Ultra-Low-Voltage Survival Kit

Mindaugas Gapševičius

15 August 2019

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Introduction to Posthuman Aesthetics (work in progress):
http://triple-double-u.com/introduction-to-posthuman-aesthetics/

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Design, Printing and Binding:
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Print-run: 50 (15 August 2019)

Software:
Scribus 1.4.5 Open Source, Desktop Publishing (Ghostscript-Version 8.71)

Fonts:
Carlito. Foundry: Łukasz Dziedzic.
License: SIL Open Font License v1.10

ISBN 978-609-96084-5-7

Published by:
Institutio Media

ISBN 978-609-96084-5-7

I would like to express my gratitude to Wolfgang Spahn, who has kindly agreed to collaborate on an interface that generates sounds from the human body and also in the production of the video tutorial. The project was kindly supported by the Nordic Culture Point and by the Lithuanian Council for Culture.

Introduction

Given that the human state of today is indivisible from technological achievements or, to be more precise, indivisible from a computational machine, this paper refers to the nature of the electric signal as the base for digital computation and invites the reader to experience electricity with their own bodies. To start with, the paper references two artistic projects related to the theme, suggests a conceptual framework for experiencing electricity, introduces the scientific basis for the experiments, and provides a step-by-step manual for the use of the tools for experiencing electricity. Focusing on information processing between organic and inorganic matter, the toolkit (Fig. No. 4) introduces two workshops: 1) an LED lit up by energy generated by the human body and 2) sound generated from a difference in temperature between a human and their environment. Proposing the building of simple interfaces between living organisms and machines without using a battery, the user becomes independent of the electricity supply.

Related Artistic Projects

Karl Heinz Jeron, *Fresh Music For Rotten Vegetables*[1]

The Workshop and participatory installation with DIY audio devices *Fresh Music For Rotten Vegetables* by Karl Heinz Jeron (Fig. No. 1) is about generating sounds from vegetables and fruits that are already unsellable in supermarkets for optical reasons. In the description of the project, the author wrote:

The electronic devices built by the participants are controlled and fed by current generated by use of the collected vegetables. According to the state of the vegetables, the sound, the colour of the sound, and the volume of the sound are varied. Thus, an improvised piece of music is created from the most simple parts, and a garnish. (Jeron, 2011).

The project is a direct reference to a "lemon battery," that is, a battery built from lemons. Interesting in this project is that the sound generated varies as the vegetables and fruits change state over time.

Fig. No. 1. Karl Heinz Jeron, *Fresh Music For Rotten Vegetables*. Source: http://jeron.org/

*1. http://jeron.org/fresh-music-for-rotten-vegetables/ (Accessed 5 November 2017).

Joe Davis, *Bacterial Radio*[2]

Bacterial Radio by Joe Davis (Fig. No. 2) uses a crystal radio mechanism, allowing for the capturing and conversion of AM radio waves. Besides being a radio, crystal radio evokes the idea of a living organism that is able to naturally generate electric current through interaction with its environment.

The technical description of *Bacterial Radio* reads as follows:

In spring 2011, I created a flat circuit design that could be constructed in a Petri dish. This circuit was then cast in negative relief in PDMS (polydimethylsiloxane) gel. Cells and growth media were then applied to circuit impressions in the gel. The cells used were E coli modified with a gene for silicatein, a ubiquitous protein native to many different marine organisms. These organisms use silicatein to polymerize silica from seawater in order to create glass endoskeletons and exoskeletons in a fantastic variety of forms. The silicatein gene used in the Bacterial Radio experiments was isolated from the marine sponge Tethya aurantia.

Silicatein is a promiscuous protein, so that if growth media is starved of silica and instead provided with metal salts or semiconductors, then the protein will try to polymerize those materials instead. In this way, electrical characteristics were imparted to the two respective cultures of bacteria used with Bacterial Radio. Bacteria were fixed and immobilized in the PDMS gel. Pins and wires were used to connect elements of the gel-embedded circuit to each other and to external components such as the antenna, the ground and headphones (Davis, 2012).

*2. http://prix2012.aec.at/prixwinner/7023/ (Accessed: 14 May 2016).

The *Bacterial Radio* project is compelling from different perspectives. First of all, it uses crystal radio, a radio mechanism that is able to catch and convert AM radio waves with no additional electricity supply. Secondly, Davis has introduced modified *E. coli* bacteria, which might replace traditional wires.

