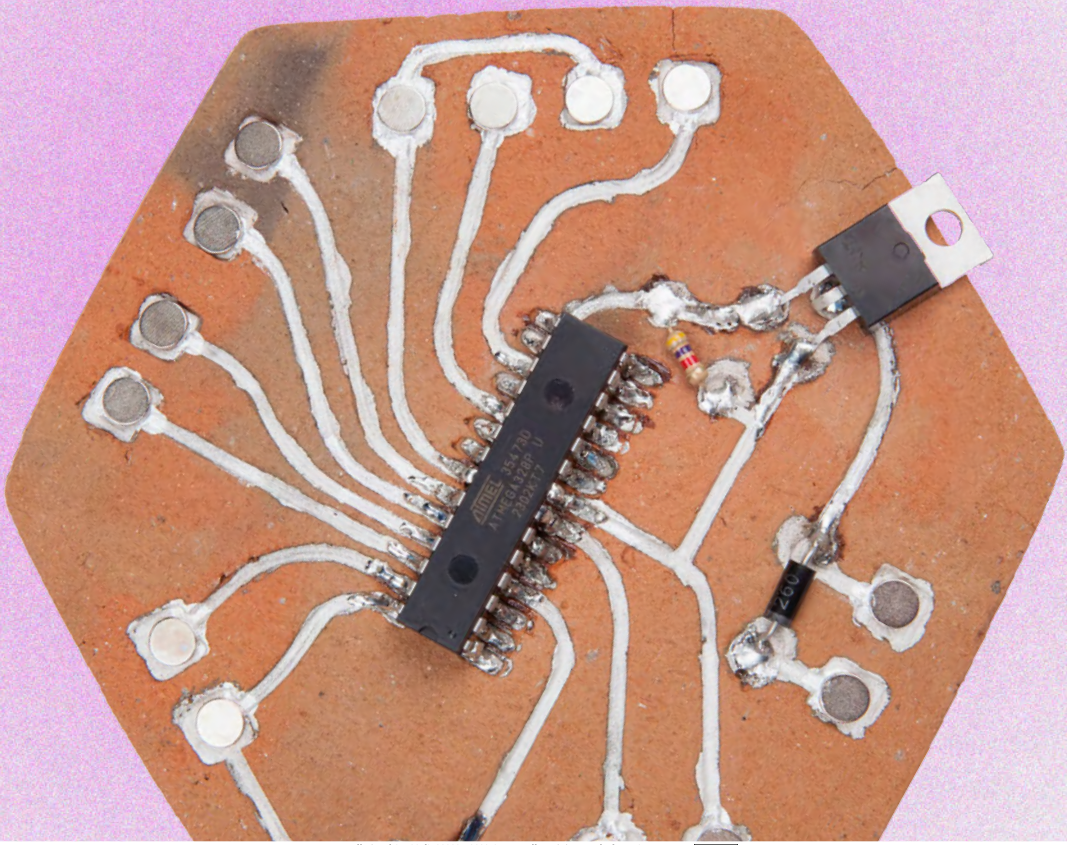
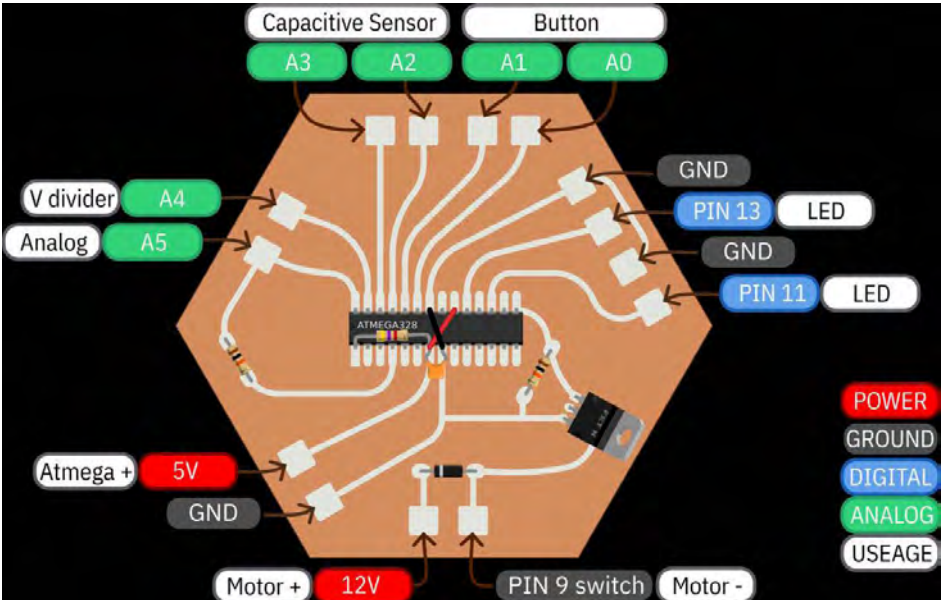
CLAY PCB



