Design for Manufacturability

"The key objective in any design for manufacturing effort is to achieve simplicity...

There are many things which are ...valid measures of simplicity ...
First is the number of parts.
Second is assembly time. (You cannot assemble something in a very short time if it's complex)
Third is the number of processes employed
(And last) ... is the complexity of the process ..."

Fred Schwager, DFM expert

What is Design for Manufacturability (DFM)?

DFM is an approach followed during the design process that has the aim of improving manufacturing productivity. It brings major benefits when used during the design of new generations of products. It is a method of working which:

1. Helps the design team focus on clear and common objectives
2. Encourages problem-ownership and prevents manufacturing problems being shifted from area to area (e.g. from direct to overhead costs).
3. Uses a top-down approach to product design in order to prevent early and wasteful focus on detail.

Designing a product is just the first stage of development, next comes manufacturing the product. Designers should keep up to date with the manufacturing process and the materials and components available. Each process will have its own advantages or limitations in production. Some offer unique properties that may be exploited in a product, while alternatively new components and materials may be available to facilitate product design and assembly.

DFM is often divided into three subdivisions. These subdivisions are:

DFA - Design for Assembly
DFP - Design for the Process
DFQ - Design for Quality
The user will find that the three subdivisions overlap and in fact, sometimes contradict. There always exists an element of trade-off in applying DFM principles. Used correctly, DFM can lead to a 25-30% reduction in production cost without capital investment in new facilities.

What Does DFM Seek to Achieve?

The goal of the DFM approach is to design products such that they are easier and less expensive to manufacture while retaining quality. To achieve this goal there are certain principles a designer must keep in mind. Some of these principles include:

- Minimizing the part count
- Minimizing fasteners
- Standardizing parts
- Using unidirectional assembly
- Using correct assembly tolerances

These principles in turn define a set of general rules that a designer should consider. Although it may seem as if designing through the use of such rules causes the design process to lose its creative side, remember that the rules are just guidelines; there is no substitute for human creativity and experience.

These techniques represent a basic set of guidelines for DFM aimed at raising the awareness of design engineers as to the importance of manufacture and assembly. The guidelines and specific techniques for their implementation are presented below:

1. **Aim for simplicity**

   Minimize part count, part variety, and assembly surfaces; simplify assembly sequences, component handling and insertion, for faster and more reliable assembly. Use unidirectional assembly

2. **Standardize**

   Standardize on material usage, components, and aim for as much off-the-shelf componentry as possible to allow improved inventory management, reduced tooling, and the benefits of mass production even at low volumes. Minimize fasteners types.

3. **Rationalize product design**

   Standardize on materials, components, and subassemblies throughout product families to increase economies of scale and reduce equipment and tooling costs. Employ modular design to allow variety to be introduced late in the assembly sequence and simplify Just In Time production.
4. **Use the widest possible tolerances**

Reduce the tolerance on non-critical components and thus reduce operations, costs, and processing times.

5. **Choose materials to suit function and production process.**

Avoid choosing materials purely for functional characteristics; material choice must also favor the production process to ensure product reliability.

6. **Minimize non-value-adding operations.**

The minimization of handling, excessive finishing and inspection will reduce costs and lead-time.

7. **Design for process.**

Take advantage of process capability to reduce unnecessary components or additional processing, such as the porous nature of sintered components for lubricant retention. Design in features and functions to overcome process limitations, such as features to aid mechanical feeding. Avoid unnecessary restriction of processes to allow manufacturing flexibility in process planning.

8. **Teamwork.**

Promote concurrent engineering. Establish a product or project based development organization involving a formalized multi disciplinary / departmental structure. Success is dependent on senior management buy-in, an open door culture, staff training and development, and an ongoing continuous improvement program.

**Design for Assembly Principles**

**Designing to a Stable Base**

This is probably the most important concept. Consider the example of an automobile assembly line. In the case, the chassis serves as the stable base. As it moves along the assembly line, parts and subassemblies are fastened to it. There is no need for reorientation of the entire chassis when each new subassembly is added.

