

README // about these slides

These are the slides for the talk presented at CHI 2025 by Jasmine Lu.

All the links in this PDF are clickable and lead you to YouTube videos, paper, etc.

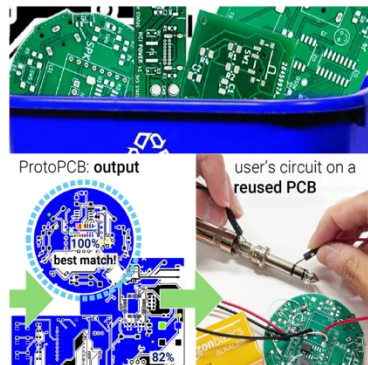
You can watch the live talk [here: https://www.youtube.com/watch?v=LvC-Mg7MbqI](https://www.youtube.com/watch?v=LvC-Mg7MbqI)

You can watch the prerecorded talk [here: https://www.youtube.com/watch?v=vqAg5TI_Q1s](https://www.youtube.com/watch?v=vqAg5TI_Q1s)

You can watch the video [here: https://www.youtube.com/watch?v=XVVxmU2W1bI](https://www.youtube.com/watch?v=XVVxmU2W1bI)

If you need a PPTX/editable version for your class, email us hci@uchicago.edu

More information on this paper (or others of our lab) at: <https://lab.plopes.org/#ProtoPCB>



ProtoPCB: Reclaiming Printed Circuit Board E-waste as Prototyping Material

Jasmine Lu, Sai Rishitha Boddu, Pedro Lopes. In Proc. [CHI'25](#) (full paper)

We propose an interactive tool that enables reusing printed circuit boards (PCB) as prototyping materials to implement new circuits—this extends the utility of PCBs rather than discards them as e-waste. Our tool takes a user's desired circuit schematic and analyzes its components and connections to find methods of creating the user's circuit on discarded PCBs (e.g., e-waste, old prototypes). In our evaluation, we utilized our tool across a diverse set of PCBs and input circuits to characterize how often circuits could be implemented on a different board, implemented with minor interventions (trace-cutting or bodge-wiring), or implemented on a combination of multiple boards—demonstrating how our tool assists with exhaustive matching tasks that a user would not likely perform manually.



[click for paper PDF](#)



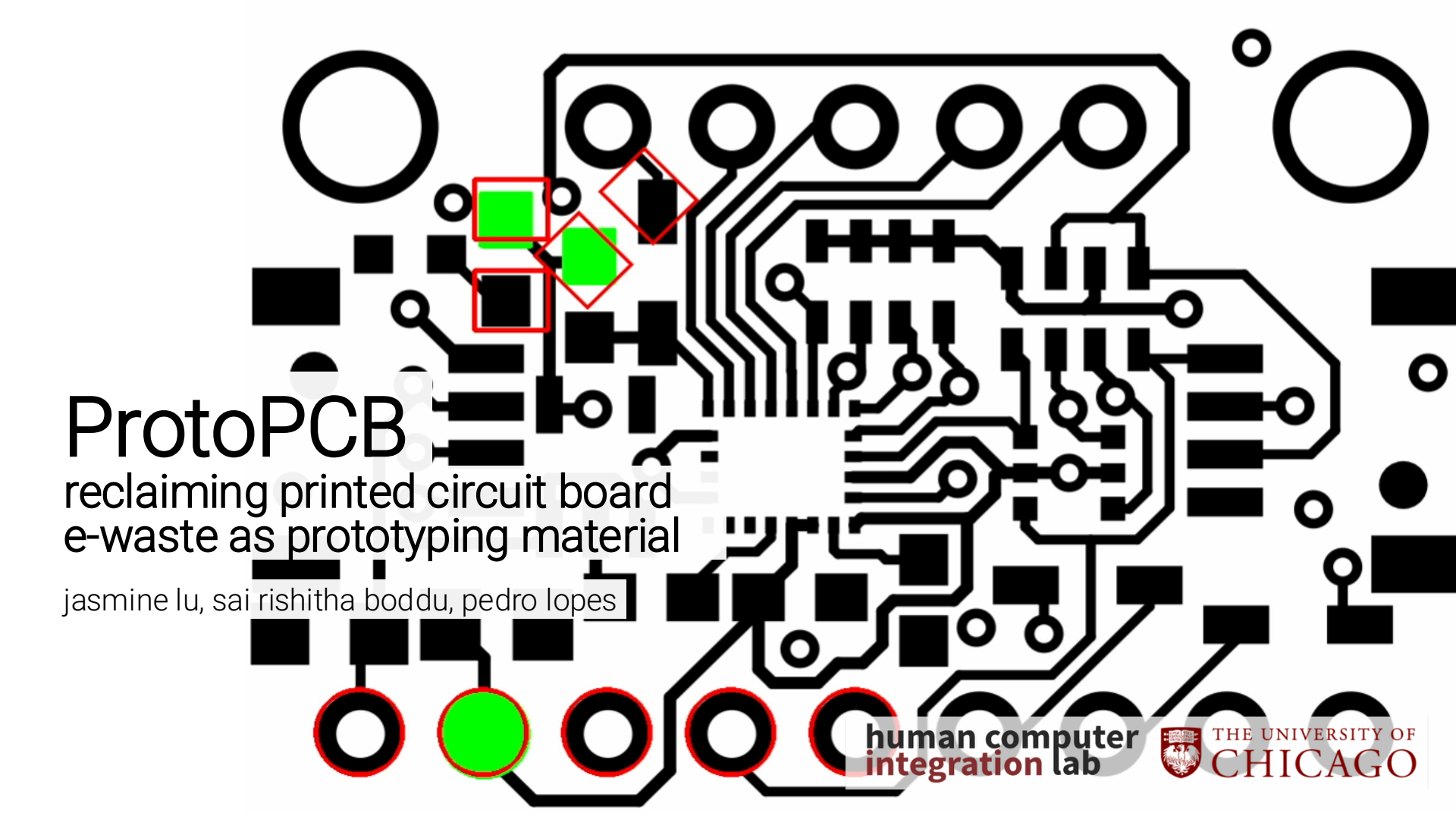
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ProtoPCB

reclaiming printed circuit board
e-waste as prototyping material

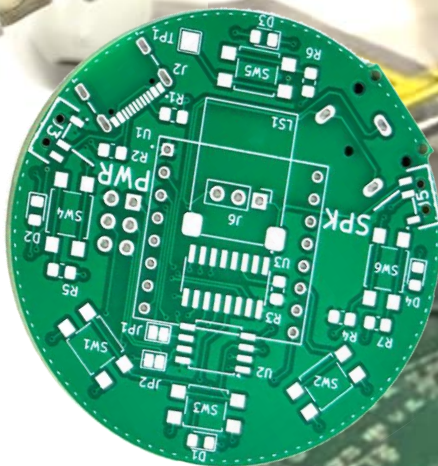
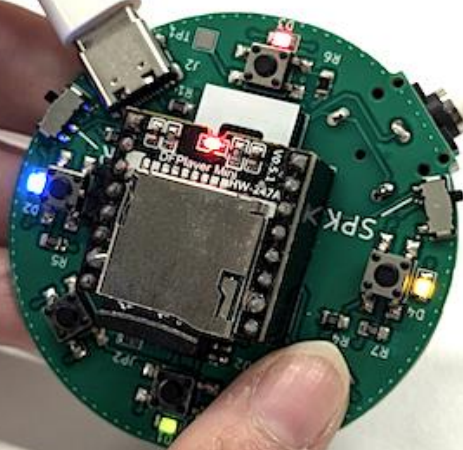
jasmine lu, sai rishitha boddu, pedro lopes

human computer
integration lab



THE UNIVERSITY OF
CHICAGO

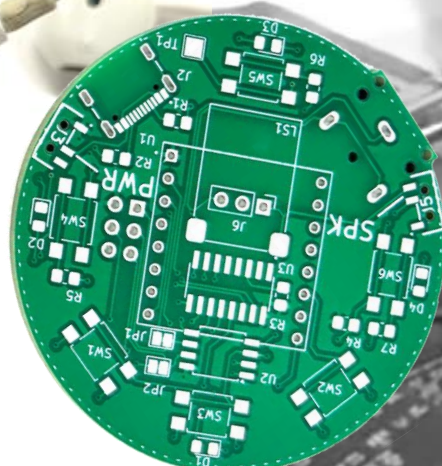
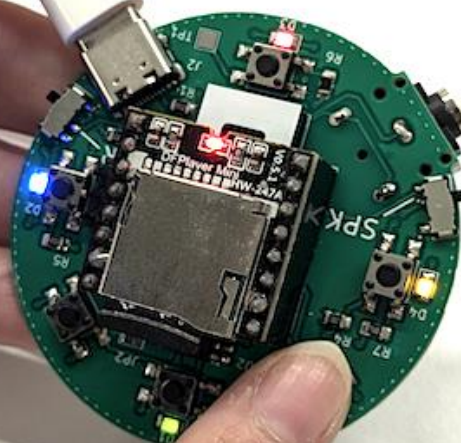
handheld game



PCB



handheld game



PCB



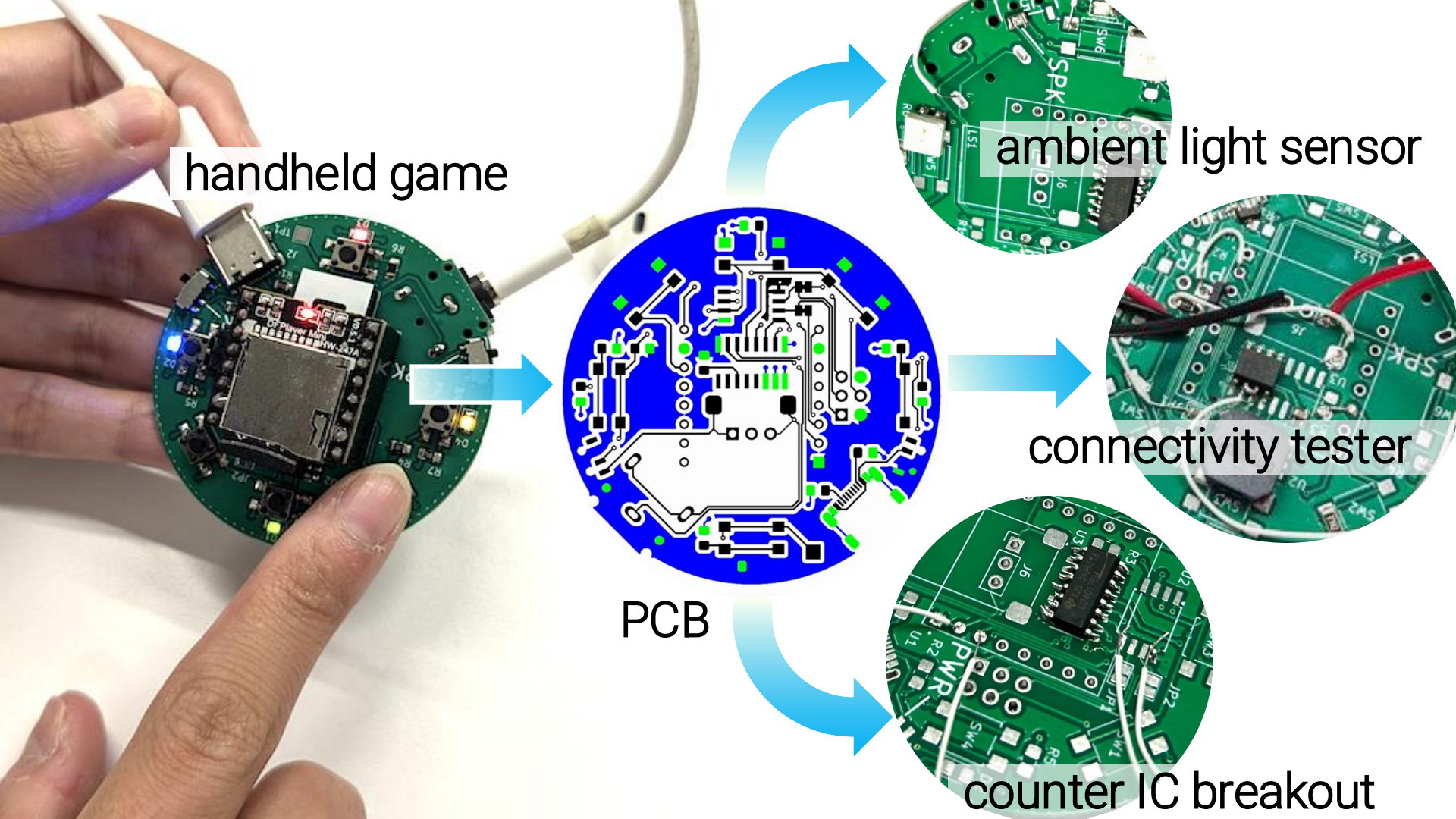
handheld game

ambient light sensor

connectivity tester

PCB

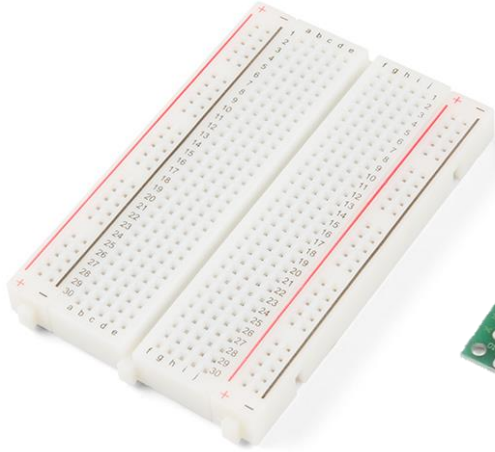
counter IC breakout



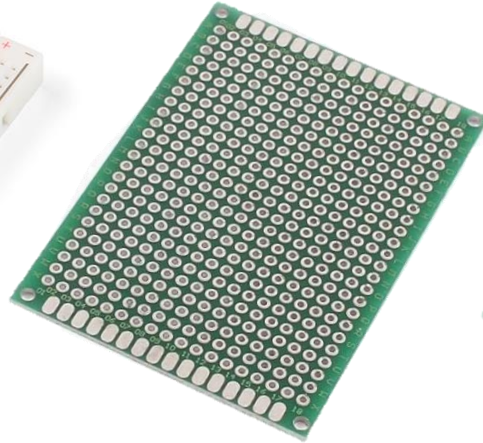
background

electronics prototyping & printed circuit boards

overview of electronics prototyping strategies



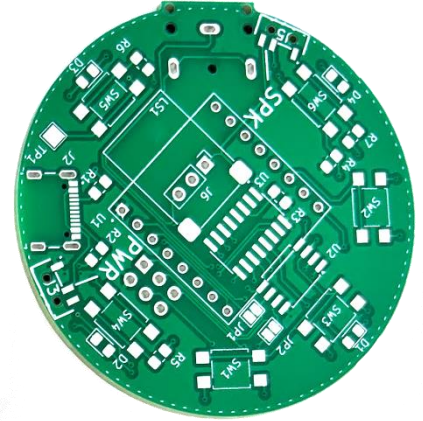
breadboards



protoboards

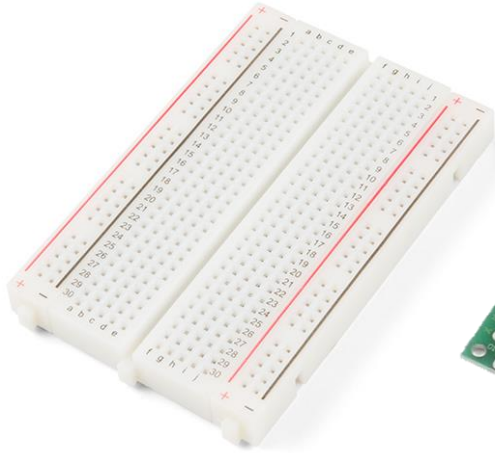


breakout boards

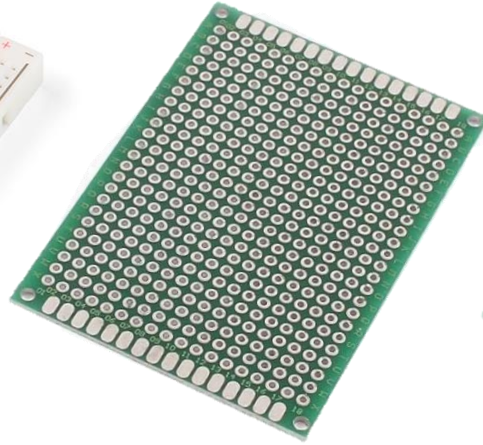


printed circuit boards

overview of electronics prototyping strategies



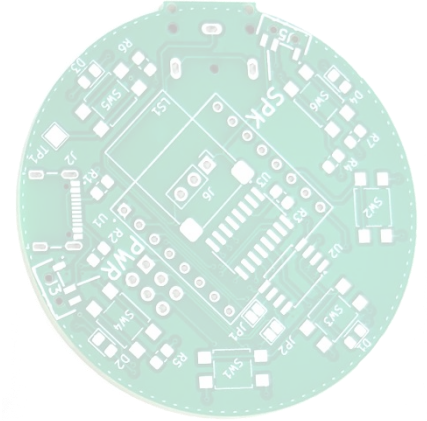
breadboards



protoboards



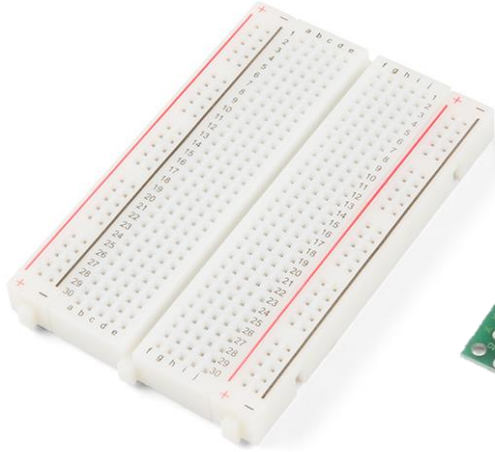
breakout boards



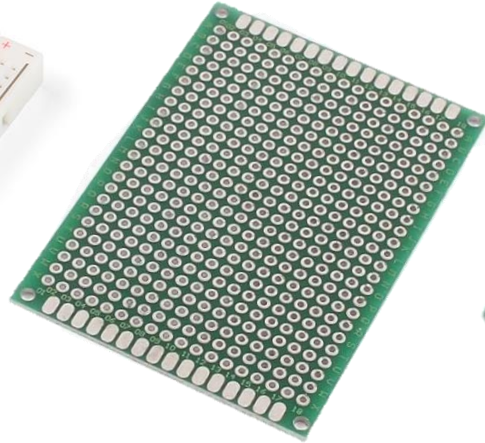
printed circuit boards

most common to early prototyping stages

overview of electronics prototyping strategies



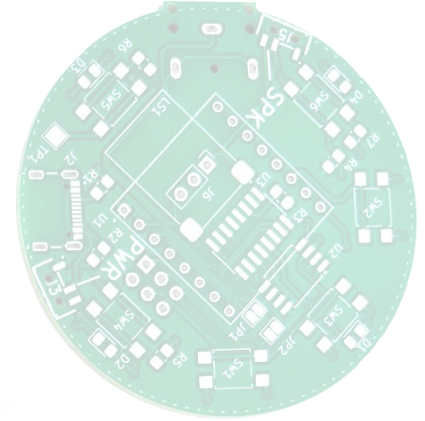
breadboards



protoboards



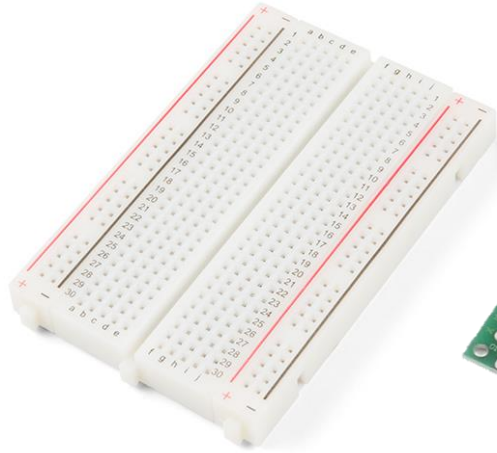
breakout boards



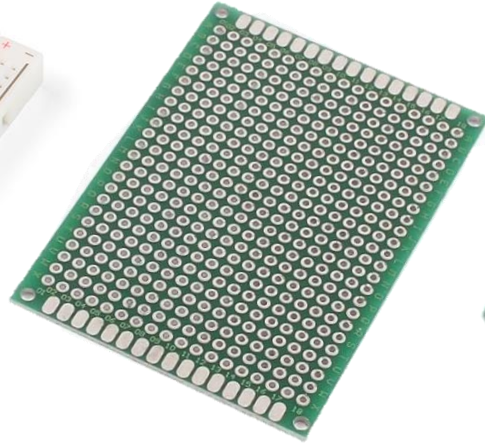
printed circuit boards

most common to early prototyping stages
inherently reusable

overview of electronics prototyping strategies



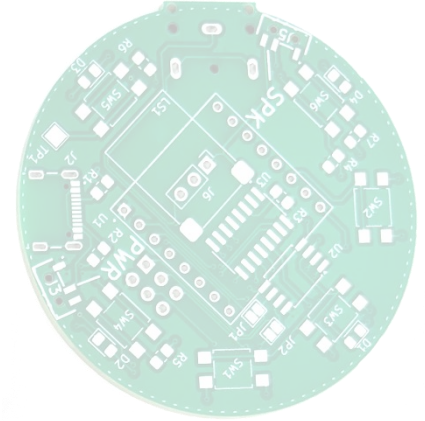
breadboards



protoboards



breakout boards



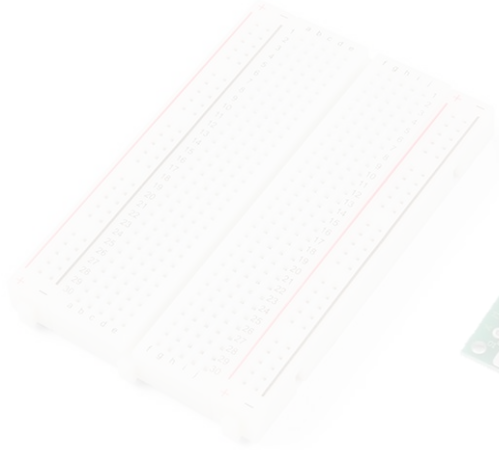
printed circuit boards

most common to early prototyping stages

inherently reusable

but limits components and design options

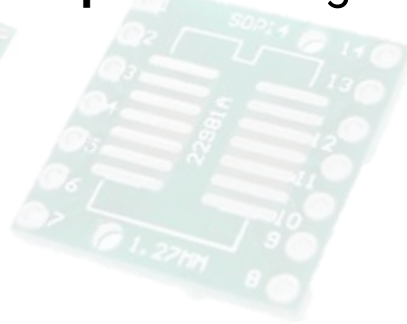
necessary for most SMD components
manufactured for a **specific** design



