

PAPER • OPEN ACCESS

On designing an automated tool for capacitors removal from waste printed circuits boards

To cite this article: C Stamate *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **591** 012082

View the [article online](#) for updates and enhancements.

On designing an automated tool for capacitors removal from waste printed circuits boards

C Stamate¹, I Doroftei¹, D Chirita¹ and A Burlacu²

¹"Gheorghe Asachi" Technical University of Iasi, Department of Mechanical Engineering, Mechatronics and Robotics, Blvd. Mangeron, No. 43, 700050, Iasi, Romania

²"Gheorghe Asachi" Technical University of Iasi, Department of Automatic Control and Applied Informatics, Blvd. Mangeron, No. 27, 700050, Iasi, Romania

E-mail: aburlacu@ac.tuiasi.ro

Abstract. The mass electronics sector is one of the most important sources of waste, both in terms of volume and materials content with dangerous effects on the environment. Printed Circuit Boards (PCBs) are the most valuable component embedded into Electrical and Electronic Equipment (EEEs). The current amount of electronic systems is impressive while manual dismantling is a very common and non-efficient solution. On average, waste PCB accounts almost from 3% to 5% of the overall weight of waste electrical and electronic equipment. At this time, in Romania, the implemented solutions for waste PCB reduction are in a research phase, with no existing technological procedures that can be replicated. In the context of the TRADE-IT project we aim to design replicable architectures for waste printed boards reduction. Starting from the largest base plate and continuing to the smallest size, Extended ATX, ATX, Micro ATX, Mini ITX are some of the most used boards in a computer. When choosing a base plate from the ATX and/or microATX range, the shape factor must fit on a universal support bracket. The shape factor identifies the size of the circuit board, the location of the slots, and the location of the display board that comes out on the back of the computer. The shape factor also identifies the location of the holes that are used to mount the base plate in the universal clamp holder. Taking into account that capacitors represent approximately 8.6% of the PCB mass, we aim at designing an automated driven tool for their removal. The design is based on a robotic arm for motion manoeuvring, a programmable screwdriver and a custom-made end tool. In the current phase the proposed design was evaluated on controlled individual tests. The initial results highlight the feasibility of the proposed design while uncovering potential challenges for real-time implementation.

1. Introduction

The mass electronics sector is one of the most important sources of waste, both in terms of volume and materials content with dangerous effects on the environment [1, 2]. PCBs are the most valuable component embedded into Electrical and Electronic Equipment (EEEs). The current amount of electronic systems is impressive while manual dismantling is a very common and non-efficient solution [3]. On average, waste PCB accounts almost from 3% to 5% of the overall weight of waste electrical and electronic equipment. At this time in Romania the implemented solutions for waste PCB reduction are in a research phase, with no existing technological procedures that can be replicated. The goal of the current research is to design a replicable semi-automated architecture for mechanical



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

disassembly that will allow better management of waste printed circuit boards (WPCB) in the chemical decomposition stage.

The mechanical disassembly step is necessary in order to avoid unwanted problems [4]:

- risk of explosion when the extremely reactive inner of the Li batteries comes in contact with the leaching solution;
- risk of leaching solution contamination with extremely toxic polychloride-biphenyls presented in some cylindrical aluminium electrolytic capacitors;
- increased total time of leaching due to screws with high thickness;
- significant and unjustified consumption of leaching agent for the aluminium dissolution due to the small commercial value of aluminium and the difficulty of aluminium recovery from the resulting solution;

In the context of the TRADE-IT project [5], we aim to design replicable architectures for waste printed boards reduction. Starting from the largest base plate and continuing to the smallest size, Extended ATX, ATX, Micro ATX, Mini ITX are some of the most used boards in a computer. When choosing a base plate from the ATX and/or microATX range, the shape factor must fit on a universal support bracket. The shape factor identifies the size of the circuit board, the location of the slots, and the location of the display board that comes out on the back of the computer. The shape factor also identifies the location of the holes that are used to mount the base plate in the universal clamp holder.

