Quality Testing of Raw Electronic Materials on the Regulated Industry

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Abstract — *A manufacturing facility is taking back control of their circuit assembly line by studying the behavior of their raw components. For this study the production line was carefully studied and some problems in the circuit assembly area were detected. Then a Fishbone analysis was carried to find the root cause of this problems. The inspection of incoming raw material didn't test the critical parameters, the sampling size was not representative of the received lots and there were no records found of any measurements. After identifying the problem, a pilot study was made on six usual components. A sample of 30 of each component was studied and tested on their critical parameters: resistance on the resistors, capacitance on the capacitors, voltage on the batteries and contamination on printed circuit boards (PCB). The resistors, capacitors and batteries do not demonstrate an adverse trend based on the Individual Variable Control Charts. However, the Ionic contamination test results suggested the process is not in control, this process was measured using the Zero Ion Test Machine (ZITM). Some recommendations were made on the steps to take before starting to gather data and get the process in control: Reconsider critical measurements, change sample size, retrain and review processes.*

Key Terms *— Control Charts, Electronics, Measurements, Production Line, Sampling Size.*

INTRODUCTION

Sometimes as times passes, the vision or purpose is lost, the importance of what is done, the why and the how is forgotten. These phenomena also happen to organizations, governments, institutions, companies and even civilizations. As time passes this organizations start experiencing this "Big problem" and results in loss of control. In regulated industries loss of control could result in monetary losses and could even cause a crippling situation. For example, what happens if a pharmaceutical company releases a defective batch of a certain product.

What is the cost of giving the customer a defective product?

- Open investigations
- Recalls
- Lawsuits
- FDA interventions
- Loss of reputation

The goal of this project is to improve the quality of products, specifically of the electronic raw material on the circuit assembly line. To do this, first there was a process familiarization with the different production lines. Many defective units of different products were found at the end of circuit assembly area, many resulting in scrapping and others in rework. In addition, reworking a unit does not warranty it will work per intended use. To have an idea of the size of the components studied make reference to Figure 1.

Figure 1
Surface Mount Capacitors vs. a US Dime

In the Technical Services department many units are returned every month for many reasons, this results in open investigations. During the research of possible causes, it was discovered that the inspection of the received raw materials was not as thoughtful as it should. For example, a lot of resistances arrived, and the inspector would inspect a non-representative sample with respect to the lot size according to the ANSI/ASQC Z1.4 standard. The measurement taken during the process are not critical, meaning the most important characteristic is not being monitored. No historic data of the measurements taken was found.

Based on the observations made on the circuits line an investigation was made on the possible causes of these defective circuits. During this process 4 employees were interviewed, employee 1 the technician in charge of the PCB soldering line and circuit inspector, employee 2 the technician in charge of debugging the circuits that don't pass inspections, employee 3 the technician in charge of running the investigations of the returned units and employee 4 the quality inspector in charge of the receiving area and parts documentation archive.

Below is a small summary of what they informed:

- Employee 1: Informed that in certain circuit board, from time to time for unknown reasons the parts don't solder correctly or don't solder at all in random locations of the circuit. He suspects its ionic contamination on the boards.
- Employee 2: In the same certain circuit. Two or three times a week the production line passes its circuits not passing the inspection. It suspects is certain component on the circuit.
- Employee 3: Certain unit composed of the circuit board mentioned above would arrive as defective. Upon inspection the same odd behavior as the one observed by employee 2 on his circuits was seen on these ones too. However, they were certain that before leaving the circuits passed all the inspection points.
- Employee 4: Takes samples of each lot that arrives according to his work instructions. Depending on the component, he measures its dimensions and other critical parameters. On PCB he takes a sample and runs a test to detect ionic contamination however the employee indicated that he has never seen the machine fail a test.

Through this first assessment several opportunities for improvement were identified. From these it was decided to study the current method used in the receiving area and propose a new method to start getting the process back in control.

