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MULTIDOF WIRELESS SENSOR SYSTEM BASED ON IMU-MEMS TECHNOLOGY SUPPORTED BY ENERGY HARVESTING METHODS

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ABSTRACT

The aim of this work was to provide power for small electronic devices called wireless sensor by use of the ambient energy. The purpose was to determine which types of harvesting would be able to supply with wireless capability. Power consumption characteristics of the multi-sensors system have been obtained experimentally. The result of these tests led to successful application of thermoelectrical generator (TEG) and magnetic harvester for supplying Inertial Mass Unit- IMU - MEMS sensor matrix. Solar panel was also tested, however obtained power was not sufficient to supply the microprocessor.

Keywords: Energy harvesting, wireless sensor, MEMS

INTRODUCTION

Taking into account the huge development of MEMS technology due to the usage of this kind of sensors in everyday use devices, especially in mobile phones and portable equipment, the whole group of new solutions were introduced, including harvesting applications. Applying MEMS technology made using those devices more comfortable and allowed to manage power usage in a given device due to the fact that, e.g. the device changed its working position. This leads to the hypothesis that in MEMS sensor, power supply can be supported with the usage of an ambient energy – energy harvesting (energy scavenging).

The goal of this paper was the performance analysis of the types of devices using this kind of power supplying, a relatively new but fast growing field of science. There are many types of energy harvesting depending on energy source: light, wind, water, vibrations, impact, temperature difference, body movements (kinetic energy) e.g. breathing and many others. The paper was divided into following sections: Thermal, Optical and Magnetic harvesting. Such division of the topics have brought the focus on applications and have forced the presented form of an electronic system.

In order to investigate power supply possibilities of the different types of harvesters, real life device was chosen as a model. This led to the practical use of harvesting as a power supply for a chosen device, but also for other devices, even for 32bit microcontroller (Kaleta 2010). The results were promising, it was possible to supply the processor with the power generated by the energy harvesting device (multi-node harvesting structure).

CONSTRUCTION OF A MULTIDOF WIRELESS SYSTEM

Multi-node harvesting structure can be used in SHM applications to recover an electric power from the wasted energy generated for e.g. vibrations. Our latest system presents this solution. It consist 14 MEMS sensors which designated 14 degrees of freedom (DOF):

- 3D accelerometer Ax, Ay, Az,
- 3D gyroscope: Qx, Qy, Qz,
- 3D magnetometer: Hx, Hy, Hz,
- barometric pressure,
- microphone,
- temperature T,
- humidity R,
- light intensity.

Figure 1. shows the structure of a wireless harvesting system with a 14 DOF block representing 14 MEMS sensors that stands for 14 DOF listed above.

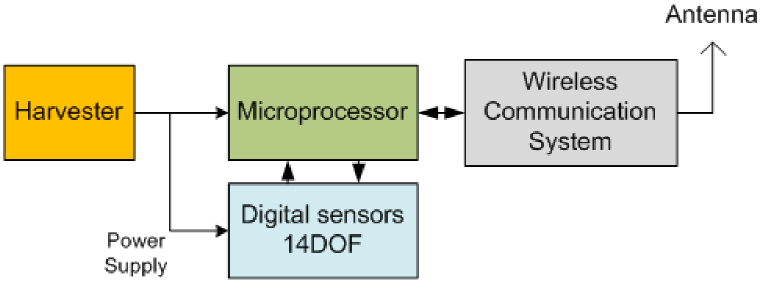

Figure 1. The structure of a wireless harvesting system with a 14 DOF block.

In order to process data received from the 14 DOF sensors, the proper microprocessors had to be chosen, taking into account the power consumption of each system elements. Tab. 1 represents the set of devices used for further tests. What is more not only measuring the certain physical value by the 14 MEMS, but also monitoring the level of recovered energy is very important.

Tab. 1. Microprocessor platforms used in tested harvesting systems and their power consumption.

	Supply voltage	Architecture	Current consumption /1 [MHz]	Clock	Performance	Company
Family line	[V]	[bit]	[µA]	[MHz]		
AVR XMEGA	1.6 - 3.6	8	260 [µA] @ 1.8 [V]	32	32 MIPS	ATMEL
MSP430	2.5 - 5.5	16	330 [µA] @ 3 [V]	5	8 MIPS	TEXAS INSTRUMENTS
PIC24F16	1.8 - 3.6	16	180 [µA] @ 1.8 [V]	32	16 MIPS	MICROCHIP
STM32L15x	1.65 - 3.6	32	233 [µA]	32	33.3 DMIPS	ST ELECTRONICS
EFM32	1.85 - 3.8	32	180 [µA]	48	60 DMIPS	ENERGY MICRO
AVR32UC3L	1.62 - 3.6	32	260 [µA]	50	64 DMIPS	ATMEL

REPLACEMENT BATTERY BY ENERGY HARVESTING METHODS

To supply the nodes consisting DOF sensors and chosen microprocessors, different combinations of harvesters and batteries were discussed. The development of the miniature networks of solid-state harvesters with a magnetic core, miniature termogenerators TEG and supercapacitors built into the structure, resulted in the need to develop an integrated network system for harvesting management for the "low power" applications.