Taking into account that capacitors represent approximately 8.6% of the PCB mass, we aim at designing an automated driven tool for their removal. The design is based on a robotic arm for motion manoeuvring, a programmable screwdriver and a custom-made end tool. In the current phase the proposed design was evaluated on controlled individual tests. The initial results highlight the feasibility of the proposed design while uncovering potential challenges for real-time implementation

In this paper we present the design of a custom tool for automatic dismantling and removal of capacitors from PCB. The proposed design is detailed while underlying the intermediary steps taken to reach the final prototype. Section 2 is dedicated to work motivation, while section 3 comprises with the design details. In the end experimental results are presented and conclusions are drawn.

2. Motivation

The design of the first prototype aims at improving the WPCB reduction by using two separated phase: a mechanical one and a chemical one. The mechanical pre-treatment aims at removing parts of the following categories: batteries, aluminium sinks, capacitors, screws (figure 1). The chemical phase

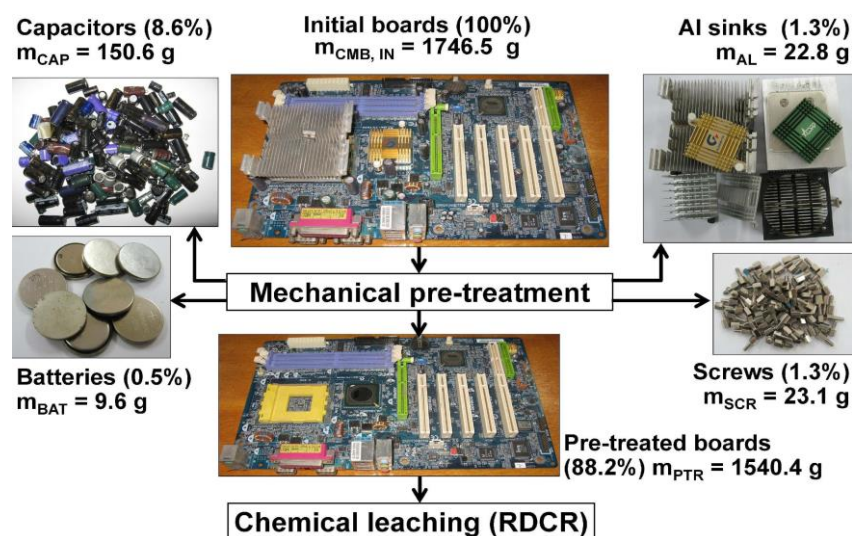


Figure 1. Flowchart of the semi-automated dismantling process [4].

is set to remove all exposed metallic parts simultaneous with the electrochemical lixiviants regeneration and the partial electrodeposition of the dissolved metals.

The mechanical phase is completed using a semi-automated procedure. The procedure is structured in two parts. First, a worker will disassemble the PCB by removing the batteries and the aluminium sinks. Next, the worker will place the PCB on a custom built frame positioned on a conveyor belt. This frame will ensure that the PCB can be transported and further manipulated by a robotic arm.

3. Custom tool design for capacitors removal

In this section the design for a custom tool for capacitors removal from waste printed circuit boards is presented. To activate the push-button with the Kolver Pluto 15 electric screwdriver, it was necessary to find an efficient solution to attach a proximity sensor to it. Due to the fact that almost all components of the extraction system are metallic, an inductive proximity sensor, low activation distances and voltage supply compatible with the screwdriver controller have been chosen, model EDU2AE/TOP/E [6].

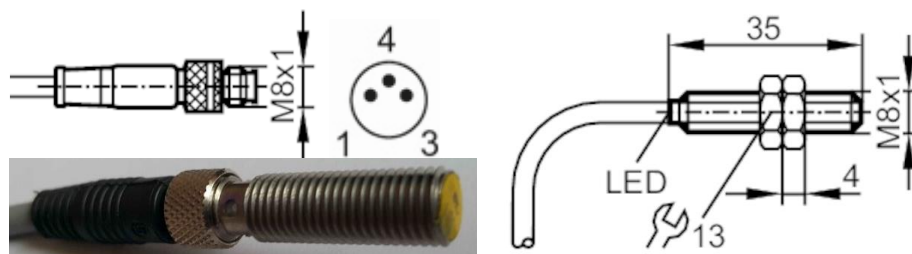


Figure 2. Technical characteristics of the inductive proximity sensor [7].

