The Value of PCB Manufacturing Quality During Prototype: You Get More Than You Pay For

Introduction

In a recent research document, Michelle Boucher, from The Aberdeen Group, writes:

> "The number of engineering changes is also a top challenge of PCB design. A strategy that enables designers to obtain early insight into behavior, allows them to catch problems earlier in the process. It also makes it easier to look for opportunities to take cost out of the PCB." - Aberdeen Group, "Why Printed Circuit Board Design Matters to the Executive..."

A casual reading of this quote points to design flows as a key contributor to the efficiency of the electronic product development cycle. And that's very true. But one needs to look a little deeper to realize that the prototype fabrication portion of the process is of critical importance in catching design errors early and effectively. It is the prototype hardware, after all, which verifies the original design intent embodied by the CAD file contents; the relationship is symbiotic.

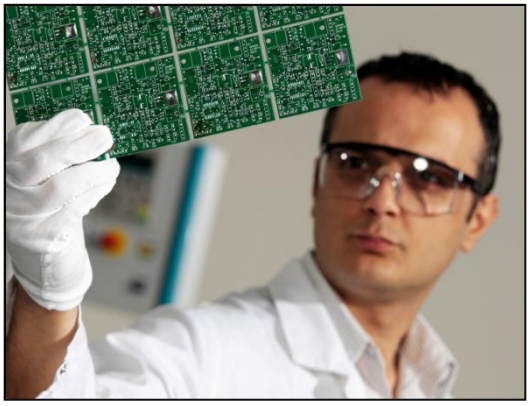

Figure 1: Minimizing engineering changes early in the prototype process leads to higher yields during production.

When a design team puts their first prototype onto the workbench for testing and verification, the team must simultaneously debug the following:

- The concepts in the schematic design
- The layout's implementation of the concepts
- The behavior of any firmware/software onboard
- The ability of the chosen parts to interact as expected from the component datasheet documentation, functional specifications, and schematic-driven simulation data
- The fabricator's ability to manufacture what the layout instructed them to build

That's a lot to debug, all at the same time. The more a manufacturing provider can shorten this list for the design team, the better. And this is where the manufacturer's quality rates become a key method for measuring your prototype provider's overall contribution to your design cycles. The more the board fabricators can remove debugging discussions that start with "I found a short in the board you built me," then the more the board manufacturer can help the design team target functional behaviors, instead of build errors. And that results in a shortening of the product design cycle in other meaningful ways.

Optimization for Production

In optimization for production, plenty of attention is paid to design issues that may reduce the overall manufacturing yield of the end product. Production, after all, is a world where shaving pennies on 10,000 units a month can make the difference between profits and losses for some products. A design that results in 98% yield

during manufacture is going to be much more competitive (price, reliability, market reputation for quality, durability, etc.) than a comparable product with a 75% yield. The wisdom is that, if the board has a low yield just getting out of the factory, that board is going to be fragile in the field, too. Designing for yield is also helping the cause of designing for durability.

The idea is the same during prototype – design for yield – but with different target criteria.

- Production designs optimize for volume production
- Prototypes optimize for quick turns
- Production optimizes component costs
- Prototypes optimize functional verification
- Production designs work to reduce manufacturing costs
- Prototypes work to reduce design errors

Manufacturing quality has a decided impact on prototyping and small-run board Return on Investment (ROI.) A Printed Circuit Board manufacturing process can greatly affect both individual design teams and the industry as a whole.

For the purposes of this discussion, manufacturing quality can be categorized as the following:

- Schedule Adherence (on-time delivery)
- Design Adherence
- Accessibility
- Yield

Let's look at these four categories affecting the manufacturing quality of a prototype PCB project.

Schedule Adherence

UPS delivers a nationwide 91% on-time delivery for domestic next-day 10:30am service[1]. Given that this performance metric has held steady over the last five years, and given that UPS ships almost three times the package volume the closest competitor, UPS's 91% can serve as a baseline metric for on-time delivery. We can now compare the three leading prototype PCB manufacturing suppliers, keeping in mind that all three competitors rely on UPS, FedEx and other shippers to deliver their product on-time to design teams. In other words, even if the product is manufactured to a schedule, the carrier can still cause delays outside the scope of both the manufacturer and the customer.

Sunstone Circuits' actual on-time delivery rate:	99+%
Competitor #1 published on-time delivery rate:	98+%
Competitor #2 published on-time delivery rate:	95+%

Other industry leaders in the prototype PCB space promote their 95% on-time delivery rate. All three deliver on-time rates that exceed that of the carrier. And, the difference between 95% and 99+% seems relatively marginal - at least in the small quantities associated with a single order.

