Necessity for DPA on passive EEE Components

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Abstract

There have been controversial opinions about the necessity for DPA on many passive EEE components and also whether DPA should be performed on qualified EEE components. We have analysed DPA results of more than 2768 lots of passive EEE components analysed from 2009 to 2013. While the average finding quota over this period is 5%, a good number of families have finding quota of more than 15% in some years. Our results indicate that DPA remains a necessary instrument to verify part quality and passive components should be subjected to DPA before approval, independent of whether they are qualified parts. In addition, DPA should be routinely employed to monitor even well established manufacturers of passive EEE components.

Introduction

The reliability of a satellite or any space flight equipment is a sum of the reliabilities of the individual components that make up this equipment. Electrical, electronic and electromechanical (EEE) components are considered as the lowest level of component size. High reliability EEE components are manufactured according to standards that make them suitable for the intended space applications. To verify this, Destructive Physical Analysis (DPA) is usually performed on a limited number of samples to determine or to verify if a given lot of EEE components fulfils the prescribed requirements for DPA. During DPA, the concerned samples of a given part are systematically disassembled (destroyed), tested and inspected to verify the part's design, technology and quality and hence draw conclusion on possible long-term or short-term risks with the concerned lot. Any deviation from the assessment criteria for the prescribed test is considered a DPA finding, which may be accepted if it is minor, or rejected if it is considered as critical. Anomalies that might not have been specified are also highlighted.

In the past years, many users and stakeholders of EEE components have forgone DPA on some parts with the assumption of proven reliability. This may mean long heritage, presence of the part on qualified parts list (QPL) or its manufacturer is on the qualified manufacturers list (QML) or for some other reasons. Yet, devices of proven reliability have sometimes been cause for anomalies at critical project phases. While some part manufacturers and users consider DPA as an important tool to verify the quality of a EEE device lot, others consider DPA as a formality or a mere project requirement that is to be fulfilled in order to satisfy the customer. Passive EEE components constitute a significant proportion of parts for which DPA is not a project requirement. They however, usually constitute a greater portion of EEE parts used to realise circuits in constituent satellite components and payload. It is therefore important for part users and equipment stakeholders to understand the risk they undertake by forgoing DPA for such components.

In this contribution, we employ a statistical approach to evaluate our DPA results from January 2009 to April 2013 and show that it is advisable to verify the quality of EEE lots using DPA, regardless of whether the concerned device is present on the qualified parts list or its manufacturer is on the qualified manufacturers list, keeping a track record of potentially risky manufacturers. Furthermore, we show typical findings in some concerned passive component families.

Evaluation procedure

In the considered period (January 2009 to April 2013) 5700 DPAs were processed by the EEE Laboratory at TESAT-Spacecom GmbH & Co KG. The DPAs were performed according to TESAT's DPA specification RA.0010.900.10, which combines both the DPA requirements of the MIL system (MIL-STD-1580) and of the ESCC system found mostly in the ESCC basic specifications. Other test requirements and assessment criteria derivable from the procurement specifications also apply. The annual finding quota for all DPAs is shown in Table 1. A total of 2768 lots of passive EEE components were deduced from the 5700 lots, implying that 2932 lots of active components were analysed in this period. The 2768 DPA lots were broken down into part families to deduce the annual finding quota for the individual families. The average finding quota for each family was calculated for the entire period. In order to find out what proportion of the findings in each family are on qualified parts, failed lots of passive EEE parts that are listed on either the MIL or ESCC qualified parts list were determined. Since we employ DPA as a means to monitor manufacturers from whom we routinely procure certain EEE components, major part manufacturers were listed and the number of findings on their parts was compared with the number of lots procured from these manufacturers and submitted for DPA in the considered period. The results are then presented and discussed with respect to families of passive EEE components using some common or critical findings as examples.

Results and discussion

Table 1 shows the number of DPA performed per year for the considered period. While the finding quota ranges from 4.91% to 6.22% from 2009 to 2012, a relatively high finding quota (13.06%) is registered for the 247 lots inspected in 2013. TESAT procured a relatively large number of connectors from a particular manufacturer in the first quarter of 2013, most of which had less plating thickness than the prescribed value. This adds to the number of findings on active EEE components to swell the finding quota so far in 2013.

