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Assessment of Average Outgoing Quality Levels in Parts Per Million (PPM)

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Assessment of Average Outgoing Quality Levels in Parts Per Million (PPM)

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GOVERNMENT ELECTRONICS AND
INFORMATION TECHNOLOGY ASSOCIATION



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**Government Electronics and Information Technology Association
(GEIA)**

**Assessment of Average Outgoing Quality Levels in Parts Per Million
(PPM)**

EIA-554-1

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ASSESSMENT OF AVERAGE OUTGOING QUALITY LEVELS IN PARTS PER MILLION (PPM)

EIA - 554-1

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ASSESSMENT OF AVERAGE OUTGOING QUALITY LEVELS IN PARTS PER MILLION (PPM)

(Formulated under the cognizance of the EIA Quality and Reliability Engineering (QRE) Standards Subcommittee and the JEDEC JC-13 Government Liaison Committee.)

1. INTRODUCTION

Improvements in manufacturing technology and methodology have resulted in corresponding quality improvements for electronic components. As a result, the traditional measure for reporting average quality levels in percent nonconforming needs to be replaced with a quantity more in line with the quality levels of today. That measure is parts per million or PPM. It is simply clearer to report estimated average component quality as 10 PPM, rather than the more cumbersome 0.001%. In this standard, the PPM terminology applies to estimating the Average Outgoing Quality (AOQ) level of a component, from lot acceptance results.

This standard was developed to provide a uniform method of measurement and calculation of average outgoing quality levels. Minimum sample sizes and a method for aggregating data are provided.

2. SCOPE

This standard is intended to provide a uniform method of calculating an estimate of the proportion nonconforming in finished components and to provide a standardized definition of the quality index referred to as Average Outgoing Quality (AOQ). The method used here is primarily directed at components whose production or procured volume is large enough, during some predefined sampling period, to give statistically meaningful information.

3. APPLICATION

This standard is intended to provide a method for the estimation and reporting of proportion nonconforming. The AOQ philosophy applies to the estimation of the average quality level of a product, not to lot acceptance plans. Since it is necessary to focus on accumulated lots to generate sufficient data for component quality characterization, the method in this standard should not be used to establish PPM levels for individual lots or to form the basis for determining acceptability of product on a lot-by-lot or batch-by-batch basis.

4. REFERENCE PUBLICATIONS

Publications referenced by this document are listed in Annex D.

5. DEFINITIONS

For the purpose of this standard the following definitions shall be used:

- 5.1 acceptance inspection - A sampling inspection or series of sampling inspections used to determine the suitability of a lot of material for movement.
- 5.2 accept number (c) - The maximum number of nonconforming components in the sample for which acceptance of the lot is allowed under the sampling plan.
- 5.3 average incoming quality (AIQ) - The average proportion nonconforming components, in parts per million, from a series of submitted lots.
- 5.4 average outgoing quality (AOQ) - The average proportion nonconforming components, in parts per million, from a series of accepted lots.
- 5.5 class - A categorization of similar characteristics for the purpose of reporting PPM nonconforming. Examples of classes include: electrical, visual/mechanical, hermetic, and functional.
- 5.6 proportion nonconforming - The unknown proportion nonconforming of the total population of components. Estimates of proportion nonconforming are derived from samples.
- 5.7 group - A subdivision of a class based on inspection conditions or criteria (e.g., device type, product family, test temperature, sample size). Lots that are members of the same group receive the same set of inspections in that group.
- 5.8 inspection - The assessment of a characteristic and its comparison to a standard. Examples of inspections include low temperature electrical test, room temperature test, visual inspection.
- 5.9 lot - An aggregate of components, produced under essentially the same set of conditions, from which the sample is randomly drawn.
- 5.10 lot acceptance rate (LAR) - An estimate of the probability of lot acceptance under the sampling plan, i.e., an estimate of the probability that the sample contains no more than c nonconforming components. The estimate is calculated as the ratio of first submission lots accepted to the total number of first submission lots inspected.
- 5.11 nonconformance - A component characteristic that does not conform to an individual specified criterion.
- 5.12 nonconforming component - A single component that has one or more nonconformances. These nonconforming components may be placed into classes for reporting purposes.

