Tester Efficiency Improvement Through Real Time In-House Statistical Process Control for RF Final Test

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ABSTRACT

RF Final test (RFT) is the stage to ensure product is conforming with the RF Test specification in the Data Sheet. Current control is the use of Reference Sample as part of setup requirement during change of device type.

It was observed that the reference sample conforms on the tolerance condition thereby ensuring the tester is complying with the agreed tolerances prior production. However, the drift in performance cannot be seen by mere comparison to tolerance. This resulted in invalid fails and shift lot performance. To address this, applying Statistical Process Control (SPC) in RF Final Test was conceptualized.

By integrating an Xbar-R control chart at machine correlation process in final test, tester-to-tester measurement variation was maintained at a minimum level. This safeguards the abnormal shift in the equipment performance during machine optimization and proactively prevents test verifications from failure analysis team, thus increasing the overall test efficiency of the process.

1. 0 INTRODUCTION

In support to AMP delivery commitment towards quality and tester efficiency improvement, the team focuses to improve tester process control for RF Test in Final Test in terms of proactively preventing invalid hold lots, yield loss and its probable causes.

Recent incidents of hold lots and low yield issues on ACP3 and GAN devices were caused by shift in the tester performance of the affected parameter. Comparing that shift from the previous machine performance, it was significant that it affects the overall Cpk of the lots being tested on the machine and often caused invalid hold.

RF Testers are released for production, only if the measurement correlation response of the machine is within the tolerance value from its reference reading. The problem arises when the machine originally has a marginally relaxed correlation, then suddenly it becomes a marginally tight correlation.

Figure 1 shows the measurement trend of efficiency from GaN device with a scope of one month. The machine was always released in production with a marginally relaxed correlation. However, there was a point that the machine was released with marginally tight measurement correlation. This resulted in a significant shift in the measurement of the product and the shift is setup induced at this point. Though it did not result in a gross rejection, the process capability (Cpk) was greatly affected, and it resulted to a potential risk of having invalid rejects and hold lots.

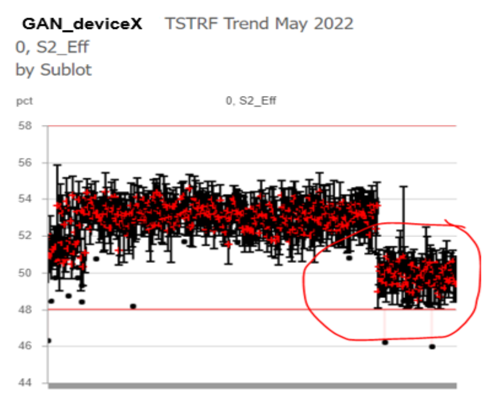


Fig. 1. Measured efficiency from GaN device shifted due to tighter machine correlation compared from previous setup.

There are also what we call a circuit-to-circuit variation where test circuits have different measurement response compared to one another. Machine correlation is done in test circuit level. Though measurement is well within its tolerance range, because of that significant difference, double distribution is observed – where the Cpk of a test circuit is much better than the other. This is well shown in figure 2 where test circuit 1 and 2 have different responses.

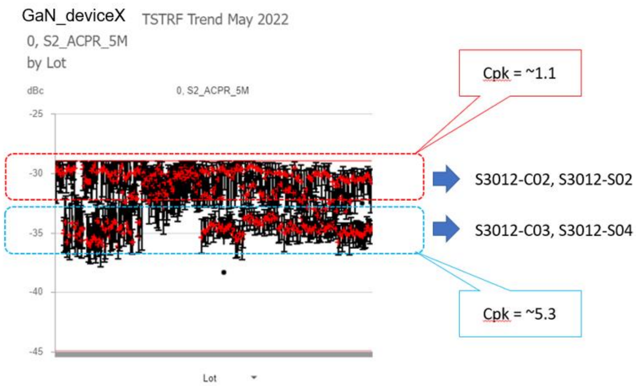


Fig. 2. Double distribution induced by difference in test circuit response.

Statistical Yield Limit (SYL) and Standard Bin Limit (SBL) are the trigger points to hold lots and line up for verification tests. This is also the point when the test process team detects that there was a shift in the measurement performance of the machine. Aside from this process is at post detection, the re-test or verification test affects the overall efficiency of the tester.

The project aims to proactively prevent such losses. Using an SPC system, designed for final test, using in-house tools and software available, the team was able to safeguard the tester measurement variations at minimum level and at the same time increase the overall tester efficiency for rack and stack RF testers.

2. 0 REVIEW OF RELATED WORK

Statistical Process Control (SPC) is already defined in the Assembly Process Control. It could be implemented statistically or dynamically depending on the statistical tool capabilities. This paper discusses calculation methods and studies which method is the most applicable to use.

