

Analytical modeling of electret-based microgenerators under sinusoidal vibrations

by

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Statement of originality

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Abstract

Recent advances in microfabrication technologies and electronics have led to a vast reduction in sizes and power consumption of electronic circuitry. This has revolutionized the field of wireless sensor networks, and in particular, Internet-of-Things, with a booming number of applications that enable the capabilities of autonomous sensing and monitoring. However, the implementation of such applications has been hindered by the slow development of scalable energy sources which provides power for operation. Batteries, which are the most common energy sources, have not kept pace with the demand of these developments. The challenge to provide power for microelectronic devices has, therefore, driven several innovations in vibration energy harvesting - a technology that has been flourished in recent years as a possible alternative to provide continuous energy for autonomous operation. During the last decade, a significant number of microscale vibratory energy harvesters has been fabricated using active materials (piezoelectric, ferroelectric and magnetoelectric) or exploiting the electromechanical coupling mechanisms (electromagnetic and electrostatic) to harvest energy from mechanical stimuli or ambient vibrations. Such transduction mechanisms have both benefits and limitations that vary depending on the employed technology and the targeted application. For miniaturization, electrostatic systems are favorable due to their compatibility with MEMS fabrication processes. In addition, electrostatic systems with pre-charged electrets can autonomously harvest energy to energize microelectronic devices such as wireless sensors and actuators. Hence, this transduction mechanism is selected as the topic of this research.

The main focus of this research is the analytical modeling approach that provides insights into the operating mechanism and trade-off involved when designing an electret-based microgenerator. Sinusoidal excitations which resemble ambient vibration stimuli were considered in this research. The modeling process was, firstly,

undertaken for a simple case when the vibration amplitude is small, and then extended and generalized for an arbitrary sinusoidal vibration. Under these conditions, an electret-based can be modeled as a sawtooth voltage source in series with an equivalent internal resistance, or a current source. These models were validated using a simulation-based method presented in the literature and showed good agreements. A performance optimization was also carried out by employing the proposed analytical model combined with voltage breakdown phenomenon and the limitation of material properties. However, a fully functional micro power generator driven by vibrations has yet to be demonstrated.

In summary, the research has expanded the capability of analytical modeling and understanding of electret-based microgenerators. These can be used in further studies and optimizations to achieve the ultimate goal of autonomous operation.

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Contents

Statement of originality	iii
Abstract	v
Acknowledgment	vii
Publications	ix
1 Introduction	1
1.1 Motivation for energy harvesting	1
1.2 Energy harvesting technologies	3
1.2.1 Light or solar energy	3
1.2.2 Radio frequency	5
1.2.3 Thermal gradient	6
1.2.4 Kinetic energy	7
1.2.5 Comparison of different energy harvesting technologies	9
1.3 Aims and objectives	11
1.4 Thesis overview	13
2 Small-scale vibration energy harvesting	15
2.1 Vibration to electricity conversion model	16
2.1.1 Linear system - Single degree of freedom	17
2.1.2 Linear system - Multiple degree of freedom	20
2.1.3 Nonlinear generators	23
2.1.4 Structural type comparison of vibration energy harvesters	27
2.2 Transduction mechanisms	29
2.2.1 Piezoelectric power conversion	29

2.2.2	Electromagnetic power conversion	34
2.2.3	Electrostatic power conversion	38
2.2.4	Comparison of transduction mechanisms	42
2.3	Conclusions	43
3	Electret-based energy harvesting	47
3.1	Electret	47
3.1.1	Physical properties	48
3.1.2	Charging methods	50
3.2	Electret-based microgenerators	53
3.2.1	State of the art	54
3.2.2	Governing equation of electret-based microgenerator	58
3.2.3	Simulation using FEM and numerical methods	61
3.3	Analytical model under constant speed motions	65
3.3.1	Theoretical model	65
3.3.2	Effect of parasitic capacitance	67
3.3.3	Comparison between theory, simulation and experiment	69
3.4	Conclusions	72
4	Microgenerator modeling and optimization: small sinusoidal excitations	73
4.1	Theoretical model	74
4.2	Influence of parasitic capacitance	79
4.3	Comparison between theory and simulation	80
4.4	Optimization strategy	84
4.5	Conclusions	89
5	Microgenerator modeling: general sinusoidal excitations	91
5.1	Theoretical model	92
5.1.1	Time interval $t_{2m} \leq t < t_{2m+1}$ or $t_{2k-2m} \leq t < t_{2k+1-2m}$	97

