

## **2.1 Design for Manufacture and Assembly**

### **Design for Manufacture and Assembly**

A set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufactured and assembled with a minimum of effort, time, and cost.

Products designed using DFMA principles should have higher quality and reliability than those developed using traditional design methods. DFMA also ensures that the transition from the design phase to the production phase is as smooth and rapid as possible.

### **Why Use DFMA?**

- Lower Assembly Cost
- Shorter Assembly Time
- Increased Reliability
- Shorter Total Time-To-Market

### **Lower Assembly Cost**

DFMA lowers assembly costs by using fewer parts, eliminating unique parts wherever possible, and decreasing the amount of labor required for assembly.

### **Shorter Assembly Time**

DFMA shortens assembly time by utilizing standard assembly practices such as vertical assembly and self-aligning parts.

### **Increased Reliability**

DFMA increases reliability by lowering the number of parts, thus decreasing the chance of failure.

### **Shorter Total Time-To-Market**

Since products developed using DFMA make the quickest and smoothest transition into the production phase, the time for a product to go from conception to the consumer (total time-to-market) is reduced. The result is a more complete and workable design the first time.

## **Design for Manufacturability Considerations**

### Materials

1. Is material available in standard stock configurations (e.g., bar stock, sheet, standard extrusion)?
2. Is material compatible with the most desirable manufacturing process (e.g., ease of forming, casting, machining)?
3. Is the material available from reliable sources?
4. Do material prices fluctuate widely over time?
5. Are special alloys and exotic materials used only for environmental or functional demands?

### Fabricated parts

1. Are specified tolerances reasonable for functional requirements?
2. Are tolerances attainable within normal capability of the manufacturing process to be used?
3. Are data points, surfaces, and tooling points clear and accessible?
4. Does parts configuration minimize the need for special processes and special tooling?

### Product Assembly

1. Are tolerance dimensions realistic?
2. Is marking and stenciling defined and visible?
3. Are assembly notes complete and definitive?
4. Is internal wiring layout critical? If so, is the location and routing specified?
5. Is harness development required? If so, can the harness be fabricated outside the unit and installed as a subassembly?
6. Does the design lend itself to automated assembly?
7. Are component parts accessible for assembly?
8. Can testing be performed without disassembling the unit?
9. Are standard connectors and assembly hardware used?
10. Are circuit cards, if used, designed to plug in?

11. Has the assembly been analyzed to meet electrical, thermal, vibration, and shock specifications?
12. Can printed circuit flex cable or molded ribbon be used in place of hard wiring?
13. Can plastic tie-wraps be used in place of lacing or spot ties?

[Source: *Practical Engineering Guides for Managing Risk: Design for Reduce Technical Risk*, AT&T, McGraw-Hill, Inc., New York, New York pp. 503-528]

## **Principles of DFMA for Mechanical Design**

- Minimize Part Count
- Make Parts Multi-Functional
- Reduce the Number of Screws and Screw Types
- Facilitate Parts Handling
- Use Standard Parts and Hardware
- Encourage Modular Assembly
- Use Stack Assemblies/Don't Fight Gravity

## **Principles of DFMA for Mechanical Design**

- Design Parts with Self-Locating Features
- Minimize Number of Surfaces
- Assemble in the Open
- Simplify and Optimize the Manufacturing Process
- Eliminate Interfaces
- Design for Part Interchangeability
- Design Tolerances to Meet Process Capability

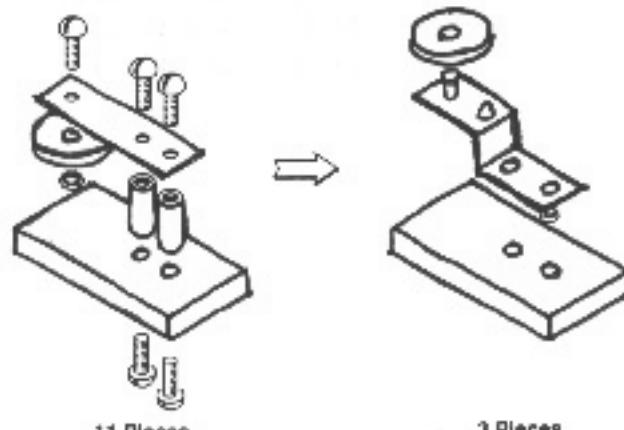
## **Minimize Part Count**

The final cost of a product is directly proportional to the number of parts. As the number of parts is reduced, product quality and reliability typically increase. This comes about because fewer parts are present to break or work loose and reduces the chances of misalignment. The following three questions can be used to determine the necessity of a particular part.

