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Study on Methods of Voltage Up-Converter for Energy-Harvesting Dynamo
エネルギーハーベスト用発電機構の電圧昇圧法の基礎研究

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1. Introduction

Together with world-wide increase in ecology movements, energy harvesting techniques have also become very popular. They are already used in large-scale energy recovery systems such as electric trains and hybrid vehicles, and middle-scale systems such as HEMS (Home Energy Management Systems). Electric trains and hybrid vehicles use their motors as dynamos when reducing velocities or braking, which provides high total-energy performances. Besides such large- and middle-scale industrial and home energy saving trends, energy harvesting from our living environment has also been a remarkable movement in recent years. Electric power generation from vibrations of objects in our living environment and temperature differences of human bodies and so on are very hot topics in recent ecology studies. However the generation power is from 100 μW to several mW, because piezoelectric materials such as PZT, PVDF, etc. have been used to convert vibration energy to electric energy. In general, piezoelectric materials provide high voltages but current drivability is extremely low, which results in low generation power.

We have proposed a new energy harvesting device which uses a concept of magnetic dynamo aiming at handy electric gadgets. The dynamo structure is published as the other paper in this Symposium. The power density of magnetic dynamos is larger than other generators. However, generated voltages are low compared with other technologies, because a magnetic dynamo has only inductive coils whose resistive parts are very small. The dynamo acts as a low impedance voltage generator. So, voltage up-conversion techniques are very important. In this paper, first we examine two kinds of diodes, PN-junction diodes and Schottky barrier diode. From the experimental results, an up-conversion circuit with diodes can't be used to our purposes. We have proposed a new up-converter structure using mechanical switches which synchronize swing or rotation of weight.

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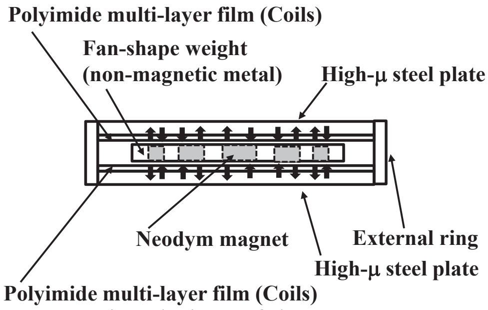
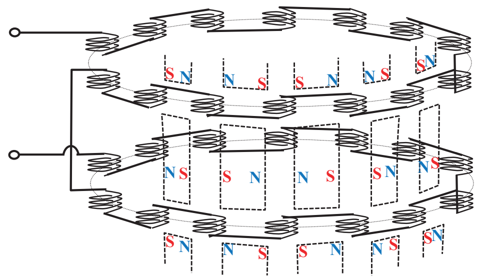


(a) Cross sectional view of dynamo.



(b) Equivalent circuit of dynamo.
Fig. 1 Proposed energy-harvesting dynamo.

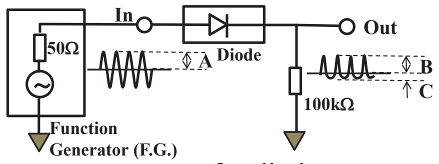
2. Dynamo configuration and wiring between coils

Illustration of our proposed energy harvesting dynamo is in the other paper in this Symposium. Assembled form is shown in Fig. 1(a). Neodym magnets are buried in non-magnetic fan-shape weight to provide magnetic flux to upper and lower high-μ steel plates through many coils. Due to mirror effect imaginary magnets with opposite polarities are produced in high-μ steel plates. As an equivalent circuit including wiring between coils is shown in Fig. 1(b), each coil is sandwiched by upper and lower magnets. All coils are connected in series to provide output voltage as high as possible. If the fan-shape weight swings or rotates, magnetic flux going through the coils changes, which generates output voltages.

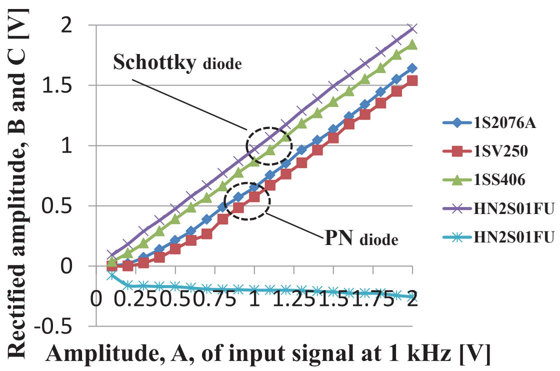
3. Characteristics of diodes and Cockcroft up-converter

Diodes are usually used to rectify AC signals to obtain DC voltages. Shottky-barrier diodes have low threshold voltages, so they might meet our requirement of low voltage operations. We measure rectification characteristics of two Schottky diodes and also two PN-junction diodes in comparison. Measurement set-up is shown in Fig. 2(a). The lowest threshold voltage is about 0.2 V, while that of PN diode is 0.4 V.