For this task, six components were chosen:

- Two Surface Mount Resistors
- Two Surface Mount Capacitors
- 3 Volts battery
- PCB Board

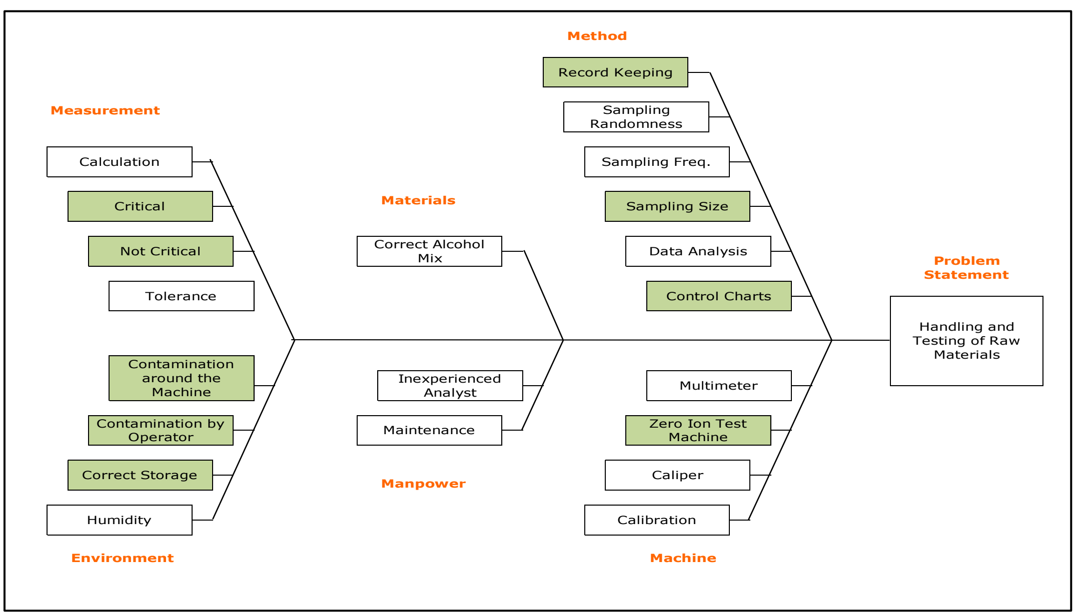

Figure 2
Fishbone Diagram

To further understand more the problem and attempt to cover all the possible causes for the process to be out of control, a Fishbone Diagram was made, seen on Figure 2.

Under Measurement is the Calculation and Tolerance, in reference to the ZITM, as it has never failed, there is uncertainty whether or not the correct calculation is being done or if the tolerance gap value is set too high. Critical and not critical in the Fishbone are in reference to the measurements taken by the Quality inspector at the receiving area.

For the Materials section of the Fishbone Diagram only the ones that required constant replacing were considered. The ZITM needs a constant alcohol mix replacement as the one used is evaporated or lost during the testing.

The Methods are the main area of interest because the sampling size and the sampling frequency must be reviewed. The sampling size should be representative in comparison to the lot size. The records of the measurements need to be kept to generate data and analyze it periodically.

There are some concerns caused by the boards problems and the ZITM that could have possible cause on the environment. For example some of this concerns are: Is the machine placed in the correct place, or should it be in a clean area? Is the operator taking the correct actions not to contaminate the boards while running the testing? Are the boards being correctly stored. Does the humidity have some effect on these boards?

The manpower does not represent a problem, there is a team in charge of maintenance and calibration and the person running the inspections has the required knowledge on the electronics area.

The operator has the correct machinery required for his inspections. These are multimeters, calipers, micrometers, a comparator and the ZIM. All calibrations are up to date.

METHODS

To start gathering data six different components were selected on frequency of use. A sample of 30 for each of these components was evaluated to generate data. [1] The samples were taken from the production line and were still sealed by the manufacturer, stored at room temperature in a not humidity-controlled area. According to the manufacturers none of the components to be tested are temperature or humidity sensitive at room temperature.

Table 1
Components List

Component	Type	Value
1	Surface Mount Resistor	10k ohms, 1/10W, 1%
2	Surface Mount Resistor	1M ohms, 1/8W, 0.5%
3	Surface Mount Ceramic Capacitor	0.22 µ Farads, 10V
4	Surface Mount Capacitor	1000 p Farads, 50V, 10%
5	Lithium Battery	3 Volts
6	Printed Circuit Board (PCB)	N/A

All the equipment had their calibrations up to date, the expiration dates and the equipment list are in Table 2. For the testing, various multimeters were used per different component, depending on the measuring capacity and precision required. For all dimensional measurements a Mitutoyo caliper was used. The ZITM facilities were also borrowed. A grounded working station was borrowed to make sure the components were safe during the testing.