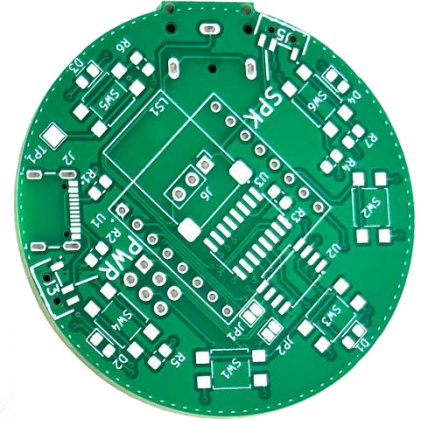
breadboards



protoboards



breakout boards



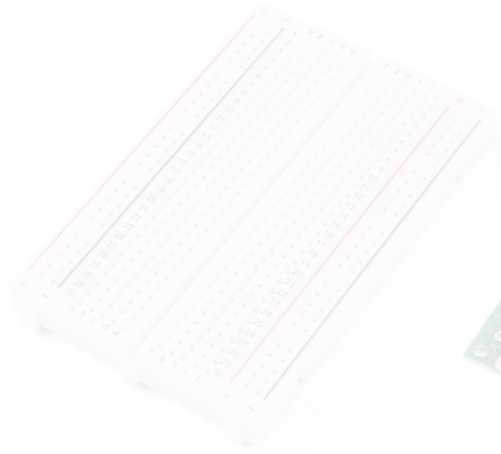
printed circuit boards

most common to early prototyping stages

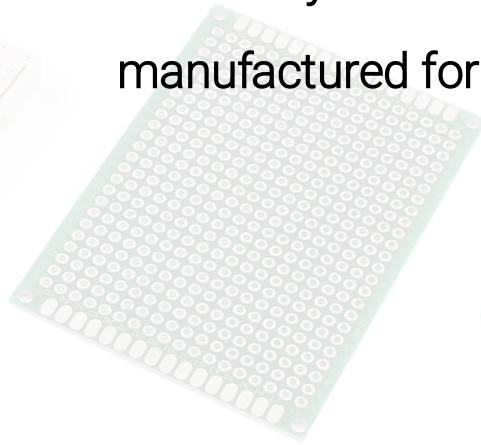
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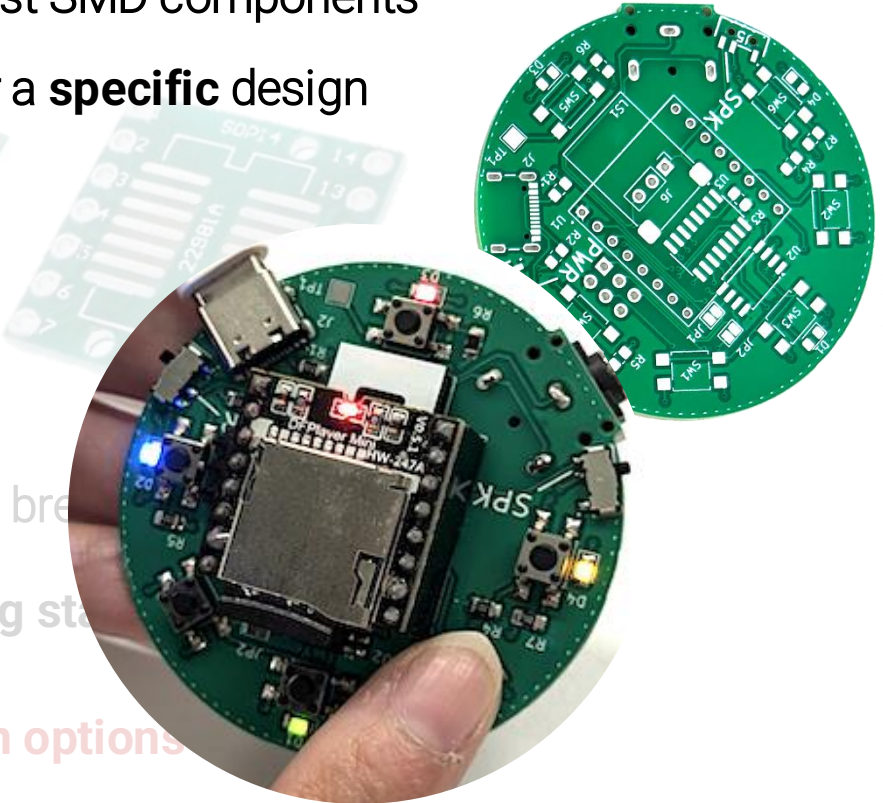
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breadboards



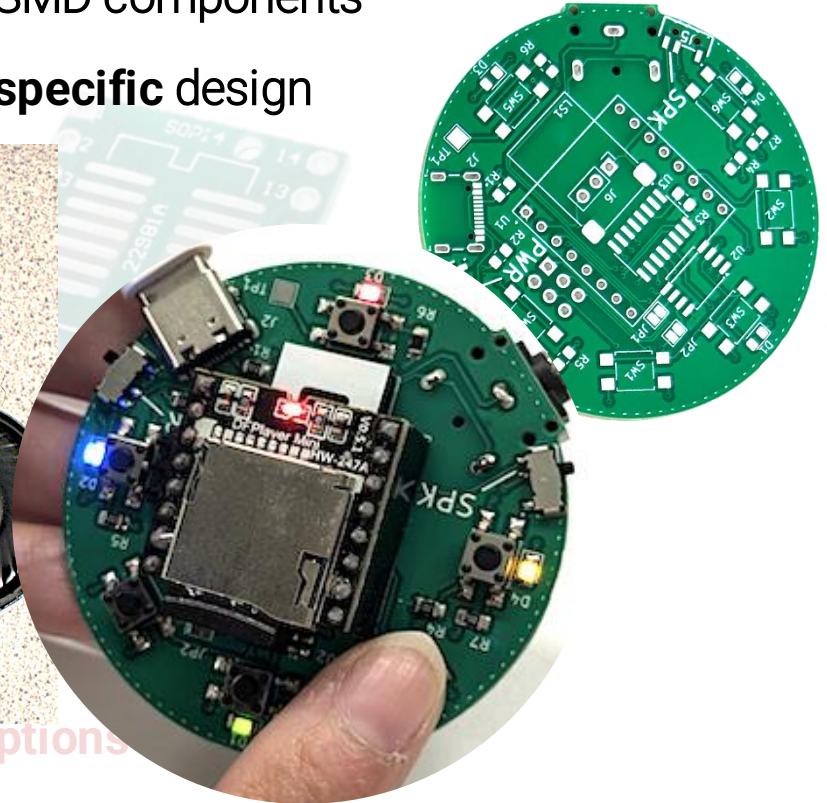
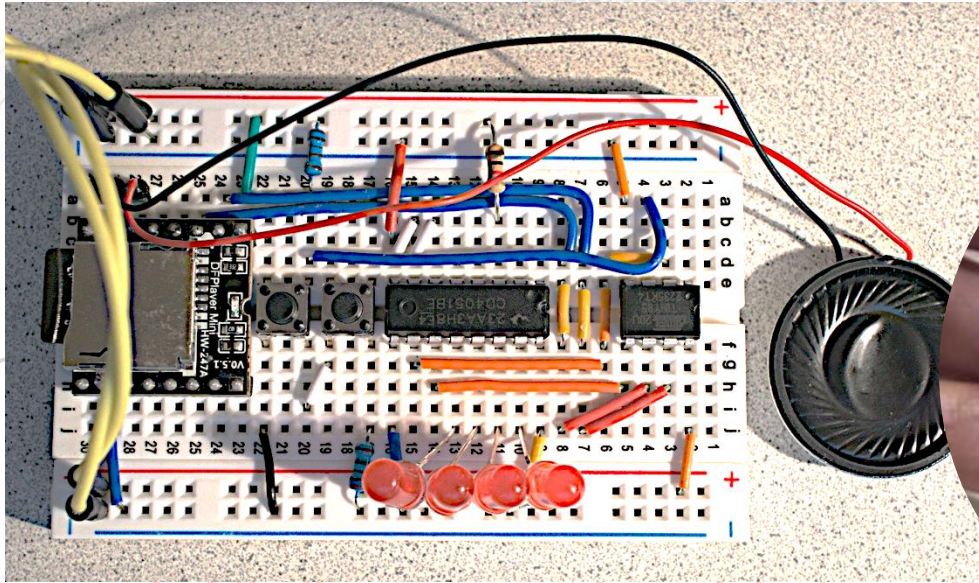
protoboards



bre

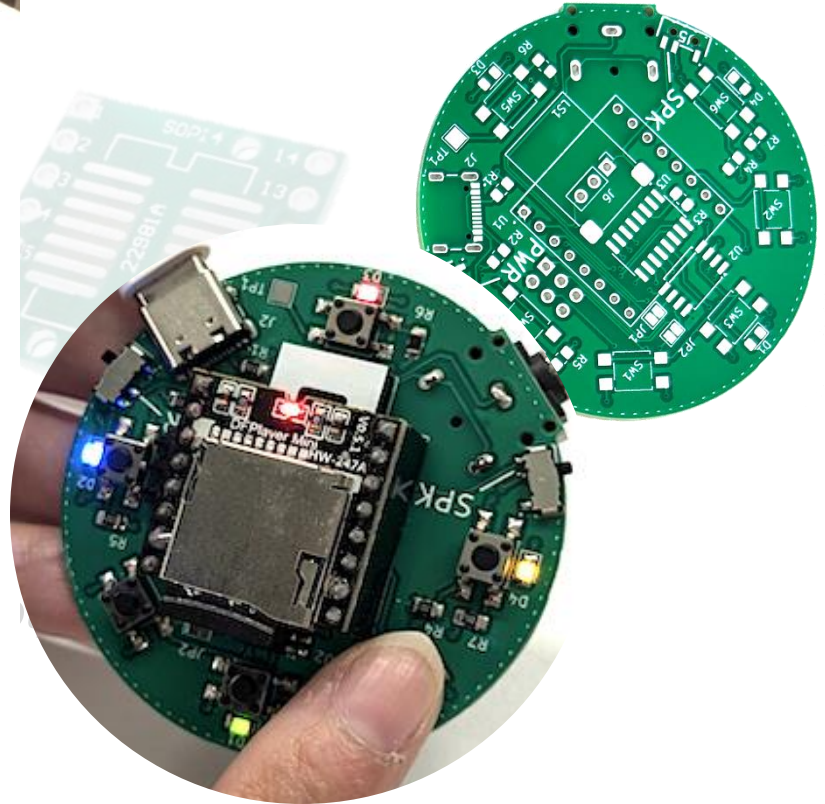
most common to early prototyping stage
inherently reusable
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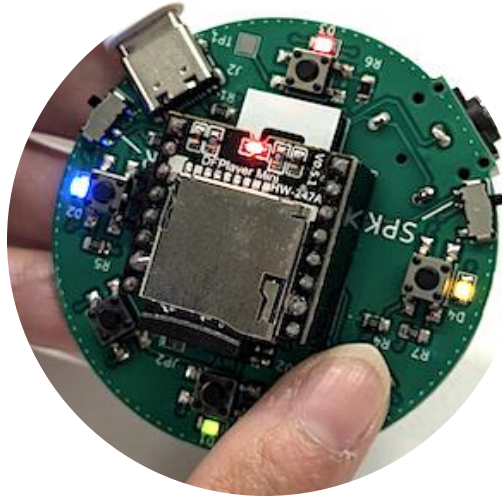
but limits components and design options

A photograph showing a collection of electronic waste (e-waste) on a white surface. In the upper center, there is a clear plastic bin filled with green printed circuit boards (PCBs). A white label with a green recycling symbol is attached to the front of the bin. To the left of the bin, there are several crumpled pieces of silver and yellow packaging material. In the foreground, a large number of green PCBs are scattered on the white surface. These boards vary in size and shape, some featuring various electronic components like resistors, capacitors, and integrated circuits. A small, purple, rectangular component is also visible among the green boards. The overall scene suggests a collection of discarded electronic components, likely for recycling or disposal.

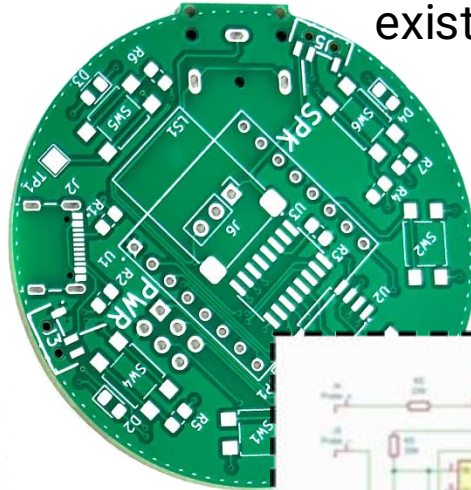


our approach

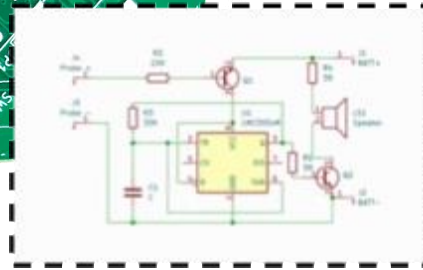
instead of manufacturing a new PCB for every prototype...
can we reuse already existing PCBs to prototype?



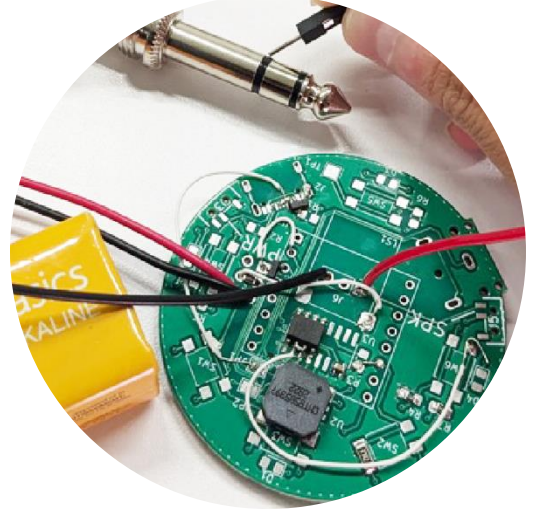
original prototype



existing PCB



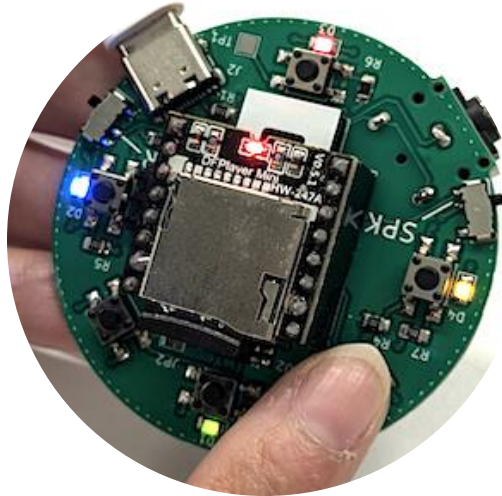
new circuit



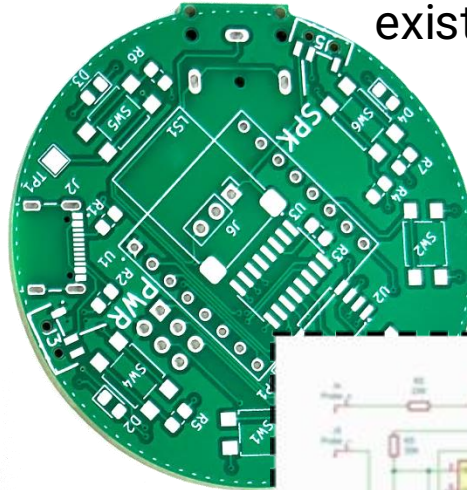
new prototype

our approach

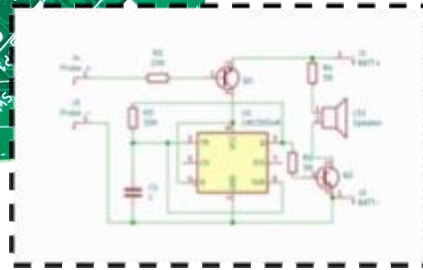
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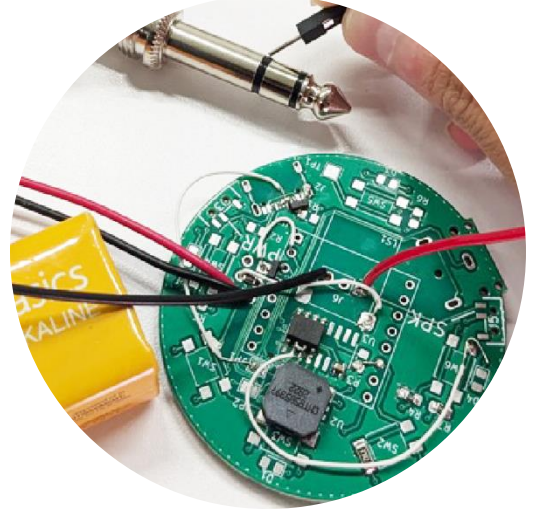
original prototype



existing PCB



new circuit



new prototype

near **impossible** to do by hand...

ProtoPCB

ProtoPCB

Select PCB File or Image from File Dialog

No file selected

Select File

Select Schematic File from File Dialog

No file selected

Select File

If no PCB is provided, ProtoPCB will run

Select Component from Schematic

computationally solves how to implement new circuits

Favorites

Recents

Desktop

Documents

00_Research...

