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In-Process DPMO and Estimated Yield for PCAs

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Developed by the DPMO and Assemblies, Attributes and Variables
Identification Task Group (5-22g) of the Assembly and Joining Processes
Committee (5-20) of IPC

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Users of this publication are encouraged to participate in the
development of future revisions.

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Assembly and Joining Processes Committee	DPMO and Assemblies, Attributes and Variables Identification Task Group	Technical Liaisons of the IPC Board of Directors
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In-Process DPMO and Estimated Yield for PCAs

1 OVERVIEW

1.1 Scope This document defines standard methodologies for calculating defects per million opportunities (DPMO) metrics related to electronic printed board assembly processes. It is intended for use in measuring in-process assembly steps rather than end product determination. Calculation of completed item DPMO is addressed in IPC-7912.

Additionally, a guide to defect categorization is provided that when used with J-STD-001 and IPC-A-610 can serve as a base for summarizing and reporting in-process defects.

Note: This document does not dictate the number of assemblies or data points needed to calculate DPMO metrics.

1.2 Purpose The purpose of this document is to define consistent methodologies for computation of **in-process** DPMO metrics for any defect evaluation stage in the assembly process.

This objective anticipates the following conditions in defect reporting and analysis:

- To facilitate process improvement, defects discovered at any stated inspection or test point should be assigned to their appropriate process step.
- All defects shall be reported at the inspection point they are found, even though one undetected previous defect may have caused the subsequent defects.
- Regardless of how these defects are assigned, the defect must be attributed to either a component, placement, termination or assembly defect.
- The assumption is that each printed board assembly that is inspected will be 100% inspected for all defects.
- The assumption of 100% inspection efficiency is made. Care should be exercised when comparing processes using manual inspection to those using automated vision inspection.
- When using a sampling inspection plan, the number of PCAs **inspected** determines the opportunity count, not the number **processed**.

1.3 Terms and Definitions

1.3.1 DPMO (Defects per Million Opportunities) DPMO is defined as the total number of defects divided by the total number of opportunities for a defect multiplied by 1,000,000. It is not strictly equivalent to “PPM” as the definition of “opportunities” has special meaning when considering electronic assembly processes.

1.3.2 DPU (Defects per Unit) DPU is defined as the average number of defects per PCA.

1.3.3 Process Step Estimated Yield The expected percentage of assemblies with no defects for a particular process step or combined process steps, based on historical defect rates.

1.3.4 Component Opportunities (o_c) The term “component” is defined as each device or piece of hardware that may be assembled onto a printed wire board (PWB). Solder, glue dots, and other similar materials are not to be included in this DPMO calculation. The PWB is considered to be one component.

The total opportunity count for each “component” is one. An electronic component with multiple leads still counts as one. Processes, such as conformal coating and cleaning operations, do not add component opportunity counts. These are captured in one assembly opportunity. The finished PCA is not an opportunity.

1.3.5 Component Defect (d_c) A component defect is damage to a component exceeding the limits of the component specification, or those described in J-STD-001, and/or damage that results in nonusability of that component. Component defects include both visible and nonvisible defects (physical/electrical). *Example:* A component could be both dimensionally incorrect and have major surface flaws, however, this results in a defect count of one.

1.3.6 Placement Opportunity (o_p) The term “placement” refers to the proper placement of components based on the bill of materials. The PWB does not have a placement opportunity. The total opportunity count for each placed component is one.

1.3.7 Placement Defect (d_p) A placement defect is any component presence and/or positioning error that has occurred during an assembly operation that violates the dimensional criteria specified for that component in J-STD-001 or IPC-A-610. *Example:* Exceeding maximum side or toe overhang. Even though a component may have more than one placement defect, any one or combination of multiple placement defects on any single component has a maximum defect count of one for that placement.

1.3.8 Termination Opportunity (o_t) The term “termination” is defined as any hole, land or other surface (such as component to component attachment) to which a component is electrically terminated. It also includes any terminal onto which a wire is electrically attached.