2.1 Test Program

The programming language Keysight Vee was used to create the present measuring application. This language was used to design all the measurement procedures, equipment drivers, and data loggings.

Updates on the current software are made locally by a group with expertise and experience in relation to development and routine adjustments for concepts that were originally developed locally. Additionally, ongoing conversations and consultations are being had with the Nijmegen-based program developer to keep them updated on the project's development.

2.2 Database

A relational database management system (RDBMS) called Microsoft SQL Server serves a wide range of business intelligence, analytics, and transaction processing applications in corporate IT settings. Using its capability to easily store and retrieve data makes it a suitable platform to use as repository for reference measurements. Furthermore, SQL is the most widely used database language and virtually any business that wants to store relational data may use it.

2.3 Minitab and SPC

Minitab provides solutions for statistical process control. It provides sophisticated dashboard and SPC charts, including the Xbar-R and Xbar-S, which employ statistical techniques to monitor processes. It is known for its classic SPC. Minitab solutions are used by manufacturers because they can spot quality problems before they become big ones, ensuring that procedures run smoothly and that products are produced with little to no waste. Businesses can immediately address and resolve any issues by using Minitab's visual process monitoring, fast alerts, and improvement analytics to identify which portions of their process are failing. With the information provided by these technologies, operators, engineers, and management can continue moving the project ahead.

3.0 METHODOLOGY

Statistical Process Control (SPC) is essential in the Assembly Process to ensure critical process input parameters are within control before full assembly. In RF Final Test, where the product cannot be altered, controlling measurement variation is crucial to avoid invalid fails or measurement drift.

Figure 3 shows an overview of the current process flow in releasing test equipment for production. To enhance control, the RF Final test reference sample is integrated with an SPC system that triggers alerts for violations.

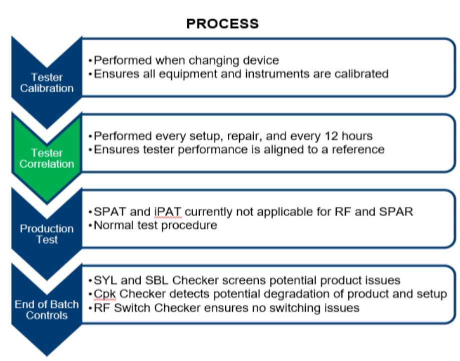


Figure 3. Equipment process control production released overview

3.1 Control Chart Selection

Figure 4 shows how the controls chart was defined. Individual and moving range (I-MR) chart was also considered in monitoring the measurement performance of the machine. However, SPC using I-MR chart provides the same function as the autocorrelation. No out-of-control points are expected if autocorrelation is passed. I-MR chart alone, with no subgroups, could not capture degradations and variations in the process. The current autocorrelation process uses 2 samples for measurement. Xbar-S is applicable for sample size greater than 10. Therefore, Xbar-R was used as control chart in detecting significant variation in the process.

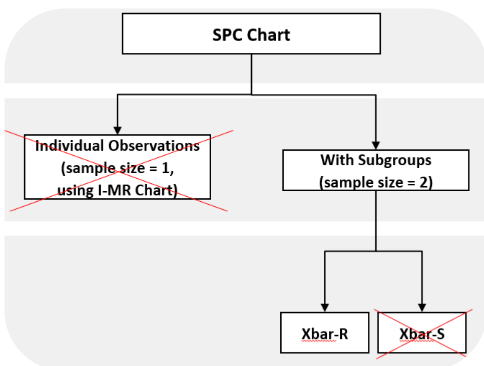


Fig. 4. SPC Chart Selection

3.2 Tester Level SPC

SPC monitoring on tester level means observations come from different test circuits used in that tester. Control limits will ensure defined circuit-to-circuit differences are maintained and controlled. Points outside the control limits could be product related. Improvement may then be related to reference sample creation.

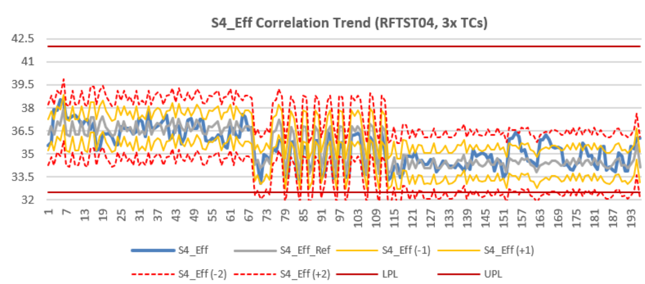


Fig. 5. Measurement response of three (3) circuits in comparison to production limit compiled in an I-MR chart.

As shown in figure 5, three test circuits have significant differences in their measured value derived from the correlation measurement. These differences between test circuits will make control limits over rejecting as shown in figure 6. If circuit-to-circuit difference are significantly large, there might be a need to review test circuit release.