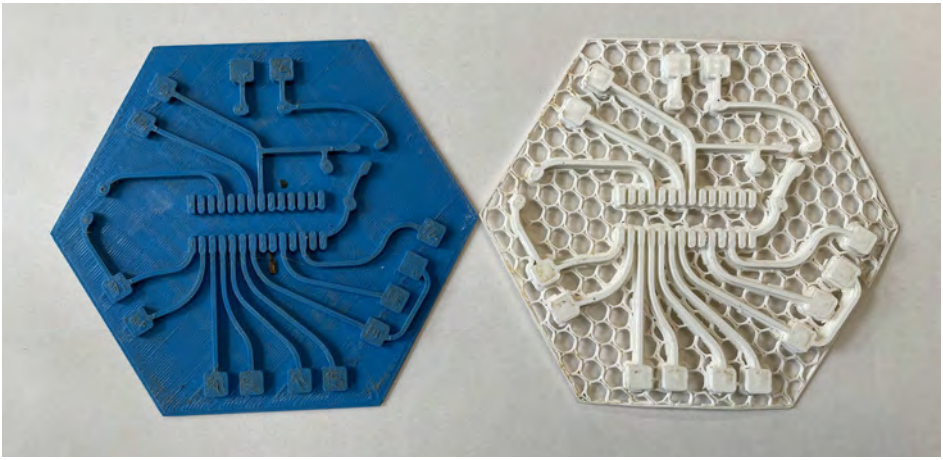
It is an open secret that the hardware in our smart devices contains not only plastics but also conflict minerals such as tungsten, tin, tantalum, silver and gold. We are investigating alternative hardware from locally sourced materials — so-called ethical hardware — to develop and speculate upon renewable practices for the benefit of both nature and humans. We are exploring different materials: sentient, low-impact, non-toxic, fairly traded, recycled and urban-mined means of production. We aim to challenge the common PCB (printed circuit board) economies in an artistic, creative, positive and responsible way, applying feminist hacking as an artistic methodology and critical framework.

Our initial idea was to develop a microcontroller PCB imprinted on clay that could work with the ATmega328P chip, commonly used in the famous Arduino Uno board (or Arduina board, as some feminists call it).

Why this chip? Because we are part of a community hackerspace — Mz* Baltazar's Lab (a feminist hacklab and artist-run off-space based in Vienna, Austria) — and the Arduino Uno has been our favourite microcontroller in the past 12 years. After using it in many prototypes, artworks and workshops, we had several malfunctioning Arduino boards left over. But their chips were still working, so the idea was to reuse them in our new project. The second challenge was to come up with an electric circuit that would allow us to receive several forms of input signal (analogue and digital sensors) and generate a variety of output signals (to control LEDs, motors and speakers), using the lowest amount of ATmega chip pins possible in order to simplify the circuit. We wanted to reduce the circuit to a single layer that could be imprinted in a piece of clay as a 'stamp'. We came up with a 3D-printed 'stamp' using a recycled polypropylene filament. This took a while, because we had to consider the clay's shrinkage rate after drying and firing.