ProtoPCB

PCB Library

proto-pcb

Downloads

iCloud

iCloud Drive

Shared

Locations

Macintosh HD

Google Drive

Network

Tags

Select a File or Image

✓ Macintosh HD

Search

Name

> Library
> System
> Users
> Applications

Recent Places

Examples
SimonSays
SimonSays
search-process

Date Modified

May 1, 2024 at 9:29 P
Mar 17, 2024 at 12:25
May 1, 2024 at 9:28 P
Today at 1:02 PM

Cancel

Open

ProtoPCB

ProtoPCB

Select PCB File or Image from File Dialog

No file selected

Select File

Select Schematic File from File Dialog

No file selected

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ProtoPCB

PCB Library

proto-pcb

Downloads

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iCloud Drive

Shared

Locations

Macintosh HD

Google Drive

Network

Tags

Select a File or Image

✓ Macintosh HD

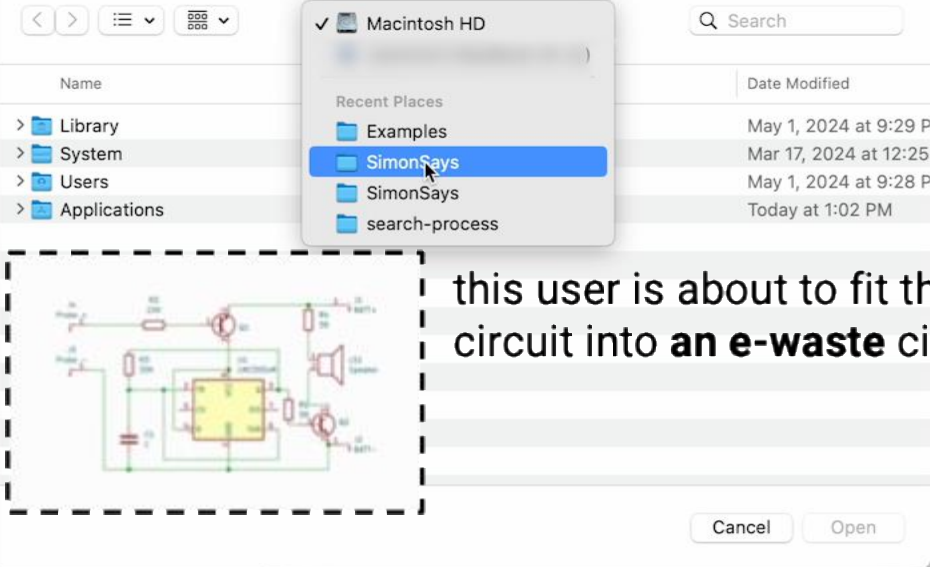
Recent Places

Examples

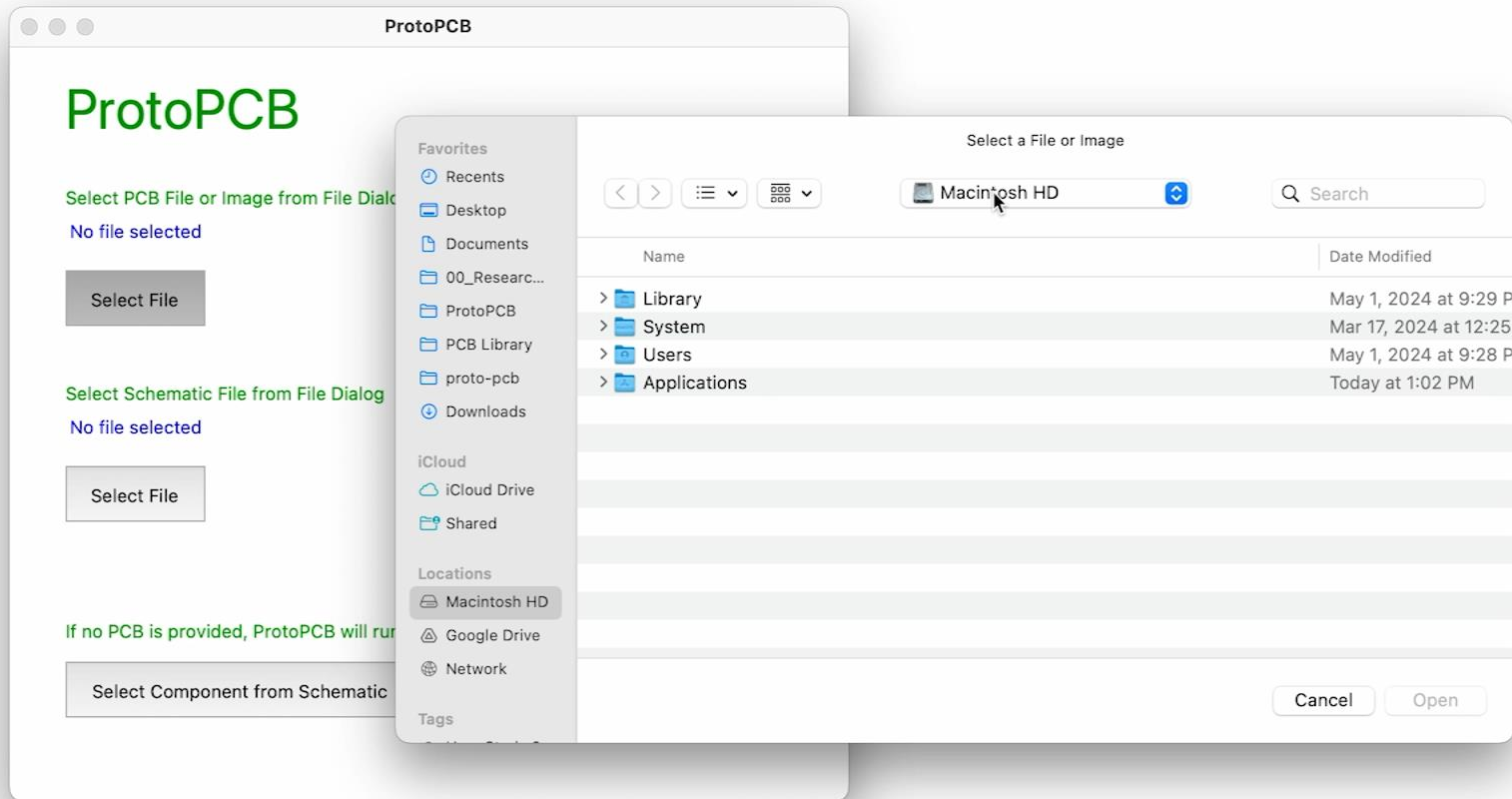
SimonSays

SimonSays

search-process



this user is about to fit this **new**
circuit into **an e-waste** circuit board

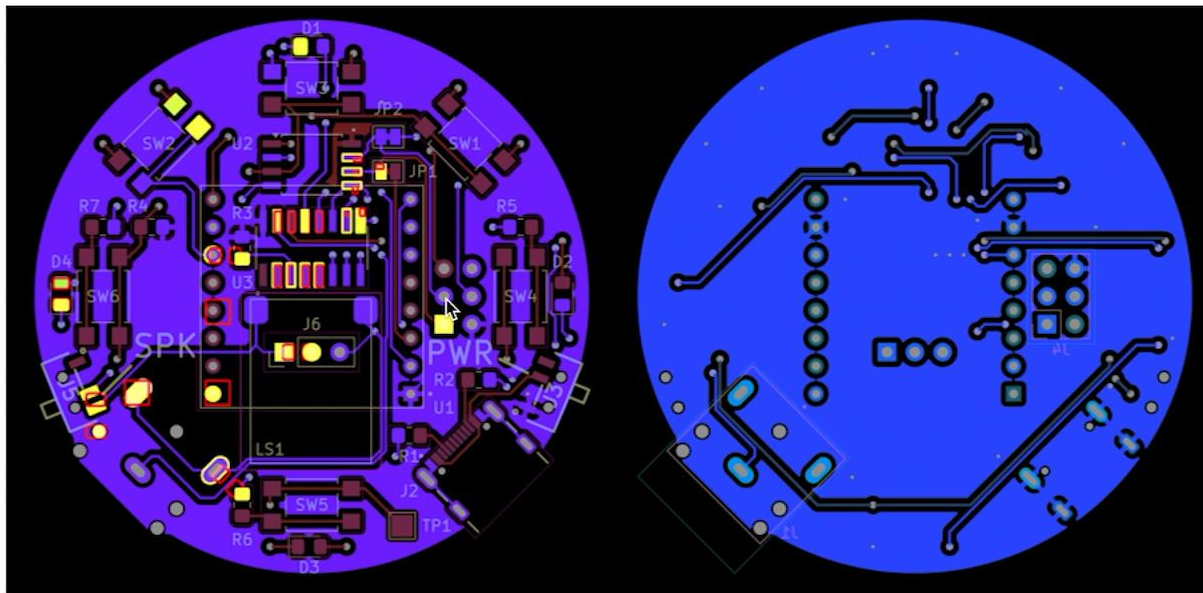


Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>



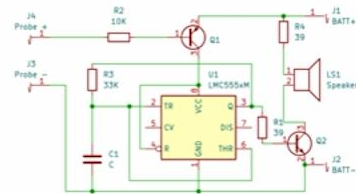
ProtoPCB // Full Circuit Match // 1 of 12

Front PCB view from ATtiny85-MP3.kicad_pcb



Searching on 42 PCB Boards from Library

Circuit schematic from Connectivity Probe.kicad_sch

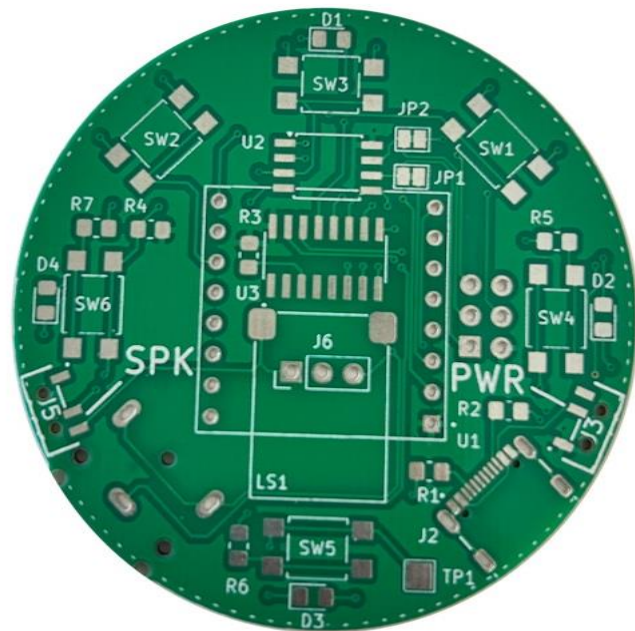


Multiple Interventions Needed

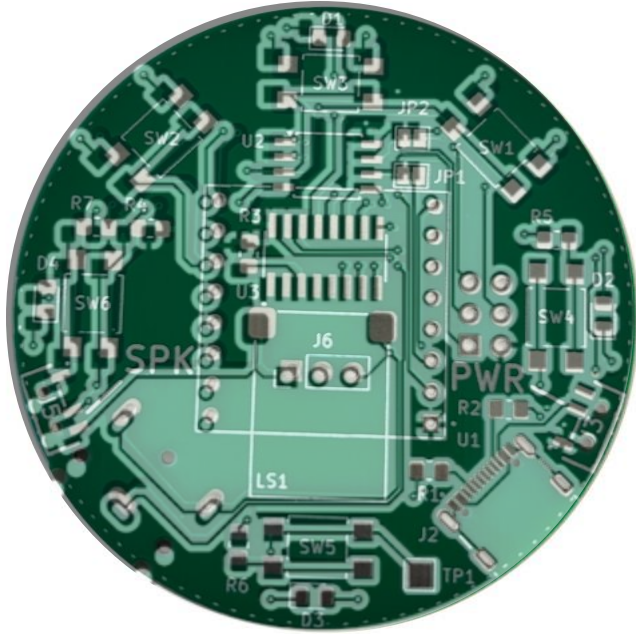
Select View: Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

implementation

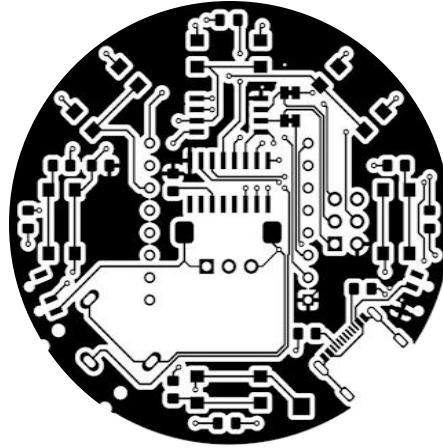
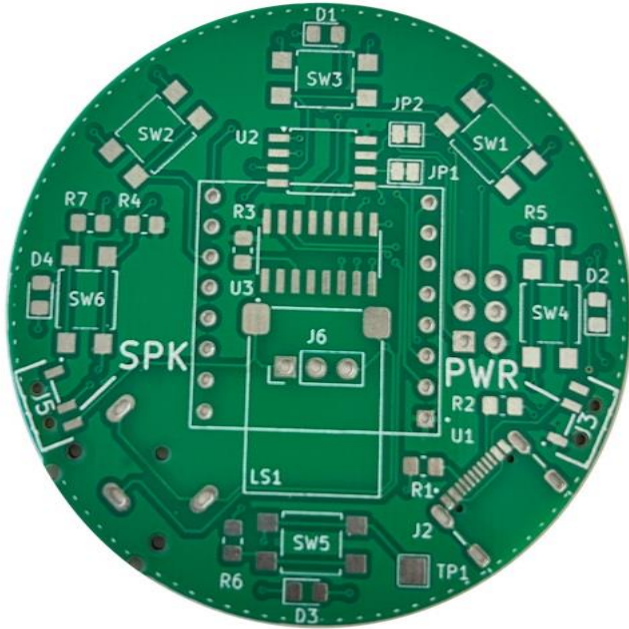
ProtoPCB isolates a board into images of its solderable pads and traces using computer vision



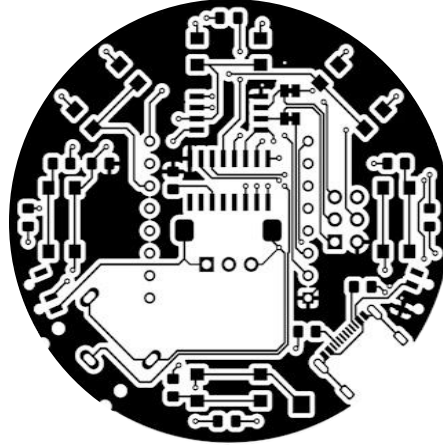
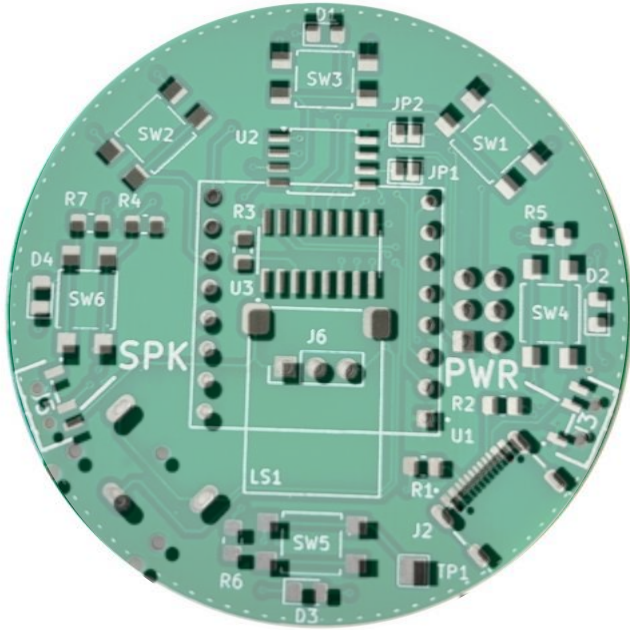
ProtoPCB isolates a board into images of its solderable pads and traces using computer vision



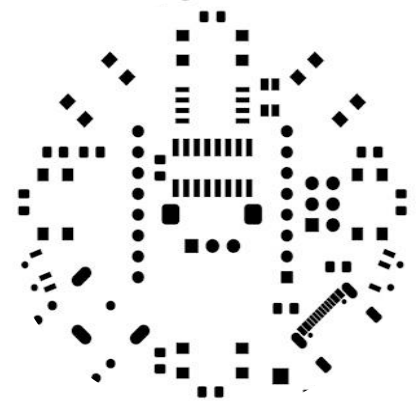
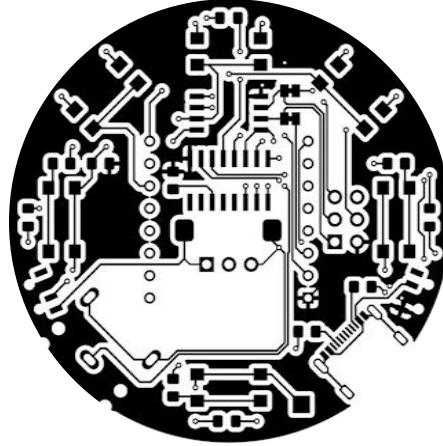
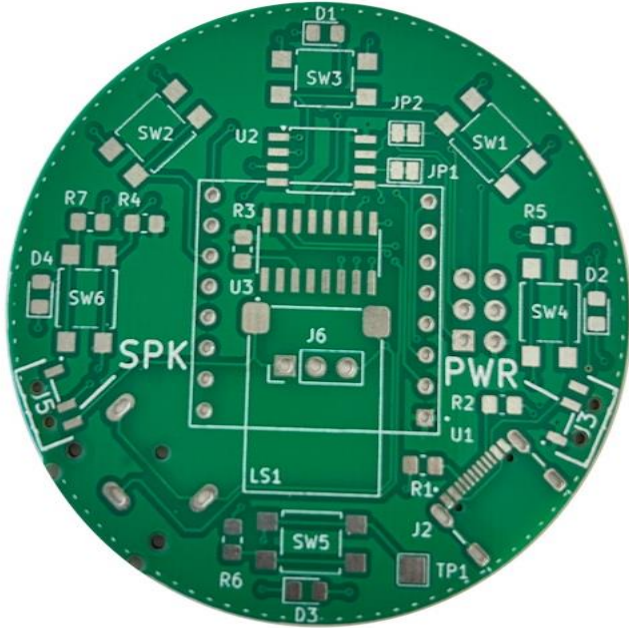
ProtoPCB isolates a board into images of its solderable pads and traces using computer vision



ProtoPCB isolates a board into images of its solderable pads and traces using computer vision

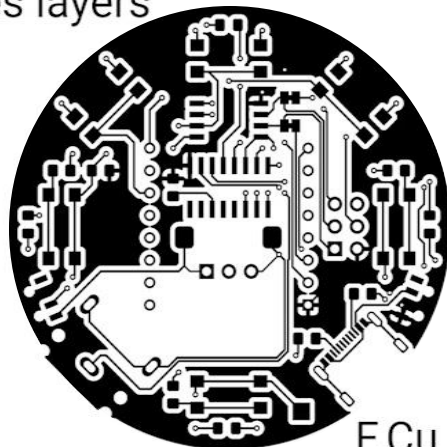


ProtoPCB isolates a board into images of its solderable pads and traces using computer vision

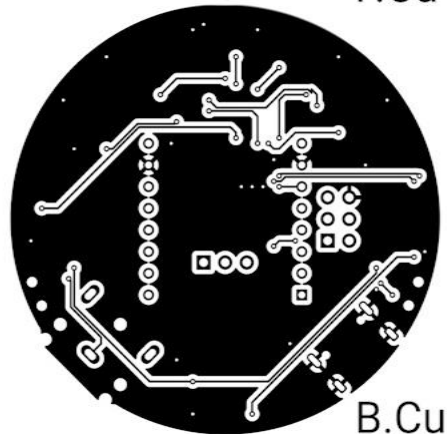


ProtoPCB isolates a board into images of its solderable pads and traces using computer vision

