Application of Structured Characterization and Control Methodology to Improve Quality and Productivity in Burnin Operation.

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Abstract

Burnin of semiconductor devices weeds out infant mortality failures and monitors reliability of manufacturing processes. Correct burnin operation increases confidence and quality of delivered products to the Customers. Motorola's training of its sub contract burnin houses in Statistical Tools and Methodology is showing them the way to 6 Sigma processes. This paper discusses actual application of a Machine/Process Capability Study on burnin process and the subsequent controls that ensures excellent biasing capability. Additional benefits of better biasing capability reduced oven downtime and increased productivity.

Introduction

Motorola's commitment in producing 6 Sigma Quality products to meet Total Customer Satisfaction drives its initiative to implement statistical methods in all fields of operation. In the field of manufacturing, the use of statistical methods was spread to front line personnel through training and problem solving team formation. Statistical methods employed are Statistical Quality Control (SQC), Design of Experiment (DOE/DOX), and Machine/Process Capability Study . Motorola's positive experience with use of the Machine/Process Capability Study (M/PCpS)[1] methodology has lead to the initiative to train and support its suppliers/subcontractors in this methodology.

Motorola's suppliers' role to help Motorola deliver 6 Sigma Quality products and services. In order that its suppliers can deliver 6 Sigma Quality, Motorola is helping them to acquire and apply statistical methods in manufacturing.

Format of Implementation

Two suppliers of services, to Motorola Malaysia Sdn Bhd, who participated in this pioneering endeavor were sub-contract burnin houses. After initial presentation of Motorola's expectation, the suppliers' management each formulated a policy on support for continuous improvement. These policies would underline their (the suppliers') commitment in establishing statistical control / characterization for their critical processes.

Once management commitment were established, selected suppliers' engineering (QA / Process) personnel were trained on the M/PCpS methodology in Motorola's facilities at Motorola's costs. These engineers would then become the core team leaders in their facilities. During class room sessions, the suppliers' candidates were exposed to actual production data as managed by Motorola's own M/PCpS teams. The classroom activities also duplicate those that cross-functional M/PCpS teams would encounter. Once the M/PCpS training was completed, the core team champions would start off a team each in their respective facility. A Motorola statistical methods engineer would attend team meetings to help the team champion to guide the team and continue training in statistical tools and concepts.

The M/PCPS Methodology

Prestudy - Opportunity Assessment

There are five distinct stages in the M/PCpS methodology. Each stage has a structured approach which is the logical progression of the previous stage. In the course of applying the methodology, we found that the initial part of opportunity assessment to be very important for the continued support for team involvement. Process owner/manger has the responsibility of defining what and where a capability study might give the best return based on the resources invested to study it. A clear statement of objective as spelled out in the methodology cover sheet often resolved questions on the reasons that the study initiated.

Post-Study - Fanout

The successful completion of the 5 stages lead to the dissemination (fanout) of the acquired improvements/knowledge to multiply return of investment. Aggressive pursuit of these fanout opportunities lead to realization of returns which in turn fuels further investment into improvement studies. This positive feedback would change the way the line personnel look at problems (problems became opportunities for improvement).

Process Delineation - Stage 1

In process delineation, the team defines the functional characteristics of the process in study. Various components and theories of operations are examined and process knowledge reviewed to document extent of prevailing understanding of the process. Brainstorming sessions with cross-functional teams generates cause-effect diagrams (also called Ishikawa or fish bone) on various causes of the problem. These cause-effect diagrams are tabulated and then ranked and ordered in a cause and effect cross reference table. The vital few dependent responses and independent input variables are identified to be studied.

Metrology Characterization - Stage 2

Measurement capability for the responses and input variables are examined and quantified. Where no measurement device exist, one is source. If the parameter to be measured is critical and the measurement capability is inadequate, the study will not continue until a capable gage is found.