This aids in:

**Minimizing reorientation of entire assembly**
The less an assembler has to move and orient both the original part and parts to be added, the faster and freer the process. It:

- Reduces number of required tools and fixtures
- Reduces final assembly and testing times
- Reduces operator fatigue and improves workplace ergonomics
- Improves overall quality

**Making the insertion point easy to see and reach**

This is closely related to one of the other major concepts, Z-axis insertion. Utilizing this concept:

- Reduces fatigue and repetitive motion problems
- Facilitates proper alignment and fastening of parts/subassemblies
- Decreases assembly time

**Z-Axis Insertion of Parts**

Z-axis insertion refers to insertion along the line of sight. If the assembler has a good view of the larger assembly as well as the parts to be added, the assembly will be faster and more precise. To further understand this concept, let’s look at the affect of part symmetry on part assembly:

First, we will examine a brief review of the principles of rotational symmetry. Alpha symmetry refers to symmetry about a part's "most repeatable" axis, and is reported as the number of degrees needed to turn an object along this axis before it repeats. For example, a square bar has alpha = 90º, a cylinder has alpha = 0º (so does a screw, for all practical purposes), and a bar that is rectangular in cross section has alpha = 180º. Beta symmetry is perpendicular to the alpha axis. It is related to whether the "ends" are identical or not, and whether the part needs to be flipped over before insertion. Values are either 0º (identical ends) or 180º (needs to be flipped).

These affect how a part is oriented before insertion into the larger assembly.

Lower symmetry values decrease the number of possibilities for incorrect orientation, therefore decreasing manipulation and assembly time.

At the same time, a part that can only be inserted in a single orientation decreases ambiguity. This, however, requires that the
assembler be adept at spatial recognition, and can increase handling time.

At the same time, remember that while decreasing symmetry will reduce assembly time it may increase the number of components, adding to manufacturing costs. As previously stated, DFM/DFA represents a tradeoff between assembly and manufacture ideals.

**Unidirectional Assembly**

Unidirectional assembly means assembling a product by adding the parts one by one all from the same direction. During the assembly the base or already assembled part doesn't need to be moved or rotated to allow the other pieces to be attached.

Symmetry is also desirable. If we can achieve the same assembly regardless of the orientation in which the part to be assembled is held, it eliminates the need for adjustments in orientation.

Unidirectional assembly saves time and money during the assembly process because the producer doesn't need to worry about the labor, equipment, or time that is needed to perform the complicated movements used in multi-directional and orientation specific assembly. By avoiding multi-directional assembly the product assembly becomes much more simple, which in return means a faster, cheaper, and easier product development.

**Design parts with self-locating features**

Make things easier to assemble, and the process will speed up. Advantages:

- Reduced assembly tooling
- Reduced operator training
- Reduced operator fatigue and frustration
- Reduces lifetime product cost
- Improves quality

**Decreasing the need for specialized fixtures**

Fixtures are devices that hold the part or assembly in a particular orientation so the part can be fastened or inserted securely. A stable base minimizes the need for such fixtures, because it acts as a fixture itself.

**Minimizing Part Count and Levels of Assembly**

This is probably one of the simplest things to do. Fewer parts mean a faster and more accurate assembly process, and fewer mistakes. It results in:
Reduced administrative overhead and inventory
Reduced number of vendors
Reduced assembly time and savings in material costs
Simplified factory layout and assembly processes

It can be accomplished by:

Minimizing numbers and types of fasteners, cables, etc.
Encouraging modular, interchangeable assemblies
Building in self-fastening features
Minimizing the number of levels of assembly

**Minimizing numbers and types of fasteners, cables, etc.**

The addition of a single screw to a product doesn't add just the cost of the screw, but also the cost of having someone align it and screw it in drilling and tapping the hole, and the machinery to do it overhead for inventory, and time and space necessary for the assembly process.

The same goes for different types of cables and connectors in electronic equipment, as well as many other examples.

**Encouraging modular, interchangeable assemblies**

Designing interchangeable parts with specific qualities makes customization easy. Other advantages:

- Reduces final assembly time
- Simplifies inventory
- Facilitates automation
- Reduces post-assembly adjustments
- Improves serviceability

**Building in self-fastening features**

This goes hand-in-hand with reducing the number of fasteners and using special characteristics of the material. Snap-fit items are easily molded from plastics, and fold-over tabs are easily stamped from sheet metal.

