Simplifying commissioning & testing of long-tail mobile, wearable & ubiquitous devices

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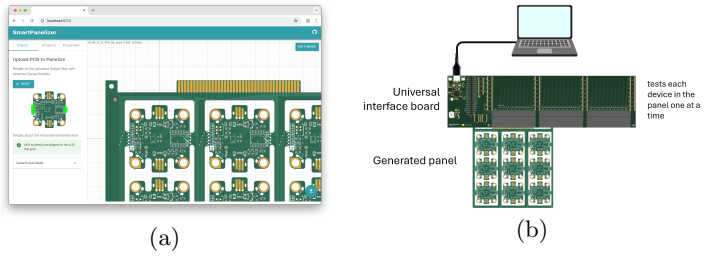

(a) (b)

Figure 1: (a) SmartPanelizer is a web application that accepts a PCB design and produces panelized fabrication files augmented with built-in test infrastructure. (b) When a manufactured panel is delivered from the factory, it may be plugged into a universal interface board which automatically uploads firmware to each device and tests it, simplifying the device commissioning and testing process.

Creating new types of mobile, wearable and ubiquitous digital devices is supported by many novice-friendly prototyping toolkits [4]. However, turning a prototype into a saleable product is still challenging; there is limited prior work on supporting novices in bridging the transition from an initial prototype to device production [3]. While the production of bare custom printed circuit boards (PCBs) and soldering the necessary components to create a PCB assembly (PCBA) has become relatively straightforward, devices may then need calibration and/or provisioning with firmware, before electrical and/or functional testing to verify device operation. These post-PCBA processes typically require significant expertise and capital investment into device-specific infrastructure.

SmartPanelizer aims to ease the post-PCBA commissioning and testing process, simplifying it for experienced device producers while empowering novice 'citizen manufacturers' [2] to carry out these steps for the first time. While the existing Pinpoint project [5] presents a simplified PCB testing workflow for the design phase, there is limited prior work on simplifying PCB commissioning and testing for production-ready devices in this way.

PCB panelization, where panels consisting of multiple instances of a device PCB are combined into a panel, is common industry practice. Panels are easier to manufacture and assemble at scale than individual devices. Our proposed workflow centers around a device designer uploading the Gerber files for a particular PCB design to the SmartPanelizer web app. The designer is able to specify a number of parameters, such as how many device instances are in the panel, and the corresponding fabrication files for a panel are generated automatically.

Beyond traditional panelization, SmartPanelizer also provides access to the signals needed for post-manufacture functional testing by identifying key signal endpoints present in the uploaded Gerber files and automatically routing them to an edge connector at the top of the panel. These identification points, known as *GerberSockets* [1], are placed by the device designer in their EDA sofware, such as KiCad. Once panels of device PCBs have been manufactured, they can be plugged into an 'interface board' to automatically upload any firmware and to test each device in turn, guided by the SmartPanelizer web app. Consolidating the connection of each device through a single edge connector avoids the manual step of attaching a programming probe to each device in turn. After testing, the individual PCBs may be de-panelised as usual.

By making use of the industry standard Gerber file format, both for the individual device design and the auto-generated panel data, SmartPanelizer interoperates with a wide range of industry software and workflows. GerberSockets embed metadata relating to signals needed for commissioning and testing into the Gerber files in the form of very small graphical Gerber objects. This metadata provides a way for the SmartPanelizer to connect to the correct signals, which it then wires to a connector at the top of the panel by automatically routing traces across the panel rails that physically hold the PCB instances in place. The Gerber data for each device instance in the panel remains unchanged. Beyond increasing the size of the panels slightly, the added test infrastructure does not increase the PCB manufacturing cost.

Unlike traditional bed-of-nails test fixtures, panels generated by the SmartPanelizer are compatible with a standard interface board which can therefore be reused for different production runs and different device types. This is well-suited to the low-volume production of a 'long-tail' of mobile, wearable and ubiquitous devices, allowing common test infrastructure to be reused in many different contexts. Simplifying the production process for citizen manufacturers can unlock this long-tail, mitigating barriers such as the cost and complexity of non-recurring engineering activities.

In summary, SmartPanelizer has the potential to make the process of commissioning and testing new hardware designs simpler, quicker, cheaper and more approachable. We believe this could increase the adoption of methodical practices among citizen manufacturers while saving time and money for more experienced hardware manufacturers.

References

[1] Kobi Hartley et al. "MakeDevice: Easing the path from hardware prototyping toolkits to manufacturable devices". In: *TEI '26*. 2026. ISBN: 9798400718687. DOI: 10.1145/3731459.3773298.

[2] Steve Hodges and Mike Fraser. "Citizen Manufacturing: Unlocking a New Era of Digital Innovation". In: *IEEE Pervasive Computing* 21.3 (2022), pp. 42–51. DOI: 10.1109/MPRV.2022.3187574.

[3] Rushil Khurana and Steve Hodges. "Beyond the Prototype: Understanding the Challenge of Scaling Hardware Device Production". In: *CHI '20*. 2020, 1–11. DOI: 10.1145/3313831.3376761.

[4] Mannu Lambrichts et al. "A Survey and Taxonomy of Electronics Toolkits for Interactive and Ubiquitous Device Prototyping". In: *IMWUT 2021* 5.2 (June 2021). DOI: 10.1145/3463523.

[5] Evan Strasnick, Sean Follmer, and Maneesh Agrawala. "Pinpoint: A PCB Debugging Pipeline Using Interruptible Routing and Instrumentation". In: *CHI 2019*. 2019, 1–11. ISBN: 9781450359702. DOI: 10.1145/3290605.3300278.