Table 2
Equipment List and Calibrations

Equipment	Calibration Exp.	Components measured
Caliper	Oct-31-2018	1,2,3,4
Fluke 287	Oct-5-2018	1, 2
Fluke 177	Feb-16-2019	3,5
RCL METER	Mar-23-2018	4
ZITM	Jan-28-2019	6

To test the resistors a grounded work station, a multimeter and a caliper were used. The work station was cleared of any other components to avoid any confusion. One by one resistance and dimensional measurements were taken and collected on a table for all 30 samples of each kind of resistance.

Procedure:

1. Set up the work station and make sure the operator is grounded. Clear any unwanted components from the table, turn on the multimeter and set it up to measure ohms. Move the caliper make sure that when it is closed the reading says is located in the 0.00 inches position.
2. Carefully release a resistor from the packing and place it on the grounded mat.
3. Measure the resistance and dimensions.
4. Write down the measurement.

The Capacitors were treated mostly the same as the resistors but instead of measuring resistance, capacitance was measured for all samples of each component.

Procedure:

1. Set up the work station and make sure the operator is grounded. Clear any unwanted components from the table, turn on the multimeter and set it up to measure Farads.
2. Carefully release a capacitor from the packing and place it on the grounded mat.
3. Measure the capacitance.
4. Write down the measurement.

Batteries were also tested in the grounded work station, to ensure no measurements were affected. The amount of voltage of each cell was measured and recorded on a table for each of the 30 samples.

Procedure:

1. Set up the work station and make sure the operator is grounded. Clear any unwanted components from the table, turn on the multimeter and set it up to measure voltage.
2. Carefully release the battery from the packing and place it on the grounded mat.
3. Measure the voltage.
4. Write down the measurement.

The PCB samples were measured for contamination using the ZITM, but before starting running test the correct levels of alcohol were present. The mix was composed of 72% isopropyl, 28% water and the tank were filled all the way to the specified line. [2] Also, hygienic actions were taken, the samples were only handled using clean room gloves and touched the least amount possible of time because the machine is very sensitive and can detect any minor cross contamination. [3] One by one the test was run for each sample; each test takes about 4 minutes per sample and every 10 samples a 1 hour pause had to be made while the tray of tested boards dried off.

Procedure:

1. Set up you ZITM make sure the tank is filled to the line. Measure the percent of alcohol on the mix, make sure is between 70% and 75%. Input the alcohol percent to the machine.
2. Do a run with no sample to clean the tank.
3. Verify the result in the lecture is 0 μ grams of contamination.
4. Make sure the machine is the right option of board.
5. Start the procces, don’t change the amount of alcohol when asked. Wait for the machine to do a fast clean check.
6. Place the sample on the machine when requested and press start.
7. Wait 3 minutes while the proccess runs.
8. Collect the result from the printer.

RESULTS

The results obtained for the 10k ohms resistors are presented in the Tables 3 and 4 and Figures 3, 4, 5 and 6. Table 3 shows the measurements taken from the samples, the data demonstrated variability. From those values the descriptive statistics for these measurements were calculated. The mean of the samples is 9.9916 k ohms, this mean is very close to the expected value, the data shows a very low standard deviation and a very low variance. In Figure 3 on the control chart shows that there is one outlier value however all other values are within the limits and observations seem to be in control. The manufacturer has specified a tolerance of 1%, the expected range is between 9,900 and 10,100 Ohms. The outlier value is within the tolerance specified by the manufacturer.

Table 3

Resistor Measurements for the 10k ohm Resistors

Sample Number	k Ohms	Sample Number	k Ohms	Sample Number	k Ohms
1	10.009	11	9.991	21	9.989
2	9.990	12	10.000	22	9.994
3	9.988	13	9.987	23	9.988
4	9.989	14	9.988	24	9.991
5	9.990	15	9.990	25	9.987
6	9.990	16	9.991	26	9.994
7	9.990	17	9.985	27	9.993
8	9.990	18	9.990	28	9.995
9	9.989	19	9.990	29	9.991
10	9.990	20	9.996	30	9.992

Descriptive Statistics: 10k ohm Resistor

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
10k ohm Resistor	30	9.9916	0.000841	0.00461	0.000021	9.9900

