fact that it was made from materials easily available in local markets, making it easy to maintain and use. Overall, the device was highly accepted having a high potential for practical applications.

Conclusion

The research concludes that the overall features of the Piezoelectric LED Lighting meet the expectations of the respondents. This confirms that the device can successfully generate power through mechanical pressure and function effectively without major issues, offering a practical and innovative lighting solution.

Recommendations

Based on the highly favorable findings and the excellent acceptability rating of the developed Piezoelectric LED Lighting, it is recommended that this system be implemented in real-world settings, particularly in high-foot-traffic areas such as school hallways, building entrances, and public transport terminals. The device's proven effectiveness in converting mechanical pressure into electrical energy for LED lighting presents a sustainable and practical solution to reduce reliance on traditional power sources.

Chapter 4

OUTPUT OF THE STUDY

This chapter presents the study's outcomes, including the design model in three-dimensional and orthographic layouts including a detailed design model with accurate measurements in 3D and orthographic layouts. It also provides essential handbook topics such as installation, maintenance, troubleshooting, and safety instructions. Additionally, it examines the machine's environmental impact, provides disclaimers, and outlines the implementation scheme to guide users effectively.

Rationale

The search for new innovations is driven by the growing need for affordable and sustainable energy solutions. This device is made possible by piezoelectric powered lighting, which uses the principles of piezoelectricity to convert mechanical energy into electrical energy. The two main issues this gadget tackles are environmental sustainability and energy efficiency.

This energy is then used to power LED, which is inherently more energy-efficient and has a longer lifespan than traditional lighting. The combination of piezoelectric energy harvesting and LED technology not only reduces reliance on conventional power sources but also contributes to lowering carbon emissions, aligning with global efforts toward sustainability.

The research has a goal is to exemplifies innovation in renewable energy, offering a practical application that merges energy efficiency, cost-effectiveness, and eco-friendliness. Its potential extends beyond residential and commercial lighting systems, paving the way for advancements in wearable technologies, smart cities, and other areas where sustainable energy solutions are critical.

Objectives

This chapter aims to present an innovative approach to energy-efficient lighting systems using piezoelectric technology. These includes the following:

- To provide schematic and 3D Model of the machine.
- To deliver a user-friendly interface along with clear assembly instructions, usage guidelines, maintenance procedures, and troubleshooting support for the device.
- To develop clear and comprehensive safety guidelines that promote correct usage, reduce risks, and ensure safe handling, operation, and maintenance of the device.

DESIGN MODEL OF PIEZOELECTRIC LED LIGHTING

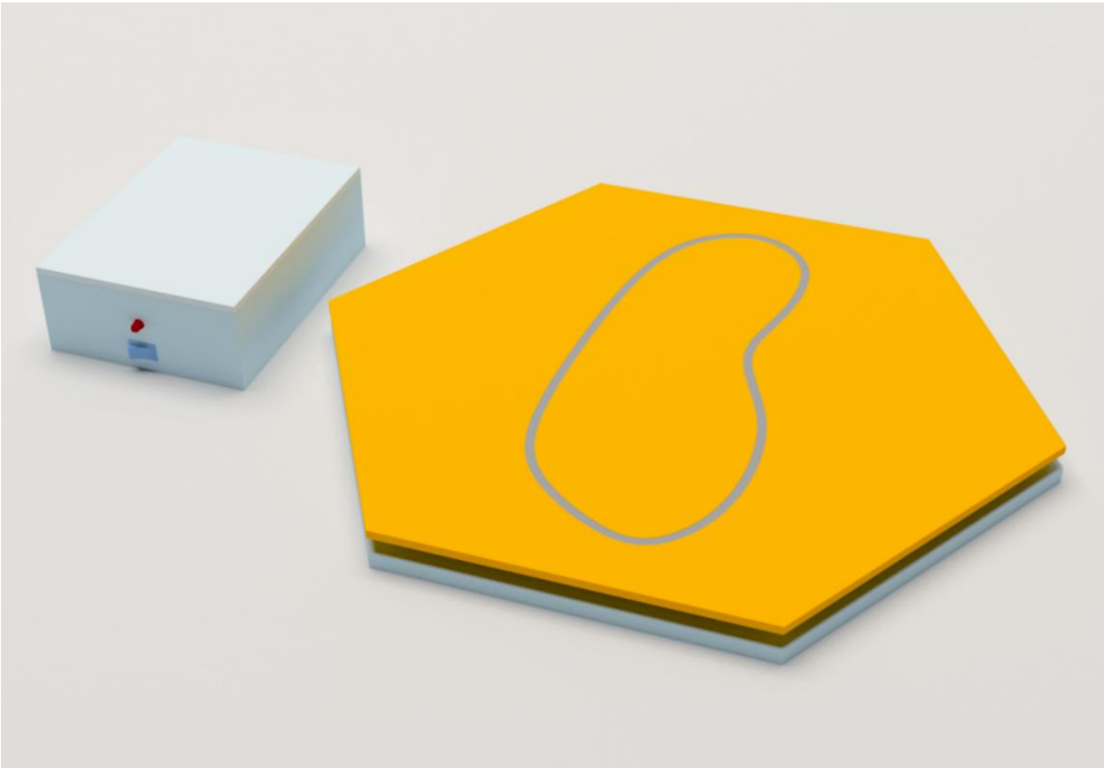


Figure 7

Isometric View of the Piezoelectric LED Lighting

3D Layout

The three dimensional representation of the device, as it is shown in Figure 8, depicts the actual features and aesthetics of the Piezoelectric LED Lighting. This highlights the developed machine in different views.

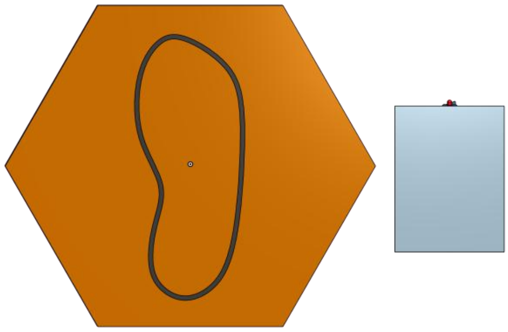


Figure 8.A
Top View

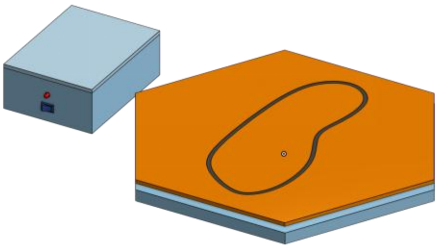


Figure 8.B
Isometric View

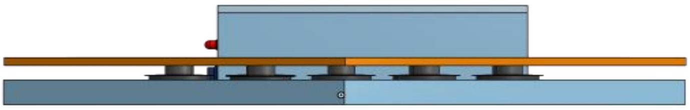


Figure 8.C
Side View

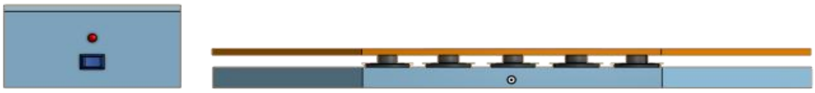


Figure 8.D
Front View

Figure 8

3D Layout of the Device

Orthographic Projection

The orthographic project, which is presented in Figure 9, depicts a two dimensional representation of the developed Piezoelectric LED Lighting that includes device's structure measurements in different views.

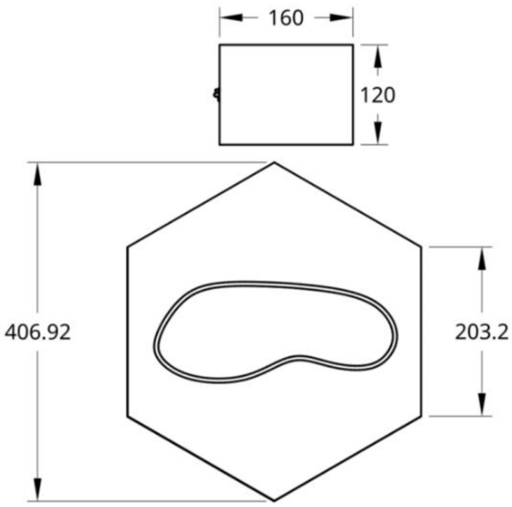


Figure 9.A
Top View

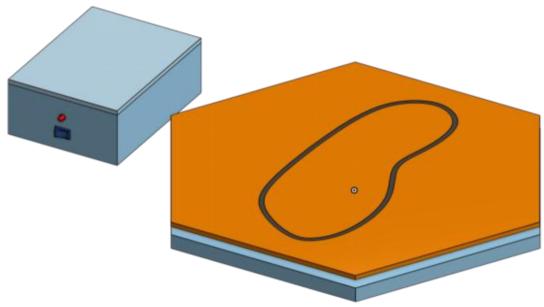


Figure 9.B
Isometric View

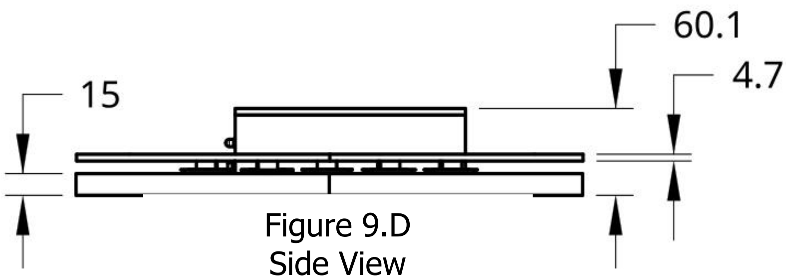


Figure 9.D
Side View

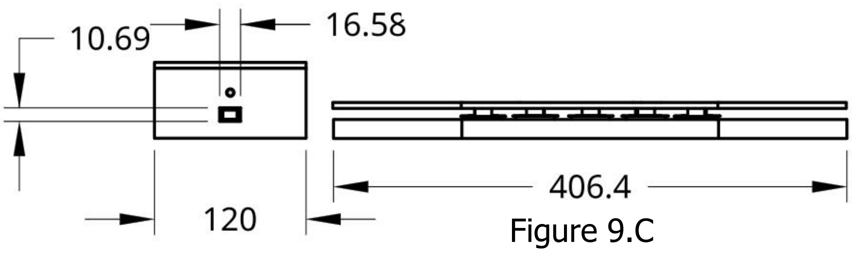


Figure 9.C
Front View

Figure 9

Orthographic Projection of the Device

Detailed Representation of the Machine's Phase

The machine's phase components are depicted in detail in this section, including their full proportions and intended use. This will make it easier to become more acquainted with each part and comprehend its function.