### **A Simple Test to Determine if a Part Can Be Eliminated**

- Must the part move relative to other parts in performing its function?
- Must the part be made of different material?
- Must the part be a separate component?

If the answer to these three questions is "NO", then the possibility of combining the part with other parts should be considered.

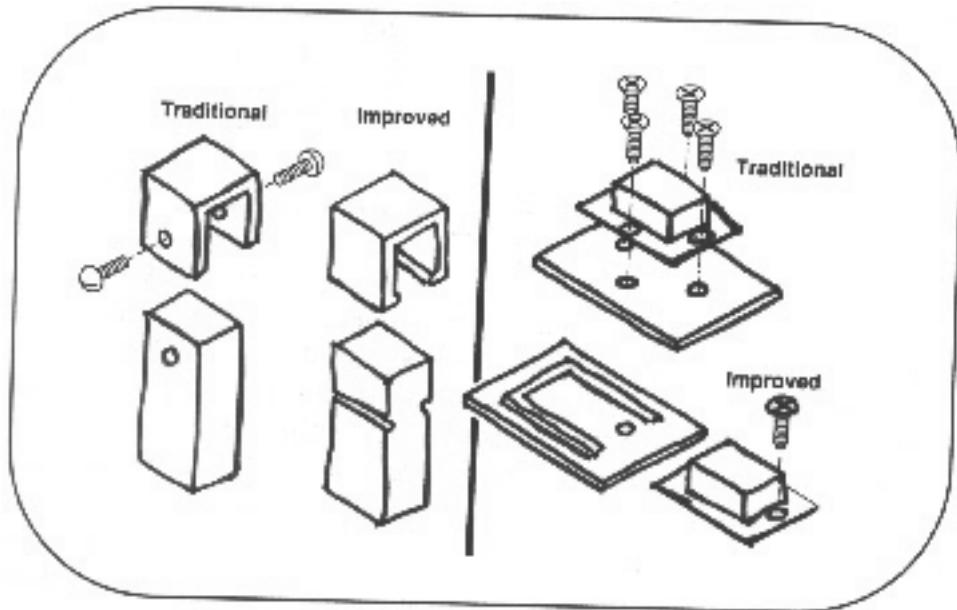


## **Make Parts Multi-Functional**

Multi-functional parts combine several functions into one part and reduce complexity.

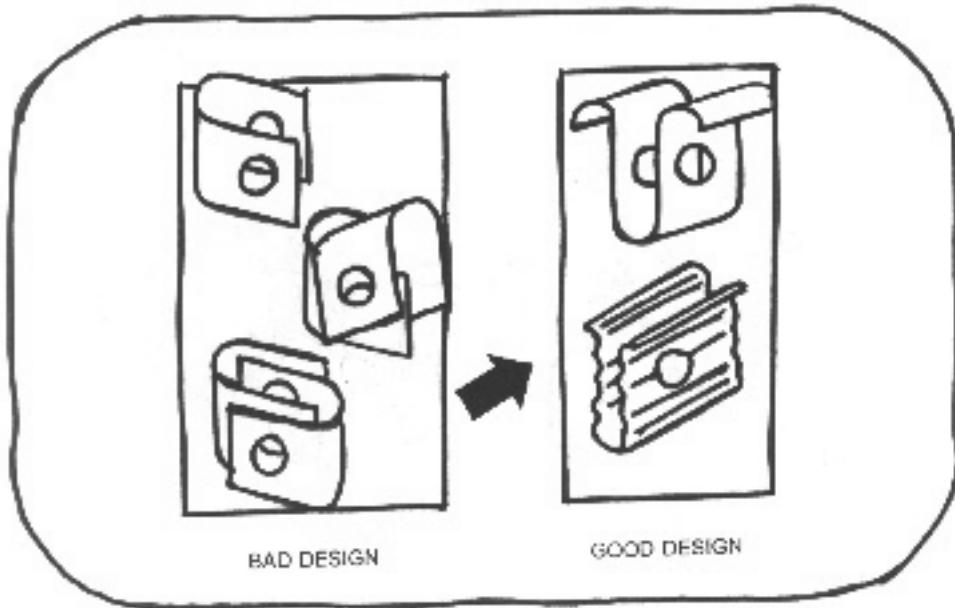
## **Reduce The Number of Screws and Screw Types**

