Design for manufacture

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As more companies embrace design for manufacture (DFM) as a method to increase both profits and throughput, a concept known as design for excellence (DFX) has come to the forefront.

DFX can be described as a critical success factor, and when properly implemented, will ensure that a product can be manufactured and tested. When properly implemented and executed, it will ensure a high degree of manufacturability and testability. Lack of a competent DFX culture and curriculum can result in design-for-failure. Electronic assembly operations typically focus on three key metrics: quality, cost and delivery. For a company to remain successful, these metrics must be achieved successfully over and over again. A strong DFX program will help achieve these targets with the least amount of effort and risk. Our industry has slowly but surely embraced DFX concepts. Sharing DFX guidelines within a company - especially at multiple global sites - is a difficult task. A website is an excellent tool for sharing knowledge. This article discusses the DFX philosophy and describes how to create and maintain a DFX website.

The Surface Mount Council (SMC) started the DFX concept more than five years ago with the goal of encouraging DFM, testability, reliability, etc. Since then, the SMC has been promoting the concept and encouraging its use. DFX was a major topic at the Surface Mount International conference in 1996; the SMC published a document containing six DFX White Papers in 1996 (copies can be obtained from the IPC - Association Connecting Electronics Industries). The document, SMC-WP-004, contains the following papers: “Design for Success,” by Dale Hiatt, Hiatt & Associates; “Design for Assembly,” by Vern Solberg, Tessera; “Design for Fabrication,” by Foster Gray, Texas Instruments; “Design for Test,” by Paul Spitz, Teradyne; “Design for Reliability,” by Werner Engelmaier, Engelmaier & Associates and Laura Turbini, Georgia Institute of Technology; and “Design for the Environment,” by Christopher Rhodes, IPC.

DFX is a methodology that involves various groups focusing on the design and manufacture of a product concurrently. It can be described as an art as well as a science. Successful DFX teams combine basic engineering skills with creative thinking, and a passion and commitment to the DFX concept. DFX will decrease product development time, product cost and manufacturing cycle time while increasing product quality, reliability and customer satisfaction. It will decrease the overall cycle time required to get a product from concept to the customer, which is a critical success factor. DFX must be part of the corporate culture, and it must have strong support from all levels of management. The goals must be measurable and the benefits must be justifiable.

Design for fun and profit

Product life cycle is defined by two key phases: conceptual and implementation. During the conceptual phase, performance and cost are the key drivers. This phase is divided into three activities: need identification, product definition and design completion. During implementation, quality and delivery become the primary drivers. The implementation phase is divided into six activities: prototype build, trial build, product verification, pre-production, first-lot conformation and general release.

In the hopes of getting the product into production and to market quickly, classic design methods encourage rapid design completion. Many times, however, the entire process slows down because critical functionality or manufacturability issues were overlooked. The resulting problems require one or more redesigns to correct the errors, while additional prototype builds are required to verify each fix. Modern design methods encourage a longer, more detailed design approach. In the end, spending more time up front actually reduces time-to-market because every critical aspect of the product is analysed in detail and errors are corrected before the design is finished.

The two methods are compared in Fig. 1.

A concurrent engineering team should be formed during the conceptual phase. Concurrent engineering is the combined application of a company’s resources, knowledge and experience, used in a parallel effort to develop, design and manufacture a product. This team represents functional areas such as design engineering, manufacturing engineering, quality engineering, manufacturing and procurement. It immediately begins to focus on topics such as functionality, manufacturability, testability, reliability, quality, cost and the environment. Working together from the start increases the probability of a successful design.

New product introduction (NPI) is a structured approach to product development, design and manufacturing that ensures good organisation, planning, communication and management. A documented NPI process is required for ISO certification. It must ensure that the product meets all design requirements specified by the customer and related regulatory agencies. In many cases, product designs evolve into a compromise between performance, manufacturability and cost. Quality and reliability should never be compromised. The DFX team should complete risk assessments at two key points: design completion and first-lot conformation. The risks should be documented and discussed with...
management and countermeasures should be applied to each risk before the project moves on.

DFX culture

Starting and maintaining a DFX program is not easy - it takes time and dedication, but the results are worth the effort. Ideas and expectations should be clearly defined before the program is started. Strategic guidelines are highly recommended:

- DFX must be part of the corporate culture; management must support and encourage DFX.
- DFX should be driven by customer needs, i.e., understand the customer’s wants and desires.
- DFX requires teamwork and creative thinking; management must support teams and open thinking.
- DFX must have measurable and justifiable goals; define the key metrics: cost, yield, delivery, etc.
- DFX must be easy to use and apply; create and document methods and procedures. Use industry guidelines and standards.