Figure 3

Descriptive Statistics for the 10k ohm Resistors

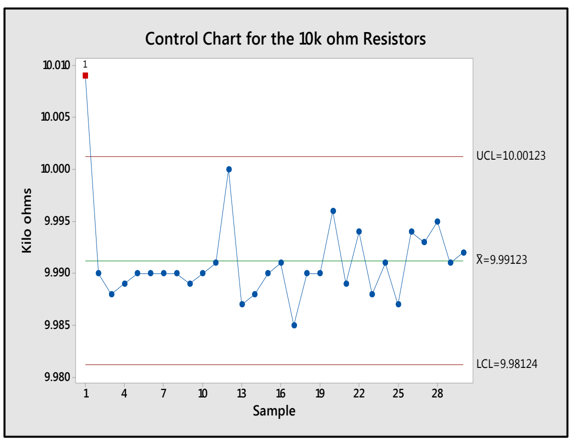

Figure 4

Control Chart for the 10k ohm Resistors

Table 4 shows the measured values of the length of the 10k ohm resistor. Visually it can easily be appreciated that these values are in control; these results can also be validated with the statistics shown in figure 5. The mean is close to the expected value, a very low standard deviation and 0 variance. These measurements are in control as expected in samples with very little variation. Small variations on these dimensions are unlikely to cause problems.

Table 4

Length Measurements for the 10k ohm Resistors

Sample Number	in	Sample Number	in	Sample Number	in
1	0.0770	11	0.0770	21	0.0775
2	0.0770	12	0.0770	22	0.0770
3	0.0770	13	0.0775	23	0.0770
4	0.0770	14	0.0770	24	0.0775
5	0.0770	15	0.0775	25	0.0770
6	0.0770	16	0.0775	26	0.0775
7	0.0770	17	0.0775	27	0.0775
8	0.0770	18	0.0770	28	0.0775
9	0.0770	19	0.0770	29	0.0775
10	0.0770	20	0.0770	30	0.0775

Descriptive Statistics: Lenght 10k ohm Resistor

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
Lenght 10k ohm Resistor	30	0.077183	0.000045	0.000245	0.000000	0.077000

Figure 5

Descriptive Statistics for the Length of the 10k ohm Resistors

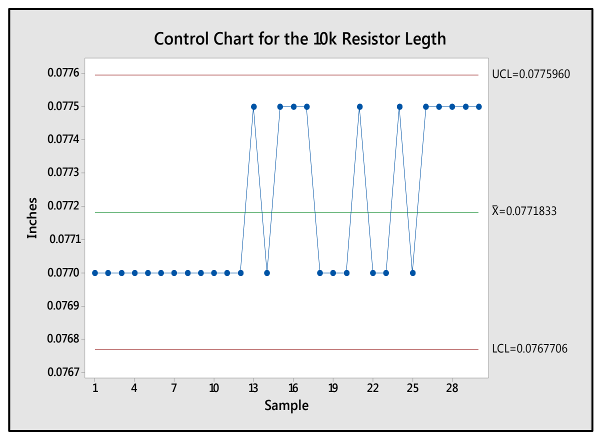

Figure 6

Control Chart for the Length of the 10k ohm Resistors

The results obtained for the 1M ohm resistors are presented in the Table 5 and Figures 7 and 8. Visually some variation can be observed on the samples measured on Table 5. On Figure 7 the mean was calculated, is very close to the expected value, the standard deviation is very low and the variance between values is almost 0. In the Control chart there is a big outlier on the beginning however all other values have a good behavior. No particular reason for out of control behavior was found for this value.

However, the outlier is out of the tolerance certified by the manufacturer.

