# Design and Fabrication of Self-Powered Micro-Harvesters

## Rotating and Vibrating Micro-Power Systems

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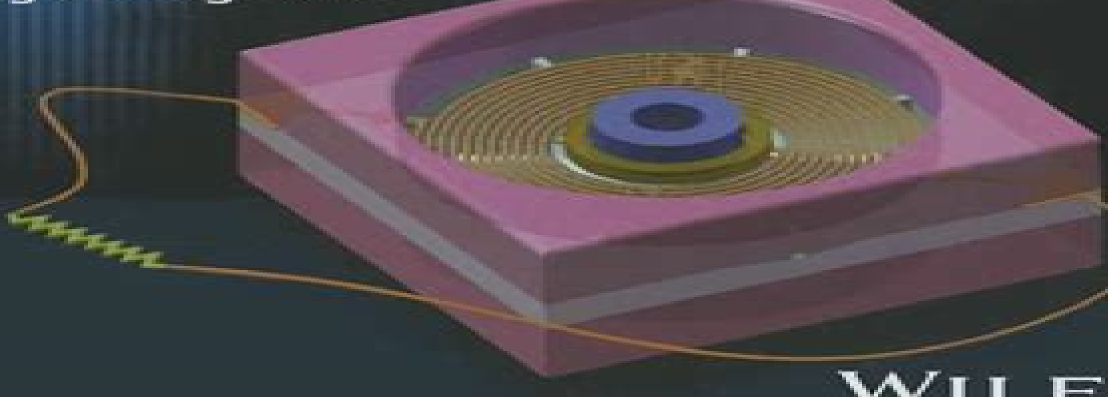

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# Design And Fabrication Of Self Powered Micro Harvesters Rotating And Vibrated Micro Power Systems

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**Design And Fabrication Of Self Powered Micro Harvesters Rotating And Vibrated Micro Power Systems:**

*Design and Fabrication of Self-Powered Micro-Harvesters* ,2013 Design and Fabrication of Self-Powered Micro-Harvesters C. T. Pan,Y. M. Hwang,Liwei Lin,Ying-Chung Chen,2014-04-09 Presents the latest methods for designing and fabricating self powered micro generators and energy harvester systems Design and Fabrication of Self Powered Micro Harvesters introduces the latest trends of self powered generators and energy harvester systems including the design analysis and fabrication of micro power systems Presented in four distinct parts the authors explore the design and fabrication of vibration induced electromagnetic micro generators rotary electromagnetic micro generators flexible piezo micro generator with various widths and PVDF electrospunpiezo energy with interdigital electrode Focusing on the latest developments of self powered microgenerators such as micro rotary with LTCC and filament winding method flexible substrate and piezo fiber typed microgenerator with sound organization the fabrication processes involved in MEMS and nanotechnology are introduced chapter by chapter In addition analytical solutions are developed for each generator to help the reader to understand the fundamentals of physical phenomena Fully illustrated throughout and of a high technical specification it is written in an accessible style to provide an essential reference for industry and academic researchers Comprehensive treatment of the newer harvesting devices including vibration induced and rotary electromagnetic microgenerators polyvinylidene fluoride PVDF nanoscale microscale fiber and piezo micro generators Presents innovative technologies including LTCC low temperature co fire ceramic processes and PCB printed circuit board processes Offers interdisciplinary interest in MEMS NEMS technologies green energy applications bio related sensors actuators and generators Presented in a readable style describing the fundamentals applications and explanations of micro harvesters with full illustration *Self-Powered and Soft Polymer MEMS/NEMS Devices* Ajay Giri Prakash Kottapalli,Kai Tao,Debarun Sengupta,Michael S. Triantafyllou,2019-02-28 This book explores the fabrication of soft material and biomimetic MEMS sensors presents a review of MEMS NEMS energy harvesters and self powered sensors and focuses on the recent efforts in developing flexible and wearable piezoelectric nanogenerators It also includes a critical analysis of various energy harvesting principles such as electromagnetic piezoelectric electrostatic triboelectric and magnetostrictive This multidisciplinary book is appropriate for students and professionals in the fields of material science mechanical engineering electrical engineering and bioengineering **More-than-Moore Devices and Integration for Semiconductors** Francesca Iacopi,Francis Balestra,2023-02-17 This book provides readers with a comprehensive state of the art reference for miniaturized More than Moore systems with a broad range of functionalities that can be added to 3D microsystems including flexible electronics metasurfaces and power sources The book also includes examples of applications for brain computer interfaces and event driven imaging systems Provides a comprehensive state of the art reference for miniaturized More than Moore systems Covers functionalities to add to 3D microsystems including flexible electronics metasurfaces and power sources Includes current applications such as brain computer interfaces event driven imaging and edge computing Reichweitenangst Jan Müggenburg,2021-12-03 Als Medien der Speicherung Miniaturisierung und Mobilisierung geh ren elektrochemische Zellen historisch betrachtet zu den M glichkeitsbedingungen des Digitalen Zeitalters Vom Smartphone ber den elektrischen Rollstuhl bis hin zum Elektroauto versprechen Batterien und Akkus eine nachhaltigere und fortschrittlichere digitale Zukunft Doch diese Entwicklung hat ihren Preis Unter dem Begriff Reichweitenangst befassen sich die Beitr ger innen des Bandes mit unserer allt glichen Sorge dass der Akku nicht mehr bis zur n chsten Ladestation reicht und wir auf halber Strecke liegen bleiben Dar ber hinaus wird die Frage diskutiert wie weitreichend die individuellen kollektiven und kologischen Auswirkungen unseres steigenden Verbrauchs an Batterien sind *Nanosensors for Smart Manufacturing* Sabu Thomas,Tuan Anh Nguyen,Mazaher Ahmadi,Ali Farmani,Ghulam Yasin,2021-06-10 Nanosensors for Smart Manufacturing provides information on the fundamental design concepts and emerging applications of nanosensors in smart manufacturing processes In smart production if the products and machines are integrated embedded or equipped with sensors the system can immediately collect the current operating parameters predict the product quality and then