Capability Determination - Stage 3

In this stage, all known best setting for the process are used to run the process. The various responses are measured and recorded. Team members are on hand to note down any variation from the expected norm. Responses are later analyzed for stability and normality then for process capability. Capability index (Cpk) is calculated and then a decision is made if optimization is required. Cpk value of 2 or greater is required to demonstrate sufficient process capability.

Optimization - Stage 4

Optimization of process is accomplished when most significant factors contributing to the process variation are identified and controlled. Design of experiments and Multi-vari studies are tools used to identify significant factors that causes process variation. Where capability has been obtained and improvement costs are economically unviable, controls are applied to maintain achieved capability level.

Control - Stage 5

Where acceptable new level of capability has been achieved, a PosiTrol (positive control) plan is used. PosiTrol plan (a checklist of controls implemented) is verified to be operational by line personnel for continued capability. This plan may include control charts.

Application of M/PCPS in Burnin Operation

Burnin Operation

Burnin or accelerated conditioning of semiconductor devices has the function of weeding out infant mortality failures and monitoring manufacturing processes. When the failure rate of test after burnin exceeds predetermined levels, the causes are investigate to check for shifts in manufacturing processes exist or if there is a reliability issue. In burnin process, the semiconductor devices are subjected to elevated temperature and voltage stress conditions. These conditions have the effect of accelerating [6] the semiconductor devices into the beginning of its useful life Cycle. Any inherent weakness that might be a device reliability issue, will surface on test after burnin #post test). Incorrect stress conditions may over stress or under stress the devices and therefore confound post test results.

Opportunity Assessment

The response chosen by the team formed was burnin oven bias (stress) voltage. This response was chosen based on opportunity and familiarity of the response by the engineering personnel. Cross functional team members were from engineering, quality assurance (QA), production and equipment groups as well as Motorola's QA and engineering personnel. To assure correct burnin, the bias voltage was adjusted and verified at the beginning of the burnin cycle and monitored manually at regular intervals throughout the cycle. Where incorrect bias voltages were detected (usually too low) during monitoring, time extension to the burnin cycle was required by specification. This is called burnin time compensation.

After agreeing on the specific response and opportunity to work on, a very clear and concise objective was documented on the study cover sheet . (Appendix A)

Functional Characteristics

The functional characteristics were documented in prose form and in graphics. Graphical forms were encouraged to show the linkage of various functional parts providing correct bias voltage. This is shown in figure 1. Cause-effect diagrams were generated from brainstorming and the vital few input parameters selected for study. Ranking and ordering on the cause-effect cross reference table identified the following variables of interest (in descending order of importance): potential meter, wiring, back plane, feedthru card contact, cable drop, power sequencer, and sequencer contact

Metrology Characterization

Two measurable parameters were deemed important by the team after reviewing list of vital few. Bias voltage had a nominal target between upper and lower specification (tolerance of 0.6V). Gage capability study with a hand held digital volt meter (DVM) easily return a capable gage of 0.9% repeatability and reproducibility [4]. The study was performed using the standard worksheet provided by the M/PCpS manual. The other was the voltage drop across voltage transmission path. A separate type of DVM had to be used to quantify the voltage drop as the value is much too low for the resolution of the initial DVM.

Process Capability Determination

The basic guideline of obtaining a reading for process capability is to run the process and measure its output enough times to account for, at least, 80% of all expected variations. As the burnin cycle was long (66 hours), time required to run a long term [7] study was estimated to be weeks. A short term study was started to get some idea what types variations would be expected. Practical issues of scheduling and burnin oven availability also complicate necessary data collection.

When initial data collection was planned, the team had to come up with the best possible conditions to set up the oven for process capability determination. 'Best possible' conditions meant that the oven was verified to be in the desired condition. This entailed some tear down and preventive maintenance work even though preventive maintenance schedule was not due.

Data collection from process monitor showed a tendency of the mean to be higher than the target. There was a spread of readings to the lower specification. Statistically, the process was not capable although in practice manual intervention of burnin time compensation and manual monitoring was used to prevent non conformance of processing.

