Piezoelectric Energy Harvester for Electrochromic Glass

THE UNIVERSITY OF SYDNEY

Daniel Miller *Supervisor: Dr. Dylan Lu*

School of Electrical and Information Engineering

FACULTY OF ENGINEERING & INFORMATION TECHNOLOGIES

Objectives

To design a piezoelectric energy harvester to power electrochromic glass. The aim is to:

- Rectify the alternating voltage output of an oscillating piezoelectric bluff body without the use of a diode bridge circuit.
- Regulate the output voltage so that is capable of powering electrochromic glass.
- Track the maximum power point (MPP) of the piezoelectric bluff body for maximum output power .

Introduction

Electrochromic glass

- This is a form of glass which becomes opaque when a DC voltage of 1-5V is applied.
- It is a good alternative to window shades or blinds and can lower the need for artificial cooling in buildings by 26% [1].
- Connecting every glass window in a building to the main power supply is difficult and costly.

Piezoelectric bluff body - A locally harvested energy solution

- This is a low maintenance piezoelectric wind energy harvester to supply power for electrochromic glass developed by The University of Sydney [2].
- The bluff body consists of attached to the end of a piezoelectric bimorph.
- Wind passing the cantilever causes it to oscillate. The vibrations misshape the piezoelectric bimorph resulting in an AC voltage output.

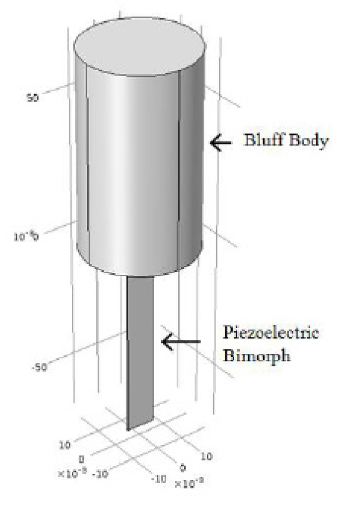

Fig. 1 Piezoelectric bluff body [2]

Existing work in piezoelectric generators

- Piezoelectric energy harvesting has recently grown in popularity. Innowattech, an Israeli company, is currently placing piezoelectric generators under roads and railways. The company wishes to harvest energy as moving cars and trains compress the piezoelectric material.
- Optimizing the mechanical-electrical coupling of the material and the circuit has been studied [3].This includes the addition of interface circuitry between the piezoelectric bimorph and the power converter.
- Research [4], [5] has attempted to lower the power losses that occur in a traditional rectifying circuit. The new converter removes the diode bridge which experiences conducting and switching losses across the diodes.

A bridgeless rectifying power converter

- The circuit removes the need of a diode bridge by altering the polarity of the voltage across the load according to the input voltage.

Principle of operation

- During the positive half cycle, **Mode A**, the first switch is closed and the converter acts as a boost converter. Switch two is controlled by pulse width modulation.
- **Mode A.i**: Switch two is closed with the inductor being current pumped by the power supply. The output is supplied by energy stored across the capacitor.
- **Mode A.ii**: Switch two is open and the inductor discharges and supplies power to the load.

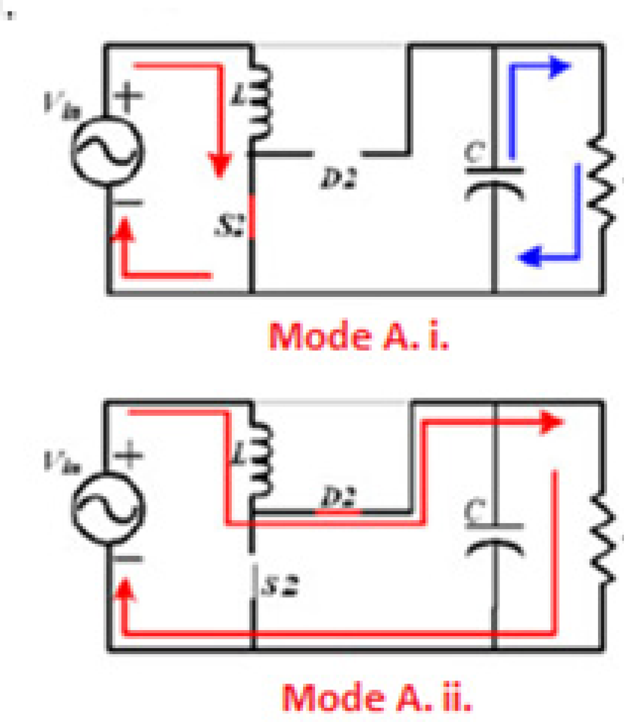

Fig. 2 Bridgeless converter in boost mode [5]