feed back the optimal parameters to machines in the production line In this regard smart sensors and their wireless networks are important components of smart manufacturing Nanomaterials based sensors nanosensors offer several advantages over their microscale counterparts including lower power consumption fast response time high sensitivity lower concentration of analytes and smaller interaction distance between sensors and products With the support of artificial intelligence AI tools such as fuzzy logic genetic algorithms neural networks and ambient intelligence sensor systems have become smarter This is an important reference source for materials scientists and engineers who want to learn more about how nanoscale sensors can enhance smart manufacturing techniques and processes Outlines the smart nanosensor classes used in manufacturing applications Shows how nanosensors are being used to make more efficient manufacturing systems Assesses the major obstacles to designing nanosensor based manufacturing systems at an industrial scale *The Bio-inspired X-Structure/Mechanism Approach for Exploring Nonlinear Benefits in Engineering* Xingjian Jing,2025-07-11 This book introduces a novel approach to designing and analyzing beneficial nonlinearity which plays a crucial role in engineering systems and cannot be overlooked in structural design dynamic response analysis and parameter selection It systematically addresses the key issue of how to analyze and design potential nonlinearities whether introduced or inherent in a system under study This task is essential in many practical applications including vibration control energy harvesting sensor systems and robotics The book provides an up to date summary of the latest developments in a cutting edge method for manipulating and employing nonlinearity known as the X shaped structure or mechanism approach Inspired by animal leg limb skeletons this method offers passive low cost high efficiency adjustable beneficial nonlinear stiffness high static ultra low dynamic nonlinear damping dependent on resonant frequency and vibration excitation amplitude and nonlinear inertia low static high dynamic either individually or simultaneously The X shaped structure or mechanism represents a class of beneficial geometric nonlinearity with flexible linkage mechanisms or structural designs in various forms quadrilateral diamond polygon K Z S V shape or others These forms share similar geometric nonlinearity and nonlinear stiffness damping properties making them flexible in design and easy to implement The book series systematically review the research background motivation essential bio inspired ideas advantages of this novel method beneficial nonlinear properties in stiffness damping and inertia and potential applications developed since 2010 and particularly focuses in this book on innovative applications of the X structure mechanism method in energy harvesting and sensor systems *Springless Electromagnetic Vibration Energy Harvesters* Mohamed Bendame,2015 The abundance of environmental kinetic energy combined with advances in the electronics and MEMS industries have opened a window of opportunities for the design and fabrication of self powered battery independent low power electronic devices Kinetic energy harvesting the process that captures vibrations from the environment or surrounding systems and converts them into electrical power o ers the prospects of unlimited power for such systems Vibration energy harvesters VEHs are vibration based micro power generators that utilize mechanical oscillators to capture ambient vibration energy and convert it into electrical power using one of three main transduction mechanisms electromagnetic electrostatic or piezoelectric A key feature of VEHs is their ability to harvest maximum environmental vibration energy from low amplitude and low frequency vibrations from a wide spectrum of frequencies Traditional VEHs use linear mechanical oscillators as their harvesting element and are tuned to harvest environmental vibrations at resonance frequency present within the application environment These VEHs are usually designed to harvest energy from high frequency vibrations in a narrow band in the vicinity of the natural frequency of the mechanical oscillator and outside this narrow band of frequencies their output power is signi cantly reduced In environments where ambient vibrations are random and only available at low frequencies conventional harvesters prove to be ine ective Although such devices are capable of generating power from vibrations with frequencies close to their resonance frequency the need for harvesters that can harvest energy from broadband vibration sources has become an interesting research topic in recent years To overcome the limitations associated with traditional vibration energy harvesters nonlinear phenomena such as hardening and softening nonlinearities magnetic levitation and pact have been sought as a solution to broadband vibration energy harvesting In this thesis we aim to address this challenge by investigating a new architecture of an electromagnetic vibration energy harvester the electromagnetic Springless vibration energy harvester SVEH The new architecture di ers from traditional harvester as it uses a double impact