Table 1: General distribution of findings

Year	No. of lots	No. of findings	Finding quote (%)
2009	1181	62	5.25
2010	1425	70	4.91
2011	1625	86	5.29
2012	1222	76	6.22
2013*	247	32	13.06

*Till April 2013

However, the final value for the year 2013 will be determined at the end of the year. With an estimated average finding quota of 5.7%, it can already be seen that about 325 out of 5700 lots needed to be verified critically before use or rejected. The only way to do this is to perform DPA on all lots in order to pick out this 5.7%, which may pose a risk to the project. To our knowledge, there is no specified range for finding quota in DPA but considering that TESAT procures its parts directly from part manufacturers or authorised distributors, 5.7% is significantly high. A finding quota above zero and the level of fluctuation of the finding quota can be regarded as an indication of the quality of the DPA laboratory and the quality of the parts manufacturing and parts procurement processes.

Table 2: Findings distribution for passive components

Year	No. of lots	No. of findings	Finding quota (%)
2009	547	27	4.94
2010	614	18	2.93
2011	818	39	4.77
2012	635	32	5.04
2013*	154	22	14.29

*Till April 2013

The finding quota for the 2768 DPA lots of passive components is presented in Table 2 for the considered period. Again the 14.29% obtained in the first quarter of 2013 is mainly from connectors procured from a particular manufacturer. Only for passive components, an average finding quota of 5.0% is deduced, which is

slightly less than the 5.7% overall finding quota but still constitutes a significantly large portion (138 lots) of all DPAs on passive components. In order to estimate the contribution of each part family to the 5% finding quota with the passive EEE components, the distribution of the findings over the entire considered period is presented in Table 3 for different families of passive EEE components.

Table 3: Findings according to families from January 2009 to April 2013

Family code	Family name	No. of DPAs	No. of findings	Finding quota (%)
01	Capacitors	1903	38	2.00
02	Connectors	125	16	12.80
03	Quartz	12	0	0
05	Filters	23	1	4.35
06	Fuses	69	0	0
07	Inductors	122	15	12.30
09	Relays	34	3	8.82
10	Resistors	192	6	3.12
11	Thermistors	55	4	7.27
13	Cables	3	0	0
14	Transformers	56	2	3.57
16	Switches	4	0	0
20	Thermostat	0	0	0
27	Fibre Optic	0	0	0
89	Miscellaneous	170	53	31.17

While no findings were reported for some families with registered DPA like quartz crystals, fuses, cables and switches, families 89 (Miscellaneous), 02 (connectors), 07 (Inductors) are seen to have significantly large finding quota (above 12%). Miscellaneous constitutes parts that cannot be clearly categorised under any of the other families. In TESAT's parts data base, these are predominantly packages and their lids and since they may not be considered as standard EEE devices, they shall not be analysed further. Looking at specific records (not shown here), we deduced a finding quota of significantly more than 15% for filters in 2009, relays in 2011, thermistors in 2011 and resistors in 2013. It is interesting to note that a finding quota of only 2% is registered for the 1903 DPAs on capacitors, which constitute much more than half of all considered DPAs on passive EEE components. Eight of the part families have finding quota above 0% over the considered period. Are these passive EEE devices qualified or unqualified parts? If they are qualified, what percentage of these findings is on qualified parts? Table 4 lists all families with a finding quota above 0%, showing the respective number of registered findings.

Table 4: Finding quota on qualified parts with respect to total number of findings.

Family code	Family name	No. of findings January 2009 to April 2013	No. of findings on QPL listed parts: (ESCC/MIL)	Finding quota of qualified parts (%)
01	Capacitors	38	14 (11/3)	36.84
02	Connectors	16	9 (5/4)	56.25
05	Filters	1	1 (0/1)	100
07	Inductors	15	15 (14/1)	100
09	Relays	3	3 (3/0)	100
10	Resistors	6	0	0
11	Thermistors	4	1 (0/1)	25
14	Transformers	2	0	0

The number of findings on qualified parts is also indicated. The numbers arranged under (ESCC/MIL) indicates how many of these lots with findings are present in the ESCC QPL or the MIL QPL. While all filters, inductors and relays with findings are qualified parts, 56.25%, 36.84% and 25% of findings on connectors, capacitors and thermistors, respectively, are on qualified parts. Without considering Miscellaneous, unqualified passive parts account for a finding quota of 1.62% while qualified passive parts account for a finding quota of 1.66%. This

implies that findings on qualified part make up 50.6% of the total number of findings on passive components. This strongly indicates that qualified parts should be equally subjected to DPA before approval.

Since DPA is used to monitor manufacturers, it is important to know which manufacturers have which number of registered findings in order to closely monitor the manufacturer and hence determine which manufacturers' parts are more vulnerable to findings and thus know which to prefer as those with higher finding quota could be considered as risky manufacturers. For the families listed in table 4 having failed parts on QPL (besides the 1 filter whose manufacturer is known), the finding quota with respect to manufacturer for each part family has been deduced. It is important to note that the manufacturers' names have been coded. Beginning with the highest supplier for the given part family, the top manufacturers have been listed on the Tables 5.1 to 5.6.

