3D Printed PCB with Detachable SMD Components without Soldering

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Abstract—As more and more electronic gadgets are being manufactured, this accumulates a large number of electronic parts. Sometimes, if any of the components get defected, the entire circuit is thrown away, thereby creating a substantial amount of electronic waste. This waste can be harmful to the environment and people's health. To tackle this problem, the idea of fixing and reusing electronic components in circuit boards instead of throwing them away. 3D Printed PCBs with detachable SMD components is the method to prototype circuit boards without soldering, reducing electronic waste. It uses 3D-printed housings to attach surface mounted device (SMD) components safely.

Keywords: 3D-Printed-Circuit, E-Waste, Sustainability, Detachable SMD Components, Reuse of Electronics, Without-Solder, Recycling.

I. INTRODUCTION

Circuit prototyping is essential for designing products. There are distinct distinctions between the two circuit prototype phases. Engineers and designers may rapidly create a circuit using breadboard circuitry by simply putting jumper wires and through-hole components onto a typical breadboard. It provides the versatility to quickly adjust the circuit by reassembling broken pieces or swapping out electrical elements when errors are found. Custom PCBs are used, but they're less flexible and often end up as E-waste [10].

E-waste, or electronic garbage, is a significant component of solid waste management globally. This paper discussed one of the suitable solutions for the electronic waste like circuits, motherboard etc. Which contains concepts, numerous graphical representations and data analysis tables. This paper presents a new method called “3D Printed PCB with Detachable SMD Components without Soldering”, which helps to reuse the SMD components in circuit prototypes. It uses 3D-printed housings to attach SMD components to custom PCBs without soldering. This allows engineers to swap components easily, like they do with through-hole components on breadboards. There are two ways that it can promote the reuse of electronic components during prototyping. Our approach is demonstrated with an example of a PCB for an SMD LED bulb. The benefits of this method and ideas for further research directions before coming to a conclusion [1, 13].

1.1 E-Waste

Global solid waste management includes electronic trash as a significant component. This paper discusses a potential solution for electronic garbage, or "E-waste," a serious environmental problem.

In India, laws and the pollution control board manage E-waste handling. This study focuses on Maharashtra state, using ARIMA (Auto Regressive Integrated Moving Average) models to Forecast trends. The average recycling capacity for processing e-waste is projected to be 163,563.15 metric tons between 2023 and 2030. Recyclers are predicted to steadily rise throughout this time, reaching 248 by 2030. Per the analysis of the E-waste change rate from 2023 to 2030, there will be an annual change in processing capacity of 6.86%. Given that the number of recyclers will increase by 7.23% a year, it also emphasizes the potential for entrepreneurship in the e-waste recycling sectors. The report highlights the potential for expansion in the recycling sector as well as the significance of policies and decision-making in the management of e-waste.

The recycling, recovery, and disposal of e-waste are the main issues surrounding its management. Globally, between 20% and 30% of e-waste is recycled while precious metals like copper (Cu), platinum (Pt), silver (Ag), and gold (Au) are recovered. However, this process is extremely dangerous and has a negative impact on people's health. The majority of e-waste is burnt at high temperatures or disposed of in landfills, and the facilities for disposing of it have not been well studied or recorded. Nevertheless, neither of the strategies is safe for the environment.

Fig. 1. Rising of Electronics Waste (e-waste).

When disposed of incorrectly, e-waste, which contains hazardous elements including lead, mercury, cadmium, and more, can endanger soil and water ecosystems. Using the right metal extraction techniques and carefully disassembling components, separating them according to their chemical makeup, are necessary for effective management. [5].

Table 1. E-waste Generation and Processed data for the years 2017–18 to 2020–21 in India [2].