oscillator as its harvesting element as opposed to the linear model Experimental results show that the new SVEH is capable of harvesting vibration energies with frequencies as low as 5Hz and amplitudes as low as 0 05 g in a frequency band of about 8Hz The harvester generates maximum output power of 12 mWatt from vibrations with amplitude of 0 5 g and an optimal load of 3 6 ohms Experimental results also show that the nonlinear center frequency of the harvester is not constant as in the case of conventional harvesters but depends on the amplitude and frequency of the external vibrations and whether the harvester is operated in the vertical or horizontal position Experimental as well as the numerical frequency response curves of the SVEH also show the existence of hardening nonlinearity in the horizontal con guration and softening nonlinearity in the vertical con guration in the system The hardening e ect allows harvesting of energy in the high frequency spectrum about 25 Hz and a bandwidth of 7 Hz while the softening e ect allows harvesting at the lower end of the frequency spectrum which is around 5 Hz and a bandwidth of 8 Hz Models of the SVEH in the vertical and horizontal con gurations were developed and nonlinear numerical and analytical methods were used to analyze the system to gain a deeper understanding of the system s behavior The experimental data is then used to validate the models The harvester s ability to harvest vibration energy from low frequency 25Hz and low amplitude vibrations 0 5g in a wide band 5Hz is one of the unique features of the SVEH demonstrated in this work **Micro-scale Piezoelectric Vibration Energy Harvesting** Lindsay Margaret Miller,2012 Wireless sensor networks WSNs have the potential to transform engineering infrastructure manufacturing and building controls by allowing condition monitoring asset tracking demand response and other intelligent feedback systems A wireless sensor node consists of a power supply sensor s power conditioning circuitry radio transmitter and or receiver and a micro controller Such sensor nodes are used for collecting and communicating data regarding the state of a machine system or process The increasing demand for better ways to power wireless devices and increase operation time on a single battery charge drives an interest in energy harvesting research Today wireless sensor nodes are typically powered by a standard single charge battery which becomes depleted within a relatively short timeframe depending on the application This introduces tremendous labor costs associated with battery replacement especially when there are thousands of nodes in a network the nodes are remotely located or widely distributed Piezoelectric vibration energy harvesting presents a potential solution to the problems associated with too short battery life and high maintenance requirements especially in industrial environments where vibrations are ubiquitous Energy harvester designs typically use the harvester to trickle charge a rechargeable energy storage device rather than directly powering the electronics with the harvested energy This allows a buffer between the energy harvester supply and the load where energy can be stored in a tank Therefore the harvester does not need to produce the full required power at every instant to successfully power the node In general there are tens of microwatts of power available to be harvested from ambient vibrations using micro scale devices and tens of milliwatts available from ambient vibrations using meso scale devices Given that the power requirements of wireless sensor nodes range from several microwatts to about one hundred milliwatts and are falling steadily as improvements are made it is feasible to use energy harvesting to power WSNs This research begins by presenting the results of a thorough survey of ambient vibrations in the machine room of a large campus building which found that ambient vibrations are low frequency low amplitude time varying and multi frequency The modeling and design of fixed frequency micro scale energy harvesters are then presented The model is able to take into account rotational inertia of the harvester s proof mass and it accepts arbitrary measured acceleration input calculating the energy harvester s voltage as an output The fabrication of the micro electromechanical system MEMS energy harvesters is discussed and results of the devices harvesting energy from ambient vibrations are presented The harvesters had resonance frequencies ranging from 31 232 Hz which was the lowest reported in literature for a MEMS device and produced 24 pW g2 10 nW g2 of harvested power from ambient vibrations A novel method for frequency modification of the released harvester devices using a dispenser printed mass is then presented demonstrating a frequency shift of 20 Hz Optimization of the MEMS energy harvester connected to a resistive load is then presented finding that the harvested power output can be increased to several microwatts with the optimized design as long as the driving frequency matches the harvester s resonance frequency A framework is then presented to allow a similar optimization to be conducted with the harvester connected to a synchronously switched pre bias circuit With the realization that the