

# An Application of Failure Mode and Effect Analysis (FMEA) Technique in the Final Inspection Process of an Integrated Circuit Industry

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**Abstract** - The objective of this study is to apply Failure Mode and Effect Analysis (FMEA) to reduce defects in the final inspection process of an integrated circuit industry. Team brain-storming cause-and-effect diagram and FMEA were utilized to investigate the quality of process. Then specialists further analyzed and evaluated level of severity, opportunity of occurrence, and opportunity of defect detection in order to calculate Risk Priority Number (RPN). Two major problems were considered for corrective actions. First problem occurred during machine process setup resulting in possible error in manually loading program by operator. Second problem occurred during loading device into machine process resulting in error in direction checking of tray chamfer. Proposed solutions were to utilize barcode scan on job order to automatically select program from the system, and to redesign instrument to protect wrong tray loading. The factory can benefit from having process guideline, controlling over quality factors, and ensuring the defect will not reoccur. Consequently, rework process was reduced from 20 case/month down to 10 case/month (50%). Cycle time was shortened from 2 hour/lot down to 1.5 hour/lot (25%). Defect was reduced from 2,600 part/million down to 1,300 part/million (50%). Productivity was increased from 1,500 unit/hour up to 1,875 unit/hour.

**Keywords** - Failure Mode and Effect Analysis (FMEA), Integrated Circuit, Risk Priority Number (RPN), Quality Control, Defective Reduction

## I. INTRODUCTION

Nowadays, competition in integrated circuit industry is intensifying. Companies are deploying various strategies to gain competitive advantages over competitors. In order to satisfy customers' needs with low cost, on-time delivery, and quality products, companies need to continuously improve themselves toward operational excellence. In order to survive under pressures from all around factors, good quality control, and continuous production process improvement greatly help companies to increase productivity with less cost. Integrated circuit industry is one of the industries that continuously improve in production efficiency, and quality. Thus, the outcomes are automatically resulting in cost reductions.

In this study, production processes of a sample integrated circuit factory were investigated. Defects were physically found in internal and external of the integrated circuits, which may be caused by uncontrolled quality related factors or by not having risk assessment under various defective issues. Thus, various quality control techniques were considered for controlling quality, and

entangling problems in the production processes. Implementation of FMEA is a good alternative for analyzing the defects and their impacts in the production processes of the integrated circuit industry.

## II. FMEA FUNDAMENTAL

FMEA is a procedure in operations management for analysis of potential failure modes within a system for classification by severity or determination of the effect. FMEA ensures that trends of the problems and risks are considered during the production process development from organizational wide operations. Documents of current knowledge and actions about the risks of failures from involving departments are collected. Potential risks are analyzed and evaluated their impacts. Gathering meeting among involving departments are crucial in order to share knowledge utilized in the process design and product design. Each FMEA is investigated and evaluated its change in functional requirements and its effects. Risks and potential failures of each FMEA are assessed in all components and all production processes. Necessity in product safety should be firstly prioritized.

Key success factors of FMEA implementation are to meet timeline requirements, and to prevent the occurrences of the potential problems. According to [1], three types of FMEA are the following.

- 1) Design FMEA (DFMEA) is to improve product design by utilizing FMEA.
- 2) Process FMEA (PFMEA) is to improve production process by utilizing FMEA.
- 3) Service FMEA (SFMEA) is to improve service by utilizing FMEA.

Implementation steps of FMEA [2] are the following.

- 1) Teams from related departments must jointly prepare FMEA.
- 2) Identify functions of components or products.
- 3) Define at least one potential failure mode for each function.
- 4) Identify the effect of failure with regarding to potential customer complain.
- 5) Specify level of severity (the severity: S) for the trend of the damage.
- 6) Identify each potential cause of damage.

- 7) Assess levels of opportunities to occur (the occurrence: O) of each of the potential causes.
- 8) Specify detection method or current controlling method.
- 9) Assess the ability of the detection method. (Detect ability: D) or controls designed to prevent damage.
- 10) Calculate Risk Priority Number (RPN) = S x O x D.
- 11) Identify the problems and carry out the implementation as planned to mitigate level of risk by firstly selecting the damage with high RPN values.
- 12) Reevaluate S, O, D, and RPN, respectively.

FMEA represents the level of risk of each defect and necessities to take corrective actions for improving product and process robustness.

### III. RESEARCH METHODOLOGY

#### A. Study and gather information from the sample plant

The sample plant manufactures integrated circuits which are mainly used in computers and mobile phones. Integrated circuits are varying in types and sizes. Most manufacturing processes of integrated circuits are automatically achieved with high technologies. However, some processes require workers to operate with the machine. Generally, the size of the plant is quite large. Major tasks of the sample plant are manufacturing integrated circuits, electrical testing, and physical inspection.