Decreasing the number of fasteners reduces assembly weight, cost, and complexity. The alternative to fasteners is to incorporate self-aligning features into parts design. If fasteners are necessary then use a common size and/or self-tapping screws.



## **Facilitate Parts Handling**

Parts should be designed with handling in mind. They should be designed to minimize the potential for becoming tangled or stuck together. The goal is quick and easy parts handling that does not require special tooling or fixturing for assembly. Making parts easily identifiable also speeds handling. Where possible we would like to make parts symmetric so that orientation is not an issue. However, if a specific orientation is necessary, the use of asymmetric features will force correct alignment, eliminating the potential of incorrect assembly.

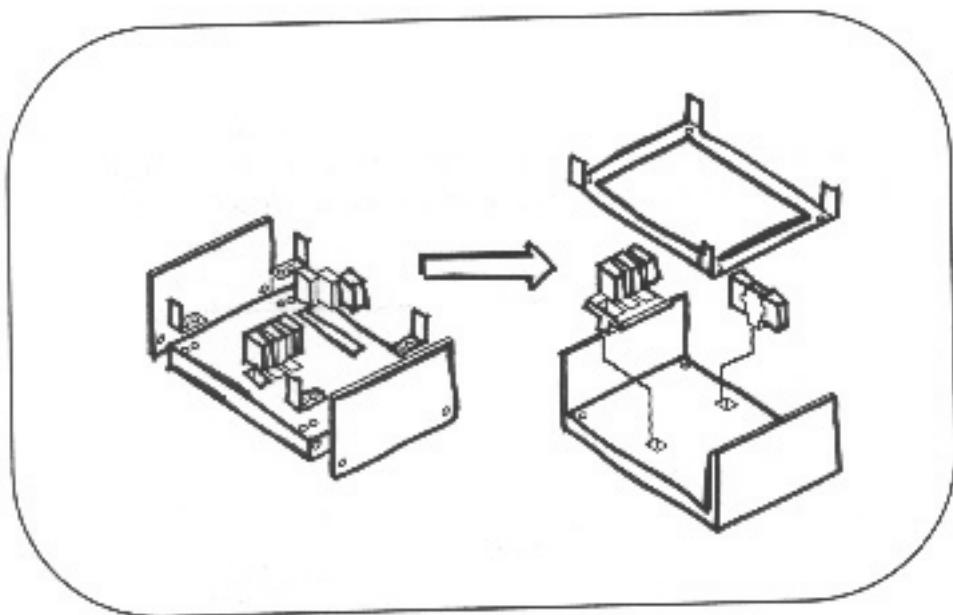


### Use Standard Parts and Hardware

The use of standard components in a design reduces the number of tools required for assembly and lowers assembly cost. Unfortunately, standardization requires increased communication between the multiplicity of design teams working on complex products and systems. Often the best way to handle this is to create a list of standard parts for each project. Generally, fasteners and hardware can quickly get out of hand. A good rule of thumb is to never design a part that you can get out of a catalog. In order to facilitate the use of standard parts, the design team should utilize various resources such as the preferred parts lists, standard parts manuals, vendor catalogs, trade magazines, etc.

