



# Using DFM to Understand Printed Circuit Board Assembly Costs

---

**James McDonough**  
**JM Engineering Consulting**

In Conjunction with



## **Introduction**

Through numerous papers and case studies the benefits of the Design for Manufacture and Assembly (DFMA) tools have been explored and expounded. For the past 4 plus years JM Engineering Consulting (JMEC) has been involved with helping Dynisco and other Roper Technologies (Roper) companies obtain success with Design for Assembly (DFA) and Design for Manufacture (DFM) application in various areas of their products life cycle. JMEC and Dynisco utilize tools such as pareto analysis along with the DFMA methodology and toolset. Many of Dynisco and Roper products are electromechanical assemblies to which DFA can be used to help in optimizing assemblies to produce more robust and simplified designs. A good design process will assign cost targets for major systems or assemblies. DFM contributes to the tracking of project costs through estimating the piece part costs in the design.

Dynisco determined printed circuit boards (PCBs) should be included in the DFM should-cost analyses after paretos identified twenty four percent of the total cost for one of Dynisco's products consisted of PCB assemblies (PCBAs). Dynisco has already established a rigorous DFM should cost process for commonly machined parts with success and now, developing a sound method for doing the same with PCB's seemed a logical inclusion. If a PCBA is part of your design, then DFM will afford you the same benefits as with your fabricated components. If you're using DFM for fabricated components why leave your PCB's to chance? Be armed with the data, that's what JMEC and Dynisco are doing.

## **PCB Module in DFM**

Use of DFM for PCBAs is applicable to the same product life cycle areas. Using the module in the development or conceptual phase allows for the most cost effective design from the earliest stages. One can compare design iterations such as larger single board designs versus multiple stacked interconnected boards. Circuit boards have the distinct disadvantage of not being conducive to being analyzed from the "napkin sketch." A greater level of detail from the board designers and electrical engineers is required to get meaningful results from the software.

If you have iterative changes to existing designs or a product refresh, you should have enough information to enter and provide the valuable guidance as to what impact the changes may have to your PCB costs. One Dynisco design activity involved an existing sensor design that consisted of 2 PCB's with a wire connection. Product refresh activities involving DFMA assisted in redesign to 1 PCB for savings of

12% (Not to mention a better DFA index). If your product development process (PDP) includes cost targets for specific systems, then the DFM PCBA module can help you maintain your metrics to plan.

A mature product line can benefit from the PCBA option in DFM as well; it will help you ensure you are paying proper prices. You also have the ability to compare US versus China suppliers. Should you need to change suppliers you will have the data and ability to have an informed discussion with your potential new or trusted suppliers. Another Dynisco PCBA success involved a high volume sensor where the DFM PCBA should-cost was used to renegotiate the price for an 8% savings yielding \$13K a year.

Competitive benchmarking can be a very productive activity and PCBAs can be included in the analysis. There are a few pitfalls with costing a PCBA from just looking at the board and components. The identification of the components themselves can be challenging. Not all components have clear case markings. By using the reference designations (D for diode, R for resistor etc) along with any case markings you should be able to get close. Once you have identified the component you can use online sites such as Digikey, Mouser or Newark to get pricing. Keep batch size in mind, although, for more common components, use reel lot size prices due to the fact that a contract PCB house will have common stock for other customers. You will have to guess on component tolerances, but using similar to what is in your design is a good practice. Most recently Dynisco utilized DFM to fully cost 5 competitor units in a comprehensive benchmark study.

### **The Nuts and Bolts (or Resistors and Capacitors)**

As with any fabricated product the components of cost are similar. Breaking the components of cost down to the basics in DFM, you will still end up with material, setup, process, rejects and tooling. Material will be the bare board constituents and the components to be placed. Setup consists of any of the automated placement equipment, solder paste application and solder machines. The first step is to select the process and material. Selecting the printed circuit board assembly process in DFM turns all materials but the four under printed wiring board heading red. Making your material selecting brings up the bare board dialog box (figure 1). As with any DFM analysis many of the values are estimated by the software. If you have the data, enter it. The more detailed the DFM analysis the more accurate the result. The important entries under the bare board process are the batch size, board type and number of holes. Board type options include single sided, double sided and multi layer. The DFM software defaults to a relatively high number of holes for smaller boards which can have a significant impact on cost. For example, a 2" x .4" example board defaults to 400 holes versus the actual 33 which results in a \$7.50

delta in process. That's half the actual cost of the board. Again, as with any of the auto populated fields, if you have known data enter it for a more accurate result.