Optimization

Cumulative data collected from multiple short term capability runs was used to identify if trends existed in the data set. Analysis by segmentation of the data was done to check for topological dependencies particular to the burnin oven. Computer software was used to manage the mass of data collected after some time. Key to bias voltage capability improvement was the training on the use of software for data analysis to pinpoint where variation occurred. As there were many common conduction paths as well as individual conduction paths from the power supply to the point of bias monitor, the segregation of common path problems and individual path problems enabled the equipment team members to work on the correct direction.

Common conduction path problems were traced to common path wiring resistance being too high. Steps were taken to resolve these. Individual path problems were traced to interconnect resistance type problems such as dry solder joint, worn connectors, frayed wires, etc. With the three dimensional plots, it was very easy to visualize the problem areas for tracing/debugging each individual point that is an outlier from the normal distribution. Time to time variation due to procedural problems were also solved by identifying when it happened and follow up with the identified operators .

After a number of iterations, it was found that the distribution tended to be normal about the target and became tighter on each iteration. The process became capable with a Cpk of close to 5.0.

Control

Review of all solutions to the biasing problem was done to extract the critical controls to be put in place. It was found that most of these critical items were accounted for in normal process tracking. It was decided not to impose redundant paperwork, but it was documented how and where traceability of control could be found. Items not controlled in normal processing were collected into a PosiTrol checklist. The most important of which was the setting of control limits of monitored bias voltage which were about half allowable specification width.

Fanout and Validation

With the completion of stage 5 where controls were put into place, a fanout plan was made to implement the same improvements and control on the rest of the ovens of the same make/model. Validation that the correct critical factors had been captured came from the ability to make the next few ovens to be capable by performing the same improvement actions. Further validation came from the monitoring. When three (3) bias points that fell out of the control limits (still within specification limits), those three points were traced to have dry solder and bad connector problems. The harshest test for determining correct control was the change of specification target of bias voltage and specification limits. The first run on capability with the new specification returned the same capability as just before change of specification.

Payback

There were a number of benefits that Motorola derived from training its supplier on statistical methodology.

Better quality - since the bias voltage applied to the products are well within the specification in the improved ovens, there is higher confidence that the product are correctly biased.

Better cycle time - total compensation time (all ovens) reported by supplier was down by 80%. Cycle time through the burnin process become more predictable and shorter.

Expectation - greater use of statistical methods to quantify and improve suppliers' processes by experiencing and realizing a successful team effort. Supplier can deliver 6 Sigma quality.

Similarly, the suppliers derived a number of benefits.

Lower costs - less downtime means higher productivity. Supplier reported initial oven used in the study failed only 3 times in 6 months and each failure traceable and corrected.

More competitive - ability to derive technical advantage through use of statistical tool for problem solving and control to protect advances made from studies.

More improvements - leverage all expertise gain apply on all other areas. Supplier reported that preventive maintenance (PM) became quantifiable based on capability index measured after the PM. More predictable PM by using capability index of bias voltage
to determine propensity to be out of conformance.

Conclusion

It is good business for Motorola to encourage its suppliers in the use of statistical methods. M/PCpS is a good tool to quantify and improve process capability and has been proven to be able to help produce 6 Sigma capability.

Acknowledgements

The author will like to acknowledge the successful work done by the M/PCpS Teams in Statsym Sdn Bhd (Jamie Voo, Team Champion) and in KESM Sdn Bhd (Gloria Aw / Rohayiah, Team Champions).

References

[1] Machine/Process Capability Study - methodology authored by Mario Perez-Wilson
[2] M/PCpS Methodology - copyrighted by Advanced Systems Consultants
[3] “Vital few” as defined by Pareto principle or Pareto analysis
[4[Precision/tolerance ratio of 10% is judged acceptable equivalent to %R&R.
[5] See Keki Bhote's “World Class Quality"
[6] Acceleration model is usually of chemical in nature and closely follows Arhenius [3] model for semiconductor devices.
[7] Long term is a relative expression. In some process, all variation may be experienced within a 24 hour time frame.

Kuala Lumpur, Malaysia, 1988