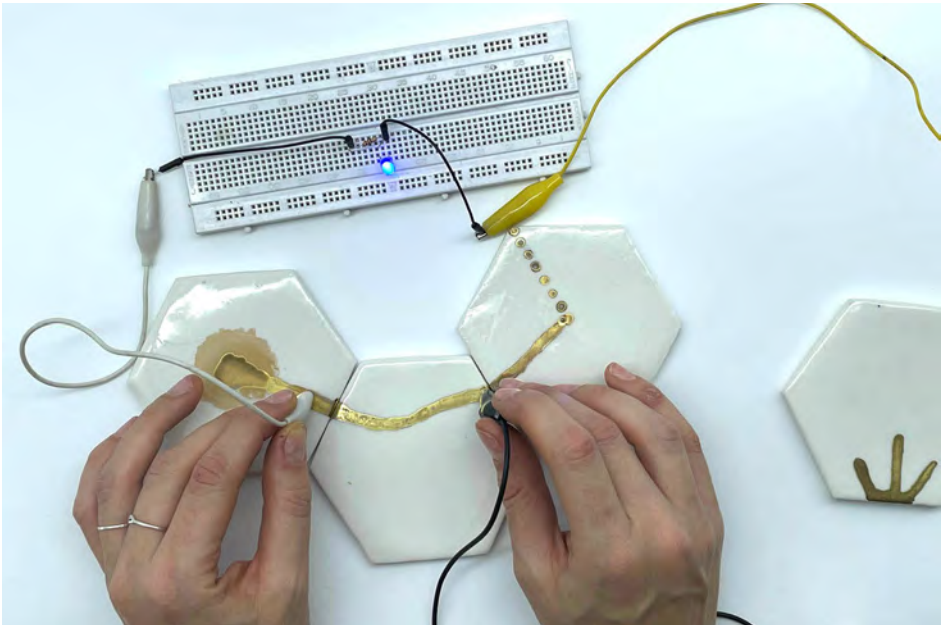
PCB Schematic of the circuit with input and output. Designed by Daniel Schatzmayer, Klemens Kohlweis and Patrícia J. Reis, Vienna, 2022



3D-printed circuit stamp, printed on recycled polypropylene filament, designed by Klemens Kohlweis, Vienna, 2022
Photo © Patrícia J. Reis

When we began the research into alternative materials for circuit building, we separated the materials into two categories: conducting and insulating. To build the base of our PCB, we needed insulating, sustainable and robust materials (eggshells? wood plates? wax? ceramics?). We immediately chose ceramics, specifically porcelain, as it plays an important role in electronic components, such as capacitors, piezo and resistors. Porcelain is an industrial-made material composed of kaolin (the main ingredient that makes it plastic and white) and stone pottery (the second ingredient that makes porcelain translucent and hard). Both are well-known commodities prospected and mined around the world, on a small scale in Europe and a larger scale in China, Brazil, South Africa and Vietnam (among others). In pottery, porcelain, also known as china clay, is a very delicate and sensitive material (we could say it has its own agency), more difficult to control than other industrial clays. Also, along with the other harder and resistant stoneware clays, it usually requires higher firing temperatures in two stages: a first firing known as ceramic bisque of around 1000 degrees Celsius; and a glazing firing of around 1200 degrees Celsius in an electric kiln. During our first experiments with porcelain, we quickly realised that the higher temperatures, and therefore electric consumption, were not compatible with our standards for ethical hardware.

Experiments with conductive material on porcelain by Patrícia J. Reis, Vienna, 2021
Photo © Patrícia J. Reis



Experiments with gold lustre conductivity
on porcelain by Patrícia J. Reis, Vienna, 2021
Photo © Patrícia J. Reis

It was when we were struggling with the question of how to manufacture clay in low-energy and low-impact ways that we came across the work of Heinz Lackinger, a pottery crafter from Donnerskirchen, Burgenland, Austria, who works with prehistoric techniques of firing clay in an open wood fire. Instead of sophisticated machines, he uses a simple hole in the ground of his 18th-century backyard. We had the privilege of spending two days with this skilled craftsman, learning how to identify and collect the clay, how to model it and fire it using old, dry branches collected from forest ground. If the clay is collected with an awareness of its many qualities, and in small quantities only, this process can be defined as 100% fair trade and congruent with locally sourced modes of hardware production. We owe the knowledge required for the following steps to Heinz Lackinger's generous knowledge transfer during his workshop, and to our own experiments with later applying this technique in the making of natural PCB clay boards.

