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Contents

1 Executive summary

Heat cost allocators and fire alarms are some of the most common devices to finish their life at the electronics recycling plant. Accordingly, these devices had been chosen in the ReconCycle project for the first two use cases. The battery needs to be removed before the devices can be recycled. This is usually a labor-demanding task and, thus, it makes sense to automate it. This deliverable shows the manual disassembly steps required to remove the battery. An automatic workflow is described to follow the same steps but now with the ReconCycle robotic setup.

2 Introduction

In this deliverable, the disassembly of two types household electronic products are considered. The first is a heat cost allocator (abbreviated as HCA) and the second a prototypical fire alarm. Both devices perform their operation under battery power. The devices usually still contain the battery on arrival at the electronic recycling plant. Recycling of the product cannot occur before the battery is removed because the battery poses - on accidental destruction - a danger to human workers, the environment and the recycling machines (fire hazard!). To remove the battery, some disassembly steps must occur. These steps are not always straightforward because the manufacturer often does not intend for the battery to be removed.

For the HCA and the fire alarm, respectively, different variants exist. From the most commonly found devices that arrive at the recycling plant, a selection has been made for those where automatic disassembly would be successful. The manual disassembly, where the disassembly is performed by a human operator, is shown first. Secondly, a possible automatic workflow to be implemented by the ReconCycle group is shown.

3 Disassembly Workflow for Kalo 1.5 Heat Cost Allocator

The Kalo 1.5 heat cost allocator is shown in Figure 1. In this section, we first analyse manual disassembly as carried out by a human operator. This analysis served as the basis for specifying the automatic disassembly workflow to be performed by robotic arms to fulfil similar actions.

3.1 Manual Disassembly Workflow

The manual disassembly is performed in 9 steps as shown in Figure 2. It consists of the following operations:

1. Place screwdriver into the gap on the rear of the HCA.
2. Lever out the internals.
3. Obtain the internals, consisting of the PCB with connected battery, a white plastic top cover, and a bottom transparent cover holding the display.
4. Lever off the white plastic top cover.
5. Lever off the PCB from the bottom transparent plastic cover.
6. The PCB is now completely free.
7. Hold the PCB and battery in both hands.