traces layers

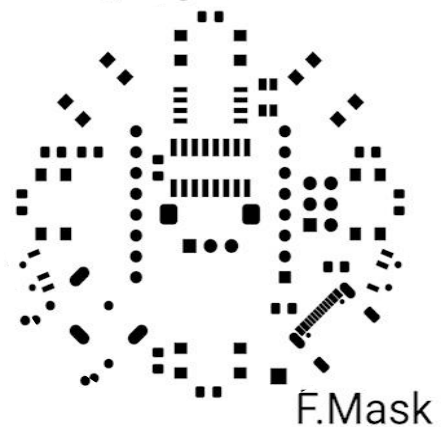


F.Cu

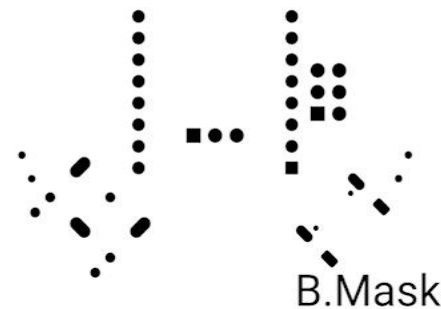


B.Cu

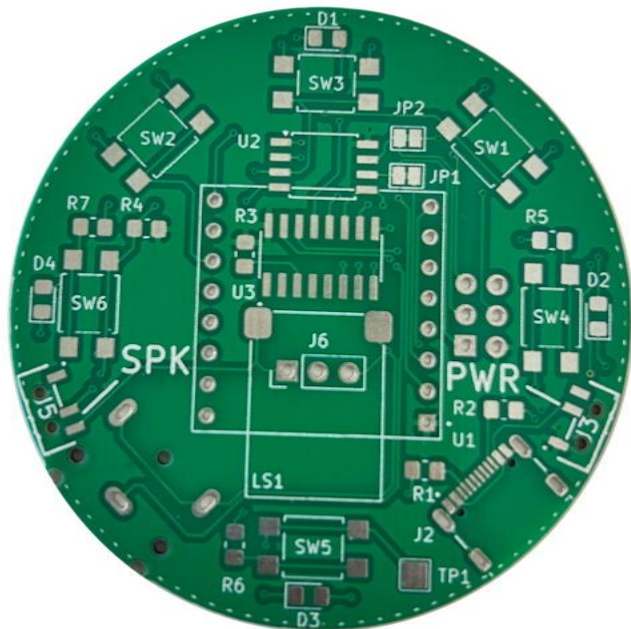
pads layers



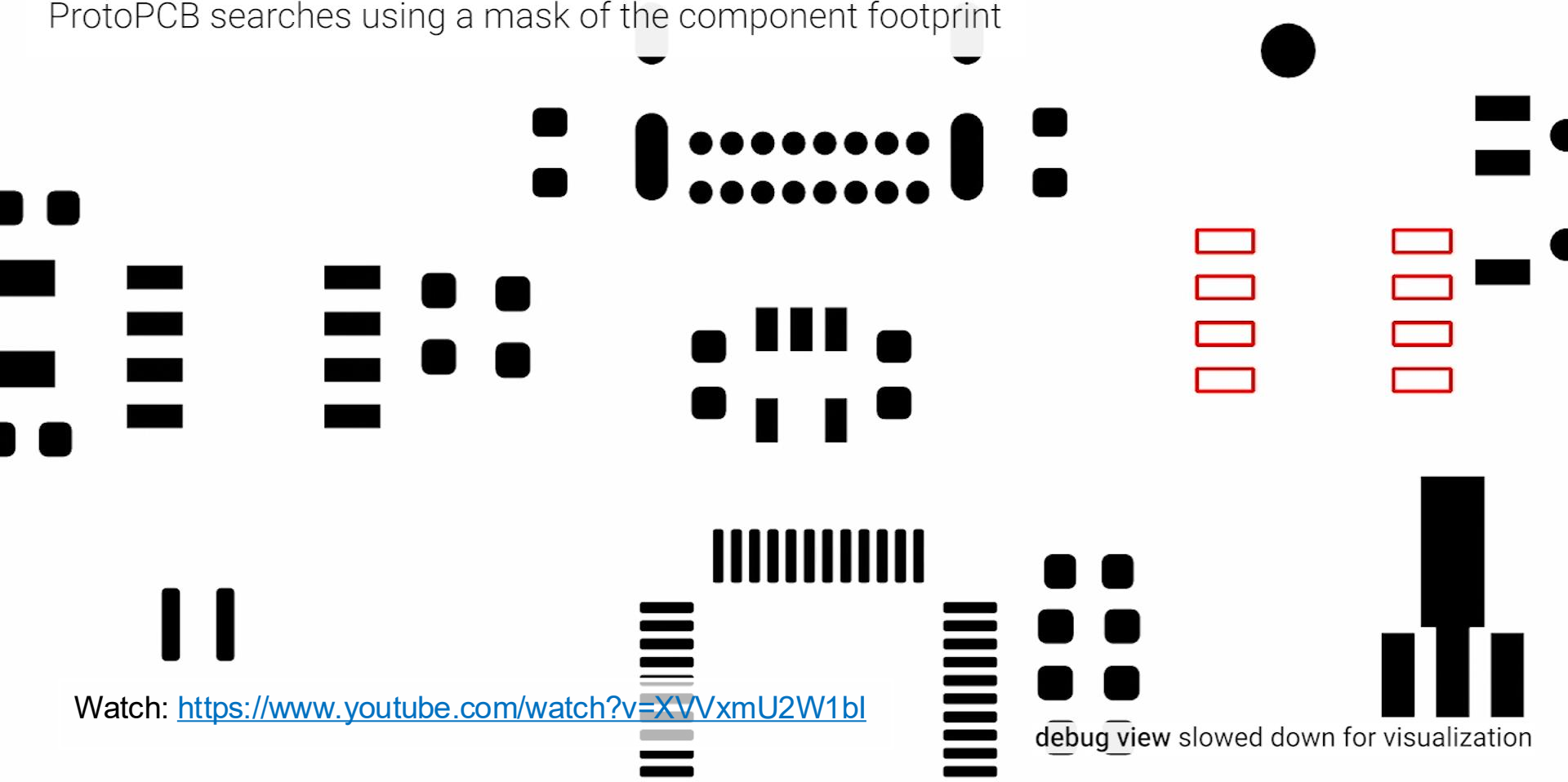
F.Mask



B.Mask



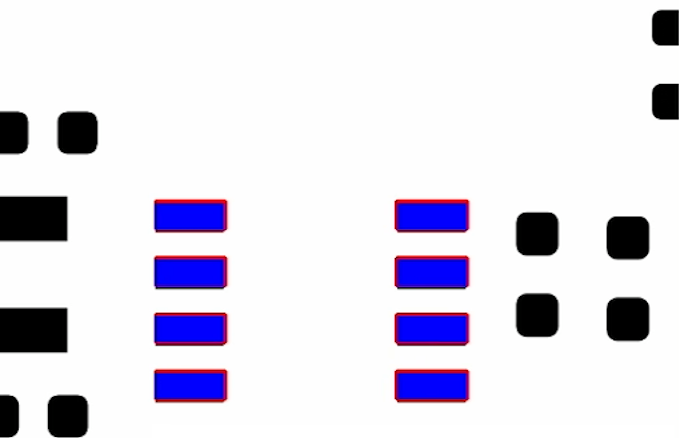
to find ways of physically fitting components to a board,
ProtoPCB searches using a mask of the component footprint



Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

debug view slowed down for visualization

this widens possible matches to also include...

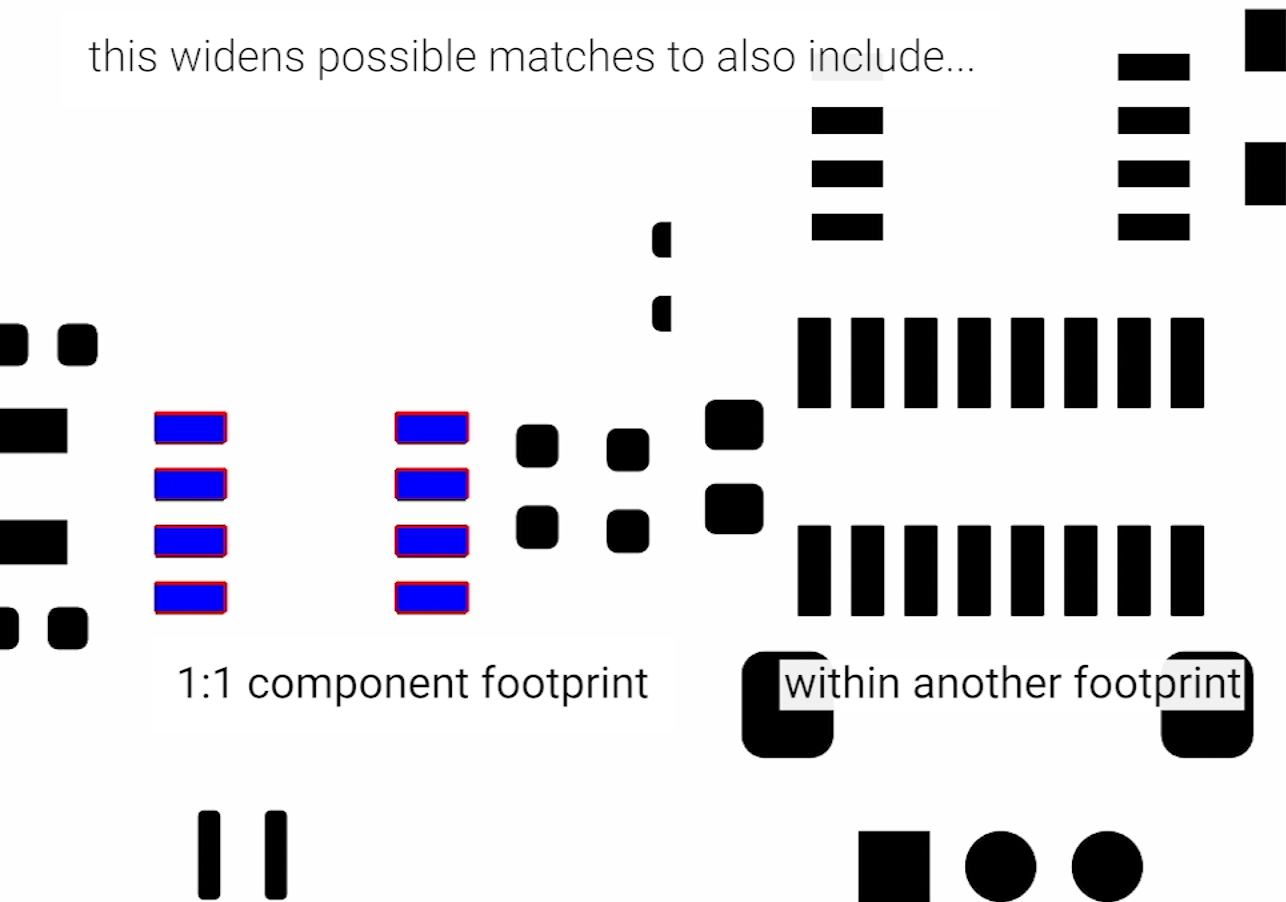


1:1 component footprint



debug view slowed down for visualization

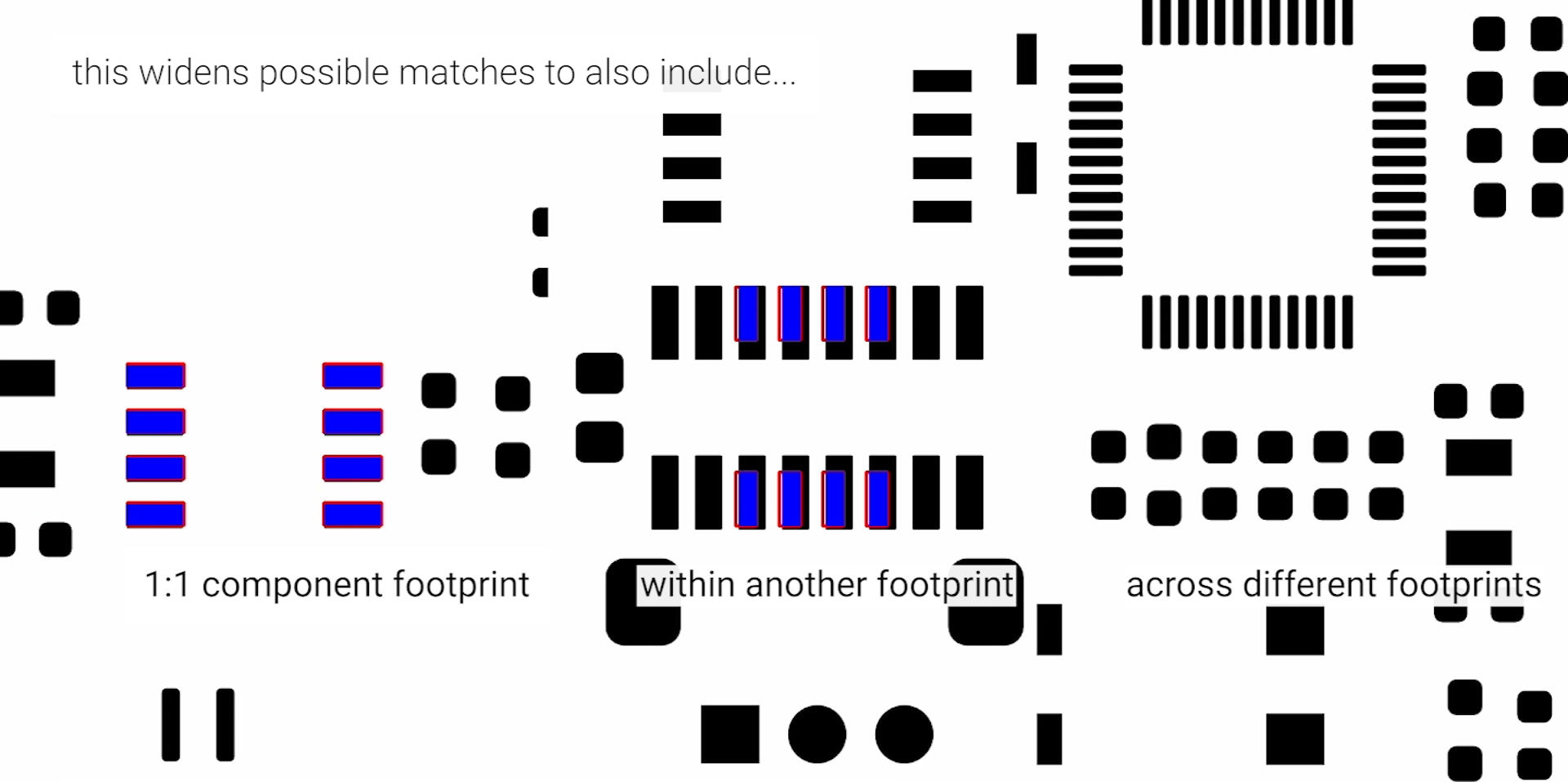
this widens possible matches to also include...



Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

debug view slowed down for visualization

this widens possible matches to also include...



1:1 component footprint

within another footprint

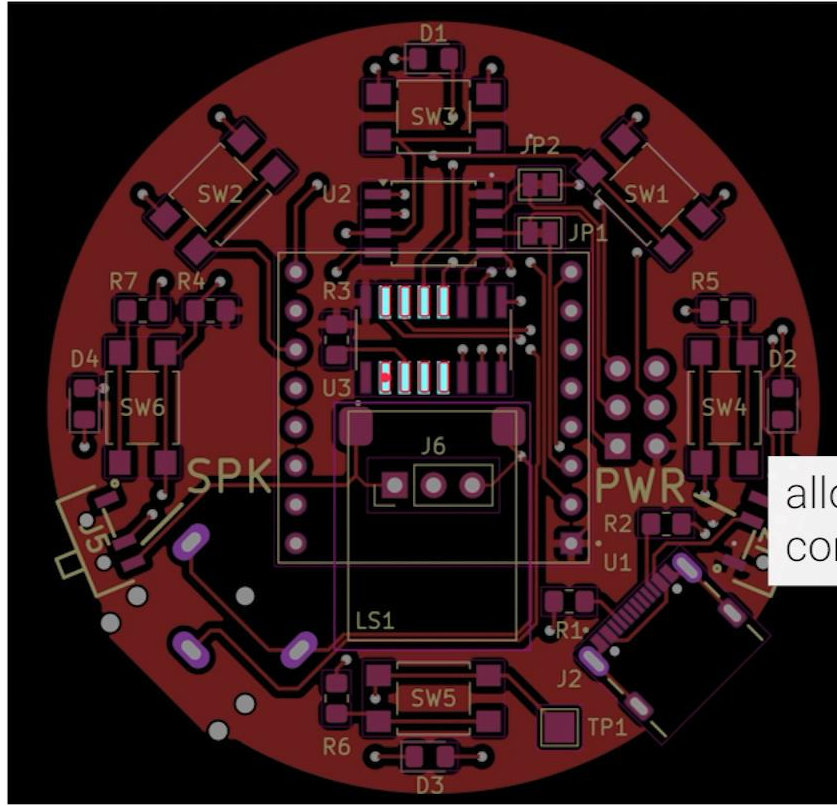
across different footprints

Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

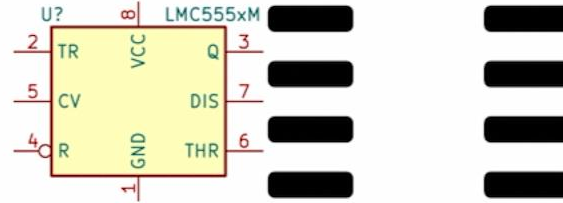
debug view slowed down for visualization

Single Component Match 1 of 16

PCB view



Close-up with match footprint overlaid



Component Name: Timer:LMC555xM

Footprint: SOIC-8_3.9x4.9mm_P1.27mm

allowing for high numbers of
component matches on boards...

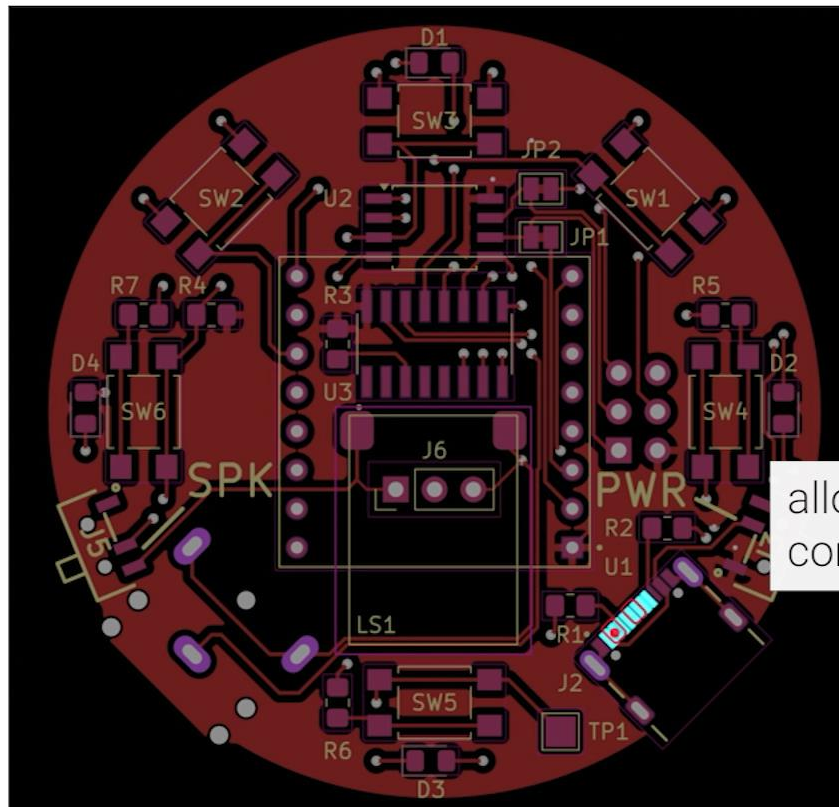
Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

Back

See Next Best Match

Single Component Match 8 of 348

PCB view



Close-up with match footprint overlaid



Component Name: Device:R

Footprint: R_0805_2012Metric

allowing for high numbers of
component matches on boards...

especially for simple &
common footprints

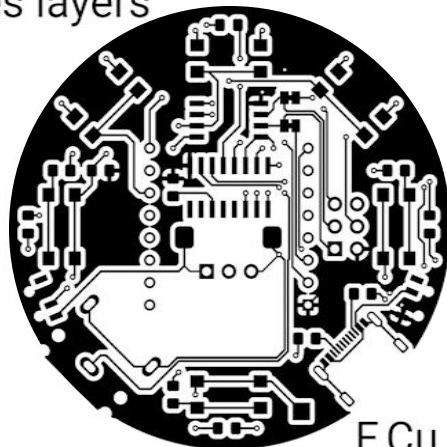
Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

