3D PRINTED MINIATURE WATER TURBINE WITH INTEGRATED DISCRETE ELECTRONIC ELEMENTS FOR ENERGY HARVESTING AND WATER FLOW MEASUREMENT

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Abstract An energy harvester fabricated by inkjet 3D printing and utilizing miniature water flow turbine with integrated mechanical and electrical components is shown. Flexibility of 3D printing design enables integration of electronic component with mechanical turbine and building of smaller and less complicated harvester than reported in literature. Turbine (ED 25.4 mm (1") and 14 mm long) is able to generate maximum 4 mW for 14 L/min of water flow and gives 0.7 V output voltage for optimal loading resistance (RL=55Ω). The harvester itself may be used as a self-suppling water-flow, zero-energetic sensor in the distributed nets of water consumption measurement.

1. Water turbine energy harvester
The proposed here harvester is based on a concept of multiphase electrical rotating generator. Almost similar concept have been presented in positions [1, 2] but our solution is based on the process of 3D printing of parts of the harvester (fig. 1). In our previous work we showed that 3D printing is enable to produce fine microstructures as a microfluidics chips with details dimensions down to 200 um [3] and with embedded actuation microstructure as in case of check microvalve [4]. Also utilized techniq can be used for preparing a biological structures as a reactors for carbon dioxide generation [5] or electrophoretic DNA separation [6].

Figure 1. 3D printed harvester: a) schematic view, b) assembled device.
The device is 8-times smaller than presented in [1] and three times smaller in comparison to [2], but density of power generated by the harvester is almost at the same level. Harvester has also two times lower “starting” water flow, 1.4 L/min in comparison to 3 L/min as reported in [1]. The harvester (fig. 1) is designed to fit geometry and dimensions of typical ½” water pipe connectors (fig. 5b). It is printed by Projet 3510 printer (3D System, USA) with Visijet M3 Crystal build material and S300 support material. Electric part of the presented device contains nine small neodymium magnets (1x3x5 mm³, magnets.eu, Poland) and 9 SMD 10 mH small (5x5x4 mm³) inductor coils (Viking NL20JT103, Taiwan).

2. Integration of electronic components
In the first version of the harvester outputs of each SMD inductors are connected with rectifiers (CS20D Graetz bridge, Diotec semiconductors, Germany). Development of application-specific mechanical components by 3D printing enables integration of inductors with smaller straight electronics elements (BAT54A, double Schotky diode, NEXPERIA, Taiwan). Conductive paths are made by magnetron sputtering of cuprum (1.2 um thick) with resistance of 0.5 Ω/cm (fig. 3). Integration of electronic components and conductive paths lead to decrease of ED from 42 mm to 25.4 mm (1”).

![Figure 2. Components of 3D printed harvester divided in two group of parts - printed (a) and non-printed (b) parts.](image1)

![Figure 3. Electronics integrations and external dimension decreasing.](image2)
3. Electrical characterisation
The harvester has good electrical parameters (fig. 4). Maximal generated power of almost 4 mW for 14 L/min of water flow is achieved for 55 Ω loading resistor (fig. 4d). Output signal waveform can be combined in 3-phase power circuit (fig. 4 a, b, c) for more effective electrical power generation. The level of the harvested energy (~4 mW) seems to be high enough to supply low-power electronic components, including wireless communication modules.

![Figure 4. Electrical characteristics of the harvester: a) in phase inductors circuit, b) antiphase inductors circuit, c) signal for next 3 coils, d) generated power as function of loading resistance, e) frequency vs flow output signal, f) generated power as function of water flow.](image)

4. Modular system
Thanks to 3D printing technique it was possible to produce modular and easy to adapt systems. It is possible to design and print modular turbines that are connected each to other to generated more power (fig. 5a). Also other components including energy management circuit, wireless communication or sensors (e. g. temperature sensors, conductivity sensors, pH sensor, MEMS microphone) can be easily mounted in 3D printing housing designed to specific sensor requirements. In developed by us system steering electronics with microprocessor (MKL05Z32VFK4), power management circuit (BQ22504RGTT) and radio communication (NRF24L01) was placed in one of the modules (fig. 5d) and connected to turbine(s).

![Figure 5. Modular system for water flow: a) modules (computer visualization), b) realization for ½” standard connectors – disconnected components, c) three turbines module, c) scheme of electronics system architecture.](image)
5. Conclusion

Low-cost power supply of distributed network system for water control and consumption measure is an important problem. Traditional powering from on-grid network is very expensive and trouble full. One of the solution is generation of energy directly from water flow with rotating water turbine. Generated in this way power can be used for system powering and also it is possible to correlate frequency of generated electricity with water flow rate. In this paper, design, system configuration and fabrication of 3D printed harvester (with embedded stainless steel bearings and electrical components) was presented. 3D Printing is recognized as technology than can change the world [7] and it was confirmed thatinkjet 3D printing can be use as simple method for fabrication a complex self-powering device. Results of energy harvesting were showed. It is finally concluded that after optimisation of the mechanical and electrical construction the proposed energy harvester it can be used for flow measurement and power supplying of low-power distributed net of sensors (temperature, humidity, conductometer etc.) for water consumption and pollution recognition in the near future. Thus a first generation of 3D printed milimechatronic device is here proposed.

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