E-waste management components	**2017–18**	**2018–19**	**2019–20**	**2020–21**
E-waste generation in India	708,445	771,215	1,014,961	1,346,496
E-waste processed in India	69413.61	164,663	224,041	354540.7
Hazardous waste recycling indicator (%)	9.80	21.35	22.07	26.33

$$Hazardous\ waste\ Indicator\ Value\ in\ 5(\%) = \frac{\text{Quantity of hazardous waste recycled or utilized in MT}}{\text{Total quantity of hazardous waste generated in MT}} \times 100$$

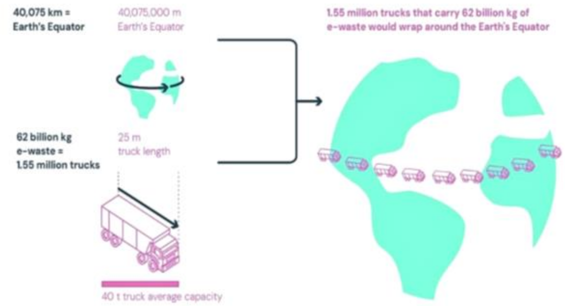
Recycling has three main advantages: a) financial gains; b) ecological advantages; and c) societal advantages [5]. The drawback of e-waste is that, due to its toxic components, it can seriously endanger human health as well as environmental elements like air, water, and soil when improperly processed [9].

Table 2. Rate of change will occur in waste processing capacity and number of recyclers from 2014 to 2030 [2].

Year	E-Waste dismantling / recycling capacity in MT	Rate of change in %	Number of Recyclers	Rate of change in %
2015	48,060	36.11	32	25.00
2016	55,410	15.29	38	15.79
2017	74,650	34.72	64	40.63
2018	77,525	3.85	78	17.85
2019	63,879	-17.60	73	-6.85
2020	85,800	34.32	99	26.26
2021	89,355	4.14	111	10.81
2022	117,392	31.38	136	18.38
2023	127652.3	8.74	150	9.33
2024	137912.5	8.04	164	8.54
2025	148172.5	7.44	178	7.87
2026	158,433	6.92	192	7.29
2027	168693,3	6.48	206	6.80
2028	178953.5	6.08	220	6.36
2029	189213.8	5.73	234	5.98
2030	199,474	5.42	248	5.65

1.2 Key Global Statistics:

In 2022, the globe is expected to create 62 billion kilograms of electronic garbage annually. determined by advancements in technology, rising consumption, limited alternatives for repair, short life periods, and a lack of infrastructure for the treatment of electronic waste [12]. The quantity of EEE that was put on the market (POM) worldwide rose from 62 billion kg in 2010 to 96 billion kg in 2022. Figure 2 illustrates the predicted growth to 120 billion kg in 2030. The annual production of e-waste rose from 34 billion kg to 62 billion kg throughout that time. By 2030, it's expected to reach 82 billion kilograms. It is anticipated to surpass 82 billion kg by 2030.



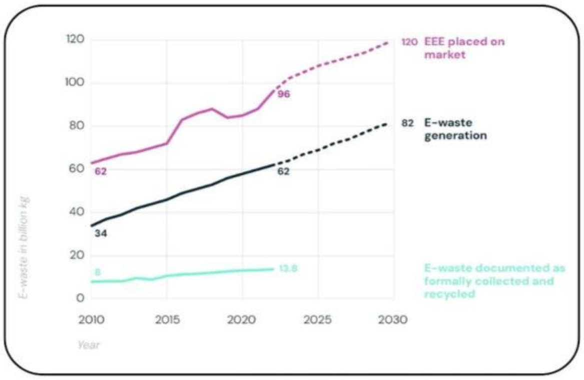


Figure 2: In 2010 There were 62 Billion kg of EEE Placed on the Market (POM); by 2022, there were 96 Billion kg. By 2030, it is Expected to Reach 120 Billion kg [24].

The quantity of e-waste that is officially recorded as collected and recycled has also advanced, from 8 billion kg in 2010 to 14 billion kg in 2022; however, this achievement has been eclipsed by the explosive rise in e-waste overall [24].

1.3 Composition of Global E-waste:

In terms of e-waste production per person, the Americas (14.1 kg), Oceania (16.1 kg), and Europe (17.6 kg) produced the most in 2022. These areas also possessed highly developed infrastructure for recycling, collecting, and treating waste; as a result, their per capita collection rates were the highest in Europe (7.5 kg), Oceania (6.7 kg), and America (4.2 kg) [24].