95.0% of 1,000 = 50 late shipments
99+% of 1,000 = 5 late shipments

[1] 2006 study by PAConsulting Group and funded by DHL; 2010/2011 study by PackageFox.

Exact shipment information from the top three prototype PCB manufacturers is difficult to locate. That said, if a quickturn prototype manufacturer ships an average of 1,000 orders per day, the difference between 95% and 99% annualizes to over 11,000 additional late shipments per year. This is a *very* different way to look at the data. That delta in on-time shipments causes project delays for over 11,000 design teams, on 11,000 different time-critical projects. Whether a late shipment strikes your design or not, that's still a whole lot of industry-wide R&D time lost to manufacturer late shipments.

Let's monetize this, so as to put it in perspective. Let's assume that a late shipment results in $1,000 in additional expense to the customer design team. This value seems high for some projects, but could easily be low for many others. Given this assumption, then, a manufacturer with a 95% on-time rate, and 50 late shipments daily, is responsible for $50,000 in additional customer cost at 50 separate customers, daily. That's an excess of $12M/year in wasted customer budgets. In contrast, a 99+% on-time performance causes between $1M/year and $2M/year in customer inconvenience. Thinking of it in these terms, even $1M seems excessive. That's why Sunstone Circuits continues work to improve on the current 99+% on-time performance

The general consensus amongst prototyping engineers is that spins equal progress. Some engineers misinterpret this as meaning that more spins are beneficial. Instead, the objective is to spin regularly, but to maximize the forward progress between spins. This will result in fewer spins overall, a shortened prototype design phase overall, and a more cost-effective development project.

Design Adherence

Design Adherence is the ability of the manufacturer to build exactly the board that the designer created. We're removing issues in the implementation of the circuit from this discussion, and focusing instead on the axiom that the layout file as submitted is the gold standard. Did the manufacturer build what was in the design file exactly as included?

Of course, such a strict adherence isn't always possible in the real world.

Violations in design adherence can be debugged back to unintentional problems, opens or shorts in the PCB itself, or caused by manufacturing issues. Or, design adherence could be caused by components that do not perform exactly as specified in the data sheet. Lastly, design adherence problems could be caused by a flaw in the circuit design itself.

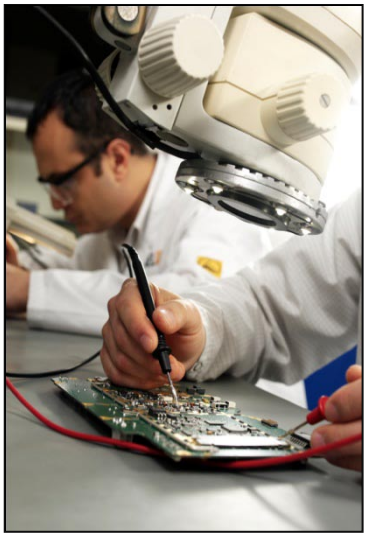

Figure 2: Checking for Design Adherence in prototypes ultimately leads to the workbench.

It is paramount to identify design adherence issues. Boucher summarizes, elsewhere in her paper, the challenges faced when design adherence issues persist until production:

> "Released designs that are found to have manufacturability problems create delays and drive up cost. Production must be halted while engineering scrambles to correct the problem. Typically the solution is whatever is fastest, not the most cost effective. Manufacturability problems also create scrap and require rework, further driving up cost."
>
> - Aberdeen Group, "Why Printed Circuit Board Design Matters to the Executive..."

This dynamic in a production product is well documented with the Motorola Razr cell phone in 2006. Two days before the device was released for sale, some savvy cell phone sales reps noticed that the stock of factory refurbished devices was abnormally high. Clearly, since the Razr hadn't even gone on sale yet, these factory refurbished devices couldn't have come from customer returns. Instead, these were likely reworked devices that failed final QC at the factory. Concluding that such a high failure rate at the factory would translate to a high-failure phone in the field, these

astute sales reps then started advising customers to hold off on purchasing that particular phone. The reps were worried for the onslaught of customer returns and the expense that goes along with handling each return/exchange. In early 2006, faced with a high rate of customer returns, some cell carriers halted sales of the Razr altogether. The problem ultimately was traced to a faulty component, and resolved at the production facility.

The type of issue experienced by the Razr in 2006 cannot always be caught in prototype, but some issues *can* be caught. In the prototype phase, design adherence helps the design team concentrate on the behavior of the design during debugging, not on whether the PCB manufacturer built what the design team specified.

