51. IWK

Internationales Wissenschaftliches Kolloquium

International Scientific Colloquium

PROCEEDINGS

11-15 September 2006

FACULTY OF ELECTRICAL ENGINEERING AND INFORMATION SCIENCE

INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING - DEVICES AND SYSTEMS, MATERIALS AND TECHNOLOGIES FOR THE FUTURE

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=12391

TECHNISCHE UNIVERSITÄT
ILMENAU

Impressum

Herausgeber: Der Rektor der Technischen Universität Ilmenau
Univ.-Prof. Dr. rer. nat. habil. Peter Scharff

Redaktion: Referat Marketing und Studentische Angelegenheiten
Andrea Schneider

Fakultät für Elektrotechnik und Informationstechnik
Susanne Jakob
Dipl.-Ing. Helge Drumm

Redaktionsschluss: 07. Juli 2006

Technische Realisierung (CD-Rom-Ausgabe):
Institut für Medientechnik an der TU Ilmenau
Dipl.-Ing. Christian Weigel
Dipl.-Ing. Marco Albrecht
Dipl.-Ing. Helge Drumm

Technische Realisierung (Online-Ausgabe):
Universitätsbibliothek Ilmenau
ilmedia
Postfach 10 05 65
98684 Ilmenau

Verlag: isle
Verlag ISLE, Betriebsstätte des ISLE e.V.
Werner-von-Siemens-Str. 16
98693 Ilrnenau

ISBN (Druckausgabe): 3-938843-15-2
ISBN (CD-Rom-Ausgabe): 3-938843-16-0

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=12391

51st Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
September 11 – 15, 2006

H. Toepfer, M. Sachs, S. Hollatz, G. Taubmann, St. Taubmann, N. Zeike,
Ch. Schaeffel

Electromechanical Design and Performance of a Power Supply for Energy-Autonomous Electronic Control Units

ABSTRACT

Contemporary wireless technologies such as RFID or personal area networks with a low power consumption, respectively, enable the set-up of distributed systems which can be widely used in fields like sensorics, logistics, remote monitoring, or surveillance. True remote operation is achieved once the power supply is realized in a self-contained manner. The common and trivial approach of using batteries turns out to be quite detrimental with respect to decentralization on a larger scale as the number of batteries would increase accordingly, leading to a prohibitive level of maintenance and costs. The approach presented in this paper attempts to convert environmental energy into electrical energy in order to power electronic control units consisting of a low-power microcontroller. In the contribution, the design of a converter for supplying a self-supporting electronic control unit under consideration of heavy-duty practical applications is described. Furthermore, results of a practical evaluation will be given and discussed.

INTRODUCTION

Self-supporting power supply for electronic control units requires energy conversion from other physical domains. Frequently, the movement of mechanical parts via the electrodynamic principle [1] or the piezoelectric effect [2] are employed. In miniaturized set-ups, the change of a capacitance under the exertion of mechanical forces can also be used [3]. Other approaches utilize temperature gradients (via the Peltier effect [4]), or even nuclear dynamos [5].

For our work, the existence of an oscillatory translational movement within the system has been assumed. On this basis, the conditions for generating the power supply for a state-of- the -art electronic unit which is supposed to operate remotely have been considered. For the operation principle under consideration, the feasibility has been shown theoretically by means of electromagnetic analyses [6]. Following the guidelines resulting from this study, a series of practical devices have been built and successfully brought into operation. The paper is organized as follows: after a description of the converter unit, its internal electrical characteristics are described. Finally, results of the operation both under laboratory conditions and from a field-test are presented.

MECHANICAL DESIGN OF THE ELECTROMECHANICAL POWER CONVERTER UNIT

As a direct consequence of our previous design studies [6], the electrodynamic principle has been implemented using a fixed coil and a moving permanent magnet. The movement is supposed to be back and forth with no further restrictions. In order to ensure flexibility and versatility, no special pre-requisites such as a harmonic oscillation with a given frequency were taken into account in the design considerations. The main body of the set-up consists of a hollow cylinder made of magnetically well-conducting material. A magnetic pellet (NdFeB) is attached to its inside surface. Another part of the same shape serves as flux conductor. Thus, a shielded magnetic circuit is formed. The magnetic flux density within the air gap is designed to be considerably high. The aforementioned constructive elements are suspended in between two solid joints. The entire set-up acts as a system of parallel springs with affixed to the bottom and the top of the arrangement, respectively. The coil is located at the inner side of the top lid. Adjacent to it, the movable magnetic part is placed in such a manner that the coil will fit into it. The mechanical construction is shown in Fig. 1.