Table 5

Resistor Measurements for the 1M ohm Resistors

Sample Number	M Ohm	Sample Number	M Ohm	Sample Number	M Ohm
1	0.9840	11	1.0001	21	1.0000
2	1.0003	12	0.9998	22	1.0000
3	1.0011	13	0.9995	23	1.0003
4	1.0000	14	1.0003	24	1.0003
5	1.0003	15	0.9996	25	0.9998
6	0.9999	16	1.0001	26	1.0002
7	0.9999	17	1.0000	27	1.0000
8	1.0001	18	1.0000	28	1.0000
9	0.9998	19	0.9999	29	0.9999
10	0.9999	20	0.9999	30	1.0000

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
1 M ohm	30	0.99950	0.000537	0.00294	0.000009	1.00000

Figure 7

Descriptive Statistics 1M ohm Resistors

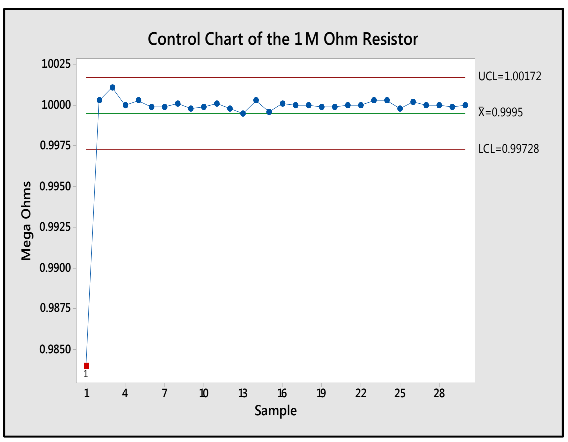

Figure 8

Control Chart for the 1M ohm Resistors

The results obtained for the 0.22 µ farads capacitors are presented in Table 6 and Figures 9 and 10. Visually inspecting the data obtained in Table 6, a tendency to be below the nominal value of 220 n farads can be appreciated. Inspecting Figure 9, the mean is close to the nominal value, a significant high standard deviation and variance were noted. This behavior is expected in capacitors with a 10% tolerance. The Control Chart in Figure 10 shows substantial variation however all the measurements are inside the limits.

Table 6

Capacitor Measurements for the 0.22 µ Farads Capacitors

Sample Number	n Farads	Sample Number	n Farads	Sample Number	n Farads
1	216	11	218	21	219
2	216	12	218	22	215
3	217	13	216	23	216
4	219	14	217	24	218
5	221	15	216	25	223
6	221	16	217	26	222
7	214	17	215	27	215
8	216	18	218	28	218
9	217	19	218	29	219
10	219	20	220	30	215

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
0.22 µ Farads (measured in nF)	30	217.63	0.405	2.22	4.93	217.50

Figure 9

Descriptive statistics 0.22 µ Farads Capacitors

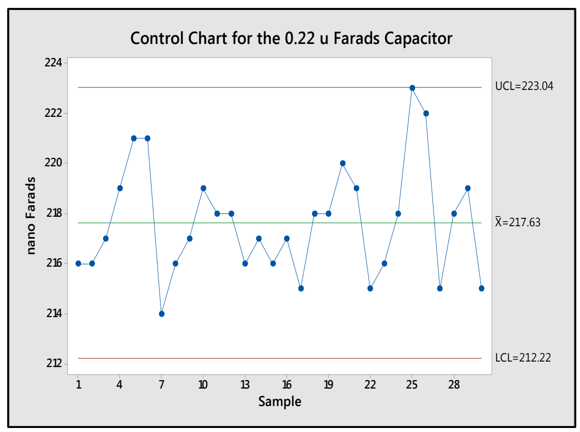

Figure 10

Descriptive statistics 0.22 µ Farads Capacitors

The results obtained for the 1000p farads capacitors are presented in Table 7 and Figures 11 and 12. Examining Table 7 a tendency to be below the nominal value and some variation can be noted. However according to Figure 11 a very low variance and a low standard deviation can be appreciated. The mean is a little off the nominal value, but the tolerance of 10% on this capacitor must be taken into consideration. Figure 12 shows the values are in control.

Table 7

Capacitor Measurements for the 1000 p Farads Capacitors

Sample Number	n Farads	Sample Number	n Farads	Sample Number	n Farads
1	0.957	11	0.960	21	0.963
2	0.941	12	0.950	22	0.964
3	0.958	13	0.967	23	0.943
4	0.957	14	0.962	24	0.960
5	0.964	15	0.964	25	0.952
6	0.980	16	0.946	26	0.975
7	0.944	17	0.966	27	0.947
8	0.955	18	0.948	28	0.988
9	0.964	19	0.963	29	0.972
10	0.966	20	0.960	30	0.966

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
1000 p Farads	30	0.96090	0.00215	0.01178	0.00014	0.96250