- 5.13 parts per million (PPM) - The unit of measurement used to describe the quality of manufactured product, giving an average number of nonconforming components for each million units.
- 5.14 sample period - The period of time selected by the manufacturer to accumulate data for the calculation and reporting of PPM.

6. SYMBOLS

The following symbols are used by this standard:

<u>Symbol</u>	<u>Formula</u>	<u>Definition</u>
AOQ'		True value of the average outgoing quality.
AOQ		Estimate of AOQ'.
c		Sample plan acceptance number.
L		Total number of lots inspected.
LR		Total number of lots rejected.
LAR	$1-(LR/L)$	Lot acceptance rate.
m	S/L	Average sample size per inspected lot.
N		Total number of components in lots inspected.
D		Total number of nonconforming components found from all samples inspected.
S	$m \times L$	Total number of components inspected.
p	D/S	Proportion of nonconforming components found in all samples inspected (AIQ).
UB ₁		Upper bound of a one-sided confidence interval for AOQ'.
LB ₂		Lower bound of a two-sided confidence interval for AOQ'.
UB ₂		Upper bound of a two-sided confidence interval for AOQ'.
σ^2		Variance of AOQ.
σ	$\sqrt{\sigma^2}$	Standard deviation of AOQ.

7. ASSUMPTIONS

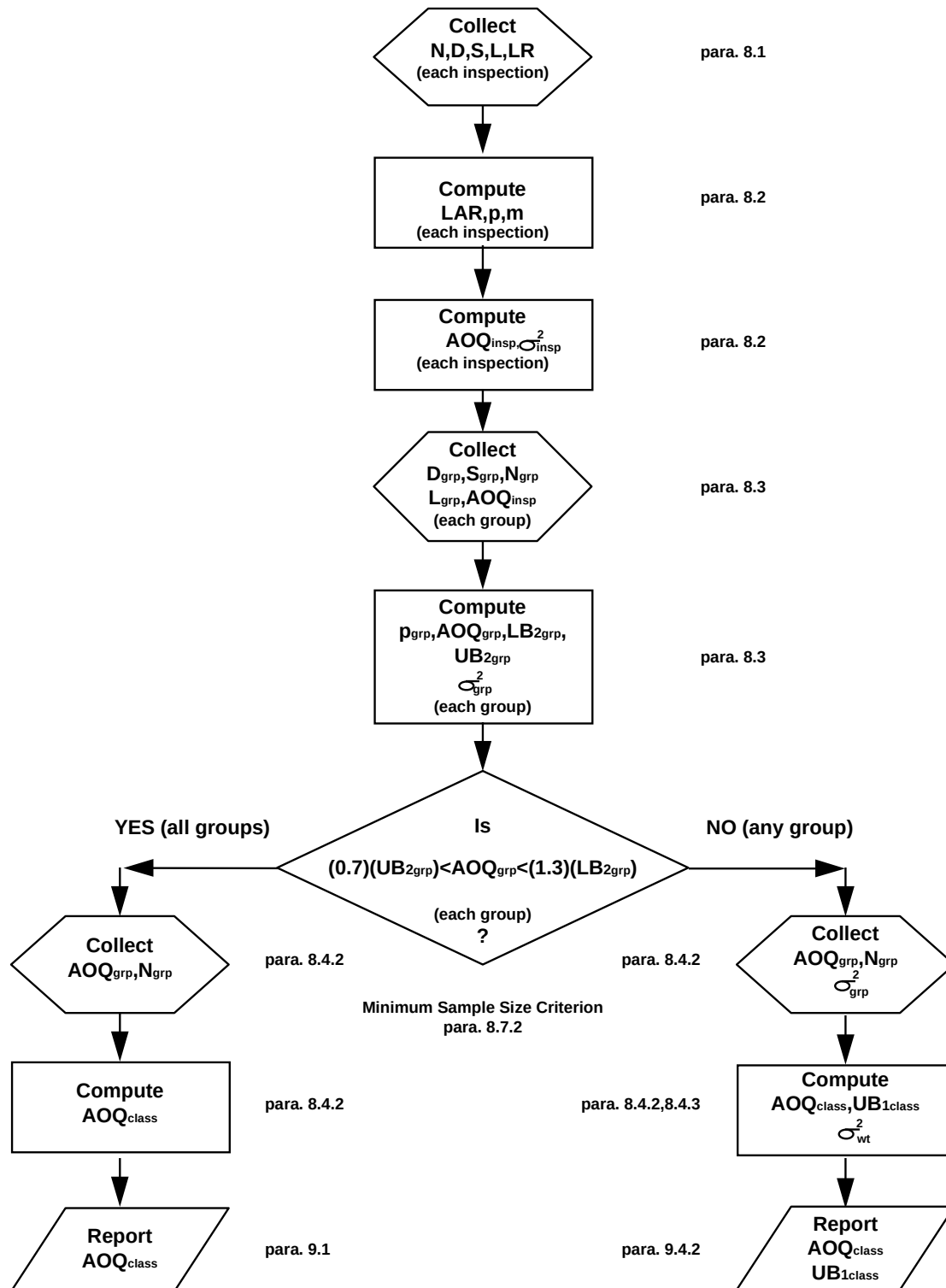
The following assumptions are used by this standard. Users should confirm that these assumptions are met for the component whose quality is to be reported.