Due to its inertia, external oscillations cause the magnet to move relative to the coil. This leads to a temporary change of the magnetic flux and – by Faraday's Law – to the induction of a voltage in the coil. The use of electromagnetic CAD tools was of essential influence on the mechanical design. This determined, in particular, the choice of materials and the design of the air gap section. Fig. 2 shows the distribution of the magnetic field in the converter structure.

An array of four such units is shown in Fig. 3. They were used in the experiments described in the following sections.

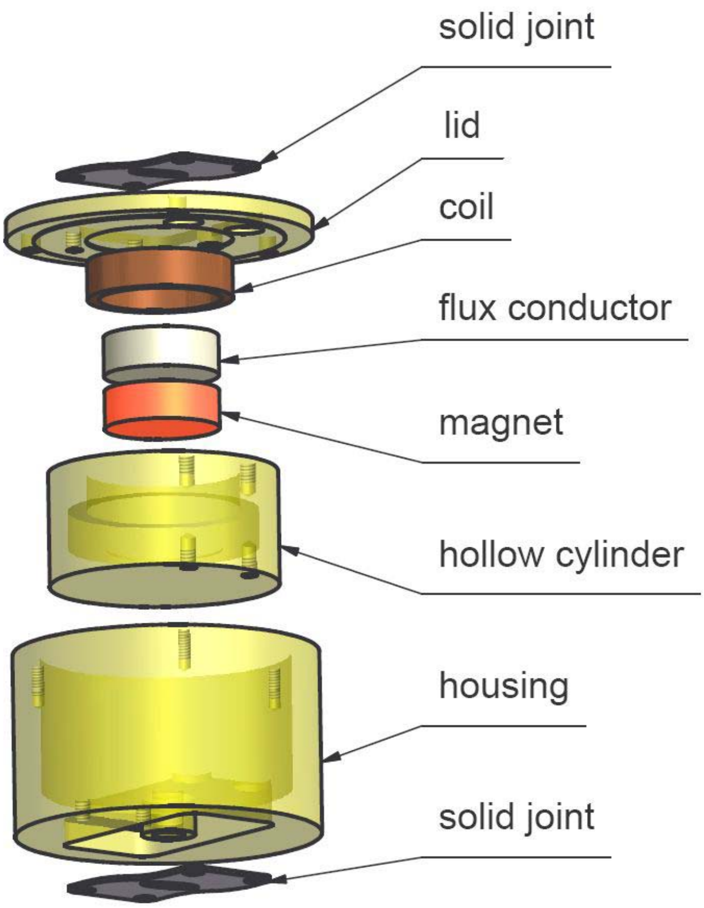

Fig. 1: Schematic of the electromechanical power conversion unit.

