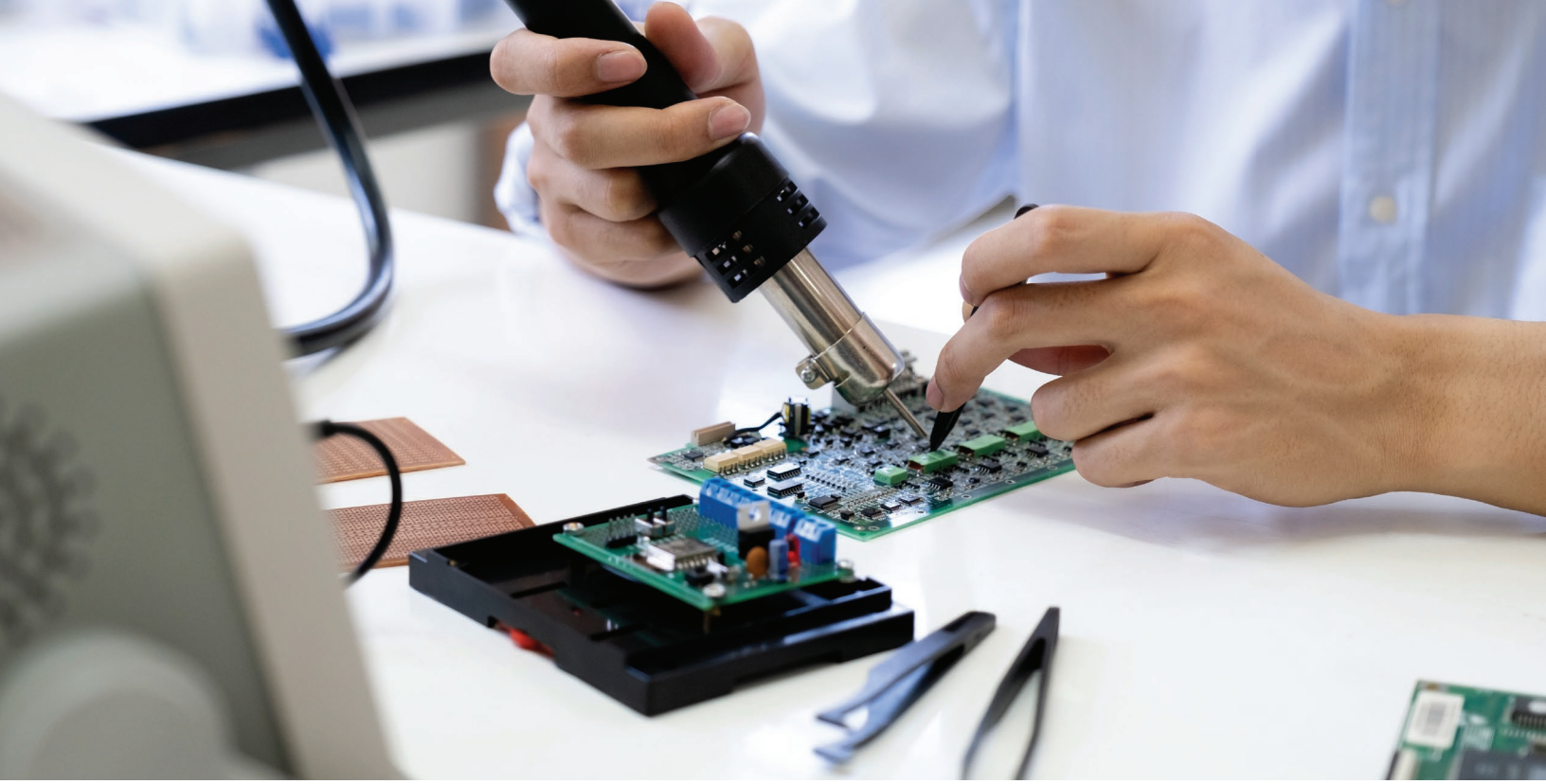

DIGITAL INDUSTRIES SOFTWARE

An intelligent DFM approach to PCB manufacturing

Executive summary
The electronics industry has evolved past manual DFM methods, and to compete in the market today, your organization needs intelligent software that addresses the full new product introduction process. In this white paper, we demonstrate that to successfully compete, you cannot stop at DFM; you must consider the benefits of the full release process to systematically streamline the panelization, documentation, and communication process with your PCB manufacturing ecosystem.

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Abstract

What was the first design for manufacturing (DFM) tool used in the printed circuit board (PCB) industry? Answer: The eye loop.

Eye loops were used until the 1990s to check PCB artwork for manufacturing suitability.

Yes, back in the day when design organizations sent actual photo-plotted films of their PCB design to the bareboard fabricator, the fabricator would put the received films on a light table and measure feature sizes for line widths, spacing between features and annular ring using an eye loop with a reticle etched onto the glass lens. If the features were beyond the capabilities of the fabricator, the job would be declined and the customer notified. If the film had extraneous features, they would be removed with an Exacto knife. Voids would be filled in using a black marker.