I. Phase 1: Piezoelectric Footstep

The developed machine composes mainly two phases, and one of those phase is the Piezoelectric footstep. This phase is where the electricity is generated. The Piezoelectric footstep is composed of various components that are presented in figure 10, while its usage discussion are presented in Table 10.

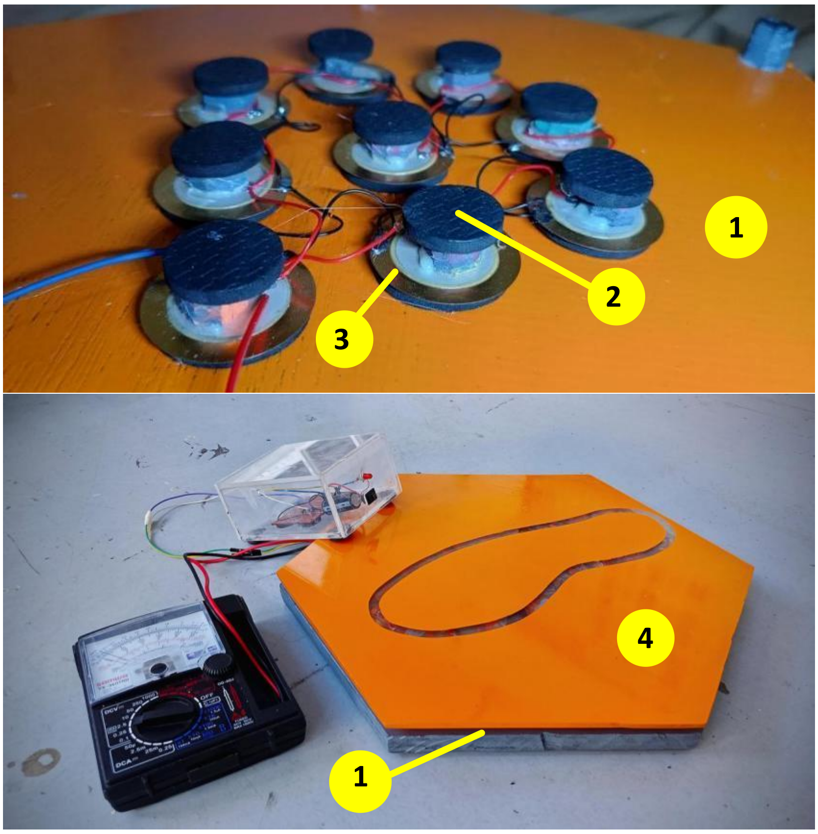


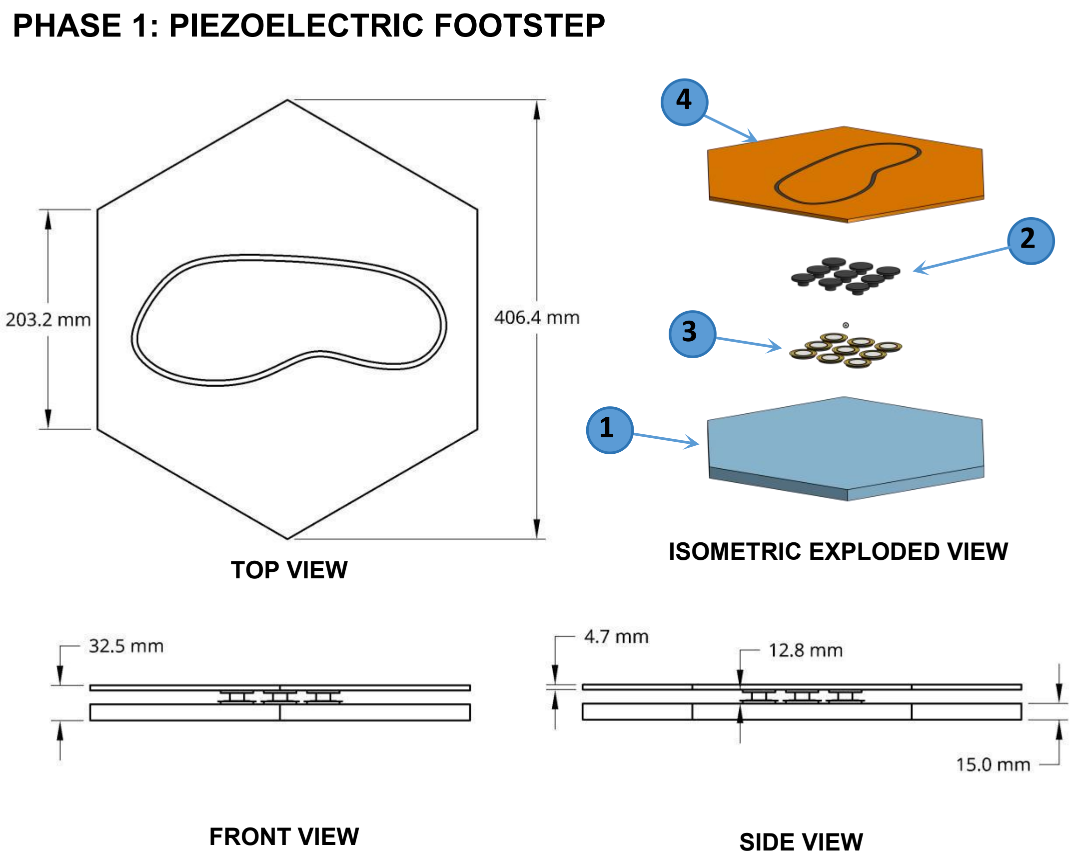
Figure 10

Piezoelectric Footstep (Phase 1) of the Device

Table 10

Piezoelectric Footstep Components

NO.	COMPONENTS	USAGE
1	Hexagonal Wood Base	It is used as the main support structure for the device, and it is made of wood in a hexagonal shape to ensure stability and balance.
2	T-Rubber	It is placed above the wood base to act as a cushion layer for absorbing pressure and protecting internal components.
3	Piezoelectric Transducers	The components that generate electrical energy when pressure is applied through footsteps.
4	Hexagonal Acrylic Plate	It is placed on top of the rubber surface to be stepped on by the user, and it is made of acrylic in a hexagonal shape for both function and design.



No.	Component	Qty.
1	Hexagonal Wood Base	1
2	T-Rubber	9
3	Piezoelectric Transducers	9
4	Hexagonal Acrylic Plate	1