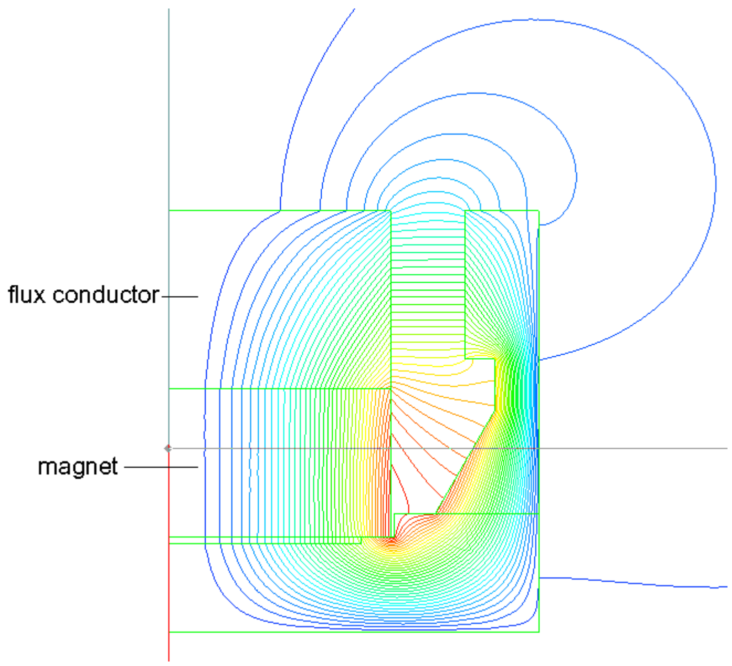

Fig. 2: Plot of the magnetic field distribution inside the structure.

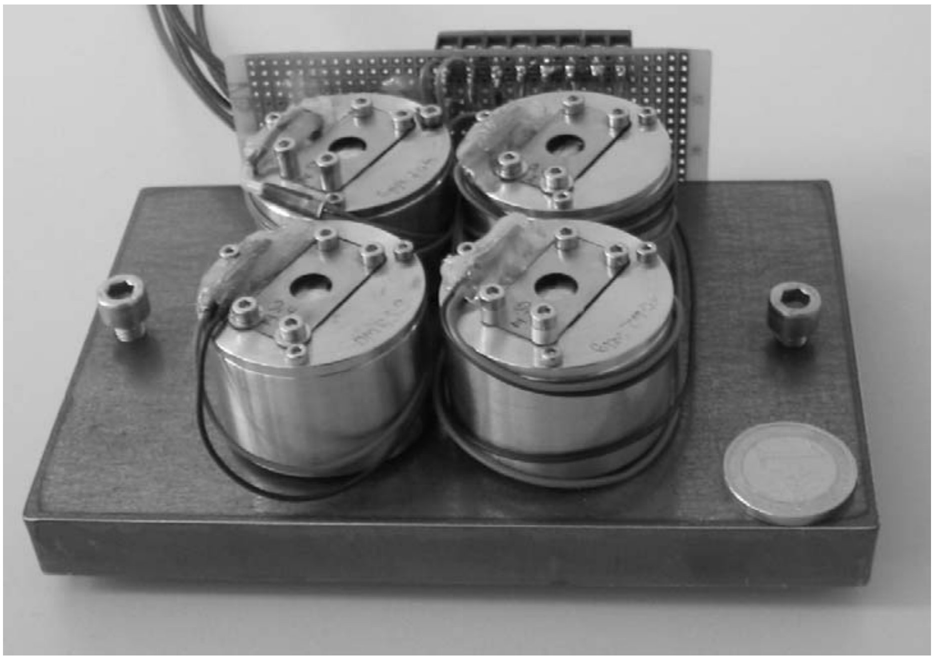

Fig. 3: Practical realization of the electromechanical power conversion unit . For comparison, a 1-Euro coin indicates the size of the set-up.

ELECTRICAL CHARACTERIZATION OF THE POWER CONVERTER

As the power converter is intented to be operated as a mechanically-driven power supply for electronic circuits, its internal characteristics as a source are of interest. The internal resistance as well as the power supplied by the converter in dependence on the current load have been measured. In the experiment, the converter was mounted on a vibrating stage controlled by a MATLAB/Simulink framework running on a personal computer. Fig. 4 shows the results for a sinusoidal excitation with a frequency of 50Hz. From the results it can be inferred that there is a good linearity in the *I-V*-curve with an internal resistance of approximately 84 Ω.