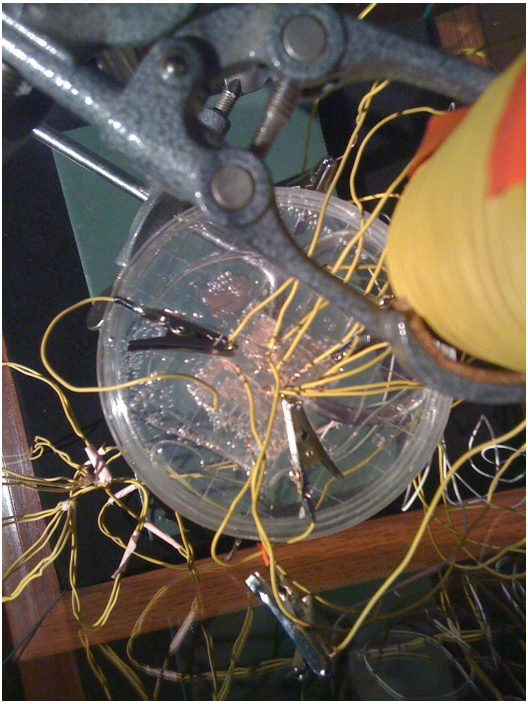

Fig. No. 2. Joe Davis, *Bacterial Radio*.
Source: https://c1.staticflickr.com

Concept

All matter has electrical properties. Given that electric signals in carbon-based organic matter and silicon-based computational machines are of the same nature, the *Ultra-Low-Voltage Survival Kit* explores the idea of generating electricity with the human body. While practically letting the user of the toolkit move subatomic particles in and out of the body, the project invites one to experience electricity. Proposing to power computational machines by one's own body, the project also suggests critical evaluation of the possibility of technology further becoming part of human bodies.

Ultra-Low Voltage and Organic Matter

Every solid, liquid, gas, and plasma is composed of neutral or ionized atoms that have differently charged subatomic particles and which, while interacting with the subatomic particles of another atom, generate electric current. The related artistic projects provided earlier in this paper trigger our imagination and invite us to think of scenarios that could bring computational machines and organisms together into a single entity. Applying features of computational machines on humans, including retinal implants and brain pacemakers, one could think of enhanced humans or, even, non-human humans. Here, critical thought provides different traditions, which could be described under one posthumanist umbrella.

In Katherine Hayles' terms, the posthuman is a state wherein the human seamlessly integrates with intelligent machines and approaches his or her body as a prosthesis. To be more precise, in Hayles' posthumanism, there are "no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals." (Hayles, 1999:2.) In such a tradition, questioning all matter as having the same electrical properties becomes crucial.

Historical Context of Electricity

Organisms can be characterized by their ability to conduct electricity, which has been known since the second half of the 18th century. Edmund Whittaker (1910) mentioned Luigi Galvani's and his assistants' experiments in the 1780s, which demonstrated convulsions in frog legs when attached to an electrical machine, and which were considered "animal electricity." A slightly different approach to electricity was presented by Alessandro Volta, who, in 1799, built his Voltaic Pile known as the first electrical battery (RSC, 2015). Described as a reaction between chemical elements, the Voltaic Pile had two electrodes of different metals placed between pads made of moist material. Such a setup made it possible to demonstrate interaction between organic and non-organic matter.

The characterization of organisms capable of electrical conductivity in reference to reactions between nerves (organic) and metals (non-organic) instead of "animal electricity" was introduced by Johann Wilhelm Ritter (Berg 2008) after a number of experiments shortly before his death in 1810.

Electric Current Generated by Organic Matter

The simplest interaction between organic and non-organic elements could be demonstrated with a lemon battery, which generates electricity from a chemical reaction between acids and two electrodes of different metals – zinc and copper (Fig. No. 3). Placed within one small or several