Figure 11

Piezoelectric Footstep Exploded Structure

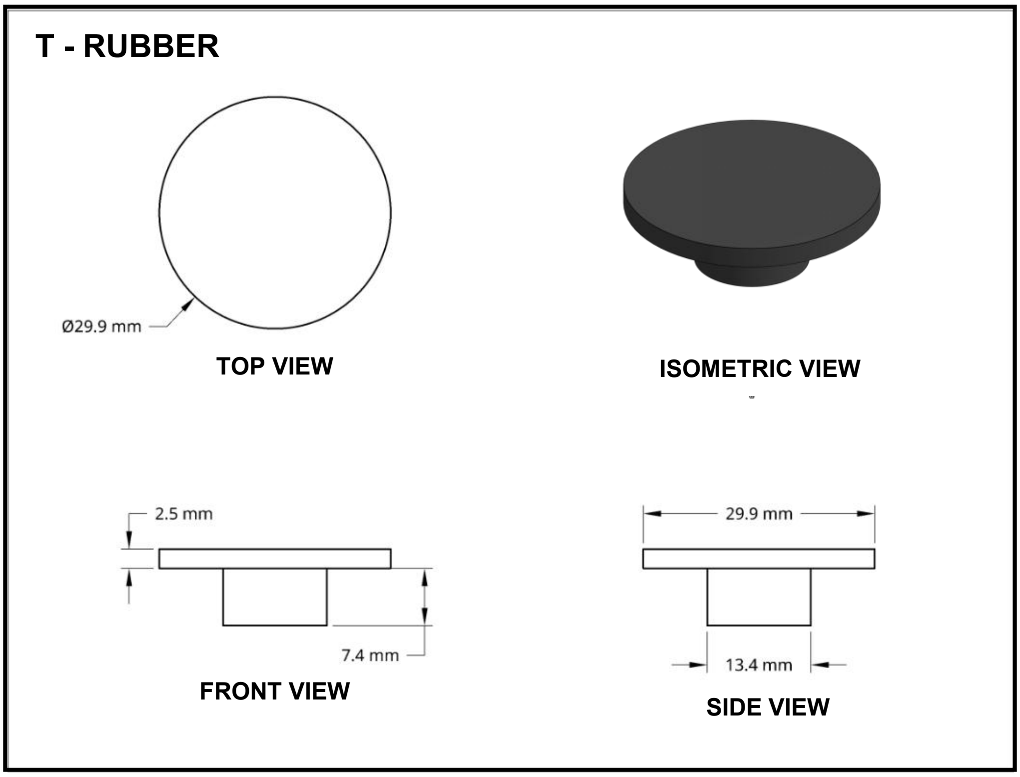


Figure 12

T-Rubber

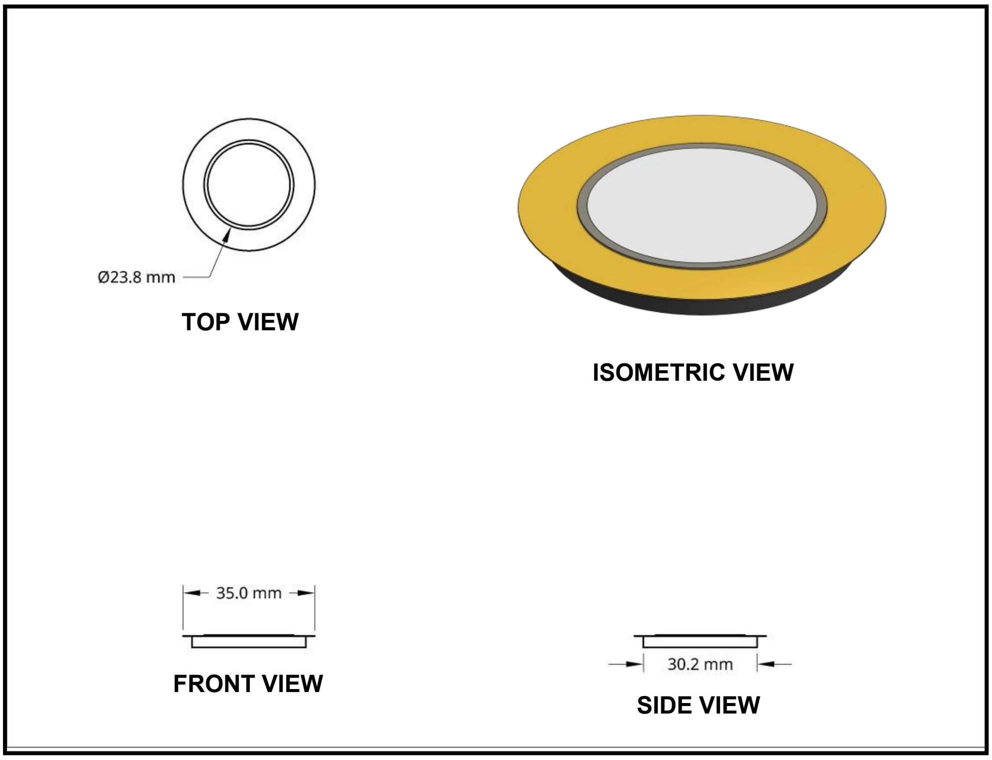


Figure 13

Piezoelectric Transducer

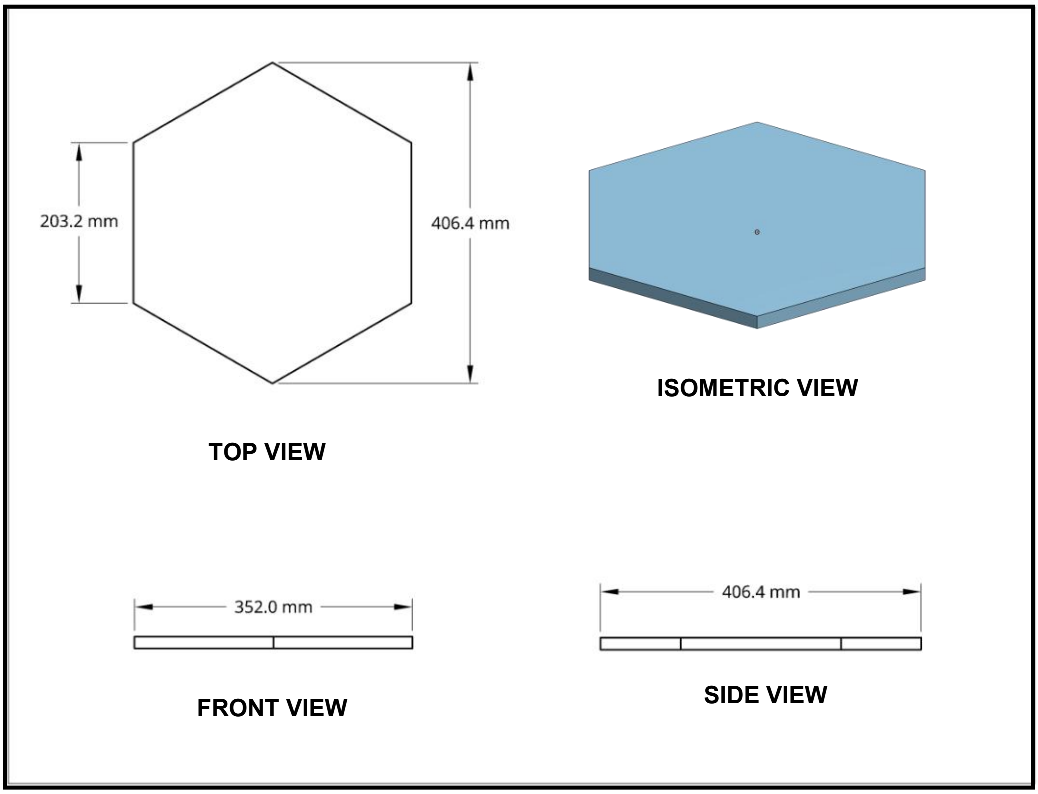


Figure 14
Hexagonal Wood Base

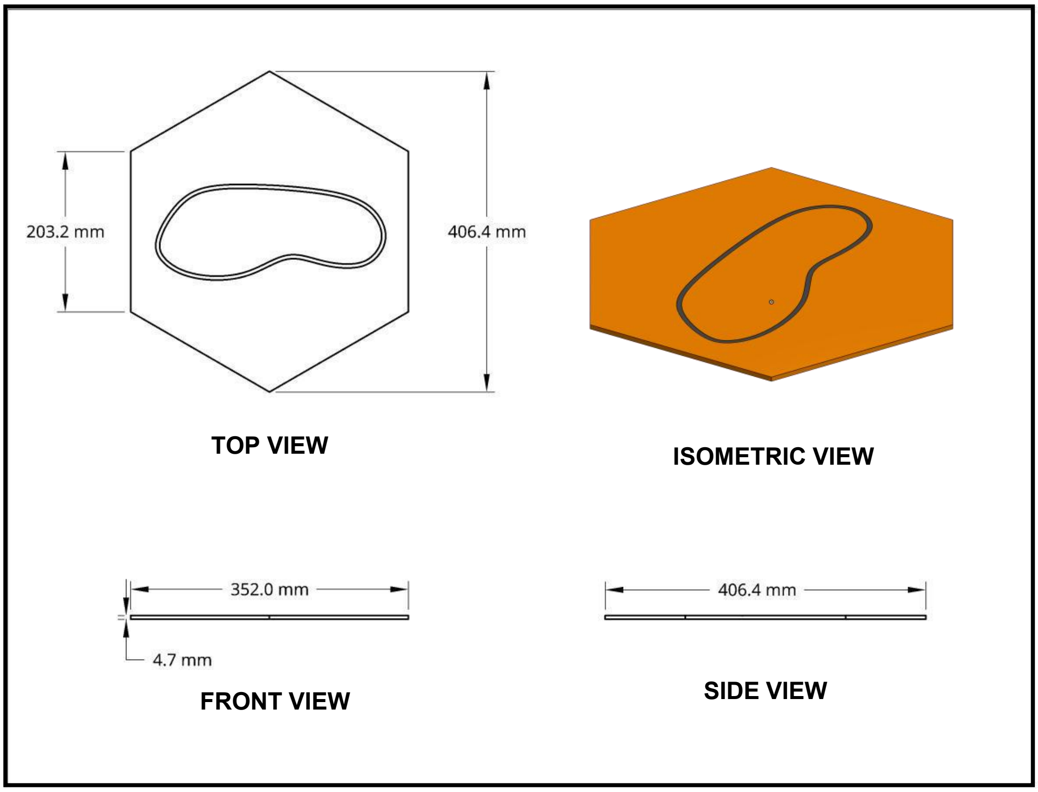


Figure 15
Hexagonal Acrylic Plate

II. Phase 2: LED Lighting Circuit

Phase II is where the electricity is stored on the Piezoelectric LED Lighting. The LED Lighting circuit is composed of various components that are presented in Figure 16, while its usage discussion are presented in Table 11.

