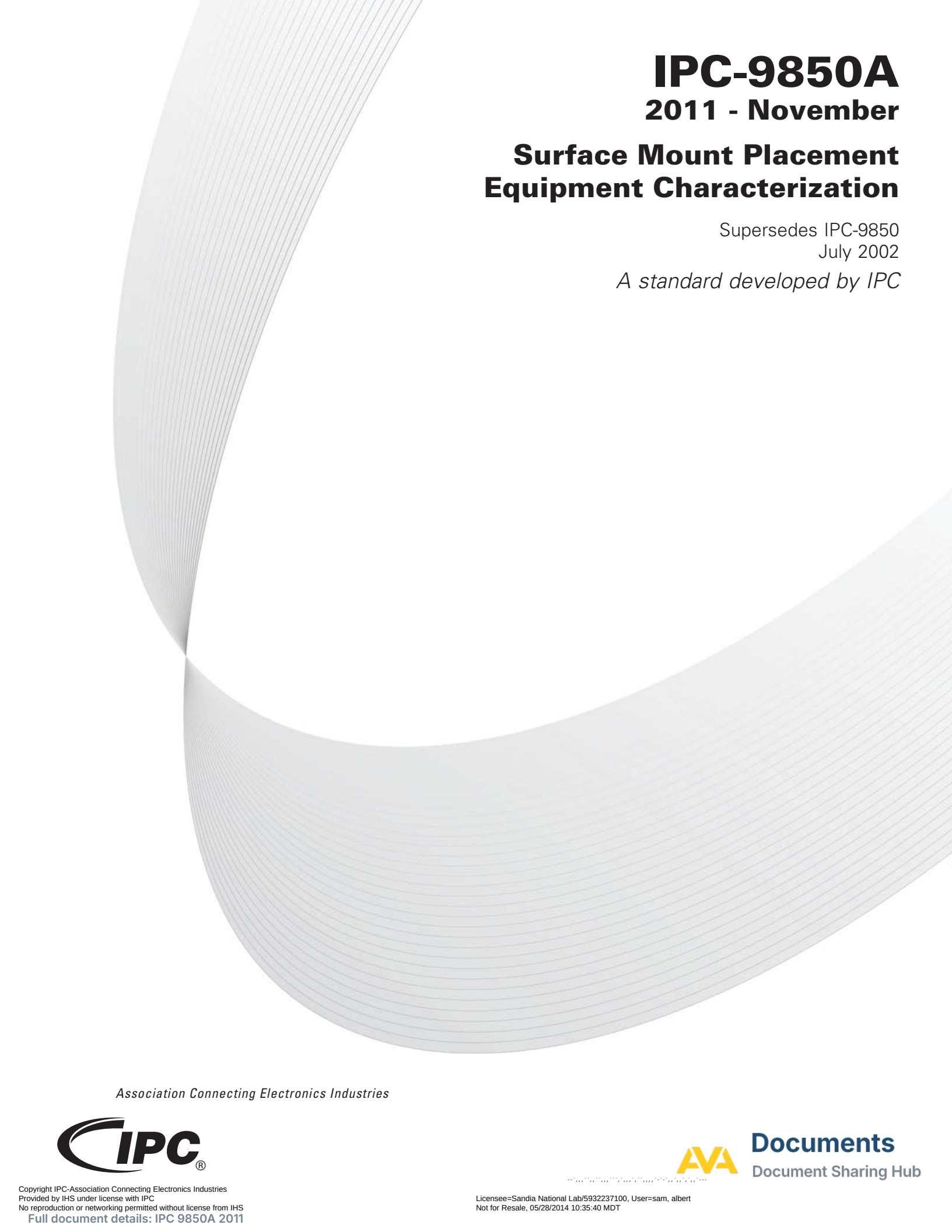




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2011 - November

Surface Mount Placement Equipment Characterization

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July 2002

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Association Connecting Electronics Industries



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IPC-9850A

Surface Mount Placement Equipment Characterization

Developed by the SMT Component Placement Equipment
Subcommittee (5-41) of the Assembly Equipment Committee
(5-40) of IPC

Supersedes:
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Surface Mount Placement Equipment Characterization

1 INTRODUCTION

1.1 Scope This standard establishes the procedures to characterize the capability of surface mount assembly equipment in specification documents, as well as in documentation used to verify a specific machine's placement capability and conformance to the specification while maintaining placement accuracy to placement throughput relationship.

1.2 Purpose IPC-9850 has been developed to standardize the parameters, measurement procedures, and the methodologies used for the specification, evaluation, and continuing verification of assembly equipment throughput and accuracy characterization parameters. These standardized tools **shall** be used to develop and report the information called out in this standard.

1.3 Background Historically, placement equipment machine suppliers have selected their own parameters and methodologies to present the specification of their machines' throughput and accuracy capabilities. The many representations of the information have made the comparisons between placement machines very difficult.

