The Complementary Role of PCB Design and 3D Printing in the Prototype Development Process

3D printing is revolutionizing the prototype development process. By fundamentally changing the mechanisms for creating and fabricating the accessory systems critical to a design project's success, 3D technology helps design engineers turn their ideas into finished products quickly.

These accessory systems, often referred to as jigs or testers, can be used to program a device or test the functionality of a circuit, making them as critical to a project's success as the PCB designs themselves.

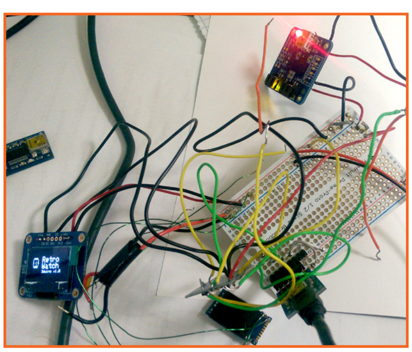
This paper will examine how PCB design and 3D printing can be utilized together to improve the process of taking an idea through prototyping and into production.

Our use case will be the production of a basic Bluetooth® smartwatch.

Proving the Initial Design Concept

Rather than start from scratch, our project team chose an open source watch design[1] using commercial-off-the-shelf (COTS) subsystem components that included:

- Organic light emitting diode (OLED)
- Bluetooth transceiver subsystem demo board
- Arduino processor pre-assembled to a breakout board



The 'messy' device we used to test functionality

Once the requisite COTS components arrived, the team started breadboarding the components. At this stage, the priority was testing functionality.

Though it is common for a design team to custom-build a breakout board using simple designs on FR4, we focused on getting the assembly to work as needed. The result wasn't pretty, but it worked. Once we successfully powered up and programmed the proof-of-concept prototype, it was time to optimize the design for the smartwatch.

[1]The watch design is from Suh Young Bae (RetroWatch Developer) and Bryan Smith (Helios Version Developer)

Always Be Optimizing

The design team now had to compress all of the functionality onto a single board that would fit inside a suitable watch enclosure. This is where 3D printing technology really helped the PCB design team.

Mechanical designers required physical parameters of the board in order to design the watch, but without guidance from the mechanical team on what the outline restrictions might be, it's difficult to finalize a PCB design. 3D printing could, for example, illustrate where holes in the circuit board should be drilled for mounting to standoffs.

By removing the guesswork for both mechanical and PCB designers, 3D printing helped accelerate the iteration and refinement of the mechanical design process without requiring changes to the board. Quick turn times on the fabrication of prototype enclosures facilitated integration of board and box, making the process much more interactive.

Integrating Mechanical and PCB Designs

While the mechanical team worked on its requirements, PCB design engineers finalized the bill of materials (BOM) for the new single-board version. The two different sets of schematics were then carefully merged into a single design.

Laying Out the Board

With the BOM established, the physical layout team got started. With each step of the workflow, we look for ways to further optimize both our process and PCB function.

Footprint Selection

Design footprints for components must align connection points perfectly with the parts to be used. Our layout team started with the BOM, auditing parts libraries to verify all landing footprints. Missing footprints were sourced or created from scratch.

At this point, a 3D printed facsimile of the circuit board, fully populated with the specified components, becomes a useful tool for test fitting the PCB into the rest of the system under design.

Initial Footprint Placement

The layout team then placed components on the board in the most logical and effective way, minimizing the distance and complexity of traces required to correctly connect all the components. This process can take up to half of the time spent on layout. It requires thinking in three dimensions to ensure that components are not too tall or bulky for the space constraints of the enclosure.

Component Placement

Confident that the component placement would work inside the enclosure and that all design considerations were accurate, our layout team got to work finalizing the trace routes in the layout.

Circuit Layout, Verification, and Preparation for Manufacture

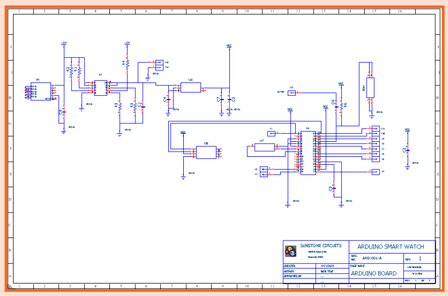
With layout under way, the mechanicals team began designing the necessary jigs, fixtures, cradles, and programming fixtures for the board being designed. By 3D printing these items, the team was primed to achieve "first light" from their prototype as soon as the boards arrived back from fabrication.