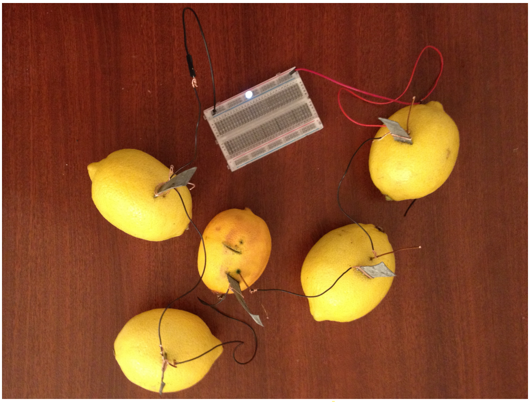

Fig. 3. Mindaugas Gapševičius, *Prototype for a Posthuman Game*. Installation detail. Lemons connected with copper and zinc electrodes produce electricity that can light up an LED.

normal-sized lemons, the setup is identical to Volta's electrical battery. In the lemon battery, the copper serves as the positive electrode, while a piece of zinc acts as the negative electrode. Citric acid triggers the chemical reaction between the negative and positive electrodes, generating a small potential difference that, in turn, becomes the electrical current (Edinformatics, 2015). The electric current could also be produced by, for example, potatoes or humans.

During the workshop, done in Vilnius in 2015, the workshop participants and I tried to experiment with different matter.[3] All the vegetables and fruits brought for the workshop generated up to 1V of electric potential through the attached copper and zinc electrodes. The human body generated 0.4V electric potential. During further experiments, while connecting five fruits and vegetables in sequence, the 4V of electric potential generated was able to light up an LED. Similarly, connecting seven workshop participants to the sequence produced 2V of electric energy. Although the amount of voltage might have been enough to light up an LED, a lack of current prevented the lighting up of the LED during the workshop.

Nevertheless, an LED can be lit up with one human body by combining several electronic components in the circuit. An example showing such an experiment was published on YouTube by the user slider2732 in 2013.[4] Here, the “battery” consists of a human body, two capacitors, a resistor, a semi-conductive stone (such as ferrite or pyrite) with copper wire, and a piece of aluminum.

*3. “Do-it-yourself” series workshop “How To Light Up LED With Your Body” with artist Mindaugas Gapševičius. Available at: http://www.letmekoo.lt/en/pasidaryk-pats-dirbtuves-kaip-iziebti-led-savo-kunu-su-menininku-mindaugu-gapseviciumi/ (Accessed 11 August 2015).
*4. No Battery - LED Flasher. Available at: https://www.youtube.com/watch?v=STPej7VQNzI (Accessed 13 May 2016).

Fig. No. 4. Ultra-Low-Voltage Survival Kit.
Photo: Mindaugas Gapševičius

Toolkit

The toolkit (Fig. No. 4) includes electronic components for building circuits for audiovisual performances that use a human body as a replacement for an energy source. The manual proposes that we reconsider properties of our bodies that could become an essential source for powering up bionic implants or external devices. To generate energy we will use (in the first experiment) a reaction between zinc and the human body to make a battery and power up an LED with it. In the second experiment we will use body temperature (to be exact, the temperature between a body and its environment) to generate energy. With that we will power an audible synthesizer that is controlled by temperature and light (Gapševičius & Spahn, 2019).

Experiment No. 1. Human Battery

In this experiment, we will build a circuit for an LED to be lit up by a human body (Fig. No. 5). This circuit uses a self-oscillating voltage booster, also known as a joule thief. For the experiment, we will use:

Components:
- A breadboard;
- A coupled inductor;
- Copper and zinc electrodes – one of each;
- A 2N3904 transistor;
- A 1 kΩ resistor (optional);
- A 10 μF capacitor;
- A low current LED;
- Jumper wires – 6 units;
- Alligator clips – 2 units.

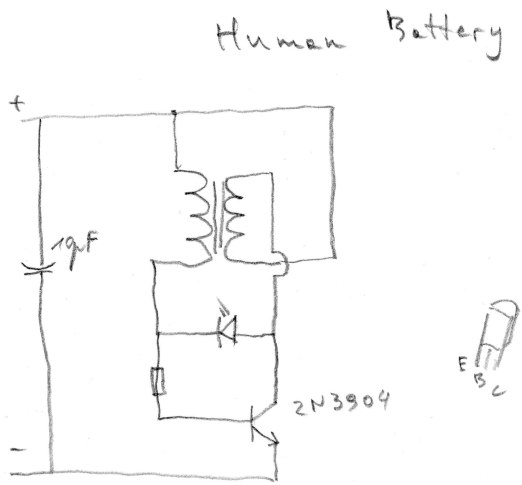

Fig. No. 5. The circuit for an LED lit up by a human body. Within the circuit, the electrode marked "+" is meant to be copper, and the electrode marked "-" is meant to be aluminum. The copper electrode could be replaced with, for example, graphite and aluminum with zinc. Other variations are also possible.