This standard simplifies the evaluation process by coupling placement throughput and placement accuracy because they are dependent on each other. This standard also specifies the methodologies by which these parameters are measured. The methodologies specified herein are consistent and verifiable, thus providing common ground methodologies between users and machine suppliers. The test boards used in this standard are for metrology reasons less complex than real-life boards so individual users will experience different levels of derate depending on their products. It is recommended for evaluation purposes that the user treats the IPC-9850 throughput rating as an initial comparison knowing that further evaluation based on actual product would be advised.

The throughput and accuracy evaluation methods of this standard specify that measurements will be made by placement of standardized components into sticky media on clear glass panels. Experience shows that surface mount equipment must perform well on sticky media before it can perform well in production. Furthermore, improved process capability on sticky tape usually translates into enhanced process capability in production. Although this method does not provide all information to perfectly predict production accuracy, this methodology was selected in order to remove as much of the variation as possible between facilities, products, process, and operators.

1.3.1 Future Considerations A number of issues including but not limited to the following items were deferred to a future revision to this standard. Users are encouraged to provide additional recommendations and support material using the Standard Improvement Form at the end of this standard:

- Placement density metric.
- Update chip component criteria (component size, C, R, shape/physical attributes) as component manufacturing technology and use changes. For instance 0402 [01005] size components may be added in the future.
- Develop the means to correlate the use and test results of more challenging test devices.
- Removing the old IPC-9850 chip board CB-A from the standard on next revision.

1.4 Implementation

1.4.1 Characterization Limitations This standard is comprised of a set of parameters that are the lowest common denominator for surface mount placement equipment. It should be recognized that additional metrics may be of value in some instances. The collection of parameters selected for this standard comprise the best subset for use as a core set of requirements to be included with an equipment supplier's general specification. This core set may change in future revisions as technology dictates. In addition, since there are many possible combinations of hardware and software features that are unique to individual machine types, this standard cannot address every one of them. Such features and options affect the overall capabilities of specific equipment model and it is left to the user to understand their implications. Additionally, it is incumbent upon the user to understand the restrictions and leeway provided for each parameter in this standard so the proper performance conclusions are reached.

1.4.2 Binding Requirements The body of this document is the standard. The word **shall** is used throughout this document whenever a requirement is intended to express a provision that is binding. Material in the appendices is provided only for information and reference and is not part of the standard.

1.4.3 Test Components Component types QFP100, 1005 [0402], and 0603 [0201] size components were selected to represent the range of component types placed by surface mount equipment. See Table 1-1 and Section 6 for documentation of these component types. The old IPC-9850 chip board CB-A with 1608 [0603] size components is still in use for now as a transition to the newer technology boards.

Table 1-1 Component Conversion

Component Names		Component Dimensions	
Metric	English/Imperial	Metric	English/Imperial
0402	01005	0.4 mm X 0.2 mm	16 mils X 8 mils
0603	0201	0.6 mm X 0.3 mm	24 mils X 12 mils
1005	0402	1.0 mm X 0.5 mm	39 mils X 20 mils
1608	0603	1.6 mm X 0.8 mm	63 mils X 31 mils
2125	0805	2.0 mm X 1.25 mm	79 mils X 49 mils

During the verification of a placement machine, one of the goals is to assess the accuracy capability of the placement machine. To isolate the contribution of the surface mount equipment to the placement error, it is desirable to reduce other effects that may contribute to the placement error evaluation process. Using nearly perfect components can reduce the effect of components on placement error evaluation. Such components minimize the error associated with Surface-Mount Technology (SMT) component-to-component variation. Using tighter toleranced components can provide better results than loose toleranced components.

For this standard, the QFP-100 component type permits the comparison of large multifunctional components that are not represented by the selected chips. To maintain consistency when utilizing slugs, all slugs **shall** have the same orientation in the supply trays. Other types of SMT components can be studied using the same basic methods defined in the standard. Glass slug components that represent micro-BGA and Flip-Chips component types are obvious extensions of the standard type of component that suppliers or users may wish to consider. Rules for adding claims about additional component types are presented later in this standard.

The slug fiducial markings can only be used to represent the position of the slug component feature if the United States National Institute of Standards (NIST) or other internationally recognized standards institute/agency has certified the slug to that effect. In this standard, references to NIST certification are intended to include any such international standards agencies.

1.4.4 Test Panels The evaluation methods of this standard specify component placement into sticky media applied on clear glass panels. This approach is advantageous for two reasons. The first is the dimensional stability of the glass panel, as opposed to epoxy/glass PCB materials (e.g., FR-4) that are much more susceptible to shrinking and warping. The second reason is that it permits use of a standard Optical Coordinate Measurement Machine (CMM) to illuminate the outline of the components. Optical CMMs are able to rapidly measure a large number of components with very high precision.