Establishing a DFM document

Even if a formal or written DFM guideline has not been created, much of what is needed to make up this documentation may already exist. In organisations that are already involved with the design process, CAD libraries and design rules created and used by the designers make a good start. As mentioned, information from standards organisations such as IPC, Electronic Industries Alliance and the Surface Mount Equipment Manufacturers’ Association is available; however, this information may not be specific enough to cover the needs of individual manufacturing processes or customer requirements. The information available from standards organisations is typically given as a range, and an organisation may wish to establish a specification for each individual item or feature for consistancy. It is always important to make sure that all DFM guidelines meet recommended industry standards (i.e., fiducial targets).

Another source of information is component suppliers; they often provide information on recommended land patterns and other pertinent information. All organisations impacted by the design need to be involved in the development of and changes to the DFM guideline. Design engineering, PCB layout, test engineering and process/manufacturing engineering are organisations that typically require input to the DFM guidelines.

The following is a list of items that should be included in any DFM guideline:

- Component selection criteria for both SMT and through-hole components
- PCB size requirements
- Land, pad and barrel size requirements
- Designator and naming conventions
- Wave solder considerations
- Component orientation requirements
- Component spacing requirements (keep-out zones)
- Fiducial requirements
- Tooling hole requirements
- Test pad requirements
- Panelisation and depanelling information
- Trace specifications
- Via requirements
- Design for testability requirements
- Applicable industry specifications.

Using the internet/intranet

Once a DFM guideline exists, it must be readily accessible; at the same time, it may be considered to be a confidential document. Working from paper documents will not ensure that recent updates are included and may pose a security risk. These problems only become worse when multiple design and manufacturing sites or geographic locations are involved.

Today, most companies have an intranet or internet access. Using a website offers a solution to these problems (Fig. 2). DFM guidelines can be placed on a website and access can be strictly controlled. This will ensure that when the DFM guidelines are updated, everyone has instant access to the new information. Colour graphics, animation and sound can be included to make it more interesting and to help communicate ideas more effectively (Fig. 3). A website can be customised to meet specific applications and needs. Using the internet allows the DFM guidelines to be viewed from any place in the world. When an intranet site is used, it too may be viewed using the internet, providing there is access to the company’s intranet. Most companies use a firewall to prevent access to their intranet by unauthorised users. Using a website will require an administrator who is responsible for maintaining the site. The individual who maintains the DFM guidelines is the logical choice for website maintenance as well. Additional training may be required for website setup and maintenance.

Managing changes to DFM guidelines

A structured process for submitting, reviewing, approving and updating change requests to the DFM guideline is highly recommended. A revision control process that includes change notification and appropriate training must be clearly defined and documented. When there is a need for additional information or to change existing information in the DFM guidelines, a request for this should be made to the DFM administrator. An easy way to do this is via e-mail. Requests should include: a statement of the problem, detailed explanation of the change requested (why it is necessary), information about components or features involved, and any other relevant information. A request form can add structure and control to the DFM request process to ensure that all variables are addressed. Requests may come from anyone in the organisation who is using or is impacted by the DFM guidelines. When the DFM administrator receives the request, it is reviewed to determine if it should be submitted for approval.

The DFM change request may be submitted to the team by a variety of methods. A review and signoff meeting may be called with the team; if multiple sites are involved, this may not be practical. Finding a time when everyone can attend may be difficult and interrupting work schedules is not always
an advantage to the company. The DFM change request may be e-mailed to the team and they may then e-mail back their responses, although this can be somewhat difficult to manage. The easiest way to get a response from the team is to post the DFM change request on a web page that all team members have read and write access to. The team members can then be notified by e-mail when an item has been posted that requires their attention. Assigning each DFM change request a unique number will make it easy to track, especially if multiple requests are posted at the same time. If the request is in a word processing program, such as Microsoft Word, a good way to handle signoff is to have the DFM review team members open the document, and under the insert function use the comment feature to indicate their approval or rejection, with comments.

It is a good idea to send notification to the requester that the request has been received, is under review, and when it was sent to the DFM review team, or provide information as to why the request was rejected. When the request has been approved, the administrator will need to verify that all processes required to support the changes are in place or are supported by a process implementation plan and schedule. When this has been verified, the DFM guidelines should be updated by the administrator. A revision history documenting all DFM guideline changes is required. When updates are made to the DFM guidelines, all organisations affected by the change need to be notified. After the completion of the first prototype that incorporates the design change, it is a good idea to perform an assessment of the design performance. The assessment can be sent to the DFM review team and the requester. The entire sequence of events is shown in Fig. 4.

Summary

DFX is not just another fad. Design for manufacturability and testability are critical success factors. Successful design and manufacturing organisations excel at DFX. Why do many companies continue to ignore a concept that leads to success? There are many reasons, but the most serious is a lack of high-level management support. New ideas and concepts succeed when individuals, teams and companies are willing to challenge current models and explore other methods. Taking advantage of internet tools is one approach that can simplify the job of managing a DFX program while providing worldwide access. These tools can provide information to and input between multiple sites in different geographical locations. Having a clearly defined process for creating, reviewing, evaluating, changing and implementing DFX guidelines is necessary to ensure success.

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