Detection of counterfeit electrolytic capacitors in power electrical systems

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Abstract: - In this paper, the necessity and key questions for detection of counterfeit components is being described. Main goal is to inform professionals from academic as well as from industry sector how to detect counterfeit parts and be confident with evaluation. For these purposes some standard and some more specific methods are described more in detail. Electrolytic capacitors are very often used in the electronic equipment's in wide range of products including computers, medical equipment, automobiles, avionics and military systems due to their high capacitance to volume ratio. This study examines suspicious samples of aluminum electrolytic capacitor purchased on open market that were unknowingly assembled in power supplies. Based on the systematic detection methodology, the counterfeit components were identified, and their reliability relative to genuine parts was assessed.

Key-Words: - **suspicious sample, electrolytic capacitor, detection, reliability**

1 Introduction

It has become necessary for all distributors of electronic components and manufacturers of electronic equipment to inspect all incoming electronic components for authenticity. Counterfeits decrease customer satisfaction and increase costs for legitimate manufacturers. They reduce yields, cause field failures, necessitate product inspection, and prompt litigation if/when they cause injury or take down high-value systems.

Concern about counterfeiting has generally focused on high-cost components, such as integrated circuits. However, less expensive passive components, such as capacitors and resistors, can also cause serious system reliability problems. In the past, counterfeit electrolytic capacitors have resulted in failures of electronic equipment even made by big world-class companies like Dell, IBM, HP, and Intel [1].

Main reasons, why counterfeit shall be identified are continuous tightening of international standards and normative for qualitative indexes of electronic systems, and also fact that system fails due to counterfeit failure can additionally be life-threatening. Therefore detection of fake components is nowadays necessity.

2 Problem Formulation

Electrolytic capacitors are known for their reliability problems, and are often the weakest link in the reliability of power electronics systems [2]–[4]. The most common failure mode for liquid aluminum electrolytic capacitors is the gradual degradation of electrical parameters, including a decrease in capacitance, or an increase in equivalent series resistance (ESR). Electrolytic capacitors can also experience catastrophic failures where there is complete loss of functionality due to a short or open circuit [5] - [7].

In this study, we evaluate suspicious samples of Aluminum Electrolytic capacitor purchased on open market. Whole received batch of 1000 suspicious capacitors were marked as Nippon Chemi-Con EKMM451VSN471MA45S. This suspected batch was used in switched mode power supplies intended for medical segment. Even each power supply was stressfully tested no deviation was observed during standard production tests.

3 Systematic detection methodology - proposal

In order to prevent counterfeit electronic parts to be implemented into manufacturer´s systems, each company should put focus on detection and avoidance system. Instead of focusing on prevention, the companies within the electronics industry currently, individually, focus on finding and eliminating counterfeits on a case-by-case basis. This is costly and inefficient. Thus, the need for screening techniques have been developed.

The DELTA Electronics (Slovakia) prepared general procedure for the counterfeit components detection (fig. 1).