5.1.2	Time interval $t_{2m+1} \leq t < t_{2m+2}$ or $t_{2k-2m-1} \leq t < t_{2k-2m}$. . .	100
5.2	Effect of parasitic capacitances	104
5.3	Validation and discussion	108
5.4	Conclusions	112
6	Conclusions and future works	113
6.1	Conclusions	113
6.2	Future works	114
	Bibliography	115
	Appendices	
A	Corona discharge station design	127
B	A liquid sloshing electret-based microgenerator	129
B.1	Concept of the microgenerator	129
B.2	Simulation	131
B.3	Fabrication and experiment	137
B.3.1	Fabrication	137
B.3.2	Experiment	139
C	Detailed solutions of differential equations presented in Chapter 5	141
C.1	Solution of equation (5.10)	141
C.2	Solution of equation (5.21)	143
C.3	Solution of equation (5.32)	145
D	Scientific genealogy	147

List of Figures

1.1	(a) Daily total solar irradiance measurement from the Solar Radiation and Climate Experiment (SORCE) shows that more than a 1 kW/m^2 is available for harvesting, and (b) evolution of global total solar photovoltaic installed capacity taken from SolarPower Europe - Global Market Outlook for Solar Power 2016 - 2020. APAC* is Asian Pacific region excluding China, MEA stands for Middle East and Africa, while RoW stands for rest of the world.	4
1.2	Diagram of a thermocouple generating electricity based on Seebeck's effect.	7
2.1	Schematic of a single-degree-of-freedom second-order spring-mass-damper system.	16
2.2	Classification diagram of different energy harvesting systems.	17
2.3	Output power of vibration energy harvesters is a function of input frequency.	19
2.4	Two configurations of two degrees of freedom system (a) an array of two SDOFs and (b) composite two degrees of freedom system.	20
2.5	Output power of an arrayed type MDOF system is the sum of performance of each SDOF system. Different colors illustrated the output power of different SDOF elements within the whole MDOF system. . .	21
2.6	Response of a composite-configured two degrees-of-freedom system in the frequency domain (a) displacement of mass m_1 , and (b) displacement of mass m_2	23
2.7	An example of a nonlinear energy harvester in which a pair of permanent magnets are employed to create a nonlinear spring.	24

2.8	(a) Frequency response of nonlinear microgenerator displacement with $\delta = 0.1$ and $\alpha = 1$ is plotted with various values of nonlinear spring stiffness. The bend to the left corresponds to a softening nonlinearity, while the bend to the right indicates a hardening nonlinearity. (b) The response of a nonlinear structure starts from a high initial frequency and sweeps slowly as illustrated as arrows to reach to the peak displacement. When the frequency crosses the peak, there is a jump in which the response drops from the peak to the branch on the left. The red dashed line illustrates the unstable response of the system.	25
2.9	An example of non-linear microgenerators employing eccentric mass or pendulum like structure which not only has wide bandwidth, but also be able to harvest energy at low frequency using electromagnetic power transduction mechanism (Romero et al. 2009).	26
2.10	A nonlinear microgenerator from Kinetron employs eccentric mass to harvest kinetic energy.	27
2.11	Two common operation modes of piezoelectric material (a) mode 33 and (b) mode 31.	30
2.12	Two common configurations of piezoelectric cantilever beam (a) bimorph and (b) unimorph.	31
2.13	A simple electromagnetic transducer.	34
2.14	Two energy conversion cycles used in electret-free generation.	39
2.15	Schematic cross section of a one-sided metalized electret consist of excess surface charges, injected space charges and aligned dipolar charges.	40
2.16	Power generated from existing prototypes is a function of (a) device volume, (b) input acceleration and (c) frequency. These plots are based on the data presented in Tables 2.3, 2.6 and 2.7.	43

3.1	Illustration of dipole relaxation frequency or relaxation time in an electret.	49
3.2	Schematic of a corona discharge to form electrets.	52
3.3	A custom-made setup of a corona discharge station: (a) a 3D model, and (b) real view of the corona discharge station used to make electrets.	53
3.4	Illustrations of early electret-based generators (a) two oppositely polarized electrets (b) single negatively charged electret.	55
3.5	Some non-resonant electrostatic energy harvesters in the literature using: (a) linear microball bearing (Naruse et al. 2009), (b) miniaturized ball bearing (Nakano et al. 2015), (c) freestanding plate (Bu et al. 2013b), (d) encapsulated conductive liquid (Boland et al. 2005), (e) conductive droplet and (f) water sloshing phenomenon of non-conductive liquid (Bu et al. 2013a).	56
3.6	Schematic of electret-based microgenerators.	58
3.7	An electret-based microgenerator is generally equivalent to a variable capacitor in series with a constant voltage source. The effect of parasitic capacitances induced by external harvesting circuits and the fringe capacitance of the microgenerator itself is lumped into C_{par} connected in parallel with the microgenerator to refine the theoretical model. . . .	60
3.8	Details of a 2D FEM model to compute the capacitance of a microgenerator under a translational vibration: (a) definition of a unit cell, (b) materials used in the FEM simulation and (c) boundary condition setup.	62
3.9	FEM capacitance results of (a) capacitance of the microgenerator in (Bartsch et al. 2009) under a constant speed rotation, and (b) the microgenerator in (Tsutsumino, Suzuki, Kasagi, Kashiwagi & Morizawa 2006) under a translational excitation resemble sinusoidal functions. . . .	63