Figure 11

Descriptive Statistics 1000 p Farads Capacitors

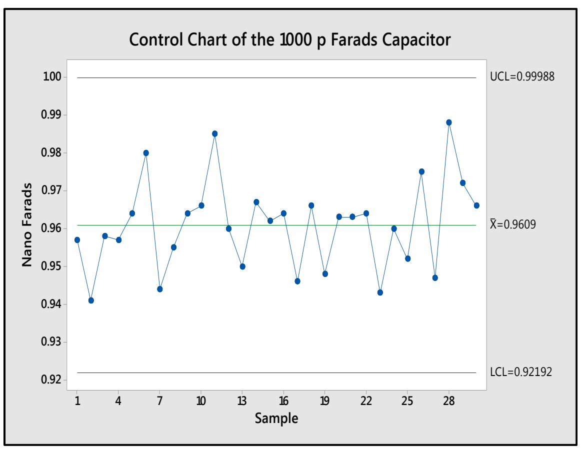

Figure 12

Descriptive Statistics 1000 p Farads Capacitors

The results obtained for the 3 volts lithium battery are presented in Table 8 and Figures 13 and 14. Batteries are an interesting component. To consider a 3 volt new lithium battery in good state, the measured value should be between 3.0v and 3.4v. On Table 8 shows all values are over 3.0 volts. The mean looks within range in respect to the range mentioned, very low standard deviation and an almost 0 variance. The Control Chart shows variations and no outliers. However, the values are in control.

Table 8

Voltage Measurements for the 3 Volts Lithium Batteries

Sample Number	Volts	Sample Number	Volts	Sample Number	Volts
1	3.285	11	3.314	21	3.322
2	3.318	12	3.302	22	3.309
3	3.323	13	3.314	23	3.316
4	3.315	14	3.314	24	3.322
5	3.301	15	3.314	25	3.290
6	3.311	16	3.308	26	3.309
7	3.304	17	3.295	27	3.320
8	3.307	18	3.308	28	3.304
9	3.316	19	3.313	29	3.296
10	3.320	20	3.325	30	3.304

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
3 Volts Lithium Battery	30	3.3100	0.00181	0.00989	0.00010	3.3120

Figure 13

Descriptive Statistics for the 3 Volts Lithium Batteries

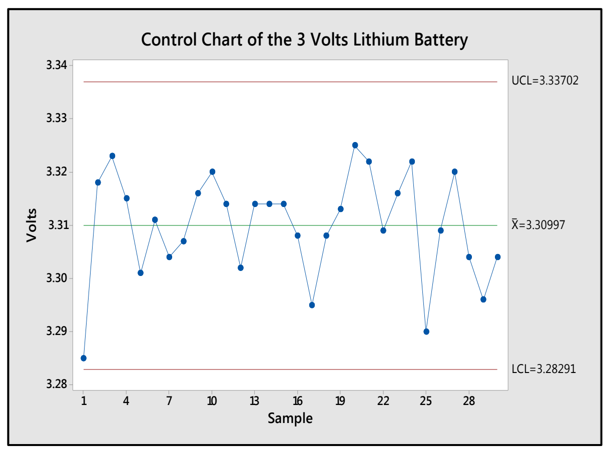

Figure 14

Control Chart for the 3 Volts Lithium Batteries

The results obtained for the PCBs ionic contamination are presented in the Table 9 and Figures 15 and 16. Most of the values are 0 except for observations 1, 2, 9 and 18. The mean is affected by the value of those observations, Standard deviation and variance are relatively low. In the Control Chart diagram, shows 4 values out of the upper limit. This process is not in control.

Table 9
Contamination Measurements for the PCBs

Sample Number	$\mu g/in^2$	Sample Number	$\mu g/in^2$	Sample Number	$\mu g/in^2$
1	1.0	11	0	21	0
2	0.5	12	0	22	0
3	0.1	13	0	23	0
4	0	14	0	24	0
5	0.1	15	0	25	0
6	0	16	0	26	0
7	0	17	0	27	0
8	0	18	0.4	28	0
9	0.5	19	0	29	0
10	0	20	0	30	0

Statistics

Variable	Total Count	Mean	SE Mean	StDev	Variance	Median
Ion Contamination	30	0.0867	0.0409	0.2240	0.0502	0.0000