Figure 2 shows the geometric dimensions and output pin configuration for this type of sensor. The TS18-05N-1 sensor is PNP output, it operates at distances between $0 \div 5\text{mm}$, and it is supplied at an electrical voltage that can vary between 10-30V DC, with a maximum consumption of 100mA when it is activated.

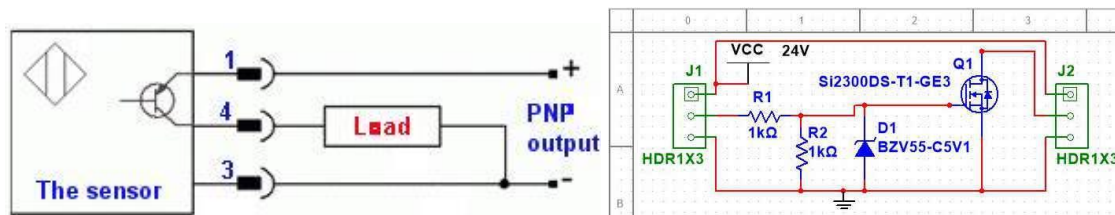


Figure 3. Circuit design for inductive proximity sensor activation.

Between the signal transmitted by the inductive proximity sensor and the EDU2AE / TOP / E electric screwdriver controller, it was necessary to interpose a 24V signal conversion module to a 5V logic signal. When the sensor is activated, a voltage of 24V is to be transmitted through a voltage divider in the MOS-FET grid Q1, which will give the 5V input of the controller to the GND (figures 3 and 4). In turn, the controller with the program for electrolytic capacitor extraction will be charged and will activate the electric screwdriver.



Figure 4. Implementation of the electrical circuit for inductive proximity sensor activation.

Thus, in order to determine the height and the pressing force that the robotic arm should use in positioning the final tool for extraction, a device with a spindle driven by the programmable screwdriver, whose metallic core is mobile, is experimentally designed. This mobile metallic core is held in a neutral position of two springs in opposite directions and has a chuck attached to the end tool, and at the other end a capacitive proximity sensor (figure 5) is positioned.

This device must be moved in the working area by the robotic arm in the motion coordinates on the three X, Y and Z axes. To extract the capacitors from the motherboard, the final tool attached to the screwdriver head will descend on the z axis to a certain distance imposed on the program. The advantage of this tool is that it does not require very high precision for positioning on the Z axis.

This device just needs to be positioned above the center of the extraction condenser and lowered until the spindle reaches the aluminium surface. While the robotic arm will advance on the z axis, this device will slide back as a result of the action of tensed arcs that will resist mechanical resistance. This elastic pushing force is controlled and its adjustment is made by the position of the capacitive proximity sensor.

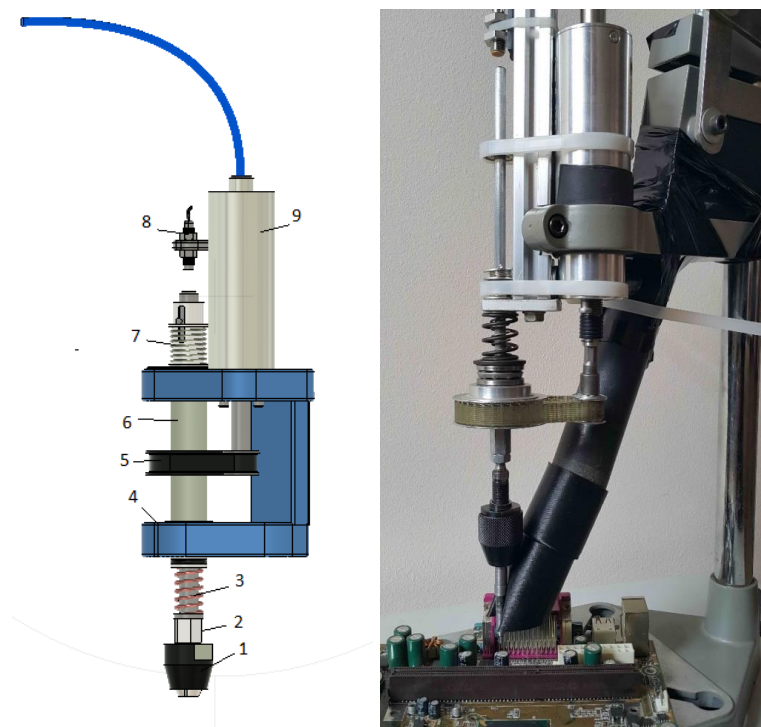


Figure 5. Custom tool elements: 1-Chuck; 2-Sliding axle with chuck; 3-Fastening spring; 4-Device support; 5- Bearings; 6- Toothed wheel assembly connected with strap; 7- The axis of rotation; 8- Spring to hold the spindle in the work area; 9- Capacitive proximity sensor with possibility of adjustment in the working area; 10-Programmable screwdriver.