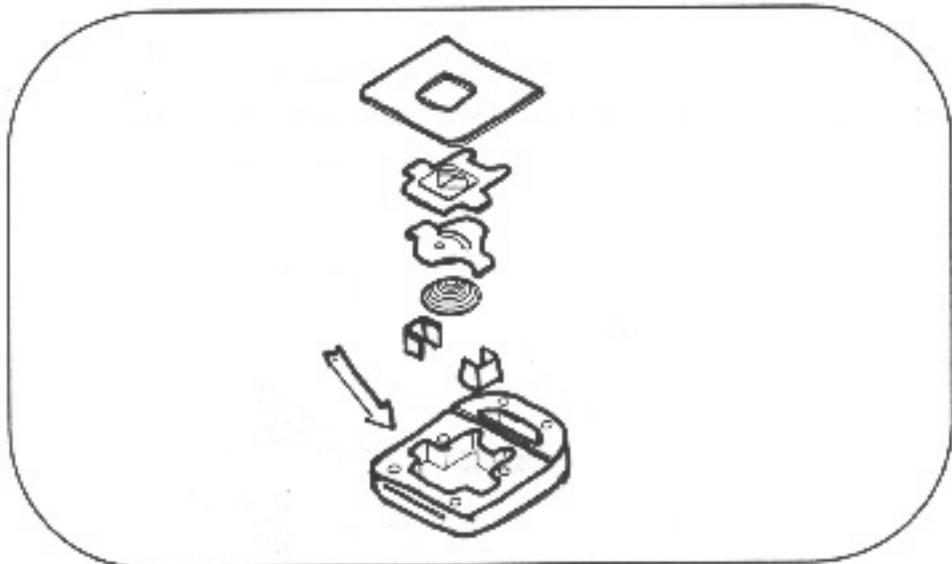
### Encourage Modular Assembly

Modular designs simplify assembly operations and make problem identification easier by reducing the number of parts. Modular assembly also simplifies inventory and improves maintenance and serviceability. By designing parts as separate, self-contained modules, disassembly time is reduced, fewer tools are required, and overall repair time is reduced.



### Use Stack Assemblies

Assembly operations should use, not fight, gravity. One way to do this is to design parts for stack assembly (i.e., assembly components from the bottom up). This makes automatic assembly possible. Stack assemblies require less reorientation of the components which speeds the assembly process. Not using gravity generally requires the use of additional tooling and fixturing.

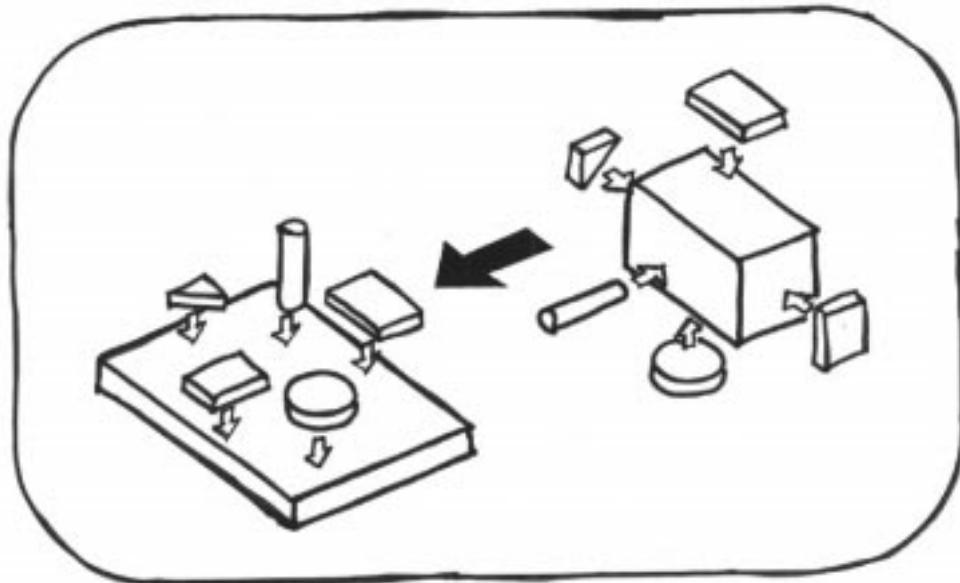


### **Design Parts With Self-Locating Features**

Self aligning parts can be placed into an exact location with no adjustment required. This makes assembly easier and faster for the assembly workers. Examples of self-locating features include projections, indentations, chamfers, molded keyways, etc.

### **Minimize Number of Surfaces**

Minimizing the number of surfaces can reduce the manufacturing and assembly requirements of a system or subsystem. This is realized by minimizing the number of times that an item must be picked up and repositioned.



