# Creating Pathways for Electronics Prototyping with Reused Components

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While electronic devices have become increasingly embedded in our daily lives and environments, these devices are rapidly made obsolete by new versions, break over time, and get thrown out as electronic waste. Meanwhile, the average consumer device can contain dozens to hundreds of electronic components that could be reused for new prototypes. We argue that electronics prototyping, manufacturing, and design should engage with the issue of e-waste and the impact of the millions of devices that are bought and thrown out by consumers. By focusing on exploring new pathways for electronic component reuse, many research opportunities emerge to enable benefits across sustainability, education, and even, electronics prototyping & design. We outline specific research directions to enable a future of more ecologically conscious electronics prototyping through reuse and discuss our effort to design tools for reuse during electronics design.

CCS CONCEPTS • Hardware • Electronic Design Automation • Methodologies for EDA

**Additional Keywords and Phrases:** electronic design automation, reuse, prototyping, sustainability

## 1 INTRODUCTION

Electronics prototyping and design has an emerging issue that needs to be grappled with – the amount of electronic waste that comes with the proliferation of electronic devices and the gradual obsoletion of many of the same devices. Electronic waste (or "e-waste") is the largest growing waste stream in the world [5] and is growing exponentially, matching the exponential growth of the electronics industry. In fact, much of the current consumer electronics industry's practices revolve around the planned obsolescence of devices as new versions get released every one to two years [19]. Meanwhile, in any one of these devices that typically get thrown out, there are dozens to hundreds of components that could likely be reused in a new electronics design. All these components require significant amounts of energy and labor to produce from the mining of rare minerals, transportation, and manufacturing – a fact most clearly demonstrated by

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the worldwide chip/component shortage caused by the COVID-19 pandemic that is still affecting electronics hobbyists to international companies alike [7, 21]. In fact, many electronics engineers were forced to scavenge for and reuse electronics components when they could not source them anew because they could no longer depend on the supply chain [1]. However, most electronics design tools are built with the implicit assumption that all the components an engineer is designing with are sourced anew. From maker toolkits to electronic design automation (EDA) bill of materials, most approaches to electronics design and prototyping never involve pathways of reuse or recycling.

It is time for us to imagine a future of electronic prototyping that prioritizes reuse and recycling. We argue that reuse and recycling of electronic components not only has clear benefits for reducing ecological impact but also directly supports domains like engineering education, right to repair, and open-source hardware. However, building out infrastructure to support reuse and recycling electronic components also has many unique challenges for our research communities to invest in. In this paper, we will outline a research vision for enabling pathways for electronic prototyping with reused components. We discuss both the major opportunities and the major research challenges in electronic component reuse. Last, we discuss our work in progress around designing tools to support integrating reuse and recycling in an electronics design workflow.

## 2 RESEARCH VISION: ELECTRONIC PROTOTYPING WITH REUSED COMPONENTS

The process of reusing electronic components is not a new concept. As noted previously, the pandemic-induced chip shortage has forced many to "dumpster-dive" to scavenge and find components from electronic waste in the trash [1]. Also, device teardowns, hacks, and projects made from reused components can easily be found on many electronics blogs [2, 9, 20]. Last, engineers from regions that have a harder time acquiring parts from manufacturers often already find themselves sourcing components from devices around them [10]. Previous HCI research has also been interested in the practice of reuse of electronic or other material waste [12, 16]. However, prior work found that when electronic waste is repurposed, upcyclers more often reuse mechanical enclosures or other materials of the device rather than reusing electronic components within the device [14]. While all forms of reuse are beneficial, we are interested in the unique challenges of electronic component reuse. More specifically, we argue that we need to engineer **tools to make electronic component reuse more widespread & accessible.** We believe that building tools to support the process of electronic reuse will enable a wider range of practitioners to participate in reuse and allow for more pathways, strategies, and knowledge around reuse to be disseminated. We identify three future research areas we believe users can be supported by interactive tools: (1) taking apart devices and identifying components, (2) testing components, (3) incorporating components in new electronic designs.