The pushing force of the end tool in the head of the pretensioning spring pin can be adjusted between 9N and 15N. Separately, two resilient pushing forces are provided until the inductive proximity sensor is activated: the elastic force of the firm gripping spring with values between 20 and 30N and the elastic force of the movable spindle holding spring in the working area between 35 and 45N. The total required push force can be adjusted and ranges between a minimum value of 64N and a maximum value of 90N.

By activating the proximity sensor, stopping the robotic arm movement and turning on the programmable screwdriver, which acts through the mobile spindle multiplication system. The mobile spindle rotates according to the program, thus rotating the final tool with which we pull out the

capacitor link pins by twisting. When the programmable screwdriver is completed, the robotic arm performs a retraction movement from the work area, up to a fixed point in the air, and then moves to the emptying area of the final tool. The cycle will be resumed but to another working point.

During the experiments using the final teeth tool, it was found that by attaching a mobile spring plate it is possible to empty the final tool. Thus, the robotic arm does not perform an extra displacement manoeuvre to empty the final tool, but must climb a number of steps on the Z axis, then resume the cycle to another extraction point.

As a consequence of these results, the final tool was redesigned, attaching inside the rod with teeth, a mobile shaft driven by a spring for emptying at the end of the extraction. This location of the spindle has been chosen because in some cases the capacitors are grouped more tightly and should not be moved from their position.

4. Experimental results

Following the selection of five standard ATX motherboards for tests, the following analysis has been performed. The electrolytic capacitor extraction tests were performed on a batch of 5 different base plates of the ATX dimensional standard. Several selection features were considered in these baseplates: the diameter of the electrolytic capacitors to be as varied (from 4 mm to 10 mm).



Figure 6. Standard ATX motherboards with liquid dielectric electrolytic capacitors.

All plates have electrolytic capacitors with liquid dielectric and additionally only plate 4 has electrolytic capacitors with solid dielectric. Analysing the capacitors on the plate of figure 6 it was observed that in terms of diameter (D) and height (H) relative to the plate, they can be classified into several classes:

- Class 1 capacitors with $D = 10 \text{ mm}$ and $H = 25 \text{ mm}$
- Class 2 capacitors with $D = 8 \text{ mm}$ and $H = 18 \text{ mm}$

- Class 3 capacitors with $D = 8$ mm and $H = 15$ mm
- Class 4 capacitors with $D = 8$ mm and $H = 12$ mm
- Class 5 capacitors with $D = 5.2$ mm and $H = 8$ mm
- Class 6 capacitors with $D = 4.2$ mm and $H = 8$ mm

From this analysis it is observed that at the same diameter (D) of capacitors we have different (H) constructive heights.

During the extraction period a single program was used for the programmable screwdriver 5 with the following feature. The working time of the screwdriver was set to 5 seconds, increasing torque, and the 1/3 scrapping device had the final gear of 6 to 7 complete rotation. During the tests, it was found that the pins of the capacitors of any size class were torn in the 2-3 strokes, the rest of the rotation being extra.

After performing the first tests of extraction capacitors on the chosen motherboard using the last version of the final tool with a diameter of 6 mm, we found the following: The vertical mounting bracket for the drill bit, which was used to attach the experimentally built device, shows side games; The device worked well with the final tool on capacitors in classes 1, 2, 3 and 4. On capacitors in classes 5 and 6, any deviation from the center of the capacitor diameter, throws the final tool or capacitor off the axis of rotation of the final tool. This is due to the low rigidity of the support on which our device was attached.

In an analysis of extracted capacitors, it was found that the diameter of the final tool has influence on the flat surface of the capacitor on which it acts. At capacitors with a surface area greater than 6 mm, as the final tool, a plastic deformation occurs when pressing the final tool for firm grip.