### **Assemble in the Open**

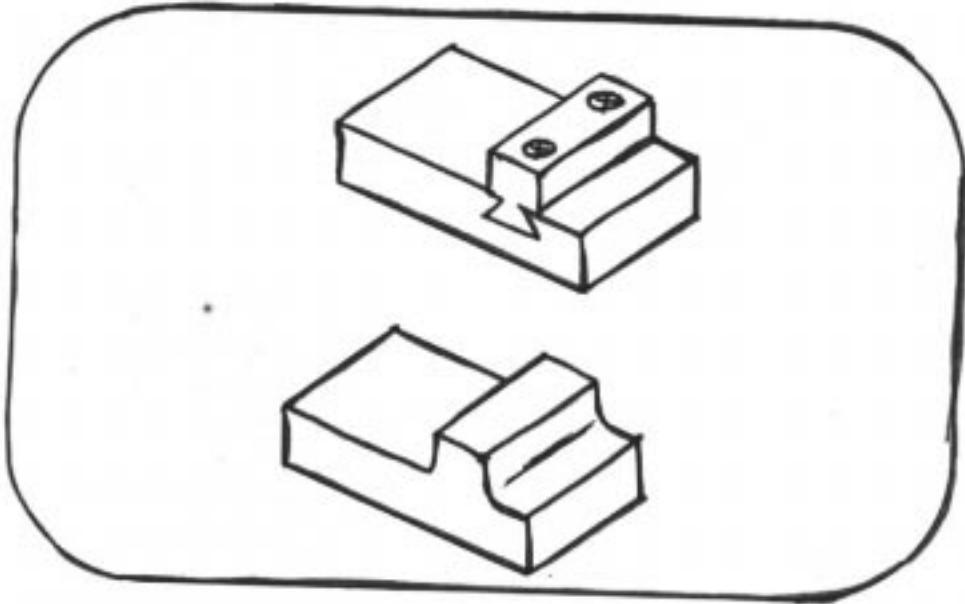
Assemblies should be designed so that assembly operations are accessible and in the open. Blind assembly can increase assembly time, cost, complexity and can contribute to quality problems.

### **Simplify and Optimize the Manufacturing Process**

Simplification and optimization of the manufacturing process reduces recurring direct and overhead costs. In designing the production process the focus should be on: smoothing material flow; minimizing the number of material moves; using processes that are easily controllable; avoiding, where possible, processes that are difficult to control (i.e., welding, brazing, etc.); performing like operations simultaneously; and separating manual and mechanized operations.

### **Eliminate Interfaces**

Interfaces increase the cost of an assembly. Each interface doubles the amount of information required and increases overall assembly time (i.e., “2 sets of dimensions, 2 sets of tolerances, 2 sets of interface features, assembly labor, assembly materials, etc.”).



### **Design for Part Interchangeability**

Using interchangeable parts is a simple way to reduce part numbers, simplify the assembly operation (i.e., part orientation is not an issue) and ultimately minimize assembly time and cost. In particular, left-handed and right-handed parts should be avoided; they often, unnecessarily, increase the potential for confusion and complexity of assembly.

### **Design Tolerances to Meet Process Capability**

Manufacturability is enhanced when part designs take into consideration process capabilities. Specification of unnecessarily tight tolerances is a significant waste of time and money. Overly tight tolerances may require additional fixturing, processes, and/or inspections. Therefore, designers must consider manufacturing and supplier capability when specifying tolerances to ensure that tight tolerances are truly necessary.

## Principles of DFMA for Electronics Assembly

- Use Standard Parts and Material Whenever Possible
- Determine Capabilities of Each Process Step
- Design for Ease of Part Orientation for Assembly
- Eliminate Multiple Solder and Cleaning Steps
- Eliminate Adjustments
- Minimize the Number of Parts
- Publish and Maintain Up-To-Date Design Guidelines
- Design for Component Variability
- Identify Defect Rates by Cause

### Use Standard Parts and Material whenever Possible

Use of standard parts and material reduces the cost, delay, and risk of processing problems. The primary advantage of standard parts and materials is that these are known quantities. As such they should minimize the potential for problems.

### Determine Capabilities of each Process Step

Process capability defines the ability of the process to produce within acceptable specification limits. By documenting process capabilities we can provide the design team with useful information for choosing processing technologies and the appropriate processing sequences.