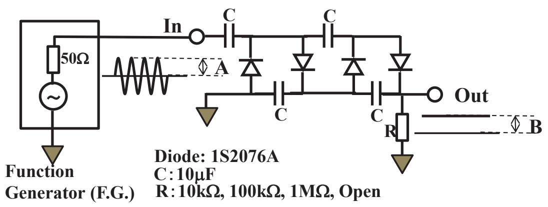
Cockcroft Walton up-converter is known to produce 4 times amplitude of input AC signal in ideal case. We measure its characteristics using four diodes as shown in Fig. 3(a). Voltages of 2.7-3.5 times amplitude of AC signal are obtained. Levels of voltages are strongly depend on load resistances.



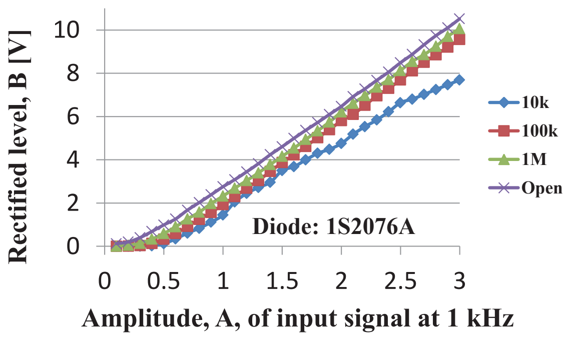
(a) Measurement set-up for diodes



(b) Input amplitude vs rectified amplitude
Fig. 2 Rectification characteristics for Schottky-barrier and PN-junction diodes.



(a) Cockcroft Walton voltage up-converter circuit.



(b) Up-conversion by Cockcroft Walton circuit.
Fig. 3 Investigated voltage up-converter circuits.

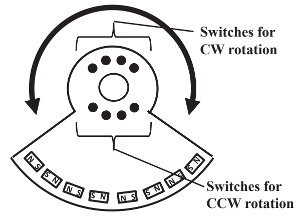
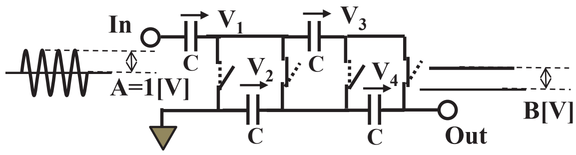
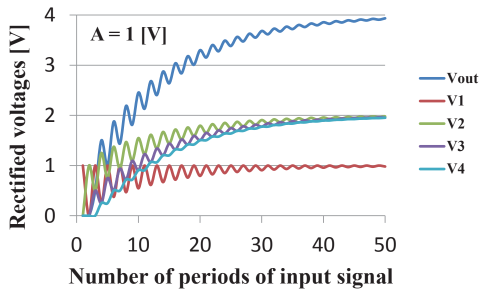


Fig. 4 Fan-shape weight with mechanical switches.



(a) Simulation model for mechanical-switch-type Cockcroft Walton voltage up-converter.



(b) Up-converted voltages at each stage.
Fig. 5 Simulation of Cockcroft Walton voltage up-converter with mechanical switches.

4. Voltage up-conversion with synchronous mechanical switches

Fig. 3(b) shows that the diode-type rectifier can't be used. Fig. 4's fan-shape weight with mechanical switches has been investigated. Two types of mechanical switches are included. One operates synchronizing to clockwise rotation of the weight, while the other counterclockwise. We simulate rectification characteristics introducing the new switches to Cockcroft Walton voltage up-converter shown in Fig. 5(a). Ideal up-conversion with zero-threshold voltage are obtained as shown in Fig. 5(b).

5. Conclusion

We have investigated a new up-conversion method to apply the energy harvesting dynamo. Simulation results show that mechanical-switch-type Cockcroft Walton voltage up-converter is very promising for our purposes.

Reference

1. T. Haremaki and M. Hikita, in Proc. of Symp. on Ultrason. Electron. Vol.34, pp.129-130, 2013.