Design for manufacturability

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Design for manufacturability (also sometimes known as **design for manufacturing** or DFM) is the general engineering art of designing products in such a way that they are easy to manufacture. The basic idea exists in almost all engineering disciplines, but of course the details differ widely depending on the manufacturing technology. This design practice not only focuses on the design aspect of a part but also on the producibility. In simple language it means relative ease to manufacture a product, part or assembly. DFM describes the process of designing or engineering a product in order to facilitate the manufacturing process in order to reduce its manufacturing costs. DFM will allow potential problems to be fixed in the design phase which is the least expensive place to address them. The design of the component can have an enormous effect on the cost of manufacturing. Other factors may affect the manufacturability such as the type of raw material, the form of the raw material, dimensional tolerances, and secondary processing such as finishing.

The design stage is very important in product design. Most of the product lifecycle costs are committed at design stage. The product design is not just based on good design but it should be possible to produce by manufacturing as well. Often an otherwise good design is difficult or impossible to produce. Typically a design engineer will create a model or design and send it to manufacturing for review and invite feedback. This process is called a design review. If this process is not followed diligently, the product may fail at the manufacturing stage.

If these DFM guidelines are not followed, it will result in iterative design, loss of manufacturing time and overall resulting in longer time to market. Hence many organizations have adopted concept of Design for Manufacturing.

Depending on various types of manufacturing processes there are set guidelines for DFM practices. These DFM guidelines help to precisely define various tolerances, rules and common manufacturing checks related to DFM.

While DFM is applicable to the design process, a similar concept called DFSS (Design for Six Sigma) is also practiced in many organizations.

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Design for manufacturability for printed circuit boards (PCB)

In the PCB design process, DFM leads to a set design guidelines that attempt to ensure manufacturability. By doing so, probable production problems may be addressed during the design stage.

Ideally, DFM guidelines take into account the processes and capabilities of the manufacturing industry. Therefore, DFM is constantly evolving.

As manufacturing companies evolve and automate more and more stages of the processes, these processes tend to become cheaper. DFM is usually used to reduce these costs. For example, if a process may be done automatically by machines (i.e.

SMT component placement and soldering), such process is likely to be cheaper than doing so by hand.

Design for manufacturability for integrated circuits (IC)

Achieving high-yielding designs in the state of the art VLSI technology has become an extremely challenging task due to the miniaturization as well as the complexity of leading-edge products. The design methodology called **design for manufacturability** (**DFM**) includes a set of techniques to modify the design of integrated circuits (IC) in order to make them more manufacturable, i.e., to improve their functional yield, parametric yield, or their reliability.

Background

Traditionally, in the prenanometer era, DFM consisted of a set of different methodologies trying to enforce some soft (recommended) design rules regarding the shapes and polygons of the physical layout of an integrated circuit. These DFM methodologies worked primarily at the full chip level. Additionally, worst-case simulations at different levels of abstraction were applied to minimize the impact of process variations on performance and other types of parametric yield loss. All these different types of worst-case simulations were essentially based on a base set of worst-case (or corner) SPICE device parameter files that were intended to represent the variability of transistor performance over the full range of variation in a fabrication process.

Taxonomy of yield loss mechanisms

The most important yield loss models (YLMs) for VLSI ICs can be classified into several categories based on their nature.

- **Functional yield loss** is still the dominant factor and is caused by mechanisms such as misprocessing (e.g., equipment-related problems), systematic effects such as printability or planarization problems, and purely random defects.
- High-performance products may exhibit **parametric design marginalities** caused

by either process fluctuations or environmental factors (such as supply voltage or temperature).

- The **test-related yield losses**, which are caused by incorrect testing, can also play a significant role.

Techniques

After understanding the causes of yield loss, the next step is to make the design as resistant as possible. Techniques used for this include:

- Substituting higher yield cells where permitted by timing, power, and routability.
- Changing the spacing and width of the interconnect wires, where possible
- Optimizing the amount of redundancy in internal memories.
- Substituting fault tolerant (redundant) vias in a design where possible

All of these require a detailed understanding of yield loss mechanisms, since these changes trade off against one another. For example, introducing redundant vias will reduce the chance of via problems, but increase the chance of unwanted shorts. Whether this is good idea, therefore, depends on the details of the yield loss models and the characteristics of the particular design.

Design for manufacturability for CNC machining

Material type

The most easily machined types of metals include aluminum, brass, and softer metals. As materials get harder, denser and stronger, such as steel, stainless steel, titanium, and exotic alloys, they become much harder to machine and take much longer, thus being less manufacturable. Most types of plastic are easy to machine, although additions of fiberglass or carbon fiber can reduce the machinability. Plastics that are particularly soft and gummy may have machinability problems of their own.

Material form

Metals come in all forms. In the case of aluminum as an example, bar stock and plate are the two most common forms from which machined parts are made. The size and shape of the component may determine which form of material must be used. It is common for engineering drawings to specify one form over the other. Bar stock is generally close to 1/2 of the cost of plate on a per pound basis. So although the material form isn't directly related to the geometry of the component, cost can be removed at the design stage by specifying the least expensive form of the material.

Tolerances

A significant contributing factor to the cost of a machined component is the geometric tolerance to which the features must be made. The tighter the tolerance required, the more expensive the component will be to machine. When designing, specify the loosest tolerance that will serve the function of the component. Tolerances must be specified on a feature by feature basis. There are creative ways to engineer components with lower tolerances that still perform as well as ones with higher tolerances.

Design and shape

As machining is a subtractive process, the time to remove the material is a major factor in determining the machining cost. The volume and shape of the material to be removed as well as how fast the tools can be fed will determine the machining time. When using milling cutters, the strength and stiffness of the tool which is determined in part by the length to diameter ratio of the tool will play the largest role in determining that speed. The shorter the tool is relative to its diameter the faster it can be fed through the material. A ratio of 3:1 (L:D) or under is optimum.[1] If that ratio cannot be achieved, a solution like this depicted here can be used.[2] For holes, the length to diameter ratio of the tools are less critical, but should still be kept under 10:1.

There are many other types of features which are more or less expensive to machine. Generally chamfers cost less to machine than radii on outer horizontal edges. Undercuts are more expensive to machine. Features that require smaller tools, regardless of L:D ratio, are more expensive.

See also

- Electronic design automation
- Reliability engineering
- Six Sigma
- Statistical process control
- ISQED
- DFM in other areas
- Design for assembly
- Design for X

References

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- Mentor Graphics - DFM: Magic Bullet or Marketing Hype (http://www.mentor.com/products/ic_nanometer_design/techpubs/request/dfm-magic-bullet-or-marketing-hype-21217) (must fill request form).
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External links

- Why DFM/DFMA is Business Critical (http://www.engineersedge.com/training_engineering/why_dfmdfa_is_business_critical_10046.htm)
- Design for manufacturing checklist (http://www.quick-teck.co.uk/TechArticleDoc/19196513481352925083.pdf) – DFM,DFA(Design for assembly checklist from Quick-teck PCB manufacturer
- Arc Design for Manufacturability Tips (http://www.arctechinc.com/wp-content/uploads/2010/06/Arc-Design-for-Manufacturability-Tips.pdf)
- DFM Concept Explained (http://www.empf.org/empfasis/archive/104dfm.htm)
- Design for Manufacturing and Assembly (http://www.dfma.com/index.html)
- Turning designs into reality: The Manufacturability paradigm (http://geometricglobal.com/wp-content/uploads/2013/03/Turning-designs-into-reality-The-Manufacturability-paradigm1.pdf)
- List of DFM links (http://www.npd-solutions.com/designguidelines.html)

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