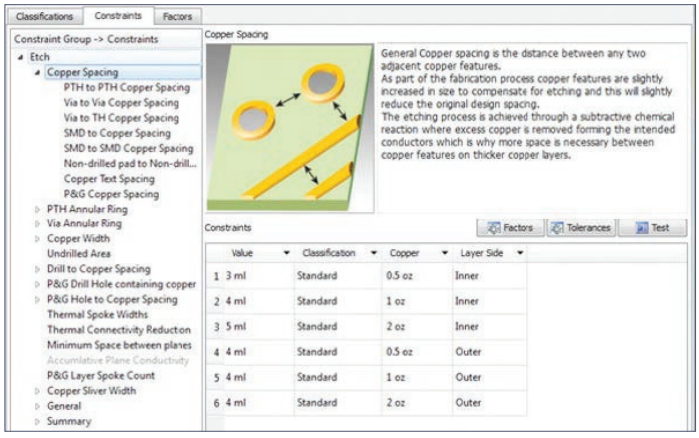
Simpler times, then. 10 mil lines and spaces. Double-sided PCBs were the norm. Manual DFM was feasible.

Needless to say, our industry has advanced in technology since those days. We have PCBs that are 64 layers, build-up technology with laser-formed stacked and staggered microvias, embedded devices, and complex rigid-flex circuits. And our design, fabrication, and assembly processes morphed into the new global economy, in many cases outsourced and off-shored.

So what does DFM look like today? Well, it's become more than DFM for one thing. We now expect our software tools to serve us more completely to take new designs to market. DFM has evolved to become an integral part of new product introductions (NPI). Today's NPI software spans design and manufacturing to accelerate the optimization of a PCB for manufacturing. It looks at the entire design-to-manufacturing release process and deliverables, then streamlines them.

Engineers at best-practice companies use NPI software to help identify ways to optimize their design during the initial release process, with a holistic view of their bareboard fabricators' and assembly suppliers' capabilities. It's no longer simply a matter of catching mistakes these days. It's about understanding the various challenges and limitations involved in the chosen manufacturing processes and then empowering the product owner to make the trade-off decisions that best serve their objectives.

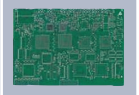
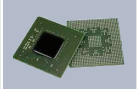
Valor NPI software uses expert system logic to automate DFM analysis. Quality DFM analysis is based on a combination of PCB technology classifications and manufacturing constraints. PCB classification can be determined automatically through intelligent design data. For example, the copper



Valor NPI intelligent DFM application will automatically derive the appropriate rules to be used for analysis based on the attributes in the design data.

weight of each layer is important in the fabrication DFM analysis because the etch compensation applied and, thus, resultant etchback are going to be different based on the copper weight used, varying between inner and outer layers. A 3-mil spacing on an inner layer made of 0.5 oz. copper may be acceptable, whereas the outer layer on the same board may need 4-mil spacing based on the use of 1 oz. copper. Furthermore, a PCB constructed with stacked vias is going to use different DFM rules than a conventional, single-lamination circuit board. Having the DFM software act on those attributes automatically saves engineering effort and delivers the desired results consistently for every user.

The ideal intelligent DFM approach would require a classification table based on design factors from which specific constraints are applied. This approach, when automated, would manage the collection of design and process requirements with ease and eliminate any confusing configurations and setup requirements. Likewise, a technology to define the ideal design requirements or limitations of manufacturing processes is also needed. A constraints implementation method would ensure that the design would be checked to properly assign a correct constraint rule. The constraints would then be used by establishing multiple analysis limits. This approach should be graphically represented to show the limits of DFM rules based on each of the manufacturers' requirements. Manufacturing tolerances would be applied to the constraints and a DFM rules engine would automatically consider those tolerances to determine conformance to, or violation of, the DFM rules.

	Simple	Standard	Complex	Flex
				
Number of layers	< 4	< 12	< 24	< 12
Number of plating cycles	1	1	< 5	< 5
Smallest drill	<= 8 mils	<= 5 mils	<= 4 mils	<= 5 miles
Maximum board thickness	<= 62 mils	<= 93 mils	<= 115 mils	<= 93 mils
IPC class	1	2	3	2
Includes Microvias	No	No	Yes	No
Rigid-flex	No	No	No	Yes

The intelligent DFM approach addresses the needs of everyone in the flow. PCB designers, manufacturing engineers, and electronics manufacturing service (EMS) companies or contract manufacturers would all realize value from this approach. The PCB designer is responsible for meeting internal design and industry guideline requirements, so this solution would address all aspects of the DFM requirements. The manufacturing engineer or NPI engineer, who is often the technical contact point between design and manufacturing, could easily evaluate the manufacturing requirements across multiple processes and suppliers' requirements. Finally, the EMS vendor for manufacturing could evaluate the manufacturing requirements against their manufacturing line processes or across multiple locations to ensure successful manufacturing.