optimized energy harvester only produces usable amounts of power if the resonance frequency and driving frequency match which is an unrealistic situation in the case of ambient vibrations which change over time and are not always known a priori an adaptable frequency energy harvester was designed The adaptable frequency harvester works by taking advantage of the coupling between a sliding mass and a beam The derivation of the nonlinear coupled dynamic mathematical model representing the physical system is presented as are the numerical and experimental results of the prototype device Passive self tuning was observed in this system and the mathematical model was found to successfully portray the physical behavior **Micro Energy Harvesting** Danick Briand,Eric Yeatman,Shad Roundy,2015-04-21 With its inclusion of the fundamentals systems and applications this reference provides readers with the basics of micro energy conversion along with expert knowledge on system electronics and real life microdevices The authors address different aspects of energy harvesting at the micro scale with a focus on miniaturized and microfabricated devices Along the way they provide an overview of the field by compiling knowledge on the design materials development device realization and aspects of system integration covering emerging technologies as well as applications in power management energy storage medicine and low power system electronics In addition they survey the energy harvesting principles based on chemical thermal mechanical as well as hybrid and nanotechnology approaches In unparalleled detail this volume presents the complete picture and a peek into the future of micro powered microsystems Литература Дагестана и жизнь ,1982 **Design and Comparison of Micro Electromagnetic Vibration Energy Harvesters** ,2015 **Investigation of Potential Platforms for Low Frequency MEMS-based Piezoelectric Energy Harvesting** Mehdi Rezaeisaray,2014 MEMS based energy harvesters have recently been investigated for scavenging otherwise useless ambient vibration energy Piezoelectric materials are fabricated on micro devices to convert the mechanical vibration energy into electrical energy The main focus for these harvesters is low frequency under 500 Hz ambient vibration which is the source of a fundamental challenge with MEMS oscillators The smaller the oscillator is the higher its natural frequencies will become Various techniques have been proposed to decrease the natural frequency of micro energy harvesters such as increasing the length of the devices or assembling extra proof mass to the fabricated devices which could potentially affect the mass production of the MEMS devices Another challenge is that most of the reported piezoelectric energy harvesters in the literature have cantilever designs These structures have a high mechanical quality factor providing a sharp peak at their resonant frequency Since microfabricating resonators with a resonant frequency exactly matching their designed value is very challenging linear cantilever designs seem to be less practical for real applications where excitation frequency could change Therefore some techniques in vibration have been adapted to widen the frequency bandwidth of the harvesters One of the most effective methods to broaden the frequency bandwidth is taking advantage of large deflection effect of oscillators However some of the proposed designs such as a fixed fixed beam design have high resonant frequencies 1 kHz whereas the focus for energy harvesters is low frequency range In this work a silicon based structure has been designed and fabricated to carry an electronic chip and potentially provide in situ supplementary power for it This design provides capability of harvesting at three different frequencies because the resonant frequencies of this structure at its first three mode shapes are within the low ambient vibration frequency range The widening frequency bandwidth has been investigated for this design Natural frequencies as low as 71 8 84 5 and 188 4 Hz have been measured using a laser vibrometer A frequency bandwidth of 10 Hz has been obtained for the 2nd mode shape of the structure under the base excitation of 0 2g A maximum open circuit voltage of 1V and maximum power output of 136nW have been obtained using this harvester In addition as opposed to the conventional silicon based harvesters polymeric materials have been investigated as the main structural material for energy harvesters Due to the much lower stiffness of polymers compared to silicon the resonant frequency of the harvesters could be reduced To prove the concept a SU 8 ESU 8 5GPa vs ESi 160GPa membrane has been designed and fabricated with Aluminum Nitride harvesting elements The membrane configuration provides the capability to widen the harvester s frequency bandwidth Testing results reveal a linear resonant frequency of 381 Hz frequency bandwidth of 146Hz maximum output power of 1 37 W and power density of 3 81 W cm2 at the base excitation of 4g with this design The much lower resonant frequency of polymeric structures compared to the similar silicon based structures more than 5 times lower makes them a strong candidate for the future harvesters The objective of this thesis is to develop a platform using silicon