Back

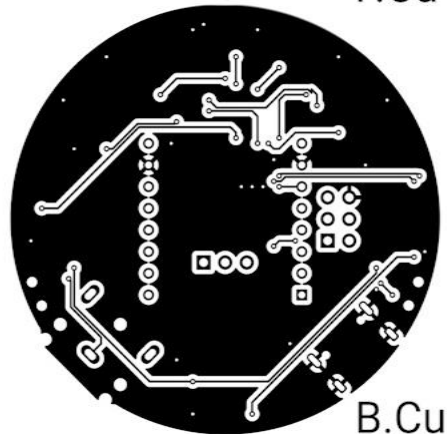
See Next Best Match

ProtoPCB isolates a board into images of its solderable pads and traces using computer vision

traces layers

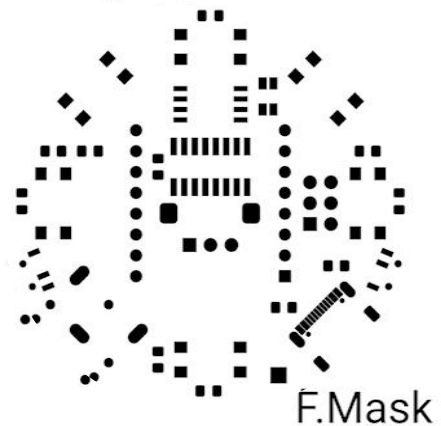


F.Cu

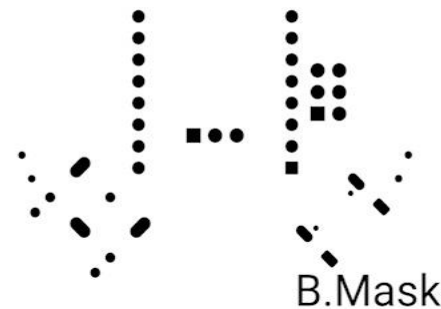


B.Cu

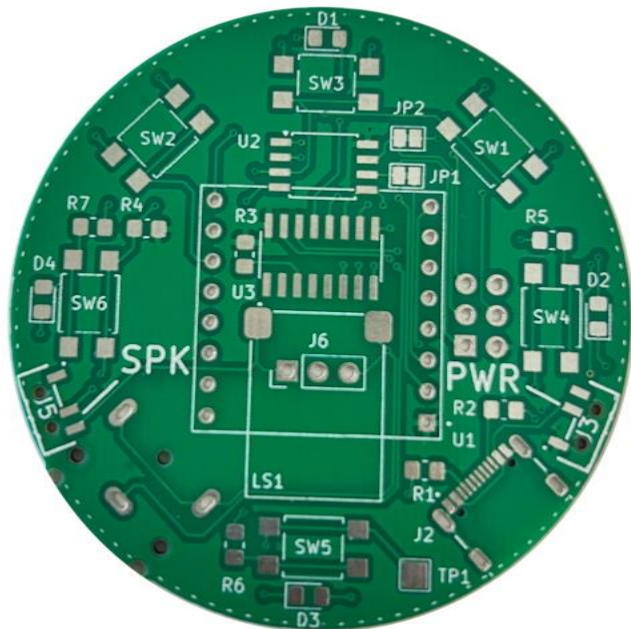
pads layers



F.Mask

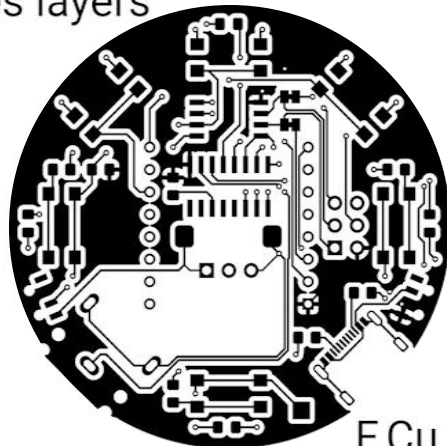


B.Mask

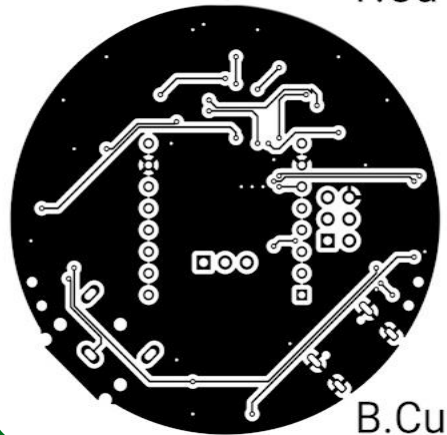


ProtoPCB isolates a board into images of its solderable pads and traces using computer vision

traces layers

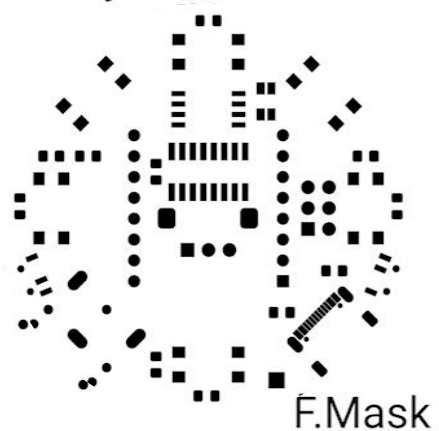


F.Cu

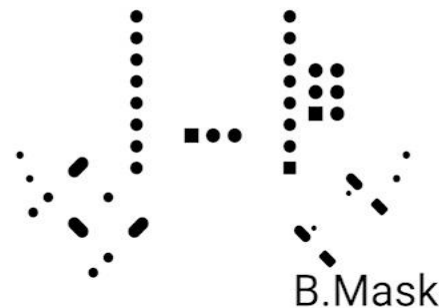


B.Cu

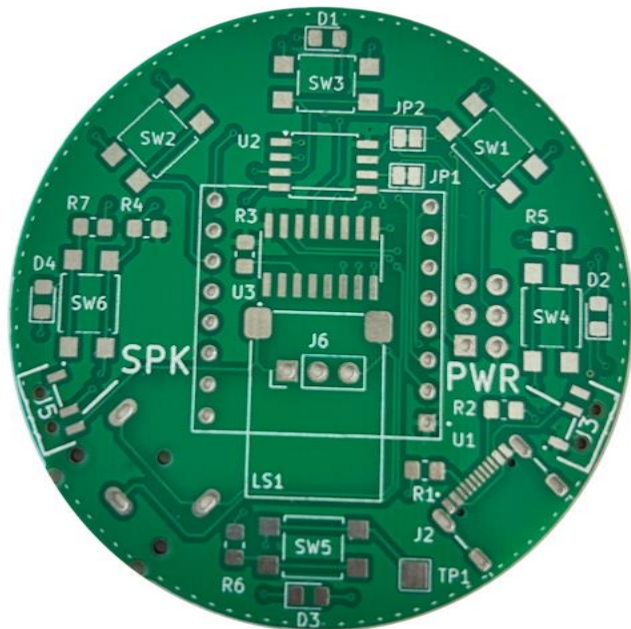
pads layers



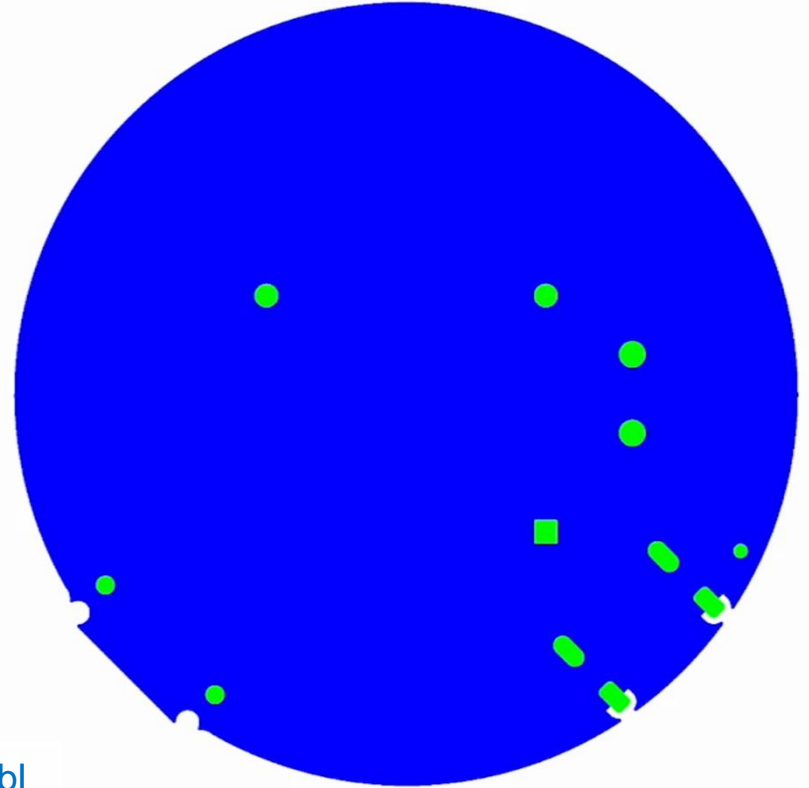
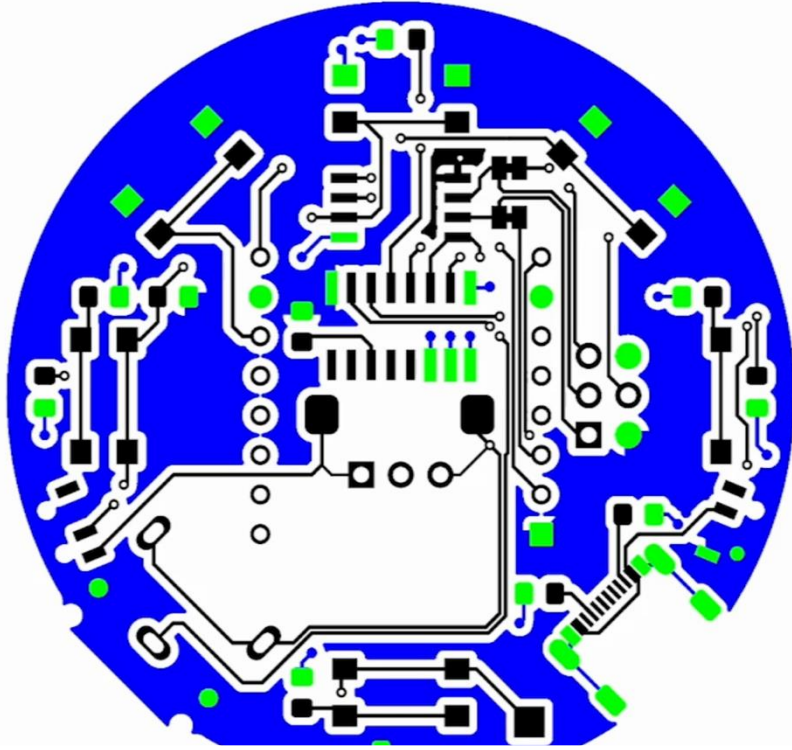
F.Mask



B.Mask



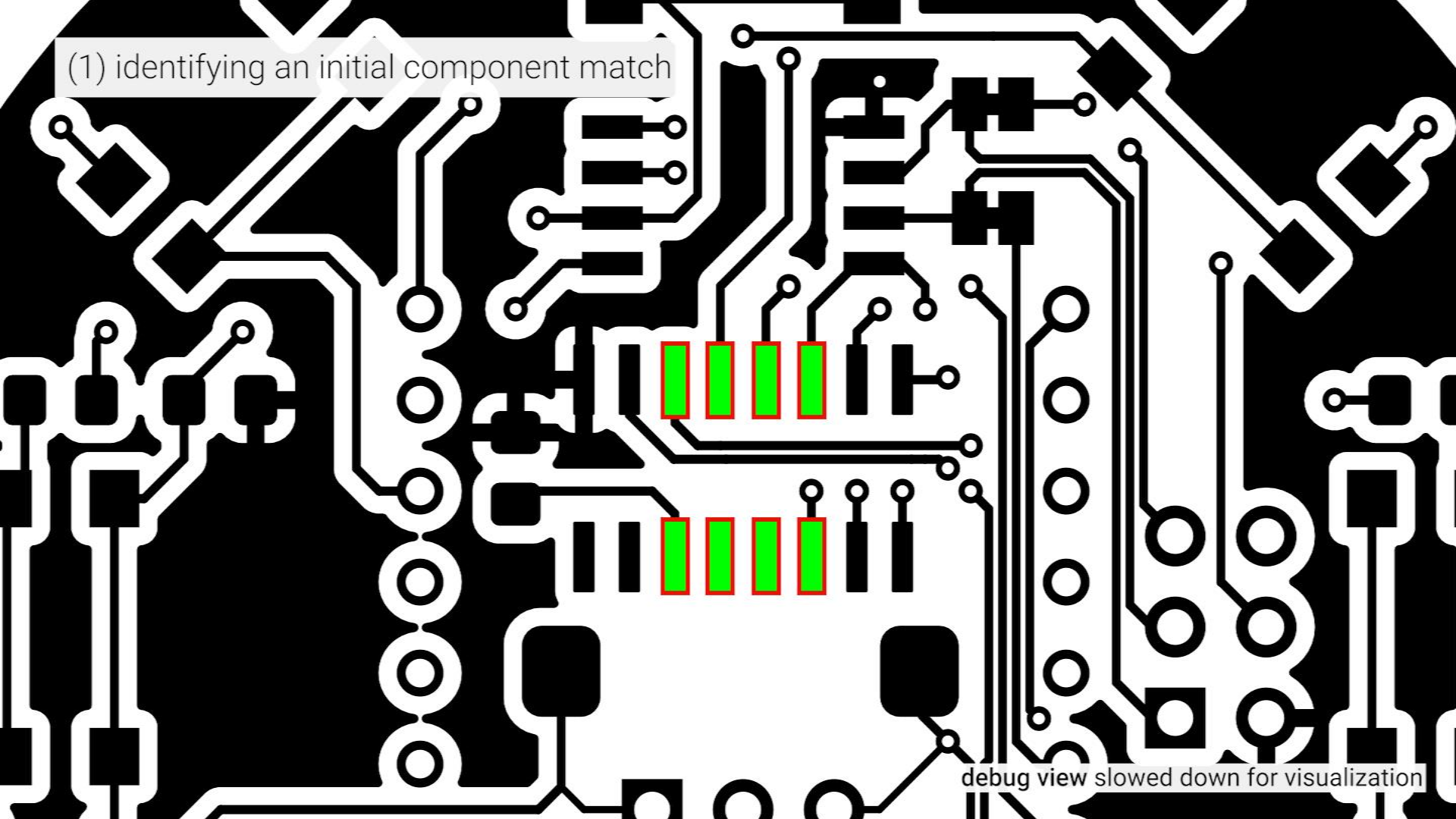
to create a mapping of connected pads,
ProtoPCB uses images of board traces (also accounting for vias)



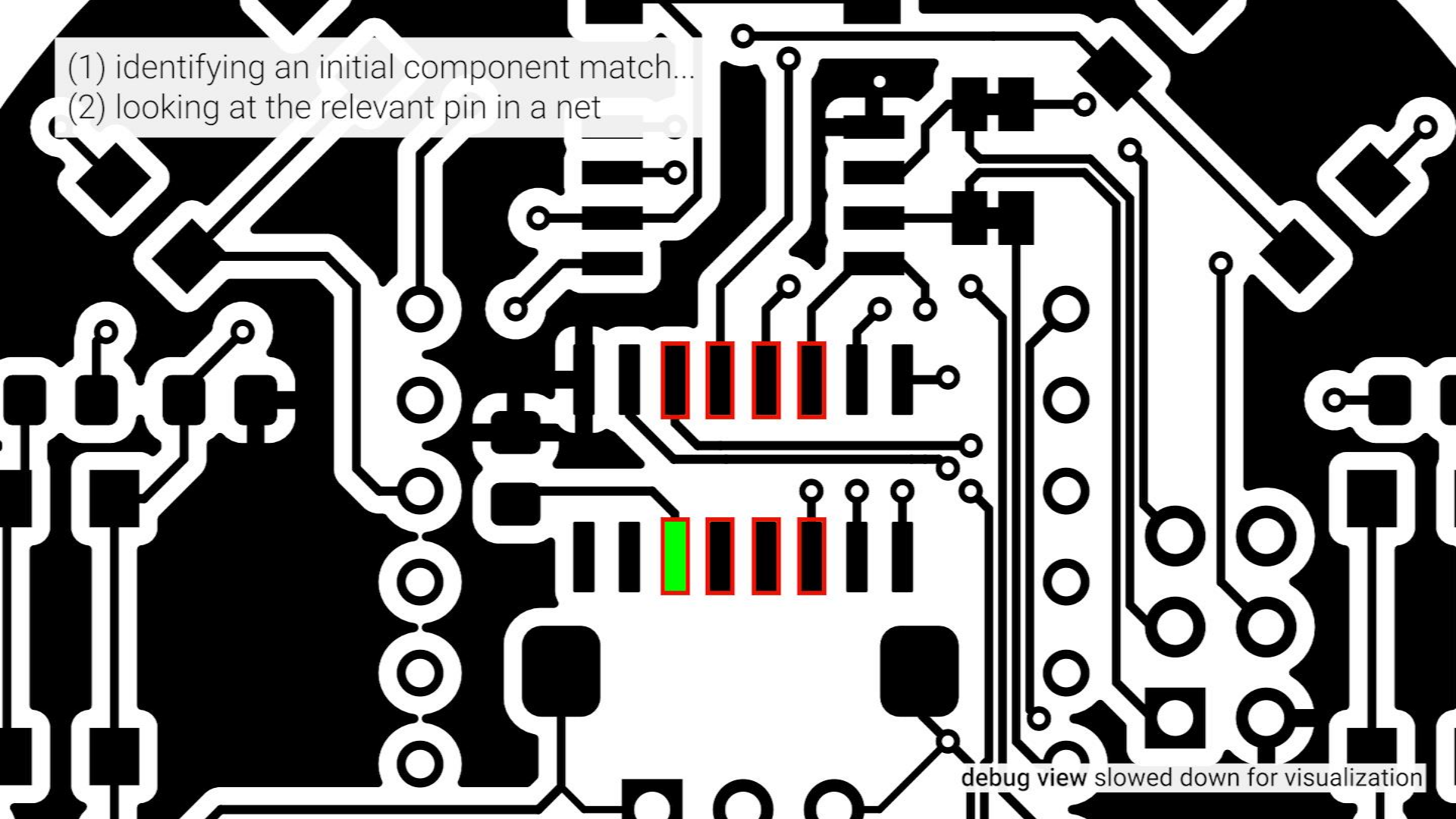
back

Watch: <https://www.youtube.com/watch?v=XVVxmU2W1bl>

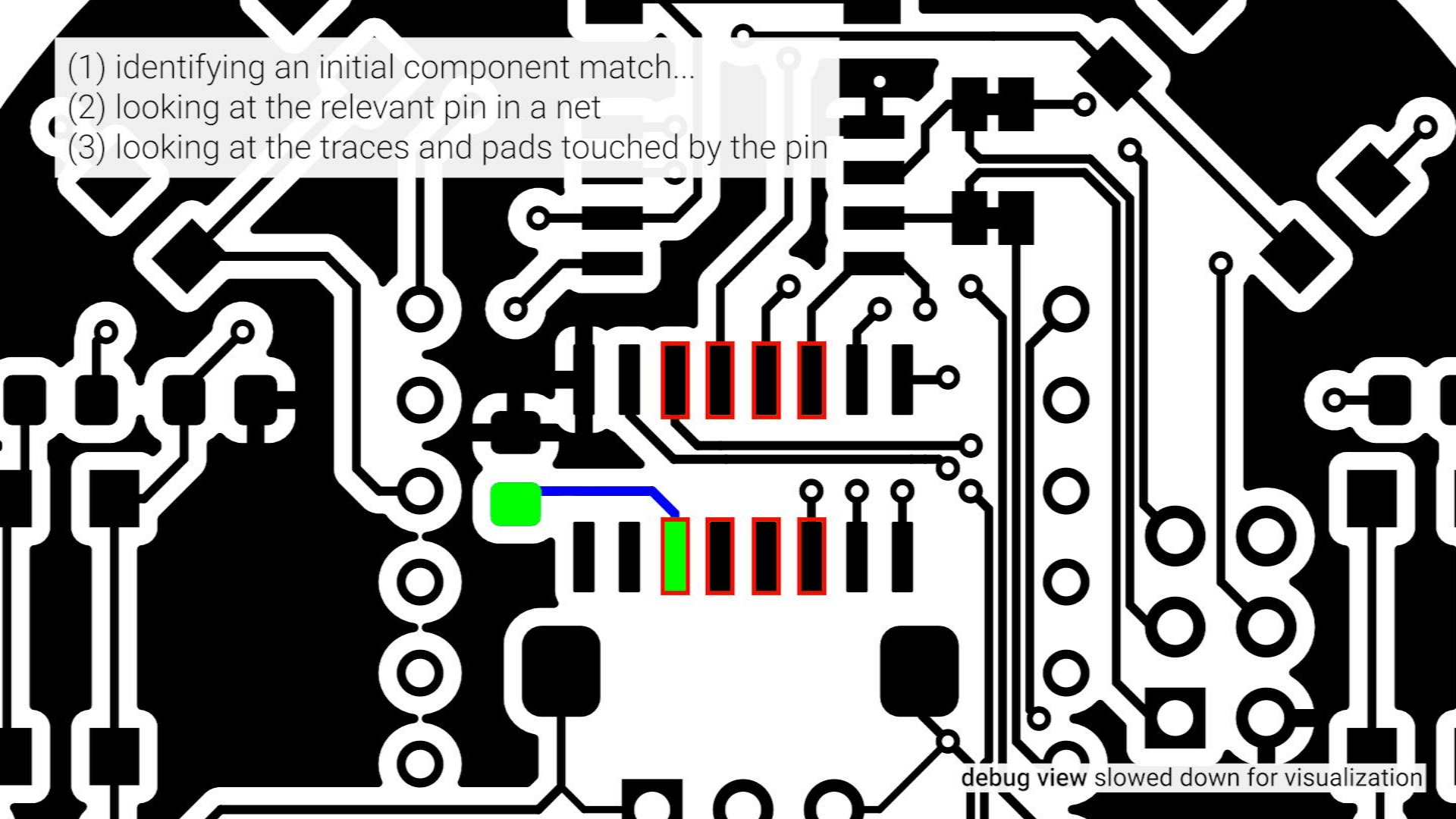
(1) identifying an initial component match



debug view slowed down for visualization

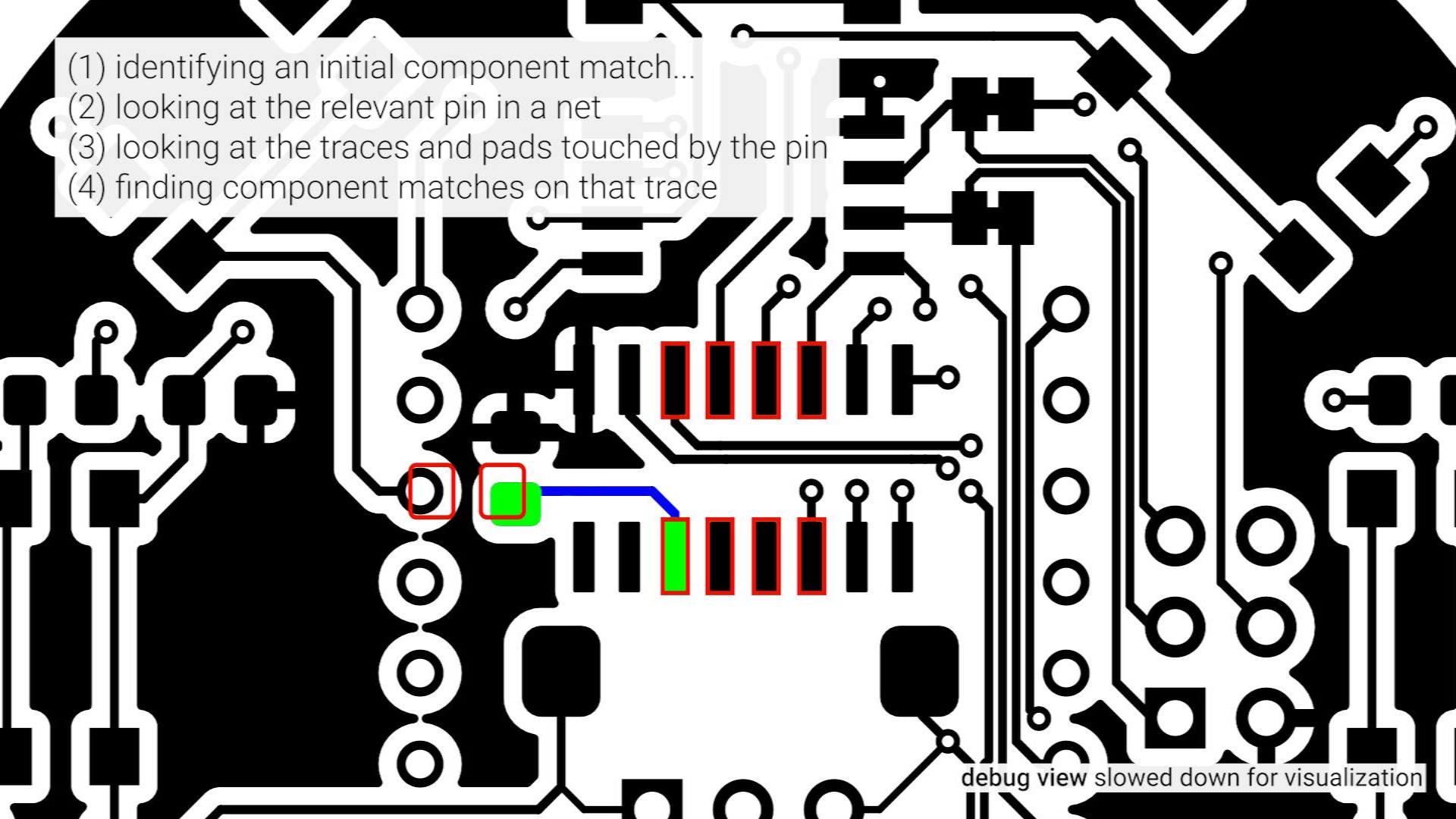
- 
- (1) identifying an initial component match...
- (2) looking at the relevant pin in a net

debug view slowed down for visualization

- 
- (1) identifying an initial component match...
 - (2) looking at the relevant pin in a net
 - (3) looking at the traces and pads touched by the pin