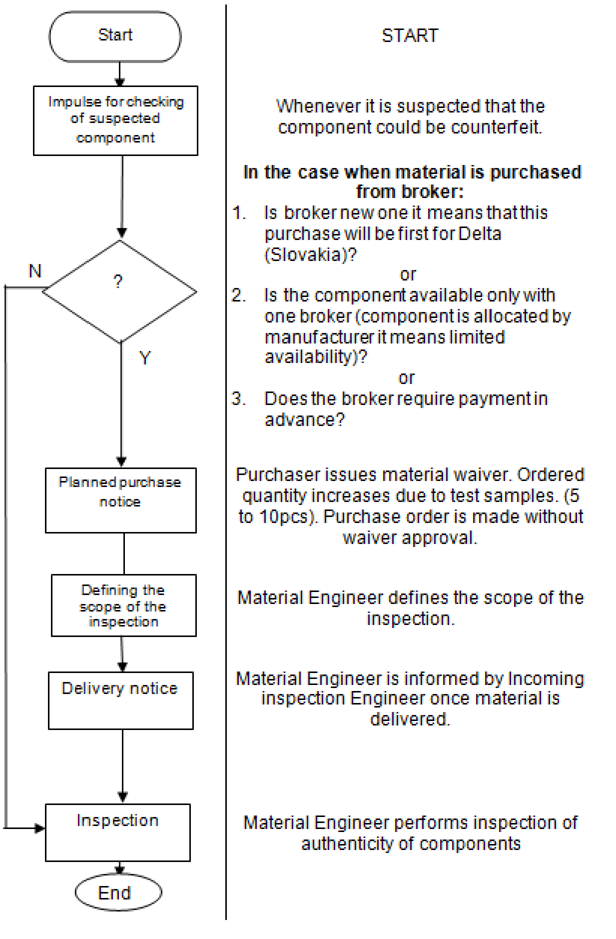

Fig. 1 Flow chart for counterfeit component detection

It must be said, that each method is not suitable for each device, and some empirical knowledge was established.

4 Counterfeit electrolytic capacitor - identification

The most common failure mode for liquid aluminum electrolytic capacitors is the gradual degradation of electrical parameters, including a decrease in capacitance, or an increase in equivalent series resistance (ESR). Electrolytic capacitors can also experience catastrophic failures where there is complete loss of functionality due to a short or open circuit. In this case study, we evaluate suspicious samples of Aluminum Electroytic capacitor purchased on open market. Whole recieved batch of suspicious capacitors were marked as Nippon-Chemicon EKMM451VSN471MA45S.

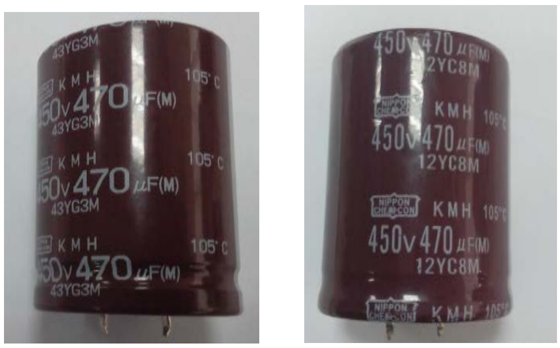

Fig. 2 Genuine sample Nippon Chemicon (left) and suspicious sample (right)

The investigation of counterfeit detection of the mentioned aluminum capacitor was based on the increased number of failed electronic systems – power supply. We have performed initial inspection on 14 samples of suspicious sample and on 2 golden samples (genuine NIPPON). The X-ray investigation of suspicious and genuine samples was performed. Fig. 3 clearly shows that the body of the capacitor for the case of suspicious sample is not placed uniformly against the sides of the aluminium can.

Both at the top and bottom part, the foil reel are shifted. Instead of that, after encapsulation of capacitors, different heights of foil reels were observed (fig.4) and also presence of wax inside the suspicious capacitor was discovered (fig.5). Our opinion for the wax presence inside of counterfeit components is that it is utilized as a spacer padding for capacitor´s contacts. Initial considerations and simple identification procedure cannot uncover the undesirable influence on the capacitor performance. For these purpose, more complex analysis will be necessary.

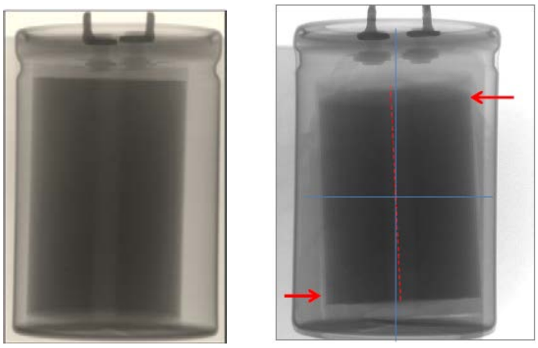

Fig. 3 X-RAY – of investigated electrolytic capacitors (left – original part, right – suspicious sample