**Future research area #1: taking apart devices and identifying components.** Oftentimes, we are socialized to treat our devices like black boxes. Tearing them down, however, can be an extremely educational exercise in learning how a device works. Navigating a modern printed circuit board (PCB) however can often be quite challenging. Issues like proprietary chips, glob-topped components, or not well-labeled components can make it impossible to identify the components on the board and reuse them in the future [6]. However, many components can be easily identified by beginners (resistors, capacitors, buttons, etc.) and others can be identified with a little experience and contextual clues (for example, common circuit components found in AV equipment). Such knowledge bases can be incorporated into support tools from guides and assistants to more advanced computer vision-aided technologies. We have started exploring this area through a mobile-based tool to support identification and inventorying of components.

**Future research area #2: testing components.** A significant challenge in sourcing parts from devices that are old, broken, or obsolete is that sometimes components in them will not work or be viable for reuse. While many components

can be easily tested with tools found on a standard electronic workbench (multimeter, oscilloscope, etc.) there are many components that can be difficult to test. This is a unique issue in the process of reusing components as it would be less of a concern when buying all components anew. While a custom testing rig for every device that components are sourced from is unlikely, investing research into more modular testing rigs for common designs and footprints could make it easier to salvage hard to test but valuable integrated circuits (IC) (for example, like [17]). While we have not started exploring this area yet, we believe it presents many research opportunities and invite researchers to join us in designing for it.

**Future research area #3: incorporating components in new electronic designs.** Incorporating the components found in new electronic prototypes can be challenging for a few reasons. For one, it can be difficult to reframe thinking about the component from its original use (the device it came from) to thinking about the component as a building block for any other type of circuit. Second, it can be difficult to recall the many other components present in a salvaged device (think of the dozens of resistors alone you're likely to find in any PCB). In our preliminary research, we found that those that do reuse electronic components often find a unique component and design new projects around an interest in reusing that specific component. This can be due to several issues like component management and inventory recall. Last, some components can be much easier to reuse than others. For example, components like switches or analog sensors are easy to use with electronic toolkits like an Arduino – in fact, often there are already libraries readily available due to their standard designs. On the other hand, microcontrollers might require knowledge about erasing and re-flashing firmware due to manufacturing security protections. Finding ways to reduce these barriers and create pathways for different experience levels (beginners to experts) may enable very creative new ways for reused components to be incorporated in new designs. We have started to explore this area through an electronic design automation (EDA) software based tool to lower the barrier of some of these issues.

## 3 BENEFITS AND OPPORTUNITIES

While reusing electronic components will always be a more difficult process than simply ordering all new electronic components, there are many benefits to consider both at an individual level and for the broader research community. We identified three key benefits of significant relevance to the electronics prototyping community.

**Benefit #1: sustainability and reducing carbon footprint**. A direct consequence of reuse over buying anew is that it removes components from landfills and avoids the manufacturing and shipping of new components. While it is difficult to quantify the exact carbon footprint of a chip, the impacts of their improper disposals are clearly visible through the tons of electronic waste generated every year and the often improper recycling and sorting of e-waste [5, 8, 13, 18].

**Benefit #2: engineering education**. Opening devices and encouraging exploration inside them is a great way to get students interested in engineering. Moreover, it empowers students to treat their devices not as black boxes but as machines that were engineered with various strategies. Going even further by reusing components can empower engineering students to feel that they can hack, mod, and engineer with electronics in creative ways.

**Benefit #3: right to repair & open-source hardware.** In creating pathways for the reuse of electronic components, many goals directly align with movements like right to repair and open-source hardware. Right to repair advocates argue for allowing consumers to have the tools necessary to do replacements and repairs at home by themselves rather than requiring the company to do it for them or requiring them to trash their devices altogether [4, 15]. Enabling the average consumer to have the tools and know-how to perform electronics fixes also would allow consumers to scavenge devices for parts for reuse. Similarly, proponents of open-source hardware advocate for engineers to make their designs open and accessible to the public so that they can remake or remix parts of their design. With open-sourced schematics,

the process of identifying components for reuse becomes accessible to anyone. Similarly, standardized designs (for more accessible repairs or remixing) would make future devices more amenable to the process of salvaging and reusing them.

