DESIGN AND CHARACTERIZATION ON PIEZOELECTRIC CANTILEVER AS A SELF-POWERED ACCELEROMETER

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MASTER OF SCIENCE IN ELECTRONIC ENGINEERING

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A thesis submitted
in fulfilment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "Design and Characterization on Piezoelectric Cantilever as a Self-Powered Accelerometer" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature : ....

Supervisor Name : ....

Date : ....

ABSTRACT

Piezoelectric cantilever working on direct piezoelectric effect has shown promising applications as a sensor as well as a micro-power generator depending on the amount of stress that is applied on the piezoelectric material at different range of frequencies. In this research, a self-powered accelerometer that consists of a wide-band energy harvesting power generator, a low operating frequency device acceleration sensor, and a signal conditioning circuit is designed. Piezoelectric cantilevers are being used in this research as a sensor to measure the vibration acceleration level and at the same time as a generator to power up the amplifier circuit. This research includes characterize the frequency response of the piezoelectric cantilever by altering its effective mass and length, design the self-powered accelerometer system, and lastly verify the output of the self-powered system with battery powered system. The result shows that increasing the effective mass of the cantilever can reduce the resonant frequency of the cantilever, while reducing the effective length of the cantilever would increase the resonant frequency. The designed self-powered accelerometer is able to operate at broadened operating frequency range of 180-310 Hz with acceleration level of not lower than 0.8-g and is able to produce linear output with a sensitivity of 231.28mV/g-level. The piezoelectric generator is able to produced constant voltage output of 1.8V and power output not less than 80µW at operating condition. While for the sensor, signal is successfully amplified at a factor of 3.2 with error deviation less than 15%. The overall result is verified and shows good agreement of 5% error with conventional battery powered accelerometer system and compatible with standard vibration source.

ABSTRAK

Piezoelektrik julur telah menunjukkan potensi yang memberangsangkan dalam aplikasi sebagai penderia dan penjana kuasa-mikro bergantung kepada jumlah tegangan yang dikenakan ke atasnya. Kajian ini melibatkan reka bentuk satu sistem terbekal diri yang terdiri daripada penjana kuasa berjalur lebar, penderia untuk mengukur magnitude getaran yang berfungsi pada frequensi rendah, dan penguat yang menguatkan isyarat penderia. kekerapan operasi yang rendah sensor pecutan peranti dan litar penyesuaian isyarat direka. Piezoelektrik julur digunakan sebagai penderia untuk mengukur magnitude getaran dan pada masa yang sama sebagai penjana kuasa dengan menggunakan sumber getaran yang sama. Kajian ini termasuk pencirian tindak balas piezoelektrik julur dengan mengubah jisim pemberat and panjang julur, mereka bentuk sistem terbekal diri yang mengukur magnitude getaran, dan akhir sekali mengesahkan output sistem terbekal diri tersebut dengan sistem bateri.. Hasil kajian menunjukkan peningkatan jisim julur boleh mengurangkan frekuensi salunannya, manakala mengurangkan panjang julur akan meningkatkan frekuensi salunannya. Sistem yang direka berupaya untuk beroperasi pada frekuensi 180-310 Hz dengan magnitude getaran tidak kurang daripada 0.8-g dan mampu menghasilkan output linear dengan kepekaan 231.28mV/g. Penjana kuasanya mampu menghasilkan voltan 1.8V dan kuasa tidak kurang daripada 80μW. Manakala, isyarat yang dihasilkan oleh penderia berjaya dikuatkan pada faktor 3.2 dengan ralat tidak melebihi 15%. Keputusan keseluruhan telah disahkan dan menunjukkan hasil yang baik iaitu degan ralat tidak melebihi 5% apabila dibandingkan dengan sistem sedia ada yang beroperasi menggunakan bateri.

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LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
MEMS	Micro-Electro-Mechanical-System
AC	Alternating Current
CS	Small Sized Cantilever (Q220-A4-103YB)
CM	Medium Sized Cantilever (Q220-A4-203YB)
CL	Large Sized Cantilever (Q220-A4-303YB)
CL1	Additional Large Sized Cantilever 1
CL2	Additional Large Sized Cantilever 2
CL3	Additional Large Sized Cantilever 3
CL1p	CL1 with Proof Mass Attached (0.15g)
CL2p	CL2 with Proof Mass Attached (0.50g)
CL3p	CL3 with Proof Mass Attached (1.00 g)
CC	Large Sized Cantilever that Act as Constant Cantilever
CLa	Large Sized Cantilever that Act as Accelerometer
DC	Direct Current
LTC3588-1	Nanopower Energy Harvesting Power Supply
PVDF	Polyvinylidenedifluoride
PZT	Lead Zirconium Titanite
RF	Radio Frequency
SFM	Scanning Force Microscopy

SiO_2	Silicon Dioxide
ZnO	Zinc Oxide

LIST OF SYMBOLS

SYMBOL	UNIT	DESCRIPTION
δ	m	Distance from Neutral Axis to the Centroid of Piezoelectric Layer
d	dimensionless	Piezoelectric Constant Matrix
D	C/m^2	Electric Displacement
ε^T	F/m	Permittivity Matrix at Constant Stress
E	N/m	Elastic Modulus for Electrode Layer
E_f	N/C	Electric Field
f_n	Hz	Natural Frequency
f_{new}	Hz	New Resonant Frequency
h_b	m	Total Thickness of the Beam
I	m^4	Area moment of Inertia
k_{eq}	N/m	Equivalent Stiffness
k_{new}	N/m	New Stiffness of the Beam
l_b	m	Length of the Beam
l_{new}	m	New Effective Length of the Beam
m_b	Kg	Total Beam Mass
m_{eq}	Kg	Effective Mass
m'_{eq}	Kg	Total Mass of Beam with Proof Mass

		Included
ρ_b	Kg/m^3	Density of the Beam
P	N	Force at that Particular Point
s^E	m^2/N	Matrix of Compliance Coefficients at Constant Electric Field Strength
S	dimensionless	Strain
t	dimensionless	Transposition of a Matrix
T	N/m^2	Stress
w_b	m	Width of the Beam
ω_n	Hz	Angular Natural Frequency

LIST OF PUBLICATIONS

JOURNAL

[1] Bong, Y.J. and Kok, S.L., 2015.Characterization on Piezoelectric Cantilever for Its Linear Response at Low Frequency for Measuring Acceleration Level of Vibration. *Applied Mechanics and Materials*, 761, pp.579-583.

CONFERENCE PROCEEDINGS

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