The screenshot displays a software interface for PCB cost estimation. On the left is a tree view of the manufacturing process, and on the right is a configuration panel with various input fields.

Section	Parameter	Value
Basic data	Batch size	50
	Overall plant efficiency, %	85
	Basic material cost, \$/in <sup>2</sup>	0.04
Board processing data	Board type	Double sided
	Board thickness, in.	0.062
	Number of holes	33
	Copper weight, oz/sq ft	0.5
	Minimum trace width, in.	0.006
	Minimum conductor spacing, in.	0.006
	Gold plated edge connectors	<input type="checkbox"/>
	Solder mask required	<input checked="" type="checkbox"/>
	Legend screen printing	<input checked="" type="checkbox"/>
	Circuit overlays, \$	971
Panel data	Length of panel, in.	24
	Width of panel, in.	18
	Number of boards per panel	250

The process tree on the left includes the following items:

- FR-4 printed circuit board
  - Bare board process
    - Printed wiring board fabrication
    - Hole drilling
    - Solder mask
    - Legend printing
    - Testing
  - Pcb Assembly
    - Solder paste-auto
    - MELF placement
    - SOT placement
    - SOIC placement
    - R1 - Chip placement
    - MELF placement
    - IC1 - SOT placement
    - SOT placement
    - Chip placement
    - PTH connector insertion
    - Reflow solder
    - Cleaning
    - Plastic bag part
    - Profit

At the bottom of the tree, there are two buttons: "Example PCB 50 pcs USA" and "Example f" with left and right arrow icons.

Figure 1

## Component Placement

Having addressed the bare board fabrication costs, it's time to address component placement and other associated PCBA operations. The operations for PCBAs in DFM are broken into 4 categories. The first two consist of the two main component insertion types, through hole and surface mount. A wide variety of component types are included for both. Selecting on a component gives you a pictorial representation as well as a brief description (figure 2). Once you have added a component placement to the tree you can modify the inputs. You can select the placement method (Auto, robot, or manual, or any of the 3 with adhesive), number of components and the number of different components. This allows you to enter all similar components, surface mount resistors for example, regardless of size or ohm value in the same operation, creating a more streamlined analysis. Alternatively if you want to enter items in more of a bill of material type structure to facilitate changes you may develop the analysis accordingly. The results in the setup line item (with the specific operation selected) represents the labor to setup the feeder for the particular component. The cost in the tooling line item is the labor cost for programming the placement equipment for this component (see again, Figure 2). The remaining two categories are whole board operations and miscellaneous operations. The whole board operation sections consist of solder paste

and solder operations, as well as testing. The miscellaneous operations are manual operations such as jumper wire operations or bonding larger components. Ensure you have every operation accounted for. If your PCBA requires more complex post component placement operations, you may import the DFM into a DFA and either use library operations or create a custom one to accommodate your specific assembly needs. The more accurate the inputs the more accurate the results.

The screenshot shows a software interface for PCB assembly cost estimation. On the left is a tree view of assembly processes, with 'SOT placement' highlighted. On the right is a configuration panel with the following settings:

- Placement method: Auto
- Fault rate: 0.002
- Number of leads: 5
- Number of components placed: 1
- Average component cost, \$: 0.1
- Setup cost per part type, \$: 1.6
- Component rework time, s: 37.9
- Replacement component required?:

Below the configuration panel is a 3D model of a component. At the bottom left is a cost results table:

Cost results, \$		Previous	Current
Calculate	material	0.10	0.10
	setup	0.03	0.03
	process	0.00	0.00
	rejects		
	piece part	0.13	0.13
	tooling	0.00	0.00
	total	0.13	0.13
Tooling investment		2	2

At the bottom right is a 'Notes' section with the text: 'A small outline transistor (SOT) is a SMD package for discrete components with three to five leads in a gull-wing shape along two sides..'

Figure 2

## Summary

If your designs include PCBAs the DFM Concurrent costing module will afford you the same benefits as with your fabricated components. Utilization during any phase of the project lifecycle can yield useful data. PCBAs require more detailed initial inputs, but in conjunction with the DFM data you will ensure that your project is the most cost effective design.

## **References**

1. Boothroyd Dewhurst, Inc. *Design for Manufacture: Concurrent Costing* © Version 2.4.0.25.