In order to streamline the evaluation methodology, a single glass panel type is specified that permits placement evaluation and verification of a variety of component types. This panel is referred to in this standard as the Placement Verification Panel (PVP). The PVP has fiducial markings at specified locations with spacing accuracy traceable to a NIST certification standard. These fiducials are used as references by both the placement and measurement machines. The panels accommodate the following components for this standard:

1. Board IC-A
QFP100 qty 36
2. Board CB-B
0603 [0201] Size components qty 129
1005 [0402] Size components qty 271
3. Board CB-A (this board will be removed from the standard on next revision)
1608 [0603] Size components qty 400



Application of the sticky media requires experience. There must be sufficient amount of sticky media to hold the component in place, but not too much as to cause interference with the measurement machine. Appendix C has guidelines on the application of the sticky media.

1.4.5 Measurement This standard has been developed with emphasis on assuring that the measurement tools are capable of properly characterizing the process. Capable measurement tools provide the customer with a methodology for verifying machine supplier claims. They also assure the machine supplier that the customer is properly evaluating the machine's performance. The proper application of an optical CMM for the evaluation of a surface mount process requires that its measurement uncertainty must be significantly less than the placement specification. The measurement capabilities required by the optical CMM depend on the type of components being evaluated and on the specification limits to which the supplier is committing. The method for evaluating measurement system repeatability shall be Gauge Repeatability and Reproducibility (GR&R). This methodology determines the measurement system's ability to consistently measure the same product repeatedly. The methodology requires that the measurement uncertainty (GR&R error) be at most 25% of the specification range of the product being measured. GR&R studies do not assess the accuracy of the measurements, just their consistency. An additional check is needed to verify that the optical CMM measurement routine is producing accurate results. See Appendix G for discussion. The accuracy of the optical CMM can only be evaluated against a certified gauge. The gauge selected for this standard is a NIST traceable glass verification panel with etched images in the shapes of the selected components. This panel is measured on the CMM, and the reported positions are compared to the actual positions of the component images provided from the panel certification.

1.4.5.1 CMM Measurement equipment that meets or exceeds the uncertainty requirement under the specified evaluation procedures for a specified component type is acceptable.

Clear PVPs allow high quality images to be processed by the CMMs. Inspection algorithms are then created to determine the centroid of these images. This data is then output in a form where means and standard deviation of the components can be calculated. Binary images are the most accurate and repeatable way to measure objects using a CMM machine.

1.4.5.2 Reporting Measurement results are recorded on standardized forms. The Placement Performance Metric is form IPC-9850-F1. The purpose of the form is to report the specification for a model type by work area configuration. Values for throughput and accuracy that are simultaneously achievable are listed in this form. Form IPC-9850-F2 is to report throughput and accuracy numbers for an entire line/machine. It is populated with the measured results from the IPC-9850-F1 form. Form IPC-9850-F1 is supported by the CMM Capability to Evaluate Metric Parameters form, IPC-9850-F3, which is used to demonstrate the measurement validity of the parameters presented in the Placement Performance Metric.

1.4.5.2.1 Forms Reproducible copies of all required forms are provided in Section 7.

1.5 Data Methods With regards to the statistical treatment of placement deviation data, it is assumed that deviations generally follow normal (Gaussian) distributions. This may not always be the case. There is nothing inherently wrong with data having some other distribution. However, depending upon the circumstances, it might mean that the specification limit of 1.33 may contain some percentage of data less than the 99.9968% normally associated with this Cpk limit. It would be prudent for the user to verify that the machine has data that reasonably approximates a normal distribution if it is crucial to the user that the machine's level of inaccurate placements precisely matches those associated with Cpk's of 1.33.

1.6 Terms and Definitions

Work Areas Any location inside a placement machine where PCBs are populated. Different work areas inside a machine can have different configurations that can have different throughput and accuracy. Some of the options that change the configuration of the work areas are number of gantries, type of heads, and type of cameras.

Fiducial Markings on substrate materials—such as PCBs or glass—that are utilized by the placement equipment vision systems to locate the position and orientation of the substrate.

Component Surface mount parts that are utilized in the construction of electronic devices.

Optical CMM Any inspection machine that can pass GR&R and the accuracy test provided in section 5.1 and 5.2 of this document.

Heads The tool holder(s) that execute the Z pickup/placement and theta rotation of components.

Placement Error The physical distance between where the component was actually placed and where the surface mount equipment was specified to place the component by the placement program data.

Slug NIST traceable glass panel with etched image of a single component and reference fiducials.

X_{dev} The placement error in the X-direction (parallel to the “9850 Verification” label found on the Placement Verification Panel).

Y_{dev} The placement error in the Y-direction (perpendicular to the “9850 Verification” label found on the Placement Verification Panel).

Θ_{dev} The rotational placement error (about the component’s X-Y area centroid location).

Maximum Lead Tip Error (MLTE) Considers the combined effects of X, Y, and Θ placement errors.

Net Throughput The number of components per hour (CPH) the machine can place on the verification PVP.