A side benefit of using intelligent CAD data is DFM systems that use algorithms based on CAD feature shapes can perform analysis in a matter of minutes compared to systems based on vector data, which can take hours to run, and who has hours to wait for DFM analysis these days?

For years, DFM for flexible and rigid-flex circuits has been ignored. However, as nearly 30% of all electronics companies have flex and rigid-flex circuits within their product portfolios, the segment merits attention. And, with more companies moving to flexible electronics, this trend and this segment's DFM needs will only continue to accelerate. The materials and manufacturing processes are quite different for flex and rigid-flex circuits, and the DFM

tools must support those needs. Being able to identify features or trace direction changes within a bend area are critical, as is maintaining sufficient clearance around a coverlay zone, for example. Needless to say, an intelligent DFM system must know the difference between a rigid PCB, a flex-circuit and a rigid-flex circuit.

Product Summary section -> Attribute	Value	Units
◢ Board Requirements		
Board Thickness	0.089200	Inch
Additional Requirements		
Board Outline Tolerance Plus	5.000000	Mil
Board Outline Tolerance Minus	5.000000	Mil
Board Thickness Tol Plus	3.000000	Mil
Board Thickness Tol Minus	3.000000	Mil
Board Thickness Type	over mask on plated copper	
Bottom Legend Color	white	
Bottom Soldermask Color	yellow	
Flammability Rating Standard	UL94V-0	
General PCB Standard	IPC 6012A	
Glass Transition Temperature (Tg)	110.000000	
Legend Sides	Both	
PCB Acceptability Standard	IPC 6012A	
Peelable Mask Side	none	
Plated Edge	Yes	
Plated Slots	No	
Qualification and Performance Standard		
Soldermask Sides	Both	
Top Legend Color	white	
Top Soldermask Color	green	

When information is communicated as a data field, it streamlines the NPI process and reduces the chances for misinterpretation and error.

Performing DFM analysis concurrent with the PCB design process increases the competitive advantage. But, to make this practical, the DFM software ideally needs to be well-integrated with the electronic design (EDA) software so that the designer can run the analysis and review the results for basic DFM within the environment of the layout tools. By doing so, they avoid having someone downstream telling them there is an issue. Downstream is no longer adequate. Upstream understanding is required to compete today.

As evidence that the electronics industry has progressed beyond just DFM, Valor NPI software is also used to design and optimize PCB panels.

Many companies are inefficient in their panel-design process, even for assembly panels or arrays. Typically, a design organization will use a 2D mechanical CAD tool to create a drawing of what they need for their assembly panels to look like when received from the bare-board fabricator. They will spend several hours creating this drawing and adding notes and dimensions, then they output it to their fabricator as a dumb drawing file. By "dumb" I mean the drawing file has no intelligence to it, no data that the fabricator can key off of in the tooling process. Rather, the fabrication engineers must recreate the assembly array within their CAM software and submit a proof image back to the designer at the OEM for approval before proceeding with tooling. Needless to say, with the technology available today, this level of manual processes is unnecessary.

Instead, the same design organization can easily create their assembly panels using the NPI software and include all the elements needed – rails, tooling holes, fiducials, and rout or v-score features. The Valor NPI software will even automatically optimize the boards within the assembly panel to minimize the fabrication material costs. When trying to drive down the costs of electronic products, reducing fabrication material costs is often an overlooked opportunity. In a study we did with four different customer designs, we found panel optimization saved an average of $126,450 annually per customer, and savings could be had with as few as four panels. Furthermore, DFM analysis done on the assembly array will identify potential manufacturing issues that are not able to be identified in the single-up stage. A couple of good examples are having a breakaway tab too close to a SMD pad or a device that overhangs the edge of the PCB obstructing machine vision access to a global fiducial.

Lastly, the NPI process involves creation, validation, and delivery of the design package to the fabrication and assembly providers. Historically, it's delivered as a package comprised of some combination of the following:

- Gerber files
- Drill files
- Netlist files
- Test files
- Centroid data
- Manufacturing BOM
- Drill drawings
- Assembly panel drawings
- Route drawings
- Stackup drawing
- Drawing notes

Ironically, for an industry that drives the digitalization of the world, we are heavily dependent on manual processes with instructions communicated through 2D, non-relational drawings and documents. What is in the drawing or documentation that cannot be represented as a data field? Nets that are intentionally shorted? A data field can be tagged to the appropriate nets. Topside soldermask color? Data field. Dielectric thickness for a given material? Data field.

Summary

The electronics industry has evolved past manual DFM methods and software that addresses the full new product introduction process with intelligence is required to compete today. Valor NPI performs DFM analysis concurrent with the design process and is integrated with the layout tools, providing the most efficient design-to-manufacturing flow. In the spirit of continuous improvement, we must also not stop at DFM but rather look at the full release process to systematically streamline the panelization, documentation, and communication process with our manufacturing partners.

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