Table 5.1: 01 Capacitors (top 10 manufacturers)

Manufacturer (Coded)	Number of DPA lots	Finding Quota (%)
M011	782	0.77
M012	375	1.33
M013	336	0.30
M014	97	3.09
M015	50	2.00
M016	48	4.17
M017	46	43.48
M018	37	0
M019	35	0
M0110	31	0

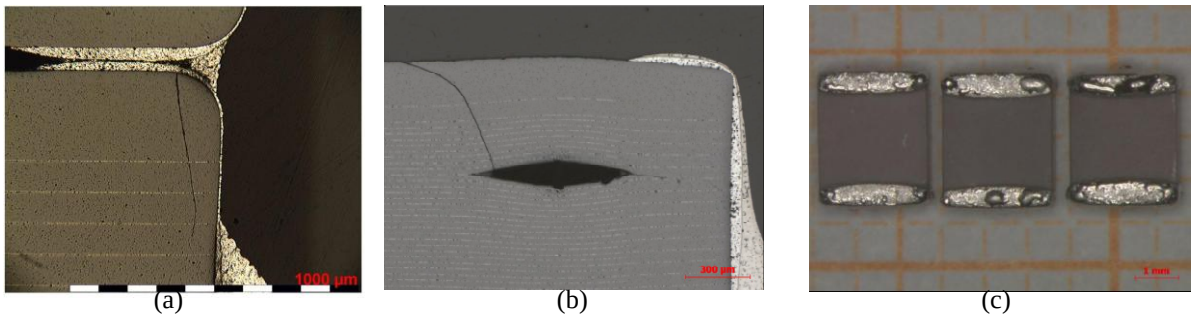
Note: 12 others supplied smaller quantities than 31 on which no findings were reported.

Table 5.2: 02 Connectors (top 10 manufacturers)

Manufacturer (Coded)	Number of DPA lots	Finding Quota (%)
M021	40	10.00
M022	26	15.38
M023	15	0
M024	11	9.09
M025	06	0
M026	05	60.00
M027	04	75.00
M028	04	0
M029	03	0
M0210	02	0

Note: 1 manufacturer has 100% finding quota (1 DPA) but he is not in the list of top 10 suppliers of connectors to TESAT.

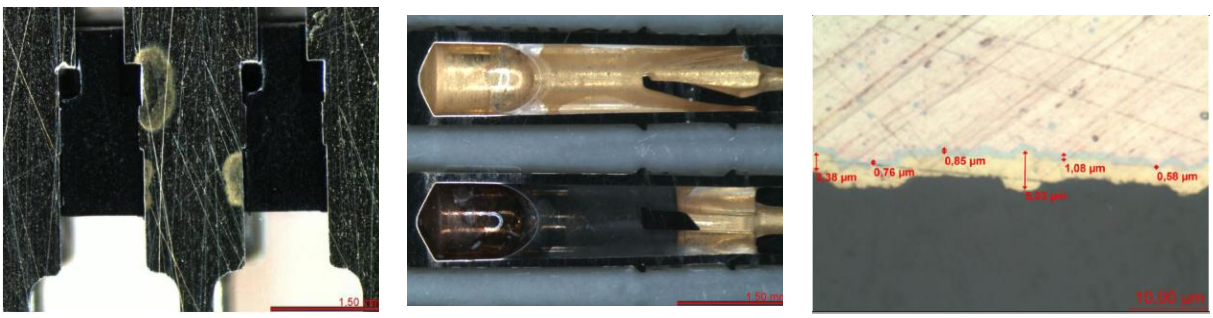
While some manufacturers of capacitors with higher number of DPA lots have less finding quota, a manufacturer with only 46 DPA lots has more than 43% finding quota. These findings have intentionally not been broken down into different capacitor groups to protect the identity of the manufacturer. Similar judgements can be made with the other families analysed here; i.e. connectors, inductors, relays, resistors and thermistors.



(a) (b) (c)

Fig. 1: Some typical DPA findings on capacitors; (a) cracks in ceramic, (b) delamination, (c) poor solder wetting

Some typical findings for capacitors and connectors are shown in Fig. 1 and Fig. 2 respectively. It is obvious that these anomalies have not been found during screening at the manufacturer and may pose reliability problems at an earlier or later stage in the project or in the life of the satellite. Fig. 3 to Fig. 6 show further examples of findings for the corresponding part families shown in the table above.