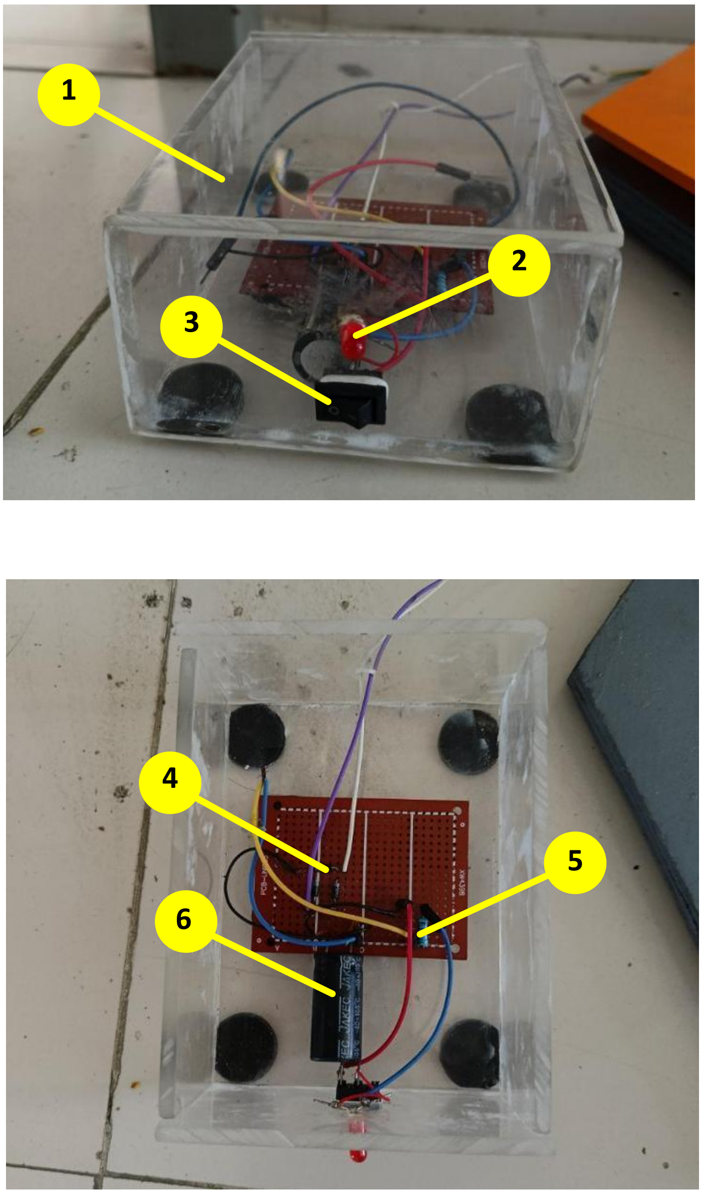


Figure 16

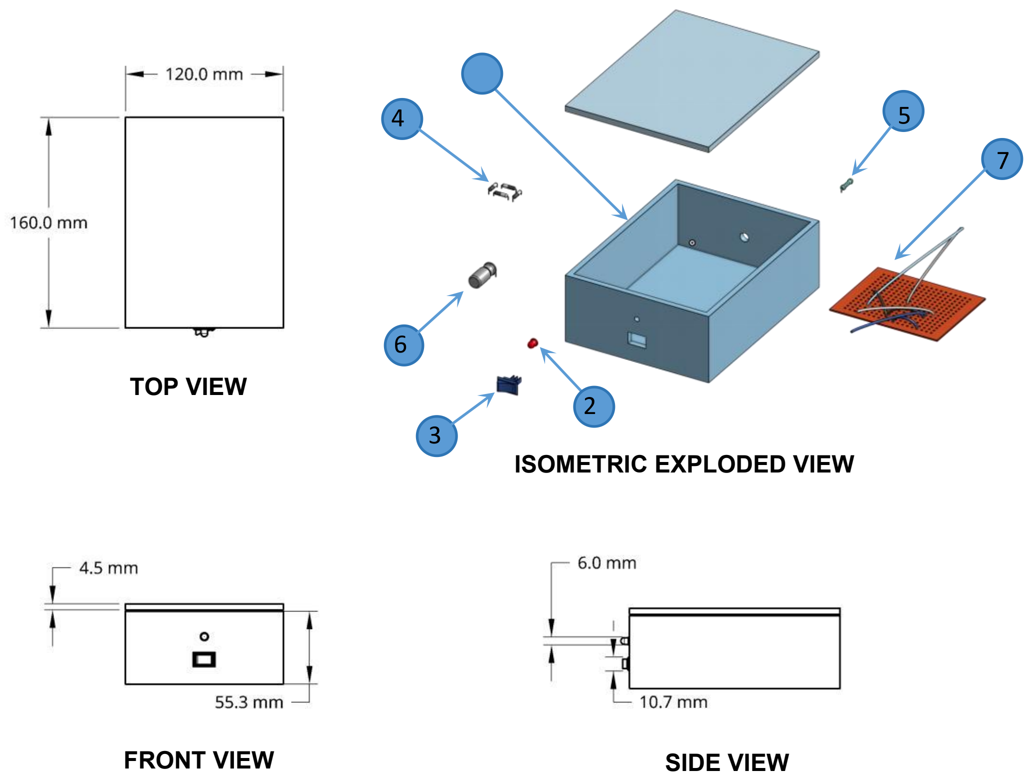
LED Lighting Circuit (Phase 2) of the Device

Table 11

LED Lighting Circuit Components

NO.	COMPONENTS	USAGE
1	Acrylic Box Container	It is used to encase and protect the electronic components, and it is made of clear acrylic for visibility and durability.
2	Red LED	The component that lights up to indicate power generation from footstep pressure.
3	Switch	It is connected to control the flow of electricity to the LED, allowing manual on/off operation.
4	Rectifier Diode	It is used to convert the AC output from the transducers into DC for consistent LED operation.
5	Resistor	It is connected in series to limit the current flowing to the LED and protect it from damage.
6	Capacitor	It is used to store and smooth the electrical energy before supplying it to the LED.
7	PCB (Printed Circuit Board)	It is used as the main platform to mount and connect all electronic components in a compact and organized manner.

PHASE 2: LED Lighting Circuit



No.	Component	Qty.
1	Acrylic Box Container	1
2	Red LED	1
3	Switch	1
4	Rectifier Diode	4
5	Resistor	1
6	Capacitor	1
7	PCB (Printed Circuit Board)	1