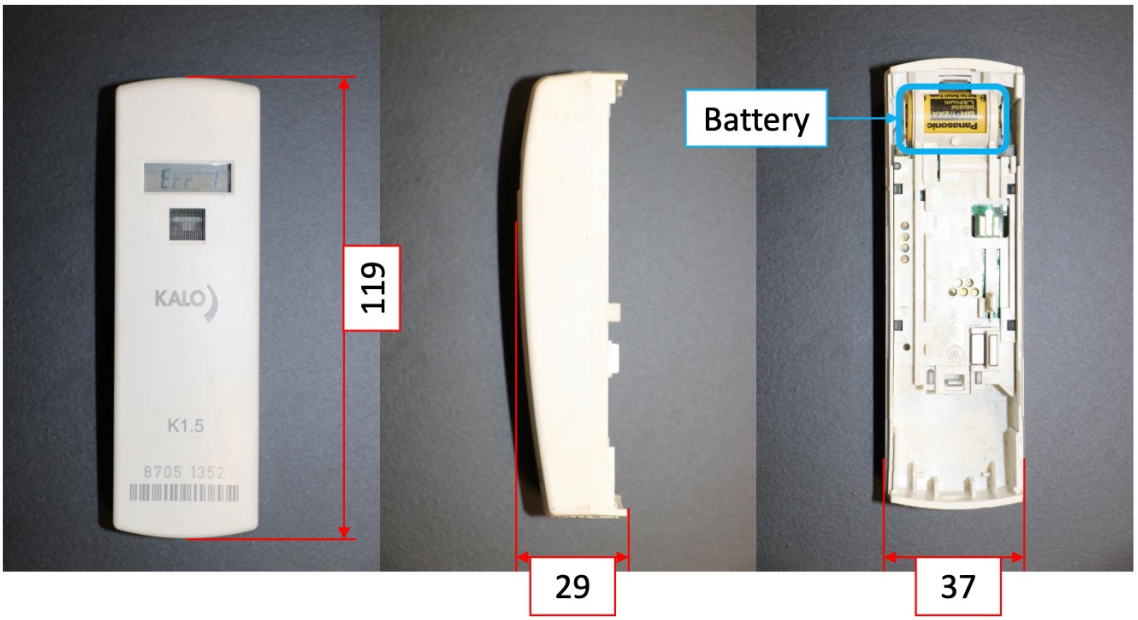

Figure 1: Dimensions of the Kalo 1.5 heat cost allocator

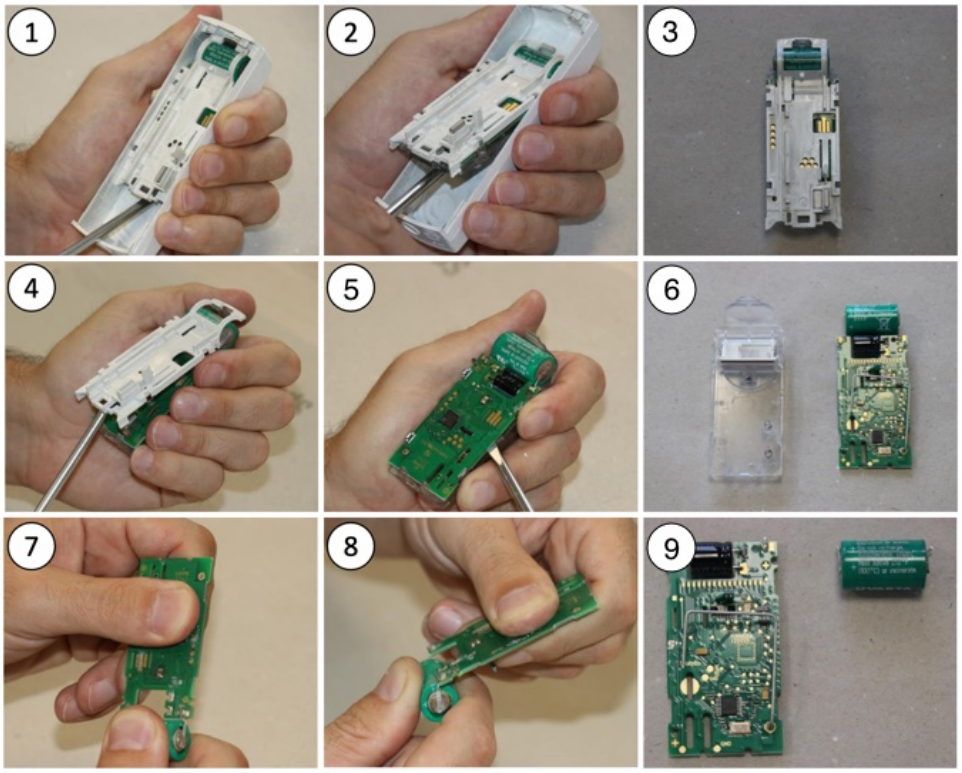

Figure 2: Manual disassembly of the Kalo 1.5 heat cost allocator

8. The battery is removed in a ripping or cutting (not shown) action that is enabled by the thin metal connections to the PCB.

9. The battery is dettached from the PCB.

3.2 Automatic Disassembly Workflow

The automatic disassembly workflow takes inspiration from this manual disassembly workflow. In Figure 3 the automatic disassembly workflow is shown. These steps contain some comments on still-required improvements, too, by which some of these steps might in the end be slightly modified and made more efficient. The steps in the workflow diagram are described as follows:

1. Picking heat cost allocator (HCA) from initial surface:
   - At the beginning, orientation of the HCA should be “Open End Up”.
     - This can be relaxed later in the project as the implemented vision algorithms will be improved.
   - Picking of the detected HCA from the initial surface will be performed with a soft robotic hand (Pisa/IIT SoftHand).