Collecting clay during the workshop
with Heinz Lackinger at Donnerskirchen,
Burgenland, Austria, November 2022
Photo © Patrícia J. Reis

Firing the natural clay during the workshop
with Heinz Lackinger at Donnerskirchen,
Burgenland, Austria, November 2022
Photo © Patrícia J. Reis

We collected our wild clay at the beginning of autumn, when the weather was dry. The soil was mainly dry but did not consist of argil alone: we found little stones, plants, even small insects. When clay is that dry, the easiest way to clean it is using a net that retains the undesirable waste. The organic waste collected should be given back to earth, back to the ground. After cleaning, we ended up with a fine powder that requires water and much care, while mixing it until a consistency of solid and malleable clay is achieved. The natural clay is very fragile and less elastic than the industrial type, so patience and care are required.

Cleaning the natural clay at Donnerskirchen, Burgenland, Austria, October 2023
© Patrícia J. Reis

Clay after cleaning and adding water, Burgenland, Austria, October 2023
© Patrícia J. Reis

For the form of our PCB board, we chose a hexagon shape, hoping to assemble the boards as tiles next to one another, connecting them electronically. We ultimately abandoned this idea since it was very difficult (with this kind of clay) to obtain straight edges that lined up neatly next to one another. After cutting the shape, we pressed the 3D-printed stamp gently against the clay to imprint the circuit. The result was engraved circuit lines that serve as a guide for painting the circuit with a conductive material.

Cutting the hexagon shape using a tile cutter, Burgenland, Austria, October 2023
© Patrícia J. Reis

'Stamping' the circuit into the clay with the 3D-printed 'stamp', Burgenland, Austria, October 2023
© Patrícia J. Reis

While searching for conductive materials that can be used in ceramics, we came across a gold lustre (often used in gold details on porcelain) that, after firing, becomes conductive (the same kind was used in our Coffee Table project). The first problem we encountered was that this product is usually sold by ceramic shops that supply no information about its ingredients, especially on the sources of the gold and its complex commodity chain. The second problem was that it is not possible to solder directly on this gold lustre, so we had to add another precious metal to the equation. The challenge was to find within the solderable and readily available precious metals, such as tin, copper, brass and silver, one that could bear the firing process, which is around 700 degrees Celsius, and at the same time maintain its conductive properties. As we know, tin, mostly used for soldering, melts at a very low temperature, copper melts at approximately 1000 degrees Celsius, but the oxidation process happens so quickly in the fire that it loses its conductive properties. And the same thing happens with brass. We were left with silver, which, although it also oxidises with the fire, maintains its conductive properties. Also, silver is cheaper than gold and widely used by goldsmiths. We were able to find a silver paint, commercialised by a German company, made with waste silver powder collected by jewellery makers — a form of urban mining of silver dust.

To paint the circuit, a huge amount of patience and dedication are required, since the final circuit lines cannot be crossed. There would have been many other ways to print the circuit avoiding this time-consuming hand painting, for instance using a stencil mask and spraying on it or using another paint-transferring technique. The reason we chose this method is because it appears to be more economical and sustainable and generates almost no waste paint.

Painting the PCB circuit on the clay boards with silver ink, Burgenland, Austria, October 2023
© Patrícia J. Reis

Boards after painting during the drying process, Burgenland, Austria, October 2023
© Patrícia J. Reis

We fired the boards in our backyard, reusing a hole that had previously been dug for this purpose. The wood was collected *in situ* and consisted of dry wood sticks and old branches from our trees. We started a normal fire to generate some heat and placed all of the boards around it so they could finish drying. It is important to achieve a temperature of around 700 degrees Celsius, but this is obviously hard to control. Our experience tells us that 20 minutes is the average time the boards need to be in the fire. After this, we should be able to see the boards glow in the fire, which is when they are ready. Using tongs, we were able to quickly transfer them from the fire to a bucket of cold water and leave them there, holding them for a few seconds with the tongs.

This is usually the ultimate ‘proof’ test for the clay. If there are no air bubbles, stones or cracks, and if dried properly, it can resist the cold water.