Repeatability One standard deviation of the placement error when placing multiple components upon multiple boards.

Total Run Time The time it takes 4 consecutive boards to exit a work area.

Land The termination areas on the PCB referred to by the IPC-T-50 Terms and Definitions as a portion of a conductive pattern usually, but not exclusively, used for the connection and/or attachment of components, also commonly referred to as pads.

1.7 Units of Measurement All dimensions in this document are provided in hard metric (SI) followed by soft English/Imperial in brackets. All components are referenced as a metric definition, i.e., 1005 is equivalent to the 0402 (1.0 mm x 0.5 mm) component type. See Table 1-1.

2 REFERENCED DOCUMENTS

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits¹

MSA-2 Measurement Systems Analysis Second Edition February 1995 published by AIAG (Automotive Industry Action Group, 26200 Lahser Road Suite 200, Southfield MI 48034)

3 PLACEMENT PERFORMANCE METRIC

3.1 Machine Performance Form IPC-9850-F1 This form reports the general performance by machine model. Individual columns shall be added for each work area configuration. This form shall be used for all configurations of an individual model type. From time to time suppliers increase throughput by changing firmware, therefore reporting the date and firmware version is important for clarification. Some model types may have more than six work area configurations; in this case, the supplier shall use additional sheets to fully define a model type. The additional forms shall increment the work area definition numbers example: Sheet 1, 1-6, Sheet 2, 7-12, etc.

The following information is reported in the body of the form, which is divided into three sections.

Section I Defines the different possible work area configurations. The supplier supplies the type of:

- Head on the front gantry.
- Head on the rear gantry (if it is a single gantry work area enter NA).
- Camera used on the front gantry.
- Camera used on the rear gantry (If it is a single gantry work area enter NA).
- Conveyor system used for the test.

Section II Defines the test conditions for the test. This will allow the user to repeat the test using the same test conditions. The parameters are:

- Number of feeders/tray.
- Type of nozzles.
- Number of each type of nozzle used.
- Type of components used during test.

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Section III Presents the simultaneously achieved speed and accuracy results. The parameters are:

- Net throughput, CPH.
- Repeatability (one standard deviation).
- Accuracy specification limits for Cpk=1.33.
- MLTE calculation specification limits for Cpk=1.33.

The repeatability and accuracy parameters are individually calculated for the X-axis, Y-axis, and Theta Θ rotation, while the MLTE calculations integrate the X-axis, Y-axis, and Theta rotation placement errors. See section 3.4.3.2.2 (Cpk for MLTE specification calculation) for details. Appendix D provides a guide for two possible methods of measuring the center locations of the components to attain the measurement error.

3.1.1 General Performance When IPC-9850 is used, Form IPC-9850-F1 **shall** be used to present the placement capability of a specific machine model when the metric is derived using the methodologies of this standard. This form should be provided upon request of a user. This form shall be filled out in its entirety. When a supplier wants to supply IPC-9850 number for an entire line/machine Form IPC-9850-F2 shall be provided as a summary of the customer's machine.

3.1.2 Performance Validation The user can use the Form IPC-9850-F1 to validate the performance of a specific individual machine after delivery. The user shall be able to perform the test per IPC-9850 instructions and achieve the same values that were stated by the supplier. If the numbers cannot be achieved, the supplier and user shall work together to determine the source of the deviation and correct the situation. All numbers reported by the IPC-9850-F1 form shall be reproducible at customer sites after install. When conducting verification test, applicable recommended procedures provided by the machine supplier need to be followed (e.g., warm-up time).

3.1.3 Adding Additional Components Supplier commitments regarding all component types shown in IPC-9850-F1 that are within the capability claims of the equipment must be included in the Machine Model type evaluation. Additionally, columns for other component types may be added at machine supplier discretion. If this is done, the following guidelines **shall** be followed:

1. At least 24 components/slugs, or as many as will fit on the Placement Verification Panel.
2. All four orientations shall be utilized equally (unless the placement machine is not capable of placing at multiple orientations).
3. The entire width and length of the area inside the Placement Verification Panel's fiducials shall be used.
4. The placement pattern and rotations should be reasonably balanced, density-wise, from left-to-right and top-to-bottom.
5. Four boards **shall** be run and measured.

3.2 Characterization Methodology

3.2.1 Test Procedure The characterization methodology for obtaining numeric values for the specified parameters was designed to be repeatable and reproducible, and independent of a specific user product. To meet this goal, a standard PVP is specified as a common test substrate for all procedures (section 6.1). This test vehicle is laminated with a layer of adhesive that is used to capture and hold the mounted components. The characterization procedure yields a set of performance parameters. These parameters are evaluated through the population of four PVPs. The four panels must be populated consecutively through a common work area on a machine, as though they were four adjacent PCBs in a production environment. The same build of consecutive four panels utilized for the accuracy and repeatability analyses **shall** be utilized to extract all other performance parameters. Machines that buffer PCBs pre- and post-population may utilize additional panels to obtain the appropriate pulse rate, however only four consecutive panels are used for the analysis. PVP carriers may be used at machine supplier's discretion, as long as the carrier supports exactly one PVP. See Appendix I for a PVP carrier designed by committee members.