However, The European Union member states haven't made much progress towards meeting their legally mandated collection targets. Recycling rates are less than 1 per cent in African nations that produce the least amount of e-waste, yet also struggling with recycling it. Though they create over 30 billion kg, or half of the world's e-waste, Asian nations are still making poor progress in handling this garbage. The areas with the greatest per capita production of e-waste in 2022 were the Americas (14.1 kg), Oceania (16.1), and Europe (17.6 kg). Because they have the most developed infrastructure for collecting and recycling, these areas have the highest recorded per capita rates of collection and recycling (7.53 kg per capita in Europe, 6.66 kg per capita in Oceania, and 4.2 kg per capita in America) [24].

1.4 Amount of E-waste Generated and Collected:

Global e-waste production reached a record 62 billion kg in 2022, with an average of 7.8 kg created per year. Of this total amount of e-waste, a rate of 22 was formally collected and recycled in an environmentally responsible way.

In 2010, 34 billion kg of e-waste were produced worldwide; on average, this amount has risen by 2.3 billion kg every year. Furthermore, the official reported rate of collection and recycling has grown, with an average annual rise of 0.5 billion kg from 8 billion kg in 2010 to 13.8 billion kg in 2022.

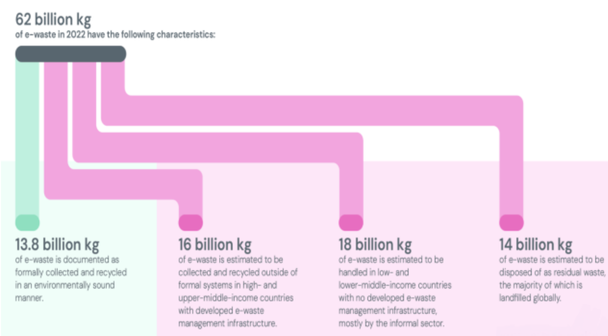


Fig. 3. E-waste generated and collected in Year of 2022 [24].

As a result, the creation of e-waste is growing at a rate that is roughly five times faster than the increase of official recycling. This is brought on by advancements in technology, more consumption, increasing electronification, short product life cycles, fewer alternatives for repairs, and a lackluster infrastructure for managing e-waste [24].

1.5 Formal Collection and Recycling of E-Waste:

Digital photographic equipment, toys, home appliances, electronic gadgets are the greatest group of e-waste in terms of mass. According to 2020 accounting, this category accounted for 20 billion kg, or about one-third of all e-waste produced worldwide. Large equipment, excluding solar panels, is another largest category with 15 billion kg in 2022. Lamps weighing 2 billion kg are the lowest category after photovoltaic panels. 5.9 billion kg, or 10%, of the e-waste produced by screens and monitors is now produced. In 2022, there will be 5 billion kg of small IT and telecom equipment, such as cell phones, GPS units, routers, desktop computers, printers, and phones. The globe produced 7.8 kg of e-waste and 62 billion kg of e-waste per person in 2022; of these, 13.8 billion kg and 1.7 kg per person were officially documented as e-waste that is collected, for a globally reported collection and recycling rate of 22.3 percent, as shown in figure 4 above [24].

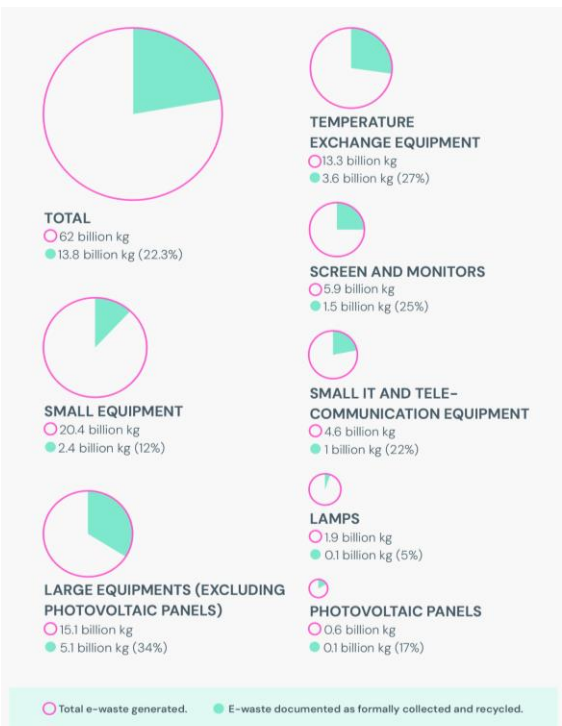


Fig.4. largest category of e-waste [24].