- During the negative half cycle, **Mode B**, the second diode is blocked causing the circuit to acts a buck-boost converter. This inverts the polarity across the load.
- **Mode B.i.**: The inductor is charged while the capacitor supplies power to the load.
- **Mode B,ii**: The inductor supplied a current to the load and charges the capacitor.

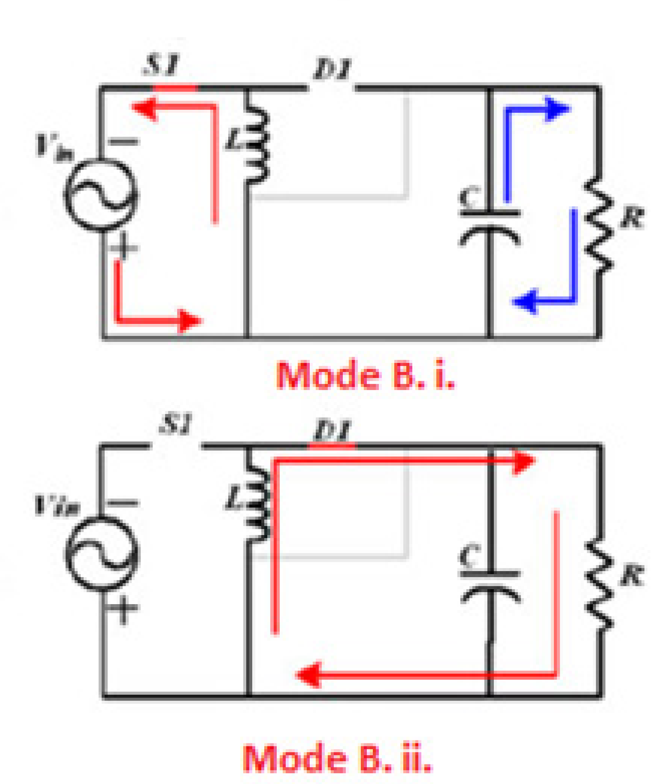

Fig. 3 Converter in buck-boost mode [5]

Maximum power point tracking for piezoelectric material

- The maximum power point occurs at half the open circuit voltage [6].
- The maximum power point can be tracked using the fractional voltage technique. The output voltage is regulated at the maximum power point voltage V_{mpp}. This voltage is a function of the open circuit voltage, V_{OC}. In this case k is equal to 0.5.

Experimental Results

Testing the operation of bridgeless rectifying circuit.

- The circuit was digitally controlled using a *Atmega32u4* microcontroller on a *Freetronics LeoStick* board. A 30 Hz input, similar to the piezoelectric output in [2], was applied using a function generator. The amplitude was varied and the converter successfully regulated a 3V DC output from different inputs ranging from 1 to 3 V_{RMS}.