When the layout was completed, the layout team confirmed that all components were connected correctly and made sure that layout matched the original schematic.

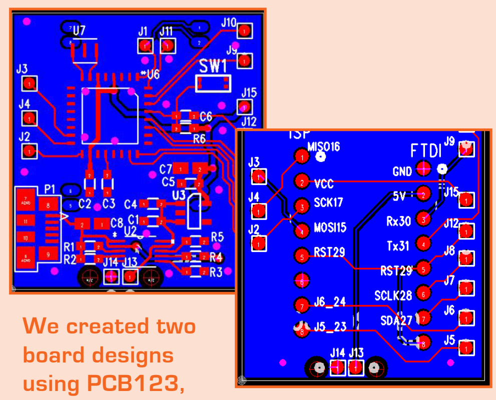
Now it was time to fabricate the first circuit boards for assembly.

Easy as PCB123

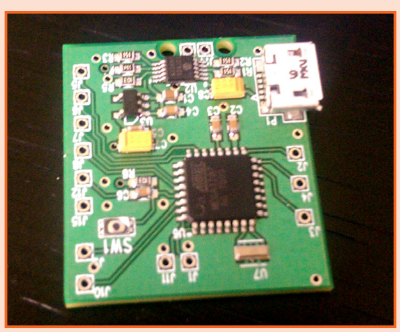
We used Sunstone Circuits® PCB design tool, PCB123®, to recreate one custom footprint for the Bluetooth radio feature. PCB123 helped ensure proper connectivity of the circuits by drawing "rat's nest" connection prompts. This would show the layout engineer how each component pin should be connected.



Our team printed out a 1:1 image of the layer with the footprint, and then test-fit the actual component to the printout.



We created two board designs using PCB123, one for the watch itself and the second for the test/bootload station needed to program the watch.



Screaming Circuits (www.screamingcircuits.com) assembled the initial boards. Ordering was very easy. They helped us improve the design in a couple spots and it only took a couple days to assemble boards that worked.

Building Fixtures

Concurrent with the jig design, the mechanical team got started on a watch enclosure and test/programming jig that would provide incoming QA and deploy the Arduino bootloader.

We used a test-bench-style jig where the watch board snaps in on top and makes contact with the pogo pins on the tester board. If the watch board is functional, the bootload will succeed.

Programming the Watches

3D Fixtures utilized a state-of-the-art 3D Systems ProJet® printer for this project. This high-performance piece of equipment achieves industrial-level accuracy in the mechanical parts produced, delivering results superior to low-end filament printer technology.

Watch programming is a two-step process. First, the Arduino bootloader was burned to the blank board, and then the bootloaded boards were programmed with functional firmware.

Jigs and fixtures demand precision and accuracy. 3D printed features must align perfectly with those on the PCBs, or valuable time and material may be wasted. We rely on 3D Fixtures for our 3D printed jigs, because their expertise lets them deliver 3D printed parts with industry-leading accuracy.

Project Results

With functional smartwatches ready for manufacture, we evaluated the effort and cost of our design project. It was clear that use of 3D printing technology had saved us both time and money.

We completed design and prototyping of our smartwatch in just 33 days. Project expenditures were lower than expected. The total cost of components, fabrication, and printing was around $3,250.

Conclusions

Though Sunstone Circuits® and 3D Fixtures are not watch design specialists posing a competitive threat to industry leaders like Pebble and Garmin, this exercise demonstrated a number of key ideas for design teams working in wearables, printed electronics, and other emerging technologies.

1. 3D printing is a viable, cost-effective solution for test or assembly jigs and customized tools needed to complete your project.
2. Early prototypes can utilize 3D printing to increase efficiencies in benchtop tech work, as well as speed up the enclosure development process.
3. There is still a need for traditional rigid PCBs in the printed electronics or wearables space, even if it’s in a manufacturing support role.