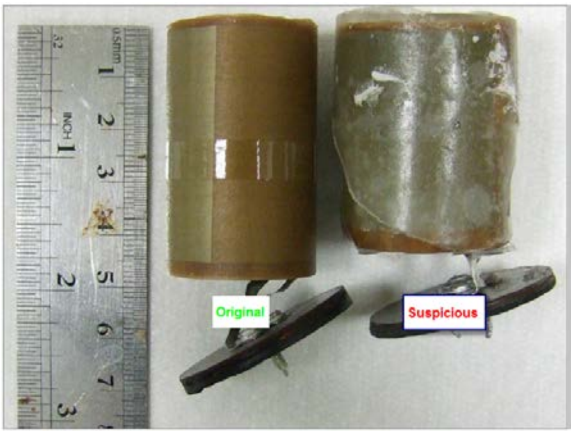

Fig. 6 Encapsulated capacitors for foil reel measurement

Fig. 7 Encapsulated capacitor with visible presence of the wax in the case of suspicious sample (right)

Based on the previous results, it may be concluded that with the use of simple actions (visual inspection, mechanical dimensions measurement, X-ray check) of the proposed systematic procedure for the identification of counterfeit components, we were able to find principal differences between suspicious and genuine component.

5 Problem Solution – functional test and dynamic behavior measurements

Tests were focused on the measurements of the capacitance and dissipation factor, during the temperature change, whereby tested capacitors were operated in target application, which is switched mode power supply for medical equipment.
The parameters of the test are listed below.

<u>Conditions of the test:</u>

- Test duration: min 3500 hours or first failure.
- Ambient temperature: 40 °C.
- Output load: 90% of nominal load.

<u>Measurements:</u>

- Current of capacitor – measured by oscilloscope for every 24 hrs.
- Voltage of capacitor – measured by oscilloscope for every 24 hrs.
- Temperature of the capacitor case: Recorded by data acquistion unit (sample rate = 1S/min).
- Temperature of the PCB under capacitor.
- Value of capacitance: measured by HP 4284A – precision LCR meter, every 24 hrs.
- Value of dissipation factor: measured by HP 4284A – precision LCR meter, every 24 hrs.

The investigation was performed for 3 power supply units. Thus 3 samples were tested, whereby two of them were of suspicious type, and one of genuine part. Tests were realized simultaneously.

Table 1 and table 2 shown values of the capacitance, dissipation factor and temperatures on the case of investigated samples as well as at the surface of the PCB under capacitor for the start of the experiment and for the end. The start of the test was on the 30th June 2014. It was planned to be running for 3500 hours or until first failure was detected.

From the table 2 it can be seen, that the end of the experiment was on 14th December 2014, when suspicious sample #2 has reached value of its capacitance, which was below acceptable threshold (378 uF for 120 Hz). The other two tested samples have been continuously showing acceptable performance).

Tab. 1 Results from the dynamic behavior measurement – start of the experiment

		Capacitance (HP 4284A Precision LCR meter) Cs-D		Dissipation		Temperature (highest over 24hrs). For all Temperature data see "Acquired Data" sheet.		
Time stamp	Capacitor	120Hz/0.5V pp	1kHz/0.5V pp	120Hz/0.5V pp	1kHz/0.5V pp	On the case of capacitor	On the PCB under capacitor	Ambient temp
Initial state (30-Jun-14)	#1	415,4 uF	422,1 uF	0,05	0,42	NA	NA	21 °C
	#2	423,7 uF	427,0 uF	0,068	0,52	NA	NA	21 °C
	#GS	409,7 uF	415,0 uF	0,058	0,49	NA	NA	21 °C

Tab. 2 Results from the dynamic behavior measurement – end of the experiment

		Capacitance (HP 4284A Precision LCR meter) Cs-D		Dissipation		Temperature (highest over 24hrs). For all Temperature data see "Acquired Data" sheet.		
Time stamp	Capacitor	120Hz/0.5V pp	1kHz/0.5V pp	120Hz/0.5V pp	1kHz/0.5V pp	On the case of capacitor	On the PCB under capacitor	Ambient temp
14-Dec-14	#1	429,4 uF	420,0 uF	0,038	0,2	54,2 °C	49,5 °C	40,5 °C
	#2	374,1 uF	349,5 uF	0,051	0,264	54,6 °C	51,5 °C	38,7 °C
	#GS	420 uF	410,4 uF	0,042	0,24	57,4 °C	51,9 °C	40,7 °C

Nevertheless based on the specifications of the test conditions, the investigation has been stopped, whereby cause of such failure was necessary to be identified.