based and polymer based energy harvesters to improve the performance of the energy harvesters by reducing the resonant frequencies and widening the frequency bandwidth Throughout this research all stages including design fabrication packaging testing and characterization of both silicon and polymer based harvesters have been developed or adapted for the purpose of this work Finite element simulations have been conducted to examine the mechanical response of the structures as well as their electrical output at the design stage A scalable microfabrication process flow has been developed in this work to fabricate piezoelectric layers on SU 8 micro structures An improved approach for cleaving fabricated devices from the silicon substrate has been developed to overcome challenges of the dicing process Various 3 D micro assembly techniques have been adapted to package the fabricated harvesters In addition 3 D printed parts were used to enhance the yield of the packaging and testing stages This technique could potentially be used for bio compatible packaging as well In conclusion the polymer based and wideband energy harvesters seem promising for real applications at low ambient vibration frequencies This research introduces opportunities to further improve the performance of the harvesters by decreasing their resonant frequencies Energy Harvesters and Self-powered Sensors for Smart Electronics Huicong Liu,Qiongfeng Shi,2021-12-29 This book is a printed edition of the Special Issue Energy Harvesters and Self Powered Sensors for Smart Electronics that was published in Micromachines which showcases the rapid development of various energy harvesting technologies and novel devices In the current 5G and Internet of Things IoT era energy demand for numerous and widely distributed IoT nodes has greatly driven the innovation of various energy harvesting technologies providing key functionalities as energy harvesters i e sustainable power supplies and or self powered sensors for diverse IoT systems Accordingly this book includes one editorial and nine research articles to explore different aspects of energy harvesting technologies such as electromagnetic energy harvesters piezoelectric energy harvesters and hybrid energy harvesters The mechanism design structural optimization performance improvement and a wide range of energy harvesting and self powered monitoring applications have been involved This book can serve as a guidance for researchers and students who would like to know more about the device design optimization and applications of different energy harvesting technologies *Electromagnetic Energy Harvester and Self-powered Embedded System* Jinyeong Moon,2016 Energy harvesting offers an important design option for creating sensing and control elements without a requirement for custom wiring or batteries The independent and care free nature of energy harvesting enables monitoring devices to penetrate wider and deeper into our daily lives making accommodation of fine sensing and control for condition based maintenance ever more feasible Finer granularity in sensing and control which is the future of energy efficiency alone is an immense benefit as it can reduce time and cost associated with a potential repair Combined with condition based maintenance it can prevent potential down time of a machine under monitoring An exciting possibility creates a self powered embedded system with an integrated energy harvester for electromechanical diagnosis This non intrusive energy harvester is designed to extract energy from magnetic fields around a power line of a load in the manner of a current transformer In contrast to the conventional usage of magnetic elements such as transformers and inductors the analysis on this current transformer reveals a critical result for any given core for any particular application power harvest is maximized when the core is permitted to saturate at an opportune time in the line cycle The design of this integrated energy harvester is fully explored in the thesis including development of new models to incorporate a fully saturating magnetic core for simulation designs of power electronics circuits for maximizing power harvest and integration of the harvester into the embedded system as a practical power supply The design of a self powered and low power embedded system vibration assessment monitoring point with integrated recovery of energy VAMPIRE is discussed in depth in the thesis The overall architecture of the embedded system is first presented followed by designs of individual subsystems the power package and the sensor package In the power package initialization energy buffer power interfaces power regulation and microcontroller design are explored In the sensor package power budget sensors data storages storage management wireless communication and corresponding user interfaces are explored Finally impedance spectroscopy for an electromechanical load is discussed Using the electrical and vibrational data that are nonintrusively collected from electromagnetically self powered embedded system structural issues of the load i e changes in the stiffness of mounts and the imbalance of a shaft can be clearly identified making it feasible for this self powered embedded system to be used for condition