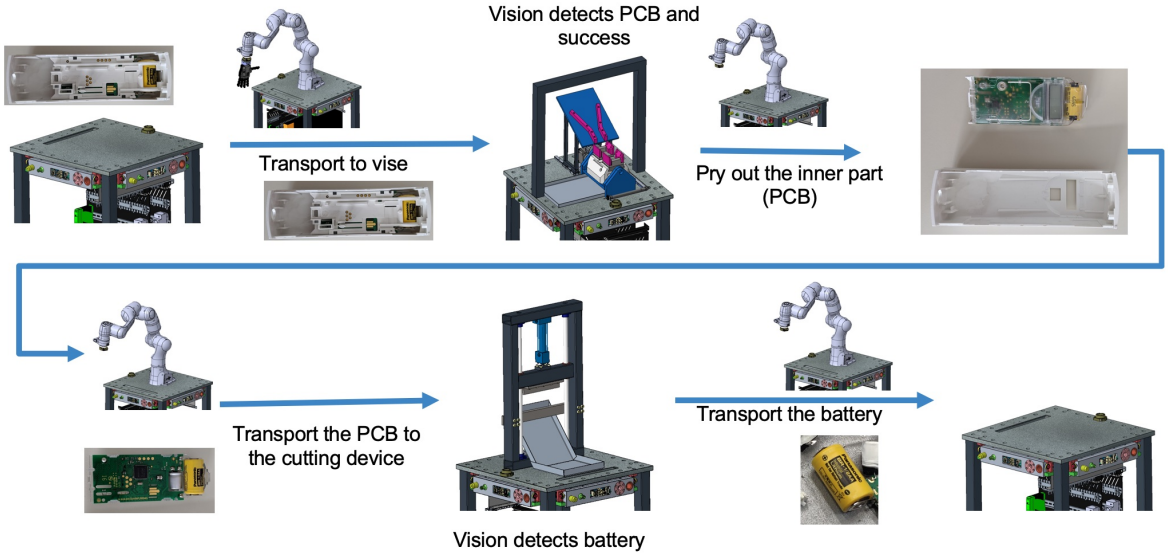

Figure 3: Automatic disassembly workflow of the Kalo 1.5 heat cost allocator

2. Placing into fixture:
    - A slide will be used to deliver the HCA to the fixture jaws
        - This ensures the compensation for the undetermined grasping position of the HCA in the SoftHand.
        - Jaws and/or slide can be adapted/exchanged for different models of HCA later in the project.
    - The HCA will be fixed in so the jaws press on the smallest surfaces.
3. First step of disassembly
    - Prying out the inner-part by a levering action.
    - Rotate the fixture so that the pieces fall out of the plastic casing.
        - The fixture (vise) will be mounted on a pneumatic revolver so it can rotate the HCA 180 degrees after applying lever action.
4. Detection of fallen pieces
    - The fallen pieces might still be assembled together in a "sub-piece" or they might fall separately: PCB and two plastic covers. These will be detected by machine vision.
5. Final disassembly
    - The sub-piece containing the battery will be picked up and inserted into an automatic cutter.
        - Pick up tool still to be decided.
    - The battery still attached on the sub-piece is clipped away by the cutting device.

  - The insertion into the clipper is force controlled until reaching an adjustable end stop.

6. Sorting

   - During the above described steps many pieces of different materials fall on the working surface. Vision will be used to classify each of the debris: plastic, PCB and battery.
   - An automatic procedure will be used to remove said pieces from the surface and sort them into respective containers.
     - This can be done by the robot, but possibly more efficiently by a specialised sweeper or a pneumatic blow-off device (the latter is commonly used by ECYC for similar proposes elsewhere in their plant.

The complete setup is shown in Figure 4. The setup comprises 7 tables connected by plug-and-produce connectors designed by JSI. Two of the tables have the robot arms (Franka Emika Panda) on them, one is equipped with the setup to pry out the PCB, and another has the cutting device. The tables can be re-positioned to improve the reach of the robot arms if necessary.