Figure 17

LED Lighting Circuit Exploded Circuit

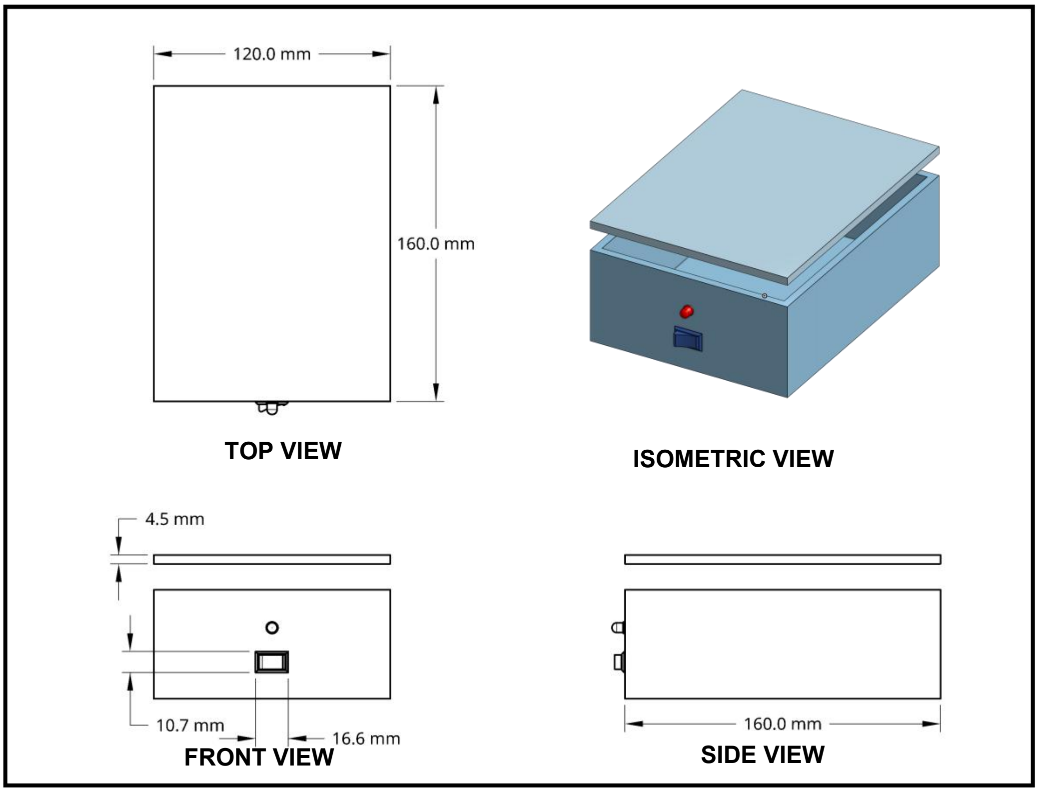


Figure 18
Acrylic Box Container

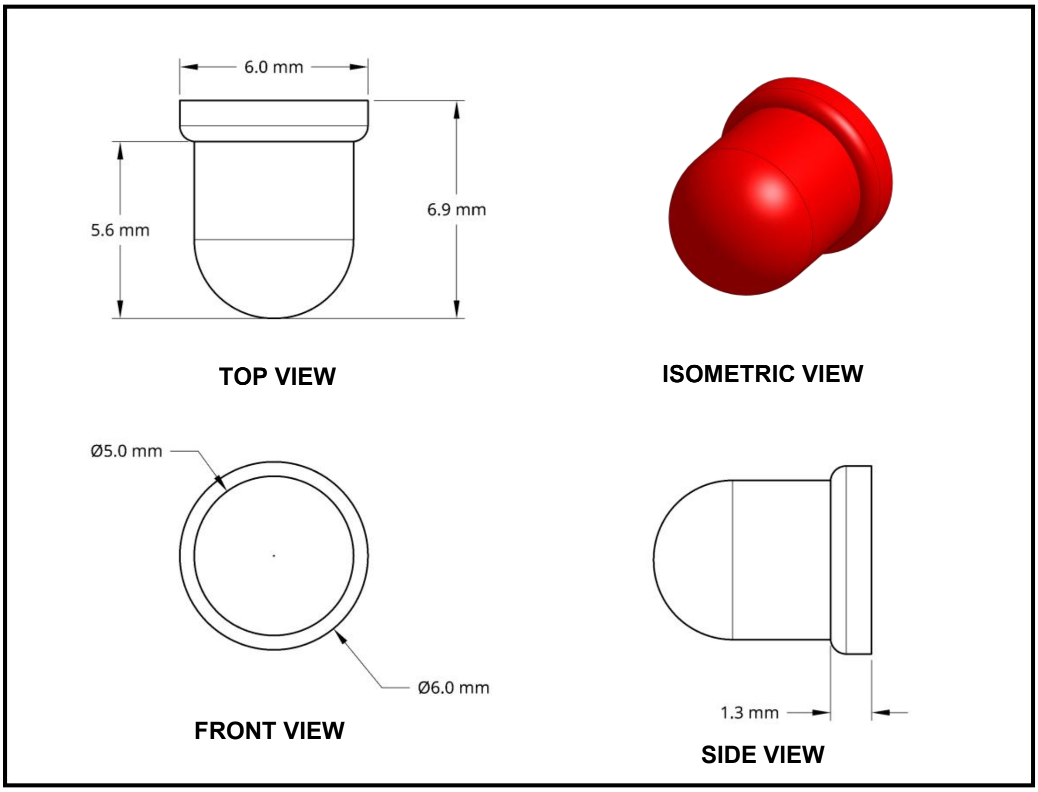


Figure 19
Red LED

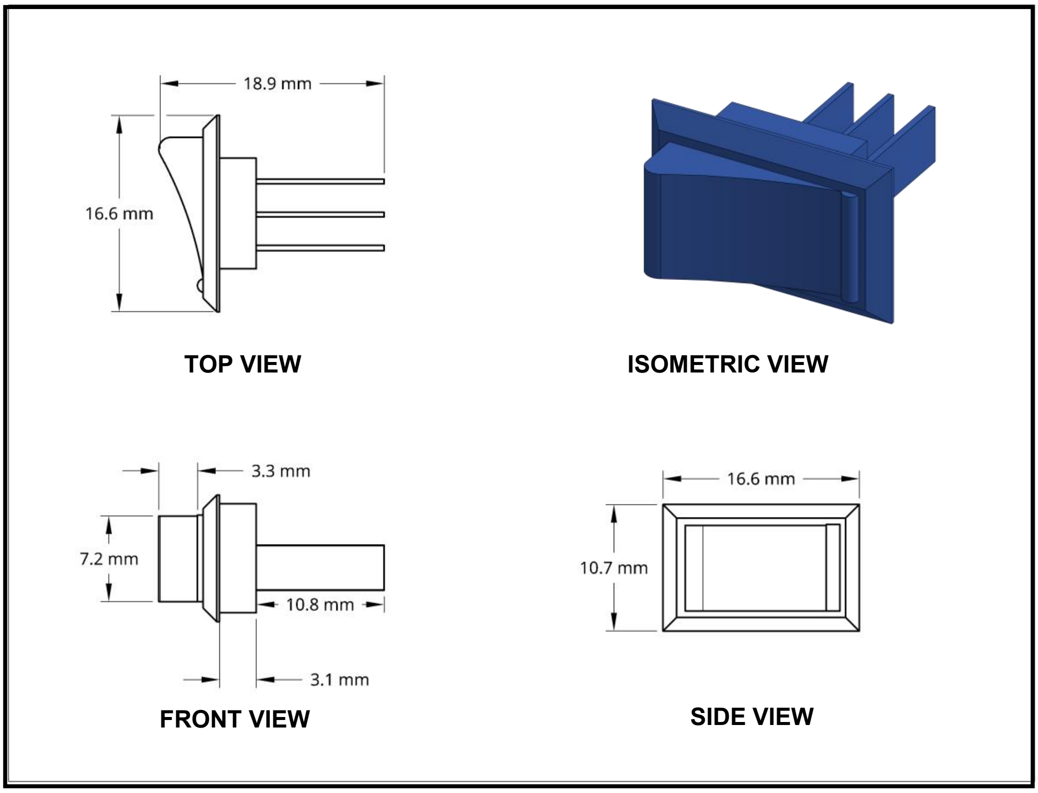


Figure 20
Switch

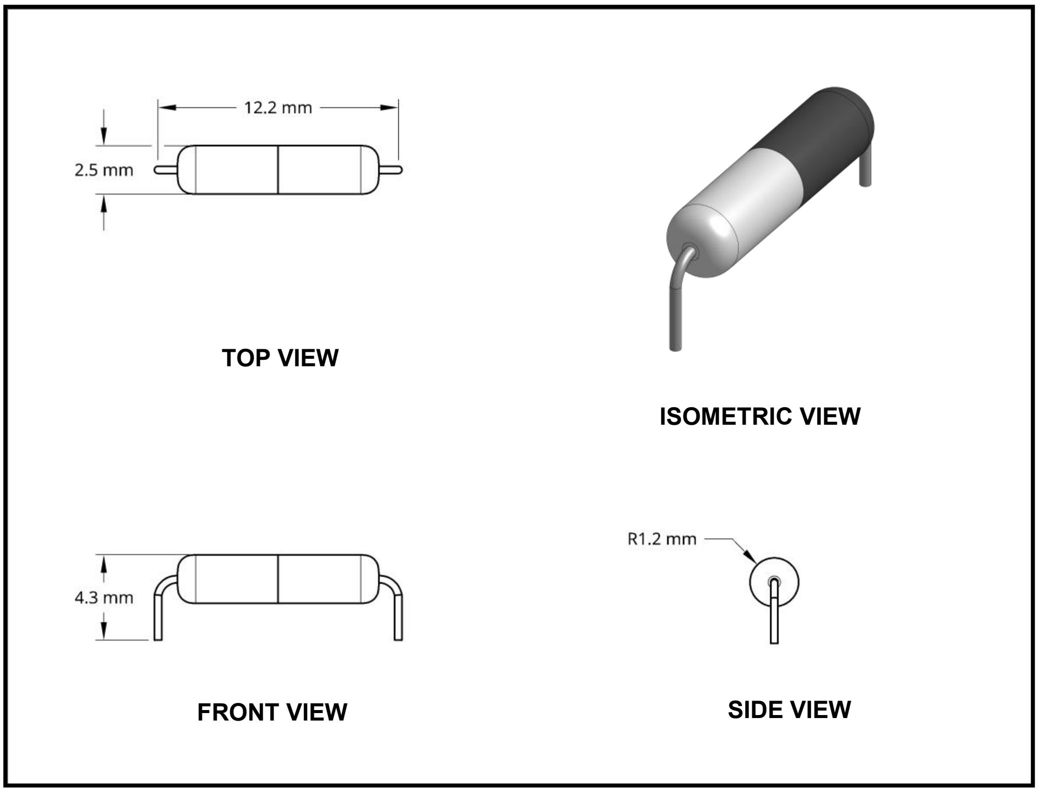


Figure 21
Rectifier Diode

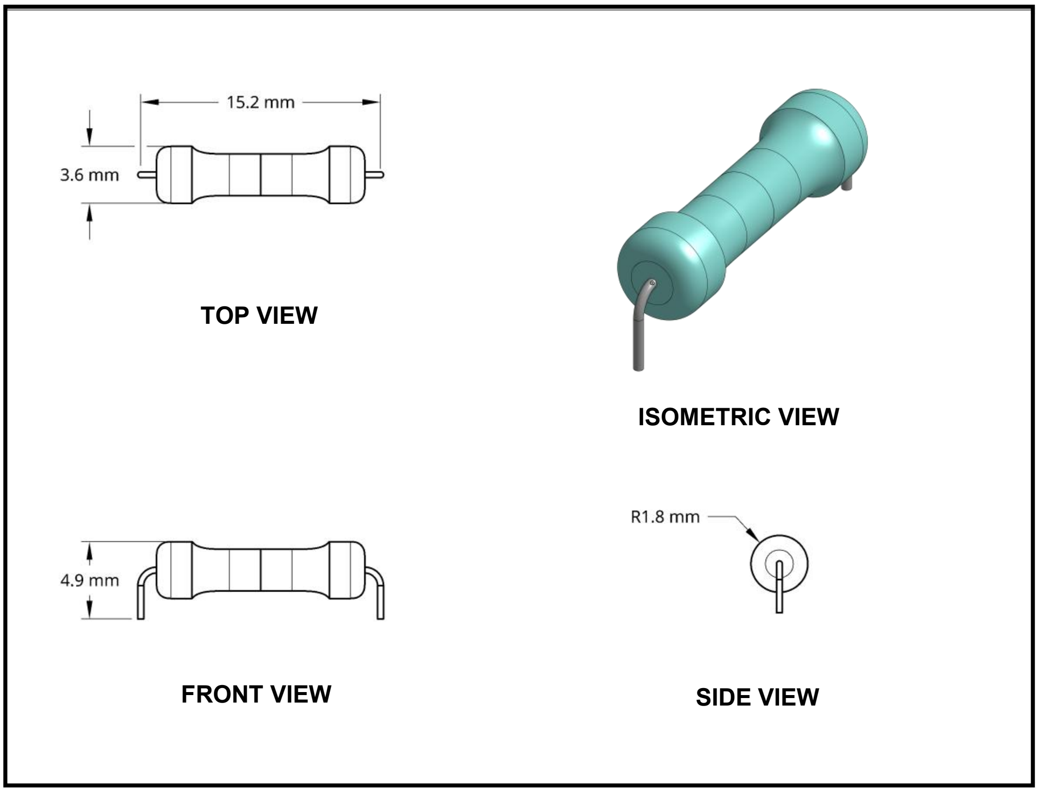


Figure 22
Resistor

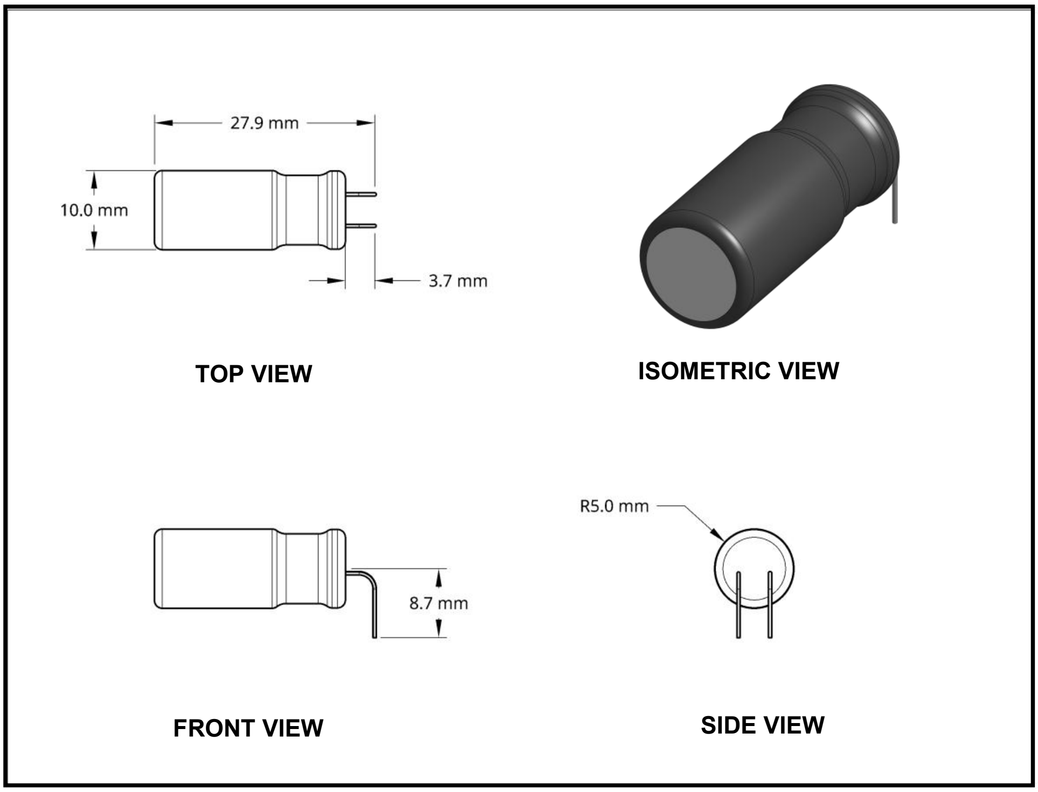


Figure 23
Capacitor

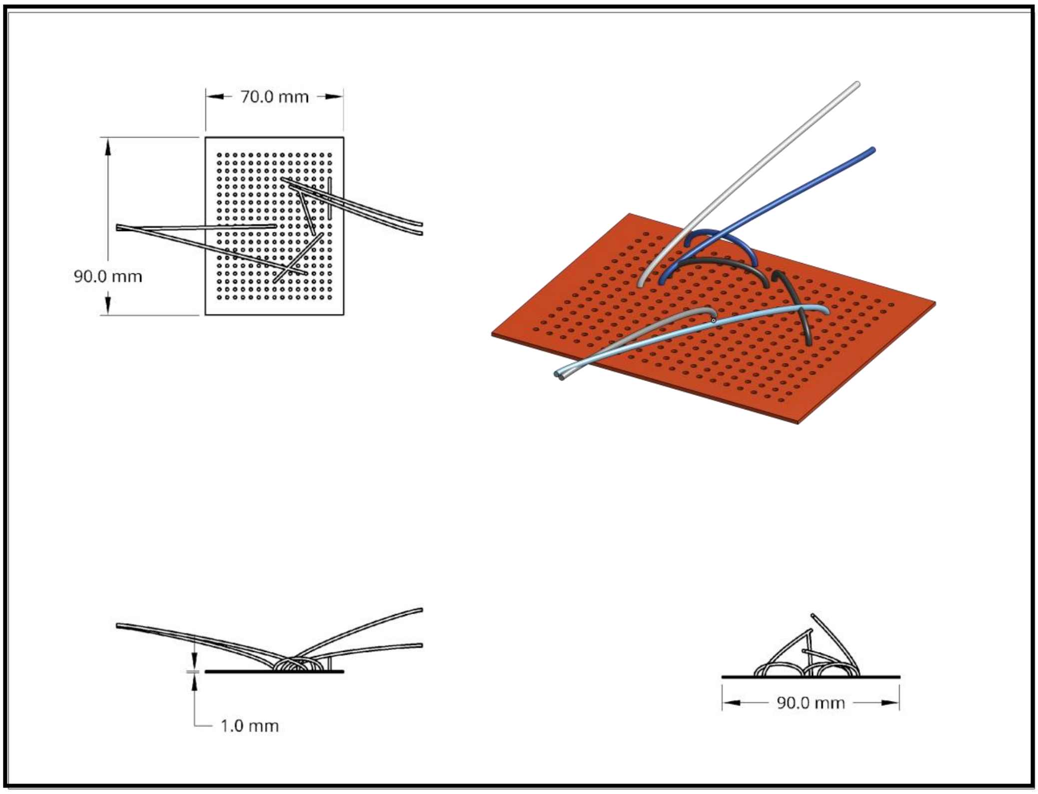


Figure 24
PCB (Printed Circuit Board)

OPERATION MANUAL OF THE PIEZOELECTRIC LED LIGHTING

PREFACE

Please read this manual thoroughly before operating the Piezoelectric LED Lighting. Proper handling and understanding of the device will help ensure safe and optimal use. Failure to comply with operational procedures may result in damage to the device or potential harm to the user. The Piezoelectric LED Lighting is a mechanical-electrical device designed to generate light through mechanical pressure, such as foot steps. It consists of two main systems: the mechanical surface area embedded with piezoelectric sensors, and the electrical circuitry responsible for converting the energy into LED illumination.

SAFETY INSTRUCTIONS