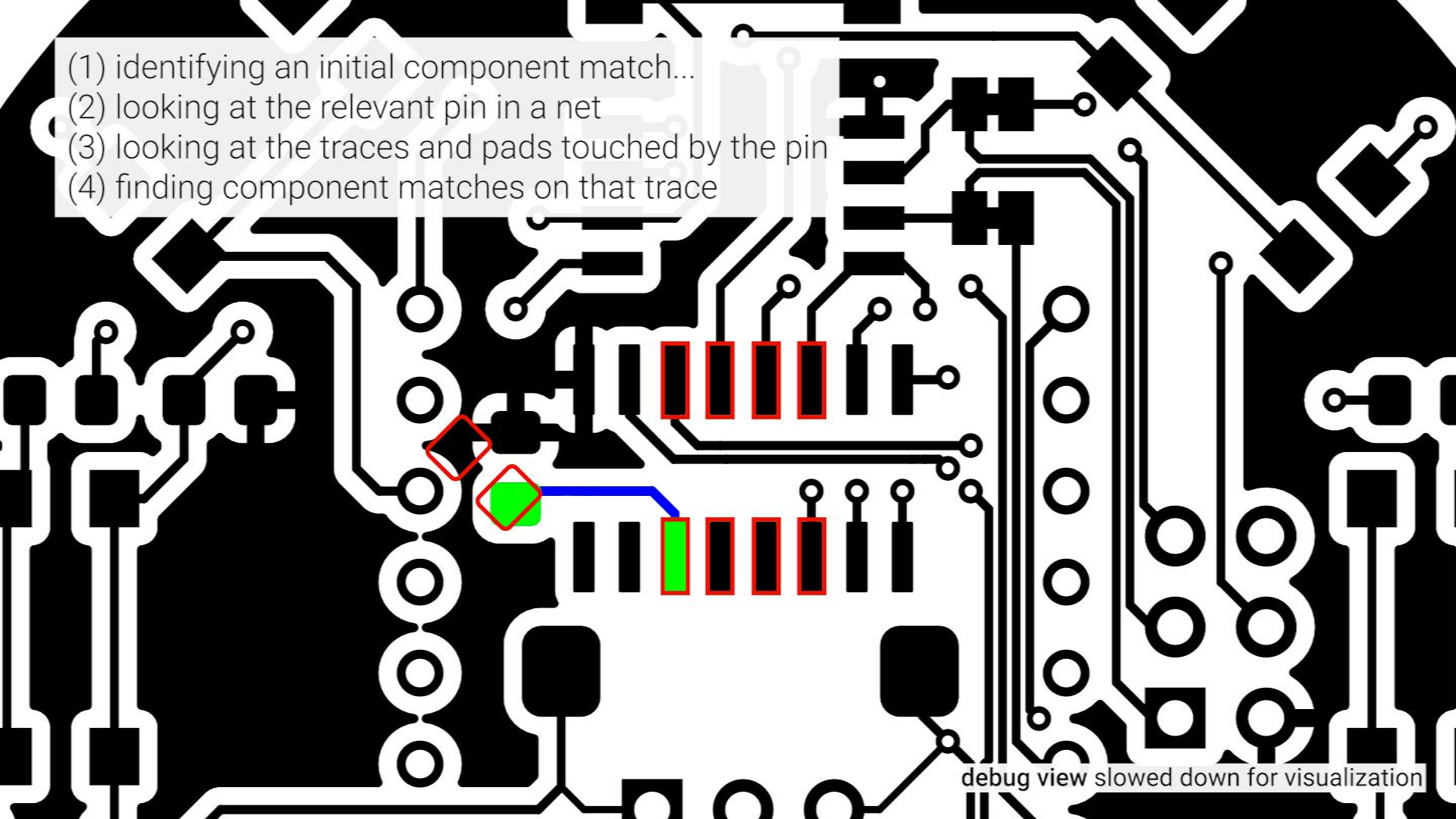
debug view slowed down for visualization

- (1) identifying an initial component match...
- (2) looking at the relevant pin in a net
- (3) looking at the traces and pads touched by the pin
- (4) finding component matches on that trace



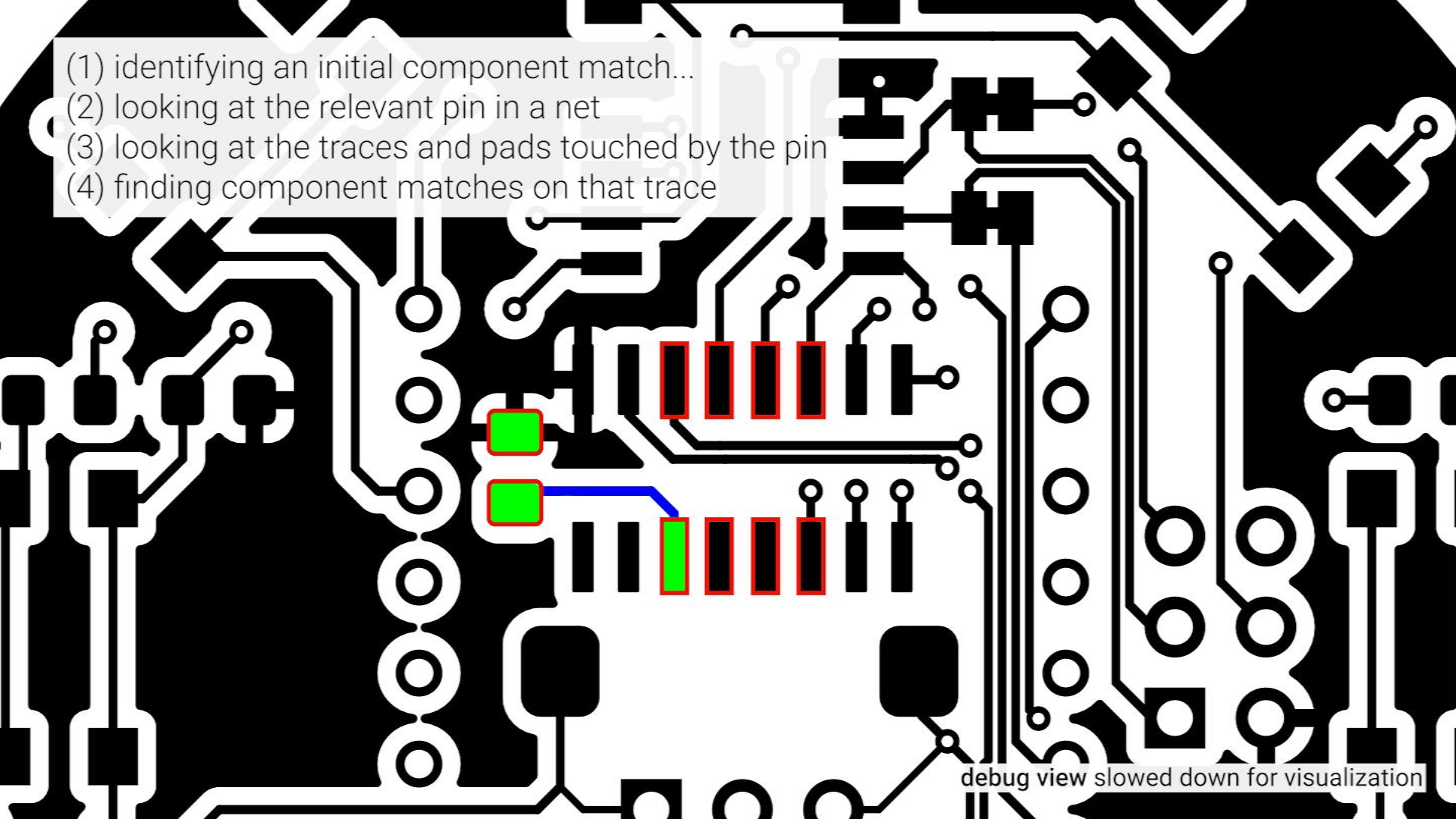
debug view slowed down for visualization

- (1) identifying an initial component match...
- (2) looking at the relevant pin in a net
- (3) looking at the traces and pads touched by the pin
- (4) finding component matches on that trace

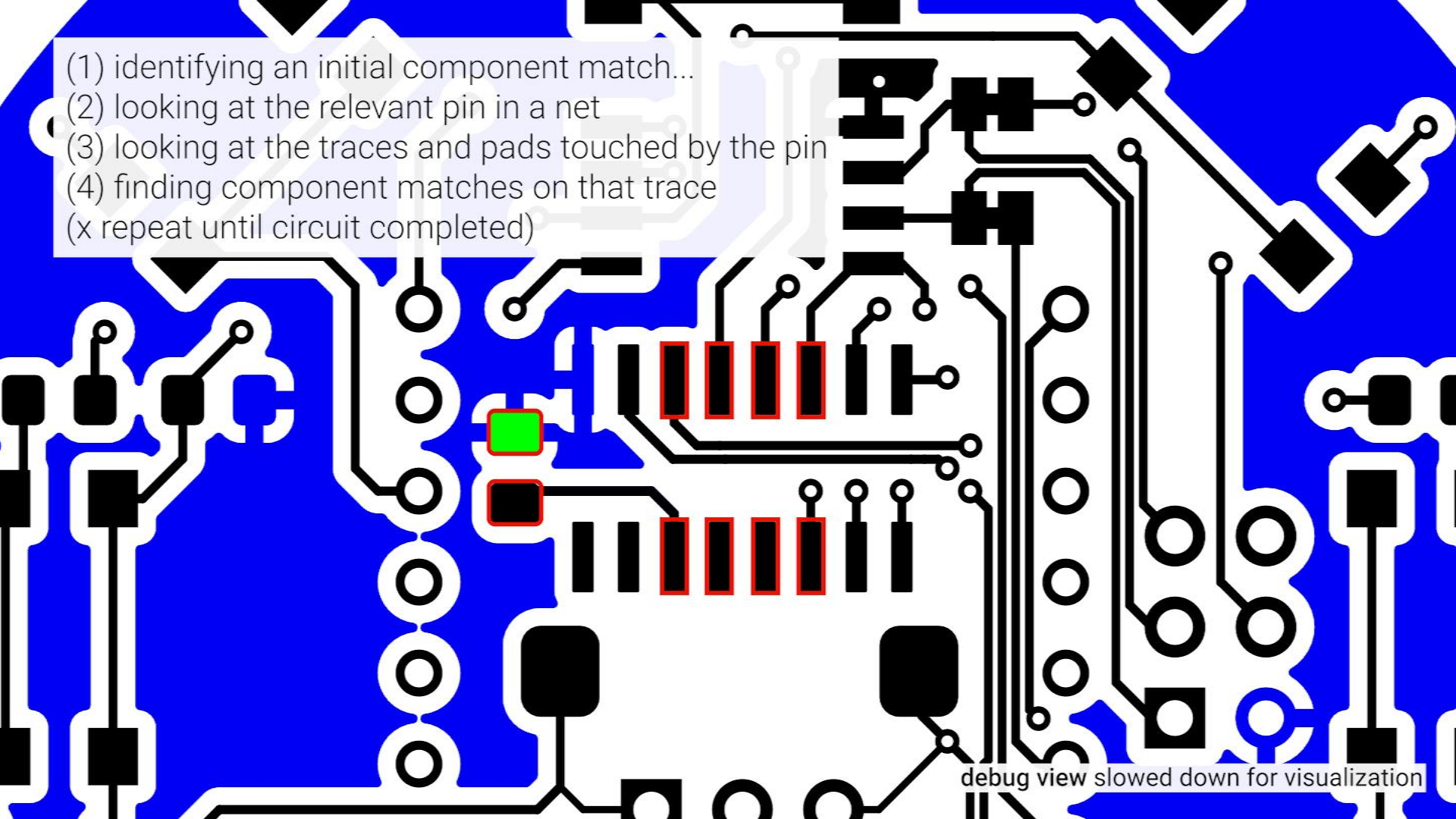


debug view slowed down for visualization

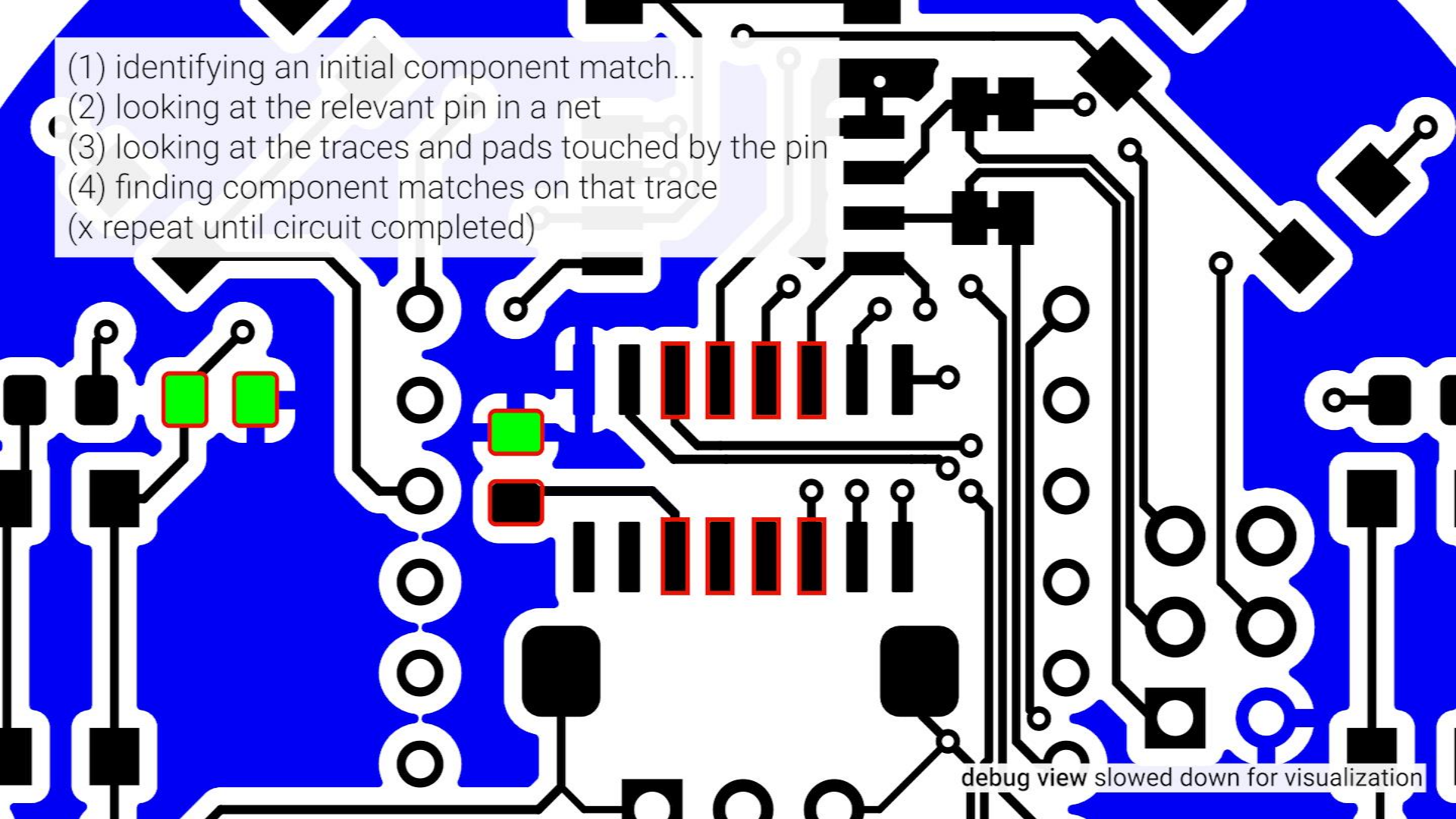
- (1) identifying an initial component match...
- (2) looking at the relevant pin in a net
- (3) looking at the traces and pads touched by the pin
- (4) finding component matches on that trace



debug view slowed down for visualization

- 
- (1) identifying an initial component match...
 - (2) looking at the relevant pin in a net
 - (3) looking at the traces and pads touched by the pin
 - (4) finding component matches on that trace
(x repeat until circuit completed)

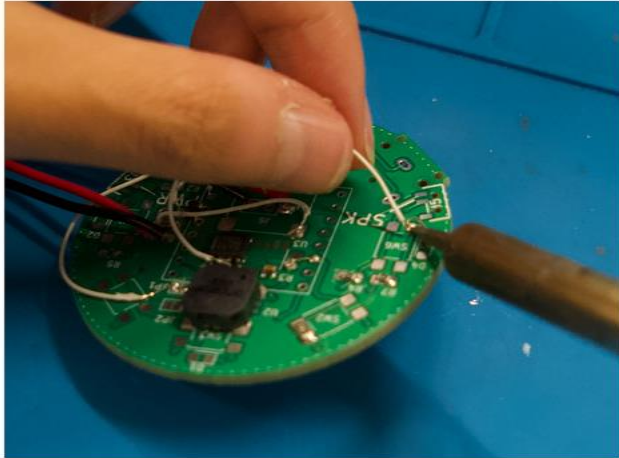
debug view slowed down for visualization

- 
- (1) identifying an initial component match...
 - (2) looking at the relevant pin in a net
 - (3) looking at the traces and pads touched by the pin
 - (4) finding component matches on that trace
(x repeat until circuit completed)

debug view slowed down for visualization

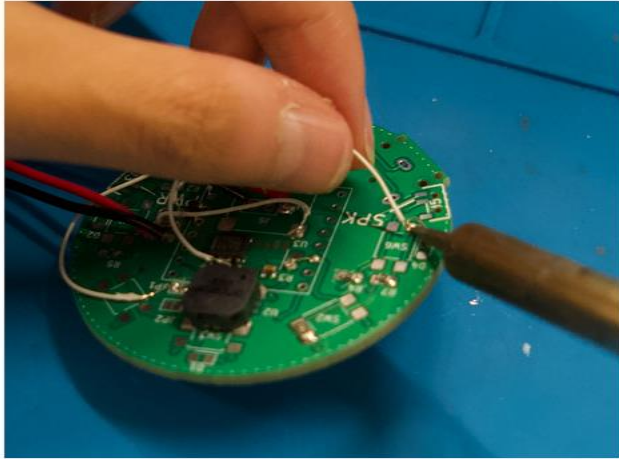
ProtoPCB also searches for interventions on the board to implement the circuit including...

adding a wire

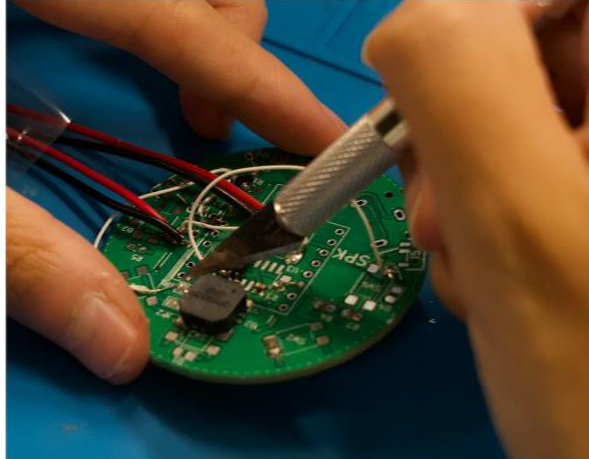


ProtoPCB also searches for interventions on the board to implement the circuit including...

adding a wire

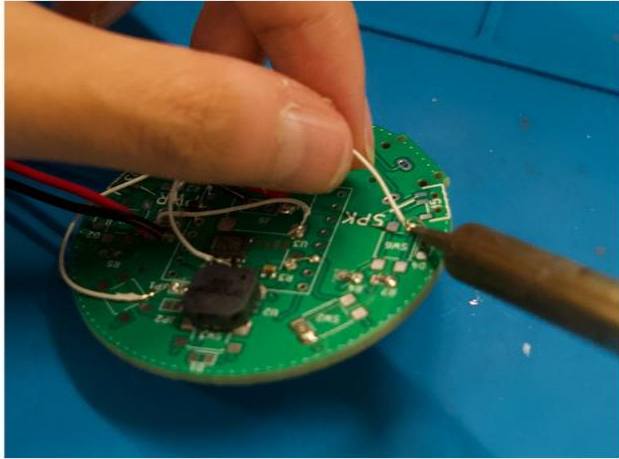


cutting a trace

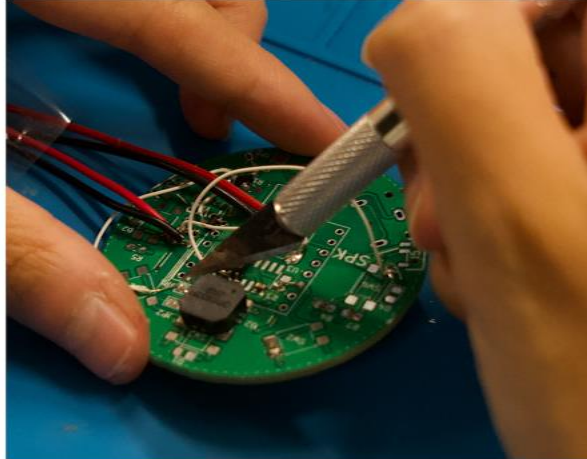


ProtoPCB also searches for interventions on the board to implement the circuit including...

