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Slime mould electronic oscillators

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ABSTRACT

We construct electronic oscillator from acellular slime mould *Physarum polycephalum*. The slime mould oscillator is made of two electrodes connected by a protoplasmic tube of the living slime mould. A protoplasmic tube has an average resistance of 3 MOhm. The tube's resistance is changing over time due to peristaltic contractile activity of the tube. The resistance of the protoplasmic tube oscillates with average period of 73 s and average amplitude of 0.6 MOhm. We present experimental laboratory results on dynamics of Physarum oscillator under direct current voltage up to 15 V and speculate that slime mould *P. polycephalum* can be employed as a living electrical oscillator in biological and hybrid circuits.

1. Introduction

"A device without an oscillator either doesn't do anything or expects to be driven by something else (which probably contains an oscillator)."

Horowitz and Hill, The Art of Electronics, 1980.

The plasmodium of *Physarum polycephalum* (Order *Physarales*, class *Myxomecetes*, subclass *Myxogastromycetidae*) is a single cell, visible with the naked eye, with many diploid nuclei. The plasmodium feeds on bacteria and microscopic food particles by endocytosis. When placed in an environment with distributed sources of nutrients the plasmodium forms a network of protoplasmic tubes connecting the food sources. The topology of the plasmodium's protoplasmic network optimises the plasmodium's harvesting of nutrient resource from the scattered sources of nutrients and makes more efficient the transport of intra- cellular components [20]. In [3] we have shown how to construct specialised and general purpose massively-parallel amorphous computers from the plasmodium (slime mould) of *P. polycephalum* that are capable of solving problems of computational geometry, graph-theory and logic. Plasmodium's foraging behaviour can be interpreted as a computation [20–22]: data are represented by spatial of attractants and repellents, and results are represented by structure of protoplasmic network [3]. Plasmodium can solve computational problems with natural parallelism, e.g. related to shortest path [21] and hierarchies of planar proximity graphs [1], computation of plane tessellations [23], execution of logical computing schemes [26,2], and natural implementation of spatial logic and process algebra [24].

In the framework of our "Physarum Chip" EU project [4] we aim to experimentally implement a working prototype of a Physarum based general purpose computer. This computer will combine self-growing computing circuits made of a living slime mould with conventional electronic components. Data and control inputs to the Physarum Chip will be implemented via chemical, mechanical and optical means. Aiming to develop a component base of future Physarum computers we designed Physarum tactile sensor [5] and undertook foundational studies towards fabrication of slime mould chemical sensors (Physarum nose) [9,27], Physarum memristive devices [11] and insulated Physarum wires [7].

A future Physarum Chip will be a hybrid living-electronic computing device. Being a bio-electronic device the chip will need components to generate waveforms and a clock, the source of regularly spaced pulses, implemented as oscillators. We experimentally demonstrate that it is possible to implement an electronic oscillator — a device which converts direct current to alternating current signal — with living slime *P. polycephalum*. Experimental setup is outlined in Section 2. Section 3 presents experimental results on Physarum resistance oscillations, input to output potential transfer function and current dynamics in Physarum oscillators. Advantages and limitations of living Physarum oscillators are discussed in Section 4.

2. Materials and methods

A scheme of experimental setup is shown in Fig. 1. Two blobs of agar 2 ml each (Fig. 1b) were placed on electrodes (Fig. 1c) stuck to a bottom of a plastic Petri dish (9 cm). Distance between proximal

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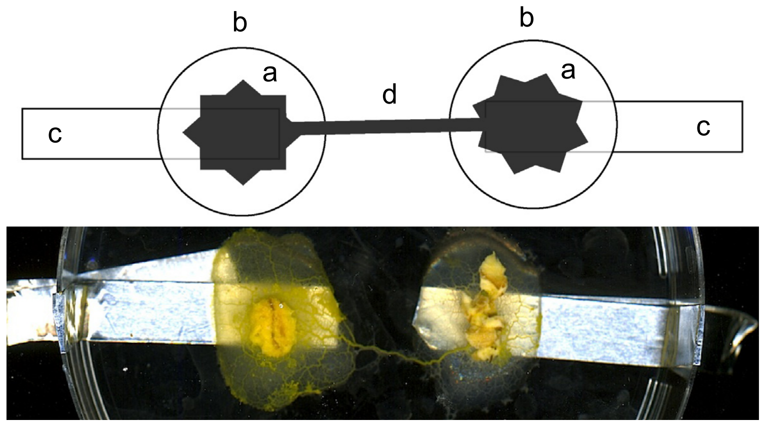