Fig. 2. shows four different types of harvesters depending on the kind of ambient energy that supplies the system, together with their power requirements.

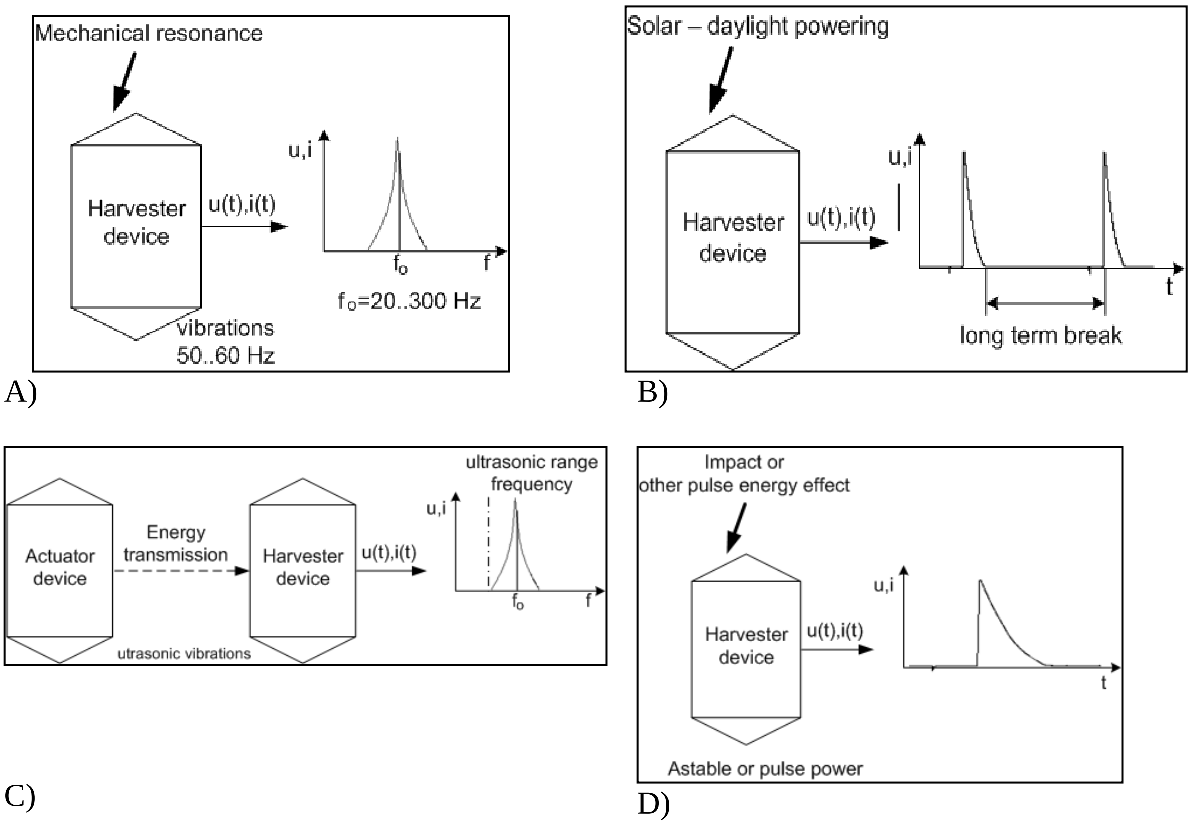

Fig. 2. Energy Harvesting sources and their power requirements – supplying via: A) low frequency mechanical resonance, B) daylight- solar, C) energy transmition, D) mechanical impact.

Due to the specified energy type that supplies the harvester, different extra battery configurations were needed. That is why in harvesters listed above:

- the battery is needed because of the narrow range of mechanical resonance. Small changes can affect the level of recovered energy – Fig. 2A,
- the battery is necessary to maintain the system which is powered by a source with intermittent operation– Fig. 2B,
- in the energy transmission systems, battery is not required, provided that the emitted energy was properly selected– Fig. 2C,

- extra battery is not needed. The system sends information at the moment when maximum energy is recovered– Fig. 2D.

After matching the sensor-microprocessor configuration with a suitable energy harvester, the whole packets, together with a wireless communication system were placed in the nodes, one of which is shown in the Fig. 3. Due to the fact that every node is equipped with the same wireless communication system, different types of sensors can be easily switched or put together by the user thanks to the dedicated software (shown in Fig. 4).

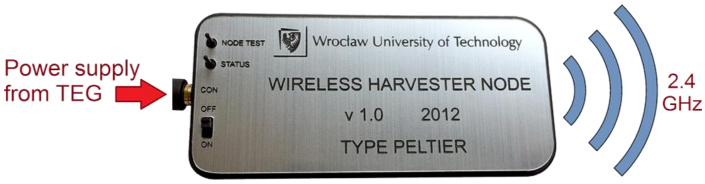

Fig. 3. Example of a Wireless Harvester Node consisting of a DOF sensor, suitable energy harvesting system and wireless communication system.