It can be seen, that in the case of sample # 2, decrease of the value of capacitance started around the beginning of the October, what is approximately after 2230 hours of operation. Threshold limit was achieved after app. 3314 hours of operation. Graphical interpretation of the capacitance is shown on fig. 8.

Reliability tests should demonstrate reliable operation of suspected aluminum capacitor in the target application. Observed capacitor is in this application used as the output capacitor of PFC stage (Bulk capacitor). For the test purposes 2 samples of suspicious capacitors were used and as reference one genuine capacitor NIPPON was.

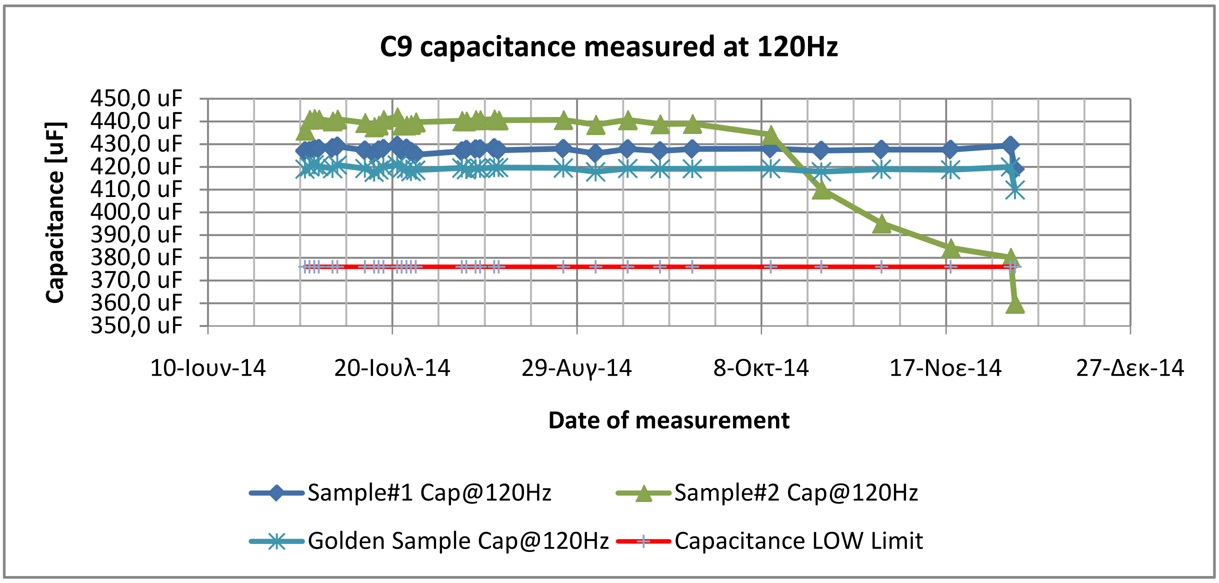

Fig. 11 Dependency of capacitance value on the date of the measurement during dynamic behavior test (120 Hz)

From beginning of reliability test (1-Jul-14) up to the end of the test (1-Dec-14) all 3 units worked over 3500hrs at ambient temperature over 30 degC. All measured values of suspected samples #1 and #2 are within its specified limits even capacitance of the sample #2 continuously decreases as is visible on the previous charts above.

6 Conclusion

Based on performed analysis it was found that suspicious aluminum electrolyte capacitors, which are being purchased on the open market have different mechanical and chemical parameters in comparison with genuine capacitors. Continuous decreasing of capacitance during operation in the target application showed predictable failure mode, which can be adapted for whole batch of affected power supplies. This can help to take on-time corrective action and eliminate failure in the field.

The investigation descrtibed in this paper was peformed due to high risk of reliability impact to the specific life-critical medical system.

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