### Design for Ease of Part Orientation for Assembly

Using uniform part orientations eases inspection and assembly tasks. Maintaining the correct orientation is important because of potential impact on quality, particularly the quality of solder joints. Orientation can be facilitated by using notched packages, chamfered packages or special markings to ensure correct placement.

### Eliminate Multiple Solder and Cleaning Steps

We would like to minimize the processing technologies utilized. The greater the number of technologies used, the greater the chance for errors and reduction in process yield. Likewise, each additional processing step increases cost, risk, and potential for delays.

### Eliminate Adjustments

Adjustments are costly and complicate processing. Process controls should be in place to minimize misalignments. Note, however, that not all misalignments must be repaired. In particular, minor misalignments may only affect the look of the product and not its functionality.

Elimination of adjustments could also include replacement of potentiometers and manual switches with phase lock loops, feedback loops, voltage regulators, etc.

### **Minimize the Number of Parts**

Minimizing the number and sizes of parts makes assembly (particularly automated assembly) easier. A potential strategy is to consider combining part functions. Reductions in part counts can also have a positive impact on system reliability. In addition, it can reduce machine requirements (i.e., placement machines have a finite number of feeders).

### **Publish and Maintain Up-To-Date Design for Manufacturing Guidelines**

An organization utilizing IPD should establish Design for Manufacturing (DFM) guidelines. These guidelines should address reliability, quality, and manufacturing requirements of the company. They should also include: board parameters (i.e., coating, plating, materials, etc.), critical process steps, process capabilities, and important machine parameters that impact component design.

### **Design for Component Variability**

We cannot address every aspect of variability but the designer should realize and make allowances for uncontrollable variations (i.e., what Deming would call common cause variation) that are inherent to any system. For example, the lead-width of fine pitch packages is controlled but still varies from item to item. Knowing this we should design pads that are large enough to reliably hold the leads regardless of width.

## **Benefits of DFMA**

- Reduced part number and part counts
- Reduced assembly operation
- Reduced product lead-time
- Reduced packaging costs
- Increased productivity and efficiency
- Reduced material cost
- Reduction in overall system/product cost
- Improved product quality and reliability

Many companies have used DFMA with great success. One example is Digital Equipment Corporation. Digital used DFMA principles when it decided to re-design its mouse. Some of the improvements realized because of DFMA were:

- The number of parts used was reduced by 50%.
- The number of assembly steps was reduced by 33%.
- The amount of time required for assembly was reduced by 53%.
- The volume of material required was reduced by 47%.
- The cost of packaging was reduced by 41%.

In addition, the project was completed in half the average time normally required.

### **Design for Manufacture/Assembly Software**

Boothroyd Dewhurst, Inc. has developed a software package that allows engineers to implement DFMA techniques within a user friendly, graphical environment. The software can quickly calculate the costs involved for different materials and manufacturing processes as well as identify areas where the number of parts can be reduced.

The software allows engineers who are not familiar with the DFMA process to reap the benefits of implementing DFMA. Engineers can change the materials or processes used and quickly determine if the costs are reduced or not. The system incorporates databases of parts and subassemblies with Design for Assembly (DFA) information associated with the manufacturing site. Subassemblies are graphically represented along with information on unnecessary parts, estimated assembly times, and approximate cost data. The system also provides an accurate cost estimate for a variety of materials and associated manufacturing processes including: injection molding, machining, sheet metal work, die casting, and powder metal parts.

Potential users of the Boothroyd Dewhurst software should note that they must have a detailed knowledge of their manufacturing process plan before they begin using the software. The software is not knowledge-based, and does not aid the user in developing a process plan. This drawback can be frustrating to new users of the tool; however, it does not diminish the importance of the software as it relates to DFMA. The primary benefit of the system is that it allows design engineers to quickly and easily consider the impact of using alternative materials and manufacturing processes. Boothroyd and Dewhurst, Inc. have documented significant reductions in parts count and cost (51% and 37%), time to market (50% faster), assembly time (62%), and manufacturing cycle time (57%) as well as improved quality and reliability (68%) by system users.

(Illustrations in Section 2.1 were adapted from *Machine Design Magazine*)