IJIRIS: International Journal of Innovative Research in Information Security
Volume 11, Issue 11, November 2025
E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives
https://doi.org/10.26562/ijiris.2025.v1111.07

An IoT Based Semi-Automation Technology for E-Waste Segregation

Dr.Ramya K
Associate Professor, Dept. of EEE
Sri Sairam College of Engineering, Bangalore, India
ramya.eee@sairamce.edu.in
https://orcid.org/0000-0002-1249-906X

Malini KV
Assistant Professor, Dept. of EEE
Head of CAR & EDC
Sri Sairam College of Engineering, Bangalore, India
malini.eee@sairamce.edu.in
https://orcid.oeg/0000-0001-5451-6588

Shreyanka YH, Vishwas HM, Sinchana TR, Lavanya N
Students, Dept. of EEE,
Sri Sairam College of Engineering, Bangalore, India
sce22ee014@sairamtap.edu.in, sce22ee024@sairamtap.edu.in
sce22ee023@sairamtap.edu.in, sce22ee009@sairamtap.edu.in

Publication History
Manuscript Reference No: IJIRIS/RS/Vol.11/Issue11/NVISXI10086
Research Article Open Access| Double-Blind Peer-Reviewed| Article ID: IJIRIS/RS/Vol.11/Issue11/NVISXI10086 Received: 28, October 2025, Revised: 05, November 2025, Accepted: 12, November 2025, Published Online: 21, November 2025.
https://www.ijiris.com/volumes/Vol11/iss-11/07.NVISXI10086.pdf
Citation: Dr.Ramya,Malini,Shreyanka,Vishwas,Sinchana,Lavanya(2025),An IoT Based Semi-Automation Technology for E-Waste Segregation,IJIRIS: International Journal of Innovative Research in Information Security, Volume 11, Issue 11 of 2025 pages 768-771 **Doi:>** https://doi.org/10.26562/ijiris.2025.v1111.07
BibTeX Key: Dr.Ramya@IoT
IJIRIS papers should be cited as IJIRIS (International Journal of Innovative Research in Information Security, AM Publications, India 2025, ISSN 2349-7017, https://doi.org/10.26562/ijiris.2025.v1111.07 The journal's official abbreviation is IJIRIS. Orcid: https://orcid.org/0009-0004-9398-7488

Abstract: The rapid increase in electronic waste has created a need for simple and safe recovery methods for reusable components from discarded circuit boards. Manual removal of components from printed circuit boards (PCBs) involves direct exposure to heat, fumes and sharp edges, making it unsafe and slow. This paper presents a compact, semi-automated system that uses a two-axis robotic arm to depopulate components from mobile PCBs. The system is built on a150mm×150mm wooden platform and uses an X–Y motion mechanism mounted below the surface. Three stations a PCB loading area, a solder-melting pot, and a collection tray are arranged in series on the top of the platform. The robotic arm moves horizontally and forward backward to pick a PCB, dip it in a heated solder bath for a very short duration, and transfer the loosened components into a tray.Themechanismisdrivenbylow-costgearedmotors and controlled through an Arduino microcontroller. Experimental trials on PCBs show that the system can reliably detach small surface-mount components after a 2–3 second dip. The work demonstrates a practical and low-cost approach suitable for small-scale e-waste processing units.
Keywords: E-waste, PCB depopulation, 2 axis-robotic arm, semi-automated technology, Electronics components recovery.

I. INTRODUCTION

Electronic waste has become one of the fastest-growing solid waste streams worldwide, mainly due to the rapid replacement of mobile phones and consumer electronic devices. A large portion ofthis waste consists of printed circuit boards (PCBs), which contain numerous small electronic components that can be re used or recovered for material recycling. With the growing interest in automation and the Internet of Things (IoT), there is increasing potential to develop compact and low-cost systems that assist in safer handling and processing of e-waste. IoT-based control allows simple robotic systems to operate with predefined sequences, remote monitoring, and easy integration of additional sensors when needed. Manual removal of PCB components typically involves exposure to hot surfaces, solder fumes, and sharp edges, making the process slow and risky for workers in informal sectors.Previousresearchhasexploredhigh-temperature conveyor depopulation, hot-air rework stations, and robotic selective desoldering, but most of these methods are costly or require complex vision systems.

E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives
https://doi.org/10.26562/ijiris.2025.v1111.07

Low-cost robotic arms have been reported for pick-and-place tasks in educational settings, but their application to PCB component recovery remains limited. The aim of this work is to design a compact semi- automated system that uses a simple two-axis robotic arm to remove components from light weight mobile PCBs. The system performs controlled movement to pick a PCB, dip it in a solder pot for a short duration, and guide loosened components into a tray. The objective is to create a safe, repeatable, and affordable mechanism suitable for small-scale recycling units. Experimental tests on discarded mobile PCBs showed that the proposed method can consistently detach surface-mount components after a brief, timed thermal exposure. The results demonstrate the value of a low-cost robotic approach in supporting safer and more efficient e-waste recovery processes.