(a) (b) (c)

Fig. 2: Example of findings on connectors (RF included); (a) single pins with corroded sections, (b) missing gold layer on a socket (female), (c) less plating thickness (usually Ni) than specified.

Table 5.3: 07 Inductors (top 5 manufacturers)

Manufacturer (Coded)	Number of DPA lots	Finding Quota (%)
M071	83	16.86
M072	12	08.33
M073	11	0
M074	06	0
M075	05	0

Fig. 3: Typical for inductors; poor solder wetting at solderability test.

Table 5.4: 09 Relays (top 5 manufacturers)

Manufacturer (Coded)	Number of DPA lots	Finding Quota (%)
M091	11	18.18
M092	10	0
M093	07	14.28
M094	2	0
M095	2	0

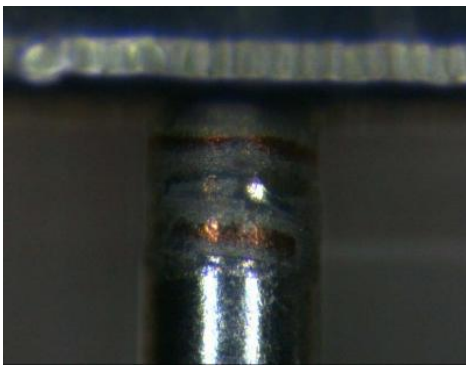


Fig. 4: Example of finding on some relays; base material found on lead at delivery.

Table 5.5: 10 Resistors (top 10 manufacturers)

Manufacturer (Coded)	Number of DPA lots	Finding Quota (%)
M101	33	6.06
M102	31	0
M103	28	0
M104	19	0
M105	17	0
M106	17	0
M107	09	0
M108	06	0
M109	04	0
M0100	04	100

Note: 7 additional manufacturers with 4 or less DPAs had no findings.

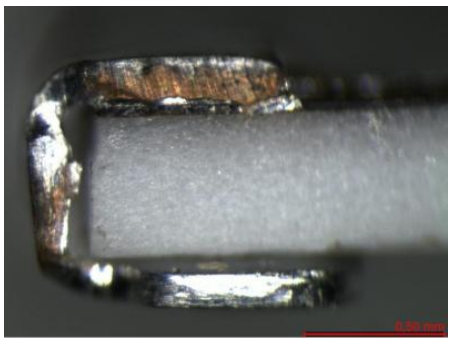


Fig. 5: Example of finding on resistors; exposed base material.

Table 5.6: 11 Thermistors (top 10 manufacturers)

Manufacturer (Coded)	Number of DPA lots	Finding Quota (%)
M111	19	5.26
M112	11	0
M113	08	12.50
M114	06	0
M115	03	0
M116	03	33.33
M117	02	0
M118	01	100
M119	01	0
M1110	01	0

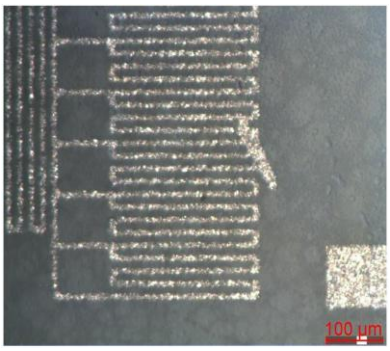


Fig. 6: Example of finding on thermistor; irregularities on meander structure.

Such weak points in some parts or with some manufacturers can be identified only during Destructive Physical Analysis, without which the concerned lots shall be approved without further verification. In a good number of these cases, the entire lot has been rejected. In the worst cases, 15-28% of the lots of passive EEE components with findings during DPA were finally rejected in some years. All other lots with findings undergo additional verification. Additional samples are taken for DPA, the manufacturer's production process is verified, and further tests may be performed on the concerned lots to verify their reliability with respect to the identified weakness at DPA.

Conclusion

Considering that the analysed lots of passive EEE components were procured directly from the manufacturers or authorised distributors, the average finding quota of 5% for the 2768 lots is considered to be too high for high reliability parts because these 5% lots can pose tremendous problem in space projects. This finding quota is expected to be much higher in a case where the parts are procured through or from unauthorised brokers or some questionable sources. Similar results may be obtained for active EEE devices. So DPA should be performed on a continuous basis, regardless of the qualification status of the parts. Additionally, findings during post procurement DPA serve as a basis for discussions with the part manufacturers and help them to supply better quality parts in subsequent production lots, which generally contribute to the reliability of space equipment and the success of space projects.

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