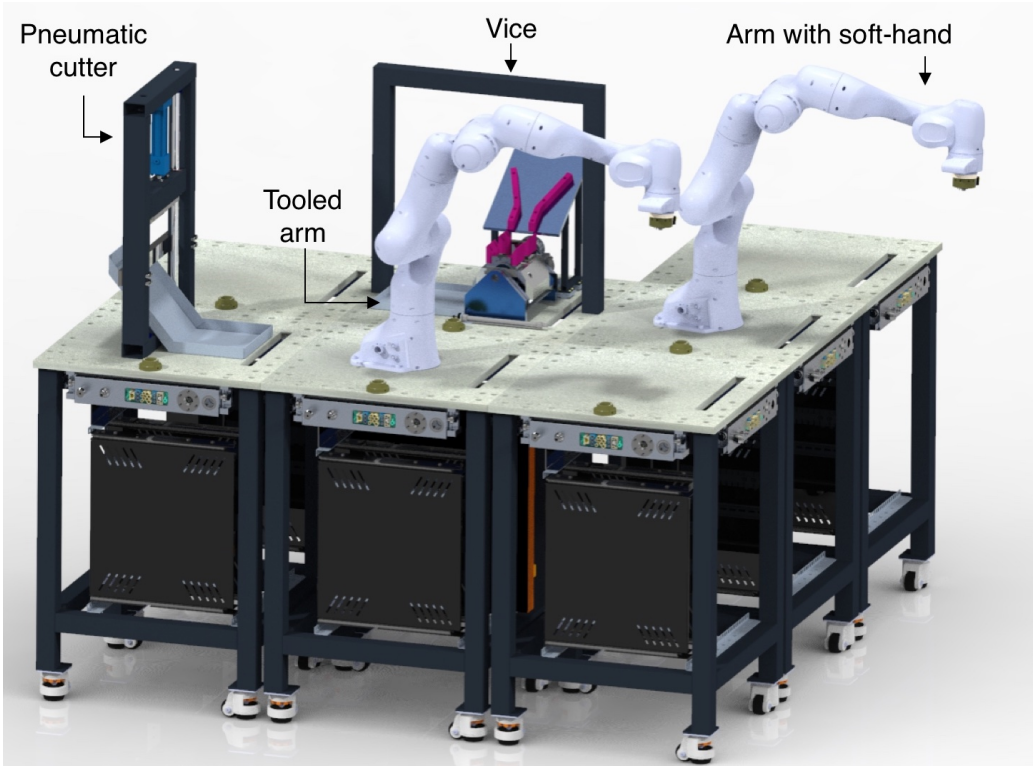

Figure 4: Robot placement for the automatic disassembly of Kalo 1.5 HCA

3.2.1 Investigation into Cutter Performance

In the automatic workflow, a pneumatic cutter is used to separate the battery from the PCB. The white plastic PCB cover may still be attached to the PCB. The same can happen with the bottom transparent piece of plastic, as shown in Figure 2. To test the idea of a pneumatic cutter

Figure 5: Testing phase for the type of cutter in the automatic setup

for the automatic workflow, a manual cutter with a human operator was used. This is shown in Figure 5. The pneumatic cutter should perform in a similar manner to the human-operated cutter.

The result of cutting with the manual cutter is shown in Figure 6. One can see that the cutting action leaves a lot of residual plastic pieces and PCB pieces. Nevertheless, the process is deemed successful because the battery has been separated from the main part of the PCB. If a small piece of the PCB remained connected to the battery, this would still be a positive result according to the requirements of ECYC, because battery recycling permits this. The remains consisting of plastic parts and PCB can now be recycled easily, too, using the existing processes at ECYC.

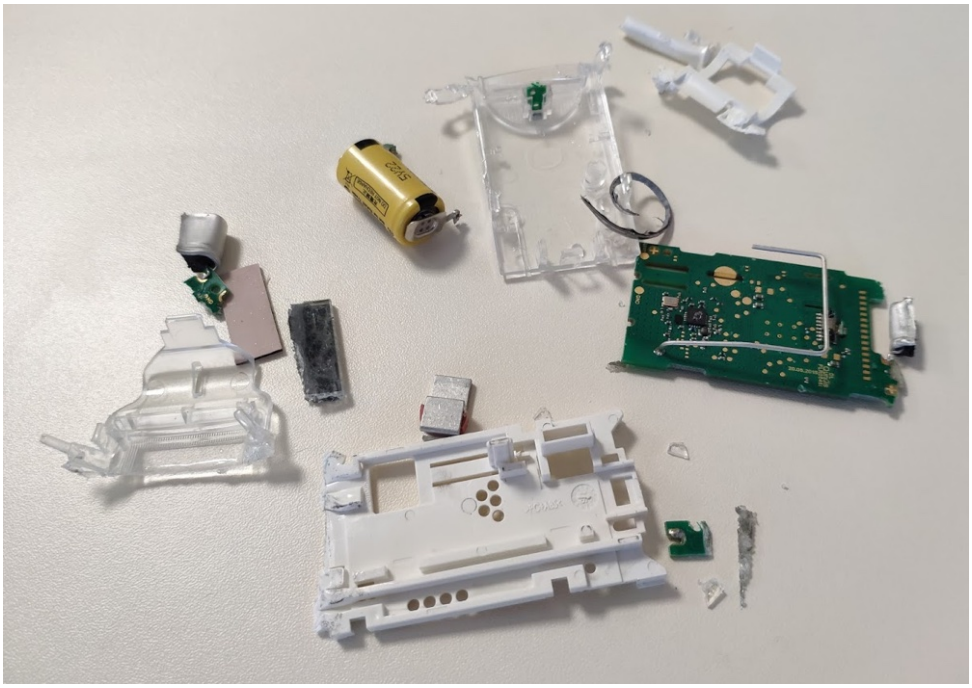

Figure 6: Result of the manual cutter on the Kalo 1.5 HCA

4 Fire Alarm Type 1 Disassembly Workflow

In this section, the disassembly workflow for a fire alarm (Type 1) is shown.