## 4 RESEARCH CHALLENGES

There are many significant research challenges on the way to a future where prototyping with reused components can become more accessible to beginners and experts alike. We outline three challenges that we think the HCI community in particular would be well-suited to tackle.

**Challenge #1: access to relevant knowledge and data.** In our preliminary research, even experts who regularly engage is electronics reuse have a hard time finding relevant information such as device schematics, component datasheets, and teardown guides. Oftentimes, sources include electronics forums, YouTube videos, or random blogs. Sources like *iFixit* [4] or FCCID [3] may have useful device information but it remains difficult to find relevant information for component reuse. Researchers can make important knowledge on reuse more accessible by creating better tools and documentation that enables learning about common device circuits or schematics, identifying electronic components, and testing components for reuse.

**Challenge #2: pathways for different levels of expertise.** While there is knowledge on component reuse that may not be accessible to a beginner, engineering curriculum and toolkits could be designed around exploring reuse for a wide range of audiences. For example, standard devices (e.g., a computer mouse) all around us that have very similar inner circuitry become electronic waste every day and have components that could easily be reused and incorporated in an Arduino-based maker project. Researchers can develop tools that enable reuse by meeting users at their different capacities.

**Challenge #3: tools designed around reuse.** When prioritizing reuse, there are many new factors to consider that are not traditionally emphasized in electronics design tools that assume components will be sourced anew. For example, reused component will have a limited quantity compared to (assumed) infinite supply from suppliers. Also, prioritizing reuse might mean building a subcircuit from scratch with on hand components rather than purchasing a new integrated circuit chip. When reusing components, information from datasheets may not be readily available and designs around scavenged components may need to be flexible to unknowns. These and other aspects of component reuse could be better supported by automated tools to make the difficulties of reuse less cumbersome.

## 5 OUR APPROACH: DESIGNING INTERACTIVE TOOLS FOR REUSE

Our work in progress explores designing interactive tools for the process of reusing electronic components. Through the design of our tool, we aim to tackle several unique challenges in the reuse electronic design workflow: (1) component management and recall, (2) identifying appropriate alternatives that prioritize component reuse, (3) preserving and making accessible relevant reuse information. We built our tool to integrate with a popular open-source EDA to demonstrate how our tool could support the process of generating full PCBs based on reused components from electronic waste. Currently, our tool's main feature is a suggestion-based interactive assistant that offers alternative components from a library of scavenged parts during the schematic design. Through our tool, we also enable several other pathways to reuse including importing schematics of old or open-sourced projects for reuse of their components, reuse with beginner friendly toolkits like an Arduino, rapid prototyping with reused components, and sharing component libraries across users. We see our tool as one approach to enabling various pathways to electronic component reuse and hope that it can inspire more discussion of other tools that could support the process of electronics reuse.

## 6 CONCLUSION

We believe it is time for the electronics prototyping community to engage with the issue of electronic waste and start exploring how reduce, reuse, and recycle can apply to the design of new electronics. From encouraging more sustainable practices to enabling more creative engineering education, there is a lot to gain from making reuse a part of the electronics prototyping workflow. However, there are a lot of significant challenges for the HCI community to tackle to enable reuse-based practices such as building supportive infrastructure and tools accessible to beginners and experts. In our work, we built an EDA tool to explore facilitating reuse in a traditional electronics design workflow. However, our approach only explores the challenge of incorporating salvaged components into new electronic designs and challenges in identifying and testing components remain largely unexplored. We hope that both our work and our outline of our research vision can inspire others to contribute towards enabling new ways for e-waste to be given a second life.

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