- 7.1 Attributes sampling inspection is being conducted on components that have completed manufacturing processes affecting the criteria being reported.

- 7.2 Equipment must be calibrated according to ISO 10012-1, ANSI/ASQC Q9001/Q9002, ANSI/ASQC-M1, or equivalent. Accuracy and precision must be in accordance with manufacturer's internal documents or applicable procurement requirements. Statistical controls for the test process shall be in accordance with EIA 557. For the purpose of estimating AOQ', test equipment can be used interchangeably provided the requirements of this paragraph are satisfied.
- 7.3 Lots of components that fail acceptance inspection are reprocessed 100%, and all nonconforming components are removed from the lot or the lot is removed from consideration for shipment and discarded. The nonconforming components that were removed may or may not be replaced by conforming components. In the case of $c > 0$ sampling schemes, nonconforming components found in the sample of accepted lots are removed from the sample and may or may not be replaced by conforming components before the sample is returned to the lot for shipment.
- 7.4 All confirmed nonconforming components observed during the first submission to final acceptance inspection are included in the calculation of the total number of nonconforming components found in samples (D) unless excluded according to 8.6. Data from resubmitted lots are not used in the calculation of AIQ (p) or AOQ.
- 7.5 Single, multiple or skip-lot sampling may be used if appropriate (e.g., multiple temperature or hermeticity inspection). Double counting of nonconforming components is not allowed.
- 7.6 The total number of components sampled (S) shall include only components actually inspected.
- 7.7 AOQ values shall be reported for inspected characteristics only. Characteristics actually inspected and accompanying inspection results comprising the data for AOQ calculations shall be included in the manufacturing internal documentation and shall be available for review.
- 7.8 Nonconformances that are not component-related shall not be included in the calculation of AOQ.
- 7.9 A single component with nonconformances in more than one class should be included only in the class(es) for which the sample was presented for inspection.
- 7.10 The estimator of AOQ given in equation (1) of 8.2 is appropriate if, for each lot, the sample size for the lot does not exceed 10% of the lot size (otherwise use the equation (1') of section 8.2).
- 7.11 The estimates of p and LAR shall be determined using the same samples.