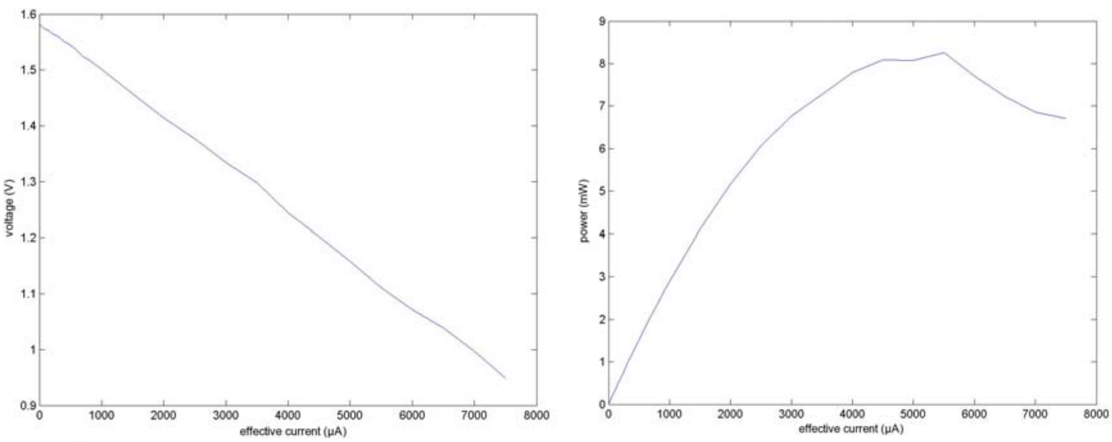

Fig. 4: *I-V* characteristics (left) and supplied power (right) of the electromechanical converter. The excitation consisted in a 50Hz vibration.

EXPERIMENTAL PERFORMANCE

The theoretical predictions of [6] have been validated through practical tests. In the laboratory, the converter was again mounted on the vibrating stage as described above. A typical experimental waveform without a load is shown in Fig. 5. Together with the information about deliverable power, there are good prospects that after rectification, the voltage will also be sufficiently high in real applications. This holds especially for contemporary microcontrollers with very modest requirements, such as e.g. the TI MSP430 [7] operating at a voltage of 1.6V or higher and requiring only about 250µA per MIPS.

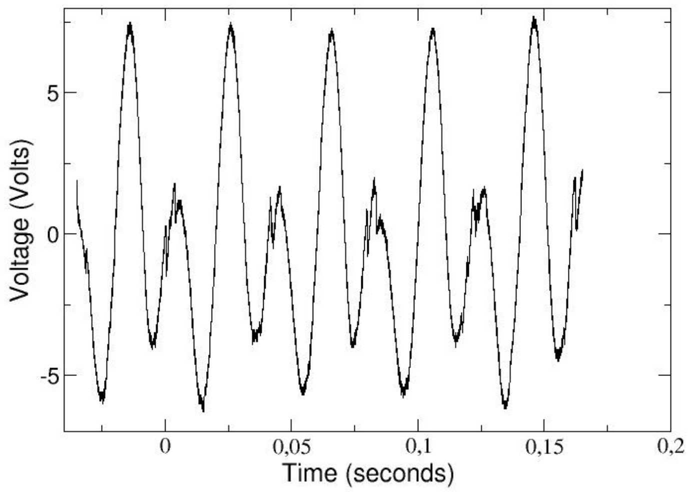

Fig. 5: Voltage vs. time for a typical electromechanical converter in a laboratory experiment. The excitation consisted in a 50Hz vibration. The measurements were made using a LeCroy wave surfer 424 sampling oscilloscope.

After these initial considerations and tests, the converter was tested in an industrial environment. It was mounted onto a steel bar, heavily vibrating in a pulsed manner. The analysis of the frequency spectrum revealed a rich content of components well above 100Hz and above 1000Hz, respectively. This leads to higher voltage peaks during the movement. Fig. 6 shows the measured voltage waveform. In this experiment, a Tektronix TDS 3034B sampling oscilloscope was used.