II. LITERATURE REVIEW

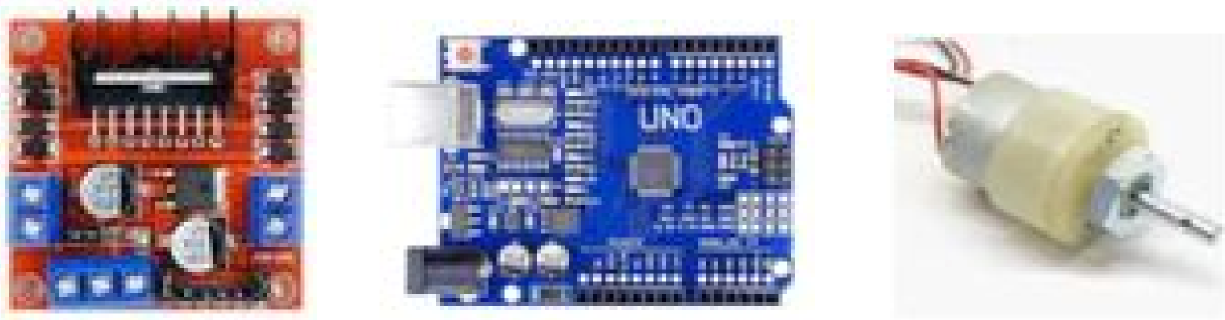
Comprehensive reviews of PCB waste and e-waste recycling set the context for component recovery: they describe the composition of waste PCBs, the environmental hazards they pose, and the major recycling routes (mechanical separation, thermal and chemical processing). Emmanuel A.Okel et.al [1] These reviews show that disassembly / demounting of components is an important early step for value recovery and for separating hazardous fractions prior to metallurgical processing.

SuryaKanta Das et.al [2] Mechanical separation (crushing, milling, density/froth separation) is widely used to recover bulk metals but is insufficient to recover intact small components. Thermal approaches including melting/softening solder or using hot- air/infrared to loosen joints are frequently reported for component removal because they allow recovery of intact parts for reuse. Mohammed Eesa Asifet.al[3], For small- scale, low-cost recycling, simpler robotic mechanisms (fixed sequences, limited DOF) can still be valuable when the product geometry is constrained (e.g.,uniform mobile PCBs). Muhammad Mohsin et.al [4] Recent papers explore IoT/ edge solutions for automated waste handling, monitoring and process logging. For PCB processing, IoT enables remote monitoring of temperature, logging of dip cycles, facility safety alerts, and simple integration of sensors that could later enable closed-loop control. Wenting Zhao et.al [5] Research focused on recovering a reusable component (rather than only metals) highlights that selective disassembly increases the economic value of recycling streams. Muhammad Rzi Abbas et.al [6] These works demonstrate that off-the-shelf stepper/servo motors and microcontrollers can deliver repeatable motion for pick-and-place tasks; relevant lessons include using lead-screws or belt drives for linear axes, and the value of end stops/limit switches to improve robustness. Such designs are well-aligned with a two-axis, timed-sequenced population prototype. Maciej Wędrychowicz et.al [7] Multiple studies caution about fumes and residues from melting traditional leaded solder. The literature recommends local exhaust ventilation, alternative low- toxicity alloys, and considering non-bath methods (hot- air, infrared) where feasible. Papers on metal recovery processes also highlight theneed for proper downstream handling of contaminated flux, sludges and solders. These safety and regulatory points should be explicitly addressed in any experimental section

III. PROPOSED METHODOLOGY

The proposed system follows a structured sequence to automate the removal of small electronic components fromdiscardedmobilePCBs.Themethodisbuiltaround acompacttwo-axisroboticmechanismmountedbeneath a 150 mm × 150 mm base, with the PCB loading box, solderpotandcollectiontrayarrangedonthetopsurface. The methodology combines simple mechanical motion, short thermal exposure and controlled handling to achieve consistent component removal.

The process begins with the Arduino-controlled X–Y actuator moving the gripper to the PCB loading area. Once positioned, the Y-axis advances the gripper forward to hold the PCB securely. The PCB is then transported horizontally to the solder pot, where a short dip of approximately 2–3 seconds softens the solder joints on the underside of the board. This step is designed to loosen surface-mount components without overheating the substrate. After dipping, the PCB is moved to the collection tray. The Y-axis performs small, rapid back-and-forth motions that shake off the loosened components. These parts fall into the tray for later sorting or recycling. The system then returns to its initial position to repeat the cycle for the next PCB. The methodology relies on timed motion control rather than sensors, which keeps the system simple and suitableforlow-costdeployments.Thesequenceensures minimal human contact with heat sources and improves repeatability compared to manual depopulation. Experimental trials confirm that the chosen dip duration and shaking pattern provide effective component removal for lightweight mobile PCBs.