- Push the transistor provided into the terminal strips with the collector leg on the left side and the emitter leg on the right side of the breadboard. Each of the three legs of the transistor should be allocated a different terminal strip (Fig. No. 6).

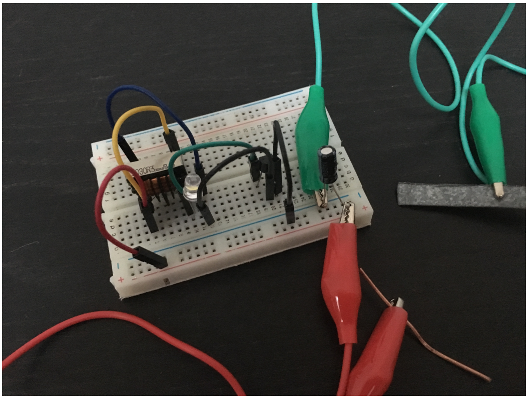

Fig. No. 6. An LED lit up by the human body. Photo: Mindaugas Gapševičius.

- Push a coil into the middle of the breadboard, left of the transistor, so each of the four legs of the coil is allocated to a different terminal strip.
- Take a jumper wire and connect the bottom-left leg of the coil with the top-right leg of the coil.
- Connect the bottom-left leg of the coil with a power rail on the breadboard.
- Take an LED and push the long leg into the terminal strip with the bottom-right leg of the coil, then push the short leg into the empty strip on the breadboard.
- Connect the short leg of the LED with the top-left leg of the coil.
- Connect the collector leg of the transistor with the long leg of the LED.
- Connect the base leg of the transistor with the short leg of the LED.
- Connect the emitter leg of the transistor with the ground rail on the breadboard.
- Take a 10 µF capacitor and push its long leg into the power rail and its short leg into the ground rail.
- Take a copper electrode and connect it to the power rail, then connect a zinc electrode with the ground rail on the breadboard. Use the alligator clips provided.

- Take both electrodes in your hands. If the circuit has been connected correctly, the LED should start blinking.

For further experimentation, try to replace the copper electrode with, for example, graphite and the zinc electrode with aluminum. Other variations are also possible, including the use of a potentiometer instead of a resistor, a Peltier element with the additional “joule thief” provided, and different coils and capacitors (Gapševičius & Spahn, 2019).

Experiment No. 2. Assembling a Symbiotic Synth

The experiment introduces and shows how a symbiotic synth works. It is a small synthesizer that is powered by body heat or, to be precise, the heat difference between the body and environment (Fig. No. 7). For the experiment, we will use:

Components**:**
- A breadboard;
- 22 kΩ resistors – 3 units;
- A 100 kΩ potentiometer;
- A 330 pF capacitor;
- A 1 nF capacitor;
- 22 nF capacitors – 2 units;
- A 1 µF capacitor;
- 220 µF capacitor – 2 units;
- BC547 transistors – 2 units;
- A LTC3108 chip with 16 pin SSOP adapter;
- A coupled inductor;
- A low current LED;
- A mini switch;
- Mono mini-jack sockets – two units;
- Airplane headphones;
- A Peltier element;
- A cooler;
- A jumper wire;

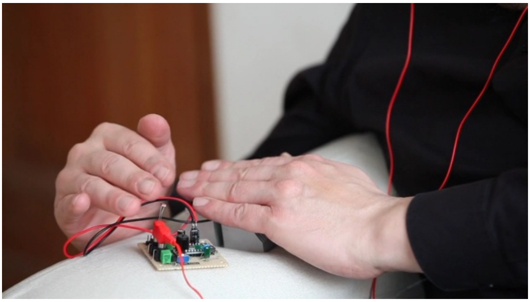

Fig. No. 7. A Symbiotic Synth. Photo: Brigita Kasperaitė.

For building the circuit, beside the circuit board, we will need some resistors and capacitors in order to produce and store the energy. We also need some capacitors and two transistors for oscillating the circuit. The most important part is a small chip LTC3108, which is a DC/DC converter. In combination with a coupled inductor 1:100 it will boost the voltage up to around two volts and with that it will power the oscillating circuit. The potentiometer will be needed for adjusting the frequency.