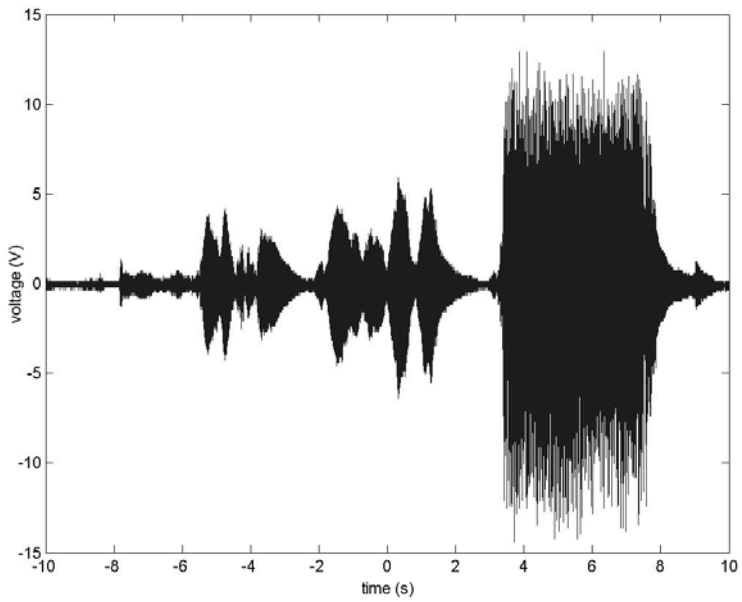

Fig. 6: Voltage vs. time for a typical electromechanical converter in a field test. The excitation consisted in a series of bursts.

CONCLUSION

Based on theoretical considerations, a practical converter has been designed and realized practically. Its operation is based on energy conversion from the mechanical domain to the electrical one. Practical tests have shown a good response even to an arbitrary and complex waveform signal. This promises a wide range of practical applications of the converter. A first prospective utilization of the device in quality assurance of processes in harsh industrial environments aims at reducing costs caused by damage-prone power-supply cables.

References:

[1] E.Philippow: Taschenbuch der Elektrotechnik, Akademische Verlagsgesellschaft Geest & Portig K.-G., Leipzig, 1976

[2] T.T. Lie, J. Han, A. v. Jouanne, K. Mayaram, T.S. Fiez: Piezoelectric Micro-Power Generation Interface Circuits, IEEE Journal of Solid-State Circuits, 41(2006)6, pp. 1411—1420.

[3] B.C. Yen, J.H.Lang: A Variable-Capacitance Vibration-to-Electric Energy Harvester, IEEE Transactions on Circuits and Systems – I: Regular papers, 53(2006)2, pp. 288 – 295.

[4] G. Mierdel: Elektrophysik, Verlag Technik Berlin, 1972

[5] A. Lal, J. Blanchard. The Daintiest Dynamos, IEEE Spectrum, September 2004, pp. 22 – 27

[6] Ch. Knoth, H.Toepfer, Electromechanical Issues of Powering Energy-Autonomous Electronic Control Units, Proc. 50th Internationales Wissenschaftliches Kolloquium, Technical University of Ilmenau 2005, pp. 215-216

[7] www.ti.com/msp430

Authors:

PD Dr.-Ing. habil. Hannes Töpfer, Dipl.-Ing. Martin Sachs, Dipl.-Ing. Sebastian Hollatz
Institut für Mikroelektronik- und Mechatronik-Systeme (IMMS) gGmbH
System Design Department
Ehrenbergstraße 27
D-98693 Ilmenau
Germany
Phone: +49 (0)3677 69 55 40
Fax: +49 (0)3677 69 55 15
E-mail: hannes.toepfer@imms.de, martin.sachs@imms.de, sebastian.hollatz@imms.de

Dipl.-Ing. Georg Taubmann, Dipl.-Ing. Steffen Taubmann
A&Z Automatisierungs- und Zeitsysteme
Industriering Nr. 3 / Parkweg 6
D-98708 Gehren
Germany
Phone: +49 (0)367 83 88 30
Fax: +49 (0)367 83 8 83 44
E-mail: g.taubmann@az-gehren.de, st.taubmann@az-gehren.de

Dipl.-Ing. Norbert Zeike, Dr.-Ing. Christoph Schäffel
Institut für Mikroelektronik- und Mechatronik-Systeme (IMMS) gGmbH
Mechatronics Department
Ehrenbergstraße 27
D-98693 Ilmenau
Germany
Phone: +49 (0)3677 69 55 60
Fax: +49 (0)3677 69 55 15
E-mail: christoph.schaeffel@imms.de, norbert.zeike@imms.de