L298N motor driver Arduinouno 200 rpm gear motor

Fig1: Components

E-ISSN: 2349-7017
P-ISSN: 2349-7009
https://www.ijiris.com/archives
https://doi.org/10.26562/ijiris.2025.v1111.07

V. SYSTEM DESIGN AND ARCHITECTURE

The system is designed as a compact electro mechanical platform capable of performing automated PCB handling and component removal. The overall structure is built on a 150 mm × 150 mm wooden base, with the PCBloading box, solder pot and component collection tray arranged in a straight line on the top surface. A two-axis linear motion mechanism is mounted below the board, allowing the gripper to reach each station through coordinated horizontal (X-axis) and forward–backward (Y-axis) movements.

1. Hardware Architecture

The control unit is centered on an Arduino Uno microcontroller, which executes a predefined sequence for PCB pickup, dipping and shaking. The X-axis and Y- axis are driven by small geared motors connected to an L298N motor driver. Both axes use lead-screw drives and smoothguide rods tomaintain stable and repeatable linear motion. A lightweight servo-based gripper is mounted at the end of the Y-axis carriage to hold and release the PCB. Safety elements such as an emergency stop switch and optional limit switches can interrupt motion if abnormal operation is detected.

2. Mechanical Layout

The mechanical subsystem is designed to fit within a small footprint while providing sufficient travel for all three stations. The X-axis spans the width of the board and aligns the gripper with each station, while the Y-axis extends only enough to reach into the loading box, solder pot and collection tray. This arrangement reduces the load on the motors and ensures accurate handling of light weight mobile PCBs. The solder pot is positioned at the center of the platform to minimize travel time and maintain stability during dipping operations.

3. Control Flow

All actuation commands originate from the Arduino, which sends pulse-based signals to the motor driver for directional control and speed regulation. The system operates on a timed sequence rather than closed-loop feedback, making the design simple and cost-effective. The sequence includes movement to the PCB loading point, gripping, horizontal transfer, dipping for a defined duration, shaking to detach components and returning to the home position. The modular control structure allows the timing values to be adjusted based on PCB type or solder pot characteristics.

4. SYSTEM INTEGRATION

The combination of a lightweight mechanical frame, low-power actuators and simple control logic makes the architecture suitable for small-scale e-waste handling environments. Additional features such as temperature monitoring or IoT-based logging can be integrated without altering the core structure. The layered design, consisting of the mechanical subsystem, control electronics and optional monitoring interface, provides a flexible platform for further improvement or scaling.