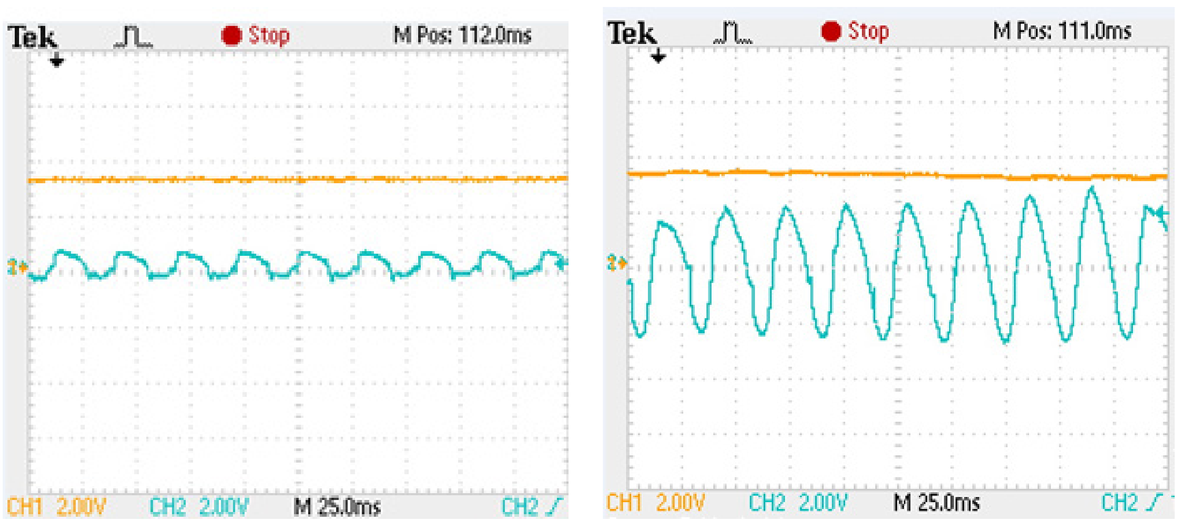

Fig.4 AC input and regulated 3V output

- The power losses in circuit exceeded the peak power of $40.72\ \mu W$ supplied by the PZT5H piezoelectric bimorph. Despite these losses the MPP was verified to occur at half the 3.12 V_{RMS} open circuit voltage.

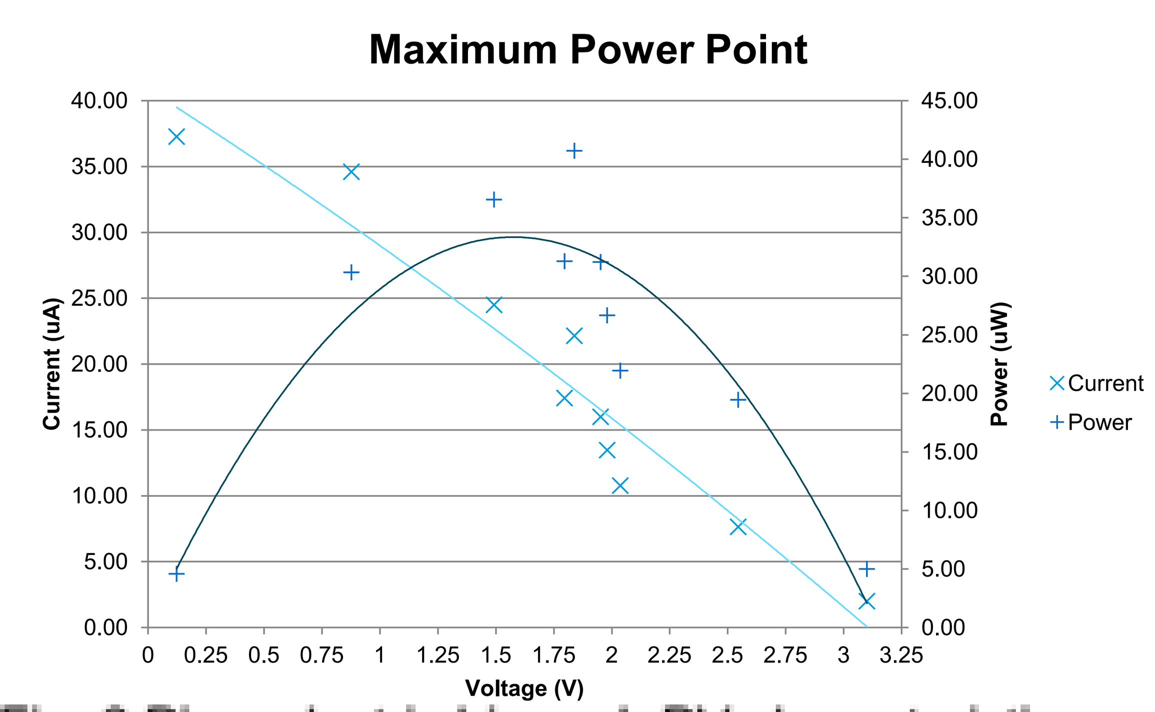

Fig. 6 Piezoelectric bimorph PV characteristics

Conclusion

This project proposes a method of harvesting energy from a piezoelectric bluff body to power electrochromic glass. For a larger power supply, the bridgeless rectifying circuit could regulate a $3V\ DC$ voltage fit to supply power to a electrochromic glass window. Unfortunately,