3.10	Under a rotational excitation, a microgenerator is equivalent to a squared-signal voltage source in series with a constant internal resistance. Parasitic capacitances induced by external harvesting circuitry and the generator itself are lumped into C_p to refine the model for a more accurate prediction of output voltage and power.	67
3.11	The output power of the analytical model is in good agreement with the simulated results and experimental data at various values of parasitic capacitances (a) 15 pF (b) 37 pF and (c) 97 pF.	70
3.12	The output voltage generated from the microgenerator shows a good match between the analytical model, simulated results and experimental data at different values of load resistors (a) 50 M Ω and (b) 200 M Ω . Parasitic capacitance used in the analytical model and simulation is 69 pF.	71
4.1	The sinusoidal variation of overlapping area can be well approximated by a parabolic function.	75
4.2	A cross-wafer microgenerator is modeled as a saw-tooth voltage source V_{oc} in series with an internal resistance R_i . Parasitic capacitance C_p is included to refine the model for practical microgenerators.	78
4.3	The effective power of the microgenerator predicted by the analytical model and the simulation at four different frequencies: (a) 5 Hz, (b) 10 Hz, (c) 15 Hz and (d) 20 Hz. C_p is evaluated as 2.27 pF.	81
4.4	The output voltage of the microgenerator predicted by the analytical model and the simulation under two different loads: (a) 10 M Ω and (b) 500 M Ω at 20 Hz excitation. The shapes of the calculated and simulated signals are different due to the approximation of instantaneous overlapping area from a sinusoid to a parabolic function.	82

4.5	Theoretical overlapping area is non-differentiable when the counter electrode crosses origin, while the FEM overlapping area derived from C_{FEM} is a smooth curve. This factor attributes to the sharp peaks observed in the analytical output voltage presented in Figure 4.4.	83
4.6	Various thicknesses of the electret and surface potentials corresponding to the dielectric strength are used to calculate the output power of the microgenerator. Owing to the limitation of internal breakdown effect, reducing the thickness of electret does not always improve the output power.	84
4.7	Breakdown voltage of air at atmospheric pressure. Data is taken from (Husain & Nema 1982).	85
4.8	Various air gap distances and their corresponding Paschen's breakdown voltage are used to calculate the output power of the microgenerator. By including the effect of voltage breakdown, reducing g does not always result in a better performance.	86
4.9	The variation of the minimum FEM capacitance C_{min} is insignificant (less than 0.15 pF) for various values of effective gap spacing $d/\epsilon_d + g$	88
4.10	Output power generated by the electret-based microgenerator is plotted with respect to electret thickness d , air gap g and electret surface potential V_0 under a 2 mm peak-to-peak excitation at $f = 20$ Hz. Due to the Paschen's breakdown voltage presented as the transparent blue surface on the left and dielectric breakdown voltage presented as the transparent green surface on the right, a smaller d and g do not result in the highest output power. In this case, the maximum power is determined as $61.7 \mu\text{W}$ when $d = 6.5 \mu\text{m}$, $g = 143 \mu\text{m}$ and $V_0 = 1000$ V and $R_L = 765 \text{ M}\Omega$	89
5.1	Schematic of an electret-based cross-wafer microgenerator.	92