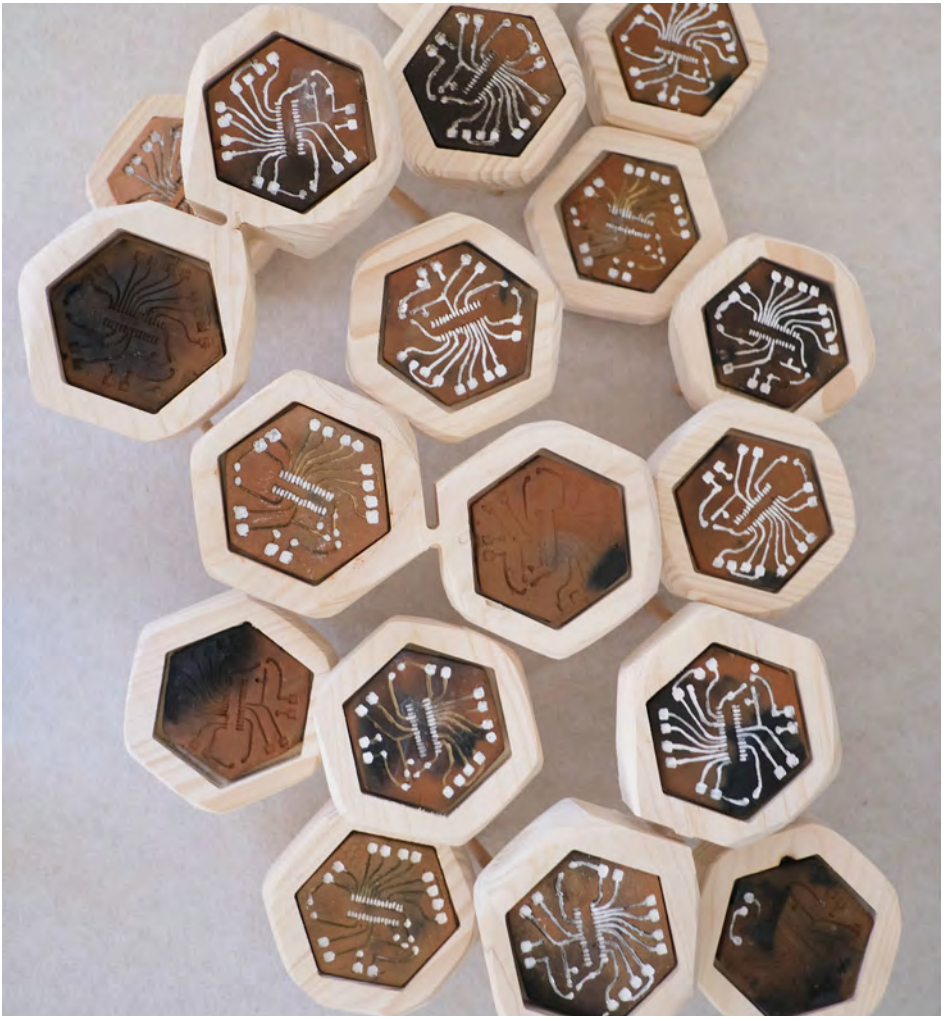
Placing the boards in the open fire,
Burgenland, Austria,
October 2023
© Patrícia J. Reis

Boards glowing in the fire after approx. 20
minutes, Burgenland, Austria, October 2023
© Patrícia J. Reis

Transferring the boards directly from the fire into a bucket of cold water, Burgenland, Austria, October 2023
© Patrícia J. Reis

Final boards after firing, Burgenland, Austria, October 2023
© Patrícia J. Reis

After this process, we bootloaded and programmed the chip and soldered all the electronic components. A full step-by-step guide of all the processes can be found on our repository page at Github:
https://github.com/FeministHardware/Making-PCBs-from-natural-clay