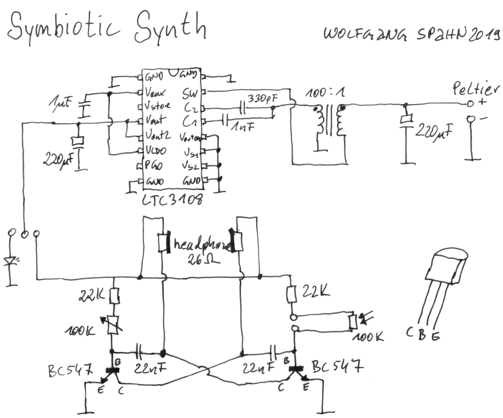

Fig. No. 8. The circuit of a symbiotic synth. Sketch: Wolfgang Spahn.

You also have to be careful with the polarity of the LED, the transistor, and the electrolyte capacitors. The headphones from airplanes, which have two mini-jacks, will be used instead of additional resistors.

Build a circuit as depicted in the sketch (Fig. No. 8). For further details, please refer to the website,[5] or print the PCB sketch for a stripboard provided.

*5. Available at: http://paperpcb.dernulleffekt.de/doku.php?id=sound_boards:symbiotic_synth (Accessed: 21 April 2019).

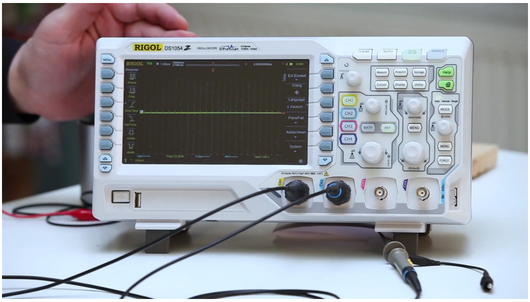

Fig. No. 9. Inspect oscillations with an oscilloscope. Photo: Brigita Kasperaitė.

In order to see if the circuit works, lay your hand down on the Peltier element. The LED should light up if the body generates enough heat, or the heat generates enough electricity. Switch the circuit to audio mode – you should be able to listen now to the synthesizer sound. That sound could be changed by readjusting a potentiometer, or by adding additional sensors like a light or a temperature sensor.

While the sound runs on headphones, the oscillations can be inspected with an oscilloscope. The oscilloscope will show the peeks and oscillations of the circuit. Listen to the sounds while taking your hand away from the Peltier element. The oscilloscope will show the frequency decrease, which means the circuit is not generating electricity. The moment you heat it up again with your hand, it will resume oscillating.

For further experimentation readjust a potentiometer, replace a jumper wire with a light sensor, replace coupled inductors, or use more Peltier elements connected in series with no or differently shaped cooling elements. Also try experiencing audiovisual performances together with other people (Fig. No. 10) (Gapševičius & Spahn, 2019).

Fig. No. 10. Wolfgang Spahn and Mindaugas Gapševičius perform with their devices. Photo: Brigita Kasperaitė.

Conclusions

The project aimed to introduce a framework for experiencing electricity. Chemical reactions between organic and non-organic matter and the difference in temperature between a human body and its environment generated enough electricity to light up an LED and to play sound. Therefore, the use of the human body in connection with a silicon-based computational machine need not be considered fantasy or a faraway future. Moreover, discussions around ultra-low voltage should garner more attention, because, on one hand, machines powered by ultra-low voltage might reduce energy use and, on the other hand, could make humanity less dependent on the production of electricity; for example, small-sized computer chips or nanorobots could be powered directly by the human body.

This paper's introduction of circuits that produce light and sound without an additional battery or voltage supply question the posthuman state, as defined by Katherine Hayles, as the merging of the human body and silicon-based technology.

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This paper is part of a broader body of research within the *Introduction to Posthuman Aesthetics* project, initiated in 2016. The paper, which is a part of the toolkit, proposes that we reconsider the properties of electricity, which is an essential ingredient of matter. While proposing the use of electricity captured from a human body, the kit brings the user of the toolkit closer to conceptualizing the future, defined by merged living and non-living matter. The first experiment to be introduced invites the user to light up an LED with energy generated by the human body. The second experiment, which was developed with Wolfgang Spahn, proposes listening to sounds generated by a difference in temperature between a human and their environment.

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