- Read and understand all instructions before operating the device.
- Ensure the device is placed on a flat, dry, and stable surface before use.
- Wear proper footwear when testing the device (avoid sharp heels or spikes).
- Use only in dry environments. Do not operate in wet or damp conditions.
- Do not jump or apply excessive force beyond normal walking pressure.
- Keep all electrical components away from moisture and heat.
- Do not disassemble or alter any internal components unless authorized.

- ❖ Children should not tamper with the device's connections without adult supervision.
- ❖ Immediately stop operation if any unusual sounds, smells, or sparks are detected.

WARNING!

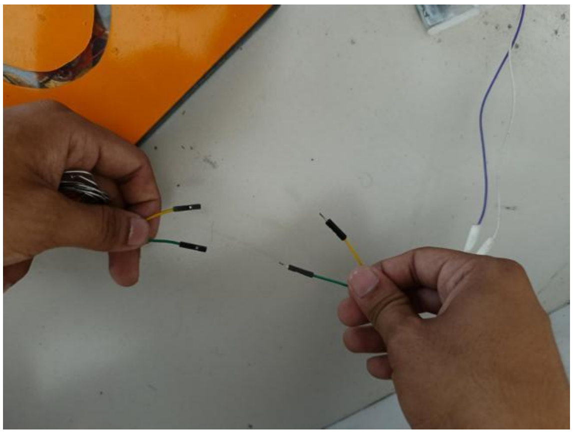
- Do not modify the device or its components without proper authorization.
- Do not apply excessive force beyond normal walking pressure.
- Always supervise use when demonstrating to children or untrained individuals.

Installation Guide of the Piezoelectric LED Lighting

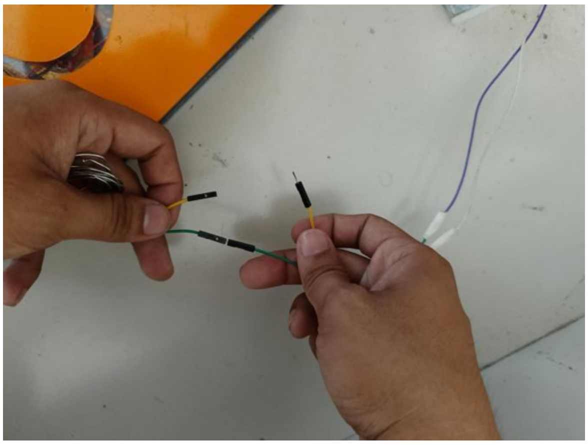
This guide helps the user to understand how to appropriately set-up the machine before starting the charging operation.

Step 1: Position the device on a flat, even surface, ensuring it is kept away from any areas with bumps, humps, or cracks.