Figure 15
Descriptive Statistics for the Ion Contamination Test

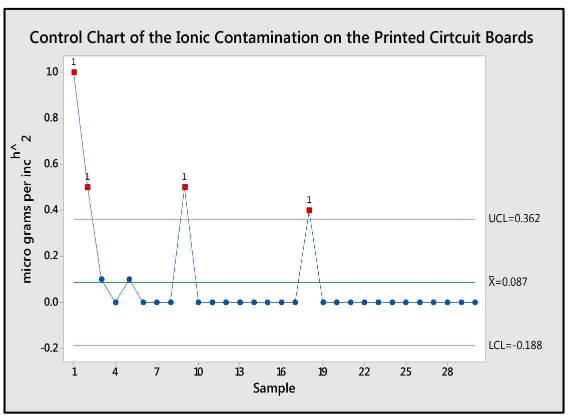

Figure 16
Control Chart for the 3 Ion Contamination Test

Discussion

The results show that the 10k ohm resistor, the 1M ohm resistor, the 0.22 μ farad capacitors and the 1000p farads capacitors tested were in control. However, the ionic contamination on PCB seems to be out of control. It is crucial for any manufacturing facility to be in control of their processes. To take control, first is required to familiarize with the process and for this is necessary to gather data on every aspect of the operations. Recommendations and steps necessary to start taking control:

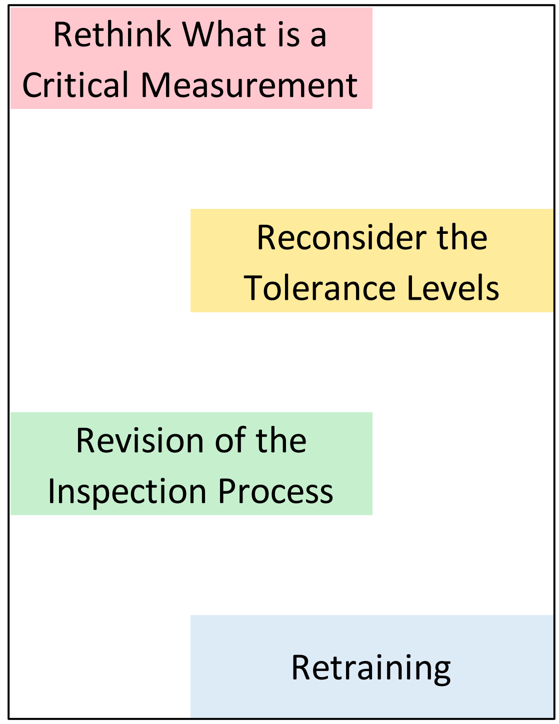

Figure 15
Summary of Recommendations

Rethink what is a critical measurement and what is not based on the component functionality. Remove measurements that don't really affect the functionality of your product. Example: measuring the dimensions of a surface mount resistance does not tell much about its functionality, it's difficult, takes time, and it's expensive. Over all, it adds cost to the process and does not add value to it. A failure in measurements can easily be caught during any of the inspections on the circuit assembly line. Based on the analysis performed, a recommendation of the parameters that must be measured in the process was made and is presented in Table 10.

Table 10
Actual Parameters vs Recommended Parameters

Component	Actual parameters tested	Recommended parameters to test
Resistor	Dimensions	Resistance
Capacitor	Dimensions	Capacitance
Battery	Dimensions and Voltage	Voltage
PCB	Ionic Contamination	Ionic Contamination

Reconsider the tolerance levels of the ZITM. The reports found from the machine show it has never failed. However, the machine reports do show some high readings from time to time. However, not enough to fail the test.

Revision of the inspection process with special focus on the sampling size. The inspection needs a representative sample size, otherwise the inspection cannot detect defective components before getting to the production line. A good sampling size to start gathering data on the different components should be dictated by the ANSI/ASQC Z1.4 standard.

Study if the inspectors require retraining on any of the procedures. For example, the IPC-TF-650 specifies the procedure for doing the Ion contamination test. It tells us the machine should be placed in an area with little or no transit, preferably on a clean area. Also, it mentions the operator should use clean room gloves and forceps at all times.

Once all adjustments have been made, start generating trustworthy and relevant data that can be used to generate control charts and any other statistical evaluation. This is the way to understand the process and keep it in control, lowering the possible future problems in the production line.

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