3.2.1.1 Component-to-Component Variability Variability due to component-to-component physical differences is reduced through the use of glass slugs to represent the QFP-100 fine-pitch components. The glass slugs are specified in section 6.3. Due to the high quantity and packaging issues of discrete components, placement test methods utilize production quality 1608 [0603], 1005 [0402] and 0603 [0201] components that are specified in section 6.5.

3.2.1.2 Machine's Component Accommodation If a head/work area configuration cannot place one or more of the components called for by the standard layout on the PVP, the supplier should report "Not Applicable" (NA) for this combination.

3.2.1.3 Machine Optimization Requirements Each supplier shall apply its standard placement optimization procedures by which the components are placed. The supplier shall not force optimization from standard production optimization to either improve accuracy or throughput (e.g., no manual manipulation to optimize the pattern to exclude certain nozzles is permitted).

3.2.1.4 Panel-to-Panel Variability To capture both “within board” and “between boards” sources of variability for each component, four PVPs are populated. The four panels are utilized to capture panel-to-panel placement variation due to the fiducial finding process. The fiducial finding process accounts for imaging system errors in reading the fiducials, mathematical analysis in accounting for panel orientation, etc.

3.3 Machine Performance Parameters

3.3.1 Work Area Definitions The Work Area Definitions section of IPC-9850-F1 reports the tested configuration for the specific model of machine. A configuration is defined as different combinations of heads and cameras that are used to assemble a PCB at a given work area. If more than six different configurations are possible within a model type, the supplier shall use additional forms to track all possible workstation configurations for that model. When more than one sheet is needed to completely define a model, the sheet numbers need to be tracked in the header information (e.g., sheet 1 of 2).

3.3.1.1 Type of Head(s) The first parameter that defines a work area is the type of heads that are used to place parts in that area. This includes if there are 1 or 2 gantries working at that location. The head type of each gantry shall be recorded along with its location Front/Rear or Right/Left (referred to on form IPC-9850-F1 as A/B). If this is a single gantry work area “NA” shall be entered in the rear head.

3.3.1.2 Type of Camera(s) The next parameter that can change the throughput and accuracy of a work area could be the type of camera used for that location. The camera pixel size and scan throughput both effect the throughput and accuracy. The camera type for each gantry shall be recorded along with its location Front/Rear or Right/Left (referred to on form IPC-9850-F1 as A/B). If this is a single gantry work area, “NA” shall be entered in the rear head.

3.3.1.3 Type of Conveyor(s) The next parameter that can change the throughput of a work area could be the type of conveyor system being used. Depending on the number of lanes (from single lane up to quad), the amount of travel can change, which affects the overall throughput of the work area.

3.3.2 Test Conditions The Test Condition parameters section of IPC-9850-F1 report the machine conditions during the execution of the throughput and repeatability/accuracy procedures. These conditions are selected to provide sufficient information for a user to interpret and reproduce the documented performance.

3.3.2.1 Number of Feeders/Trays For this standard, this refers to the number of component feeders or matrix trays used by the machine during the performance evaluation. The number of feeders used affects the throughput of some types of machines. Sometimes multiple feeders per part number are required to maximize the throughput.

3.3.2.2 Type of Nozzles For this standard, this refers to the type of nozzle utilized by the spindles during the performance evaluation. Some machines may use more than one type of nozzle to pick and place a particular component type.

3.3.2.3 Number of Nozzles For this standard, this refers to the number of nozzles used by the heads/spindles during the performance evaluation.

3.3.2.4 Type of Component This refers to the type of component used for the test (e.g., capacitors, resistors, live QFPs, type of glass part, etc.).

3.3.3 Throughput Results This refers to the time periods necessary to complete cycle of placing components on a PVP. Figure 3-1 shows how these parameters are defined. The measured Total Run Time parameter is used to calculate the Net Throughput parameter used in this form.

Obtaining the time-based parameters requires the use of a stopwatch, an oscilloscope, or the machine’s internal timestamp events. Oscilloscopes and machine internal timestamps are normally more accurate at measuring the start and end of each cycle that are not easily detectable with the naked eye. The ability to measure a time-based parameter must be documented.

the user to assure that measurements are precise, (i.e., both repeatability and accuracy are acceptable). The stopwatch, oscilloscope, or internal timer must have resolution of at least 0.01 seconds or better. Internal timers must be verifiably accurate with the use of oscilloscope or other external timer.

3.3.3.1 Net Throughput For this standard, it is the number of components per hour (CPH) the machine can place on the verification panel. This definition is implemented to provide a measure of equipment capability in a term that is common in the industry. This CPH will not exactly predict the CPH users will experience with their own product, but should provide a fairly good way to compare different placement machines.