This example shows how a snap-fit tab can take the place of a separate screw. Not only does one eliminate the screw, but also time is saved because the tab is self-aligning.
Minimizing the number of levels of assembly

Some subassembly is good, but don't go overboard. By decreasing the number of assembly levels, you:

- Simplify specifications
- Facilitate the assembly process
- Simplify factory layout

Using Unique Characteristics of the Material

Plastics may be transparent, translucent, or opaque, and are flexible and can be easily bent, shaped, or molded. Metals can be stamped or pressed into shape. These characteristics allow these materials to be utilized in special ways:

- Built-in springs
  Plastic, being flexible and easily molded, not only uses its unique characteristics, but also can reduce part count by designing a spring as part of another part.

- Pressed or molded parts
  Pressed metal flanges and tabs increase the precision of insertion, and may help reduce part count, too.

- Injection-molded buttons or signs
  A good example of injection-molded buttons is the keys on a computer keyboard. By molding the letters into the keys, they don't wear off like paint or decals would, and the decal application step is eliminated. Decals, however, are desirable where they would not get a lot of wear, because they are less expensive than injection-molded signs.

Eliminating need for special tools

Specialized tools and machines often need specialized training. In many cases, these tools may be necessary, but their use often increases handling time because the tool must be picked up and manipulated before it is used. A classic example is the Torx driver, used for automobile headlight adjustment among other things. These come in several sizes that can be easily confused. Why not use a simple Phillips screwdriver instead? However, Torx drivers are more easily used in automated assembly, and hence the tradeoff continues.
Ergonomics

Looking at the concept further, we will consider more deeply the two dimensions of ergonomics and aesthetics. *Ergonomics* encompasses all aspects of a product that relate to its human interfaces.

Increasing the comfort level of the worker increases productivity and makes for a happier work force. One can accomplish this by:

- Facilitating parts handling and manipulation
  
  If parts are easier to handle and accurately locate, assemblers will experience less fatigue and frustration.

- In addition, it:
  
  - Enables automatic assembly and/or feeding techniques
  - Simplifies the assembly process
  - Reduces tangling and nesting of parts
  - Reduces total assembly time

To determine the *ergonomic needs* of a development project, the following questions must be asked:

- How important is ease of use?
- How important is ease of maintenance?
- How many user interactions are required for the product’s functions?
- How novel are the user interaction needs?
- What are the safety issues?

Aesthetic Needs

To determine the *aesthetic needs* of a development project, the following questions must be asked:

- Is visual product differentiation required?
  
- How important are pride of ownership, image and fashion?
  
- Will an aesthetic product motivate the team?
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<tr>
<th>Needs</th>
<th>Level of Importance</th>
<th>Explanation of Rating</th>
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<tbody>
<tr>
<td>Ergonomics</td>
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<tr>
<td>Ease of use</td>
<td>Low</td>
<td>Critical for a portable telephone since it may be used frequently, may be needed in emergency situations, and can be operated by motorists while driving. The product's function must be communicated through its design.</td>
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<td>Medium</td>
<td>As with many integrated electronics products there is very little maintenance required.</td>
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<td>High</td>
<td>There are many important user interactions such as changing the battery, dialing, programming the features, sending and receiving calls.</td>
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<td>Design solutions associated with some of the customer interactions are straightforward, such as the numeric keypad, since there is a wealth of human factors data which dictate the basic dimensions. However, other interfaces, such as the hinged cover which folds and opens the phone, were quite different from earlier models and therefore required careful study.</td>
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<td>There were few safety issues for ID to consider on the StarTAC itself. However, since many customers use cellular telephones in automobiles, a line of accessories needed to be designed for safe, convenient, hands-free operation.</td>
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<td>There were hundreds of models of cellular phones on the market when the StarTAC was introduced. Its appearance (including its size and shape) was essential for differentiation.</td>
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<td>The StarTAC was intended to be a highly visible product used by people for business and personal communication in public areas. It had to be physically attractive for everyday use.</td>
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<td>The StarTAC's novel form turned out to be an important inspiration to the development team and selling point for senior management.</td>
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