Let's look at an example based on a standard RMA rate of about 2% for PCB manufacture. We'll continue with a cost of $1,000/day in design team costs for each day of delay. Then our earlier example firm, generating 1,000 orders per day of prototype boards, should expect to generate about 20 customer rebuilds daily. If the RMA rebuild requires 3 days to get to the customer, then design teams lose $60,000, cumulatively, per day to Manufacturing RMA. In contrast, Sunstone's RMA rate of less than 1% would translate to a RMA-related loss one-third of the baseline established. That improved RMA rate annualizes to almost $10 million dollars of saved customer R&D budget.

Just as the Razr example demonstrates that one can rate a product's quality in part by examining the RMA rates, so too can one get a feel for a prototype PCB manufacturing partner from their RMA rates. Sunstone's RMA rate is less than 1% of all orders. This low level of RMA work shows that Sunstone brings extra value by 1) clearly and proactively publishing their Quickturn manufacturing criteria, 2) providing tools and utilities that design teams can use to incorporate the Quickturn criteria from design start, 3) ensuring that Sunstone complies with all customer-supplied production manufacturing instructions, and 4) offering 25-point design reviews by request, ensuring that customers can make full use of Sunstone's manufacturing expertise. By working so carefully to ensure accurate prototypes, Sunstone plays a key part in making the move from prototype to production more effective and problem-free for design teams. The attention to these details at Sunstone pays off for the customer design team in the long run.

Accessibility

Given that the role of a prototype manufacturing partner is a collaborative one, helping to make as much progress per spin as possible, a partner you can reach on your own schedule and terms is important to your overall productivity. The design team may be under a scheduling deadline for a project and working nights and weekends. If your PCB partner isn't also available for technical assistance during those times, the design team may be delayed until the next day on a key piece of technical information. Furthermore, with current global business practices, the design team may be on a very different time schedule from the manufacturing facility. While it might be tolerable to work with 16 hour time differences to the production facility, the prototype manufacturing provider needs to be much more accessible than the production facility.

This is why you'll find industry leaders like Sunstone Circuits offering 24/7/365 technical support coverage. The Sunstone business model is to make experts available all the time (average customer service phone call wait time is 6 seconds), because the customer calling might be working nights on a critical project, or might initiate a live technical support chat from their office in a time zone 14 hours apart. Electronics design and manufacturing is a global business, not a regional one; serving the industry is now a round-the-clock enterprise.

In fact, Sunstone recently added 24/7/365 live chat via the Sunstone.com website. Now customers can ask questions or interact with a Sunstone Technical Support expert through the phone, through asynchronous written form (email) and through synchronous written form (chat). Whether the value of live chat comes from time zone differences, language preference, physical challenges, or other issues, Sunstone makes their experts as accessible as possible, thereby increasing their value as a consultant on every customer's prototype work.

Yield

As previously mentioned, production yield levels are a key leading indicator for ongoing service levels during the product's lifecycle. Though yield becomes critically important for production, it is still of importance through the prototyping process. Sunstone's build processes, coupled with the consultative expertise and accessible experts, means that Sunstone delivers a higher level of prototype yield overall. And since this higher yield reduces waste and production costs, Sunstone is able to maintain a competitive pricing structure against lesser-performing competitors.

Conclusion

PCB manufacturing efficiencies can have a number of direct impacts on a design team's effectiveness. When the design team uses a prototype manufacturing partner that places a deep-rooted cultural value on working together with customers to ensure accurate, efficient, speedy fulfillment of orders for prototype boards, then the design team benefits by:

- Reducing the number of debug factors to contend with on the test bench
- Maximizing progress per design spin
- Reducing the overall number of design spins required
- Maintaining development schedule due to a lack of delays from the PCB fabrication process
- Increased attention to the manufacturability of the design, both in the design team and at the PCB manufacturing facility
- Increased odds that a reliably manufactured production design will increase the product's profitability and reduce the long-term service costs to support the product

And the industry wins through:

- Reduced waste
- Reduced budget over-runs due to manufacturing delays

Project-by-project efficiencies translate into significant industry-wide savings of resources, and efficient operations at the facility, thereby keeping costs down overall for design teams, and improving the ROI for each product developed. And of course, a new product developed with higher performance, higher value and higher margin, just means that the product becomes a company money-maker that much faster.

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Citations

Why Printed Circuit Board Design Matters to the Executive: How PCBs Are a Strategic Asset for Cost Reduction and Faster Time-to-Market, Boucher, Michelle, The Aberdeen Group

PC World Online, "Motorola: Razr Problem Is History", Sumner Lemon, IDG News, March 15, 2006 http://www.pcworld.com/article/125094/motorola_razr_problem_is_history.html