The total opportunity count for each “termination” is one; e.g., a 208 lead component has 208 opportunities. A wire typically has one termination at each end for a total of two opportunities. Note that if a single component termination connects to multiple lands on the PWB (i.e., split pad or shield) then only the terminations of the component count, not the number of lands. In this case only one termination opportunity would count. In the event of a defect to either one or both of the split pads, the maximum count of defects would be one.

1.3.9 Termination Defect (d_t) A termination defect is any electrically joined termination that violates the requirements specified in J-STD-001.

A single connection may exhibit more than one defect, however any one or combination of multiple termination defects on any single termination will have a maximum defect count of one. If two terminations are shorted by one solder bridge, each termination is counted as a defect.

Example: An IPC Class 2 “L” lead may exhibit both insufficient heel solder and insufficient side joint length, however one defect is counted.

1.3.10 Assembly Opportunity (o_a) An assembly opportunity is an overall opportunity for a defect that is not captured within termination, component and placement opportunity categorization (reference Appendix A). Examples of processes that provide such opportunities are conformal coating and cleaning. Whether considering one or multiple processes, each PCA has only one assembly opportunity.

1.3.11 Assembly Defect (d_a) An assembly defect is a defect that applies once to a PCA. Examples would be solder balls or a board flooded in the wave. Each assembly defect should be logged at the process step where the defect is found. It is recognized that the total number of assembly defects for a series of processes may exceed the number of opportunities in extreme cases. This result is expected (more than one assembly defect per assembly, on average) and would impact a combined DPMO including the result. The intent of this document is not to rely on such combined metrics.

2 APPLICABLE DOCUMENTS

IPC A-610 Acceptability of Electronic Assemblies

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

IPC-7912 Calculation of DPMO and Manufacturing Indices for Printed Board Assemblies

3 CALCULATION OF IN-PROCESS METRICS

The DPMO metric is calculated according to the following equation:

Equation 3-1:

$$DPMO_x = [d_x/o_x] \times 10^6$$

Where the subscript x refers to a defect category, as follows:

p = placement defect or opportunity
t = termination defect or opportunity
c = component defect or opportunity
a = assembly defect or opportunity

The DPMO of the unique process steps may be combined according to the following procedure:

Equation 3-2:

$$DPMO_{combined} = [(\sum d_1 + \sum d_2 + \dots + \sum d_n) / (\sum o_1 + \sum o_2 + \dots + \sum o_n)] \times 10^6$$

Subscript 1 through n denotes the n^{th} process step.

Combining DPMO for processes with different defect categories (e.g., placement, termination) may result in a misleading figure.

The formulas presented herein can be used in a variety of ways to investigate PCA assembly performance. For example, one can investigate the performance of a particular component type by excluding all other component types from the calculation.

3.1 Calculation of In-Process Metrics - Assumptions

The following lists assumptions for calculation of in-process metrics:

1. All defects must be logged if multiple defects occur across a PCA at a particular process step.
2. A defect logged in one category is not to be logged in another category. For example, a PCA that experiences catastrophic failure (flooded in the wave solder operation) would be logged as one assembly defect but would not be logged for any other defects (not termination defects in this example).
3. There are no longer opportunities and defects in subsequent process steps once an assembly is scrapped.
4. Rounding of intermediate results is not preferred. If rounding is necessary, at least four significant digits should be retained to ensure accuracy of combined results.
5. Appendix A provides a base listing of the defects. Other defects or process indicators may be added as necessary.

3.2 Calculation Examples Figure 3-1 is a hypothetical process that will be used to illustrate In-Process DPMO calculations. Table 3-1 represents the bill of material for that hypothetical board, and there are 100 PWBs at start of the processes.

The following example shows combined DPMO (via Equation 3-2) only for defect classifications, however the user may elect to calculate DPMO for any combination of processes desired. This document is intended as a guide.