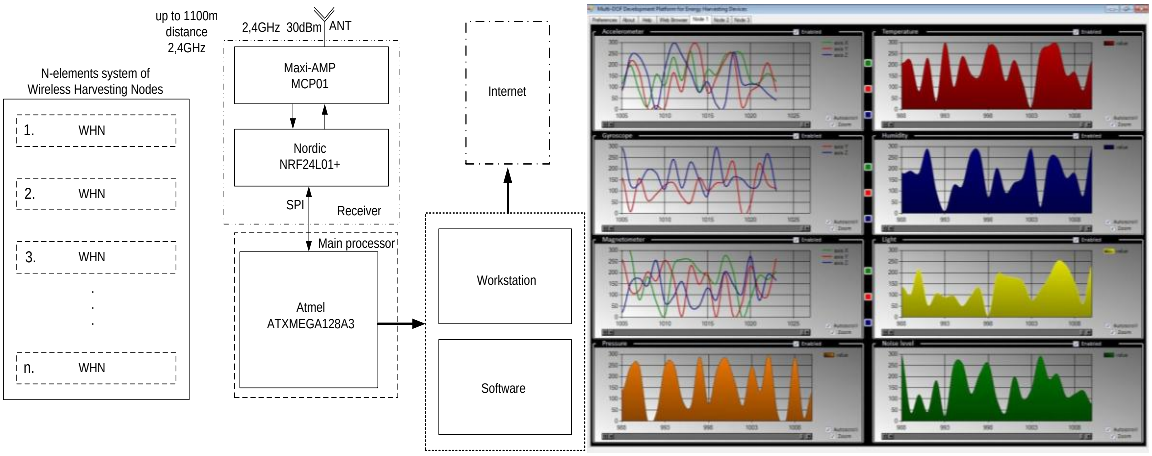

Fig. 4. Receiving part of the MultiDOF wireless sensor platform: main Rx-Tx station and the MultiDOF software.

RESULTS AND CONCLUSIONS

Properly selected conditioning circuit provides the harvesting system with a certain current and voltage output. The creation of a wireless node, to measure certain physical quantities and to monitor the level of recovered energy, requires selection of an appropriate hardware platform such as a microprocessor and wireless transmission system. Fig. 5 represents the scheme of a wireless IMU-MEMS sensor.

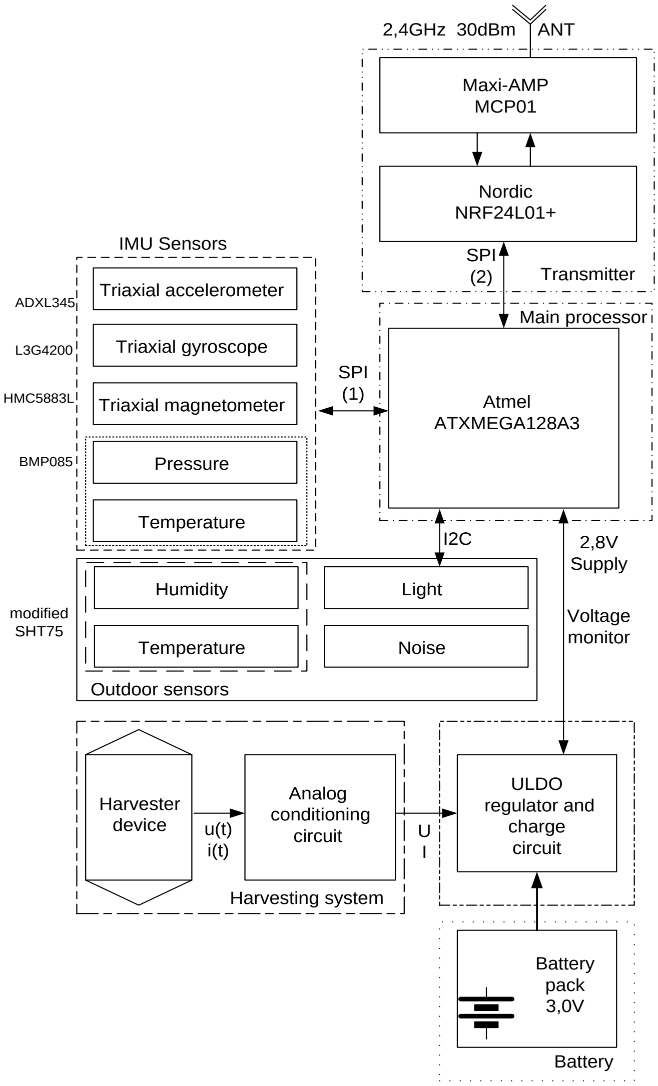

Fig. 5. IMU-MEMS wireless sensor.

System integrator of wireless harvesting nodes operations:

- one receiver allows operation of the programmed number of harvesting nodes,
- data is acquired by the management software from the receiver,
- receiver may be also used as a web server.

Software allows to monitor the parameters provided by 14 sensors via web page, or in service mode. The software is designed to support systems with the ADIS16488 module and the most precise IMU iMEMS modules (Analog Devices2012).

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