3.3.3.2 Measurement Procedure for Total Run Time Use a stopwatch, oscilloscope, or internal timer to measure the time from the exit of the work area of the first panel to exit of the fifth panel. The first panel is not included in either the throughput or accuracy measurement. To minimize measurement error, some easily detectable and clearly defined point in the cycle should be utilized. Machines that buffer PCBs pre- and post-population may utilize additional panels to obtain a sustainable pulse rate though a work area, but only the set of four consecutive glass verification panels is necessary for a proper characterization procedure.

3.3.3.3 Calculation Method Net Throughput The number of components placed on 4 glass verification panels, divided by Total Run Time, and multiplied by 3600.

Example for QFP-100:

Net Throughput = $(36 \times 4 / \text{Total Run Time}) \times 3600$

3.3.4 Accuracy Results The following is the measurement procedure utilized for collecting data for repeatability and accuracy. Four standard panels are treated with adhesive (see Appendix C for guidelines for adhesive application). The four panels are consecutively populated with the placement program specified for the part type. The panels are then placed on a capable Optical CMM and the component placement error along the X, Y and Θ axes are measured.

The measurement system verification for these parameters is discussed in Section 5.0 *Measurement System Analysis (MSA) Capability Form IPC-9850-F3*.

3.3.4.1 Repeatability For this standard, repeatability is defined as one standard deviation of the placement error when placing multiple components upon multiple PVPs. A deviation is defined as the placement error experienced when the machine places a component. The placement error is defined as the distance between the actual center location of the component to the specified CAD location with reference to the board fiducials. Appendix D provides a guide for two possible methods of measuring the center locations of the components. The errors are defined where X_{dev} refers to the placement error in the x-direction. For use of this document, the x-direction is defined as parallel to, and the y-direction is perpendicular to, the lettering on the placement verification panel. Θ_{dev} refers to the rotational placement error (about the component's X-Y area centroid).

Calculation Method

The average of the X_{dev} 's, $\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$ and Standard

Deviation of the X_{dev} 's, $s_x = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2}$,

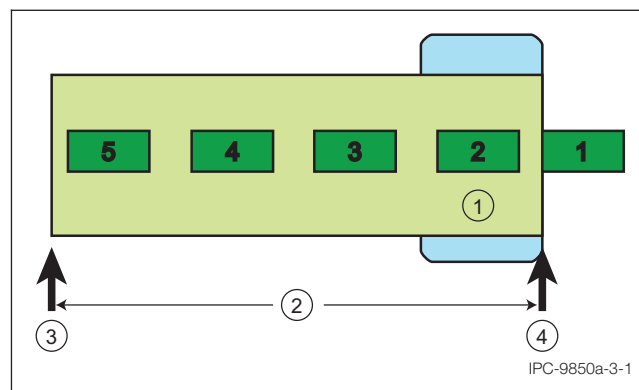


Figure 3-1 Performance Parameter Description for a Four-Panel Build

1. Work Station
2. Total Run Time
3. Fifth Board Exits Work Station
4. First Board Exits Work Station

Where i refers to the slug or component number, X_i refers to the x error of the i^{th} slug or component, and n refers to the total number of slugs or components placed over all boards and all locations. Example, for the placement of QFP-100, 36 slugs are placed per PVP on a total of 4 panels; thus $n=36*4 = 144$.

3.3.4.2 Accuracy In industry, many suppliers specify performance against their own unique specification limits and capability index values (e.g. $\pm 40 \mu\text{m}$ with $C_{pk} \geq 1.5$). One aspect of this IPC-9850 standard is instead of having a different specification limit and a different sigma level for each supplier, results from each **shall** be provided in terms of the specification limits required to sustain C_{pk} of 1.33. Specification limits are directly comparable from one machine to another when machines are reported at the same C_{pk} levels. The standard way to report accuracy is to separately report it in terms of X, Y, and Θ (rotational) axes.

Section 3.3.4.2.2 defines an additional way to report machine accuracy. The essential advantage of this method is that it relates more directly to the soldering process than the traditional method, because there are combinations of the X, Y, and Θ deviations that separately may fall within spec, but when combined, sometimes prevent the formation of an adequate solder joint.

3.3.4.2.1 Spec Limits for X, Y and Theta For this standard, spec limits for C_{pk} are the specification limits for which the machine is capable of placing the specific component type with reference to the panel fiducials. This parameter indicates the machine's ability to provide a centered placement for a given value of the process capability index, C_{pk} . Users who wish to use some other level of defect rate (besides C_{pk} of 1.33) can easily convert the information provided here to evaluate machine performance against the preferred capability level.

Calculation Method

$$SL = 3s \times C_{pk} |avg|$$

See Appendix A for discussion of capability indices and Appendix B for discussion of the specification limits associated with C_{pk} values and an example of this calculation.