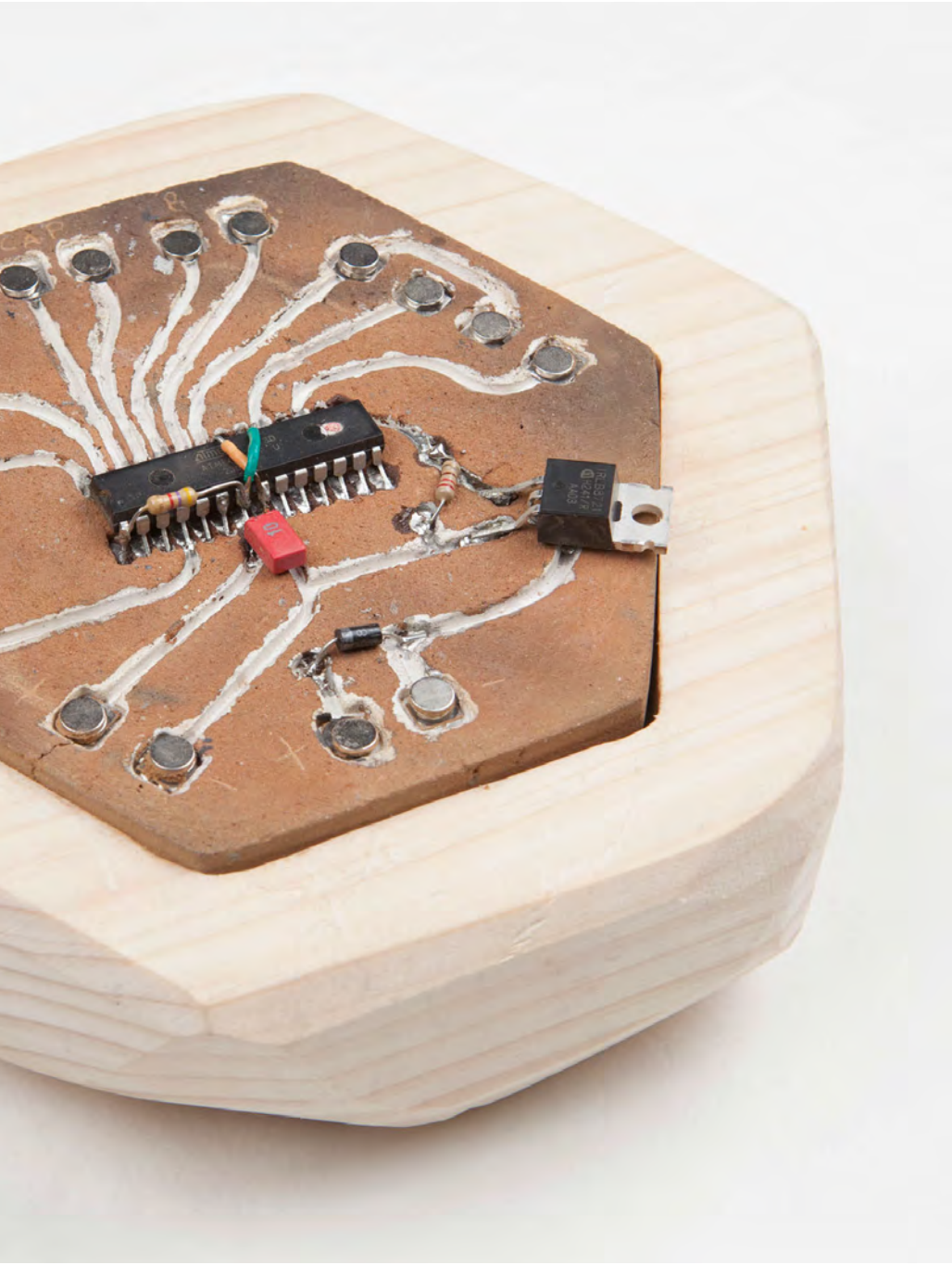
Boards after soldering all the components
© Janine Schranz

In October 2023 we had the privilege of being invited to give a two-day workshop on this topic by the Hangar, Visual Arts Research and Production Centre in Barcelona, Spain. For us, this was an opportunity to test the complexity of manufacturing the PCB using the process described while facing the challenges already mentioned in the 'Who has land to make a fire?' project (2023), namely how to make an open fire in a public infrastructure of a densely populated city. With the amazing help of our hosts, we were able to re-enact the barbecue scene and reuse an old metal pan and old wood that had already been cut and disposed of by the construction workers around the corner. The two-day workshop was intense and – one could say – a little stressful because of the short timeline. However, the participants were highly motivated and worked extra hours to finally complete their wild clay PCB boards.