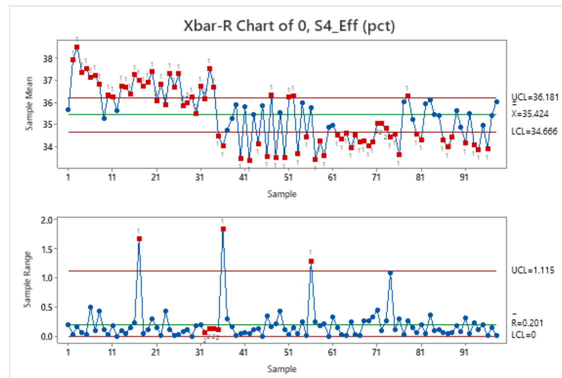


Fig. 6. XBar-R of correlation results from three (3) test circuits of same device and package.

3.3. Management and Procedure

Applying SPC in Final Test involves specific procedures to effectively manage and maintain quality control during this stage. Below are the key requirements in SPC for final test.

- Inhouse Application to create an Automated Data collection system for SPC use.
- An SQL Database that will hold all the reference reading as historical data for XBar-R calculations.
- Notification and Result Dashboard: Integrating an SPC with the production software allows an automated statistical analysis and real-time notification for end user.
- Root cause analysis: If any out-of-control conditions or variations are detected, use the SPC tools to investigate the root causes. This can involve analyzing data patterns, performing hypothesis testing to identify the sources of variation and take appropriate corrective actions.
- Process Improvement: Based on the insights gained from SPC analysis, implement process improvements to enhance the Final Test stage.

4.0 RESULTS AND DISCUSSION

Pre-requisites for final test SPC system are the database creation and population, test program update and integration, deployment and user acceptance dry run.

The SPC formula for Xbar-R was encrypted in the test program routine. The test program uploads the measurement result from the machine correlation to SQL database. After uploading, the test program, again, does a query to retrieve the last two-hundred (200) machine correlation measurement available – that is equivalent to approximately 2 months of data. Then the formula will be applied on the retrieved data to compute for the control limits. The control limit will be dependent on the overall population response. To validate the results, the control chart created using the test program was compared to the control chart using minitab. Figure 7 shows a comparable result between the two charts.

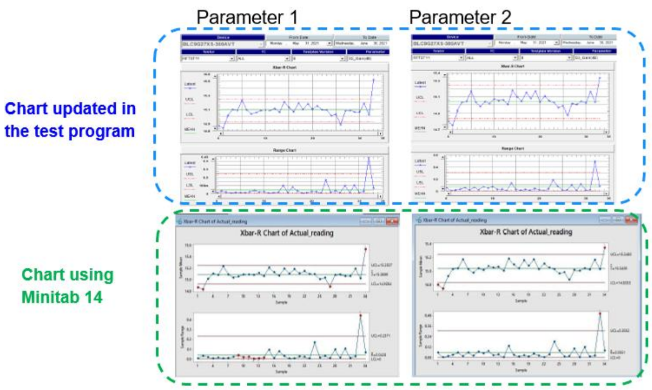


Fig. 7 . Control chart comparison between the modified test program and Minitab.

Figure 8 shows the eight (8) rules available for Xbar-R control chart. K-values are user defined. Initially, 5 out of 8 rules can already be implemented for Final Test SPC. These rules were used in releasing the machine for production test.

Test No.	Control Chart Rule	K – Value	Purpose of Test	Applicable?
1	1 point > K standard deviations from center line	6	Identifies subgroups that are unusual compared to other subgroups.	✔
2	K points in a row on same side of center line	9	Identifies shifts in process centering or variation. Provides greater sensitivity when combined with Test 1.	✔
3	K points in a row, all increasing or all decreasing	6	Detects trends.	✔
4	K points in a row, alternating up and down	14	Detects systemic variation. Ideally, pattern of variation in a process is random.	✔
5	K out of K+1 points > 2 standard deviations from center line (same side)	2	Detects small shifts in the process.	✘
6	K out of K+1 points > 1 standard deviation from center line (same side)	4	Detects small shifts in the process.	✘
7	K points in a row within 1 standard deviation of center line (either side)	15	Detects a pattern of variation that is too good to be true. Detects too wide control limits.	✔
8	K points in a row > 1 standard deviation from center line (either side)	8	Detects a mixture pattern where points tend to fall away from the center line and instead fall near the control limits.	✘

Fig. 8 . Control Chart Rules.