3.3.4.2.2 Spec Limits for MLTE Many defects are due to the combination of moderately large X, Y, and Θ placement errors, rather than just one prevailing X, or Y, or Θ placement error. This approach considers the combined effects of X, Y, and Θ placement errors and is referred to as Maximum Lead Tip Error (MLTE). The word maximum is a part of the metric name because the metric refers to the tip error experienced by the lead most impacted by the particular combination of the X, Y, and Θ deviations as shown in Figure 3-2. By definition, S_x refers to the component span (lead tip to lead tip) in one direction (X) while S_y refers to the component's span in an orthogonal direction (Y). MLTE evaluation for the chip components is not performed, since the end-cap to land proportions do not necessarily provide meaningful results.

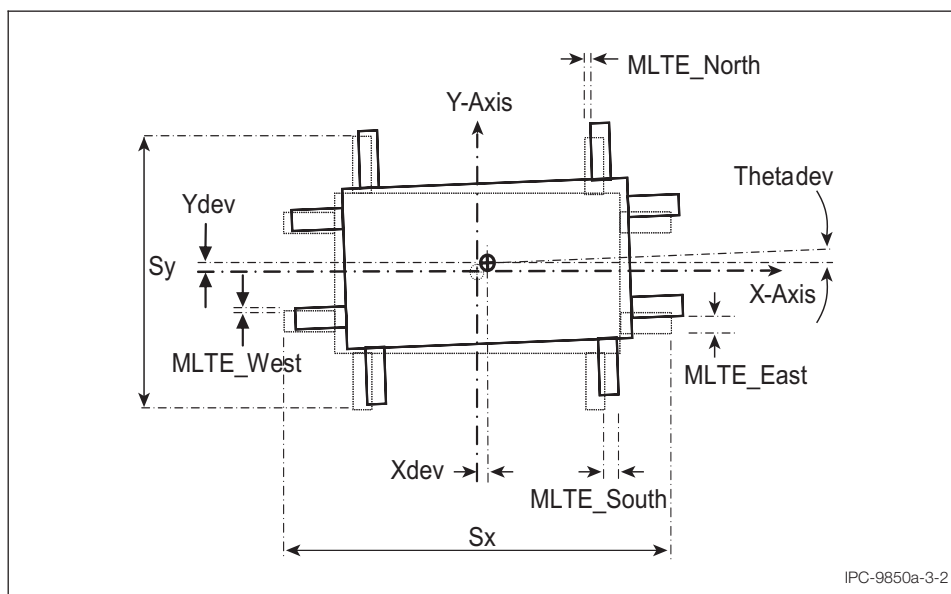


Figure 3-2 Maximum Lead Tip Error Due to Placement Machine (Combined X_{dev} , Y_{dev} and Θ_{dev})



Calculation Method Calculation methods are provided for the IC-A board. For each placed component, the four MLTE values shown in Figure 3-2 are calculated, one MLTE value for each quadrant. Standard deviations and averages and Cpk values are then calculated per quadrant, using the same formulas in section 3.3.4.2.1. The smallest of the four obtained Cpk values is then used as the value for the Spec Limit for MLTE.

Calculation formula for the MLTE values, assuming that positive rotation is clockwise:

$$MLTE_North = X_{dev} + \frac{S_y}{2} * \sin(\theta_{dev})$$

$$MLTE_South = X_{dev} + \frac{S_y}{2} * \sin(\theta_{dev})$$

$$MLTE_West = Y_{dev} + \frac{S_x}{2} * \sin(\theta_{dev})$$

$$MLTE_East = Y_{dev} + \frac{S_x}{2} * \sin(\theta_{dev})$$

MLTE calculation for ball devices is outside the current revision of this standard. As a guideline: if a user makes an extension to the standard by using a ball type glass slug, each MLTE calculation needs to include all three parameters X_{dev} , Y_{dev} and θ_{dev} , since all three will affect the lead error for a ball device.

4 LINE SUMMARY FORM IPC-9850-F2

Form IPC-9850-F2 reports the general performance by entire line or machine (see section 7, *Forms and Diagrams*). In some cases one machine is an entire line, while in other case many machines makeup 1 line. In either case the correct number of work areas is proposed by the supplier to meet the user's throughput and accuracy needs. For the purpose of this standard, it does not matter if a line is made up of one or many machines. The IPC-9850-F2 form allows both scenarios to be tracked on one form, giving users the ability to compare proposals.

This form is intended to be a summary of the IPC-9850-F1 forms. On the IPC-9850-F1 form all the work areas configuration are defined and measured and should be provided for more detail for the user. All the data for throughput and accuracy are stored on this form. The IPC-9850-F2 provides a summary of a specific line configuration combining different work areas configuration of one model or different models and work area configuration into one line. The IPC-9850-F2 form should be submitted to users with all corresponding model type IPC-9850-F1 forms.