Fig. 1. Top: A scheme of experimental setup. (a) Physarum, (b) agar blobs, (c) electrodes, (d) protoplasmic tube. All parts of Physarum shown in dark grey form a single cell. Bottom: A snapshot of agar blobs occupied by Physarum and connected by a protoplasmic tube.

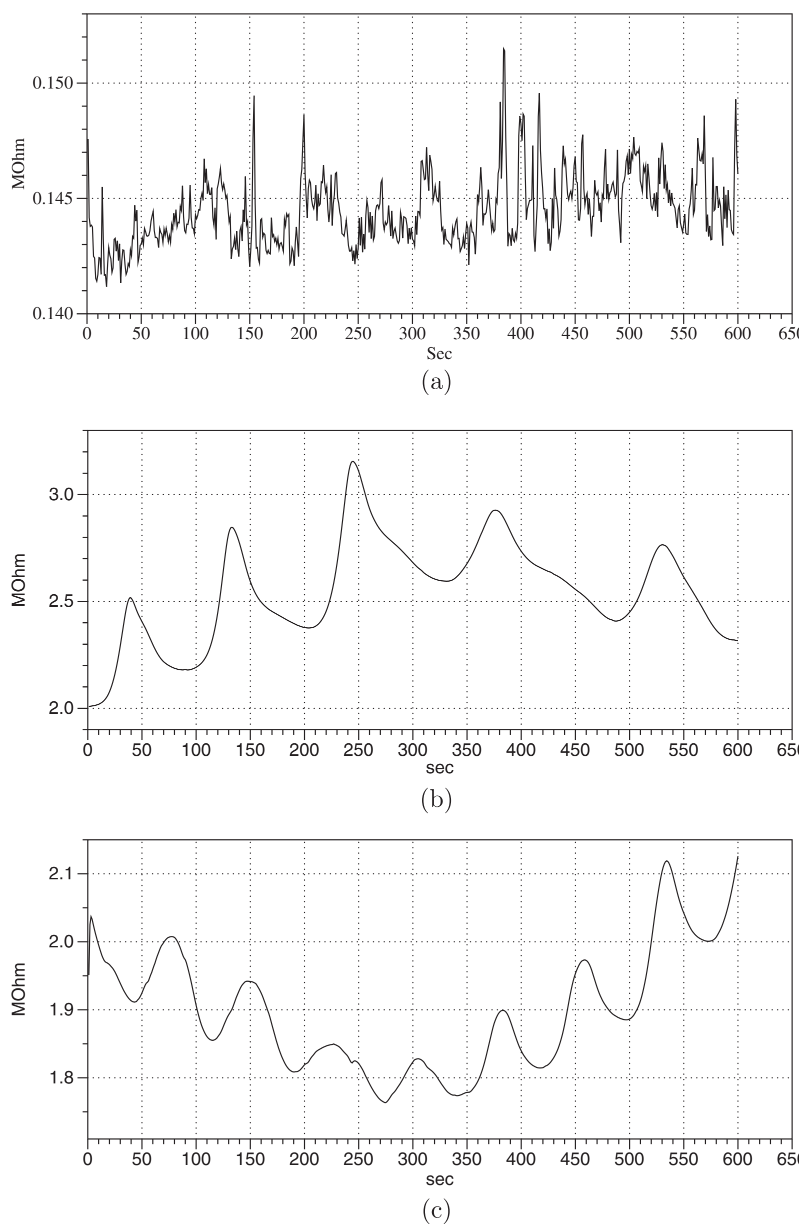

Fig. 2. Resistance of (a) of agar blobs, colonised by Physarum, blobs are connected with each other by a silver wire, (bc) agar blobs, occupied by Physarum, blobs are connected with each other by a protoplasmic tube. The resistance is recorded during 10 min. Vertical axis is resistance in MOhm, and horizontal axis is time in sec.