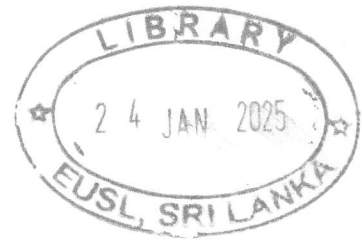


**DEVELOPMENT OF A LOW-FREQUENCY PIEZOELECTRIC
SOUND ENERGY HARVESTER USING A SINGLE-COILED
ACOUSTIC METAMATERIAL CAVITY**

BY



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Project Report
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JULY 2024**

ABSTRACT

With urbanization, environmental pollution including noise pollution, and the demand for energy sources increase rapidly. Instead of controlling noise pollution using sound absorbers by converting it into wasted energy, the sound energy can be harvested to be utilized in various applications through different transduction methods to overcome the energy requirements of low-power instruments. While sound energy is a more abundant, clean energy source from everywhere, the harvesting process should follow step by step process as sound energy is a low energy density source. To optimally use the effect of low sound energy density, the sound energy should be amplified, then converted into electricity, and after manipulation of the harvested voltage, it can be utilized. With the aim of amplifying sound energy, various approaches are researched, and acoustic metamaterials trending as they allow manipulation of sound waves in different ways. From the beginning, different types of resonators have been used for sound amplification, while Helmholtz resonators playing a dominant role. Nowadays, the Helmholtz resonator is being modified in several ways to achieve maximum sound amplification. Considering all these aspects, in this work the Helmholtz resonator has been modified with acoustic metamaterial as a single coiled acoustic metamaterial cavity. The design of the harvester was confirmed through COMSOL multiphysics simulation analysis and the sound pressure level variation was observed using a sound meter within the tested frequency range, 100 Hz-2000 Hz. Then with the integration of the Lead Zirconate Titanate (PZT) plate, the sound energy was converted into electric energy. To evaluate the performance of the harvester, the voltage was measured through a cathode ray oscilloscope, a programmed millivoltmeter, and using a multimeter with a voltage doubler and rectifier circuits. Using a storage capacitor, the storing voltages were experimented. With sound pressure level analysis, the fundamental resonance frequency of the harvester was identified as 300 Hz while the fundamental peak of all the voltage measurements was aligned with the obtained fundamental frequency. The huge discrepancy between theoretical resonance frequency and experimental resonance frequency showed a path to modify the Helmholtz resonance frequency equation, with the modification of acoustic compliance and inertance after identifying the unsuitability of the

Helmholtz resonator equation for the larger dimension apparatus. The Helmholtz resonator equation was modified for a larger harvester with a quarter-wavelength cavity and a half-wavelength zig-zag path (that can be considered as a narrower neck) and the calculated value through the modified equation was perfectly aligned with the experimental value. The harvested voltage with the harvester was six times greater compared to the generated voltage without the harvester and therefore obtained 16 dB gain with the maximum power of $1.44 \mu\text{W}$. Furthermore, the proposed acoustic metamaterial can be modified in several ways, such as integrating custom piezoelectric plates, rescaling to lower dimensions, integrating multiple piezoelectric plate configurations, and multiple harvester configurations in future studies.

Keywords: Noise pollution, sound energy harvesting, acoustic metamaterials, Helmholtz resonator, Piezoelectric

TABLE OF CONTENTS

ACKNOWLEDGEMENT	iii
DECLARATION	iv
ABSTRACT	v
TABLE OF CONTENTS	vii
LIST OF FIGURES	x
LIST OF TABLES	xii
LIST OF ABBREVIATIONS	xiii
INTRODUCTION	1
1.1. Methods of Sound Energy Transduction.....	3
1.1.1. Piezoelectric sound energy harvesting [11]–[13]	3
1.1.2. Electromagnetic sound energy harvesting	5
1.1.3. The use of Capacitor Plates in Harvesting Sound [8]	6
1.1.4. Triboelectric Plates: The transformation of Sound into Electricity by using Friction [8, 16]	7
1.2. Acoustic Metamaterials for Sound Energy Harvesting [9]	9
1.3. Realistic use of Sound Energy Harvesting	13
1.4. Research Objectives and Aim	16
BACKGROUND THEORY	17
2.1. Background Theory of Basic Helmholtz Resonator: Design, Acoustic Compliance, and Acoustic Inertance	17
2.1.1. Design:	17