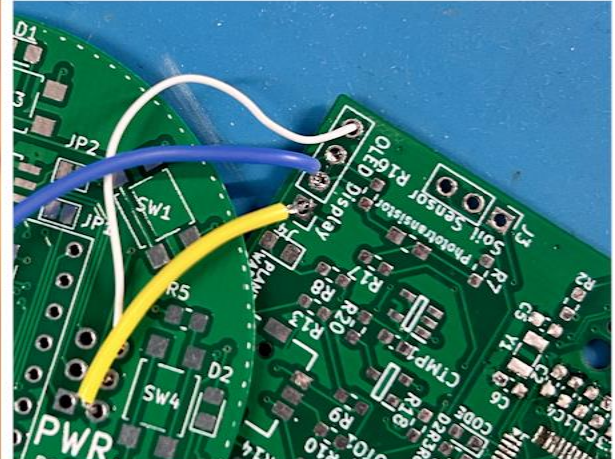
adding a wire



cutting a trace

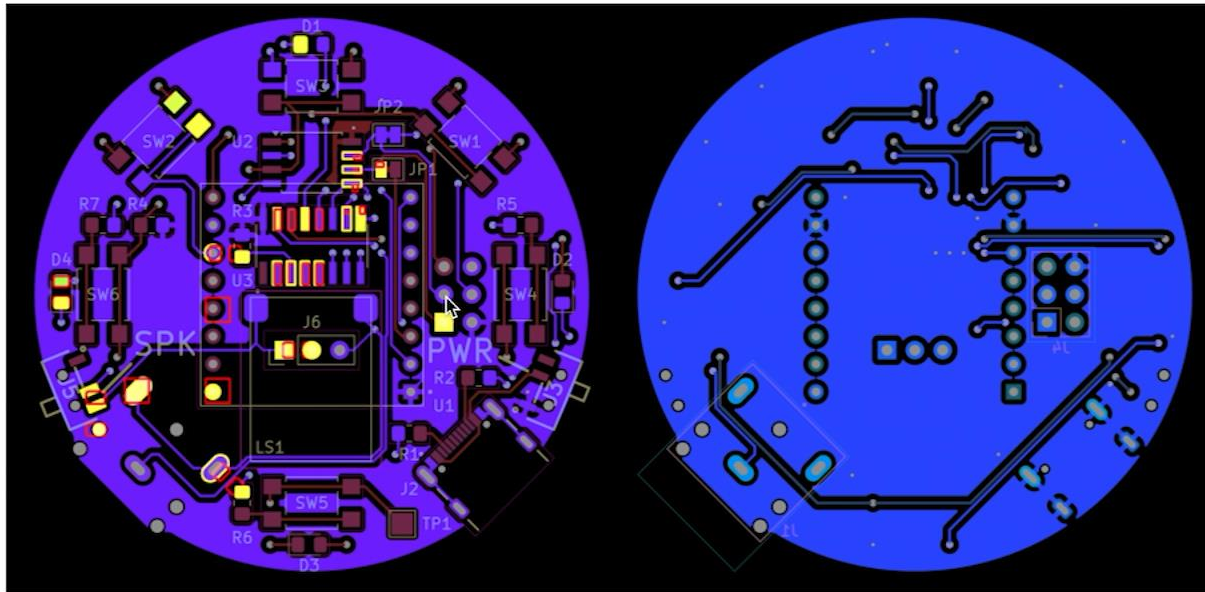


using multiple boards



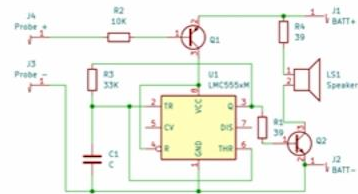
ProtoPCB // Full Circuit Match // 1 of 12

Front PCB view from ATtiny85-MP3.kicad_pcb



Searching on 42 PCB Boards from Library

Circuit schematic from Connectivity Probe.kicad_sch



Multiple Interventions Needed

Select View:

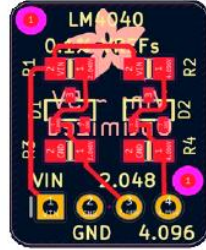
technical evaluation

can circuits be implemented
on **completely different PCBs?**

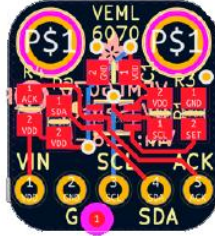
we tested this on 9 random
open-source PCBs

Low Complexity

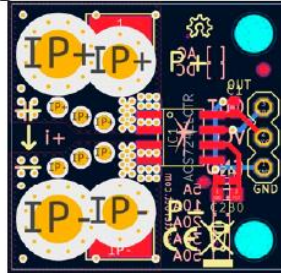
① LM4040 Breakout



② VEML6070 Breakout



③ ACS72X Breakout

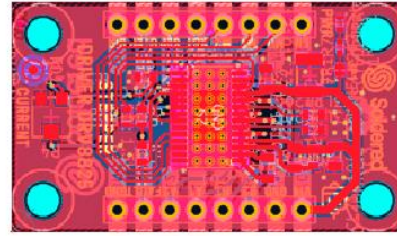


Medium Complexity

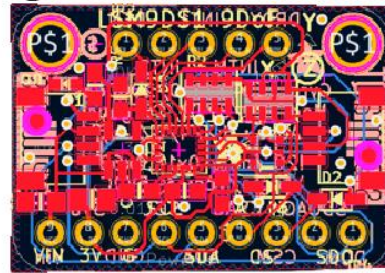
④ BioAmp EXG Pill



⑤ Stepper Driver Breakout



⑥ LSM9DS1 Breakout

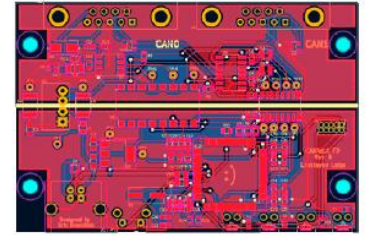


High Complexity

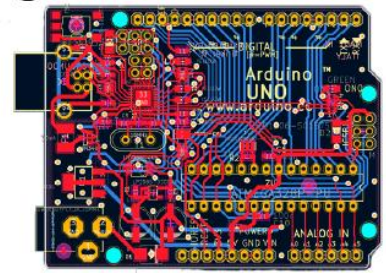
⑦ Circuit Playground

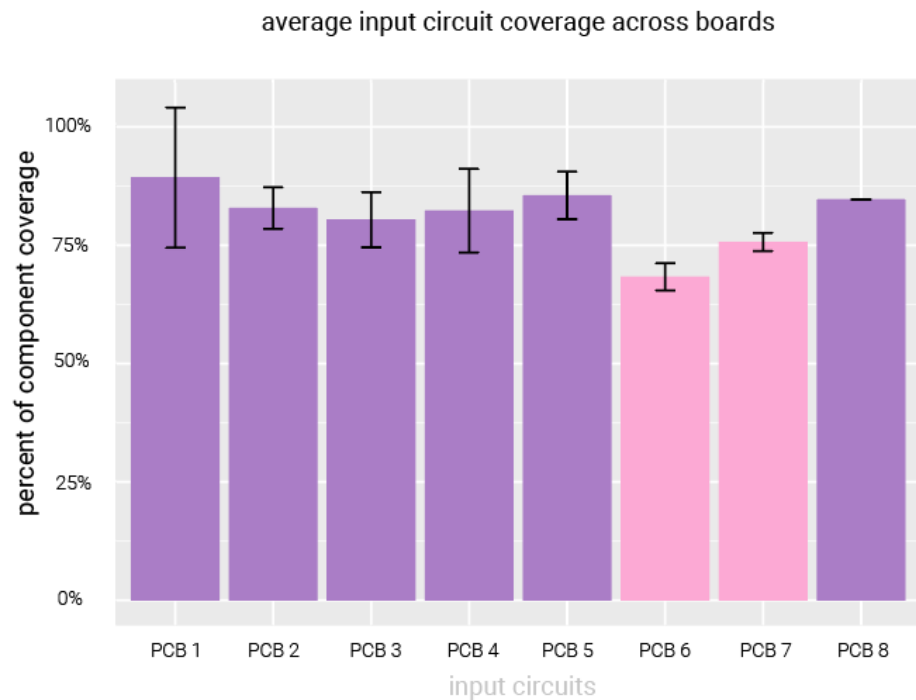
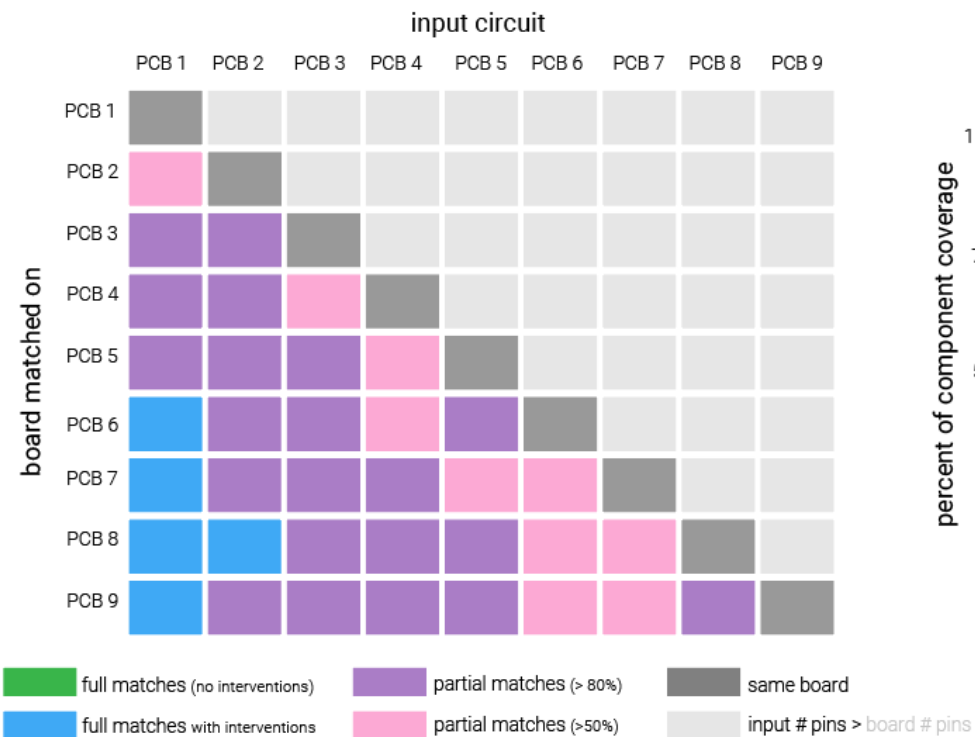


⑧ CANTact



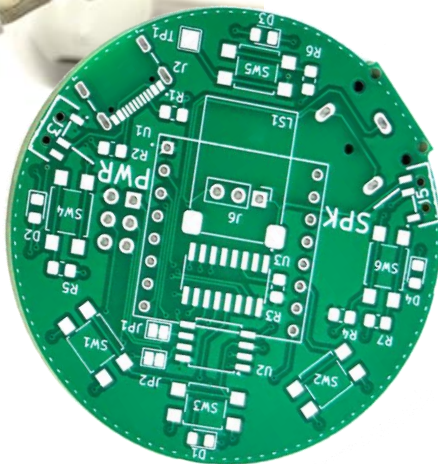
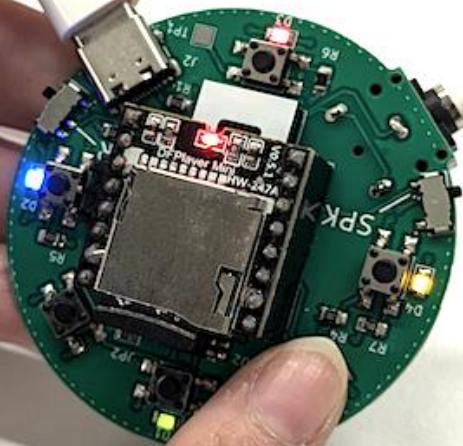
⑨ Arduino UNO