II. RELATED WORK

2.1 Electronics Refurbishment & Redeployment:

Researchers are working on recycling methods for standard PCB waste, but these methods aren't widely applicable yet. Some efforts are exploring alternative materials like paper, wood and water-soluble substances for sustainable PCBs that can be easily recycled [8, 14, 16].

In terms of component reuse, some projects like Curve Boards [17], propose custom shaped breadboard designs to reuse through-hole components. Others everyday use objects like binder clips for easy circuit disassembly [18]. This work focuses on promoting detachable SMD component reuse during PCB prototyping by simplifying assembly and disassembly of surface mounted components without soldering [6, 11].

2.2 Circuit Fabrication and Dismantling:

While soldering PCB has seen advancements, removing components remains difficult and energy intensive. Current methods like heating or conductive epoxy are costly [19, 20], environmentally harmful, or risk damaging components. The method of 3D Printed PCBs eliminates soldering altogether, making it easier to assemble and disassemble PCBs, reducing damage risk, and enabling solder-free component replacement and reuse.

III. REFURBISHED PCB

This is a new way to quickly prototype PCBs that makes it easy to put them together and take them apart, and can be reused with SMD components. A special 3D-printed housing that holds small SMD components securely in place on the PCB. The cavities in this housing match the components' locations on the PCB exactly. Users just put the components in the spaces and then attach the whole housing to the PCB with bolts or snap-fit method. Without the need for solder, the electrical connections are made when the housing presses the components into the PCB.

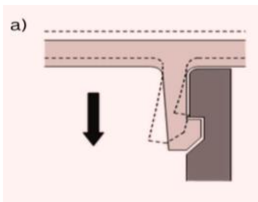
To reuse the detachable SMD components and just take them off the board. The paper included comprehensive designs for refurbished PCBs, such as:

1) The anchoring mechanism for the housing;
2) The layout of the cavities in various types of electrical components;
3) The process of designing and fabricating a 3D printed prototype circuit board.

3.1 The Anchoring Mechanism for the Housing:

For 3D Printed PCBs to work well, make sure the electronic components stay firmly connected to the PCB baseboard. There are two experiments for this: Snap-Fit and Screw Bolting.

Snap-fit: This anchoring system comprises four or more bespoke clips that are positioned around a housing's edges and at each of its four corners. The groove heights on these clips are precisely matched to the thickness of a FR-4 baseboard. Because of this, the housing and baseboard may fit snugly together without the need for any more physical labor beyond just pressing them together.



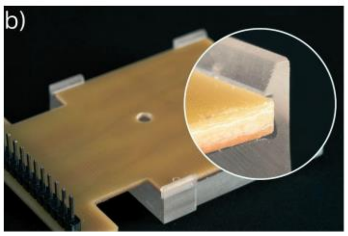


Figure 5: Snap-fit slots for PCB.

Although snap-fit assembly is simple, our testing revealed that it does not guarantee even electrical connections throughout the PCB. Adding more snap-fit slots would help, but they take up a lot of space on the board. Each slot occupies about 9 mm^2. Therefore, unless the board is tiny, snap-fit housing may cause issues with PCB design or fail to offer dependable connections. Because of this reliability problem, we don't recommend this design.

Bolting screws: A different method attaches the housing to the PCB baseboard using bolts and nuts as small as 1 mm in diameter. Although bolting requires more manual assembly work, it allows us to distribute fixed hardware, and therefore the downward force, uniformly throughout the PCB, regardless of component size.

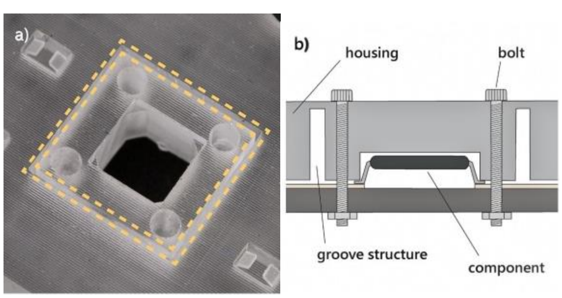


Fig. 6. Design of the Bolting Structure: a) around the IC cavity (highlighted); b) depiction of the grooves around a component from a side sectional perspective.

