Theme A: Power Electronics for Energy Harvesting

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The Bristol team have developed a number of power management prototypes for electromagnetic energy harvesters. These rectify and boost the harvester's low, alternating output voltage. The circuits maximise the power to the load, by accurately matching their input to the output impedance of the harvester. The circuits are self-starting and entirely autonomous, only requiring the variable power from the harvester. The quiescent power consumption is low, typically 44 µW at $2V_{DC}$ output, which permits the miniaturisation of the mechanical harvester to around 150 µW. Low-power maximum power point tracking control (Fig. 1) has been implemented, which transfers up to 69% of the energy harvester's maximum extractable power to the supercapacitor at 2V output, dropping down to 57% at 4.5V. The achieved conversion efficiency is 75-80%.

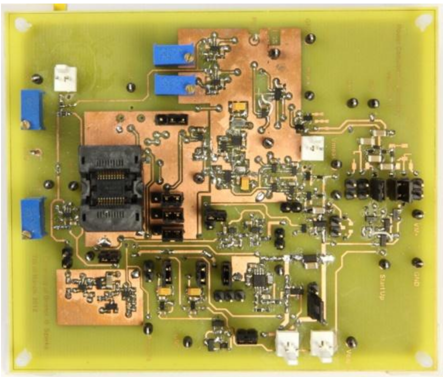

Fig. 1: Self-powered, zero energy start-up, adaptive power electronics for energy harvesting

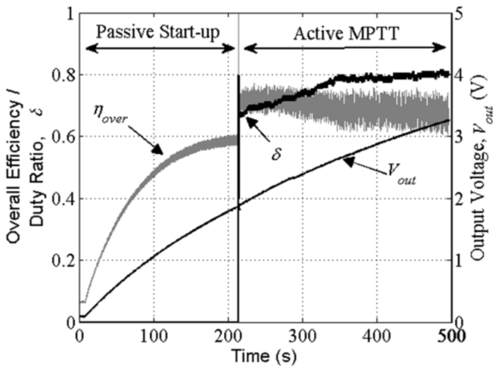

Fig. 2: Zero energy start-up, optimisation of the control parameter (δ) and efficiency (η) as the output voltage increases

Maximum power is extracted from a harvester because the power electronic circuitry emulates an optimum resistive load on its input. The required optimal load varies with the frequency of the vibration. The actual emulated load is a function of the output and input voltages. Here, a low-power model-based feed-forward control has been developed, that, as shown in Fig 3, extracts close to the maximum theoretical power that can be extracted with a resistive load. In order to design, prototype and test the circuits, specialised hardware and software (Fig. 4) are used. The equipment allows for low-power, low-current, high-frequency data acquisition for long periods of time as well as the rapid prototyping of control circuits.

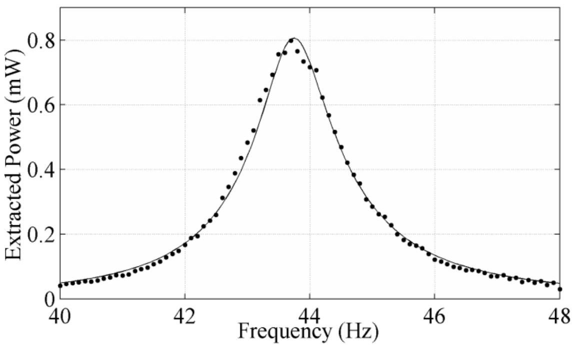

Fig. 3: Measured generated power (•) compared to the theoretical maximum power (–) extracted by resistive loa

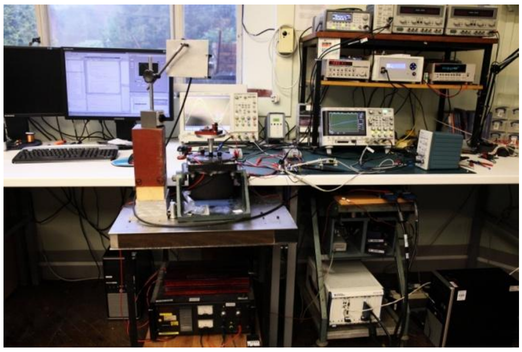

Fig. 4: Equipment used for testing and design of energy harvesting power electronics

Publications

see http://www.holistic.ecs.soton.ac.uk/publications.php

G. D. Szarka, S. G. Burrow, P. P. Proynov, B. H. Stark, “Maximum Power Transfer Tracking for Ultra-Low-Power Electromagnetic Energy Harvesters”, IEEE Transactions on Power Electronics, 2013.

G. D. Szarka, S. G. Burrow, B. H. Stark, “Ultra-Low Power, Fully-Autonomous Boost Rectifier for Electromagnetic Energy Harvesters”, IEEE Transactions on Power Electronics, Vol. 28/7, 2013.

P. P. Proynov, G. D. Szarka, J. N. McNeill, and B. H. Stark, “Switched-capacitor power sensing in low-power energy harvesting systems”, IET Electronics Letters, Jan 2013.

G. D. Szarka, B. H. Stark, S. G. Burrow, “Review of Power Conditioning for Kinetic Energy Harvesting Systems,” Vol.27, Iss.2, pp.803-815, IEEE Transactions on Power Electronics, 2012.

P. P. Proynov, B. H. Stark, J. N. McNeill, and G. D. Szarka, “Constant impedance emulation using non-synchronous boost rectifier for energy harvesting”, APEC 2013.

G. D. Szarka, B. H. Stark, S. G. Burrow, P.P. Proynov, “Comparison of Low-Power Single-Stage Boost Rectifiers for Sub-Milliwatt Electromagnetic Energy Harvesters”, SPIE Microtechnologies 2013, Grenoble.

G. D. Szarka, P.P. Proynov, B. H. Stark, S. G. Burrow, “Microwatt Maximum Power Transfer Tracking Digital Control Circuit for a Full-Wave Boost Rectifier for Efficient Power Extraction”, PowerMEMS 2012, Atlanta. Won best student paper award.

P. P. Proynov, G. D. Szarka, B. H. Stark, and J. N. McNeill, “The Effect of Switching Frequency, Duty Ratio, and Dead Times on a Synchronous Boost Rectifier for Low Power Electromagnetic Energy Harvesters”, APEC 2012.

G. D. Szarka, P. Proynov, B. H. Stark, S. G. Burrow, N. McNeill, “Experimental Investigation of Inductorless, Single-Stage Boost Rectification for sub mW Electromagnetic Energy Harvesters,” International Symposium on Low Power Electronics and Design ISLPED, pp.361-366, Fukuoka, August, 2011.

Other Resources, News and Events

see www.holistic.ecs.soton.ac.uk/resources.php

Video: Power Conversion for Future Energy Harvesters - Dr Bernard Stark from University of Bristol talks about the key functionalities of energy harvesting power electronics and explains the challenges that face the design process of power conversion circuits for energy harvesting.

Our paper ‘Microwatt maximum power transfer tracking digital control circuit for a full-wave boost rectifier for efficient power extraction’ presented at PowerMEMS 2012 received Best Student Paper Award.