DESIGN AND ANALYSIS OF EXPERIMENTS

FOR SURFACE MOUNT KEYBOARDS

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## DEDICATION

This thesis is dedicated to my father and mother for their support and encouragement during the duration of this course of study. This thesis would not have been possible without them.

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by

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# ABSTRACT

The engineers at Honeywell have designed a new commercial keyboard using Surface Mount Technology. The process required experimentation at different stations to determine the critical factors affecting productivity. Factorial experiments were chosen to determine these factors. The three machines considered important were the Screen Printer, the Pick and Place Machine and the Curing Oven. An overall factorial experiment was performed using a variable from each of the three machines. The results prompted one individual experiment for each machine. DESIGN-EASE analysis was performed on the experiments. Confidence intervals on the mean data values were performed. The results from these experiments provide parameters for optimal production and future analysis.

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# Chapter 1

## INTRODUCTION/SURFACE MOUNT TECHNOLOGY

The traditional methods of manufacturing electronic assemblies have essentially reached their limits in terms of cost, weight, volume and reliability. Surface Mount Technology (SMT) makes it possible to produce more reliable assemblies at reduced weight, volume, and cost [1]. The engineers at Honeywell, Inc.-Keyboard Division realized this in their design of a new commercial keyboard. However, they required optimal values of variable process parameters to effectively implement their manufacturing process. The design and analysis of experiments for surface mount keyboards provides these parameters for optimal production.

Surface Mount Technology has its roots in relatively old techniques such as flat packs and hybrids. It is used to mount electronic components on the surface of printed circuit boards or substrates. Conventional technology, by contrast, inserts components through holes in the board. This simple difference changes the design, materials, processes, and assembly of component packages in electronics.

In the 1950's, surface mount devices called flat packs were first used for high reliability military applications. However, they had to be mounted too close to the board surface, were very costly, and required discrete soldering.

In the 1960's they were replaced by dual-in-line packages (DIPs) which were easier to insert and could be wave soldered easily. Following DIPs, surface mount technology expanded to hybrid components. These components feature surface mount devices soldered inside a through-hole or ceramic package body. Hybrid development greatly influenced the surface mount technology of today which uses leadless ceramic chip carriers (LCCCs), small outline integrated circuit (SOIC) packages and plastic leaded chip carriers (PLCCs) [1].

The benefits of surface mount technology are important in both design and manufacturing. Because the surface mount components are small and can be mounted on either side of the board, the most important design-related benefits are savings in weight, real estate, and electrical noise reduction. The important manufacturing-related benefits include reduced board cost, reduced materials handling cost, and a controlled manufacturing process.

The present keyboard assembly at Honeywell has a printed circuit board assembly line with axial insertion of components. This requires one operator. It is followed by the hand assembly of nine parts that employ six operators and one inspector. The components are then wave soldered using two operators. The solder problems are touched-up and fixed which requires an additional two operators. The board is then put through an electrical test and goes to sub-assembly. This

requires another operator. The dimensions of the finished circuit board are 16.5" long and 1.5" wide. The finished keyboard measures 19.25" long and 8" wide.

In contrast, the surface mount assembly line requires two operators to laminate the board to the membrane. Only one operator is required to oversee the screen printing of the conductive adhesive, the automated machine insertion of components (pick and place), and shielding and curing of the membrane in the oven. Another employee places the membrane on the keyboard after the electrical test. The dimensions of this finished circuit board are 3.25" long and 2" wide. The finished keyboard measures 19.25" long and 6.5" wide.

The savings in real estate area on the circuit board are 18.25 square inches or 74%. The savings in real estate area for the overall keyboard are 29 square inches or 19%. The number of operators is reduced from 13 to 5. There is a significant cost decrease associated with this reduction. There is also a reduced component count with the surface mount process of 2 components and the 21 potential interface contact problems associated with it. Finally, there is greater reliability with the new process because of automated assembly.

A detailed description of each station in the entire process is given in the following process description sheets.

**Table 1.1**

**Process Description Sheet**

**Backing board prep and laminate**

**Process Description**

Load pallet on assembly line and place backing board in pallet, remove adhesive cover liner, laminate adhesive to backing board.