#### B. Physical inspection process

There are 8 steps for physical inspection process as shown in Table 1.

TABLE I : PHYSICAL INSPECTION PROCESS

| Step | Process  | Description  |
|------|--|--|
| 1    | Checking the job order and order quantity                        | This process helps to cross-check the correction of the upstream process.                            |
| 2    | Setup the machines.  | Setup the machines and install programs in the machines for mass production.                         |
| 3    | Put the device in the machines                                   | Handling the device into machine for inspection  |
| 4    | Inspecting lead legs around the device and marking on the device | To inspect lead legs around the device and marking on the device according to customer's requirement |
| 5    | Take device out of the machine                                   | Handling the device out of machine after inspection  |
| 6    | Visual inspection of the device                                  | Recheck the product before sending to the next process   |
| 7    | Strapping tray   | Strapping tray to ensure no device falling out of the tray   |
| 8    | Counting the device  | To ensure the quantity of device is correct  |

#### C. Causes and problems

Quality problems are shown in Figure 1 and described as the following.

- 1) Damaged lead legs causing from the device movement and incomplete process from the machine operator.
- 2) Total number of devices is incorrect because of machine miscount and operator miscount.
- 3) Device is placed at the wrong orientation because the machine operator may put the device into the machine with wrong orientation.
- 4) Different code devices are mixed during the inspection process.

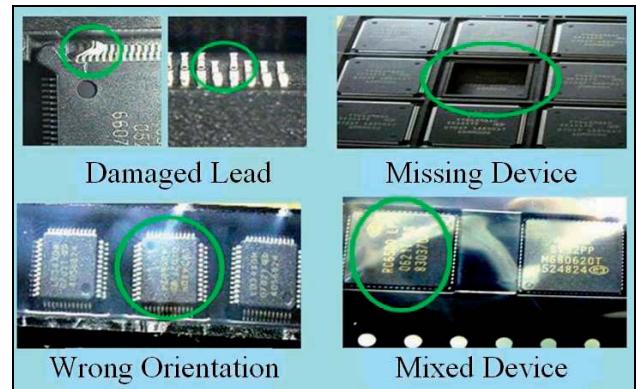


Figure 1 Production Process Problems of Integrated Circuit Devices

#### D. Cause analysis

##### 1) Checking the job order and order quantity.

The potential problem is that the devices did not completely dry. Team members from engineering, production, maintenance, quality control, and training departments were brain storming to analyze the causes of the problems. From the analysis, the major cause of the problem is from machine operator ignoring to check information from the previous stage.

##### 2) Setup the machines.

The potential problem is damaged lead legs of the devices. The main cause of the problem was that machine operator wrongly selected inspecting program from the machines.

##### 3) Put the devices in the machines

The potential problem is wrong orientation of the devices. The main cause of problem was that machine operator loaded tray chamfer with wrong direction into the machine.

##### 4) Inspecting lead legs around the device and marking on the device

The potential problem is that different code devices are mixed together during the inspection process. The main cause of problem was that inspector wrongly checked the device code during the inspection process.

##### 5) Take device out of the machine

The potential problem is the damaged lead legs around the device. The main cause of problem was that machine operator carelessly handled the tray causing the devices falling out of the tray pocket and damaged the lead legs.

#### 6) Visual inspection of the device

The potential problem is placing the device in the opposite direction. The main cause of problem was that the operators replaced the problem tray with new tray but did not check the direction of the new tray causing wrong orientation in the tray.

#### 7) Strapping tray

The potential problem is that the number of tray is incorrect. The main cause of problem was that the operator miscounted the while strapping tray.

#### 8) Counting the device

The potential problem is unmatched quantity of tube. The main cause of problem the operators wrongly count the tube.

After understanding the process flow and potential cause of defects, effect analysis was performed team member brainstorming. First, severity of potential defect score was rated by comparing with table of impact severity (Severity: S). Second, occurrence of potential defect score was given by comparing with table of occurrence (Occurrence: O). Third, detection of potential defect score was evaluated by comparing with table of detection (Detection: D). Finally, Risk Priority Number (RPN) was calculated by

$$RPN = S \times O \times D$$

#### E. Design of Problem Solving Framework

Designated by team member brainstorming, the following processes with RPN value over 125 are considered to have corrective actions.

##### 1) Lead leg damage

The damage caused by operators wrongly loaded wrong inspection program into the machine. Team members suggested to automatically loading inspection program by using bar code scanning on the job order to ensure no human error (see Figure 2).

##### 2) Device with wrong orientation

The wrong orientation devices caused by operators neglected to check tray chamfer is in the correct direction before inputting device tray into the machine. Team member suggested installing tray chamfer checking tool to prevent human errors (see Figure 3).