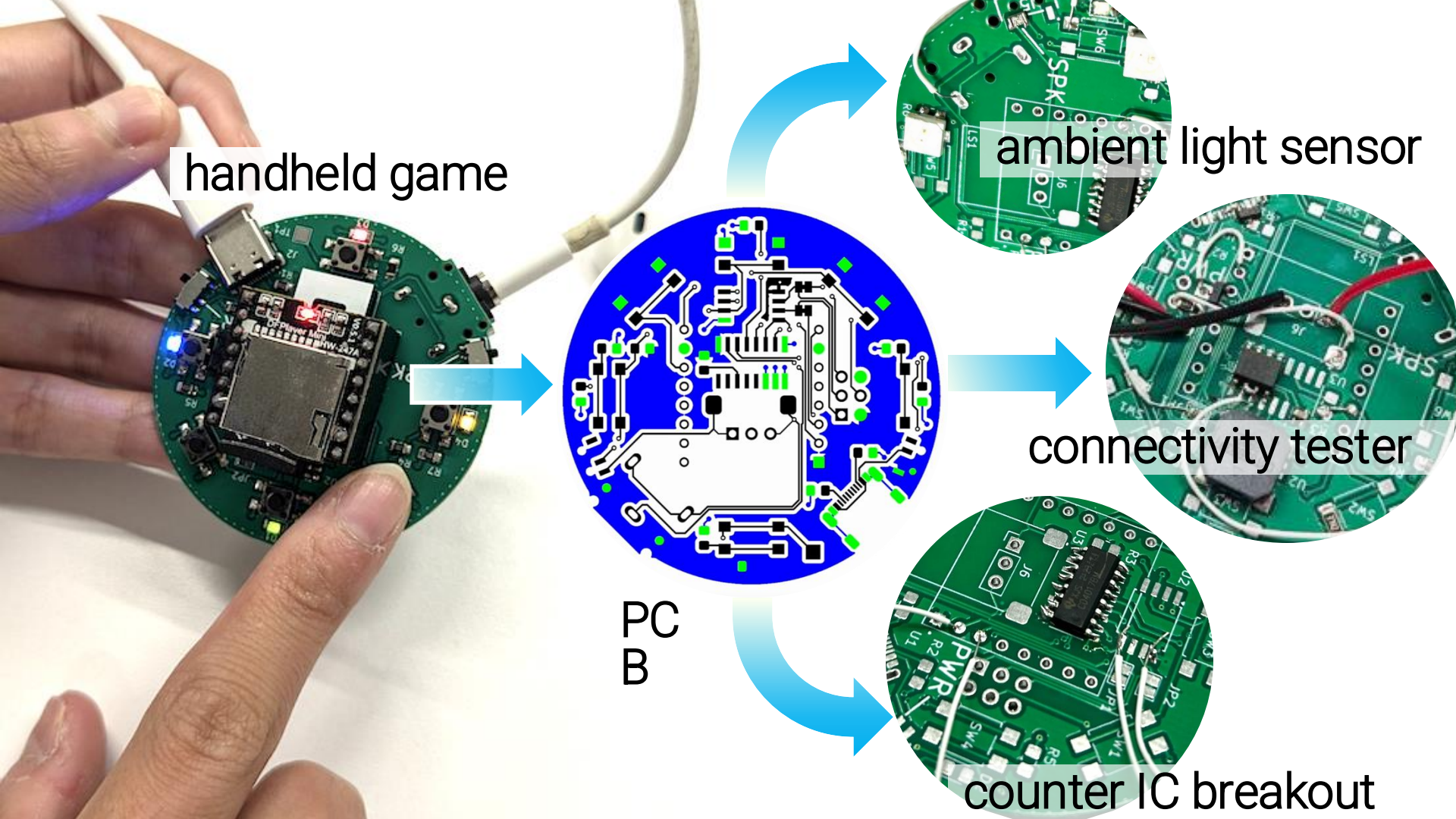


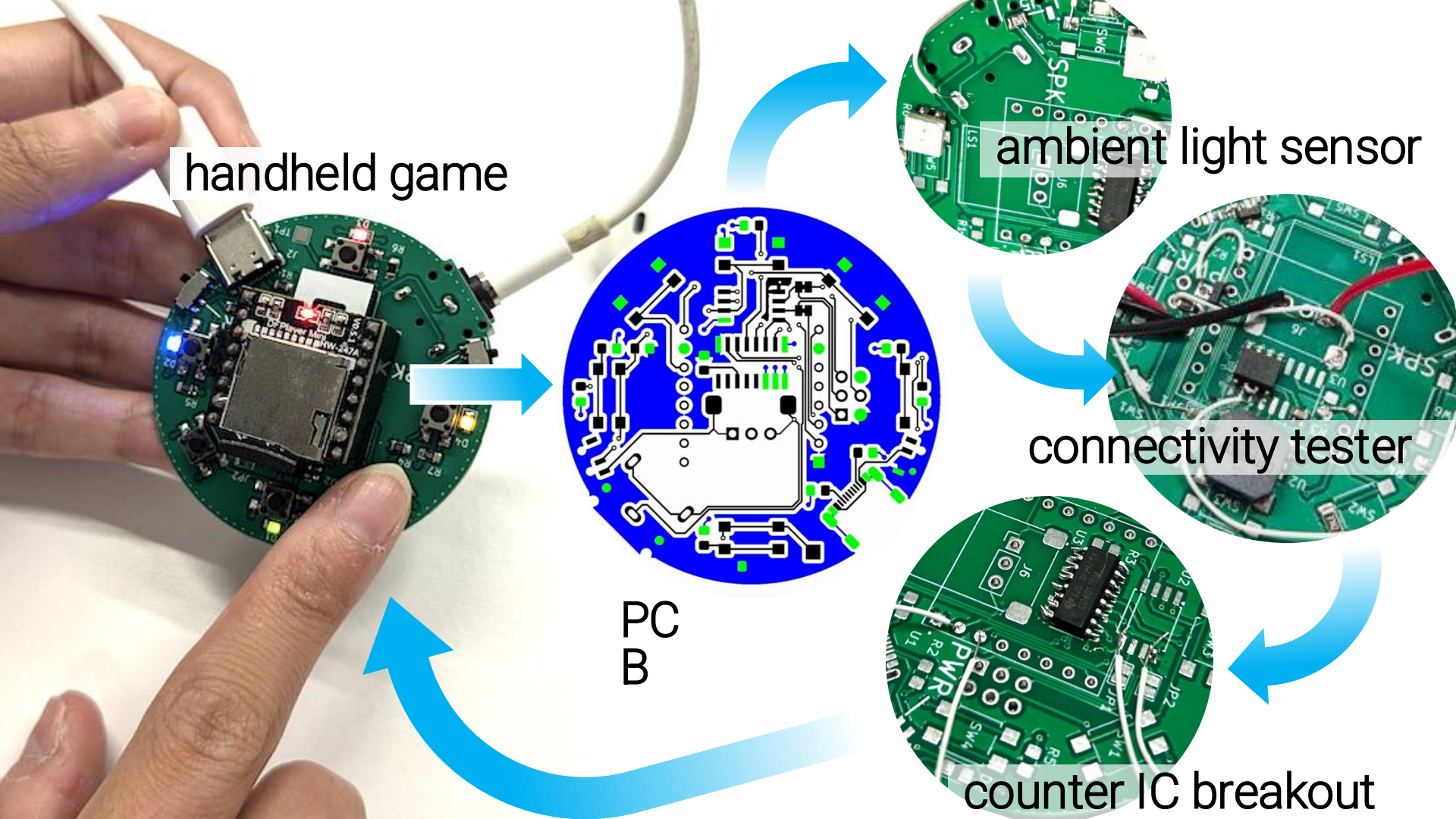
conclusions

handheld game

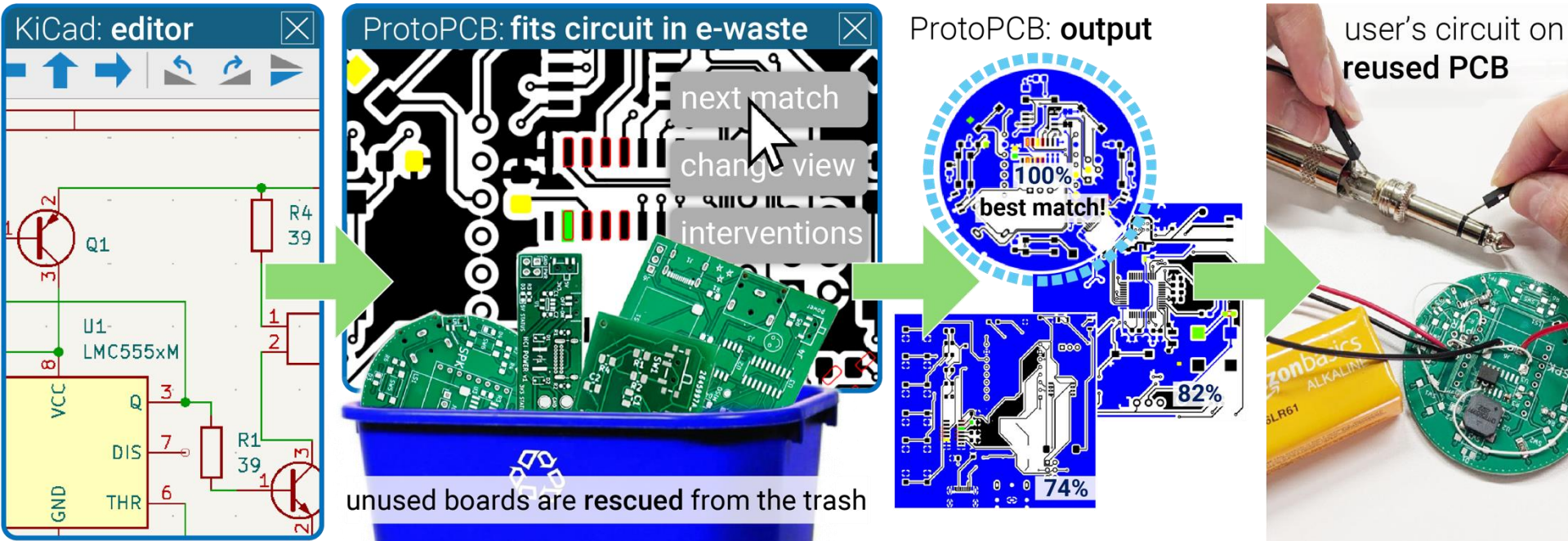


PC
B

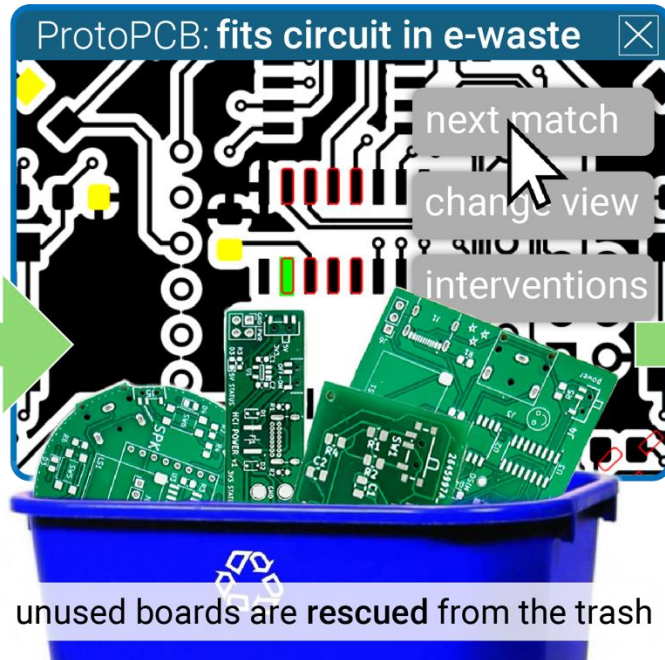
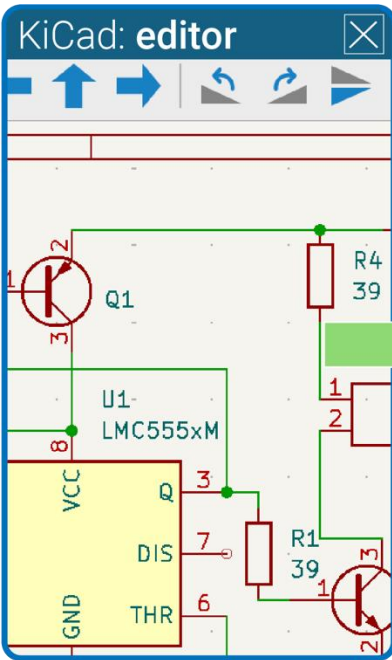




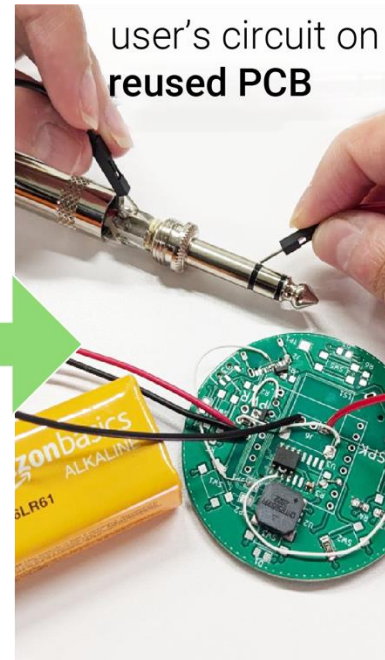
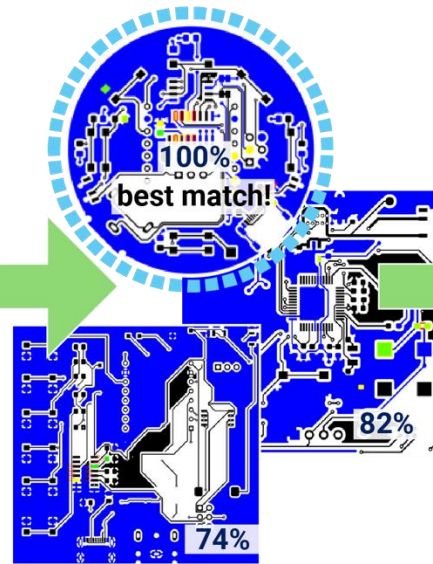
ProtoPCB offers a new prototyping strategy



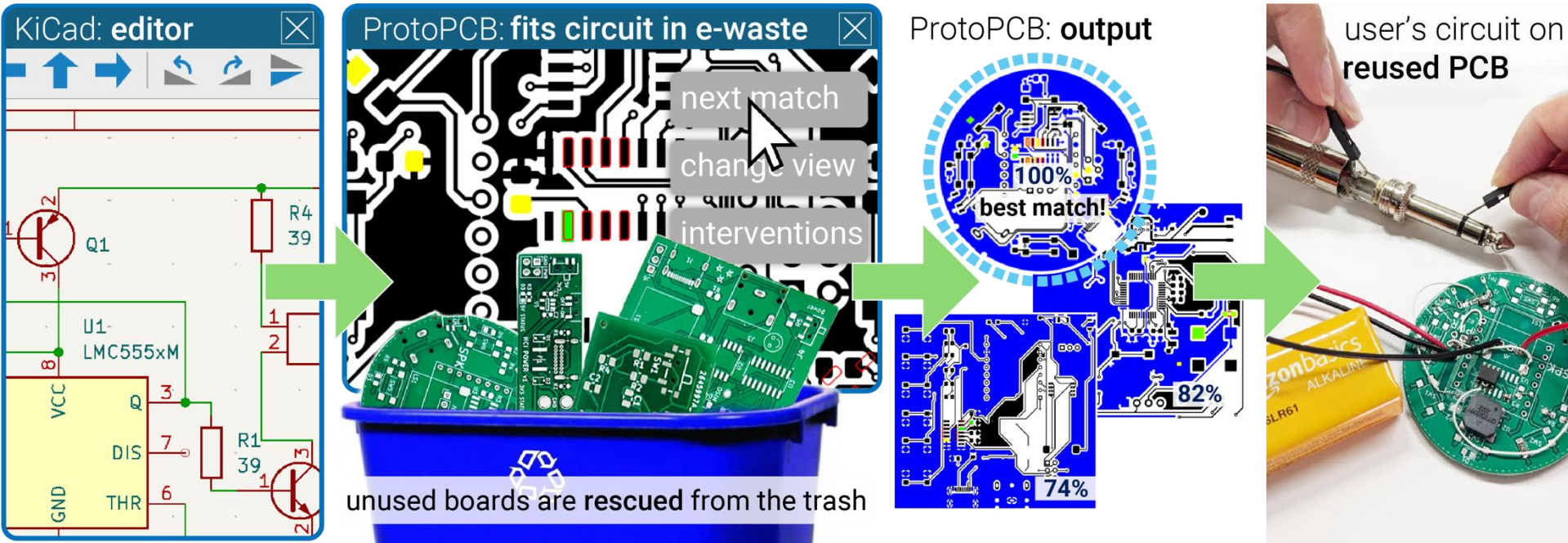
ProtoPCB offers a new prototyping strategy conceptualized by prioritizing reuse



ProtoPCB: output



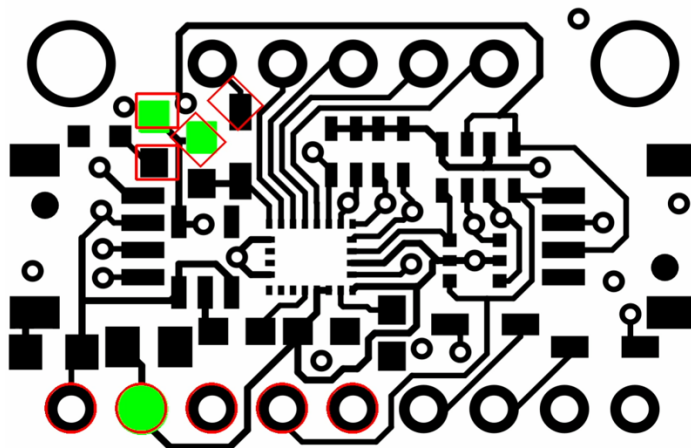
ProtoPCB offers a new prototyping strategy conceptualized by prioritizing reuse



thinking within the constraints of
waste & what we already have

computational recycling

ProtoPCB

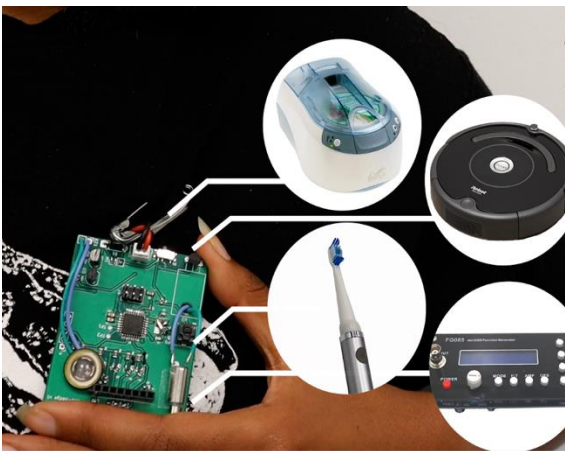


assist reuse of printed circuit boards

CHI'25

computational recycling

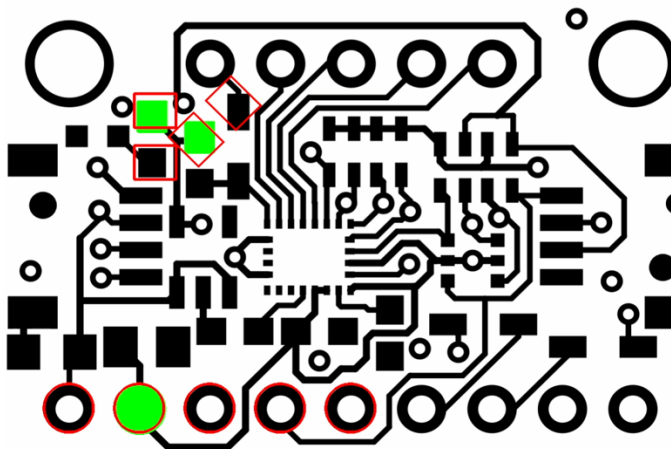
ecoEDA



assist reuse of components

UIST Honorable Mention UIST'23

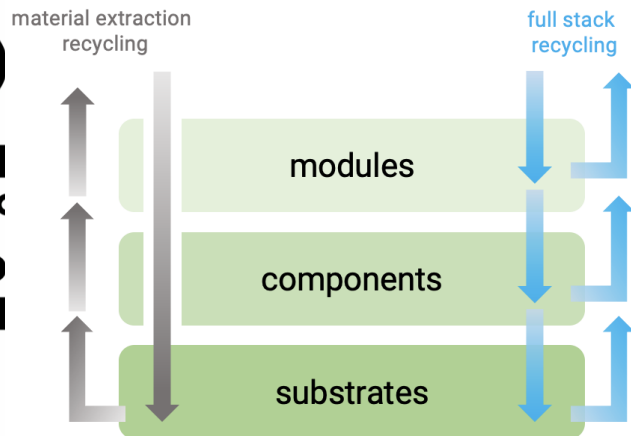
ProtoPCB



assist reuse of printed circuit boards

CHI'25

Full Stack Recycling



full stack recycling approaches

CACM'25

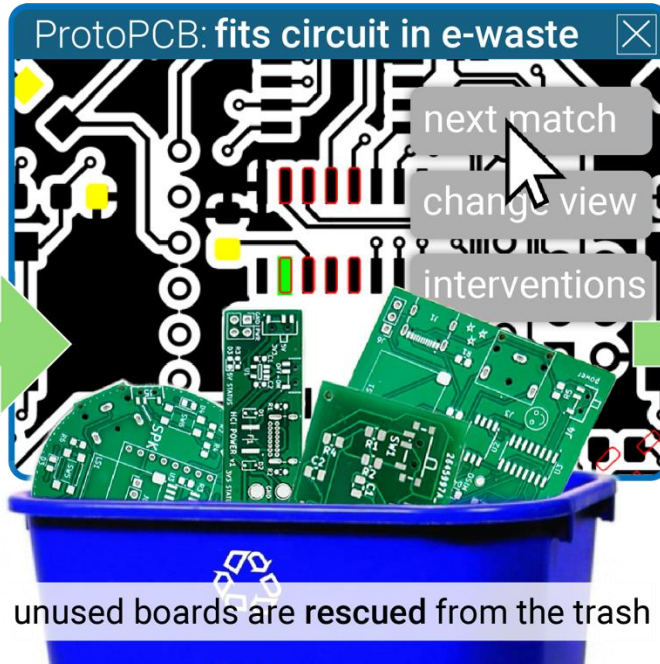
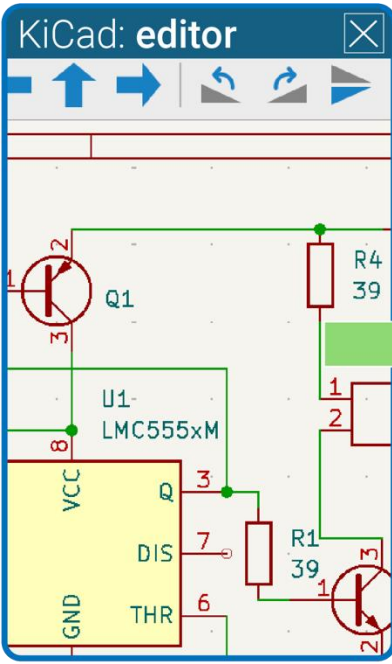
ProtoPCB

reclaiming printed circuit board
e-waste as prototyping material

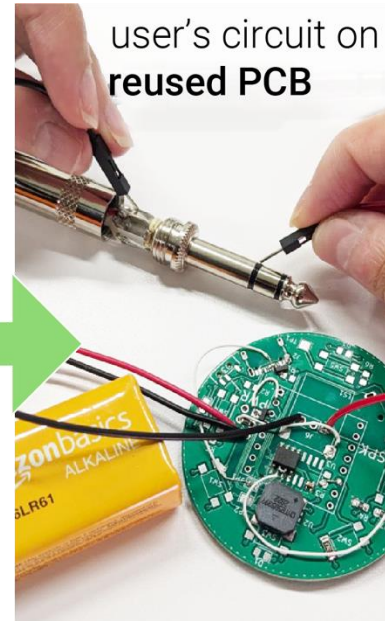
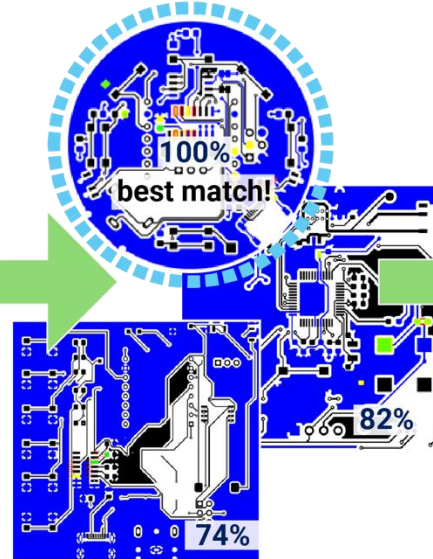
jasmine lu, sai rishitha boddu, pedro lopes

thanks! questions?

→ email jasminelu@uchicago.edu



ProtoPCB: output



README // about these slides

These are the slides for the talk presented at CHI 2025 by Jasmine Lu.

All the links in this PDF are clickable and lead you to YouTube videos, paper, etc.

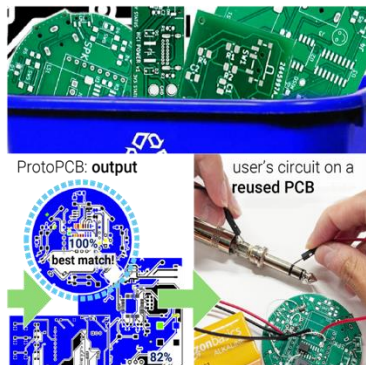
You can watch the live talk [here: https://www.youtube.com/watch?v=LvC-Mg7MbqI](https://www.youtube.com/watch?v=LvC-Mg7MbqI)

You can watch the prerecorded talk [here: https://www.youtube.com/watch?v=vqAg5TI_Q1s](https://www.youtube.com/watch?v=vqAg5TI_Q1s)

You can watch the video [here: https://www.youtube.com/watch?v=XVVxmU2W1bI](https://www.youtube.com/watch?v=XVVxmU2W1bI)

If you need a PPTX/editable version for your class, email us hci@uchicago.edu

More information on this paper (or others of our lab) at: <https://lab.plopes.org/#ProtoPCB>



ProtoPCB: Reclaiming Printed Circuit Board E-waste as Prototyping Material

Jasmine Lu, Sai Rishitha Boddu, Pedro Lopes. In Proc. [CHI'25](#) (full paper)

We propose an interactive tool that enables reusing printed circuit boards (PCB) as prototyping materials to implement new circuits—this extends the utility of PCBs rather than discards them as e-waste. Our tool takes a user's desired circuit schematic and analyzes its components and connections to find methods of creating the user's circuit on discarded PCBs (e.g., e-waste, old prototypes). In our evaluation, we utilized our tool across a diverse set of PCBs and input circuits to characterize how often circuits could be implemented on a different board, implemented with minor interventions (trace-cutting or bodge-wiring), or implemented on a combination of multiple boards—demonstrating how our tool assists with exhaustive matching tasks that a user would not likely perform manually.



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