**Equipment Required**

46" flow line work station with stop block and condition lights, and 1 pallet buffer.

**Direct Materials Required**

Backing board (1)
Adhesive laminate layer (1)

**Process Control Parameters**

Variable Process Parameters
None

Attribute Process Parameters
Adhesive contamination
Adhesive not laminated properly
Bubbles in adhesive

**Estimated Yields**

Phase B 95%
Phase C 99%

**Process Cost**

Flow line work station
Laminating system
Empty pallet storage system
Backing board storage system

**Hours/M**

4.569

**Personnel requirements**

1 operator

**Expense budget considerations**

Operator smock

**Table 1.2**

**Process Description Sheet**

**Membrane cleaning and laminate to backing board**

**Process Description**

A blank membrane is fed through the clean machine, then centered on the pallet guide pins. The circuit area is then placed onto the exposed adhesive on the backing board and is laminated to the backing board with a roller. The surface of the membrane in the circuit area is then cleaned with a solvent.

**Equipment Required**

46" flow line work station with stop block and condition lights and 1 pallet buffer.

**Direct Materials required**

Membrane (1)

**Process Control Parameters**

Variable Process Parameters
- None

Attribute Process Parameters
- Adhesive contamination
- Membrane not laminated properly to b/board
- Bubbles in membrane lamination
- Dirty circuit surface
- Membrane to b/board alignment

**Estimated Yields**

Phase B 95%
Phase C 99%

**Process Cost**

Flow line work station
Laminating system
Membrane clean machine
Solvent cleaning system

**Hours/M**

4.569 (est)

**Personnel Requirements**

1 operator

**Expense Budget Considerations**

Operator smock
Clean machine rolls
Solvent
Solvent application medium

**Table 1.3**

**Process Description Sheet**

**Screen Print Conductive Adhesive**

**Process Description**

The pallet is fed into the screen printer. The printer aligns the stencil to the circuit by means of fiducial alignment. The screen is then lowered into place over the circuit area of the membrane. Conductive adhesive is then applied from a dispense system to the top of the stencil. The screen is then flooded with the adhesive by the flood bar. The squeegee then forces the adhesive through the stencil onto the circuit area. The stencil is then lifted and the board exits the printer.

**Equipment Required**

In-line automatic screen printer with fiducial alignment

**Direct Materials Required**

Conductive adhesive

**Process Control Parameters**

Variable process parameters
- Squeegee pressure
- Squeegee durometer
- Snap-off
- Adhesive viscosity
- Squeegee Distance

Attribute process parameters
- Smearing
- Voids
- Incomplete adhesive application

**Estimated Yields**

Phase B 95%
Phase C 99%

**Process Cost**

Screen Printer
Flow line adaptation

**Hours/M**

3.034

**Personnel Requirements**

1 setup/operator

**Expense Budget Considerations**

Stencil cleaning materials
Flood and squeegee bars
Operator smock
Stencils
Spare parts

**Table 1.4**

**Process Description Sheet**

**Screen Print Buffer**

**Process Description**

The buffer allows the stations behind the printer to continue production for the amount of units stored in the buffer because of the printer's need for frequent adjustments, preventative maintenance, and setup time.

**Equipment Reqwuired**

Flow line buffer unit

**Process Control Parameters**

Variable process parameters
None

Attribute process parameters
None

**Estimated yields**

N/A

**Process Cost**

Flow line buffer

**Hours/M**

To be determined

**Personnel Requirements**

None

**Expense Budget Considerations**

None

**Table 1.5**

**Process Description Sheet**

**Pick and Place Machine**

**Process Description**

This machine places both the components needing structural adhesive and the ones that do not. This unit therefore dispenses this adhesive. The objective is to get maximum productivity through placement of all chip type parts.

**Equipment Required**

Pick and place module

**Process Control Parameters**

Variable process parameters
- Nozzle diameter
- Pressure
- Vacuum
- Temperature
- Duration

Attribute process parameters
- Correct component location
- Dispensed dot shape
- Dispensed dot stringing

**Estimated Yields**

Phase B 97%
Phase C 99%

**Process Cost**

Pick and place system
Feeders
Feeders tools

**Hours/M**

7.916