8. PROCEDURES

PROCEDURE FLOW CHART



8.1 Data accumulation for a single inspection.

Using the results from the first submission into final acceptance inspection, sum the number of observed nonconforming components (D), sum the number of sampled components (S), sum the number of components in lots inspected (N), sum the number of lots rejected (LR), and sum the number of lots inspected (L). The sample period shall not exceed one year.

8.2 Computing AOQ and variance for a single inspection.

8.2.1 Using the data totals from 8.1, the single inspection AOQ ($AOQ_{\text{inspection}}$) given by Schilling (1982) is:

$$AOQ_{\text{inspection}} = p \times LAR \times 10^6 \quad \text{ppm} \quad (1)$$

if the sample size does not exceed 10% of the lot size.

8.2.2 When $c = 0$, an approximation of the variance σ^2 for AOQ, as defined in equation (1), is given in Annex C as:

$$\sigma^2 \approx \frac{(L-1)p}{mL^3} \{L-1+2mp(3-2L)\} \times 10^{12} \quad \text{ppm}^2 \quad (2)$$

If this approximation yields a negative result, then use the exact formula found in Annex C (page 31).

8.2.3 If the sample size for any lot exceeds 10% of the lot size, then AOQ defined in equation (1) should be multiplied by $\left(1 - \frac{S}{N}\right)$. Equation (1) then becomes:

$$AOQ_{\text{inspection}} = p \times LAR \times \left(1 - \frac{S}{N}\right) \times 10^6 \quad \text{ppm} \quad (1')$$

Similarly, equation (2) becomes:

$$\sigma^2 \approx \frac{(L-1)p}{mL^3} \{L-1+2mp(3-2L)\} \left\{1 - \frac{S}{N}\right\} \times 10^{12} \quad \text{ppm}^2 \quad (2')$$

8.3 Combining inspections within a group.

For groups with more than one inspection, compute AOQ for each inspection within a group. Next compute the overall group AOQ by summing the AOQs for each inspection. It is important that lots within a group receive the same set of inspections. This means that a lot can belong to only one group within a class.

8.3.1 Example: One group of components is tested at three temperatures (low, room, and high). Let the AOQ for each test be denoted as follows:

$AOQ_{inspection1}$ = AOQ for low temperature test,
 $AOQ_{inspection2}$ = AOQ for room temperature test,
 $AOQ_{inspection3}$ = AOQ for high temperature test.

The overall group AOQ is calculated as follows:

$$AOQ_{group} = AOQ_{inspection1} + AOQ_{inspection2} + AOQ_{inspection3} \quad \text{ppm} \quad (3)$$

8.4 Combining groups within a class.

To combine groups within a class such as electrical, mechanical, or hermetic, construct a weighted average according to the following guidelines:

8.4.1 For each group compute AOQ_{group} .

8.4.2 Let $AOQ_{group\ i}$ be the AOQ for group i and $N_{group\ i}$ be the total number of components in lots for group i . Also let there be k groups (e.g., $i = 1$ to k). Combine group AOQs within a class using weighted averages according to the following algorithm:

$$AOQ_{class} = \frac{(AOQ_{group1} \times N_{group1}) + (AOQ_{group2} \times N_{group2}) + \dots + (AOQ_{groupk} \times N_{groupk})}{N_{group1} + N_{group2} + \dots + N_{groupk}} \quad \text{ppm} \quad (4)$$

8.4.3 Let σ_i^2 be the variance of the AOQ estimate for group i . The variance of AOQ_{class} is then found from equation (4) to be:

$$\sigma_{wt}^2 = \frac{(\sigma_{group1}^2 \times N_{group1}^2) + (\sigma_{group2}^2 \times N_{group2}^2) + \dots + (\sigma_{groupk}^2 \times N_{groupk}^2)}{(N_{group1} + N_{group2} + \dots + N_{groupk})^2} \quad \text{ppm}^2 \quad (5)$$

Note that this is not a weighted average of σ_{group}^2 values.