4.1 Manual Disassembly Workflow

The manual disassembly process of Type 1 fire alarm is shown in Figure 7. The steps illustrated in Figure 7 are as follows:

1. Type 1, prototypical fire alarm before disassembly.
2. A screwdriver is inserted into the back through a gap.
3. The screwdriver pushes onto the front cover of the fire alarm separating the enclosure of the fire alarm.
4. The worker separates the enclosure using their hands.
5. The worker pulls off the electric components and the battery from the enclosure, ripping the connecting wires apart.

Figure 7: Manual disassembly of a fire alarm

4.2 Automatic Disassembly Workflow

The automatic process for this fire alarm will be defined and reported later in the project. Currently the focus lies on the automatic disassembly process of the Kalo 1.5 HCA.

5 Additional Manual Disassemblies for Heat Cost Allocators and Fire Alarms

According to the workplan, we need to address also variants of the devices presented above. Hence here we show two more examples of manual disassembly workflows. The ReconCycle system is – later in the project – supposed to generalise to these or similar cases. Hence, after month 22 (=18+4), we will have to begin considering these cases for automation, too.

Thus, in this section disassembly workflows are shown for the second type of HCA and fire alarm. The disassembly workflows use the same levering action as has been seen for the first set of devices.

5.1 Disassembly Workflow for Heat Cost Allocator Ista

The manual disassembly process of HCA Ista is shown in Figure 8. The steps illustrated in Figure 8 can be described as follows:

1. HCA Ista before disassembly.

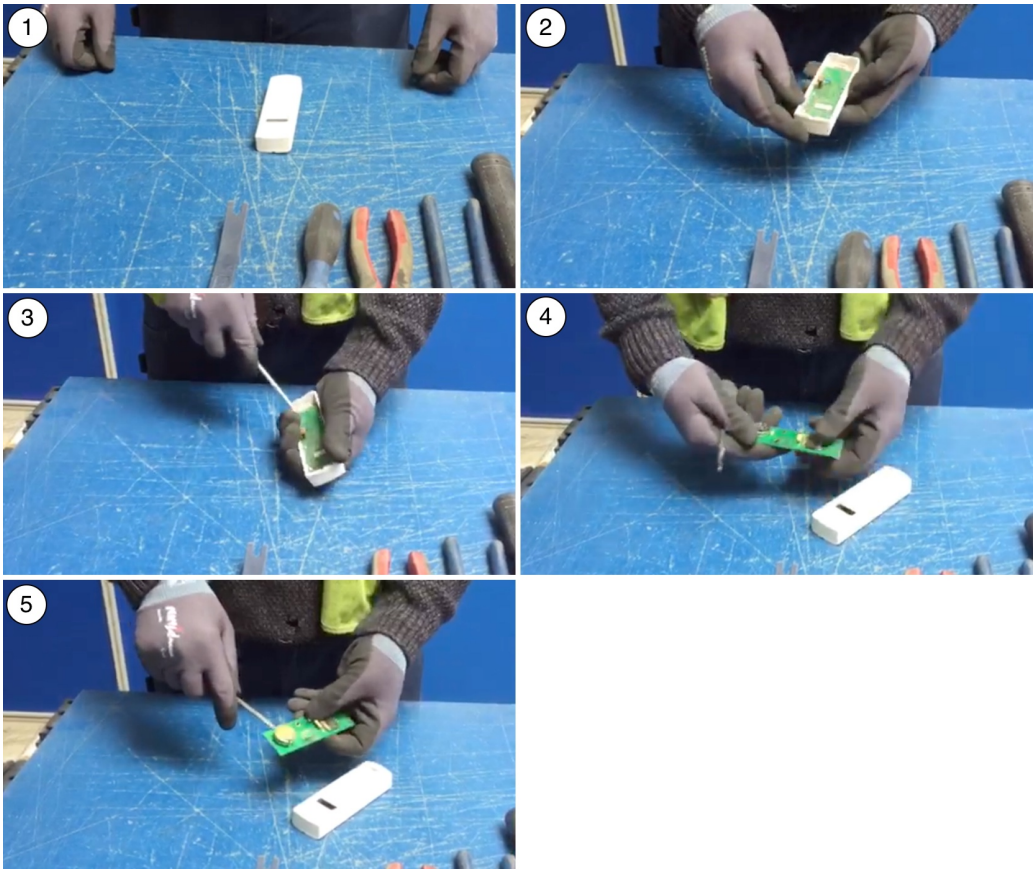

Figure 8: Manual disassembly of HCA Ista

2. The back of HCA Ista. On this model, the PCB is the only component inside the plastic housing.

3. Use a screwdriver to lever out the PCB from the housing by inserting the screwdriver between the housing and the PCB.

4. The PCB has been removed. The battery is a circular coin battery attached to the PCB.

5. The battery is removed with a levering action by placing the screwdriver in the gap between the battery and the PCB.

5.2 Disassembly Workflow for Fire Alarm, Type 2

The manual disassembly process for Type 2 fire alarm is shown in Figure 9. The steps illustrated in Figure 9 can be described as follows:

1. Device before disassembly.

2. A screwdriver is inserted into the back through a gap (same as in Section 4.1).

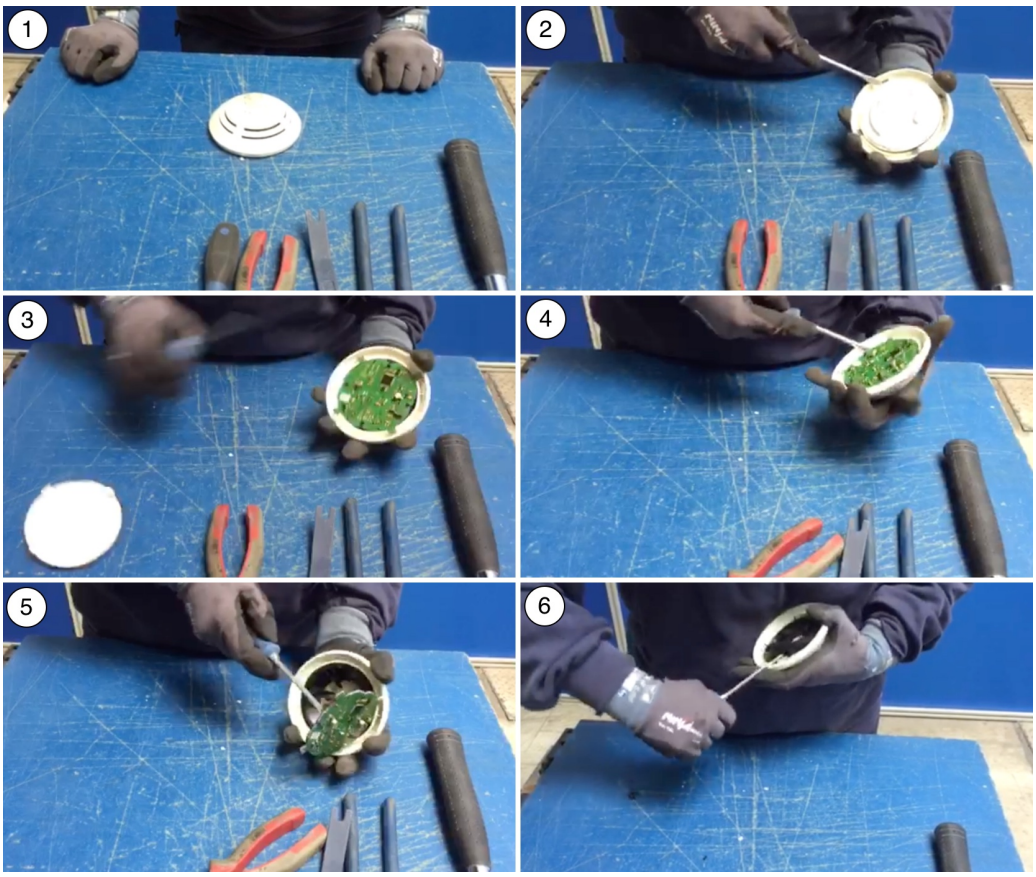

Figure 9: Manual disassembly of a fire alarm, Type 2

3. The back panel is removed by the levering action using the screwdriver.
4. The screwdriver is inserted in the gap between the PCB and the plastic housing.
5. The PCB is levered out.
6. The inner housing section is levered out.

The disassembly workflow for Type 2 fire alarm is similar to the disassembly workflow for Type 1 fire alarm in Section 4.1. The same levering action is used to open the plastic enclosure.