##### 3) Putting devices in the tray in the wrong orientation

Putting devices in the tray in the wrong orientation caused when operators found tray with damaged devices and need tray replacement. Then operators replaced the tray but they may be negligent to check tray chamfer causing devices were put in the tray with the wrong orientation. Team member suggested installing tool to help replacing tray with less human error.

##### 4) Incorrect number of tube

Incorrect number of tube caused by operators required counting 100 tubes/package. Consequently, human error in counting occurred. Team members suggested creating a slot that can hold 10 tubes for easy counting.

##### 5) Mixed device

Mixed device caused by operator wrongly check the mark on the device. Team members suggested second operator to double check the mark on the device to ensure

the correction. Then both operators must sign a release form to certify their checking.

#### 6) Lead damage from moving

Lead damage caused by operator carelessly handle device during movement. Team members suggested 100% gross visual checking on device lead before moving to the next step.

#### IV. RESEARCH RESULTS

After the implementation of FMEA technique, potential causes of defects were reduced by considering level of severity of defect, effect of the defects, opportunity of occurrence, and ability of defect detection. Two highest RPN value processes of the final inspection process were machine process setup with RPN = 192 and loading device into the machine with RPN = 168. Soon after the FMEA implementation, RPN of the two processes were dramatically decreased to 8 and 7, respectively. Other causes of defects that have been remedied are shown in Table II.

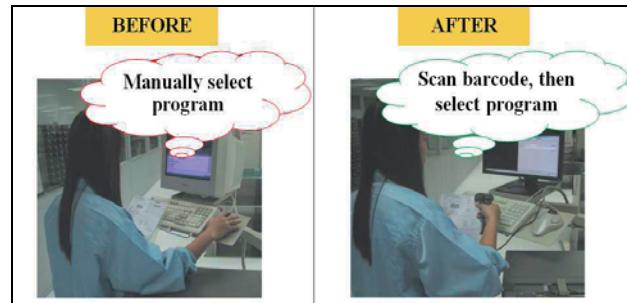
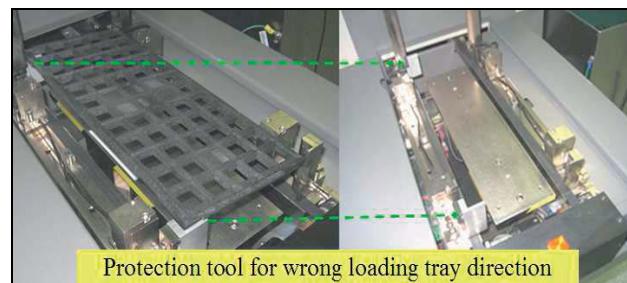


Figure 2 Loading Program Automatically by Bar Code Scanning



Protection tool for wrong loading tray direction

Figure 3 Installing Tray Chamfer Checking Tool to Prevent Human Errors

TABLE II : FMEA for Final inspection process of Integrated Circuit product

| Process Product Core Team | Final inspection process<br>Integrated Circuit<br>Jiam, Rujirek, Phasan, Prasitchai, Laddarwan | Process Responsible<br>FMEA Original date<br>Engr./Prod./QA.<br>20 Nov,2009 | FMEA Number<br>999-056<br>Page<br>1<br>Prepare by<br>Jiam Jun-a-nun<br>Start date<br>1 Sep,2009 | Page Total<br>2<br>Review Date<br>20 Nov,2009 | pages |
|---------------------------|--|---|---|---|-------|
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| Process Function                         | Potential Failure Mode              | Potential Effect(s) of Failure                             | SEV | Class | Potential cause(s) of Failure                                      | OCC | Current Process                                     |                       | DET | RPN | Recommended Actions   | When             | ผลการแก้ไข   |     |     |     |    |
|--|-------------------------------------|--|-----|-------|--|-----|---|-----------------------|-----|-----|---|------------------|--|-----|-----|-----|----|
|  |                                     |  |     |       |  |     | Controls Prevention                                 | Controls Detection    |     |     |   |                  | SEV  | OCC | DET | RPN |    |
| 1) Check information in the job order    | devices do not dry removes moisture | Product 100% may do rework process                         | 6   |       | Over look to check before process information                      | 2   | Check before process information completely         | Sampling check by QA. | 7   | 84  | Next review date  | Next review date | Next review date   | -   | -   | -   | -  |
| 2) Setup and installing the machines     | Damaged lead                        | Customer unsatisfy, Function of device can not use         | 8   |       | Select wrong inspecting program from the machine                   | 3   | Check program correct with device before loading    | Sampling check by QA. | 8   | 192 | installed the system for loading program automatically by bar code scanning | 30 Oct,2009      | Testing and buff system before release to production.          | 8   | 1   | 1   | 8  |
| 3) Input the device into the machines    | Unit wrong orientation in tray      | Customer unsatisfy, Unit out of spec and efficiency reduce | 7   |       | Over look to check chamfer of tray before Load device into machine | 4   | Check chamfer of tray before load into machine      | Sampling check by QA. | 6   | 168 | redesign and use tool to protect edge of tray                               | 22 Oct,2009      | Install and testing tool can detect wrong orientation          | 7   | 1   | 1   | 7  |
| 4) Inspecting lead and marking of device | Mixed device                        | Customer unsatisfy, Function of device can not use         | 8   |       | Error to check the code marking                                    | 2   | When teach mark need to refre job order information | Sampling check by QA. | 8   | 128 | 2nd operator recerity marking format and information is correctly           | 7 Oct,2009       | Revise instruction for 2nd operator recerity marking and audit | 8   | 1   | 7   | 56 |