4.1 Model Column This column indicates to the user which model is used for this work area. It allows the user to cross reference the correct IPC-9850-F1 form to get more data.

4.2 Work Station Definition # This column references which IPC-9850-F1 work area number is being called out. This number is located at the top of every column on the IPC-9850-F1 form.

4.3 Heads and Cameras This is a summary of the head and camera configuration called out by the work area number.

4.4 Chip Boards CB-B and CB-A and IC board IC-A This is a summary of the IPC-9850-F1 results for that workstation definition. Only the CPH is referenced for the throughput metric and the specification limits at 1.33 are referenced for accuracy.

4.5 Totals The totals are the sum of the individual CPHs for the work areas listed. Since the CPH measurement includes transfer time in and out of the work area adding the CPHs does give a theoretically good number (assuming each workstation has the same build time). Whether it is machine to machine or work area to work area it is the job of the optimization software to get the build times as close as possible to each other. How well this balance happens will change product by product within a facility. While there is value in knowing which supplier has better optimization software, it is not under the scope of the IPC-9850 standard.

5 MEASUREMENT SYSTEM ANALYSIS (MSA) CAPABILITY-FORM IPC-9850-F3

Form IPC-9850-F3 functions as a tool for evaluating the measurement capability for the Placement Performance Metric (form IPC-9850-F1). The measurement capability information presented on the form **shall** be gathered and reported according to this standard. Data provided in the IPC-9850-F1 and F2 forms shall originate from equipment characterized in accordance with this section. The reported information should be acquired no more than 90 days prior to the machine performance study.

The parameters of this section **shall** be used to evaluate the measurement system's ability to appropriately measure the test vehicles produced during the machine performance evaluation analysis in a repeatable and reproducible manner. This evaluation **shall** be made for each component type. The specification limits reported in the performance reporting form **shall** never be smaller than the specification limits provided by the MSA reporting form. Suppliers that add additional component types to the Placement Performance Metric **shall** also report their measurement capabilities for the same component types.

5.1 MSA Evaluation To evaluate a measurement system the uncertainty of the system needs to be measured and calculated into a single number. This number represents the uncertainty that is attributed to the measurement gauge. This error is then evaluated against the specification range to determine the Process-to-Tolerance (PT) ratio. The results are reported in terms of the upper and lower specification limits that yield a PT ratio of better than 25%. The forms variances that are included in the total gauge error are repeatability, reproducibility, bias, and artifact uncertainty.

In some cases the user may not have an AVP to measure the bias. In such cases, the CMM uncertainty over the distance measured as derived from the latest calibration report shall be used. While these approximations will not be as accurate as measuring the AVP they will be more accurate than not including any data for bias.

Measurement Procedure The intent of this procedure is to determine the expanded uncertainty of the CMM. This measurement uncertainty procedure follows the NIST SEMATECH protocol for quantifying uncertainties from a gage study. However this does not include calculations of sensitivity coefficients, drift, etc. to simplify use in the standard.

Calculation Method Use the sum of squares to combine all the variances. Note that the Bias_Variance listed below is actually comprised of the sum of squares for Non-Linearity, Resolution, and Hysteresis. Calculate the smallest possible specification limits that can be measured using this inspection process. For an approximate 95% level of confidence a K_value of 2 should be used in calculations.

$$EMU = K_Value * \sqrt{(GR\&R_Variance)^2 + (Non_Linearity)^2 + (Resolution)^2 + (Hysteresis)^2 + (Artifact_Uncertainty)^2}$$

Note: EMU denotes Expanded Measurement Uncertainty

And

$$Smallest_Placement_Specification_Limits = \pm (EMU * 4)$$

5.2 Gauge Repeatability and Reproducibility Capability This verification procedure determines the CMM's ability to repeat and reproduce the component location and rotation placed onto the PVP.

While multiple GR&R methodologies are available, this standard uses the ANOVA method and recommends the use of the spreadsheet discussed in Appendix G. The variance will be reported on the IPC-9850-F3 form.

5.2.1 Measurement Procedure Obtain a single glass verification panel with a specific part type populated according to the procedures described in the machine placement performance metric (see Section 3). Measure the populated PVP at least three consecutive times. The PVP is to be completely removed and replaced from the CMM for each run. At least 24 components need to be measured for each run.

The same PVP plate **shall** be subjected to an additional measurement cycle (three more measurement sets) using an identical procedure. At least two operators should be utilized to obtain the three sets of data. The entire GR&R evaluation **shall** be performed in a time period no longer than it takes to perform the measurement of the consecutive four PVPs for the placement performance evaluation. Appendix G explains this procedure in detail using the *IPC-9850-MSA.xls* spreadsheet.

For the 1005 [0402] components, the center of the component **shall** be measured using the lead outline and component outline. The same measurement procedure applies to the PVP populated with slugs. However, since the CMM uses the fiducial markings on all glass slugs, regardless of the specific component image, it is only necessary to evaluate the