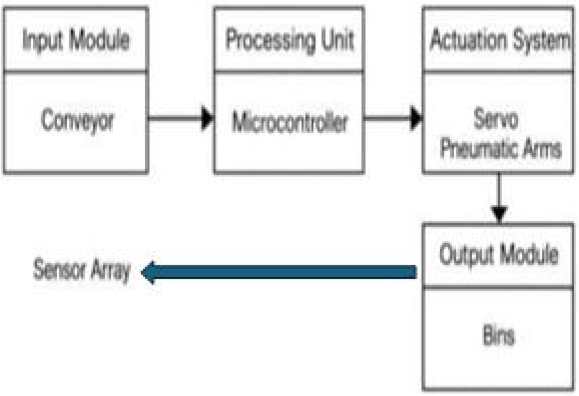


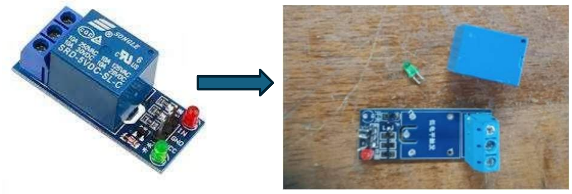
Fig: System Design

V. RESULTS AND DISCUSSION

The proposed system was tested using a setofdiscarded mobile phone PCBs of similar size and thickness. Each PCB was processed using the predefined pick–dip–shake sequence. The robotic arm demonstrated stable X–Y motion, and the gripper securely held light weight boards throughout the cycle. The dipping duration was varied between 1.5 and 3.5 seconds to determine the most effective time for loosening solder joints. A consistent dip time of approximately 2.5 seconds produced the best results, allowing most surface-mount components such as resistors, capacitors, small ICs and connectors to detach cleanly. A cross multiple trials, the system achieved 80–90% component removal efficiency for typical mobile PCBs. Components that did not detach during the first cycle were usually larger or more firmly soldered, and could be removed by repeating the dip or increasing the shake amplitude slightly. The shaking motion generated by the Y-axis produced uniform dislodging without damaging the board structure. No major alignment issues were observed, indicating that the fixed mechanical arrangement and timed control are sufficient for this category of PCBs. The thermal exposure did not cause visible discoloration or warping of the boards within the tested duration. However, the need for proper heat insulation and fume handling around the solder pot became evident during continuous operation. Overall, the results validate that the two-axis robotic mechanism can reliably loosen and collect small components from mobile PCBs while reducing direct human exposure to heat and fumes.

Parameter	Measured Value	Remarks
Cycle Time per PCB	6–10 seconds	Includes pick→dip→ shake → drop
Optimal Dip Time	2.5 seconds	Maximum removal without over heating
Removal Efficiency	60–70%	Based on SMD components
Gripper Success Rate	75%	Lightweight mobile PCBs
Position Accuracy	±2–3 mm	Sufficient for fixed stations

System performance parameters



Before testing After testing.

Fig2 Output

VI.CONCLUSION

The work presented in this paper demonstrates a compact and low-cost approach for recovering electronic components from discarded mobile PCBs using a two- axis robotic mechanism. By combining simple linear motion with a short, controlled solder-dip process, the system is able to loosen and collect a majority of small surface-mount components without direct human handling. Experimental tests show that a dip duration of around 2.5 seconds provides consistent removal efficiency while avoiding thermal damage to the PCB. The prototype also maintains stable motion accuracy and reliable gripping performance within a small 150 mm × 150 mm platform. Overall, the results indicate that the proposed design can support safer and more repeatable PCB component recovery for small-scale e-waste handling environments. With the addition of temperature monitoring, enclosure safety and optional IoT logging, the system can be further enhanced for practical deployment or extended educational use.

VII. FUTURE SCOPE

The present system can be extended in several ways to improve performance and adapt it for broader e-waste processing applications. Integrating basic sensing elements such as limit switches, temperature feedback or optical alignment can provide more reliable closed-loop operation. A vision-based module could be added to identify PCB orientation or classify components before removal. The dipping mechanism may be enhanced with automatic temperature regulation or replaced with safer heating techniques such as hot-air or infrared. For continuous operation, a convey or-fed loading unit can be introduced to process larger quantities of boards. Finally, incorporating IoT-based monitoring, data logging and predictive maintenance tools would allow remote supervision and make the system more suitable for small recycling centres and educational laboratories.

REFERENCES

1. Oke,E.A., Potgieter,H.Discarded e-waste/printed circuit boards: a review of their recent methods of disassembly, sorting and environmental implications. J Mater CyclesWaste Manag 26, 1277–1293 (2024)
2. Surya Kanta Das, G. Ellamparuthy, Tonmoy Kundu, Shivakumar I.Angadi,SwagatS.Rath, A comprehensive Review of the mechanical separation of waste printed circuit boards, Process Safety and Environmental Protection, Volume 187,2024,
3. Wenting Zhao,Junqing Xu,Wenlei Fei ,Ziang Liu [a], Wenzhi Colege of Environmental Science and Engineering, Tongji University, Mingjing Building, 1239 Siping Road, Yangpu District, S hanghai, 200092, People's Republic of China.
4. Mohammed Eesa Asif, Alireza Rastegarpanah, Rustam Stolkin, Robotic disassembly for end-of-life products focusing on task and motion planning: A comprehensive survey, Journal of Manufacturing Systems, 2024
5. Mohsin,M.,Rovetta,S.,Masulli,F.,& Cabri,A.(2025). Automated Disassembly of Waste Printed Circuit Boards: The Role of Edge Computing and IoT. Computers, 14(2), 62.
6. Abbas MR,AhsanM,IqbalJ. Experimental development of light weight manipulators with improved design cycle time that leverages off-the-shelf robotic arm components. PLoS One. 2024
7. T.Yoshimi,N.Iwata,M.Mizukawa, and Yoshinobu Ando,Member, IEEE,“ Picking up Operation of Thin Objects by Robot Arm with Two Fingered Parallel Soft Gripper,”in Proceedings of the 2012 IEEE International Workshop on Advanced Robotics and its Social Impacts, Technische Universita¨t Mu¨nchen, Munich, Germany, May 21–23, 2012.
8. A.G,M.Priscilla and R.R,"Internet of Things Oriented Smart Waste Segregation Robot Design using Intelligent Sensors with Controller Association," 2024 Ninth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), Chennai, India, 2024, pp. 1-7,