Because each bolt only takes up 0.8 mm^2 of space per hole on the board, circuit trace routing is not greatly hampered by its footprint. In order to generate pressure at its best without endangering the housing, Torque each nut to a value of 0.01 N m. Every example in the paper is based on the snap-fit mechanism unless otherwise noted.

3.2 Cavity Design:

To design the housing to hold different types of SMD components securely in place mechanically. For two-terminal components like resistors, capacitors, LEDs etc. These packages used here are standardized package sizes like 0603, 0805, and 1206 for the SMD components [25]. These components are very small and can vary slightly in height. To manage this, a cavity design is created with flexible tabs that can adjust to the height differences. These tabs press against the components and the PCB to ensure a good connection and prevent the housing from bending.

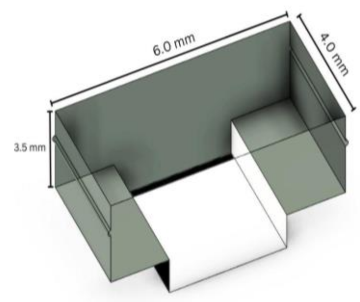


Fig. 7. LED housing cavity design with lock mechanism

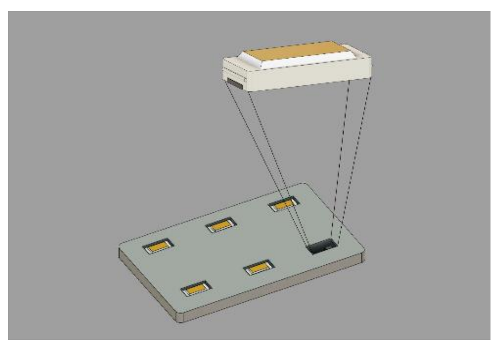


Fig. 8. 3D Printed PCB with locking mechanism

For Integrated Circuits (ICs) like micro-controllers and transistors, there are two main types: Type 1 comprises pins that protrude from the container that holds whereas Type 2 just exposes the pins on the bottom. A separate cavity is designed for each type to address their specific challenges. Solid volumes are placed at the top of every pin row for Type 1 ICs in order to create a consistent pressure distribution. To fit Type 2 ICs, a precise negative volume is created in the housing.

The IC corners are subjected to pressure using a bolting procedure. Localized deformation of the housing structure might result from this, potentially affecting adjacent components. To prevent this, carve grooves are done around each bolted component to absorb energy and prevent deformation from spreading.

By creating unique cavities for each specific form factor component that isn't in standard packaging. Each of these designs is checked for correct electrical connectivity and kept in a library of components.

3.3 Design Workflow:

With Autodesk Fusion 360, which provides integrated 3D modeling and PCB design capabilities, the PCB housings are designed. A unique IC component library is created to make the design process easier. It includes the 3D cavity designs and bolt hole locations alongside the footprint and symbol of each IC. Here the designed housing is dependent on the LED packages, the size of LED is 5730. To fix SMD LED Bulb in the cavity a lock mechanism is designed. Fig.9 shows the lock housing mechanism [3].

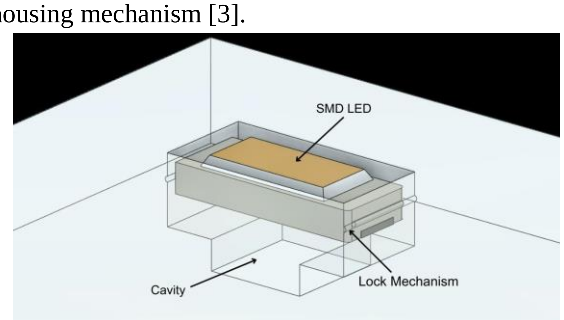


Fig. 9. SMD LED and cavity design using snap mechanism.

IV. Discussion

4.1 Housing Waste and Sustainable Alternatives:

3D Printed PCBs make it easy to swap SMD components on a prototyping board that can reuse them in unique designs. But using resin-based 3D printing for the housings adds to material consumption. To fix this, we're trying biodegradable and recyclable materials like PLA and MDF [21, 22].