At class 1 capacitors, the final tool dropped 1.2 mm in the capacitor mass and in one case the capacitor did not turn to break the condenser legs. At class 2, 3 and 4 capacitors, the working teeth of the final tool plunged into the capacitor surface, and at the 5 and 6 capacitors, they sank 0.2 mm only in the tip area of the final tool teeth. This demonstrates that the diameter of the final tool must be as close to the diameter of the extracted condenser. In addition to the class 5 and 6 capacitors the liquid dielectric has not been released from the inside of the aluminum cylindrical housing during its torsion until it breaks the contact terminals from the PCB, which demonstrates that it is an efficient method of extracting capacitors from the ATX motherboards (figure 7).

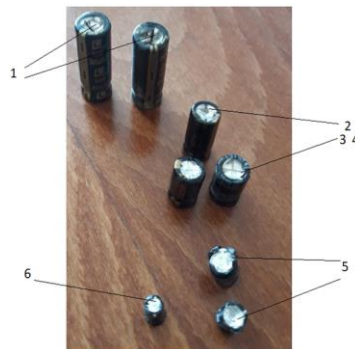


Figure 7. Deformation of the flat surface of the condensers during extraction.

During the tests a vacuum cleaner head of various shapes was attached (figure 8) and due to the minimum distance it was laid out, the area from which the condenser and the suction head were extracted, it was found that: it has no absorption power for the capacitors in the classes 1, 2, 3 and 4. It should also be added that it was not possible to add a vacuum suction accent to the extraction area because the final tool could no longer be visually positioned.



Figure 8. The final tool with a condenser cutter on the tool head.

Figure 8 shows the CAD model of the final tool (left image) and the component parts of this subassembly (right image) with which the electrolytic capacitors were extracted from the ATX motherboards. The final tool is made up of a metallic cylinder inside of which a pin is pushed by a spring and locked by a screw. The pushing force adjustment of the pin that will release the capacitor attached to the tip of the end tool will be done by spring pre-tensioning with the adjustable screw cap between 9 N and 15 N. The end piece of the final tool was machined in the form of a teeth, followed by hardening and anticorrosion treatments to withstand mechanical wear, respectively chemical

5. Conclusions

This work was focused on designing a custom tool for capacitors removal from waste printed boards. This research was done in the context of new technologies for improving recycling waste printed circuit boards. The goal was to design a tool that will automatically remove capacitors from waste printed circuit boards. The tool is built using a programmable screwdriver, a capacitive proximity sensor and a custom end-effector. The design was a result of multiple analyses on the waste printed circuit board construction and on the type of the capacitors used for implementation. In the current stage the validation and measurements on effectiveness of the tool were carried on different types of printed boards. These preliminary tests revealed good results and future work will include tests with a robotic arm that are aimed to evaluate the tools performance in automated extraction procedures.

6. References

- [1] Perez-Belis V, Bovea M and Ibanez-Fores V 2015 An in-depth literature review of the waste electrical and electronic equipment context: trends and evolution *Waste Management & Research* **33** 3-29
- [2] Zeng X and Li J 2016 Measuring the recyclability of e-waste: an innovative method and its implications *Journal of Cleaner Production* **131** 156-162
- [3] Achillas C, Aidonis D and Vlachokostas C 2013 Depth of manual dismantling analysis: a cost-benefit approach *Waste Management* **33** 948-956
- [4] Dorneanu S-A 2017 Electrochemical recycling of waste printed circuit boards in bromide media. Part I: preliminary leaching and dismantling tests *Studia Universitatis Babes-Bolyai, Chemia* **62** 177-186
- [5] *** Proiect PN-III-P1-1.2-PCCDI-2017-0652, TRADE – IT <https://tradeit.utcluj.ro/>
- [6] *** Product catalogue KOLVER Control units, EDU 2AE/TOP/E, 2018
- [7] *** Product catalogue IE5388, Inductive sensor, IEB3002BAPKG/0,8M/FH/AS, 2016

Acknowledgments

This work was supported within the research program PN-III-P1-1.2-PCCDI-2017-0652, project No. 84PCCDI - 01/03/2018 TRADE-IT, TORA.