FMEA for Final inspection process of Integrated Circuit product

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| Process Function                     | Potential Failure Mode    | Potential Effect(s) of Failure                             | SEV | Class | Potential cause(s) of Failure                          | OCC | Current Process   |                       | DET | RPN | Recommended Actions                                 | When             | ผลการแก้ไข   |     |     |     |    |
|--------------------------------------|---------------------------|--|-----|-------|--|-----|---|-----------------------|-----|-----|---|------------------|--|-----|-----|-----|----|
|                                      |                           |  |     |       |  |     | Controls Prevention   | Controls Detection    |     |     |   |                  | SEV  | OCC | DET | RPN |    |
| 5) Take device out of machine        | Damaged lead              | Customer unsatisfy, Function of device can not use         | 8   |       | Not beware handling and movement device                | 2   | When handling or movement unit use top cover to protect unit bounce | Sampling check by QA. | 8   | 128 | Visual inspection lead 100% by nake confirmed again | 7 Oct,2009       | Revise instruction for Visual inspection lead 100% by nake confirmed again | 8   | 1   | 7   | 56 |
| 6) Gross visual inspection of device | Wrong orientation in tray | Customer unsatisfy, Unit out of spec and efficiency reduce | 7   |       | There are change new tray that came from tray problem. | 3   | If there are change new tray need to checking orientation also      | Sampling check by QA. | 7   | 147 | Design new tool for tranfer device to new tray      | 20 Oct,2009      | Revise instruction for use tool to change new tray                         | 7   | 1   | 1   | 7  |
| 7) Strapping tray                    | Wrong quantity of tray    | Device can use but uncomfortable                           | 6   |       | Error quantity when bundle tray                        | 2   | Use full4 tray and one tray top cover before bundle                 | Sampling check by QA. | 6   | 72  | Next review date                                    | Next review date | Next review date   | -   | -   | -   | -  |
| 8) Counting quantity of the device   | Wrong quantity of tube    | Device can use but uncomfortable                           | 6   |       | Counting tube error                                    | 3   | Count100 tube for full packing standard                             | Sampling check by QA. | 8   | 144 | Use slot help to counting tube                      | 15 Oct,2009      | Revise instruction for use slot to counting tube                           | 8   | 1   | 1   | 8  |

The benefits of implementing FMEA are tremendous. Some distinct benefits are the following.

1) Rework processes were reduced from 20 cases/month to 10 cases/month (50% rework reduction)

2) Working time is reduced from 2 hour/lot to 1.5 hour/lot (25% working time saving) resulting in productivity improvement.

3) Wastes were reduced from 2,600 ppm to 1,300 ppm (50% waste reduction).

4) Productivity increased from 1,500 pieces/hour to 1,875 pieces/hour (25% productivity improvement). Number of workers was reduced from 58 persons to

5) 46 persons. The 12 reduced workers can be assigned to work on other jobs saving the cost of hiring 12 new workers in the amount of 933,120 Baht/year. The number of wastes was decreased to 1,300 ppm saving the cost in the amount 374,400 Baht/year. In total, the company can save up to 1,307,520 Baht/year.

6) Other electronics companies with similar processes can adopt this study as a guideline for FMEA implementation.

#### V. SUMMARY AND SUGGESTION

In the past studies, FMEA implementations were mainly in automotive industry. The advantages of implementation are waste reduction, cost reduction, productivity improvement, and customer satisfaction improvement. In this study, FMEA was applied to integrated circuit industry, which is different from the automotive industry in term of the technology, and small size of electronics parts. Thus, level of severity, opportunity of occurrence, and opportunity of defect detection must be adapted in concordance with integrated circuit processes.

## VI. ACKNOWLEDGEMENT

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