based maintenance *Design, Modelling and Fabrication of a Hybrid Energy Harvester* Mohammed Ibrahim,University of Waterloo,2014 As sources of energy are becoming more scarce and expensive energy harvesting is receiving more global interest and is currently a growing field Energy harvesting is the process of converting ambient energy such as vibration to electrical energy that can power a multitude of applications Vibration energy is the by product of everyday life it is generated from any perceivable activity While typically viewed as noise there is a strong potential for harvesting this energy and deploying it to useful applications The focus of this thesis will be using vibration as the ambient source of energy Hybrid energy harvesters employ more than one of the harvesting technologies In this thesis two hybrid harvesters that utilize piezoelectric magnetostrictive and electromagnetic technologies are designed modelled and tested Both of these harvesters have beams that are spiral in shape The use of the spiral geometry allows the system to have a lower natural frequency as opposed to the traditional cantilever beam while still maintaining a high volume of active material The first harvester that is discussed is the P MSM harvester It utilizes piezoelectric and magnetostrictive material Both materials are configured in a spiral beam geometry and allowed to resonate independently The resonance frequency of these two materials is designed to create wideband energy harvesting This allows the harvester to be operating efficiently even if the ambient vibration shifts a small amount The second harvester that is discussed is the P MAG harvester It utilizes piezoelectric and electromagnetic technologies It also incorporates a spiral geometry for the piezoelectric layers and includes a magnet attached at the centre The magnet is placed in the centre of the spiral to reduce the natural frequency of the system and to also actively contribute to the harvesting This harvester has two sources operating at the same resonant frequency which allows it to have a larger power output than if the sources were separated Finally finite element analysis was used to model both harvesters ANSYS was used for the piezoelectric material and COMSOL was used for the electromagnetic material The results are compared to the experimental and are in good agreement The Design of Low-frequency, Low-g Piezoelectric Micro Energy Harvesters Ruize Xu (S.M.),Massachusetts Institute of Technology. Department of Mechanical Engineering,2012 A low frequency low g piezoelectric MEMS energy harvester has been designed Theoretically this new generation energy harvester will generate electric power from ambient vibrations in the frequency range of 200 30OHz at excitation amplitude of 0 5g Our previous energy harvester successfully resolved the gain bandwidth dilemma and increased the bandwidth two orders of magnitude By utilizing a doubly clamed beam resonator the stretching strain triggered at large deflection stiffens the beam and transforms the dynamics to nonlinear regime and increases the bandwidth However the high resonance frequency 1 3kHz and the high g acceleration requirement 4 5g shown in the testing experiments limited the applications of this technology To improve the performance of the current energy harvesters by lowering the operating frequency and excitation level different designs have been generated and investigated Moreover a design framework has been formulated to improve the design in a systematic way with higher accuracy Based on this design framework parameter optimization has been carried out and a quantitative design with enhanced performance has been proposed Preliminary work on fabrication and testing setup has been done to prepare for the future experimental verification of the new design **Development of Electromagnetic Micro-Energy Harvesting Device** Pratik Patel,University of Waterloo,University of Waterloo. Department of Mechanical and Mechatronics Engineering,2013 The use of energy harvesting devices has generated much research interests in recent years There are numerous energy harvesters available in the market that are piezoelectric electromagnetic electrostatic or combination of piezoelectric and electromagnetic Many of the harvesters have shown great potential but are either severely limited in power generation since they are actually never optimized to its potential One of the goals of this thesis is to develop an electromagnetic micro energy harvester that is capable of working at low frequencies 5 30 Hz and is capable of producing electrical power for small devices Generally batteries have been used to power low voltage electronics however the need for self sustaining and reliable power source have always been a major issue This project aims to make a harvester of size AA battery that can be used as a reliable and continuous source of power for bio medical as well as industrial applications Firstly a linear harvester is developed for applications where there is no set natural frequency The linear harvester consists of a stator and a mover The stator includes copper coils outer iron case and delrin holder for the coils while the mover consists of permanent magnets iron pole and cylindrical rod The working principles