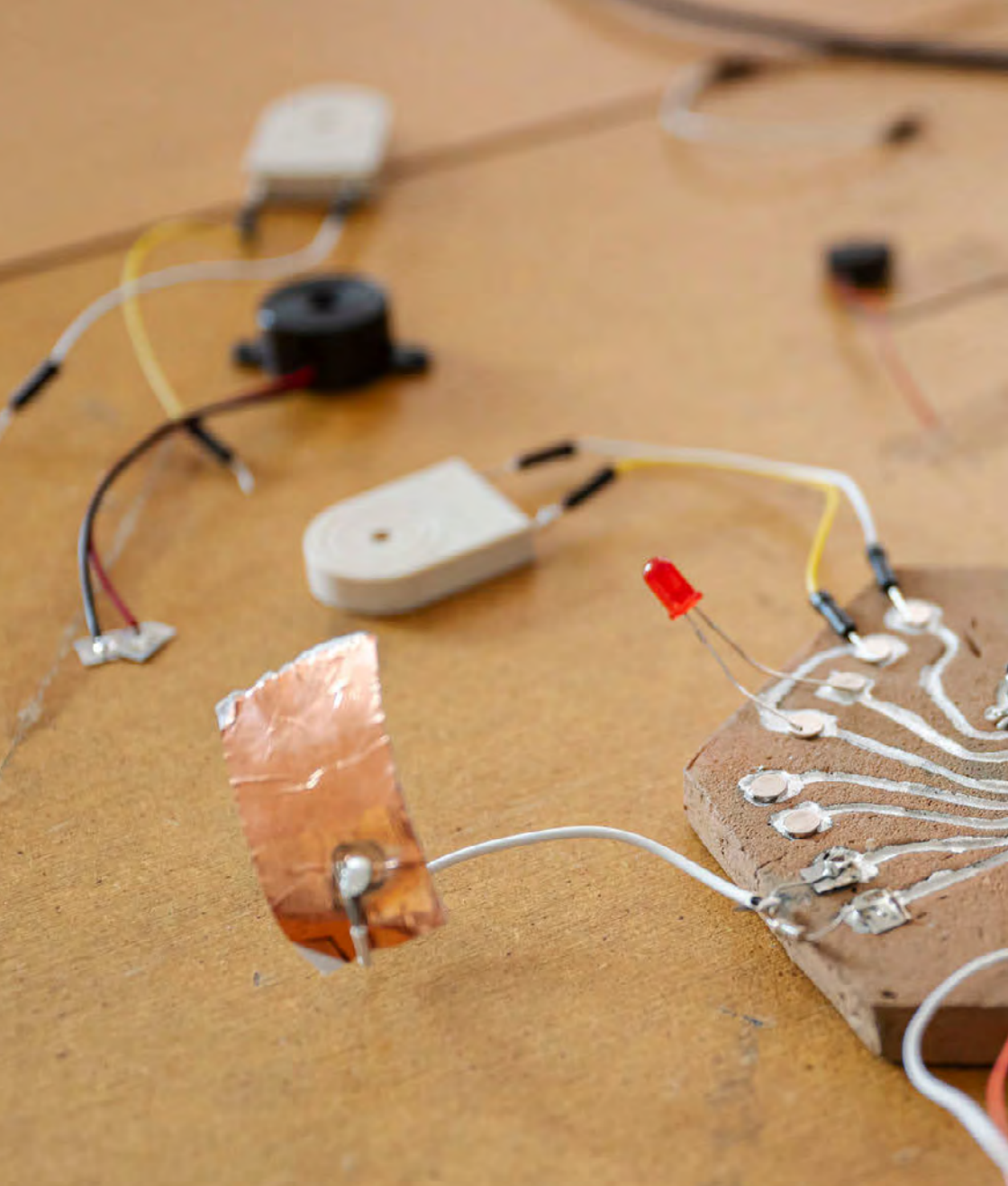
Feminist Hardware: Making Printed Circuit Boards with Natural Clay by Patrícia J. Reis and Stefanie Wuschitz, Hangar, Visual Arts Research and Production Centre, Barcelona, Spain, 18 and 19 October 2023

Patrícia J. Reis and Stefanie Wuschitz, Final Clay PCBs, 2023
Photo © Janine Schranz

Board after soldering all the electronic components
© Janine Schranz



Boards after being fired, before soldering the electronic components
© Janine Schranz



Board in action at PIFcamp in Slovenia, 2024.
Photo © Violetta Wakol