By study, two more materials for housing fabrication were found to work for an SMD LED Bulb PCB: PLA used with 3D printing and MDF used with CNC milling. However, neither method could make the small tabs needed for two terminal components because they need more precision than these machines can achieve [4, 15].

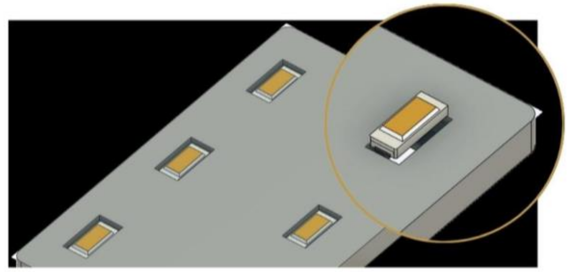


Fig. 10. 3D printed PCB with detachable LED as a SMD component

4.2 Oxidization:

During the development of 3D Printed PCB, we noticed that FR-4 surfaces can oxidize, which might affect the connections. It was found that when handled with gloves, FR-4 doesn't oxidize even after a month of regular use. But if handled with bare hands, it starts oxidizing within two weeks. Despite oxidation, the prototypes still worked fine. So, when directly handling FR-4 PCBs during assembly, it is recommended to wear gloves [7].

4.3 Assembly Exertion:

In this prototype, SMD components don't require desoldering or soldering. Instead, you screw and unscrew bolts for assembly and disassembly. For example, assembling and disassembling the SMD LED Bulb took 5 minutes and 3 minutes, respectively, for the first assembler. Keep in mind that the time may vary depending on the person, so further investigation is needed to understand assembly efforts better.

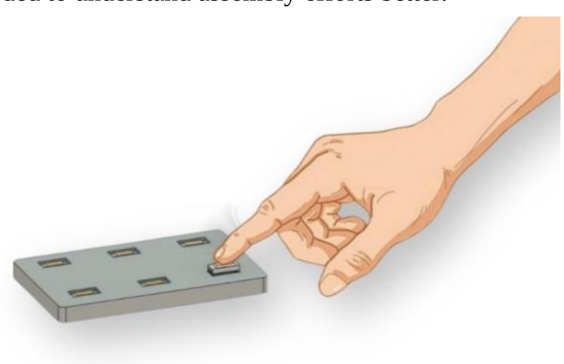


Fig. 11. Fitting the SMD component without soldering.

4.4 Adapting Existing PCB Prototype Workflow:

Since assembly and disassembly are the main differences between 3D printed PCB and traditional PCB prototyping, it can easily fit into daily prototyping workflows with minimal effort. To confirm this, we'll soon deploy refurbished PCB among electronic designers for a longitudinal study. This study will help us understand how this PCB can be easily included into design processes and how it can improve the recycling and reuse of electrical components in prototypes.

V. ADVANTAGES

3D Printed PCB offer several advantages over traditional soldered method:
Simplified Assembly: The assembly process by eliminating the need for soldering, reducing both time and costs, especially beneficial for prototyping or small-scale application.

Component Reusability: Without solder connections, components can be easily removed and replaced without damaging the PCB or nearby components. This makes it ideal for adaptive design processes or situations where components may need to be swapped out repeatedly.

Reduced Risk of Damage: Solderless connections eliminate the risk of heat damage to sensitive components that can occur during soldering. This is especially advantageous for sensitive components such as integrated circuits and SMD (surface- mount devices) components.

Repairability: Without solder connections facilitate troubleshooting and repairing of the electronic circuits. Components can be quickly disconnected or disassembled and replaced, allowing for rapid diagnosis and resolution of issues without the need for specialized tools or skills.

Flexibility in design: Without solder PCB systems oftenly offer flexibility in terms of layout and changes in design. Components can be easily rearranged on the PCB without the need to desolder and resolder connections, enabling fast prototyping and design iterations.

Accessibility: Solderless PCB connections can be advantageous in educational purposes or DIY projects where soldering equipment may not be available or where safety concerns exist. It allows enthusiasts, hobbyists, and students to experiment with electronics more easily.