developed are used to optimize and improve the efficiency of energy harvesting system The linear harvesting system is tested with the permanent magnet to iron pole ratio of 1 25 and permanent magnet to coil ratio of 0 73 The power density of the linear harvester is determined to be 4 44e 4 W cm3 Thereafter optimization is done in comsol to improve the performance of the energy harvesting system The optimized magnet to iron ratio is determined to be 3 175 and permanent magnet to coil ratio of 0 7938 The optimized ratios are used to develop an inertial type non linear energy harvesting device The structure of the non linear harvester is same as the linear one except two stationary magnets are added at the top and bottom of the harvester that act as a non linear spring The non linear harvesting device is tested and the power density of the system is determined to be 2 738e 2 W cm3 The non linear harvester was tested at acceleration level of 1g and it was determined that the harvester worked best at natural frequency of 8 66 Hz The maximum power produced was 38 1 mW The non linear type of harvester is easy to assemble and optimize to match ambient natural frequency of numerous vibrating systems Two frequency tuning methods are looked at for the non linear energy harvesting system One is by changing the magnetic air gap and the second is by changing the thickness of the stationary top and bottom magnets It is determined that changing magnetic air gap is more effective at tuning for a range of natural frequencies For applications where the natural frequency of the system doesn t exist such as buoys and beacons at sea the linear energy harvester works best For applications where the system vibrates at a certain natural frequency the non linear harvester should be used Finally this thesis is concluded with a discussion on the electromagnetic micro harvester and some suggestions for further research on how to optimize and extend the functionality of the energy harvesting system

Design & Fabrication of Non-linear Bistable Vibration Electromagnetic Harvesters Niranjana Sundaresan,2017 The paper explores the design and analysis of a wideband bistable electromagnetic vibration energy harvester using two different approaches a planar nested spring and compression spring The operational bandwidth of the nonlinear bistable vibration energy harvester was increased by introducing a pair of repulsively positioned NdFeB permanent magnets By utilizing FR4 as the structural material and designing it as a nested spring we achieved a low operational frequency while constraining the size of the harvester The design of nested spring was further fine tuned using COMSOL simulations Air gap between the repulsive magnets was further optimized to produce maximum results The maximum measured power of the nested nonlinear bistable was found to be 2 3 W at an acceleration of 0 5 g at a resonant frequency of 60 Hz In the case of the spring based electromagnetic vibration energy harvester the output was found to be 2 5 W at an acceleration of 0 5 g Also concept of Engineering design was used to arrive at a solution in an effective manner Due to this two kinds of prototype were created

**MEMS Energy Harvesters with a Wide Bandwidth for Low Frequency Vibrations** Nuh Sadi Yuksek,2015 We have designed and built macro scale wideband electrostatic and electromagnetic power harvesters for low frequency vibration Initially MEMS capacitive plates for power harvesting have been designed modeled and fabricated and characterized It was designed with a 2 2 mm2 movable metallic plate with a thickness of 10 micro m suspended by four straight beams above a fixed electrode with a gap of 10 micro m to form a variable capacitor The suspension beams are made with a width thickness and total length of 20 micro m 10 micro m and 1500 micro m respectively It was found that the single cavity device can harvest almost 180 nW peak power across a 100 k omega load resistor at 5g The harvested power was dependent on excitation amplitude and supplied DC voltage The MEMS capacitive energy harvester was integrated with two impact oscillators at 18 Hz and 25 Hz for transferring energy from low frequency structural vibration with varying mechanical spectra to high frequency vibration of a high resonance frequency cantilever at 605 Hz The results demonstrate that the device was able to harvest power on a wide range from 14 to 39 Hz at 1g excitation The harvested power was 96 nW on a

100 k omega load resistor We also studied a macro scale electromagnetic power harvester with multi impact oscillations to achieve a broad bandwidth at low frequency vibrations The device consists of three low frequency cantilever designed to resonate at 12 Hz 19 Hz and 40 Hz a high frequency cantilever with resonance frequency of 210 Hz and a pick up coil fixed at the tip of the high frequency cantilever This results in a wide bandwidth response from 11 62 Hz at 1 g A maximum output power of 23 5 micro W can be harvested at 1 g acceleration on an optimum load resistor of 22 omega

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**Design And Fabrication Of Self Powered Micro Harvesters Rotating And Vibrated Micro Power Systems Introduction**

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