2.1.2. Operation:	18
2.1.3. Acoustic Compliance (CA) [34]:	18
2.1.4. Acoustic Inertance (LA) [34]:	18
2.1.5. Resonance Frequency:	19
2.1.6. Helmholtz Resonator vs. LC Circuit Analogy	20
2.2. Background Theory of modified Helmholtz Resonator with Half-Wavelength Zigzag Neck and Quarter-Wavelength Cavity for Sound Energy Harvesting	22
2.2.1. Design and Operating Principle	22
2.2.2. Theoretical Considerations	23
2.2.3. Advantages and Considerations	24
2.2.4. Piezoelectricity and Sound Energy Conversion	25
2.2.5. The Working Principle of Piezoelectric Plates	25
2.2.6. Sound Energy Harvesting using Piezoelectric Plates	26
DESIGN AND CONSTRUCTION	28
3.1. Design Optimization using COMSOL Multiphysics	28
3.2. The fabrication of the physical prototype	31
3.3. Piezoelectric Plate Integration	32
3.4. Bill of Materials (BOM):	33
EXPERIMENTAL SETUP AND MEASUREMENTS	34
4.1. Sound Source and Measurement	34
4.2. Voltage Measurements and Data Acquisition	35
RESULTS AND DISCUSSION	37
CONCLUSION	47
FUTURE WORKS	48

REFERENCES.....	49
APPENDIX A: Sound meter readings with frequency	54
APPENDIX B: Direct voltage measurements	59
APPENDIX C: Normalized voltages	60
APPENDIX D: Calculation of voltage gain, power gain, and power gain in dB	63
APPENDIX E: Voltage measurements through storage capacitor	64
APPENDIX F: Modification of the HR equation for larger dimension resonators .	65

LIST OF FIGURES

Figure 1.1 : Working flow for sound energy harvesting [2]	2
Figure 1.2: Basic principle of sound energy harvesting with different transduction methods [9]	3
Figure 1.3: Working principle of Piezoelectricity [14].....	4
Figure 1.4: An energy harvesting system using electromagnetism [15].....	5
Figure 1.5: Schematic of capacitive energy harvester [8].....	7
Figure 1.6: Working mechanism of sound driven in TENG (Triboelectric Nanogenerator) proposed by [16]	8
Figure 1.7: Modified Helmholtz resonator with tapered neck	11
Figure 1.8: Modified Helmholtz resonator with tapered neck	11
Figure 1.9: Modified Helmholtz resonator with cone shaped cavity	11
Figure 1.10: Modified Helmholtz resonator with helix structure	11
Figure 1.11: Spiral Helmholtz resonator	12
Figure 2.1: Conventional Helmholtz resonator [2]	17
Figure 2.2: The spring mass model.....	21
Figure 2.3: The spring-mass model with damper	21
Figure 3.1: Different geometries tested through simulation	29
Figure 3.2: Final design of the harvester confirmed through simulation analysis.....	29
Figure 3.3: Block diagrams.....	31
Figure 3.4: Workings on fabrication process	32
Figure 3.5: The final prototype	32
Figure 3.6: PZT plate integration at the bottom of the cavity	32
Figure 3.7: Dimensions of PZT plate.....	33
Figure 4.1: Schematic diagram of the experimental setup.....	34
Figure 4.2: Experimental setup	34
Figure 4.3: Voltage patterns obtained for different sound frequencies through Arduino programmed millivolt meter	36

Figure 4.4: Circuit Diagram.....	36
Figure 5.1: SPL variation through the studied frequency range of 0 Hz – 2000 Hz (Data shown in Appendix A).....	37
Figure 5.2: Graph for direct voltage measurements vs frequency (Data given in Appendix B).....	39
Figure 5.3: Aligning of SPL variation with direct voltage measurements	39
Figure 5.4: Graph for voltage vs frequency (Data given in Appendix C)	40
Figure 5.5: Graph for increased voltage vs frequency (Data given in Appendix C)	41
Figure 5.6: Graph for normalized end voltage vs frequency for where the plate is integrated both inside and outside the cavity (Data given in Appendix C)	42
Figure 5.7: Graph for increase in voltage vs frequency for where the plate is integrated both inside and outside the cavity (Appendix C).....	42
Figure 5.8: Graph for Voltage gain variation, power gain variation, and power gain in dB variation with frequency	43
Figure 5.9: Graph for increase in stored voltage of capacitor vs frequency (Data given in Appendix E).....	44

LIST OF TABLES

Table 1.1: Output voltages from three different sound sources [7]	2
Table 1.2: Properties of commonly used piezoelectric materials [2].....	5
Table 1.3: Harvested energy through various approaches	10
Table 1.4: Modifications of Helmholtz resonator in previous studies.....	10
Table 2.1: Helmholtz resonator and LC circuit analogy.....	20
Table 3.1: Dimensions of the resonator	30
Table 3.2: Bill of Materials.....	33