5.2	Instantaneous overlapping area $A(t)$ is a triangle wave with respect to the displacement $x(t)$	92
5.3	Instantaneous overlapping area is represented by a piecewise function which is analogous to a sinusoidal function folded into $(k - 1)$ segments between 0 and 1 in the y-axis.	94
5.4	Illustration of different time intervals corresponding to different electrodynamic responses of the electret-based microgenerator.	96
5.5	Under a sinusoidal excitation with angular frequency ω , an electret-based microgenerator can be modeled as (a) a voltage source in series with an internal resistance, or (b) a current source, depending on the analyzed time interval. Lumped parasitic capacitance C_p is added to refine the model for an accurate prediction.	100
5.6	An illustration of the superscript n which corresponds to the time interval $[t_n, t_{n+1}]$ when $k = 2$. The indexes k and $(k + 1)$ are excluded from the analysis.	102
5.7	Output powers generated from the microgenerator using the analytical model are in good agreement with the simulation under various excitation amplitudes and air gap distances. The left figures are for $k = 2$, while the right ones are for $k = 3$. The air gap values from top row to bottom row are respectively 100, 150 and 200 μm	110
5.8	The calculated output voltage using the analytical model shows an adequate fit to the numerical simulation under two different excitation amplitudes, (a) $k = 2$ and (b) $k = 3$, with the same load resistance $R_L = 100 \text{ M}\Omega$ and the same air gap distance $g = 200 \mu\text{m}$. The discrepancy is due to the approximation from sinusoidal functions to parabolic functions and the linearization presented in Section 5.1.	111

5.9	The non-differentiation of theoretical overlapping area highlighted in circles attributes to the discrepancy of sharp peaks in the analytical model comparing with smooth curve in the numerical simulation. . . .	112
B.1	The electret-based microgenerator proposed employs the sloshing phenomenon of a conductive liquid to vary the system capacitance for power generation, (a) stationary condition, and the sloshing conditions, including (b) non-contact and (c) in contact with the electret.	130
B.2	Illustration of different scenarios where the liquid is filled with (a) less than half of the container, and (b) more than or equal to half of the container.	133
B.3	FEM capacitances of the liquid based microgenerator under a 2.5-cm peak-to-peak vibration at 5 Hz with a 1 and 10 μm thick electrets made from Teflon PTFE.	134
B.4	The Matlab Simulink-based model of the liquid-sloshing microgenerator with 100 V per-charged electret under 2.5 cm peak-to-peak vibration at 5 Hz.	136
B.5	Time average output power of the liquid microgenerator with 1- μm thick PTFE electret with and without the effect of parasitic capacitances induced by external harvesting circuitry.	136
B.6	(a) Output voltage of the liquid-based microgenerator with 5 pF parasitic capacitance at $R_L = 10 \text{ M}\Omega$, and (b) FEM capacitance variation in the time domain is similar to a parabolic wave, leading to a similar output voltage signal presented in Chapter 4.	137
B.7	A prototype of the liquid-based microgenerator, (a) a PMDS housing is bonded with a copper substrate, and (b) the completed assembly of the prototype.	138

B.8 The liquid-based prototype using Gallium as the conductive liquid can generate up to 1.6 V peak-to-peak voltage when being hand-shaken. . . 139

List of Tables

1.1	Four essential ambient energy sources that can be harvested (Mikeka & Arai 2011).	2
1.2	Solar power density measurements taken under various conditions. Data is taken from Roundy et al. (2003a) .	5
1.3	Seebeck coefficient of most metals ($\mu\text{V}/\text{m}$) at 300 K. Data source is from (Da Rosa 2012).	8
1.4	Acceleration and frequency of common mechanical vibration sources in daily life (Lee et al. 2009 , Aktakka et al. 2011 , Romero et al. 2009).	9
1.5	Comparison of strengths and weaknesses between some widely-used energy harvesting technologies.	10
2.1	Comparison of three common structural models used to convert mechanical vibrations to electricity.	28
2.2	Specification of some common piezoelectric materials.	32
2.3	Comparison of recent small scale piezoelectric generators.	33
2.4	Properties of fine copper wire from American Wire Gauge standard.	36
2.5	Properties of some common materials to make permanent magnets used in MEMS applications presented in (Arnold & Wang 2009).	37
2.6	Comparison of recent small scale electromagnetic generators.	38
2.7	Comparison of recent small scale electrostatic generators.	44
2.8	Comparison between common transduction mechanisms used in vibration energy harvesting.	45
3.1	Properties of wellknown electret materials in the literature.	50
3.2	The parameters of the device published in (Bartsch et al. 2009).	69

4.1	Analytical model of electret-based microgenerators under rotational and sinusoidal motions.	79
4.2	Parameters used to compare the analytical model and simulation	82
5.1	Example of range of m and the number of segments expressed the overlapping area $A(t)$ with different values of k	94
5.2	Parameters of the device presented in (Tsutsumino, Suzuki, Kasagi & Sakane 2006) are used to validate the analytical model.	108
5.3	Lumped capacitances used in the analytical calculation and FEM capacitances used in the numerical simulation under different air gap distances and k , units are in μm for air gap g and pF for capacitances. .	109