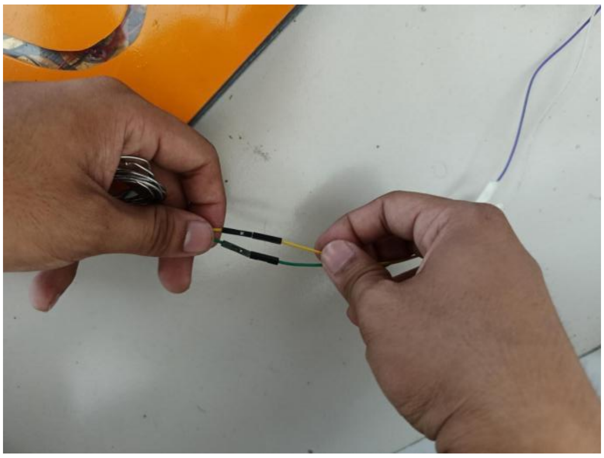
Step 2: Locate the wire terminal of the series - parallel transducers and securely connect it to the main circuit.

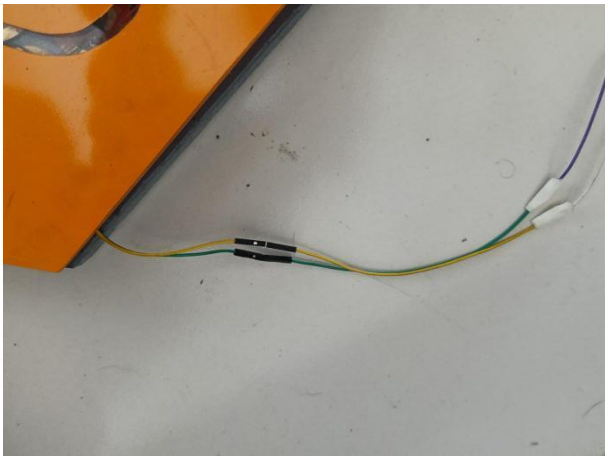


Step 3: Connect the male green jumper wires of the LED Lighting Circuit towards the female green jumper wires of the Piezoelectric Footstep.



Step 4: Connect the male yellow jumper wires of the LED Lighting Circuit towards the other female yellow jumper wires of the Piezoelectric Footstep.





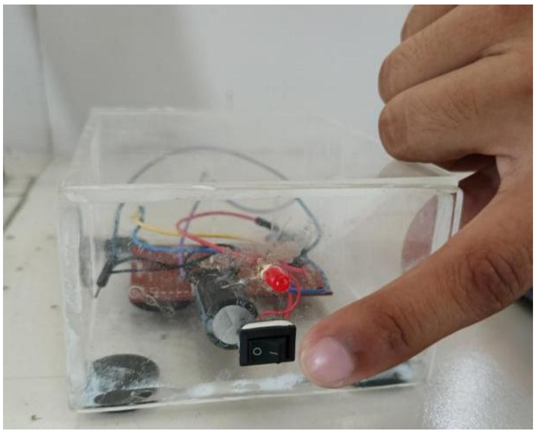
Step 3: Mount the acrylic surface atop of the transducers.

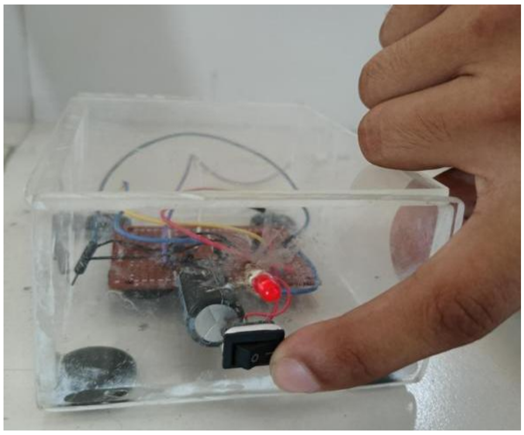
Operational Guide of the Piezoelectric LED Lighting

This section represents the guidelines of how the developed Piezoelectric LED Lighting can be operated appropriately and in a safe way.

Step 1: To start the charging process, step on the foot shape illustration of the acrylic plate. This ensures proper distribution of force on the piezoelectric discs.

Step 2: After letting the device charge for a while you may turn on the LED Lighting circuit using the switch in front of it.





Maintenance Guide

To make sure the Piezoelectric LED Lighting operates well, here are the guidelines, as shown in Table 12, on the critical components/aspects need to maintain every before and after operating the machine.

Table 12
Maintenance Guide of the Piezoelectric LED Lighting

Need To Maintain	Results if not Maintained	Required Actions
❖ Piezoelectric transducers	The overall electric power produced would be lowered as the broken Piezoelectric discs would act as a resistance in the overall flow of the circuit.	Replace if the Piezoelectric transducers are cracked
❖ Wirings & Connections	The electric current would not flow properly leading to reduced electrical output or zero output.	Look for loose wires, broken solder joints, or corrosion on terminals. Re-solder or replace connectors as needed.
❖ Bridge Rectifier (Diodes)	LEDs are polarity-sensitive. If AC is going directly to the LED due to a faulty bridge, the reverse voltage might damage or shorten the LED's lifespan.	Ensure that the AC-DC rectifier and voltage regulation components are working properly. If the LED isn’t lighting up as expected, check diodes and capacitors. Replace if needed.
❖ Capacitor	Piezo elements generate spiky, high-voltage pulses. Without a working capacitor to absorb and smooth those spikes, sensitive components (like LEDs or micro-controllers) can get fried or behave erratically.	Regularly check for bulging tops, leaks, discoloration, or burn marks—these are signs the capacitor is failing. Use a multi-meter to test capacitance if performance seems off. Replace if needed.
❖ Resistors	Current can’t flow to the LED and the LED won’t light up at all. If the resistors are shorted too much current might reach the LED, burning it out.	Look for discoloration: Burn marks or darkening could mean overheating. Replace if needed.
❖ LED	Low light or might not light up at all.	Make sure the LED hasn’t burnt out or come loose. Replace if necessary.
❖ Switch	A degraded or broken switch might internally short potentially damaging components like the LED or capacitor.	Clean or replace if faulty

Troubleshooting Guide

Here are some methods for troubleshooting the piezoelectric LED lighting system in case there are any problems or issues that may arise when it is operating.

Table 13
Troubleshooting Guide of the Piezoelectric LED Lighting

Issue/Problem	Possible Cause	Required Action
a) LED not lighting up	➢ Piezoelectric transducers are damaged ➢ Loose wiring/soldering ➢ Capacitor discharged	✔ Apply mechanical force to transducers. If no light is detected when using a multi-meter, then your LED is faulty and should be replaced with a brand new one. ✔ Inspect and re-solder loose connections. ✔ Wait for capacitor to charge or replace if faulty.
b) No charge generated from Piezoelectric Footstep to LED Lighting Circuit or Circuit towards LED.	➢ Broken wire/solder joint. ➢ Faulty diodes in bridge rectifier. ➢ Insufficient capacitor charge	✔ Inspect & re-solder connections ✔ Replace damaged diodes. ✔ Check the condition of the capacitors and replace if deemed faulty. Ensure to use a larger capacitor (e.g., 20,000 μF) when replacing.
c) Components shorted	➢ Faulty diodes in bridge rectifier ➢ Shorted Capacitor	✔ Replace damaged diodes. ✔ Replace capacitor
d) Capacitor tor swelling/leaking	➢ Overvoltage issue. ➢ Incorrect polarity connection.	✔ Use capacitor rated above 16V when replacing. ✔ Ensure correct capacitor polarity (+ and -)
e) Resistor Overheating	➢ Incorrect resistor value	✔ Always ensure to use recommended resistance (470Ω + 1kΩ) when replacing capacitors.
f) LED very dim	➢ Low voltage generation ➢ Insufficient capacitor charge	✔ Increase force on piezoelectric transducers. ✔ Check the condition of the capacitors and replace if deemed faulty. Ensure to use a larger capacitor (e.g., 20,000 μF) when replacing.
g) LED not lighting up but electricity is generated and capacitor is charged	➢ Faulty Switch	✔ Replace Switch

KEY CONTACTS

Please refer to the technical staff and designer contact information below if you require more assistance troubleshooting a sophisticated issue or problem with the machine's functionality and structure.

TECHNICAL PERSONNEL'S CONTACT DETAILS

Contact Person	:	Brosnan F. Nadal
Cell Number	:	09936914929
Email	:	broskie.nadal@gmail.com

Name	:	Nash Ashley B. Duhaylungsod
Email	:	nashoyyy@gmail.com
Contact Number	:	09934008591

Name	:	Vincent R Colorito
Email	:	vincentruiz012@gmail.com
Contact Number	:	0962309891

Name	:	Matthew Seth Molero
Email	:	matthewsethmolero0710@gmail.com
Contact Number	:	09569855735

Name	:	Joevic L. Pitogo
Email	:	joevicoypitogo@gmail.com
Contact Number	:	09164432076

DESIGNER'S CONTACT DETAILS

Contact Person	:	Janica Kate E. Ortigas
Cell Number	:	09692815140
Email	:	janicaortigas40@gmail.com

Contact Person	:	Tim David L. Mayol
Cell Number	:	09058042309
Email	:	timmayol0@gmail.com

Contact Person	:	Kevin Balansag
Cell Number	:	09208083650
Email	:	kevinkevz0808@gmail.com

Contact Person	:	Jesse Angelo A. Maraat
Cell Number	:	09609295374
Email	:	jessemaraat@gmail.com

Contact Person	:	Andrea Marie Amistoso
Cell Number	:	amistosoandrea0@gmail.com
Email	:	09605157131

Environmental Information

The Piezoelectric LED Lighting prototype was developed with an emphasis on sustainability and environmental responsibility, aiming to harness renewable energy sources. The prototype functions effectively under normal environmental conditions without the emission of harmful substances or pollutants during operation. Although the device currently provides a meaningful demonstration of renewable energy application in small-scale systems. Its ability to generate light without the use of external electricity showcases its potential for eco-friendly lighting solutions in low-energy environments or emergency situations. The device's short illumination time highlights opportunities for further enhancement, while still reinforcing its value as a sustainable prototype. The materials used in the construction of the device, such as acrylic panels, piezoelectric discs, and lightweight electrical components, were selected for their recyclability and availability from local sources. These choices help minimize environmental degradation and reduce hazardous elements used in the device, further supporting its environmentally safe operation.