Cost Effective: 3D Printed PCB can lead to cost savings since they eliminate the need for soldering devices and materials. Additionally, the ease of assembly and modification can reduce labor costs associated with assembly and maintenance.

Maintenance: In certain applications, such as in field service or industrial uses, without solder connections can facilitate easier maintenance and troubleshooting, as technicians can quickly swap out components without the need for soldering equipment.

VI. FUTURE WORK

There are many electronics circuits consisting of ICs, Transistor, Fuse, Optocoupler and other components which mostly get spoiled and this component should be replaced by new components using the method of assembly and disassembly, which is time consuming and also risky (cause component damage). To eliminate this, issue a method of 3D printed PCB with detachable SMD components is presented.

In the future, there will be two different methods to make 3D printed PCBs:

1) Multi-layer 3D Printed PCBs
2) 3D Printed PCBs using Flexible Circuit

Multi-layer 3D Printed PCBs:

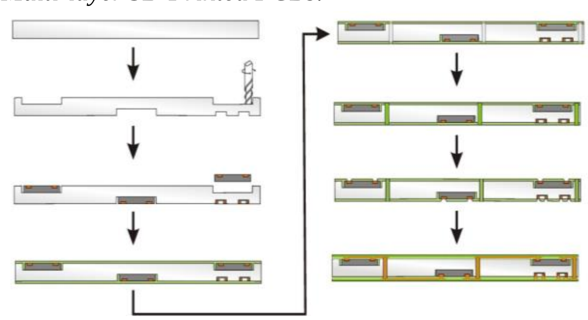


Fig. 12. Step by Step Process for Double-Sided 3D Printed Circuit Assembly and Interconnection Without Solder.

In 3D printed PCBs having the housing for the SMD components, this logic can also be implemented as multi-layer 3D printed housing with SMD components by simply adding multiple 3D printed housing layers [23] as shown in fig.12 Multi-layer 3D Printed PCBs are just like a sandwich, multiple housing layers are sandwiched to make a complete circuit. This reduces the size of pcb and also makes it easier to assemble and disassemble the SMD components.

3D Printed PCBs using Flexible Circuit:

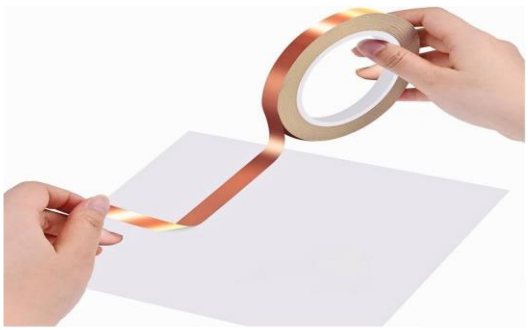


Fig. 13. Copper Conductive tape.

This flexible PCB is the same as 3D printed PCB but without any external circuitry. It consists of copper conductive foil to make connections for prototypes as shown in figure 13 or by using Flexible PCBs at the bottom of 3D printed PCB for making connections between components as shown in figure 14.

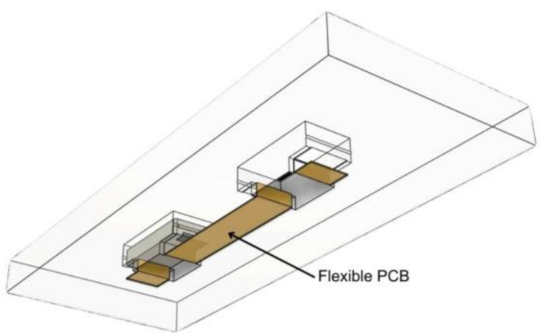


Fig. 14. 3D printed PCB for making connections between components.

VII. CONCLUSION

By concluding 3D Printed PCB with Detachable SMD Components without Soldering, a method that allows for the fixing and reusing of circuit boards without soldering, can help reduce electronic waste and promote the reuse of electronic components during circuit prototyping. It showcases two sets of scenarios and one additional example, which demonstrate both the salvage and reuse of SMD components that can ease to assemble and disassemble, that can simply reduce the risk of damage to components, and offers flexibility in design. To conclude with discussions on the advantages of this approach and future research directions.

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