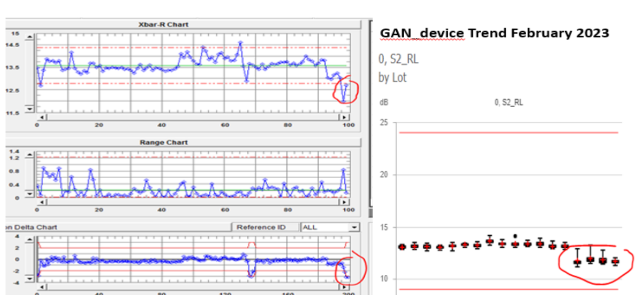
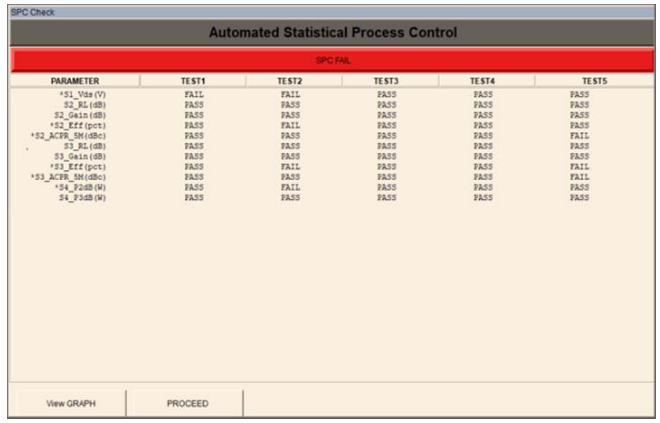


Fig. 9. Detailed SPC result from test program SPC result was compared with the succeeding lots and variations outside the control limit aligns with the production response.

The program tests the machine correlation based on the define Xbar-R control chart rule. If the machine correlation passed, then the user can proceed to production. Otherwise, the tester needs to be reoptimized.


SPC Check

Automated Statistical Process Control

SPC FAIL

PARAMETER	TEST1	TEST2	TEST3	TEST4	TEST5
*S1_Vds(V)	FAIL	FAIL	PASS	PASS	PASS
S2_RL(dB)	PASS	PASS	PASS	PASS	PASS
S2_Gain(dB)	PASS	PASS	PASS	PASS	PASS
*S2_Eff(pct)	PASS	FAIL	PASS	PASS	PASS
*S2_ACPR_5M(dBc)	PASS	PASS	PASS	PASS	FAIL
S3_RL(dB)	PASS	PASS	PASS	PASS	PASS
S3_Gain(dB)	PASS	PASS	PASS	PASS	PASS
*S3_Eff(pct)	PASS	FAIL	PASS	PASS	FAIL
*S3_ACPR_5M(dBc)	PASS	PASS	PASS	PASS	FAIL
*S4_P2dB(W)	PASS	FAIL	PASS	PASS	PASS
S4_P3dB(W)	PASS	PASS	PASS	PASS	PASS

View GRAPH   PROCEED

Fig. 10. Test program pop-up panel after machine correlation was done. SPC result is checked using the recent machine correlation and will include in the population the last 200 machine correlation measurement done at tester level.

From Figure 11, the retest count before SPC was implemented was 426 out of 5200, or 8.19% re-test verification versus the first test. After SPC implementation, this number of retest count was reduced to 50 out of 3100 or 1.61% re-test verification. Tester efficiency was improved by 6.58%.

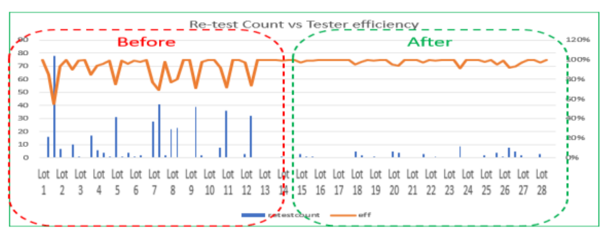


Fig. 11. Machine Re-test count vs Tester Efficiency before and after SPC was implemented.

In addition, the SPC tool and system used for the project was built in-house using local resources which resulted in a cost-avoidance of 20K USD compared to market price.

5.0 CONCLUSION

SPC using the measured data from machine correlation measurement helps to easily identify setup induced variation and degradation. The integration of SPC in the test program immediately detects significant measurement variation prior to equipment released for production run. Since the process is automated, machine buyoff is easily managed. It proactively minimizes scrap due to invalid rejection and improves tester efficiency by minimizing test verifications from failure analysis team.

6.0 RECOMMENDATIONS

The evaluations done in this paper are related to the actual performance of all correlating RF parameters. The tool can effectively detect any variation in the tester, circuit or even if the sample unit itself is deviating. Thus, efficiently helps to monitor process behavior, discover issues in internal systems and find solutions for production issues.

7.0 ACKNOWLEDGMENT

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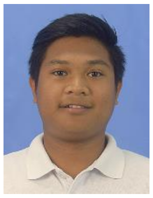

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