Moreover, the piezoelectric system used in this prototype produces zero carbon emissions during energy generation. Its low-impact design ensures that it does not contribute to air pollution or greenhouse gas emissions, making it an ideal alternative environmentally. The development of the Prototype reflects a commitment to innovation with environmental responsibility, encouraging further research and design improvements to enhance energy capture and extend lighting duration in future iterations. Yet with its current limitations in power duration, the Piezoelectric LED Lighting prototype remains a green and practical initiative toward promoting renewable energy technology and sustainable design in the field of energy-efficient lighting.

Disclaimer

The researchers in this study used piezoelectric LED lighting, which is merely regarded as a medium or a tool for data gathering and processing. Despite the efforts made to guarantee appropriate and correct operation, it is crucial to realize that this machine is not error-free and that faults or deviations may occasionally occur because no machine is ever regarded perfect.

Therefore, it is important to consider the device's limits and potential margin of error when interpreting the findings and conclusions presented in this research paper.

Any unforeseen effects resulting from the use of this machine during research or operations related to its installation are not the responsibility of the researchers.

Scheme of Implementation

The implementation of the Piezoelectric LED Lighting will take place in Cebu Technological University-Main Campus over a period of (5) five days. This aims to evaluate the effectiveness of the lighting system in harvesting piezoelectric energy and providing sustainable illumination. The process will also assess user interaction and acceptability within the chosen environment.

Further testing and monitoring will be conducted to determine the equivalent amount of mechanical input required to generate sufficient energy for sustained LED illumination. Additionally, it will test the time duration needed for the piezoelectric system to achieve stable lighting without causing technical issues or energy disruptions.

At the end of the implementation process, observations and documentation will be completed. A matrix will be created to provide the equivalents between the amount of mechanical input (e.g., footsteps) and the LED lighting duration and brightness.

Implementation Result and Documentation

Figure 25

Device Implementation Day 1

On the first day of implementation, the piezoelectric LED lighting system was set up on the stairs of the 4th floor in the Automation Building.

The system collected energy from 123 steps, generating a total voltage of approximately 1.15V. As a result, the LED light glowed for about 32 seconds, starting very dim light slowly fading out. However, a malfunction was observed: the acrylic plate protecting the piezoelectric plate occasionally moved out of place after being stepped on, which affected the system's performance.

Figure 26

Device Implementation Day 2

On the second day, adjustments were made to the piezoelectric plate and the acrylic cover to ensure the acrylic plate stayed in place after being stepped on, addressing the issue from the previous day. The system collected energy from 100 frequent steps, producing a total voltage of 1.05V. The LED light illuminated for around 32 seconds, starting dim and slowly fading to no visible light. No malfunctions were detected during this day of implementation.

Figure 27

Device Implementation Day 3

The system setup was further adjusted on the third day to ensure the acrylic plate remained stable and did not move during use. The system collected energy from 50 steps, but the voltage generated was relatively low at 0.7V. As a result, the LED light glowed for about 15 seconds, starting bright and gradually fading out. Despite the reduced performance, no malfunctions were found, and the system operated without issue.

Figure 28

Device Implementation Day 4

On the fourth day, another adjustment was made to the piezoelectric plate setup to stabilize the acrylic plate. The system collected energy from 85 steps, generating 1V in total. The LED light glowed for approximately 26 seconds, starting dim and gradually fading to no visible light. The system functioned without any malfunctions, and no issues were observed throughout the day.

Figure 29

Device Implementation Day 5

By the fifth day, the piezoelectric plate and acrylic cover were once again adjusted to ensure maximum stability. The system was able to collect energy from 200 frequent steps, producing a voltage of 1.55V. The LED light illuminated for around 40 seconds, starting bright and gradually fading to low brightness. No malfunctions occurred, and the system operated optimally by the end of the implementation period.

Table 14

Matrix of Implementation

Day	Steps Collected	Voltage Collected	LED Glow Duration (seconds)	Observations
1	123	1.15V	32	LED Light is dim. Acrylic plate occasionally moves out of place.
2	100	1.05V	32	LED Light is dim. No malfunctions observed.
3	50	0.7V	15	LED Light is very dim. No malfunctions observed.
4	85	1V	26	LED Light is dim. No malfunctions observed.
5	200	1.5V	40	LED Light is bright. No malfunctions observed.

Overall Observation

Based on the implementation matrix, the piezoelectric LED lighting system reveals a direct and consistent correlation between the frequency of mechanical input (steps) and energy output. Across the five-day testing period, it was observed that higher step activity significantly increased voltage generation, resulting in longer and more stable LED illumination. For instance, on the fifth day—when the system recorded the highest activity with 200 steps—it produced 9.3V, allowing the LED to glow for approximately 12 seconds. In contrast, on the third day with only 50 steps recorded, the voltage dropped to 1.8V, and LED glow time reduced to 4 seconds, with noticeable dimming.

This performance variation clearly demonstrates that the system's efficiency is heavily reliant on the volume of mechanical stress applied to the piezoelectric plates. When foot traffic is high, energy harvesting is maximized, providing strong and sustained lighting. However, in low-traffic periods, the system yields limited voltage output, resulting in shorter illumination times and reduced brightness. Despite initial mechanical issues observed on the first day specifically the instability of the acrylic plate all subsequent adjustments led to stable and malfunction-free operations, proving the design's adaptability and potential for refinement.

This analysis underscores the importance of optimizing the system to account for fluctuating user activity. Future improvements may include the integration of small-scale energy storage components to reserve excess energy during peak usage, ensuring consistent lighting during periods of inactivity. Additionally, exploring multi-point energy harvesting across higher foot traffic zones could enhance the system’s scalability and effectiveness in real-world applications. Overall, the implementation demonstrates the viability of piezoelectric energy harvesting as a sustainable lighting solution, provided the system is fine-tuned for varying mechanical input conditions.

Charging Operation

In this section, researchers tested the device's charging operation to observe and determine the outcomes of charging the Piezoelectric LED Lighting across different step counts.

Figure 30
200-Step Charging Process for LED Lighting

Figure 30 presents the outcome of the LED lighting after the charging process. At this stage, the LED initially emits a bright glow, which gradually fades over a span of approximately 42 seconds. The transition remains smooth and consistent, indicating stable energy discharge. No issues were observed with the electrical components during or after the charging cycle, confirming the system's reliable performance under the given load.

Figure 31
400-Step Charging Process for LED Lighting

Figure 31 illustrates the LED lighting behavior following a successful charging cycle. The LED begins with a bright and steady glow for approximately 15 seconds before gradually fading over the next 31 seconds. Throughout the process, the system operated smoothly without any issues, completing the cycle as intended. This consistent performance highlights the device’s ability to manage energy efficiently, producing stable illumination with improved light distribution and minimal flickering.

Figure 32
600-Step Charging Process for LED Lighting

Figure 32 shows the performance of the LED lighting system after undergoing higher charge cycles. At this stage, the LED maintains a bright and steady glow for approximately 18 seconds before gradually fading over the next 38 seconds. The increased energy input results in more sustained illumination, enhancing lighting consistency. The device operated as intended, with no issues detected in any of its functional components, confirming the system's reliability and efficiency during extended use.

Figure 33
800-Step Charging Process for LED Lighting

Figure 33 presents the result of the LED lighting system after undergoing higher charge cycles. The LED maintains a bright and stable glow for approximately 21 seconds before gradually fading over a span of 45 seconds. The extended duration of brightness reflects improved energy storage and output performance. The device was successfully charged without any significant issues, demonstrating consistent functionality and reliable operation throughout the process.

Charging Operation Remarks

Table 15 presents the overall remarks on the charging operation of the piezoelectric LED lighting, specifically in relation to the number of steps required to light the LED.

Table 15
Overall Remarks on the Charging Operation

Number of Steps	LED Appearance Observation	Device Observation
200 Steps	Starts off bright and eventually fades slowly in a span of 42 seconds.	There were no electrical component problems when the machine finished charging.
400 Steps	Starts of bright and remains bright for around 15 seconds and eventually fades around 31 seconds. It illuminated in a total of 46 seconds.	The constructed device had no issues during the charging process and completed the operation as planned.
600 Steps	Higher charge cycles keeps the duration of the bright state longer for about 18 seconds and eventually fades around 38 seconds. It illuminated in a total of 56 seconds	The gadget functions as planned and there are no issues with any of its functional parts.
800 Steps	Higher charge cycles keeps the duration of the bright state longer for about 21 seconds and eventually fades around 45. It illuminated in a total of 1m and 06 seconds.	The gadget was successfully charged by the machine without any significant problems.

Based on Table 15, the piezoelectric LED lighting successfully transfers mechanical energy into electrical power, with constant increases in brightness and efficiency. As the number of charging steps increases, the LED brightens and becomes more stable, displaying consistent performance over time. The system minimizes energy loss while providing consistent illumination, making it a promising solution for sustainable lighting.

On the other hand, charge storage and energy retention could be improved further. Improving power control can enhance reliability even more, especially under changing conditions.